An Institiuid Teicneolaíochta, Sligeach

Title of Dissertation:

An Examination into the Feasibility of Powering Small Water Services Infrastructure using Wind Energy Micro-generation Auto-production

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This dissertation is submitted as part fulfilment of the M.Sc. in Environmental Protection, Institute of Technology, Sligo.

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DECLARATION

I hereby declare that this dissertation is all my own work and contains no plagiarism.

Any text, diagrams or other material copied from other sources (including, but not limited to, books, journals and the internet) have been clearly acknowledged and referenced as such in the text.

I also declare that the data collected for this dissertation has not been submitted to any other Institute or University for the award of any other third level qualification.

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ABSTRACT

This study examines the potential for the use renewable energy to meet some or all of the electricity requirements of small water services infrastructure. In particular the use of wind powered micro-generation auto-production is examined.

While undertaking a literature review it became apparent that there is a lack of information relating to the use of micro/small wind turbines to power water services infrastructure. Furthermore, there is limited information relating to feasibility or site suitability guidelines for small scale wind. In Ireland, no such formal guidance exists.

This study examines the theory and technology behind wind energy and the factors which influence the likely success or otherwise of a micro wind project. It includes the development of a feasibility template for a micro wind project comprising desk study and site survey elements. The template was used as a screening exercise to examine the feasibility of the use of wind micro-generation to power water services infrastructure in County Galway. Implementation of the feasibility template for a candidate site was undertaken with the aims of refining the methodology and proving the effectiveness of the template.

The conclusions of this study include the following:

- The feasibility template developed has the potential to be a useful tool for anyone considering installing a micro-wind turbine on their site.
- There is potential for the use of wind micro-generation at water and wastewater infrastructure sites.
- The economic payback period for micro-generation is much higher in Ireland than internationally and that in order to promote the development of the micro-generation industry in Ireland, appropriate feed in tariff rates are required.

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1 INTRODUCTION

1.1 BACKGROUND

Wind energy has been used for thousands of years to move ships, to pump water, to mill grain and more recently to generate electrical power. Today's wind energy generators predominantly exist as three bladed turbines supported by large cylindrical tower structures. The sizes of the generators available range from very small 50W units used to provide auxiliary power on yachts right up to very large offshore structures with overall heights of up to 198m, rotor diameters of up to 126m and power generation capability of up to 7.58MW (the Enercon E-126).

In most cases groups of turbines occur as wind farms in both onshore and offshore environments. The power generated by wind farms feeds into the electricity supply distribution network to augment power generation from other sources consisting mainly of fossil fuel powered generation plants.

In recent years, in an effort to save costs on the purchase of electricity, individual organisations have developed their own wind generation on site. This process, known as auto-production, enables electricity consumers to take charge of their cost of energy by producing energy on site. Although the primary aim of auto-production involves supplying the energy needs of a single site any surplus energy generated can be exported to the electricity grid. If it is feasible for larger electricity consumers to auto-produce using wind power, it may be feasible for smaller electrical consumers to do so also.

1.2 RESEARCH FOCUS

The operation of water and wastewater treatment infrastructure represents a significant cost to local authorities throughout Ireland, with energy costs the most significant contributing factor. This study focuses on the potential to offset some of the energy costs by locating wind micro-generation on site at water/wastewater infrastructure facilities. The theory is that during suitable weather conditions, a micro wind turbine at a water/wastewater treatment site will be able to meet most, if not all, of its electricity requirements feeding any surplus energy produced back into the electricity grid. The surplus energy exported will help to offset the cost of the electricity imported from the grid during calmer weather.

The focus of this research is to explore the theoretical feasibility of this proposal on a broad scale, using County Galway as an example and on a narrower scale using a site specific case study to examine the feasibility of the proposal. By doing so, a feasibility template will be produced to enable others to carry out feasibility studies.

1.3 OVERALL RESEARCH AIM AND INDIVIDUAL RESEARCH OBJECTIVES

The overall aim of this research is to examine the potential for powering local authority water and waste water infrastructure using on site micro wind energy auto-production.

Individual research objectives identified include:

- An investigation into the technology available for wind powered micro-generation,

- Examination of the factors effecting the siting of micro wind turbines, with the objective of producing site assessment guidelines for anyone considering the installation of a micro wind turbine,
- Examination for the potential of wind micro-generation for County Galway,
- The preparation of a Case Study feasibility examination of a potential site, to prove the applicability of the site assessment guidelines developed,
- An economic analysis of the overall research aim, and
- Recommendations for future research in this area.

1.4 VALUE OF THIS RESEARCH

There is a lack of information relating to micro wind auto-production in Ireland. While it has been shown that large scale wind turbines can successfully act as auto-producers there are very few examples of the use of micro wind power for this purpose.

If it is both theoretically and physically shown that auto-production using micro wind power is feasible the possibilities for its exploitation are immense.

It is hoped that this research will be used as a guide for anyone considering micro wind power auto-production and that it will form the basis for a guide as to how to undertake a feasibility assessment at a potential site.

2 LITERATURE REVIEW

The aim of this literature review is to provide background information relating to wind energy and in particular to micro-generation for the purposes of auto-production. To understand the principles on which this proposal is based it is necessary to first provide information on wind energy theory, micro-generation, auto-production and the factors which influence the success or otherwise of wind micro-generation.

2.1 THE NEED FOR RENEWABLE ENERGY IN IRELAND

One of the key drivers behind the development of renewable energy is climate change, which is globally regarded as the most serious environmental problem we face (Sustainable Energy Authority of Ireland 2010a). Put simply, "*climate change is a significant change in the average weather or climate that a region experiences*" (Environmental Protection Agency 2010). While some change in climate over time is normal, the magnitude of the change which has occurred is not. Man-made climate change has been the difference.

Man-made climate change has occurred due to human activity in areas like energy production, transport, agriculture and industry. The greenhouse gases (GHG's) that have arisen as a result of these activities have built up in the atmosphere causing a heating effect. The associated results have included increased average temperatures and more extreme weather events including increased storm activity, flooding, droughts and coastal erosion (Environmental Protection Agency 2009).

Generally, the Irish climate is experiencing changes consistent with those occurring globally (Sweeney et al 2009, p. 3) including temperature and rainfall increases. The associated predicted negative effects of these changes include sea-level rise, more intense rainfall and storms, more severe river and coastal flooding and water quantity and quality problems (Environmental Protection Agency 2009).

One of the main contributors to climate change, both in Ireland and globally is the energy sector and the associated CO_2 emissions. In 2009 the energy sector, which includes electricity generation, heating and transport, accounted for 67% of national GHG emissions, 41.5Mt CO_2 eq1 (Sustainable Energy Authority of Ireland 2010b). 88.6% of Ireland's energy requirements are met by imported fossil fuels. The rest is met by domestic fossil fuel supply, e.g. peat and natural gas, and to a lesser extent, renewables (O' Reilly 2008, p. 3).

The development of the renewable energy sector is a critical part of Ireland's climate change strategy. In particular, wind energy development is seen by many as the easiest way for us to increase our share of renewables.

2.2 THE DEVELOPMENT OF WIND ENERGY IN IRELAND

Wind has been harnessed for thousands of years, first to move sail ships and later to grind corn and pump water. Windmills began to appear in Europe in the 12th century. The Dutch used wind energy to drain flooded land protected from the sea by open dykes (Chiras 2009, p. 1).

In Ireland, windmills were introduced into the country by the Anglo-Normans, with the first known windmill located at Kiscalan, County Wexford in 1281 (Institute of Engineers of Ireland 2000). By the late 19th century the use of wind for pumping water on large estates was widespread. During the 1920's and 1930's an Engineer named Maurice Sweeney built at least 13 wind powered public water schemes for Galway County Council (Institute of Engineers of Ireland 2000).

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The first significant wind farm of the modern era was constructed in 1992 at Bellacorick in County Mayo by Bord na Mona (Sustainable Energy Authority of Ireland 2010c). By the start of 2000, there were 10 wind farms in Ireland with a total of 70 MW of installed wind capacity (Institute of Engineers of Ireland 2000). Although initially slow to gather momentum wind farm development really started to take off in 2002 and by December 2010, 110 wind farms were in operation with a total installed capacity of 1425 MW (Eirgrid 2010).

The growth of installed wind capacity is illustrated in Figure 2.1.

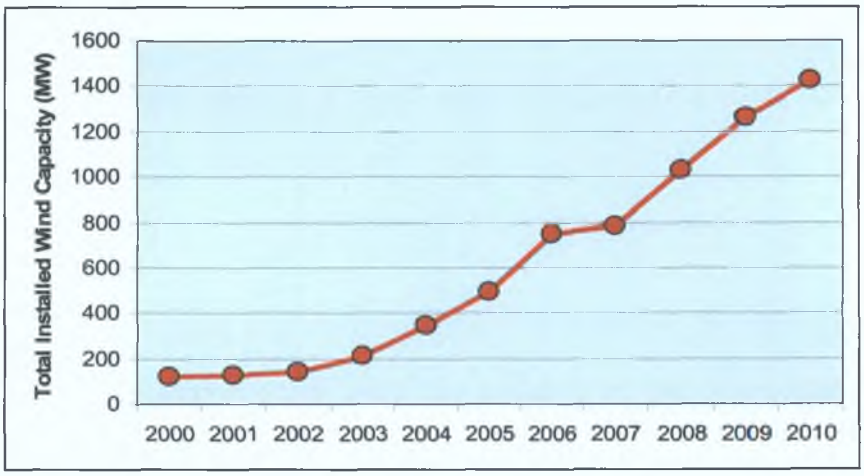

Figure 2.1: Installed Wind Capacity in Ireland 2000 – 2010 (Eirgrid 2010)

2.3 POLICY CONTEXT

Ireland, like all European Member States, is committed to the development of renewable energy in accordance with Council Directive 2009/28/EC. Under the terms of the Directive, each Member State was set an individual binding renewable energy target. Ireland's overall target is to achieve 16% of energy from renewable sources by 2020.

Directive 2009/28/EC also required each Member State to prepare and submit a renewable energy action plan setting out the approach and strategy to be adopted to meet the required renewable energy targets. Irelands National Renewable Energy Action Plan (NREAP) as submitted to the European Commission in mid 2010 sets out the government's approach to deliver on the 16% target. In relation to electricity, the Government has set a target of 40% electricity consumption from renewable sources (RES-E) by 2020 (Department of Communications, Energy and Natural Resources 2010).

2.4 MICRO-GENERATION AND ITS ROLE IN IRELANDS ENERGY MIX

Before discussing the role that micro-generation may have in Ireland's renewable energy future, it is first necessary to define micro-generation.

Section 82 of the United Kingdom Energy Act 2004 defines micro-generation as "*the small-scale production of heat and/or electricity from a low carbon source*." The various technologies which fall into the micro-generation category include solar (thermal which provides hot water and photovoltaic, PV, which produces electricity), micro-wind, micro-hydro, heat pumps, biomass, micro combined heat and power (CHP) and small-scale fuel cells (Department of Trade and Industry 2006a).

In Ireland, Micro-generation is classified by ESB Networks as *"grid connected electricity generation up to a maximum rating of 11kW when connected to the three phase portion of the distribution grid (400V)"* (Sustainable Energy Authority of Ireland 2010d).

The vast majority of domestic and agricultural customers are connected to the single phase portion of the distribution grid (230V) and for these customers to be classified as micro-generators the maximum technical rating permitted is 5.75kW. These ratings are in line with Irish conditions prescribed in European standard EN 50438. However ESB Networks accept applications for generators up to 6kW (Sustainable Energy Authority of Ireland 2010d).

Note: Internationally, the definition of micro-wind in terms of generation capacity varies greatly. For the purposes of this study micro-wind shall relate to wind generators up to 15 kW and small scale wind shall relate to wind generators between 16 and 50 kW, Generators larger than 50 kW are outside the scope of this study.

In terms of the extent of the development of micro-generation in Ireland, the most recent information is contained in the SEAI prepared report "*A Report on Micro-generation in Ireland*" (2010). It includes details of the total metered micro-generation in Ireland at the end of 2010 as included in Table 2.1.

December 2010	kW Installed Capacity	Market Share by Capacity	No. of Installations	Market Share by Installation
Micro CHP	3.00	0.2%	3	0.7%
Micro Hydro	20.80	1.1%	4	1.0%
Solar PV	120.78	6.2%	55	13.1%
Micro Wind	1,818.15	92.6%	357	85.2%
Total	1,962.73	100.0%	419	100.0%

Table 2.1: Total Installed Capacity of Micro-generators (A Report on Micro-Generation in Ireland, SEAI, 2010)

Of note is that there is almost 2 MW of grid connected micro-generation in Ireland, the majority of which is attributable to micro-wind generation. The report states that "*the average size for a micro-wind installation is 5.1 kW.*"

The geographical spread of the metered micro-generation in Ireland is illustrated in Figure 2.2.

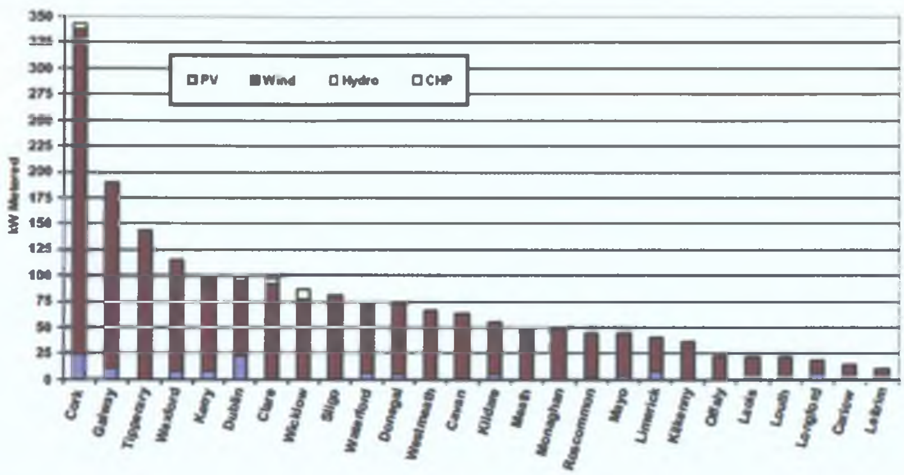

Figure 2.2: Installed Capacity by County (A Report on Micro-Generation in Ireland, SEAI, 2010)

The SEAI report states that "*the factors which shape this graph may include population, nature of settlement, access to the resource, economics, activity and density of suppliers and public and local authority acceptance of the technologies.*"

It must be stressed that the figures provided above relate only to metered, i.e. grid connected micro-generation installations. Current feed in tariffs (payment made for electricity produced/exported) are only available to domestic electricity consumers. This fact coupled with a lack of grant aid for certain micro-generation technologies, including micro-wind, means that the quantity of non-domestic micro-generators is unknown.

The SEAI prepared document titled "*Your Guide to Connecting Micro-generation to the Electricity Network*" (2009), states that the benefits of micro-generation include:

- Lower electricity bills,
- It hedges against future electricity price rises,
- Less greenhouse gas emissions,
- Reduced reliance on fossil fuels and
- Reduced electrical losses on the ESB network (approximately 7% of the electricity generated in large power stations is wasted in being transported to the consumer)

In terms of the role of micro-generation, although it is acknowledged that large scale wind generation will contribute most to Irelands 40% RES-E target, the National Renewable Energy Action Plan (Department of Communications, Energy and Natural Resources 2010). states that *"the introduction of a robust framework for the development of a vibrant micro-generation sector is an important component of building societal acceptance of energy infrastructure and ownership of the national renewable energy targets. The micro-generation area has the potential to create employment and enable participation by a wide section of the community. The Government is committed to developing a comprehensive micro-generation framework which will be taken forward up to 2020."*

In the UK, a study commissioned by the Department of Trade and Industry (2006b) suggests that "*by 2050, micro-generation could provide 30 – 40% of the UK's electricity needs and help to reduce household carbon emissions by 15% per annum.*"

A discussion document produced by the Irish Wind Energy Association (2010) concluded that micro-generation will play an important part in assisting Ireland to reach its targets for electricity generated from renewable sources but that the barriers which exist most be removed.

The barriers identified were:

- Financial (level of feed-in-tariff)
- Standards/Quality of Equipment
- Planning
- Grid
- Manufacture, Research and Development

Of direct relevance to this dissertation is the IWEA's proposal to encourage appropriate site assessment for small wind projects and the development of new site assessment methods for small wind. One of the aims of this study is to formulate a site assessment checklist for micro wind projects which could potentially be used as a first step for anybody considering investing in wind energy.

2.5 POWERING WATER SERVICES INFRASTRUCTURE WITH RENEWABLE ENERGY

The operation of water services infrastructure is very energy intensive. In general, water and wastewater treatment plants and pumping stations operate for at least 18 hours per day and in many cases 24 hours per day, 365 days per year. One of the few benefits of the almost constant operation is the consistency of the associated electrical demand, which is advantageous when considering the introduction of wind power.

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A number of Irish local authorities have been increasingly engaged in exploring their own energy supply and demand, both in terms of cost savings and environmental impact (Ó Gallachóir 2001).

For example, Kerry County Council (KCC) has an annual electricity bill of €2.2m arising from an annual electricity consumption of 29GWh, spread over approximately 360 loads. 58% of KCC's total annual electricity consumption is attributable to water and wastewater pumping and treatment. Feasibility studies conducted by the Kerry Energy Agency indicated the development of a 6.8 MW wind farm, three small scale hydro-electric schemes with a total installed capacity of 1.75 MW and a landfill gas plant with a capacity of 450 kW as a financially viable hybrid renewable energy supply (Mc Kenna et al 2007).

2.6 AUTO-PRODUCTION

Auto-production can be defined as the generation of electricity by an energy user for his own use and may or may not include co-generation (electricity generation from more than one source), (Sustainable Energy Authority of Ireland 2010f). Figure 2.3 illustrates the principle on which auto-production is based (adapted from McNamara 2006).

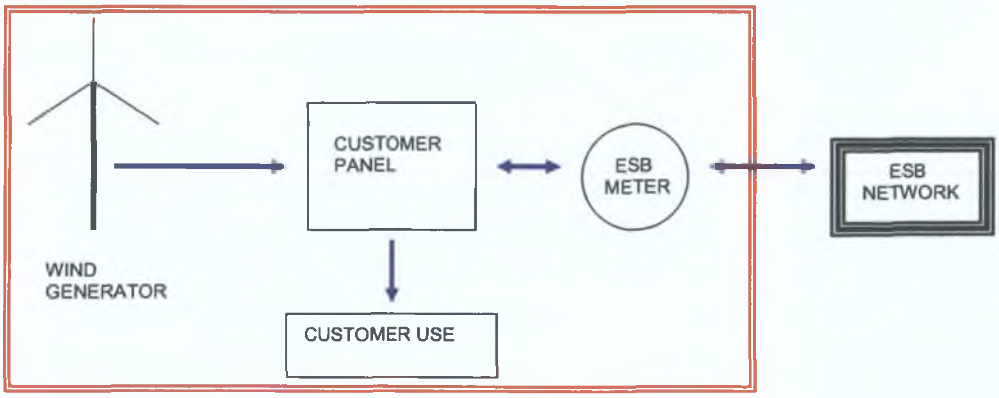

Figure 2.3: Principle of Auto-production

The wind turbine generates power which is channelled through the consumers electrical control panel. The resulting electricity is used on site to meet the energy requirements of the customer with any excess electricity exported beyond the site boundary via an electricity meter into the electricity distribution network.

