Feasibility Study of Small and Micro Wind Turbines for Residential Use in New Zealand

An analysis of technical implementation, spatial planning processes and of economic viability of small and micro scale wind energy generation systems for residential use in New Zealand

Nikolaus Reuther
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LEaP Research Report No. 30
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Contacts: **Dr. Hamish Rennie** e: Hamish.Rennie@lincoln.ac.nz; p: 03-325 3838 ext. 8002
Dr. Shannon Page e: Shannon.Page@lincoln.ac.nz; p: 03-325 3838 ext. 8115
Dr. Susan Jarvis e: Sue.Jarvis@lincoln.ac.nz; p: 03-325 3838 ext. 8290

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Contacts - email: leap@lincoln.ac.nz
web: http://www.lincoln.ac.nz/leap

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Abstract

Even though there might not seem to be any similarity between a holiday lodge on the verge of New Zealand's Banks Peninsula, a satellite earth station on the unmanned Black Island in the middle of the Ross Ice Shelf in the Antarctica and an American stargazer on his property in the middle of the Arizona desert, they all have something in common. They, among many other people across the globe, use the free resource wind to generate eco-friendly electricity, facilitating small and micro scale wind turbines. Japan, the USA and the UK, for example, have already installed thousands of domestic wind turbines. In New Zealand small and micro scale wind energy generation still has not established itself among other distributed energy generation methods on a domestic scale, even though the conditions for wind energy generation are perfect in many places.

The aim of this study was to assess the potential of domestic wind turbines in New Zealand. It established an overview of small and micro scale wind energy generation planning and implementation processes to gain insight into effectiveness, feasibility and straight forwardness of the processes involved. Hereby, economic, technical and planning aspects of domestic wind energy generation systems were analysed to investigate the benefits from small and micro scale wind energy generation.

The study revealed that:

- The definition of benefit varies and has to be clear beforehand as a small or micro wind turbine is only valuable when some benefit is achievable;
- Good wind resources with at least 6 m/s annual average wind speeds are required to achieve good overall performance;
- Rural or semi-rural areas are more adequate for good turbine performance as they provide more consistent and uninterrupted wind flows;
- Economies of scale effects apply for wind turbines; the bigger and higher a wind turbine, the better it will perform on a given site;
- Consent authorities deal with small and micro wind turbines in a different way. Planning processes are not consistent and transparent enough to attract more potential investors;
- A lack of sufficient qualitative information on small or micro scale wind energy projects exists in New Zealand;
- A lack of one integrated, comprehensive and overarching legislation and the nonexistence guaranteed electricity buy-back rates (feed-in tariffs) deters potential investors and prevents market growth;
- Manufacturer and installation company's data are often biased and whitewashed; information about additional costs (that may account for over 80 percent on top of acquisition costs) are often swept under the carpet.

Keywords: Wind Energy, Renewable Energy, Distributed Generation, Small Wind Turbines, Micro Wind Turbines, Wind Energy Economics

(Picture Source: Proven Energy)

"We can't solve problems by using the same kind of thinking we used when we created them."
Albert Einstein (1879 – 1955)

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Abbreviations

AAWS	Annual Average Wind Speed
AC	Alternate Current (electrical potential)
AEE	Assessment of Environmental Effects (aka. EIA – Environmental Impact Assessment)
AEO	Annual Energy Output
AS(/NZ)	Australian Standard (/New Zealand)
CA	Consent Authority
CF	Capacity Factor
COE	Cost Of Energy
dBA	Decibel (A-weighted filter) (measurement of sound pressure level)
DC	Direct Current (electrical potential)
DG	Distributed Generation/Generator
DP	District Plan
DWT	Domestic Wind Turbine(s)
EA	Electricity Authority
EECA	Energy Efficiency and Conservation Authority
EEC	Energy Efficiency and Conservation Act 2000
FiT	Feed-in Tariff
GDP	Gross Domestic Product
GST	Goods and Services Tax
GW	Gigawatt
GWh	Gigawatt hour
HAWT	Horizontal Axis Wind Turbine(s)
ICP	Installation Control Point (Connection point for AC mains)
IEC	International Electrotechnical Commission
kW	Kilowatt
kWh	Kilowatt hour
LD	Local Distributer
L_{max}	Single highest sampled level of sound
L_{10}	Level of sound exceeded for no more than 10% of the monitoring period
MED	Ministry for Economic Development
MfE	Ministry for the Environment
MW	Megawatt
MWh	Megawatt hour
m/s	Metre per second (velocity)
NPS	National Policy Statement
NPSREG	National Policy Statement for Renewable Electricity Generation 2011
NPV	Net Present Value
NZWM	New Zealand Electricity Market
NZEECS	The Draft New Zealand Energy Efficiency and Conservation Strategy 2010
NZES	The New Zealand Energy Strategy 2050
NZS	New Zealand Standard
PV	Photovoltaic
RC	Resource Consent
RMA	Resource Management Act 1991
ROI	Return On Investment
RP	Regional Plan
RPS	Regional Policy Statement
SDC	Selwyn District Council
SMW	Small and Micro Wind
SMWT	Small and Micro Wind Turbine(s)
VAWT	Vertical Axis Wind Turbine(s)
W	Watt
WBoP	Western Bay of Plenty
WSD	Wind Speed Data