At times when the wind resource is not available or not fully meeting site requirements, electricity is imported from the electricity distribution network, again, via an electricity meter.

In recent years, large scale, mainly industrial electricity consumers have begun to examine the feasibility of using auto-production to provide some or all of their on-site power requirements. Examples of auto-production installations in Ireland include Dundalk Institute of Technology (DKIT) in County Louth and Munster Joinery in Ballydesmond, County Cork. Both projects involved the use of large wind turbines, with a single 850kW Vestas V52 turbine at DKIT and two 2MW Enercon E82 turbines at Munster Joinery.

In particular, the DKIT turbine is a landmark project as it is the first auto-production application for a wind turbine in Ireland, the first large commercial urban turbine in Ireland and is believed to be the first and only large commercial wind turbine on a college campus in the world (Staudt 2007).

The only known example of wind power use for water or wastewater treatment exists on the island of Inis Meain, one of the Aran Islands, located off the coast of County Galway. Three wind turbines with a combined capacity of 675 kW (3 x 225 kW) were constructed in 2002 to provide power to an energy intensive desalination plant, used to augment the islands water supply scheme. For various reasons including the intermittent use of the desalination plant and associated operational problems, the wind turbines on Inis Meain are almost exclusively used to augment the electricity needs of the Aran Islands.

Plate 2.1: DKIT Vestas V52 Wind Turbine (Staudt 2007)

A number of local authorities including Galway City Council and Galway County Council have carried out feasibility studies in relation to the introduction of medium scale wind power auto-production at large water and wastewater treatment plants but as yet, these have not progressed beyond feasibility stage.

Internationally, there are numerous examples of wind power auto-production at water and wastewater treatment plants using wind turbines of 100 kW size and larger. In the United Kingdom, Hull WWTP has 1.3 MW of installed wind capacity and Loftsome Bridge WTP (Selby) has 2.6 MW of installed wind capacity. In the United States, the Atlantic City WWTP has 7.5 MW of installed wind capacity, comprising five 1.5 MW turbines. In all cases, excess electricity generated is fed into the national grid.

The development of wind energy auto-production using large scale turbines, as discussed, is well developed and has proven to be successful. The feasibility of the technology in the micro-generation context does not appear to have been investigated to any great extent. This dissertation will address the apparent lack of information. Before doing so, it is necessary to provide some information on the basics of wind generation theory, in order to better understand the factors which determine success or failure.

2.7 MICRO-WIND AUTO-PRODUCTION

Micro-wind auto-production has been practiced for many years as a means of providing power, for example, on farms or at remote locations where there is no electricity network.

There are few documented examples of smaller micro scale wind turbines at water and wastewater treatment plants. In the US, at Browning in Montana, four 10 kW Bergey wind turbines provide approximately one quarter of the power requirements of the wastewater treatment plant. The website for Browning (www.browningmontana.com) includes the statement; "the potential for replication of this project is high".

The main reason why water and wastewater treatment are being investigated is due to the attractiveness of their almost constant energy requirement. Most treatment plants operate for between 18 and 24 hours per day, 365 days per year. Although the use of wind power to provide some or all of the required electricity at these plants has not been exploited yet, there is potential to do so in the future.

2.8 CURRENT WIND TURBINE TECHNOLOGY

Modern wind turbines, whether small or large scale, exist in two configurations: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT) (Boyle 2004).

HAWT's are the most common turbine type in use today. They operate with their axis of rotation in parallel with the wind direction. They can be single, double, triple or multi bladed and depending on the orientation of the blades with respect to the wind direction they are classified as up wind or down wind. All HAWT's have some sort of mechanism for keeping the rotor faced into the wind. In small turbines this may consist of a tail vane, larger turbines use a motorised yaw system, (Bansal et al 2002).

VAWT's, often called cross wind axis machines, are less common and operate with their axis of rotation perpendicular to the wind direction, (Bansal et al 2002). Examples of a HAWT (Biotechnology Blog 4 JNTU B.Tech Students 2008) and VAWT (Suite 101 2010) are illustrated in Plate 2.2.

Plate 2.2: HAWT (left) and VAWT (right)

In terms of wind micro-generation, the use of HAWT's is much more prevalent than the use of VAWT's and so for this reason only HAWT's will be discussed further.

The key components of a wind turbine are illustrated in **Figure 2.4**.

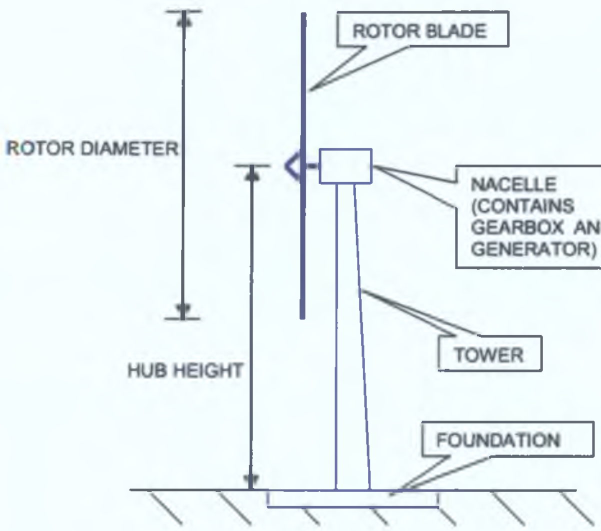

Figure 2.4: Wind Turbine Components

As illustrated wind turbines consist of a tower, rotor blades and a nacelle which contains the gearbox and generator. Figure 2.5 illustrates the internal view of a micro-wind turbine.

Another key component of a micro-wind generation system is an inverter. Its purpose is to convert the direct current (DC) produced by the wind turbine to alternating current (AC) which is the power form used by electrical consumption units (lights, pumps, etc). The inverter also synchronises the electricity produced by the turbine with the electricity from the grid, to ensure there is no interruption to supply and prevents the export of electricity to the grid during a power cut (for safety reasons). ESB Networks require that the inverter used complies with the European standard EN 50438 (Sustainable Energy Authority of Ireland 2010d).

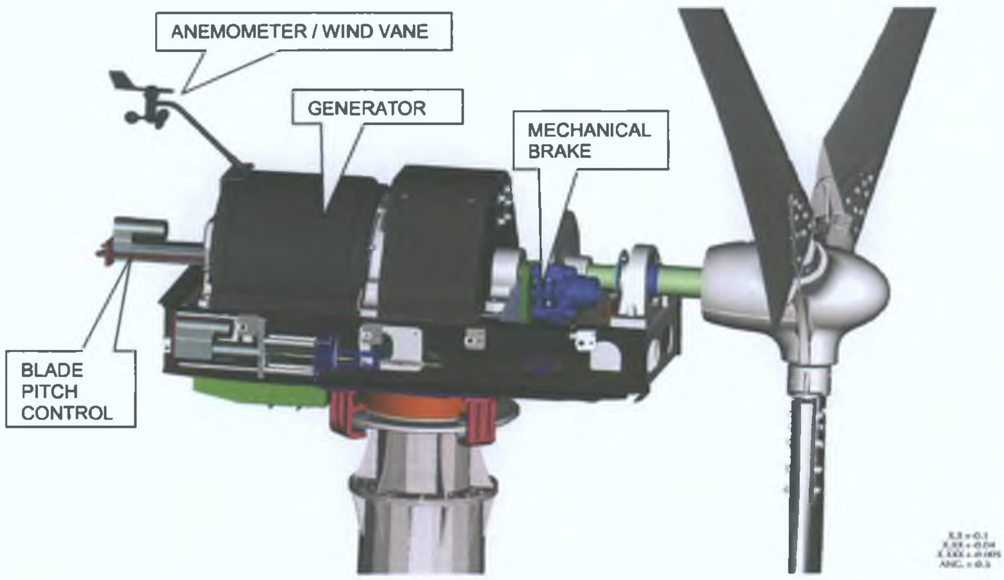

Figure 2.5: Micro-wind Turbine – Internal View (image sent by email from C&F Green Energy Feb 2011)

In terms of the energy output of wind turbines, the most important properties (adapted from Sustainable energy Authority of Ireland 2010f) are:

Wind Speed and **Wind Resource** at a particular site. These will be discussed further in Sections 2.7 and 2.8.

Swept Area: This is the area of the imaginary circle created by the rotating blades of a wind turbine. For example a turbine with a blade length of 10m (equals the radius of the circle) has a swept area of $\pi r^2 = 3.14 \times 10^2 = 314m^2$. The swept area is the region in which energy is collected from the wind and so the greater the swept area, the greater the amount of energy that can be collected.

Annual Energy Output: This is the amount of power generated, in kilowatt-hours, in a one year period at a given wind speed. It is a very useful measure of turbine performance and a useful means of comparing different turbines.

Other less relevant properties related to wind turbine output include:

Power Curves: These are a graphical representation of the performance characteristics of a specific wind turbine. A typical example of a power curve is illustrated in Figure 2.6.

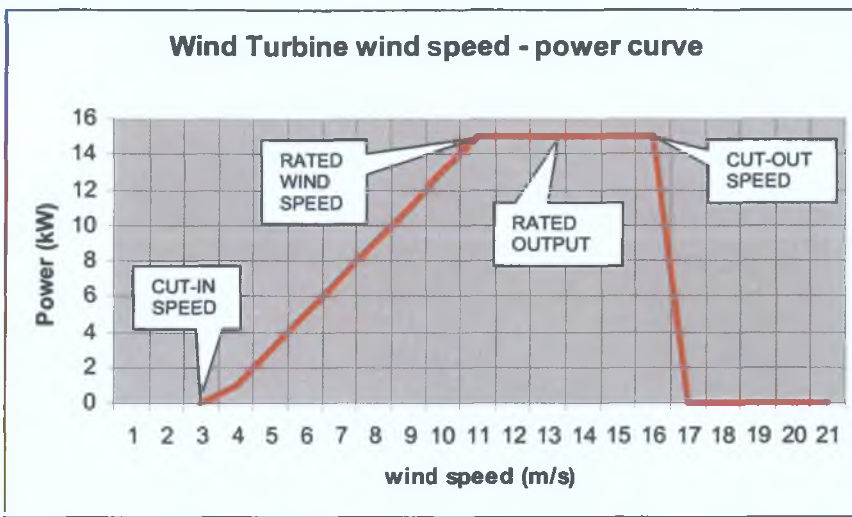

Figure 2.6: Sample Power Curve (15kw wind turbine)

Power curves presented by manufacturers can often be optimistic and not based on real data and so must be independently verified before they can be given any credence.

Cut-In Wind Speed: The wind speed at which a wind turbine starts to generate electricity.

Rated Wind Speed: The lowest wind speed at which the rated output power of a wind turbine is produced. In average weather conditions a wind turbine will operate at a lower wind speed than the rated wind speed. Again, it is important to stress that it is the performance of the turbine in average conditions which is more important than its performance at higher, less frequent wind conditions.

Cut-Out Wind Speed: The wind speed at which the wind turbine shuts down and stops to generate electricity. Traditionally the protection mechanism used for wind turbines in very high wind conditions was known as furling, where the rotor (blades and hub) rotated relative to the wind, effectively turning the blades out of the wind. More recently, micro wind turbines have employed a technique known as pitch control, where the individual blades gradually rotate out of the wind. As wind speed increases, the blades pitch further allowing the maximum possible wind generation potential of the turbine in conditions which would force a non pitch controlled turbine to shut down (cut-out).

Peak Output: The maximum amount of power a wind turbine can produce. Although often cited on turbine specifications, for the same reasons discussed in relation to rated wind speed often included on turbine specifications, peak output is not very important.

2.9 WIND ENERGY THEORY

The most important element of wind energy theory is the power available in the wind, P_w.

$$P_w \text{ (in watts)} = \tfrac{1}{2} \, . \, \rho A \, . \, V^3$$

where ρ = air density (in kg/m^3), A = turbine swept area (m^2) and V = wind speed (in m/s), (Bansal et al 2002).

It is important to note that the power available in the wind is not equal to the amount of power that can be generated by a wind turbine, due to the losses incurred in the energy generation process.

The electrical power output that can be generated by a wind turbine is as follows:

$$P_e = P_w . C_p . \mu_c$$

Where C_p = coefficient of performance and μ_c = conversion efficiency, (Lara et al 2010).

The coefficient of performance relates to the fact that not all of the available energy can be recovered from a wind stream. The maximum theoretical value of C_p is 0.593 according to the Betz limit. This means that the maximum power that can be realised from a wind system is 59.3% of the total wind power. In practice, C_p values range from 0.25 to 0.45, increasing as the size of the turbine increases, (Bansal et al 2002).

The conversion efficiency, μ_c, equals the product of the mechanical (η_m) and electrical efficiency (η_g) of the conversion to electricity of the energy available at the turbine hub, i.e.

$$\mu_c = \eta_m . \eta_g.$$

The electrical power output efficiency will, most probably, lie in the 25% to 30% range and will vary depending on wind speed, turbine type and the nature of the load, (Bansal et al 2002).

2.10 ELECTRICAL POWER UNITS

Throughout this study reference will be made to KVA and kW. The relationship between these units is as follows:

KVA which is an abbreviation of Kilo Volt Amps translates to 1000 x Volts x Amps, i.e. 1 KVA equals 1000VA.

1000VA equates to 1000 Watts, so 1 KVA equates to 1 kW.

2.11 WIND RESOURCE

Wind speed at a particular height can be estimated from a known value at a given height using the following conversion formula, which is a form of the power law equation.

$$v_2 = v_1 \times (z_2/z_1)^{\alpha}$$

where, v_2 = the unknown wind speed at height z_2

v_1 = the known wind speed at the measurement height z_1

α = the wind shear exponent, (Bansal et al 2002)

Surface Characteristic	Shear Coefficient
Water	0.10
Level Ground, Grass Surface	0.15
Hilly Open Ground	0.20
Few Trees, Occasional Buildings	0.22
Many Scattered Trees, More Buildings	0.24
Suburbs	0.30
Urban Areas	0.40

Table 2.2: Typical Wind Shear Coefficients

In 2003, Sustainable Energy Ireland (now called the Sustainable Energy Authority of Ireland, SEAI) produced the Wind Atlas for Ireland. The atlas shows the 'constrained wind resource' at 50m, 75m and 100m above ground level for the whole of the Republic of Ireland as illustrated in Figure 2.7.

Micro-wind turbine hub heights vary from 10m to 20m in height. Using the Wind Atlas for Ireland and knowing the wind speed at 50m (the lowest height in the wind atlas), it

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is possible to estimate the wind speed at the appropriate micro-wind turbine hub height.

For example, if it is known that the wind speed at 50m is 7.5 m/s and we want to estimate the wind speed at 15m on a hilly site with few trees (wind shear exponent from Table 2.1 is 0.2, we can do so by using the formula above as follows:

$$v_2 = 7.5 \times (15/50)^{0.2}$$

resulting in an average wind speed estimate of 5.9 m/s at 15m.

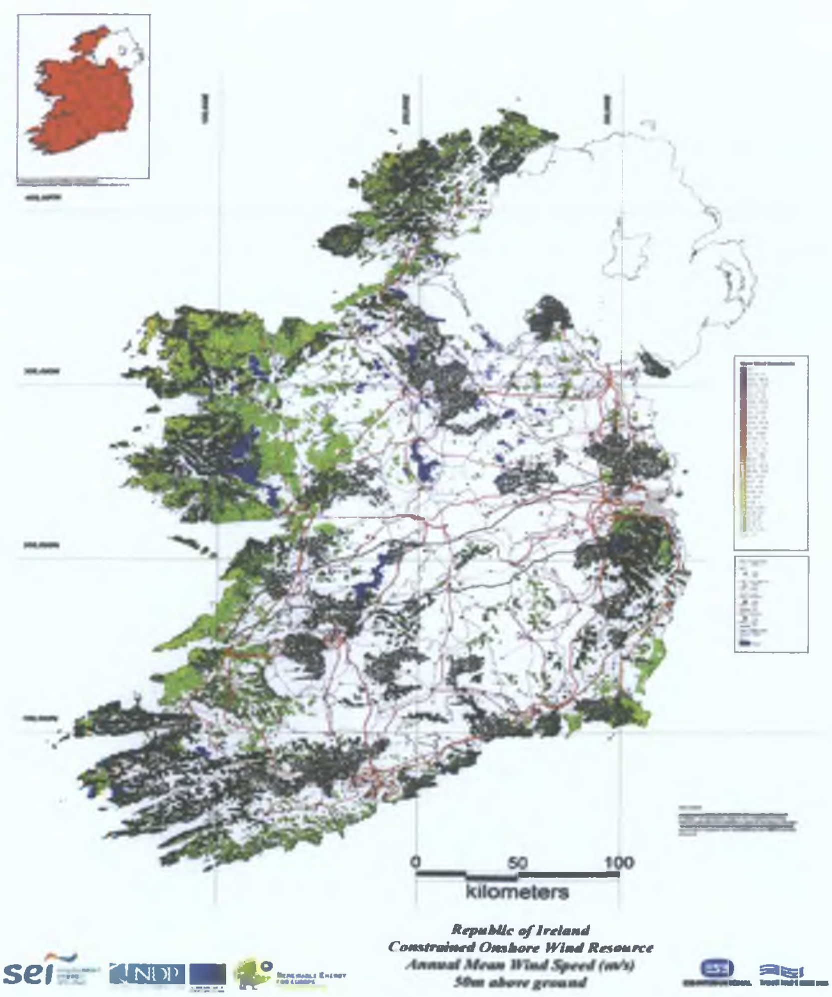

Figure 2.7: Wind Atlas for Ireland – constrained wind speed at 50m (SEI 2003)

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The darker colours (green), evident mainly along the west coast, indicate those areas with the greatest potential for wind exploitation at 50m above ground level. The main factors affecting the wind resource are distance from the coast, exposure above the surrounding terrain and land cover (which determines surface roughness). In central Ireland the predicted mean wind speed at 50 m generally ranges from 6.5 to 7.5 m/s; relatively sheltered areas may be below 6 m/s. Along the west coast, and particularly in open areas with few trees, wind speeds of 7-8 m/s are projected. Higher wind speeds are predicted (and experienced) on many hills and mountains and especially in the western half of the country (SEI 2003).

The SEI Wind Atlas is a very useful first step in the examination of the potential for micro scale wind development at a particular location.

2.12 PLANNING CONSIDERATIONS

In Ireland, the most relevant guidance in relation to large scale wind development is provided in the *Wind Development Planning Guidelines published by the Department of the Environment, Heritage and Local Government.* This document provides guidance to both planning authorities and wind developers in an effort to promote a consistent approach to wind farm development in Ireland. There is no such corresponding guidance for smaller scale and micro scale wind development.

In an effort to promote the development of smaller scale and micro renewable energy development in Ireland and to reduce the obstacles for promoters, planning exemptions were introduced by the Department of the Environment, Heritage and Local Government (DEHLG) in 2007 and 2008. Statutory Instrument (SI) 83 of 2007 Planning and Development Regulations 2007 relates to the installation of domestic wind turbines and SI 235 of 2008 Planning and Development Regulations 2008 relates to the installation of commercial and agricultural wind turbines. Projects meeting the criteria set out in these SI's are exempt from planning permission, unless they contravene SI 600 of 2001, which includes restrictions on planning exemptions.

As the focus of this research relates to the promotion of micro-generation auto-production at local authority water and wastewater treatment infrastructure sites, which are treated as commercial installations by the ESB, only the provisions of SI 235 of 2008 and the planning exemption restrictions in SI 600 of 2001 will be discussed further.

The exemptions included in SI 235 of 2008 are set out below.

- Turbine must not be attached to a building.
- Only one turbine per site.
- Total height must not exceed 20m.
- Rotor diameter must not exceed 8m.
- 3m minimum clearance required between ground and lowest point of blades.
- Turbine mast must be the total maximum height of the assembly including turbine and blades plus 5m from the nearest party boundary or non-electrical overhead lines.
- Turbine mast must be the total maximum height of the assembly including turbine and blades plus 20m from the nearest 38kV electricity distribution line.
- Turbine mast must be the total maximum height of the assembly including turbine and blades plus 30m from the centerline of the nearest transmission line i.e. 110kV plus.

- Noise levels must not exceed 43db(A) or 5 db(A) above background noise at the nearest inhabited neighboring dwelling.
- No advertising can be placed on the turbine and the turbine must be matt finished.
- The blades must not interfere with telecoms signals.
- Consent must be sought from the Irish Aviation Authority if the turbine is to be within 5km of an airport.
- The area must not be within an Architectural Conservation Area.

If a micro wind project proposal conflicts with any of the listed exemptions the planning permission is required. In addition, in relation to SI 600 of 2001, the following extract provides details of where the exemptions provided for in SI 235 of 2008 may not apply.

"Article 9(1) Development to which article 6 relates shall not be exempted development for the purposes of the Act—

(a) if the carrying out of such development would—

(vi) interfere with the character of a landscape, or a view or prospect of special amenity value or special interest, the preservation of which is an objective of a development plan for the area in which the development is proposed or, pending the variation of a development plan or the making of a new development plan, in the draft variation of the development plan or the draft development plan,

(vii) consist of or comprise the excavation, alteration or demolition (other than peat extraction) of places, caves, sites, features or other objects of archaeological, geological, historical, scientific or ecological interest, the preservation of which is an

objective of a development plan for the area in which the development is proposed or, pending the variation of a development plan or the making of a new development plan, in the draft variation of the development plan or the draft development plan, save any excavation, pursuant to and in accordance with a licence granted under section 26 of the National Monuments Act, 1930 (No. 2 of 1930),

(b) in an area to which a special amenity area order relates,"

It is recommended that any prospective micro-wind project is discussed with the planning section of the relevant Local Authority to determine if any of the restrictions contained in SI 600 of 2001 are applicable. If a decision is reached that a proposed project is not exempt from planning, the promoter must enter the planning process and apply for planning permission.

2.13 ECONOMICS OF WIND MICRO-GENERATION

An important step in analysing the potential for wind energy at any site is the financial viability of the project (this will be detailed further in the Case Study in Chapter 3). According to SEAI (Sustainable Energy Authority of Ireland 2010g), the key factors which determine financial viability include:

- Electrical demand and load profile
- Capital cost and operating costs
- Site suitability
- Cost of alternatives
- Turbine selection (performance, robustness, design life)
- Credit/payment for electricity fed back to the network

The following sub-sections of Section 2.13 are adapted from the information contained within the FAQ section of the SEAI website (Sustainable Energy Authority of Ireland 2010g). Sections 2.13.1 to 2.13.6 are based on the SEAI information but are adapted to be relevant to the commercial, that is, non-domestic context.

2.13.1 Electrical Demand and Load Profile

Wind micro-generation is more suitable to sites where there is a constant 'base-load' demand for electricity, such as water or wastewater treatment plants and pumping installations, which in many cases operate for between 18 and 24 hours per day. A turbine installed at such a site has the potential to displace imported power required to meet the base-load demand. Economic analysis should factor in the various options of tariff available from the electricity supply company. The ‘load factor’ is the ratio of the maximum electrical demand relative to the average demand over the same period.

In the case of non-domestic consumers, who cannot currently avail of feed in tariffs, the value of the energy produced by a micro-wind turbine is dependant solely on how much of the energy produced can be consumed on site, i.e. auto-production. Each kWh of electricity produced and consumed on site reduces the amount of electricity required to be purchased from the electricity supply company.

According to information provided in the FAQ section of the SEAI website (Sustainable Energy Authority of Ireland 2010g), over-sizing a turbine may mean payback is affected in the long term and under-sizing a turbine may mean an opportunity is missed to maximise the potential of the site for reducing the customer's bill. Under-sizing a unit is preferable to over-sizing an installation however as it prevents an inefficient system being installed. The sizing of micro-wind turbines is discussed further in Chapter 4.

SEAI go on to say that appliances which require demand throughout the day and night (such as water services infrastructure) improve the viability of the site with regard to micro-generation. The demand should also be throughout the year and not just seasonal.

2.13.2 Capital Cost and Maintenance Costs

The initial capital investment associated with the purchase of a wind turbine is significant. For example the estimated cost of a 6 kW wind turbine, installed and commissioned, is approximately €28,000 (excluding VAT). This figure date, obtained by email in April 2011 relates to one particular manufacturer operating in Ireland.

The maintenance associated with a modern micro-wind turbine is likely to include an annual inspection comprising preventative maintenance including greasing as well as the periodic replacement of certain turbine components.

It is important that capital and maintenance costs over the lifetime of the turbine are determined in order to evaluate the likely economic payback period. This information should be requested from turbine manufacturers when considering the choice of turbine. The ultimate aim is to reach beyond the break-even point. A turbine system which does not reach a break-even point has in effect produced power during its lifetime that has been more expensive than would have otherwise been available from the grid.

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2.13.3 Site Suitability

The output of a wind turbine is dependent on available wind resource at the site. Because the power output of a wind turbine is proportional to the cube of the wind speed (see Section 2.9) even a small increase in wind speed can have a significant effect on the power produced. Average wind speeds are more important than the occasional high wind speeds which might be available at a site. The Renewable UK document *Generate your own Power* states that "*for a wind turbine to be worthwhile your site's annual average wind speed needs to be at least 4.5 metres per second.*" (Renewable UK 2010).

Chapter 3 examines in detail the factors which influence the suitability of a particular site for micro-wind development.

2.13.4 Cost of Alternatives

In order to carry out an economic appraisal of the introduction of micro-wind energy it is necessary to consider the cost of alternatives. For the purposes of this study, the supply of electricity from the national grid is presented as the only alternative power supply option (the use of other renewable energy micro-generation types is outside the scope of this study).

The quantity of electricity produced by the micro wind turbine has a value which is equal to the saving made by not importing that electricity from the electricity grid. The value saved will depend on the relevant tariff structure in place with tariff selection dependant on electrical consumption patterns.

2.13.5 Turbine Selection

Turbine selection is one of the most important decisions to be made when considering any wind energy development. For large turbines there are in the region of ten major manufacturers but for smaller scale turbines there are many more.

To be cost effective a turbine must be robust and reliable with the ultimate goal of lasting beyond its payback period. It is in the interest of the owner to keep the turbine generating for as long and as efficiently as possible to get to a point where the turbine has paid for itself and it is producing clean energy at a cost less than the retail price of electricity.

2.13.6 Credit/Payment for Electricity Fed Back to the Network

In Ireland at present, only domestic micro-generators receive payment for excess electricity generated and fed back in into the electricity network. Since 2009, domestic micro-generators can receive a payment of between 9c and 19c/kWh from the ESB for excess electricity generated. This payment mechanism or 'feed in tariff' (FiT) is much lower than that which exists throughout Europe as illustrated in Table 2.3 (Irish Wind Energy Association 2010).

Country	FiT rate/unit	Cap (on power produced)	Conditions
Germany	€0.57	None	Exported units for 20 years
Portugal	€0.45	None	Exported units
Spain	€0.44	None	Exported units
France	€0.58	None	Exported units
Italy	€0.44	None	Exported units
UK/N. Ireland	£0.241 - £0.345*	None	All generated units
Ireland	€0.19 - €0.09	3000 units at higher rate, then lower rate	Domestic only, exported units for 3 years, first 4000 users only
*: Value depends on micro-generator capacity			

Table 2.3: European Feed in Tariffs (FiT's)

The absence of a non-domestic FiT in Ireland affects the financial viability of micro-generation installations and contrasts with other countries where attractive FIT's promote the uptake of micro-generation technologies. The proof of this is evident from the fact that in Northern Ireland alone there are more installations of wind turbines than in the Republic of Ireland (Irish Wind Energy Association 2010).

The IWEA Discussion Document makes the following recommendations in relation to the financial aspects of micro-generation:

- The level of the feed-in-tariff (FiT) should be increased and paid for all units generated, whether exported or not.
- The rate of the FiT should be increased so that the payback term of a micro-generation unit is reduced to the region of 6-8 years, therefore becoming a more attractive option for users.
- The FiT needs to be available to all customers irrespective of the supply company they use or the type of tariff they are on.

The Programme for Government document released on the 5th March 2011 by the newly elected Fine Gael/Labour Party coalition Government contained the following in relation to FiT's:

"We will provide ReFIT for micro-generators wishing to produce electricity for their own homes, farms and businesses and facilitate them to sell surplus electricity to the grid. The tariff will not be significantly above single energy market price for electricity."

(Department of the Taoiseach 2011)

Based on this statement it is likely that a non-domestic FiT will be introduced in the future. For the purposes of the economic analysis in this study, a FiT of €0.09 per unit of electricity generated for all exported units will be assumed.

2.14 GRID CONNECTION

In a grid connected micro-wind turbine installation the output of the wind turbine is connected to the mains electricity supply at a premises via a controller and inverter. Excess electricity generated can be sent onto the grid while electricity can be drawn from the grid when the turbine is not producing enough electricity to meet site needs.

Form NC6, available to download from the ESB Networks website is used to apply for a grid connection. It should be accompanied with type-test certification for the inverter in conformance with European Standard EN50438.

ESB Networks currently supply an import/export meter free of charge to consumers on submission of form NC6. Such a meter is necessary if it is proposed to export electricity to the grid.

Form NC6 is included in Appendix A.

3 THE SITING OF MICRO-WIND TURBINES

3.1 INTRODUCTION

There are currently no formal guidelines for the siting of micro-wind turbines in Ireland. The SEAI website is a useful resource providing information on all aspects of wind micro-generation but it does not provide a site assessment methodology. The IWEA '*Micro and Small Wind* Generation' (Irish Wind Energy Association 2010) discussion document encourages appropriate site assessment and the development of new site assessment methods for small wind projects. The following extract is taken from the aforementioned IWEA discussion document:

"Annual average wind speed is a key determinant of the financial performance of any wind project. In the case of small wind, full site assessment is expensive relative to the total project costs. We have seen small wind turbine installations at what are clearly poor wind sites (next to buildings, behind trees, etc.), possibly due to over-optimism and/or ignorance on behalf of the supplier or site owner. The resulting poor performance can ultimately tarnish the name of the wind industry."

Wegley (1978) emphasises the importance of the siting of small wind installations stating that "*the greatest cause of dissatisfaction among owners has been improper siting*" and that "*a relatively small investment to locate the best available site can easily yield savings of several thousand dollars over the lifetime of the system.*"

It is clear that the development of guidelines for the siting of micro-wind turbines is a critical step in the development of small wind in Ireland.

3.2 REFERENCE LITERATURE

In the absence of Irish siting guidelines, a literature search was undertaken to identify the most relevant information with respect to the siting of micro-wind turbines internationally. The documents selected, from which information has been abstracted, include:

- A Siting Handbook for Small Wind Energy Conversion Systems – H. L. Wegley, M.M. Orgill and R.L. Drake – United States Department of Energy – 1978.
- Small Wind Turbine Purchasing Guide – Canadian Wind Energy Association,
- Power from the Wind, A Practical Guide to Small Scale Energy Production – Dan Chiras (2009), and
- Windletter Magazine (American Wind Energy Association) – Small Wind Column – Mick Sagrillo.

3.3 FACTORS EFFECTING THE SITING OF MICRO-WIND TURBINES

3.3.1 Available Wind Resource

The most important factor in any wind development project is the wind resource available at a particular site. "*Direct monitoring by a wind resource management system provides the clearest picture of the available resource*" note the authors of the US Department of Energy's booklet, *Small Wind Electric Systems*. They say that, for best results, wind speed should be monitored over a period of at least one year. Chiras (2009) says that the best way to measure wind resources on-site is by using a pole-mounted anemometer located on the site at the height of the proposed wind turbine.

In the absence of direct measurement for reasons of time and/or cost, alternative but less accurate methods for estimating the available wind resource at a particular site

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include using wind maps as outlined in Section 2.11, and also by using natural indicators.

Wegley (1978) refers to the usefulness of natural or ecological indicators in determining site suitability and in particular, the examination of vegetation deformation by high average winds, to estimate average wind speed, and therefore, power at a given site. Flagging is a phenomenon where the branches of a tree permanently stream downwind, like a flag blowing in the wind. The technique is most relevant in coastal areas, in valleys and in mountainous terrain where winds are often highly variable over small areas and difficult to characterise.

A scale known as the Griggs-Putnam Index of Deformity, illustrated in Figure 3.1 (appears in the US Department of Energy's 'Small Wind Electric Systems' publication), is used to estimate the available wind resource.

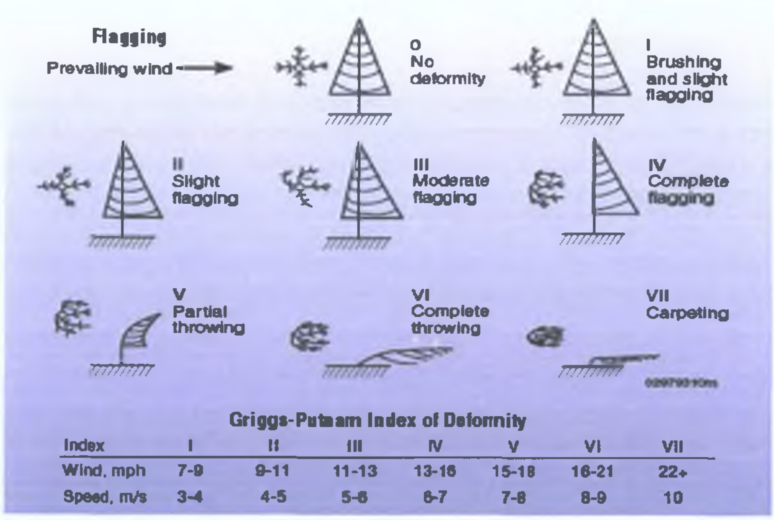

Figure 3.1: Griggs-Putman Index of Deformity

It should be noted that as important as estimating the average wind speed at a site is the estimation of the frequency at which the range of wind speeds occur. This exercise enables more detailed analysis of the potential annual wind generation capability of a turbine and can be extrapolated from available wind data.

3.3.2 Altitude

As distance above sea level increases the speed and the power of the wind also increases. A general rule is that the higher the site is above sea level the more likely it is to have a good wind resource. Furthermore the higher the site is above the immediate surrounding area, a hill for example, the better the wind exposure is likely to be at that location.

3.3.3 Aspect and Obstructions

In Ireland the prevailing winds arrive from a south westerly direction. If there are obstructions in this direction the productivity of the turbine will be reduced. The obstructions, depending on their nature, will either slow down or cause turbulence in the air flow. If a large proportion of the wind during a year is coming from this direction it is clear that the turbine will not be exposed to ideal conditions. If there are similar obstructions in other directions (other than the prevailing wind direction) they would not have as great an impact on the output of the turbine. However it is preferable to have no obstructions close to the turbine in any direction.

Figure 3.2, taken from the Canadian Wind Energy Associations 'Small Wind Turbine Purchasing Guide' publication, illustrates the likely turbulence caused by obstructions such as a house or tree. In the same document the following rule of thumb regarding the micro-siting of wind turbines is provided:

"To optimize performance, the bottom tips of the turbine blades should pass at least three times above the top of any physical barriers within 90 – 150m of the wind turbine tower"

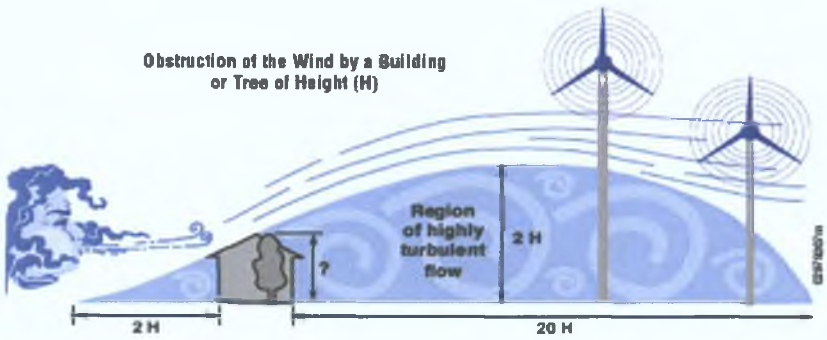

Figure 3.2: Obstruction of the Wind

It should be clear that the more exposed a site is to the wind the cleaner the air flow over the blades and the more productive the turbine will be. The turbine will also demand less maintenance if the air flow is less turbulent. The least desirable location for obstructions is close to the turbine in the direction of the prevailing wind. (SEI, FAQ)

3.3.4 Surface Roughness

Wegley (1978) refers to the effect of the type of surface over which wind flows and the associated effect on wind speed, stating that a rough surface (trees, buildings, etc) will produce more friction than a smooth surface (lake, flat field, etc). The greater the friction the more the wind speed is reduced near the surface. Knowing the surface roughness and its affect on the vertical wind speed profile is valuable when determining tower height.

3.3.5 Terrain Effects

When the site of a proposed micro-wind turbine is in flat terrain, the main issues which must be addressed are determination of surface roughness and the impact of any obstructions. In hilly terrain, topographical features can have a significant effect on airflow, making wind resource assessment more complex.

Wegley (1978) states that in complex (hilly) terrain, topographical features affect airflow on a much larger scale than surface roughness and that when considering the various siting factors and their effects on wind power, topographical features should be considered first, barriers or obstructions second and roughness third.

3.3.5.1 Ridges

Wegley (1978) refers to ridges as *"elongated hills rising from about 500 to 2000ft (150 to 600m) above surrounding terrain and having little or no flat area on the summit."* Siting wind turbines on ridges has the advantages of increased wind speeds at higher altitudes and the fact that airflow generally accelerates over a ridge.

As with smaller obstructions, turbulence can occur on the leeward side of a ridge and so such locations should be avoided if possible.

3.3.5.2 Passes, Gaps and Valleys

Passes, gaps and valleys all have similar characteristics in that they usually occur between ridges or mountains. More accessible than mountainous terrain, airflow can often funnel through these topographic features presenting good wind potential. The orientation of such features in relation to the prevailing wind direction will determine the wind potential with the best results obtained when the pass, gap or valley is parallel to the prevailing wind.

3.4 OTHER FACTORS TO BE CONSIDERED

Other factors which should be considered during the evaluation stage of a micro-wind development project include:

3.4.1 Space

The greater the available space at a site, the greater the options for siting the turbine away from obstructions. Planning regulations state the distances the turbines must be from party boundaries and the noise levels allowable at nearby premises. For a commercial application to be eligible for exemptions from planning requirements the turbine must be its total height plus 5m from the nearest party boundary. It is recommended that consultation with the relevant planning authority take place rather than assuming that planning exemptions are applicable.