Chapter 1
Introduction

1.1 Setting the Scene

Even though there might not seem to be any similarity between a holiday lodge on the verge of New Zealand's Banks Peninsula, a satellite earth station on the unmanned Black Island in the middle of the Ross Ice Shelf in the Antarctica and an American stargazer on his property in the middle of the Arizona desert, they all have something in common. They, among thousands and thousands of other people across the globe, use the free resource wind to generate eco-friendly electricity, facilitating small and micro scale wind turbines.

Japan, the USA and the UK, for example, have already installed thousands of domestic wind turbines (IEA Wind, 2009). However, in New Zealand small and micro scale wind energy generation still has not established itself among other distributed energy generation methods on a domestic scale, even though the conditions for wind energy generation are perfect in many places.

1.2 Aim

The aim of the study is to assess the feasibility of small and micro wind turbines (SMWT) for residential use in New Zealand. It establishes an overview of small and micro scale wind energy generation planning and implementation processes to gain insight into effectiveness, consistency and straightforwardness of the involved processes. Hereby, technical, planning and economic aspects of small and micro scale wind energy generation systems are analysed to investigate the benefits from residential small and wind turbines.

1.3 Objectives

The following objectives will help to achieve this dissertation's aim:

- To gather information about available technology and its limitations, as well as the installation and grid connection processes, requirements, timeline and costs; and to illustrate the responsibilities of the different authorities and market players;
- To analyse and assess the wind resource requirements for small and micro wind turbines that promote an adequate economic return within the turbine's lifespan;
- To analyse and assess practicalities of resource and building consent application processes;
- To generate an overview of the key factors of the economic viability of domestic scale wind energy generation in New Zealand.

1.4 Methodology

In order to achieve the aims and objectives of this dissertation, a literature review outlines the functioning of New Zealand's Energy Market, an overview of global and national distributed renewable energy generation, wind turbine technology and operation technicalities as well as a summary of current legal aspects of small and micro wind turbines which sets the scene for the research context.

In order to analyse the technical implementation, spatial planning processes and economic viability of small and micro scale wind energy generation systems for residential use in New Zealand, case studies are carried out two rural properties and on one reference site with good wind resources. In the case studies small and micro wind energy system in rural areas are assessed. Their feasibility is measured by looking at the two different system options (standalone and a grid connected systems) and nine different turbines (with a rated capacity of 10 kW or less) that are available on the New

Zealand market. The technicalities and the spatial planning processes are explored and each turbine's economic viability (in form of a cash flow analysis) is evaluated.

1.5 Scope and Limitations

This dissertation looks at distributed generation from the renewable resource wind. Electricity is generated with small and micro wind turbines, also called domestic wind turbines (DWT), with a total capacity not exceeding 10 kilowatt (kW). The distinction between small and micro is made as followed:

- Micro wind turbines with a rated capacity of less than 1 kW that are mainly for micro scale application (e.g. holiday bachs, boats, etc.), on grid connected premises or in combination with other means of distributed electricity generation;
- Small wind turbines with a rated capacity of up to 10 kW that are capable of generating enough electricity to power a dwelling or, for larger turbines, a farm;
- Both, small and micro turbines are either connected to batteries that store surplus generated electricity or to the utility feeding excess generation into the local grid.