When considering space requirements at a site, consideration should be given to the type of turbine tower proposed. While some turbines use unsupported tubular steel poles, others require guy wires incorporating anchor points. Many modern turbines include tilting towers which can be easily raised or lowered for maintenance or repair. The spaced required for this type of turbine will depend on the overall height of the tower and rotor diameter.

During the site assessment it may be discovered by a competent trained assessor that the options for siting the wind turbine are limited by planning exemptions, safety considerations, obstructions and cost of cabling back to the premises. So a substantial parcel of land might just provide one or two small viable areas for construction.

3.4.2 Proximity to nearby residents

Careful consideration must be given to the location of the turbine for safety and planning reasons. The planning requirements outline the limitations with regard distances from dwellings, noise levels, siting near airports and power lines.

A balance must be found between siting the turbine as far away as possible from potential obstructions (buildings, tanks, etc) and minimising cabling costs and line losses in connecting to the control building or premises. The site assessment should encapsulate all of these considerations when choosing an optimal turbine location.

3.4.3 Noise

Technological advances in micro wind turbine design and manufacture mean that most of the sound originating is attributable to aerodynamic noise (Department of the Environment, Heritage and Local Government 2006). In most cases the noise arising is close to ambient noise levels.

The level of noise at your premises or the nearest neighbour's premises (whichever is closer) should not be above 43dB(A) (or 5dB(A) above the background noise). The European Standard in relation to noise testing for wind turbines is EN 61400-11:2003 (Sustainable Energy Authority of Ireland 2010g).

As part of turbine selection, noise should be considered. Most manufacturers will provide information for the noise arising at various distances from the wind turbine.

3.4.4 Visual Impact

The visual impact of a micro wind turbine depends on the height of the tower, the diameter of the rotor, the land use surrounding the turbine (including the presence of trees) and proximity to domestic properties. In most cases visual impact is not a significant issue in relation to micro-wind turbines.

3.4.5 Shadow Casting/Flicker

Shadow flicker occurs when sun shines through rotating wind turbine blades. It can present problems if wind turbines are sited close to residential dwellings. The small diameter and likely location of micro-wind turbines, particularly where they are proposed at water and wastewater treatment plants, greatly reduces the probability of shadow flicker occurring. Therefore in the majority of cases shadow flicker will not be an issue. It should however be considered at feasibility stage.

3.4.6 Impact on Ecology

Although more likely to be an issue relevant to large scale wind development, there is the potential that micro-wind turbines may impact on birds and bats in particular. If there is any evidence that ecology may be a relevant issue, it is recommended that consultation with the National Parks and Wildlife Service, takes place. Evidence of ecology might include the presence of bat roosts, bird nesting areas or badger sets.

3.4.7 Proximity to Archaeological Sites

SI 235 of 2008 Planning and Development Regulations 2008 requires that in order to be exempt from planning, wind turbines must not be within an Architectural Conservation Area. If a proposed turbine location is Architectural Conservation Area, consultation should take place with the relevant authority during the planning process.

3.4.8 Proximity to Airports

SI 235 of 2008 Planning and Development Regulations 2008 requires that where a planned turbine is within 5km of an airport, consent must be sought from the Irish Aviation Authority.

3.4.9 Site Access

Site access must be considered to ensure that all of the equipment associated with the installation of a micro-wind turbine (tower, rotor blades, crane, etc) can be delivered safely to site.

3.4.10 Proximity to Existing Services

Once a site has been selected for a wind turbine every effort should be made to identify existing services both over and underground. Where they exist, as-constructed site drawings should be examined and in all cases the relevant bodies should be consulted. This may include ESB Networks, Eircom and Bord Gais. Consideration should also be given to services along transport routes to the site and in particular to overhead power lines.

3.4.11 Ground Conditions

Ground conditions may have an impact on the feasibility of a wind turbine proposal and will influence the foundation base design. In particular, where soft ground is encountered, it may be appropriate to have plate bearing tests carried out in order to obtain the bearing capacity of the ground which will influence the foundation design.

3.4.12 Electromagnetic Interference

Micro-wind turbines have the potential to produce electromagnetic interference. However this is unlikely to be a significant issue; where problems do arise, it is likely to be highly localised and should be able to be technically overcome. The small diameter of micro-wind turbines limits any potential effects on television and radio reception.

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4 THE DEVELOPMENT OF A FEASIBILITY STUDY TEMPLATE

4.1 INTRODUCTION

In order to examine the feasibility of a micro-wind proposal it is necessary to consider a potential project in detail and to work through a number of steps resulting in an overall determination of feasibility or otherwise. For such an exercise to be valid it must consider all of the aspects which determine feasibility and identify show-stoppers at the earliest possible stage in order to minimise time input and cost, particularly for unfeasible options.

The objective of this chapter is to develop such a template by considering the most pertinent issues arising from the literature review, in the most logical sequence. The feasibility template consists of three parts, a desk study, site study and turbine selection.

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4.2 PART 1 - DESK STUDY

As with larger wind projects and indeed, development projects of any kind, it is recommended that a desk study is undertaken before any site work which is usually where most cost is incurred. Only if the desk study concludes that a project is feasible should site studies be undertaken. By addressing feasibility in this manner, both time input and cost can be minimised. The items which should be considered at desk study stage are:

4.2.1 Determination of Electrical Demand and Turbine Sizing

When considering a micro-wind project it is important to first check if ones electrical demand is both large enough and at the same time, small enough to warrant micro-generation auto-production. If average daily demand is too small or intermittent it is very unlikely that micro-generation auto-production would be economically feasible. Similarly, if average daily demand is too high, it is unlikely that wind micro-generation would have any significant impact in reducing electricity costs.

Average daily electrical demand is best determined from a user's electricity utility bill which includes details of the number of units and associated cost of electricity consumed in a given period, usually two months. From this an average hourly electrical demand can be deduced. Having calculated average electrical demand in kW/h it is the possible to select a wind turbine based on an estimated turbine electrical power output efficiency of 30% as discussed in Section 2.9.

The following example illustrates how average electrical demand and turbine size are calculated:

- Two – monthly electricity bill includes a consumption figure of 4,400 units.
- To convert this to an average hourly consumption, multiply by 6 (one year's consumption) and divide by 365 (to get a daily consumption) and then by 24 (to get an hourly consumption). Based on the example of 4,400 units the average hourly usage works out at 3 units/hour or 3 kW/h.
- Based on a turbine efficiency of 30%, the recommended turbine size for a 3 kW/h electrical demand is a 10 kW turbine.

There are other factors such as cut-in wind speed, rated wind speed and cut-out wind speed (see Section 2.8) which influence turbine choice but turbine selection only becomes an issue if a project is feasible.

4.2.2 Determination of Site Wind Resource

In an effort to keep costs to a minimum at project feasibility stage, the use of on-site wind measurement is considered surplus to requirements. Instead, the available wind maps for Ireland (SEI Wind Atlas) should be used to estimate the available wind resource at a site. This is achieved by first extracting the wind speed at 50m for the site under consideration from the Wind Atlas and then using the conversion equation from Section 2.11, that is:

$$v_2 = v_1 \times (z_2/z_1)^{\alpha}$$

The appropriate wind shear component can be estimated from either local knowledge or by using aerial photography from the Ordnance Survey of Ireland (OSI) website, www.osi.ie. If in doubt a wind shear component of 0.2 should be used at desk study stage.

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If the estimated wind speed at the site under consideration is less than 5 m/s, it is unlikely that wind micro-generation will be a feasible option from an economic perspective.

4.2.3 Examination of Site Topography

Discovery Series mapping which is available from the OSI can be used to carry out an initial topographical examination bearing in mind the factors effecting the siting of turbines as discussed in Section 3.3. Characteristics which might suggest the unsuitability of a site and are easily deciphered from Discovery Series maps include the presence of forestry or tightly packed contours upstream and in the prevailing wind direction of the turbine location indicating hilly or mountainous terrain.

4.2.4 Examination of Aerial Photography

Aerial photography or Ortho mapping is also available free of charge on the OSI website and can be used to identify other features which may affect the siting of a wind turbine including domestic dwellings and/or other buildings which may have implications relating to obstructions, noise, shadow effects, etc.

4.2.5 Miscellaneous Items

Other items which may have an impact on project feasibility include:

- Prevailing wind direction and obstructions
- Local sites of interest (airport, archaeology, etc)
- Extent/verification of site ownership, and
- Service record details (underground/overground)

4.3 PART 2 - SITE ASSESSMENT

If after having undertaken Part 1, the desk study element of the feasibility exercise, a project is still feasible or in some cases marginally feasible, it is appropriate to progress to Part 2, the site assessment element. During the site assessment all of the factors detailed in Sections 3.3 and 3.4 should be investigated. Many of these items do not require detailed investigation unless special circumstances are encountered such as soft ground conditions.

4.4 SUMMARY FEASIBILITY TEMPLATE

Following a review of the various factors which influence the siting of micro-wind turbines and with reference to a number of publications, with a particular focus on factors specific to Ireland, a step by step guide has been compiled which it is hoped will form a standard site assessment methodology for the siting of micro-wind turbines in Ireland.

It is assumed that basic project details are known and recorded in advance of undertaking a feasibility study. Such details should include:

- Site Name,
- Site Address & Coordinates,
- Contact Name and Details, and
- Site Function, for example; water pumping.

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Item	Task Complete
Part 1 - Desk Study (pre site visit)	
Access and if possible obtain relevant mapping from the Ordnance Survey of Ireland (www.osi.ie). It is suggested that Discovery Series and Ortho mapping (aerial photography) be examined/obtained.	
Obtain any available electricity bills to determine average annual, monthly, daily and hourly electricity consumption. If the project relates to a new development, estimate or obtain electrical load information (from electrical designer/contractor)	
From SEI Wind Atlas, obtain average wind speed at 50m. Use formula (with shear factor of 0.2): $v2 = v1 \times (z2/z1)^{\alpha}$ to obtain average wind speed at likely hub heights (i.e. 10m, 15m and 20m)	
Determine prevailing wind direction from Met Eireann wind data.	
Using Discovery Series Mapping, examine site topography for suitability for a wind turbine. (Refer to guidance in Chapter 3)	
From mapping, identify potential obstructions (will be verified at site visit stage).	
Verify extent of site ownership (boundaries) using Land Registry website (www.landdirect.ie).	
Obtain services drawings or as built drawings of site infrastructure. Use "dial before you dig" service (ESB, Eircom, Bord Gais, etc) to identify underground services.	
Is wind turbine within 500m of an airport/airstrip? If yes, consultation with Irish Aviation Authority is required.	
Identify the locations of domestic dwellings from aerial photography.	
Identify the location/s of any archaeological features in the vicinity of the site.	
Determine the electrical supply available at the site, whether single phase or 3-phase. The 3 phase network is available to view on the ESB Networks website. (http://www.esb.ie/esbnetworks/en/about-us/our_networks/index.jsp)	
Prepare for site visit (print out mapping of site and surrounding areas, ensure appropriate equipment (camera, measuring tape, PPE, etc)	

Table 4.1: Feasibility Study – Part 1: Desk Study

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Part 2 – Site Assessment	
Item	**Task Complete**
Travel site access route to determine suitability and identify any potential obstacles (narrow roads/tracks, sub-standard road surfaces, etc)	
Verify locations of nearby domestic dwellings identified in Part 1	
Verify locations and magnitude of any obstructions within 150m of site (buildings, trees, etc)	
Verify the locations of services identified during the desk study stage. Mark up locations of all over ground and where possible, underground services. Ductile iron manhole/valve lids may indicate sewerage/water infrastructure.	
Determine & record ground conditions (as far as possible)	
Check if noise nuisance possible/likely? (domestic dwellings downwind of turbine location)	
Check if shadow casting/flicker possible/likely?	
Record potential visual impact issues.	
Consult with site owner and check for potential impact on habitats (bats, badgers, birds, etc)	
Record the location/s of any local chimney flues	
Based on observation, select appropriate wind shear factor and recalculate estimated average wind speed at hub heights of 10m, 15m and 20m.	
Note any natural features which might indicate a wind speed greater than that calculated or a localised prevailing wind direction (deformed trees).	
Select appropriate potential turbine locations on the site with reference to access, facilitation for raising/lowering turbine, planning, etc. Mark locations on map.	
Based on potential turbine location options, determine distance to proposed inverter location.	
Based on potential turbine location options, determine distance to existing/proposed fuse box and electricity cabinet (containing electricity meter).	
Ensure all details required to make electrical connection application (using Form NC6) are obtained.	

Table 4.2: Feasibility Study – Part 2: Site Assessment

IT Sligo

4.5 PART 3 – TURBINE SELECTION

If the conclusion of a feasibility study is that the site under consideration is suitable for micro-wind then it is appropriate to progress to turbine selection.

Choosing a micro-wind turbine is a potential mine field due to the vast selection of equipment available in the market place. Factors which should be considered include:

- Turbine size (needs to be matched to electrical demand)
- Turbine efficiency (manufacturers specification sheets may over estimate so the importance of reference sites cannot be over stated)
- Tower height options
- Build quality (turbine, blades, tower)
- Method of tower raising/lowering
- Reliability
- Maintenance requirements (and associated cost)
- Local technical back-up
- References

For the purposes of this study, it is not proposed to carry out an extensive turbine selection exercise (detailed market analysis is outside the scope of the study).

When an appropriate wind turbine and tower height have been chosen it is recommended that consultation take place with the planning authority, i.e. the planning section of the relevant local authority, regarding the requirement for planning. If it is concluded that planning permission is required, an application should be progressed.

5 MICRO-WIND FEASIBILITY IN COUNTY GALWAY

5.1 INTRODUCTION

In order to examine the potential for, and feasibility of, wind powered micro-generation auto-production, this study will focus on one particular local authority in Ireland, namely, Galway County Council.

A significant proportion of Galway County Council's (GCC's) annual budget relates to the provision of water services. Based on information provided by GCC it is evident that the energy consumption associated with the operation of water services infrastructure (water/wastewater treatment, water/wastewater pumping, etc) represents 63% of total energy consumption. On an annual basis, Galway County Council consumes approximately 25,733,120 kWh of electricity to power its water services infrastructure with an associated cost of approximately €4 million euro.

In an effort to reduce the extent and cost of the electricity purchased, Galway County Council is in the process of addressing energy efficiency at the various sites which should always be the first step in trying to reduce energy costs. Another potential area where cost savings may be possible is the introduction of renewable energy generation at appropriate locations to meet some of their electricity requirements. The theory is that by auto-producing electricity savings can be made by having to import less electricity from the national grid.

A screening exercise for all water and wastewater infrastructure sites in the county will narrow the focus of this study with the objective being to identify potential sites for micro-wind in the county. From the list of potentially feasible sites, two sites will be selected as case studies for further investigation.

The screening factors for the county scale feasibility exercise are:

- Electrical Demand, and
- Wind Resource Potential

5.2 COUNTY GALWAY WATER SERVICES INFRASTRUCTURE

Galway County Council currently has 180 electrical consumption locations associated with the provision of water services. These relate to water and wastewater treatment and pumping installations with scale ranging from single booster pumps located in kiosks at the side of county roads to large treatment plants. The largest consumer of electricity is the Luimnagh WTP, a key element of the Tuam Regional Water Supply Scheme which provides treated water to a significant portion of County Galway.

Using the MapInfo computer software package and based on information provided by Galway County Council Figure 5.1 illustrates the extent of Galway County Council's water services infrastructure.

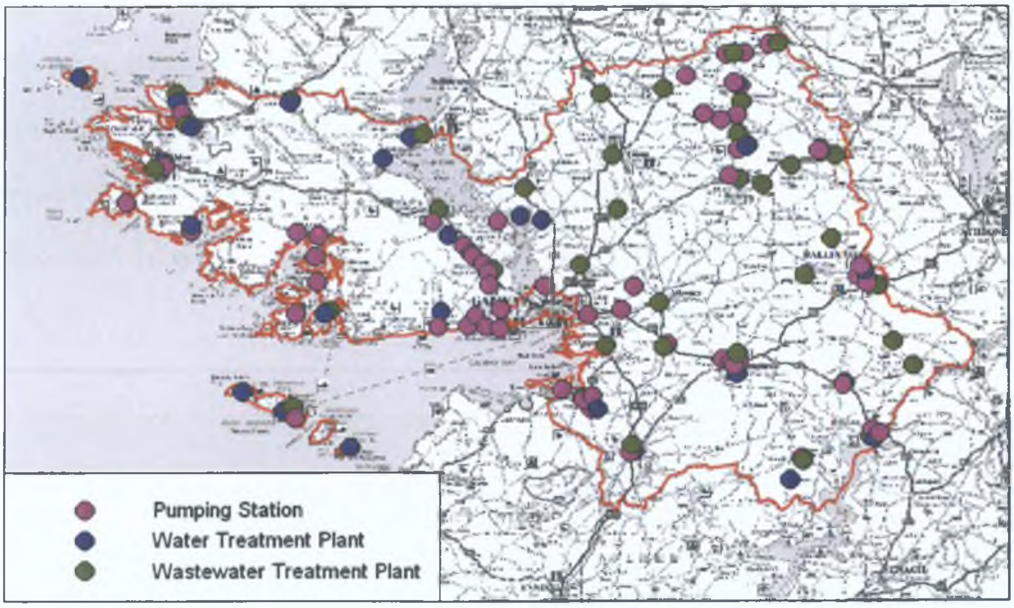

Figure 5.1: Water Services Infrastructure, County Galway

5.3 ELECTRICAL DEMAND

As a first step in screening for potential sites for micro wind it is necessary to decide on a range of electrical demands suitable for micro-wind up to 15 kW. Based on the range of turbines available in the market it is considered that an appropriate range of turbines is from 5 kW up to and including 15 kW machines. Turbines less than 5 kW in capacity would not have a significant enough energy saving potential to warrant the investment by a local authority particularly when there is no REFIT for non-domestic micro-generators.

Based on an estimated turbine efficiency of 30% as detailed in Section 4.2.1, the range of electrical demand associated with a turbine capacity range of 5kW to 15 kW is 1.5 kW to 4.5 kW. For average daily demands larger than 4.5 kW, larger scale wind turbines may be appropriate.

Applying the limit of the 1.5 kW to 4.5 kW range to the 180 electrical consumption locations associated with the provision of water services infrastructure in County Galway, reduces this list to the sites included in Table 5.1.