The case studies carried out during the development of this dissertation are limited to two rural properties, one in the Selwyn District in the South Island and one in the Western Bay of Plenty District in the North Island. A New Zealand wide wind data and special planning process assessment would go beyond the scope of this dissertation. The limitation to small and micro scale wind energy generation in rural or semi-rural areas in New Zealand has been chosen for specific reasons that will be discussed in Section 4.3.2.

The socio-economic acceptance of wind turbines in general, small and micro wind turbines (SMWT) and community scale wind energy projects including ways to promote and increase their application has been widely discussed by others (e.g. Ashby, 2004; Toke, 2005; Gipe, 2006; Barry 2007; Thomson, 2008). This dissertation will therefore not go into details about socio-economic factors and the efficiency of different policy instruments that promote distributed generation. In lieu thereof economical, technical and spatial planning procedures and their practicability, straightforwardness, necessary steps, involved parties and regulatory processes will be examined and critically evaluated.

1.6 Structure

In order to achieve the aim and objectives of this dissertation, it is structured in 9 chapters. Chapter 2 gives an overview of New Zealand's Electricity Market while Chapter 3 deals with New Zealand's wind resources and distributed wind energy generation. Chapter 4 and 5 discuss technological, legal, planning and operational aspects of the planning and implementation process for small and micro wind generation systems with an installed capacity of up to 10kW.

Chapter 6 then introduces the methodology and carries out case studies, developing small or micro wind energy system on the chosen case study sites. The findings in the literature review and the analysis of the case studies in Chapter 7 lead to the discussion in Chapter 8 which is based on the practicability and straightforwardness of the different implementation steps (i.e. technical planning, spatial planning, economics, etc.) and the overall process efficiency. The main question hereby is how complex, practicable and economic viable the whole process is. Chapter 9 will then present the final conclusion, outlook and recommendations for investors, industry, government and policy makers.

Chapter 2
New Zealand's Electricity Market

2.1 Introduction

Chapter 2 describes the New Zealand Electricity Market. Section 2.2 gives an overview of the market share of renewable energies, different market players and functions. Policies, regulations and strategies related to renewable energy generation are outlined in Section 2.3. Residential electricity demands in combination with demographic changes over the last decade are described in Section 2.4.

2.2 Electricity Market Framework

In 2010, 62 percent of the country's total primary energy supply derived from fossil fuels while 38 percent (310.25 Petajoule) were generated by renewable energies. In the fourth quarter of 2010, the share of renewable energy supply in New Zealand was 76.5 percent while the annual share accounted for 74.2 percent (32,211 GWh). The total net electricity generation added up to about 43,401 GWh, an increase of 3.1 percent to 2009 and renewable share increasing by 5.3 percent (MED, 2011a). A growing gross domestic product and the increase in population over the last few decades are closely linked to an increasing energy demand (MED, 2010b). As the population will grow further (Statistics New Zealand, 2009) this will result in an increasing energy demands over the next decades. To meet the growth in demand and to ensure future electricity supply, it is logical that new capacity will have to be installed over the next years. Table 1 gives a summary of New Zealand's net electricity generation in 2010 and the share of renewable energies.

Table 1
New Zealand's net electricity generation in 2010 (Data source: MED, 2011a)

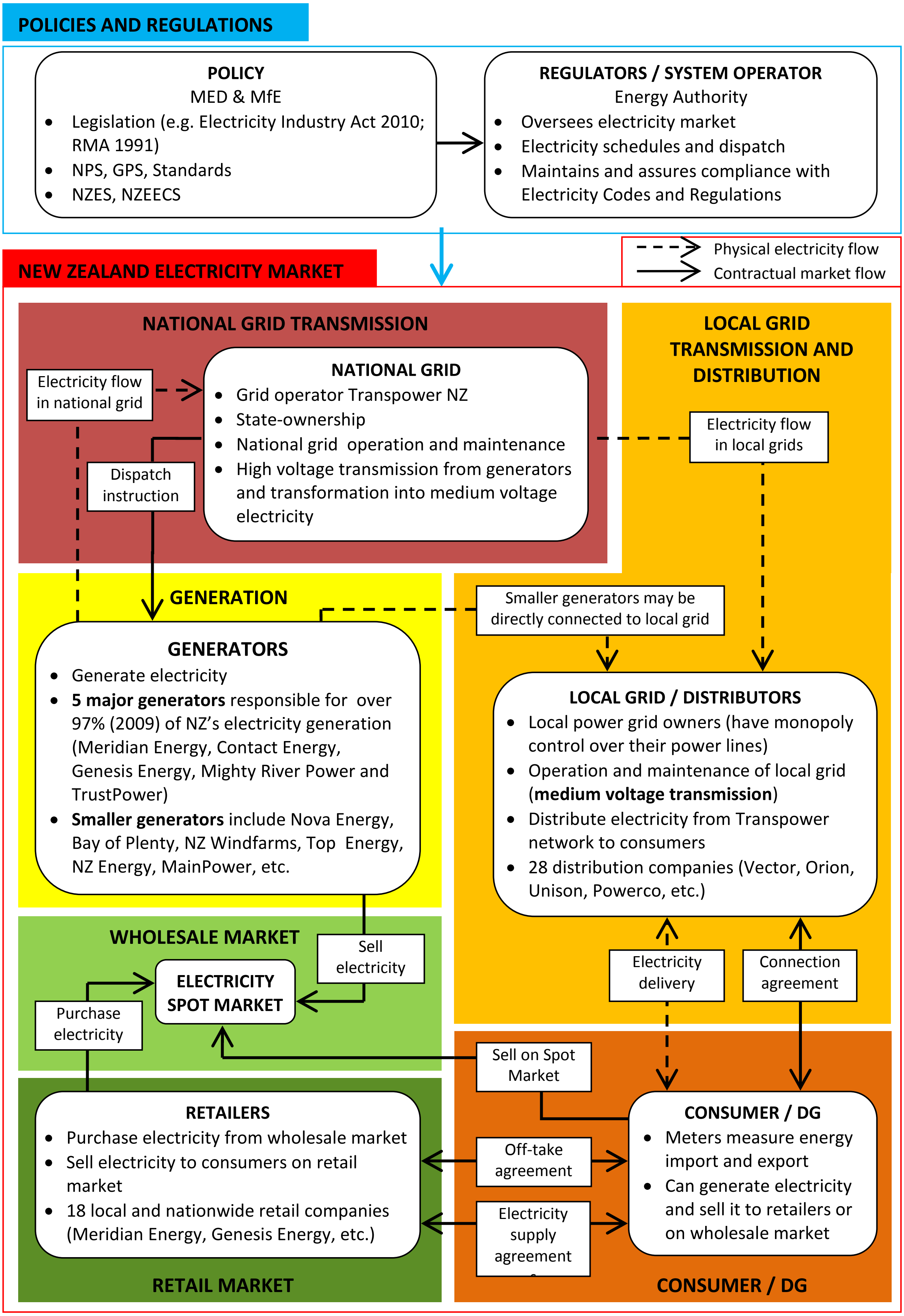
Generation type	Generated GWh	Total share	Renewable share
Hydro	24,471GWh	56.4%	76.0%
Gas	9,205 GWh	21.2%	--
Geothermal	5,551GWh	12.8%	17.2%
Coal	1,932 GWh	4.5%	--
Wind	1,618 GWh	3.7%	5%
Other (Wood, Biogas, Oil, Waste Heat)	586 GWh	1.4%	1.8%
TOTAL	**43,401 GWh**	**100%**	**--**
Renewable	**32,211 GWh**	**--**	**100%**

About two decades ago a massive unbundling and decentralisation reform fundamentally changed New Zealand's electricity sector. However, in the late 90s further labour-led reforms involved the regulation and governance of the industry to be re-centralised leaving the generation, distribution and retailing in a mix of private and state or public ownership (Meade, 2004).

The Electricity Industry Reform Act 1998 separated distribution from generation and retailing. However a vertical integration of generation and retail under the roof of the same corporation was still possible, leaving the 5 largest electricity generators (Meridian Energy, Contact Energy, Genesis Energy, Mighty River Power and TrustPower) with about 94% generation and retail market share (MED, 2011a). It should be considered that three of the largest generators/retailers are state-owned companies, i.e. their dividends are distributed into government pockets. The 28 local distribution networks (line companies) (see Appendix A.1) are owned or partly owned by community electricity trusts local bodies, public shareholders and community cooperatives (ENA, 2011a; ENA 2011b).