Location	Infrastructure Type	Annual Consumption (kWh)	Average Hourly Consumption (kW/h)	Wind Resource at 50m (m/s)	Estimated Wind Resource at 15m (m/s)
Glenamaddy	Water Pumping	13,509	1.5	7.5	5.9
Derryrush, Costelloe	Water Pumping	13,714	1.6	7.75	6.1
Kinvara	Water Treatment	13,917	1.6	7.25	5.7
Clarenbridge	Water Treatment	14,788	1.7	7.5	5.9
Parkmore, Tuam	W/water Pumping	15,525	1.8	7.0	5.5
N'town Morris, Tuam	Water Pumping	15,981	1.8	6.75	5.3
Tullyvoheen, Clifden	Water Treatment	16,013	1.8	8.25	6.5
Galway Rd, Tuam	Water Pumping	16,050	1.8	7.0	5.5
Old Galway Rd, Loughrea	W/water Pumping	16,253	1.9	7.25	5.7
Brackernagh, B'sloe	Water Pumping	16,413	1.9	6.75	5.3
Ballyglunin, Tuam	Water Pumping	16,686	1.9	7.0	5.5
Milltown Rd, Tuam	Water Pumping	17,637	2.0	6.75	5.3
Laurencetown	Water Pumping	17,760	2.0	6.75	5.3
Cleaghmore, B'sloe	W/water Pumping	18,106	2.1	6.5	5.1
Tynagh Village	W/water Treatment	18,262	2.1	7.0	5.5
Eyrecourt	Water Treatment	18,448	2.1	6.75	5.3
Rosdubh, Rosmuc	Water Pumping	18,619	2.1	7.75	6.1
Williamstown	W/water Treatment	19,816	2.3	7.5	5.9
Kilconnell, B'sloe	Water Pumping	20,294	2.3	7.0	5.5
Hearnsbrook, Killimor	Water Pumping	21,283	2.4	7.0	5.5
Camp St, O'ard	W/water Treatment	21,410	2.4	7.5	5.9
Castlelambert	Water Pumping	21,725	2.5	7.25	5.7
Keekil	Water Pumping	24,550	2.8	7.0	5.5
Craughwell	Water Pumping	26,048	3.0	7.25	5.7
Mountbellew	W/water Treatment	27,347	3.1	6.75	5.3
Williamstown	Water Pumping	27,451	3.1	7.25	5.7
Poolboy, B'sloe	W/water Pumping	27,638	3.2	6.75	5.3
Ahascragh, B'sloe	Water Pumping	28,131	3.2	6.75	5.3
Cleggan/Cladaduff	Water Treatment	29,490	3.4	9.0	7.1
Inis Oirr	Water Treatment	31,701	3.6	9.0	7.1
Bunowen Rd, B'sloe	Water Pumping	31,936	3.6	6.75	5.3
Tully	Water Pumping	320,85	3.7	8.75	6.9
Killimor, B'sloe	W/water Treatment	33,762	3.9	7.0	5.5
Cornamona	Water Pumping	35,576	4.1	6.75	5.3
Clifden	Water Pumping	38,403	4.4	8.0	6.3

Table 5.1: Water Service Infrastructure (1.5 kW to 4.5 kW range)

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5.4 WIND RESOURCE

Included in the last two columns of Table 5.1 is the wind resource information for each of the 35 sites included. As detailed in Section 4.2.2, the wind speed at a given location is estimated using the information contained in the SEI Wind Atlas. Each of the 35 sites was overlaid on the 50m wind speed map, as illustrated in Figure 5.2.

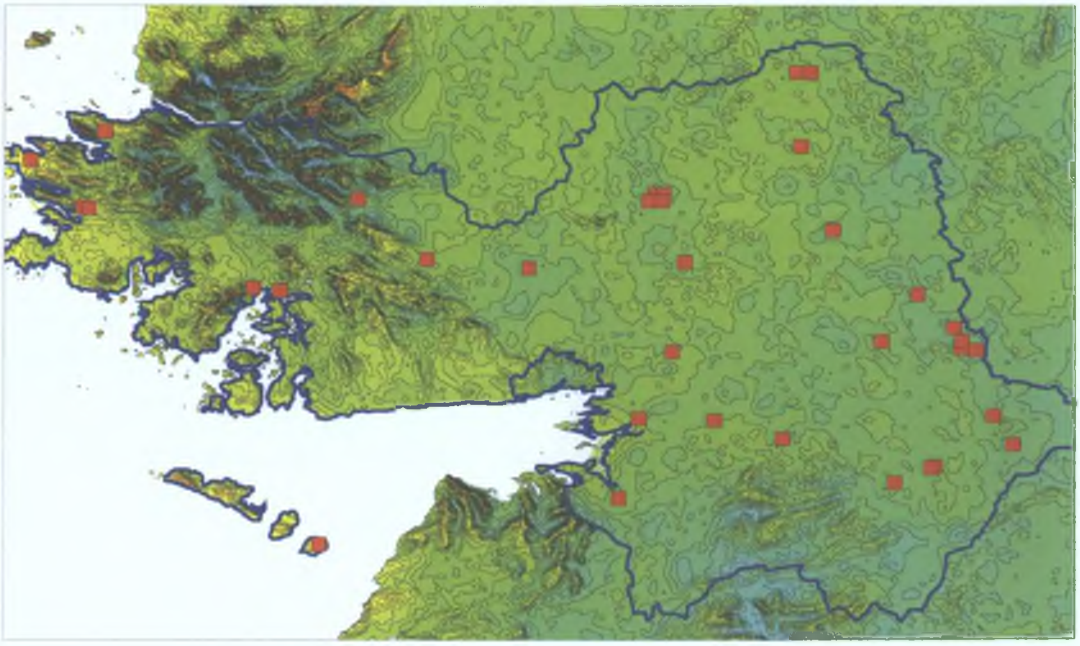

Figure 5.2: Shortlisted Sites and Associated Wind Speeds at 50m

These 50m wind speeds were then converted to 15m wind speeds using the formula referred to in Section 4.2.2 with a wind shear factor of 0.2 used in all cases (appropriate for desk study stage).

As stated in Section 4.2.2, the minimum wind speed considered feasible for effective wind micro-generation is 4.5 m/s. All of the 35 sites included in Table 5.1 meet the minimum wind speed criterion and so are theoretically feasible for micro-wind development.

5.5 CONCLUSION

The desk study undertaken in this Chapter reveals that of the 180 publicly operated water services infrastructure sites in County Galway, 35 are deemed to be theoretically feasible as potential micro-wind sites. A case study will examine one of these sites in greater detail with the objective of proving the validity of the feasibility study template developed in Chapter 4.

It should be emphasised that the feasibility methodology undertaken uses average wind speed data derived from the 2003 SEI Wind Atlas. In order to achieve more accurate wind speed data at a particular site, some form of on-site wind measurement would be required.

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6 CASE STUDY

6.1 INTRODUCTION

Having identified a number of potentially feasible micro-wind projects in Chapter 5 (Table 5.1) and with the objective of proving the feasibility study template developed in Chapter 4, this chapter includes a case study. One location was selected at random from Table 5.1. The case study relates to the Kinvara Public Water Supply Scheme (PWSS) located in South County Galway.

6.2 KINVARA PWSS

Kinvara is a popular coastal tourist village located at the head of Kinvara Bay and the edge of the Burren in South County Galway.

The public water supply scheme is fed from two groundwater boreholes in the townland of Loughcurra South. Raw water is chlorinated and fluoridated and pumped to a storage reservoir in the townland of Northhampton. It then enters the distribution network and the supply regime includes gravity and pumped supply. As well as serving the village of Kinvara, the public water supply scheme serves a large rural network including group water schemes.

In order to address treated water quality concerns on the scheme, a new water treatment plant is under construction at the reservoir site at Northampton. Once complete, the existing limited treatment (chlorination and fluoridation) at the Loughcurra South source site will be decommissioned. The existing borehole pumps and electrical controls will be maintained at Loughcurra South. This case study examines the feasibility of employing a micro-wind turbine at Loughcurra South to provide some of the power required to pump raw water from the boreholes, via a rising main to the new WTP at Northampton.

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Figure 6.1: Kinvara PWSS Raw Water Source at Loughcurra South (image Authors own)

6.3 PART 1 – DESK STUDY

Item	**Task Complete**
Part 1 - Desk Study (pre site visit)	
Access and if possible obtain relevant mapping from the Ordnance Survey of Ireland (www.osi.ie). It is suggested that Discovery Series and Ortho mapping (aerial photography) be examined/obtained.  The location of the site under consideration is indicated by the red square on the mapping above and at the point indicated on the Ortho mapping below.	YES

<table>
<tr><td></td><td></td></tr>
<tr><td>Obtain any available electricity bills to determine average annual, monthly, daily and hourly electricity consumption.

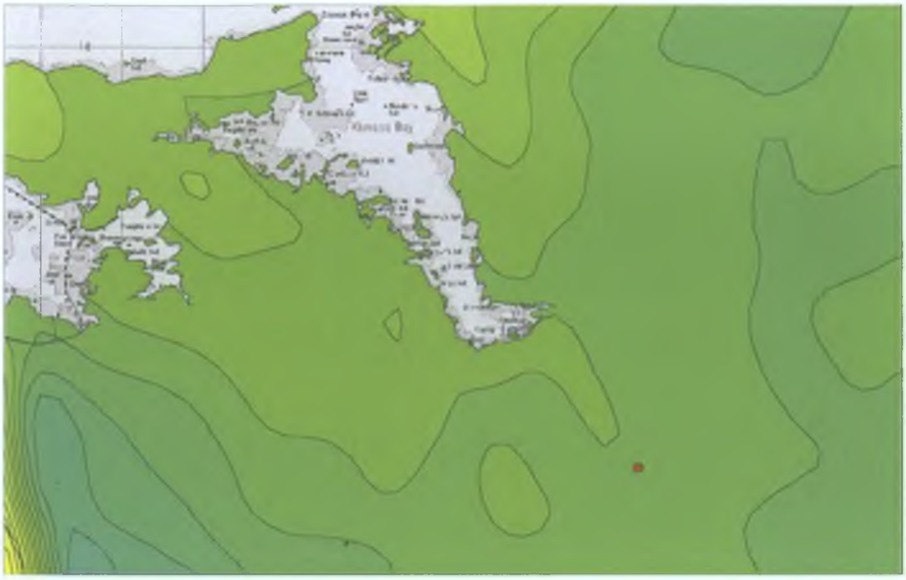
If the project relates to a new development, estimate or obtain electrical load information (from electrical designer/contractor)

Table 5.1 includes the relevant electrical demand information. The electrical demand associated with the Kinvara raw water borehole pumping arrangement is as follows:

• Annual Electrical Consumption: 13,917 kWh

Records kept by the Kinvara PWSS indicate that the borehole pumps operate almost 24 hours per day which is an ideal profile for an auto-production project. Based on this fact, the average hourly electrical consumption is 1.6 kW per hour.</td><td>YES</td></tr>
<tr><td>From SEI Wind Atlas, obtain average wind speed at 50m. Use formula (with shear factor of 0.2): $v2 = v1 \times (z2/z1)^{\alpha}$ to obtain average wind speed at likely hub heights (i.e. 10m, 15m and 20m)

The 50m wind map for the proposed site is as below:</td><td>YES</td></tr>
</table>

<table>
<tr>
<td>


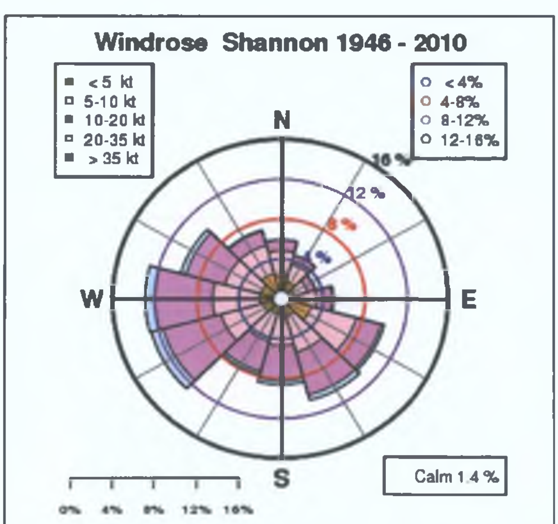
The wind map gives a 50m wind speed of 7.25 m/s.

Using the formula above with a shear factor of 0.2 results in wind speeds as follows:

- 10m hub height wind speed: 5.25 m/s
- 15m hub height wind speed: 5.70 m/s
- 20m hub height wind speed: 6.04 m/s

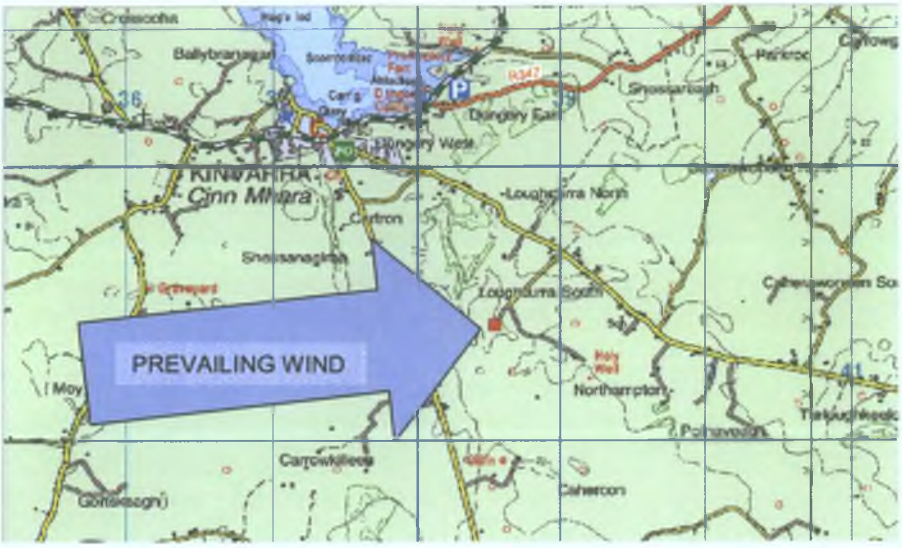
The estimated wind speeds are feasible for micro-wind development.
</td>
<td></td>
</tr>
<tr>
<td>
Determine prevailing wind direction from Met Eireann wind data.

The nearest Met Eireann weather station with the relevant wind data is Shannon Airport, located 47km south of Kinvara. The wind rose for this location is shown below:



</td>
<td>YES</td>
</tr>
</table>

<table>
<tr>
<td>The available information shows that the prevailing wind is almost directly westerly in direction. Applying this wind direction to the Kinvara site is illustrated below:

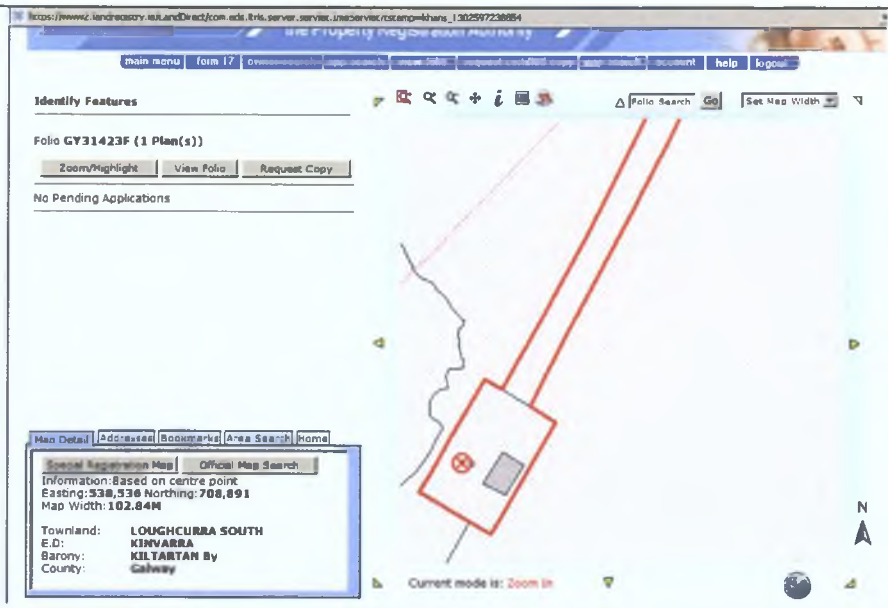


The prevailing wind direction is important when determining obstructions and their relative effect on the site wind resource.</td>
<td></td>
</tr>
<tr>
<td>Using Discovery Series Mapping, examine site topography for suitability for a wind turbine.
(Refer to guidance in Chapter 3)

The discovery mapping indicates relatively flat topography (no tightly spaced contour lines). None of the features detailed in Section 3.3.5 (ridges, passes, etc) are evident.</td>
<td>YES</td>
</tr>
<tr>
<td>From mapping, identify potential obstructions (will be verified at site visit stage).

No obvious obstructions can be identified from either the mapping or the aerial photography. There are no buildings within 150m of the site boundary.</td>
<td>YES</td>
</tr>
<tr>
<td>Verify extent of site ownership (boundaries) using Land Registry website (www.landdirect.ie).

The extent of the land holding owned by Galway County Council at Loughcurra South is shown outlined in red below. This information will be used during the site visit to determine if there is enough available space at the site for a micro-wind turbine.</td>
<td>YES</td>
</tr>
</table>

 	
Obtain any available services drawings or as built drawings of site infrastructure. Use "dial before you dig" service (ESB, Eircom, Bord Gais, etc) to identify underground services. The relevant enquiries were made and findings are summarised as follows: • Gas: There is no gas network in the vicinity of the site. • Telecoms: There is no telecoms infrastructure in the vicinity of the site. • Water: As Built drawings were obtained from Galway County Council. These clearly show the routes of all water pipelines and chambers present. • Wastewater: There is no wastewater infrastructure in the vicinity of the site. • Electricity: ESB's "Dial before you Dig" service was used. A drawing was provided by ESB Networks showing the extent of their infrastructure at Loughcurra South. There is an overhead power line running to the site but it terminates outside the site boundary. The details are included in Appendix B. The extents of the services identified should be verified at site visit stage.	YES
Is wind turbine within 500m of an airport/airstrip? If yes, consultation with Irish Aviation Authority is required if project progresses. There is no airport/airstrip within 500m of the site.	YES
Identify the location/s of any archaeological features in the vicinity of the site. The area surrounding the Kinvara site is rich in archaeology. There is no archaeology within the site. The nearest archaeological features are identified below with the information taken from the "Sites and Monuments" database. The locations of the records identified should be considered if site extension is an option.	YES

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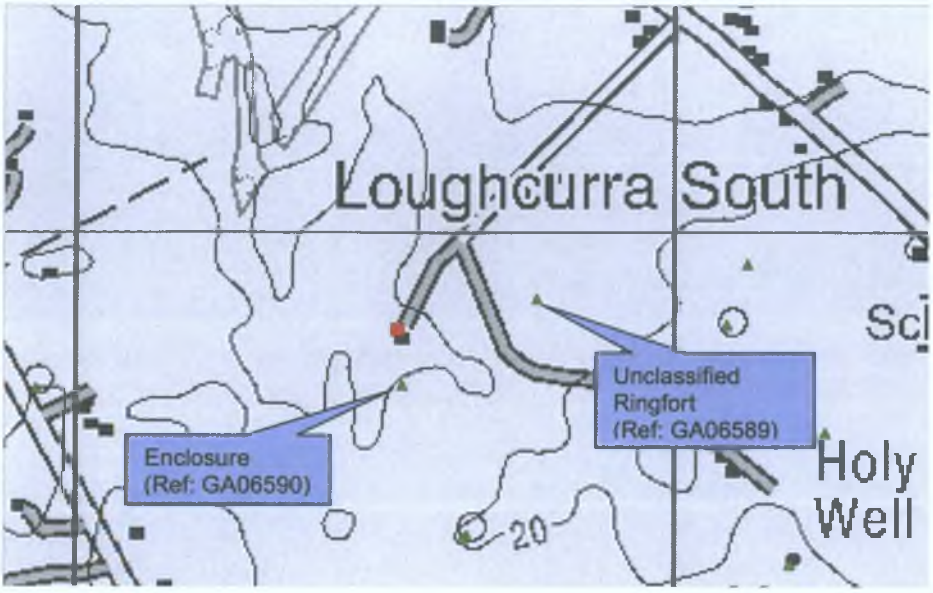
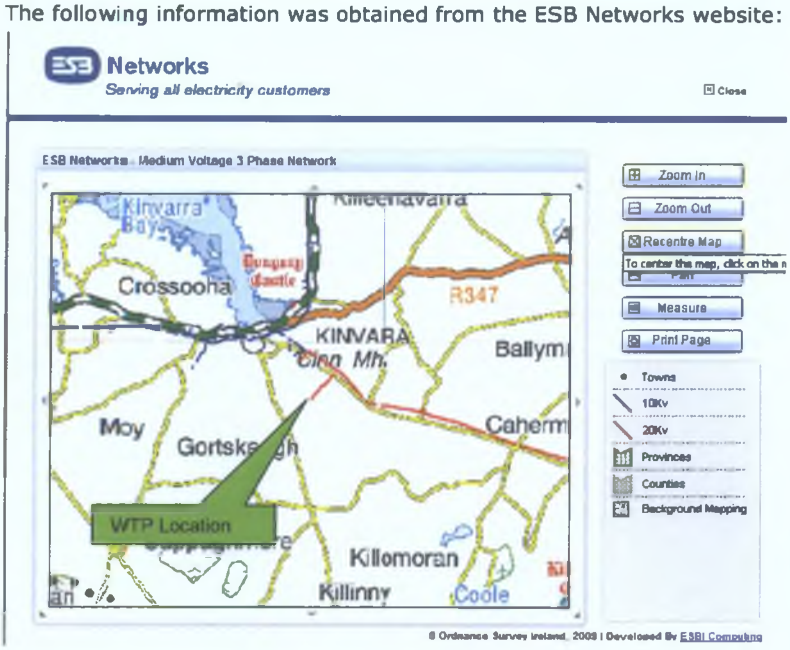
<tr>
<td>
</td>
<td></td>
</tr>
<tr>
<td>Determine the electrical supply available at the site, whether single phase or 3-phase. The 3 phase network is available to view on the ESB Networks website.