Figure 1 provides an overview of the New Zealand Electricity Market (NZEM), the different market players and involved authorities, as well as the directions of physical electricity flow and contractual market flow. It is of importance to understand how the market functions and where and with whom distributed SMW generators have to interact to feed their excess electricity into the local grids.

Figure 1
New Zealand Electricity Market overview



2.3 Electricity Policies, Regulations and Strategies

The legal framework relevant for the NZEM is set by government policies developed by the Ministry of Economic Development (MED) and the Ministry for the Environment (MfE). The regulation of NZEM is carried out by the Energy Authority (EA). The EA is responsible for system and market operation and management, electricity scheduling and dispatch, and maintenance and assurance of participators' compliance with Electricity Codes and Regulations developed by the EA (EA, 2011).

Strategies play a major role to guide the direction for New Zealand's economy. The two main non-statutory strategies for its energy sector are the New Zealand Energy Strategy and the Draft New Zealand Energy Efficiency and Conservation Strategy (MED, 2011b):

- **The New Zealand Energy Strategy 2050 (NZES) and the Draft New Zealand Energy Strategy**
  The New Zealand Energy Strategy 2050 is a statutory document. It gives direction regarding the role of energy in New Zealand's economy. One of its targets is to increase the share of renewable energy sources in electricity generation to 90% by 2025 (MED, 2007).
- **The Draft New Zealand Energy Efficiency and Conservation Strategy 2010 (NZEECS)**
  Alongside the energy strategy the NZEECS promotes energy efficiency, energy conservation and the use of renewable energy in New Zealand for the next 5 years. This statutory planning document was developed under the Energy Efficiency and Conservation Act 2000 (MED, 2010a).

The NZES has, among other goals, set out to remove barriers to small and micro scale distributed renewable electricity generation (MED, 2007). The strategy vaguely addresses the barriers without going into much detail of how to remove these and how to promote ways to increase the share of renewable distributed generation methods. The NZEECS also addresses barriers and some ways to promote distributed generation (MED, 2010a). Both strategies focus on the big picture without giving much attention to small and micro scale generation, a market sector that has been experiencing high growth rates over the last decade in other countries like the USA, Germany, and other European countries, where renewable energy policy instruments have been developed over the past decades (Porter, 2006; REN21, 2010). It took three and a half years to bring the National Policy Statement for Renewable Energy Generation 2011 on its way, the first statutory policy instrument that promotes renewable electricity generation on a small and micro scale (see Section 5.2.2).

2.4 New Zealand's Residential Electricity Demand

New Zealand's electricity demand has seen a slight increase over the past few years. The demand normally peaks in winter and decreases again during the summer months (Transpower, 2011b). The quarterly electricity demand over the last three years is illustrated in Figure 2.

The average annual electricity demand per household has not changed significantly over the last decade. It oscillates around 7,700 kWh per year and household while the residential and average electricity price steadily increased. Residential electricity price are about 43 percent higher than the average national electricity price (see Figure 3).

Figure 2
Quarterly electricity demand in New Zealand
(Data source: MED, 2011a)