(<u>http://www.esb.ie/esbnetworks/en/about-us/our_networks/index.jsp</u>)

The following information was obtained from the ESB Networks website:



The ESB Networks information shows that the Loughcurra South site is served by a 3-phase 20 kV electrical supply.</td>
<td>YES</td>
</tr>
</table>

Site Coordinates (from Discovery Mapping) 138,550 (Easting), 208,820 (Northing)	YES
Prepare for site visit (print out mapping of site and surrounding areas, ensure appropriate equipment (camera, measuring tape, PPE, etc)	YES

6.4 PART 2 – SITE ASSESSMENT

A site visit was undertaken on the 12th of April in order to carry out the site assessment element of the feasibility study.

Part 2 – Site Assessment	
Item	**Task Complete**
Travel site access route to determine suitability and identify any potential obstacles (narrow roads/tracks, sub-standard road surfaces, etc) Access to the site is via the county road network, a 500m long 4m wide surfaced road and a 200m long 4m wide gravel surfaced access road. Access to the site is good with no constraints identified.	YES
Verify locations of nearby domestic dwellings identified in Part 1 The nearest dwellings is located 520m north of the site and 515m west of the site. The wind turbine will have no adverse effects (shadow flicker, noise, etc) on the nearest dwellings.	YES
Verify locations and magnitude of any obstructions within 150m of site (buildings, trees, etc) There is a 5m high small control building on the site of the proposed turbine. There are no significant trees (other than hedgerow) within 150m of the site. There is a 5m high cliff located approximately 100m south and west of the site. In order to avoid any obstruction effects a 15m hub height is recommended. Positioning the turbine rotor at 15m will greatly lessen the effect of any turbulence arising.	YES
Verify the locations of services identified in during the desk study stage. Mark up locations of all over ground and where possible, underground services. Ductile iron manhole/valve lids may indicate sewerage/water infrastructure. The services encountered on site do not differ from the service drawings obtained.	YES

Determine & record ground conditions (as far as possible) The Loughcurra South site is situated in a limestone region with very little soil cover. The proposed location of the wind turbine consists of flat limestone with approximately 300mm soil cover. These ground conditions will provide a solid base for the turbine foundation.	YES
Check if noise nuisance possible/likely? (domestic dwellings downwind of turbine location) Noise nuisance unlikely due to large distance (>500m) to nearest dwelling. Will depend on the wind turbine choice. Check again during turbine selection stage.	YES
Check if shadow casting/flicker possible/likely? No domestic dwellings close enough to be affected.	YES
Record potential visual impact issues. No properties overlooking site. Site not in the line of sight of any protected views. Conclusion is that there are no visual impact issues.	YES
Consult with site owner and check for potential impact on habitats (bats, badgers, birds, etc) Galway County Council caretaker consulted. No evidence of any potential impact on habitats.	YES
Record the location/s of any local chimney flues. No flues in vicinity of site.	YES
Based on observation, select appropriate wind shear factor and recalculate estimated average wind speed at hub heights of 10m, 15m and 20m. Site contains grass and hard surfaces. Surrounding fields are low grass and a seasonal lake (turlough). Most appropriate shear factor from Table 2.2 is 0.15. Using the relevant formula with a shear factor of 0.15 results in revised wind speeds as follows: • 10m hub height wind speed: 5.69 m/s • 15m hub height wind speed: 6.05 m/s • 20m hub height wind speed: 6.32 m/s	YES
Note any natural features which might indicate a wind speed greater than that calculated or a localized prevailing wind direction (deformed trees). None present.	YES
Select appropriate potential turbine locations on the site with reference to access,	YES

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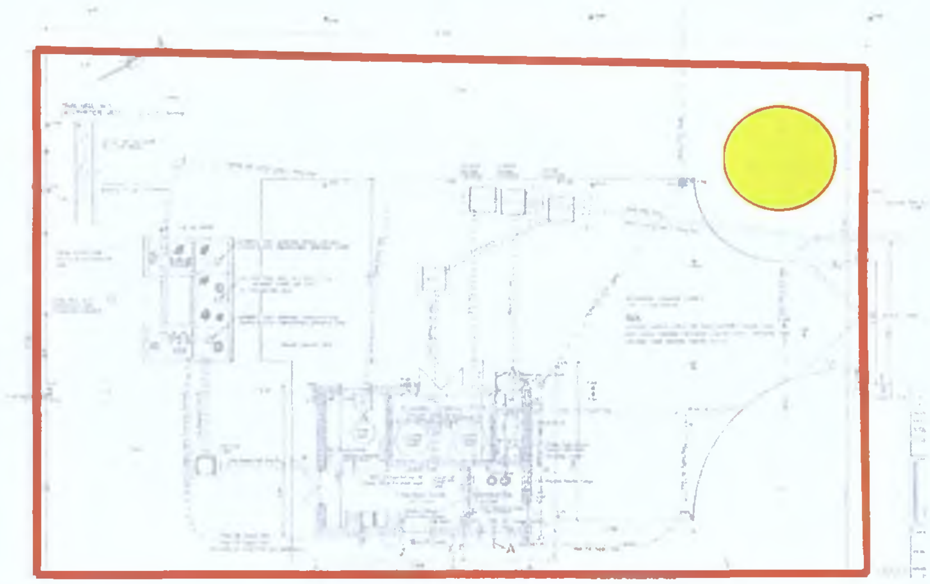
facilitation for raising/lowering turbine, planning, etc. Mark locations on map. The following figure is an extract from the As Built Drawings for the Kinvara PWSS source site at Loughcurra South. The site boundary is outlined in red and the proposed turbine location identified by the yellow circle.  The location chosen avoids existing site services and facilitates the operation of raising/lowering a tilt tower. In addition, the proposed turbine position minimises the effect of obstructions in the direction of the prevailing wind.	
Based on potential turbine location options, determine distance to proposed inverter location. Distance to inverter = 15m.	YES
Based on potential turbine location options, determine distance to existing/proposed fuse box and electricity cabinet (containing electricity meter). Distance to existing electrical control panel = 15m	YES
MPRN No. for Existing Connections MPRN No. = 10015838609	YES
Ensure all details required to make electrical connection application (using Form NC6) are obtained.	YES

6.5 PART 3 – TURBINE SELECTION

The conclusion of Parts 1 and 2 of the feasibility for a micro-wind turbine on the Kinvara PWSS is positive. The feasibility desk and site studies undertaken suggest that, in theory, the site at Loughcurra South is suitable for a micro-wind turbine.

The next stage involves the selection of an appropriate turbine and the economic analysis of the selection made.

As stated in Section 4.5, the detailed analysis and selection of a turbine from the extensive range of micro-wind turbines available on the market is outside the scope of this study. Instead a turbine will be selected from one of two of the more popular turbine manufacturers operating in Ireland, an Irish company called C&F Green Energy and a Scottish company called Proven Energy.

Based on the electrical demand characteristics of the Loughcurra South site with an average hourly electrical consumption is 1.6 kW per hour, and on the assumption that any turbine proposed will have an efficiency of 30%, the most appropriate turbine models are as follows:

- C&F Green Energy: Model – Proven 11 (5.2 kW rated power)
- Proven Energy: Model – CF 6e (6 kW rated power)

The Specification sheet for each turbine is included in Appendix C.

Using the power curve for each turbine it is possible to obtain the theoretical energy output. As stated in Section 2.8, caution should be exercised when using manufacturer's power curves which will always relate to ideal conditions, which are in practice unlikely to occur in reality.

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6.5.1 C&F Green Energy – Model CF 6e

The power curve for the CF 6e is illustrated in Figure 6.2.

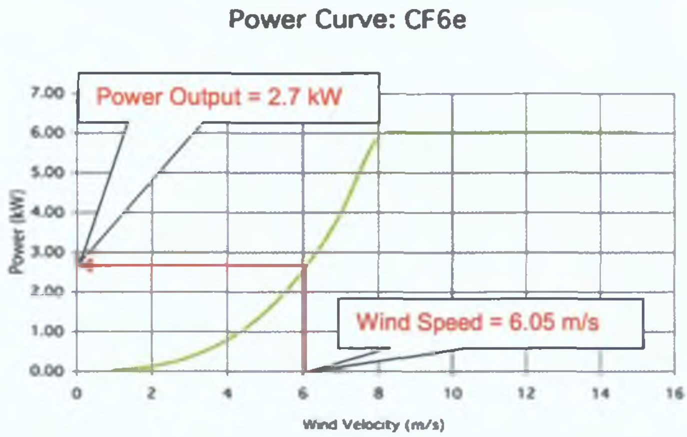

Figure 6.2: C&F Green Energy CF6e Power Curve (C&F Green Energy 2011)

In Part 2 (Site Assessment), site specific estimated average annual wind speeds were calculated for a number of hub heights. The relevant hub height for the CF6e is 15m (see specification sheet in Appendix C). The associated wind speed is 6.05 m/s.

Using the power curve in Figure 6.2, the power output based on a wind speed of 6.05 m/s is 2.7 kW. To put it simply, if the wind speed is 6.05 m/s, a CF6e turbine at Loughcurra South will generate 2.7 kW of electricity per hour. This equates to an annual energy production of 23,652 kWh per year.

6.5.2 Proven Energy – Model Proven 11

The power curve for the Proven 11 is illustrated in Figure 6.3.

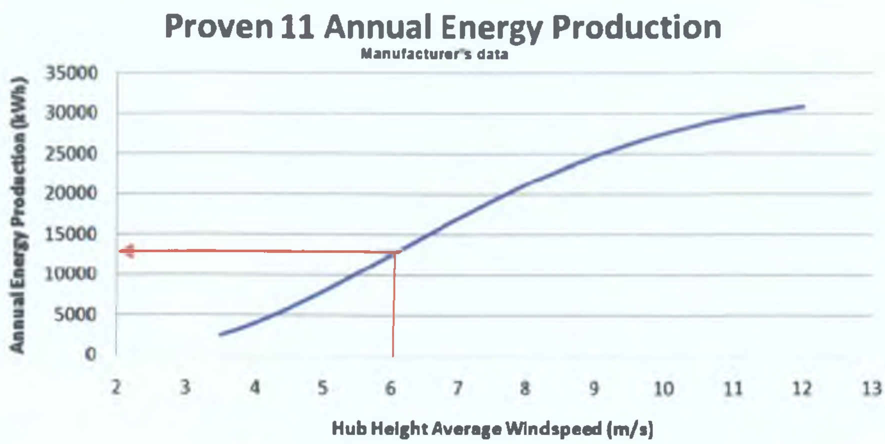

Figure 6.3: Proven 11 Power Curve (Proven 2011)

Using the power curve in Figure 6.3, the power output based on a wind speed of 6.05 m/s equates to an annual energy production of 13,000 kWh per year.

It should be noted that the estimated annual energy production is theoretical only and is based on average wind speeds as obtained from the 2003 SEI Wind Atlas. The calculation does not factor in the frequency distribution for particular wind speeds.

Another method of estimating annual energy production, as detailed on the Renewable UK website (www.bwea.com/edu/calcs.html) includes the use of the following formula:

Electricity Produced = B x 0.3 x 8760

Where, B = the rated capacity of the wind turbine in kW,

0.3 = a capacity factor which takes into account the intermittent nature of wind and the various losses, and

8,760 = the number of hours in a year.

Using the above formula, the annual energy production for the CF6e turbine is 13,666 kWh/year and for the Proven 11 turbine is 15,768 kWh/year.

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It can be seen that the Renewable UK energy production estimation method differs greatly from the power curve analysis undertaken. A shortcoming of this estimation method is the fact that it ignores the rotor diameter and the associated wind swept area.

The reality is that the actual energy production for the two turbines lies somewhere between the values estimated and that in order to achieve more detailed and non theoretical estimates, on-site wind speed monitoring would be required.

For the purposes of illustration, the values of annual energy production obtained from the power curve analysis will be used.

6.5.3 Turbine Comparison

Turbine	Annual Energy Production (kWh)	Kinvara PWSS Electrical Demand (kWh)	Surplus/Deficit of Power Generated (kWh)	Rotor Diameter (m)
CF6e	23,652	13,917	+9,315	8.0
Proven 11	13,000	13,917	-917	5.5

Table 6.1: Turbine Comparison

It is seen from Table 6.1 that while the C&F turbine theoretically produces far in excess of the required electricity required, the Proven turbine does not produce the minimum required electrical demand. The main reason for the difference in energy production relates to the different rotor diameters.

6.6 ECONOMIC ANALYSIS

Although, the C&F turbine would appear to be the preferred choice based on performance, economic analysis is required to determine which turbine provides the best value for money.

While prices were sought from both Proven and C&F Green Energy, only C&F responded with a quotation, based on the information supplied in relation to the Kinvara site. The all in price (materials, civil and electrical installation and commissioning) for the CF6e is €29,680 excluding VAT.

The quotation provided will be used to undertake economic analysis of micro-wind versus the alternative which is the purchase of electricity from the network.

A number of assumptions are made as follows:

- Annual electrical consumption figure of 13,917 kWh is split evenly between day and night use.
- Electricity Charges are based on the ESB's Statement of Charges Document for 2011 (ESB 2011). The applicable rates are €0.366 per kWh (day) and €0.056 per kWh (night) with no standing charge or capacity charge applicable.
- A non-domestic Feed in Tariff of 9c per kWh will apply for all excess electricity exported to the national grid (based on the Fine Gael/Labour Government's Programme for Government (Department of the Taoiseach 2011).
- Annual maintenance of the turbine is €750 (based on information provided by manufacturer).
- No provision is made for the likely year on year increase in energy prices. Such detailed cost scenario predictions are outside the scope of this study.

Table 6.2 includes the constituents and associated financial information to enable a simple economic analysis.

Description	Amount
Annual Electrical Consumption	13,917 kWh
Associated Cost (assuming power purchase from ESB) Day Rate: 6,958.5 kWh x €0.366 Night Rate: 6,958.5 kWh x €0.056 Total Cost	 €2,546.81 €389.68 €2,936.48 (A)
Annual Energy Production from Wind Turbine	23,652 kWh
Surplus of Production over consumption	9,735 kWh
Value of Exported Surplus (€0.09 per kWh)	€876.15 (B)
Annual Turbine Maintenance Cost	€750.00 (C)
Annual Cost Saving with Turbine (A + B - C)	€3,062.63 (D)
Capital Cost of Turbine (excl VAT)	€29,680.00 (E)
Payback Period (E / D)	9.7 Years

Table 6.2: Economic Analysis

The analysis undertaken suggests a payback period of 9.7 years. Based on a 25 year life span (as stated by the turbine manufacturer), the investment made would appear to represent an excellent return on investment. As stated previously, more detailed economic analysis including energy price increases would result in an even shorter payback period.

6.7 EFFECT OF FEED IN TARIFF

The economic analysis undertaken in Section 6.6 included a feed in tariff (FIT) rate of 9c per unit of electricity exported to the grid. This figure was assumed at a very low level based on the current FIT rate available to domestic micro generators in Ireland. Table 6.3 includes the FIT rates available to other European countries as included in the IWEA's Micro and Small Wind Generation Discussion Document. It is included in this study to demonstrate the differences which exist and the effect that these have on the payback period of the example included in Section 6.6.

Country	Feed in Tariff Rate (rate / per kWh)	Conditions	Payback Period (based on example provided in Section 6.6)
Ireland	€0.09 [1]	N/A[1]	9.7 years
UK/ N Ireland	€0.0275 - €0.393 [2 and 3]	For all units generated	3.0 years
Germany	€0.57	Exported Units (for 20 yrs)	3.8 years
Portugal	€0.45	Exported Units	4.5 years
Spain	€0.44	Exported Units	4.6 years
France	€0.58	Exported Units	3.8 years
Italy	€0.44	Exported Units	4.6 years

Notes:

1: Based on an assumed FIT. No non-domestic FIT currently available.

2: Converted from pounds sterling (£0.241 - £0.345) at exchange rate of EUR 1 = GBP 0.87705 on 20/05/2011

3: FIT depends on micro-generator capacity. For a 6kW wind turbine appropriate FIT = £0.28 (= €0.32)

Table 6.3: Feed in Tariff Comparison

It is clear from Table 6.3 that Ireland must first of all provide a FIT rate for non-domestic micro-generators and secondly must provide a comparable rate to our European counterparts if the development of wind micro-generation is to be facilitated in Ireland.

6.8 CASE STUDY CONCLUSION

The case study undertaken suggests that in general, the development of a micro-wind turbine at Loughcurra South site is a feasible. The principle features of the site which make it feasible are:

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- The available wind resource,
- A constant electrical demand profile of sufficient quantity,
- The site topography,
- The lack of obstructions

The main constraint is likely to be the available site area which is inadequate with respect to the requirements of SI 235 of 2008 Planning and Development Regulations 2008. This means only that the proposed turbine is not exempt from planning permission. Possible solutions to overcome the area constraint include the purchase of additional land adjacent to the site or alternatively a long term agreement with the adjacent landowner.

From an economic perspective, the development of a micro-wind turbine at Loughcurra South is financially feasible with an estimated payback period of just under 10 years.

7 CONCLUSIONS & RECOMMENDATIONS

7.1 CONCLUSIONS

This study illustrates the potential for the use of micro-wind auto-production to provide some of the electricity requirements of water services infrastructure in County Galway.

The first element of the study involved background research into the theory and technology of wind with an emphasis on micro-wind. The factors affecting the feasibility of a micro-wind project were then investigated.