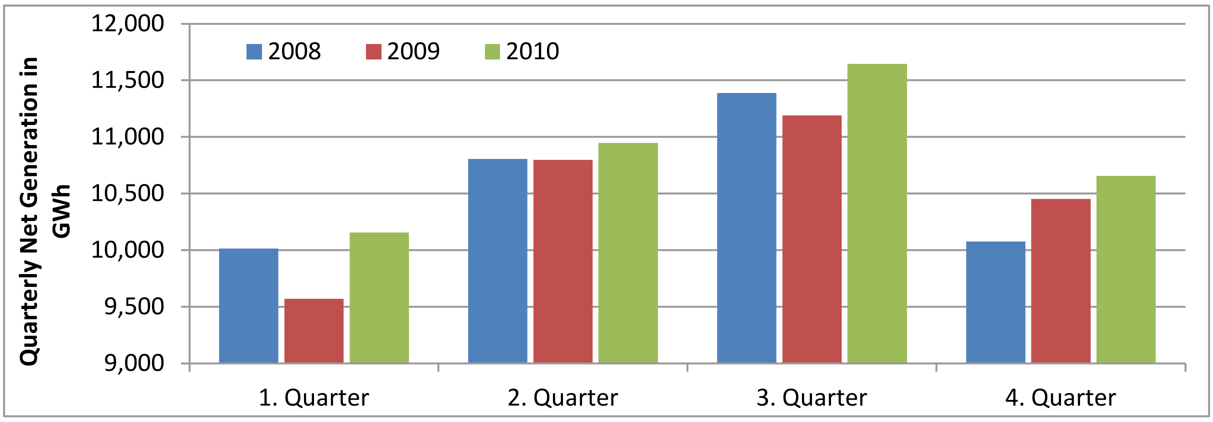
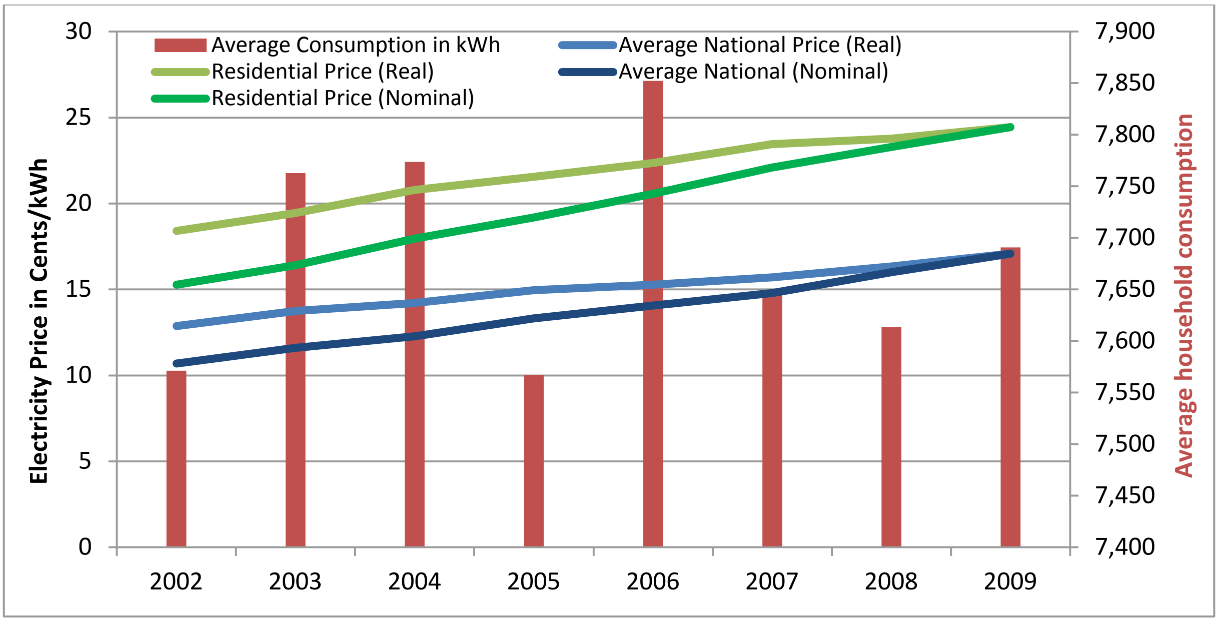


Figure 3
Electricity price development and average residential electricity consumption per household (residential connection point) (Data source: MED, 2011a)



In 2009, the average household demand amounted to approximately 7,695 kWh while steady population and GDP growth causes an annual increase in electricity demand of approximately 1.5 to 2 percent (MED, 2010b). This has not affected the average household energy demand. Table 2 shows average quarterly, monthly and daily electricity demand.

Table 2
Average quarterly, monthly and daily electricity demand at an average annual consumption of 7,700 kWh (Data source: MED, 2011a)

1st Quarter (Summer)	1,793 kWh/quarter	598 kWh/month	20 kWh/day
2nd Quarter (Autumn)	1,963 kWh/quarter	654 kWh/month	22 kWh/day
3rd Quarter (Winter)	2,064 kWh/quarter	688 kWh/month	23 kWh/day
4th Quarter (Spring)	1,880 kWh/quarter	627 kWh/month	21 kWh/day

Like the global trend in energy costs, New Zealand's electricity prices gradually increase. In February 2011, the average residential electricity price (nominal incl. GST) stood at 25.3 cent/kWh compared to 15.3 cent/kWh in 2002. The national average electricity price (nominal) rose from 10.7 to 17.8 cent/kWh with a real annual increase of 3.2 percent while the average annual inflation rate was about 2.8 percent (MED, 2010b; MED, 2011a, RBNZ, 2011).