The second element of the study examined the areas of site assessment and site specific wind resource assessment. It involved the development of a feasibility template to act as a site assessment tool for micro-wind projects. This, according to the Irish Wind Energy Association is an area which was lacking in guidance.

The third element of the study investigated the potential for micro-wind development to power water services infrastructure in County Galway identifying 35 potential sites out of a possible 180 sites throughout the county.

The final element involved the development of a case study to prove the value of the feasibility (site assessment) template developed. A site, part of the Kinvara Public Water Supply Scheme, was selected at random from the list of 35 potential sites and the feasibility template was used to examine the potential for micro-wind development at that site.

It can be concluded that the feasibility template as developed has the potential to be a useful tool for anyone, whether a domestic, agricultural or commercial electricity consumer, considering installing a micro-wind turbine on their site. It is hoped that by using such a template, those considering micro-wind will avoid siting turbines in unsuitable sites which is the main reason for poor turbine performance.

It can also be concluded that there is potential for the use of wind micro-generation at water and wastewater infrastructure sites not only in County Galway, but throughout the country. Although not investigated in this study, the potential for the exploitation of wind to power more diverse (telecoms masts, etc) electricity consuming infrastructure would appear to be significant, particularly bearing in mind the likely future electricity price increases.

The economic analysis undertaken concludes that the likely payback period for a wind micro-generation is much higher in Ireland than is the case internationally and that in order to facilitate the development of the micro-generation industry in Ireland, appropriate feed in tariff rates are required. Without the appropriate feed in tariff structure micro-wind generation will not develop to any significant extent as it has done, for example, in the United Kingdom.

7.2 RECOMMENDATIONS

Arising from this study it is recommended that the micro-wind feasibility template is placed in the public domain via the Irish Wind Energy Association or the Sustainable Energy Authority of Ireland. By doing so, guidance will be available to anyone considering the development of a micro or small wind project.

Following the installation of a micro-wind turbine at a water or wastewater infrastructure site, a study should be undertaken to analyse and monitor the performance of the turbine in order to:

- Verify the available wind resource at the particular site,
- Measure the contribution that the turbine makes towards the annual electricity demand, and
- Compare actual electrical power output from a turbine to theoretical power output.

This study only addressed the feasibility of wind micro-generation. It may be appropriate to investigate the feasibility of alternative micro-generation technologies or hybrid micro-generation technologies.

Of the 180 water services infrastructure sites in County Galway, only 35 or 19.5% were potentially suitable for wind micro-generation, from an electrical demand perspective. Other sites with larger electrical demands, both in County Galway and throughout the country, may be appropriate for larger scale wind turbines. The potential of powering the larger sites should be investigated with detailed economic analysis carried out to determine potential cost savings to local authorities and ultimately to the taxpayer.

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APPENDIX A – ESB NETWORKS FORM NC6

Form NC6

ESB Networks Serving all electricity customers

For Official Use Only
Notification No:
MPRN:

MICRO-GENERATION NOTIFICATION FORM

INTRODUCTION

This notification form outlines the information ESB Networks Ltd. requires about any Micro-Generation unit connecting to the Electricity Distribution System.

This form is for Micro-Generation in a one off connection with a maximum output of 6kW single phase and 11kW three phase. For larger generators and for planned multiple installations please complete either NC5 or NC5A generator application forms. For more details please see http://www.esb.ie/esbnetworks/download_documents/index.jsp.
It is important to enclose copies of the Interface Compliance Test Certi cation of the proposed equipment.
It is the owner's responsibility to ensure that the micro-generation unit and interface complies with "Conditions Governing Connection and Operation of Micro-Generation" and that the installation complies with ETCI standards.

When the noti cation form is fully completed please send the form and all available certi cation documentation to:

Micro-Generation Notification,
ESB Networks Ltd.,
P.O. Box 29,
Garrycastle,
Athlone,
Co. Westmeath

IT Sligo

MICRO-GENERATOR NOTIFICATION FORM

Please return this form to:
Micro-Generation Notification
ESB Networks Ltd., P.O. Box 29,
Garrycastle, Athlone, Co. Westmeath

Please fill in all sections in BLOCK CAPITALS

Site Details:	Site Name:
	Site Address: ______________________
	Site Co-ordinates: Easting: Northing:

Applicant Details:	Full Name of the applicant: ______________________
	Address of the applicant: ______________________
	Number (If available)
	Telephone No. Mobile:
	Email Address:
	Installer/Consultant: Phone No:

Micro-generation Interface details		Unit 1	Unit 2	Unit 3
	Micro-generation interface unit manufacturer/ model/type			
	Serial number of micro-generator interface unit			
	Are interface protection settings as per Table 1 in "Conditions Governing the Connection and Operation of Micro-generation?			

Micro-generator details		Unit 1	Unit 2	Unit 3
	Micro-generator details			
	Micro-generation rating (kVA)			
	Single or multi-phase			
	Type of prime mover and fuel source [wind, solar, micro-CHP, diesel. if others specify]			

Form NC6

ESB Networks Ltd.
Directors: Bernard Byrne Des Geraghty Gina Quin John Redmond Luke Shinnors
Registered office: Clanwilliam House, Clanwilliam Place, Dublin 2, Ireland. Registered in Ireland No. 465172

APPENDIX B – ESB SERVICES CONSULTATION INFORMATION

Address: **RPS Consulting Engineers Ltd.** **Date:** **19-Apr-11**

Re ESB Networks: **Loughcurra Sth, Galway** **Our Ref: 2011/04/19-007**

Dear Colm

I thank you for your recent enquiry regarding networks at the above location. Enclosed are drawings indicating the approximate location of ESB underground (UG) cables and overhead (OH) lines.

ESB makes no representation that the drawings accurately show the location of ESB cables. We have enclosed booklets called 'Avoidance Of Electrical Hazards When Digging' and also 'Avoiding Danger from Overhead Electricity Lines'. Please read carefully.

If works don't commence before or continue beyond 6 weeks following the date of issue, then you must obtain an updated map. Each new job requires a new map. It is imperative that before any works commence you first locate and trace the routes of all electric cables by using appropriate locator equipment (in both power and radio modes).
Before using a mechanical excavator, ONLY MANUAL means should be employed to prove the location of ESB cables. Even where manual excavation is used, extreme caution must always be exercised, as failure do so could result in serious injury or electrocution. Under no circumstances should iron bars be used iring manual excavation. Careful Hand Digging of Trial Holes using 'HSA Code of Practice for Avoiding inger from Buried Services should be used for accurate cable location and prior to using a mechanical cavator in the vicinity of electrical cables. See H.S.A. Code of Practice publication "Avoiding Danger From iderground Services" for further guidelines

ease note that, if during excavation, damage or interference occurs to our cables, causing damage to y property, injury or death to any person or loss of supply to any customers, ESB may at its discretion rve a STOP WORK Notice, and notify the relevant Health and Safety Authority immediately. The user will so be liable to reimburse the ESB on a full indemnity basis, The full costs, expenses and damages arising irectly or indirectly) as a result. It is essential before excavating in the vicinity of ESB cables that the ESB twork Controller in the area you are working in is contacted.

ESB will extend every assistance in indicating the route of the cables and arrangements can be made by contacting the relevant ESB office. ESB cannot, however, accept responsibility for the absence or incorrect position of any particular cable on ESB's records and drawings supplied. Please note that a charge may be made where a movement of networks is required, and/or where ESB provide staff outside of normal working hours.

Please ensure that all contractors and their personnel involved in excavations have been furnished with this map. If further copies are required please contact us at the number below.

Yours faithfully,

John Finnegan
Central Site,
ESB Networks,
Osprey House,
Lower Grand Canal St.,
Dublin 2.

Phone: **+353 1 7026449**

RPS	Project No				
Recipient	Colm Boyd				
Register No	10	File Ref			
Date Rec'd	26 APR 2011				
PM					
Copied to	A	I	C	Sign	Date
Scanned				Date	

ESB NETWORKS

TITLE: **2011/04/19-007**

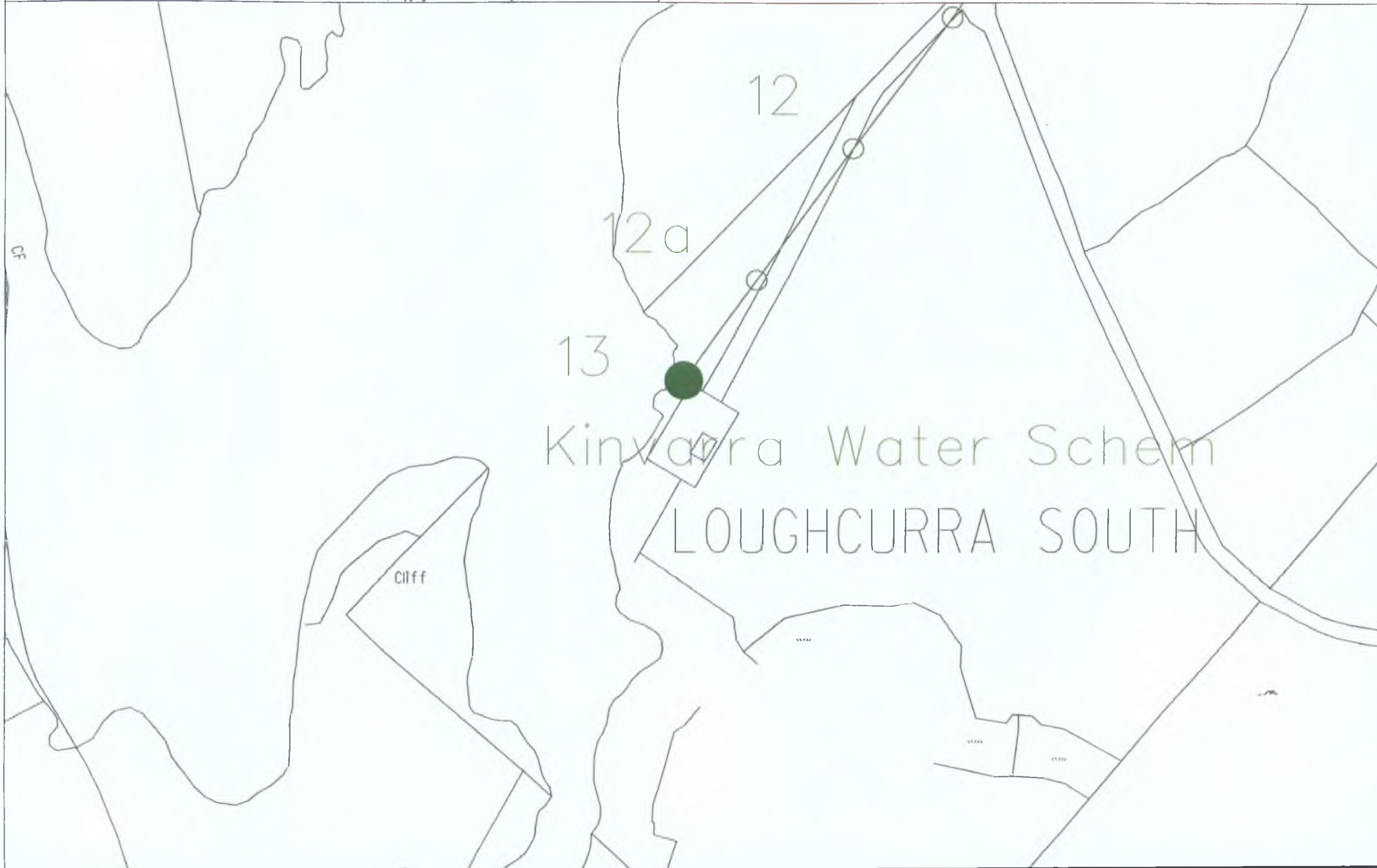
COLOUR CODE:
- BLACK - 38KV & HIGHER VOLTAGE OVERHEAD LINES
- GREEN - MV (10KV/20kV) OVERHEAD LINES
- BLUE - LV (400V/230V) OVERHEAD LINES
- CYAN - 38KV & HIGHER VOLTAGE UNDERGROUND CABLE ROUTES
- RED - MV/LV (10KV/20KV & 400V/230V) UNDERGROUND CABLE ROUTES

SCALE: 1:1250
DATE: 19-APR-2011

Maps reproduced by permission: Ordnance Survey Ireland Licence No. EN 0023709, Copyright Ordnance Survey Ireland Government of Ireland

WARNING

THIS MAP INDICATES THE APPROXIMATE LOCATION OF ESB NETWORKS TRANSMISSION (400KV, 220KV, 110KV, 38KV) AND DISTRIBUTION (20KV, 10KV, 230V/400V) UNDERGROUND CABLES AND OVERHEAD LINES IN THE GENERAL AREA OF THE PROPOSED WORKS. ESB NETWORKS TAKES NO RESPONSIBILITY FOR THE ACCURACY OR COMPLETENESS OF THIS MAP. LOW VOLTAGE (230V 400V) SERVICE CABLES (E.G. HOUSE SERVICES, FACTORY SHOP SERVICES, PUBLIC LIGHTING LAMP SERVICES, ETC) ARE NOT INCLUDED BUT THEIR PRESENCE SHOULD BE ANTICIPATED. THE DEPTHS OF UNDERGROUND CABLES MUST NEVER BE ASSUMED. ADDITIONAL MORE DETAILED INFORMATION IS AVAILABLE FOR HIGH VOLTAGE TRANSMISSION UNDERGROUND CABLES (38KV, 110KV, 220KV, 400KV) FROM THE LOCAL ESB NETWORKS TRANSMISSION REPRESENTATIVE - SEE ATTACHED LIST FOR CONTACT DETAILS OR CALL 1850 372 757. NO WORK SHOULD BE CARRIED OUT IN THE VICINITY OF 38KV OR HIGHER VOLTAGE UNDERGROUND CABLES WITHOUT PRIOR CONSULTATION WITH ESB NETWORKS. BEFORE ANY MECHANICAL EXCAVATION IS UNDERTAKEN, THE ACTUAL LOCATION OF ALL UNDERGROUND ELECTRICITY CABLES MUST BE ESTABLISHED AND VERIFIED ON SITE USING:
(A) UP-TO-DATE MAP RECORDS; (B) CABLE LOCATOR EQUIPMENT OPERATED IN BOTH POWER AND RADIO MODES; (C) CAREFUL HAND DIGGING OF TRIAL HOLES USING 'SAFE DIGGING PRACTICE'. REFER ALSO TO "HSA CODE OF PRACTICE FOR AVOIDING DANGER FROM UNDERGROUND SERVICES".
ESB TAKES NO RESPONSIBILITY AND SHALL BEAR NO LIABILITY IN RELATION TO ANY DAMAGE, INJURY DEATH OR LOSS OF SUPPLY AS A RESULT OF DAMAGE OR INTERFERENCE WITH ITS NETWORKS.



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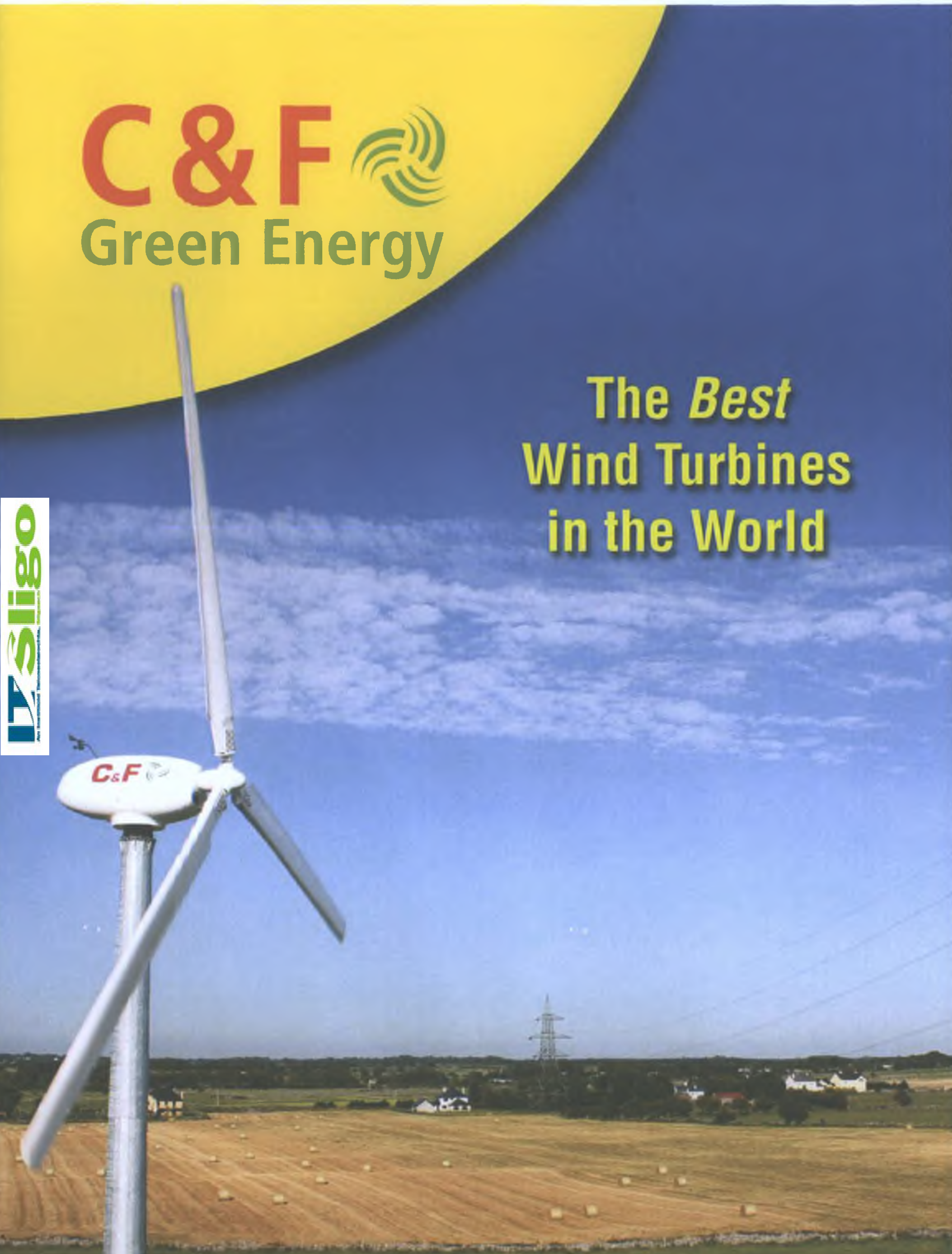
APPENDIX C – TURBINE SPECIFICATION SHEETS



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C&F
Green Energy

Generator

Designed and built at C&F in Athenry, Co. Galway Ireland. This axial flux permanent magnet air cooled multiple generator will give a lifetime of efficient, trouble-free electrical production.

This is achieved through multi plate axial configuration which also facilities modular construction with multiple independent outputs. This feature gives us the ability to design turbines to specific customer needs.

Blade Pitch Control

(Pitch Actuator)

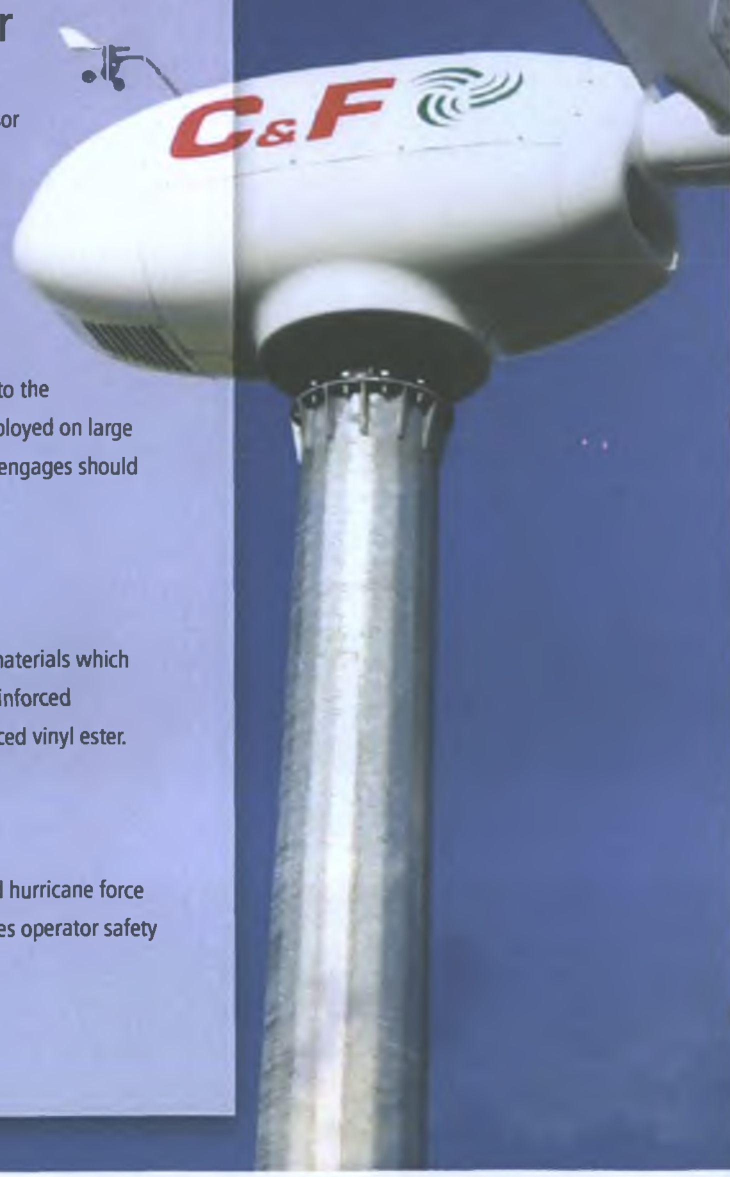
The blades are automatically controlled to optimise aerodynamic performance under different operating conditions. Bigger blades give more power but demand a more sophisticated control mechanism. C&F have adopted mega turbine pitch control technology, giving us perfect control over each model.

This guarantees power production at the lowest wind speed as well as at the highest wind speeds. The overall result is the most efficient micro turbine available in the world today.

Wind Vane Cup Anemometer

(Yaw Actuator)

A wind direction vane is monitored by the turbine microprocessor which then activates the yaw motor to align the turbine into the wind. This feature, usually employed on large turbines, improves performance and energy yield.



Electro Mechanical Brake

An electro mechanical brake is employed as a failsafe back-up to the blade pitch brake. This is an essential safety feature usually employed on large turbines and it acts in such a way that the brake automatically engages should a fault be detected.

Blades

Our blades are manufactured from aerospace type composite materials which are stronger than steel. The CF6/11 turbines use carbon fibre reinforced polypropylene while the larger machines use glass fibre reinforced vinyl ester.

Mast

All C&F turbines employ a monopole mast which can withstand hurricane force winds. The mast is erected using a hydraulic ram which enhances operator safety and facilitates ongoing safety.

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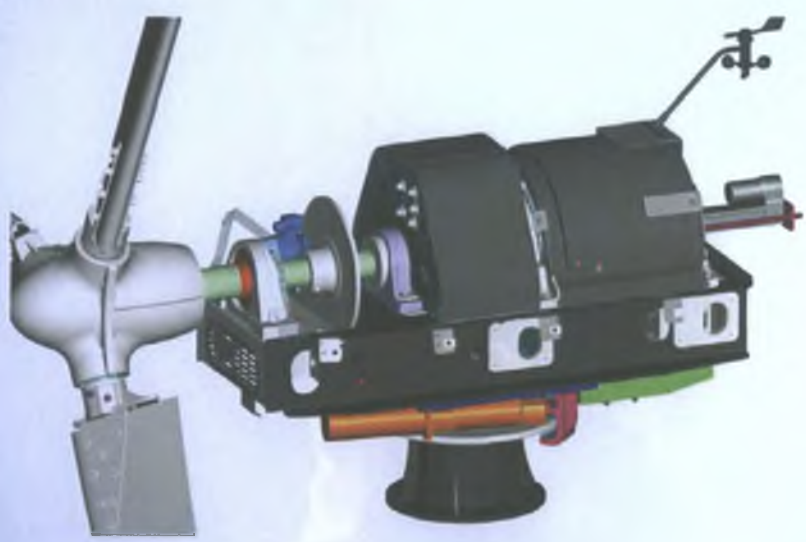
Controller/GSM

C&F have developed their own microprocessor to control their range of turbines. The microprocessor is GSM enabled allowing the machine to be remotely monitored and controlled over the internet or even by mobile phone. This facility allows us to monitor your turbine and ensure that it is operating to its full potential at all times. This provides the customer with peace of mind that their investment is continuously working for them.

Connection Options (Grid Tie or Off Grid Connections)

We offer a complete hybrid solution including backup DC power, battery storage and control systems.



CARBON CREDITS

Leading the way in the green energy field, C&F Green Energy is currently establishing a carbon credits system for its customers. Once your turbine has been installed, the turbines output will be monitored on an ongoing basis. C&F will then issue the customer with an accredited certificate detailing the carbon credits produced each year. This can, in turn, be offset against a carbon tax.

SPECIFICATION SHEET

Rotor Diameter	6 m
Tower	10 m Monopole
Max. Power	6 kW
An. Yield @ 5 m/s av.	11,300 kWh
Rated Wind Speed	9 .5 m/s
Min active wind speed	1.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	8 - 14 Tonnes
Noise @ 5 m/s at 60m	40dBA
Rated RPM	220 rpm
Method of Installation	Hydraulic Tilt Installation

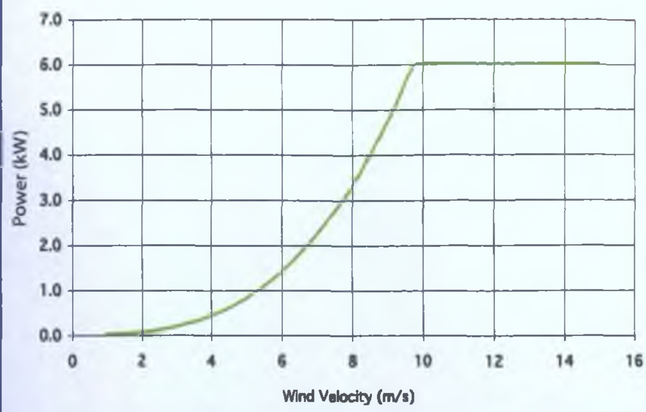
GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	8,670
5	11,290
5.5	13,978
6	16,570
6.5	18,932
7	20,969
8	23,915

Single Phase

CF 6d

Power Curve: CF6



SPECIFICATION SHEET

Rotor Diameter	8 m
Tower	15 m Monopole
Max. Power	6 kW
An. Yield @ 5 m/s av.	17,000 kWh
Rated Wind Speed	8.0 m/s
Min active wind speed	1.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	8 - 14 Tonnes
Noise @ 5 m/s at 60m	42 dBA
Rated RPM	220 rpm
Method of Installation	Hydraulic Tilt Installation

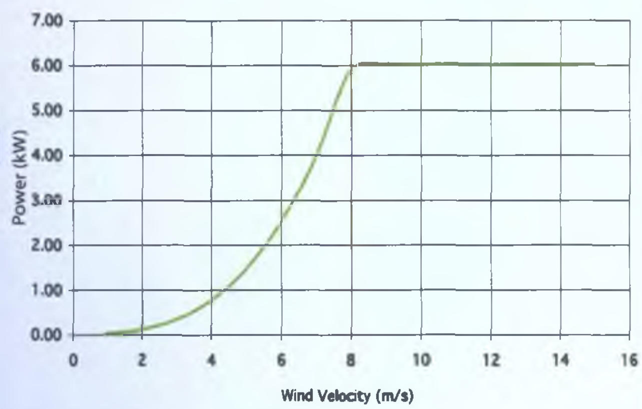
GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	13,761
5	17,065
5.5	20,188
6	23,000
6.5	25,400
7	27,356
8	29,905

Single Phase

CF 6e

Power Curve: CF6e



SPECIFICATION SHEET

Rotor Diameter	9 m
Tower	15 m Monopole
Max. Power	11 kW
An. Yield @ 5 m/s av.	24,000 kWh
Rated Wind Speed	9 m/s
Min active wind speed	1.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	14 - 19 Tonnes
Noise @ 5 m/s at 60m	42 dBA
Rated RPM	220 rpm
Method of Installation	Hydraulic Tilt Installation

GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	18,880
5	24,170
5.5	29,450
6	34,400
6.5	38,820
7	42,550
7.5	45,530
8	47,765

Single or Three Phase

CF11/ CF11i

Power Curve: CF11

SPECIFICATION SHEET

Rotor Diameter	10.8 m
Tower	15 m Monopole
Max. Power	15 kW
An. Yield @ 5 m/s av.	34,400 kWh
Rated Wind Speed	9 m/s
Min active wind speed	2.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	19 - 23 Tonnes
Noise @ 5 m/s at 60m	40 dBA
Max RPM	110 rpm
Method of Installation	Hydraulic Tilt Installation

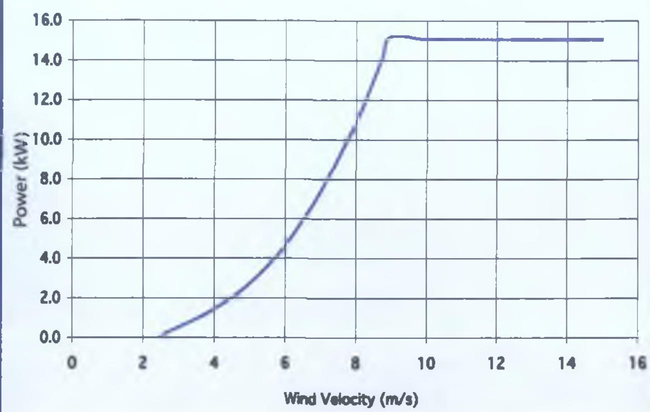
GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	26,980
5	34,400
5.5	41,730
6	48,570
6.5	54,630
7	59,700
7.5	63,750
8	66,750

Single or Three Phase

CF15/ CF15i

Power: CF15



SPECIFICATION SHEET

Rotor Diameter	12.8 m
Tower	20 m Monopole
Max. Power	20 kW
An. Yield @ 5 m/s av.	47,750 kWh
Rated Wind Speed	9 m/s
Min active wind speed	2.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	26 - 30 Tonnes
Noise @ 5 m/s at 60m	40 dBA
Rated RPM	110 rpm
Method of Installation	Hydraulic Tilt Installation

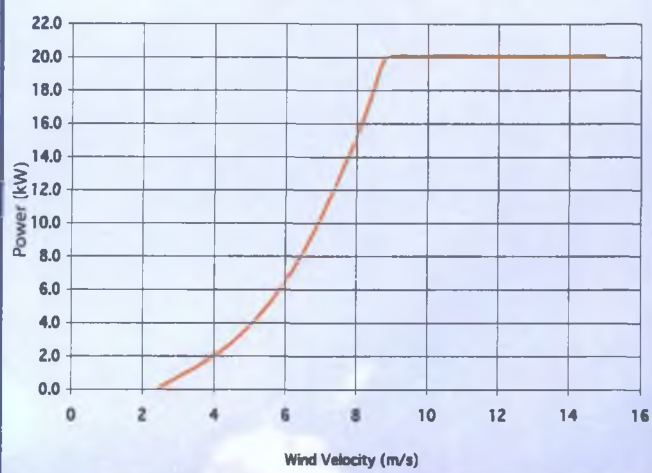
GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	37,600
5	47,750
5.5	57,700
6	66,930
6.5	75,050
7	81,820
7.5	87,160
8	91,100

Single or Three Phase

CF 20

Power: CF20



SPECIFICATION SHEET

Rotor Diameter	20 m
Tower	29 m Monopole
Max. Power	50 kW
An. Yield @ 5 m/s av.	117,250 kWh
Rated Wind Speed	9 m/s
Min active wind speed	2.2 m/s
Cut out wind speed	NONE
Annual Carbon Savings	70 - 80 Tonnes
Noise @ 5 m/s at 60m	TBA
Rated RPM	50 rpm
Method of Installation	Crane

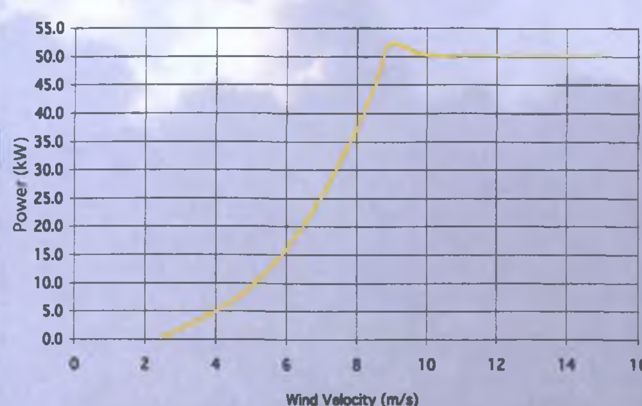
GSM CONTROLLED AS STANDARD

Annual Average Wind Speed in m/s	Annual Yield kWh
4.5	92,150
5	117,250
5.5	141,940
6	164,900
6.5	185,160
7	202,100
7.5	215,500
8	225,400

Single or Three Phase

CF 50

Power: CF50



C&F Green Energy

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C&F GROUP
Global Contract Manufacturers

C&F Green Energy is part of the globally renowned Irish owned C&F Group. C&F was first established in 1989 in Galway, Ireland and now employs over one thousand people in over six sites worldwide. With manufacturing locations in Ireland, Germany, the UK, The Czech Republic, the Philippines and China. C&F is a global company with a local face.

The proof of our engineering capabilities can be seen from our customer list which includes IBM, EMC, BMW, Mercedes, Ford, VW, Thermo King to name but a few, all of which have awarded us multiple global contracts.

C&F Green Energy was officially established by the C&F Group in 2006. The group recognized the need to provide a more powerful and safer wind energy solution for the home, farm and business owner. With its experience in the manufacturing area, C&F set about designing an innovative wind turbine that would combine unrivalled performance and power with clean aesthetics and reliability.

With this in mind the company has assembled a world class team of industrial design experts in this field to deliver solutions based on innovation and engineering excellence. The group's success is attributed to its unrivalled levels of workmanship quality, streamlined manufacturing processes and un-surpassed levels of customer care and retention. This team has developed an innovative range of medium-sized turbines that incorporate the same advanced technologies that are used in Mega-Watt sized machines. Leveraging off the company's expertise in manufacturing and design and its global reach, has enabled C&F Green Energy to offer this advanced technology at very competitive prices.

Our commitment to customer service and our confidence in our products are evident in the fact that all customer contracts will be directly with C&F Green Energy and all warranties will be carried by C&F Green Energy. This includes the full parts, labour and service warranty that is available for 10 years. As founder and CEO of the C&F Group I am determined to make C&F Green Energy the world leader in small and medium sized generation. We build the best turbines in the world.

John Flaherty
CEO C&F Group

- C&F Tooling Ltd., Ireland
- C&F Green Energy, Ireland
- C&F Automotive Trading as Iralco, Ireland
- C&F Manufacturing (UK) Ltd.
- C&F Automotive Germany GmbH
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IT Sligo

Proven 11
PRODUCT SHEET

Established in Scotland in 1980 Proven Energy is an industry leader manufacturing and supplying many hundreds of wind turbines every year. With an operational fleet spanning 60 countries and every continent Proven Energy's high performance wind turbines accrue over 30 million run hours annually.

Inspiration, innovation and a commitment to development have ensured these wind turbines produce electricity in a variety of wind regimes without the necessity to be stopped for self protection.

Proven Energy has more Proven 11 wind turbines installed across the world than any other product. First installed in 1996, there are now over 2,000 Proven 11 wind turbines globally.

Proven Energy products stand out from other small wind turbines because of their patented blade hinge design, which allows the wind turbines to regulate their speed, optimising output. As the wind gets stronger, the blades pitch and cone to reduce their aerodynamic efficiency.

The wind turbines use a direct drive generator and therefore have no gearbox, resulting in higher reliability, reduced noise, lower servicing costs and no reduction in performance in cold weather.

IT Sligo

Community installation, Isle of Eigg

2000+

Proven 11 wind turbines installed globally

Domestic installation, Scotland

Proven 11 product specifications

Wind turbine type	Down-wind, self regulating rotor Direct drive with permanent magnet generator	Tower heights and types	- 9m, 11.6m and 15m tilt up monopoles with gin poles - 9m and 15m hydraulic options available; 20m available in 2011 - Lattice tower available in North America
Rated power	5.2kW	Connections	Grid connect Battery charging
Rotor diameter	5.5m	Cut-in speed	3.5m/s
RAE	8,949kWh (based on 5m/s wind speed at hub height)	Cut-out speed	None

Specifications are subject to change without notice

Nov 2010

WWW.PROVENENERGY.COM 01355 597 000 INFO@PROVENENERGY.COM

Proven 11

PRODUCT SHEET

PROVEN ENERGY

ESTABLISHED IN 1980

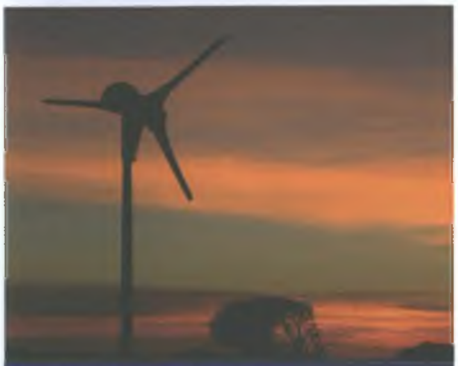
Application matrix			
Application	Grid connected Battery charging	Wind turbine	300v wind turbine - Black - White 48v wind turbine - Black - White
Controller options	- 300v grid connect controller (v2) - 48v grid connect controller (system 1) - 48v grid connect controller (system 2)	Tower options	9m, 11.6m or 15m gin pole tilt tower 9m and 15m hydraulic tilt tower available; 20m coming soon

"Before we decided on installing a Proven 11, we looked into other forms of investment but despite our extensive research, we couldn't find anything that would match or exceed the excellent return on investment that we get with our wind turbine. Interest rates are low at the moment and that meant that the Proven 11 was a fantastic investment."

Captain Spencer, Proven 11 owner

Agriculture installation, England

The AEP Curve (Annual Energy Production) demonstrates the energy the Proven 11 wind turbine will generate on sites with a given average wind speed at hub height. The ability to calculate kWh / year allows for clear estimations of financial viability to be calculated.



Domestic application Falkland islands

Proven 11 Annual Energy Production

Manufacturer's data