Chapter 3
Distributed Wind Energy Generation in New Zealand

3.1 Introduction

In Chapter 3 New Zealand's wind resources (Section 3.2) and global, as well as local, trends regarding small and micro scale distributed wind energy generation are assessed to determine barriers and opportunities (Section 3.3).

3.2 New Zealand's Wind Resource

Ashby (2004), the New Zealand Wind Energy Association (NZWEA) and many others have described New Zealand's wind resources as some of the world's best and amongst the countries with the greatest potential for wind energy generation (NZWEA, 2011a; SEANZ, 2011a). EECA (2001) stated in their *Review of New Zealand's Wind Energy Potential to 2015* the extraordinary potential of New Zealand's wind resources. MED (2010b) describes wind energy generation potential that is almost two and a half times higher than New Zealand's annual total electricity generation of 2009.

Located in the middle of the south-west Pacific Ocean and within the so-called "Roaring Forties", New Zealand is exposed to predominating westerlies, but also strong easterly winds that travel un-interrupted across the Tasman Sea and the Pacific Ocean hitting the coasts of the island nation's long but thin landmasses (NZWEA, 2010a). This isolated location also means that New Zealand's entire electricity demand is required to be met within the country as international electricity imports or exports are not feasible, both technically and economically.

3.3 Small and Micro Scale Wind Energy Generation

3.3.1 A Global Trend

A global trend emerging in the wind energy industry is the upcoming popularity of small and micro scale distributed wind energy projects. Easier site finding, consenting processes and grid connection make small and micro scale wind energy projects an attractive prospect to developers (GWEC, 2010). Several countries have introduced legislation or other measures (e.g. subsidies, cheap loans, etc.) to encourage distributed renewable energy generation. Many experience growing popularity of a broad variety of small and micro scale wind energy projects in most diverse geographical sites throughout their countries (REN21, 2010). Alone in the United States, a 15% market growth (or the installation of some 9,800 new small wind turbines) took place between 2008 and 2009. Global sale trends have resulted in a rise of 21,000 small wind turbines during 2009 (AWEA, 2010). However, these numbers include wind turbines ranging up to 100kW but regardless indicate the uprising of small distributed generation systems.

IEA Wind (2009) states that distributed wind energy generation appears to experience a growing popularity besides large scale developments. Even countries with wind resource of poorer quality seem to have recognised the global trends and introduced policy support and other ways to promote the use of renewable energies on small scales (e.g. Germany, UK, Australia, etc.). The decentralisation of the energy supply and a move towards more distributed generation in close proximity to the energy demand is finding its way into the global energy markets. This new market segment has been growing steadily over the last few decades, attracting large investments and creating millions of jobs worldwide (Barry, 2007; REN 21, 2011).

3.3.2 The Situation in New Zealand

In spite of global trends, New Zealand's government and energy sector have not yet fully integrated distributed SMW generation into an industry that generally aims for large scale, centralised wind energy generation projects (e.g. West Wind, Te Uku or Te Apiti wind farms). Wind project developments in New Zealand are described as complex and expensive. Resource planning processes have been stated as one of the main obstacles for SMW in New Zealand. Further, the lack of information, supporting policies and incentives is limiting the industry while market access is often hard to obtain as local retailers are not legally bound to buy the electricity fed into the grid (Barry, 2007; Thomson, 2008). Manufacturers are in short supply and the branch is unattractive to investors because of high development costs and the lack of special loan schemes or other incentives. Long amortisation periods of capital investment are common as projects often do not yield a profit within a reasonable timeframe (Stevenson, 2010). Small scale wind electricity generation is not considered to be competitive to conventional large scale generation forms (Menz and Vachon, 2006).

On the other hand, SMW generation seems to be less prone to local opposition than large wind farms. Barry & Chapman (2009) stated that this pattern can be seen especially for SMW projects that are owned by local communities or community members. In general, power supply from the environmentally friendly resource wind is approved by 88% of New Zealanders (Nielsen Research, 2008).

3.3.3 Opportunities for Small and Micro Scale Wind in New Zealand

For many remote areas in New Zealand, electricity supply through local grids is often not economically viable or technically feasible. Extending the local grid to remote premises in vast areas can be costly and technically challenging. Supplying these remote premises with electricity is often achieved with fossil fuel burning generators.

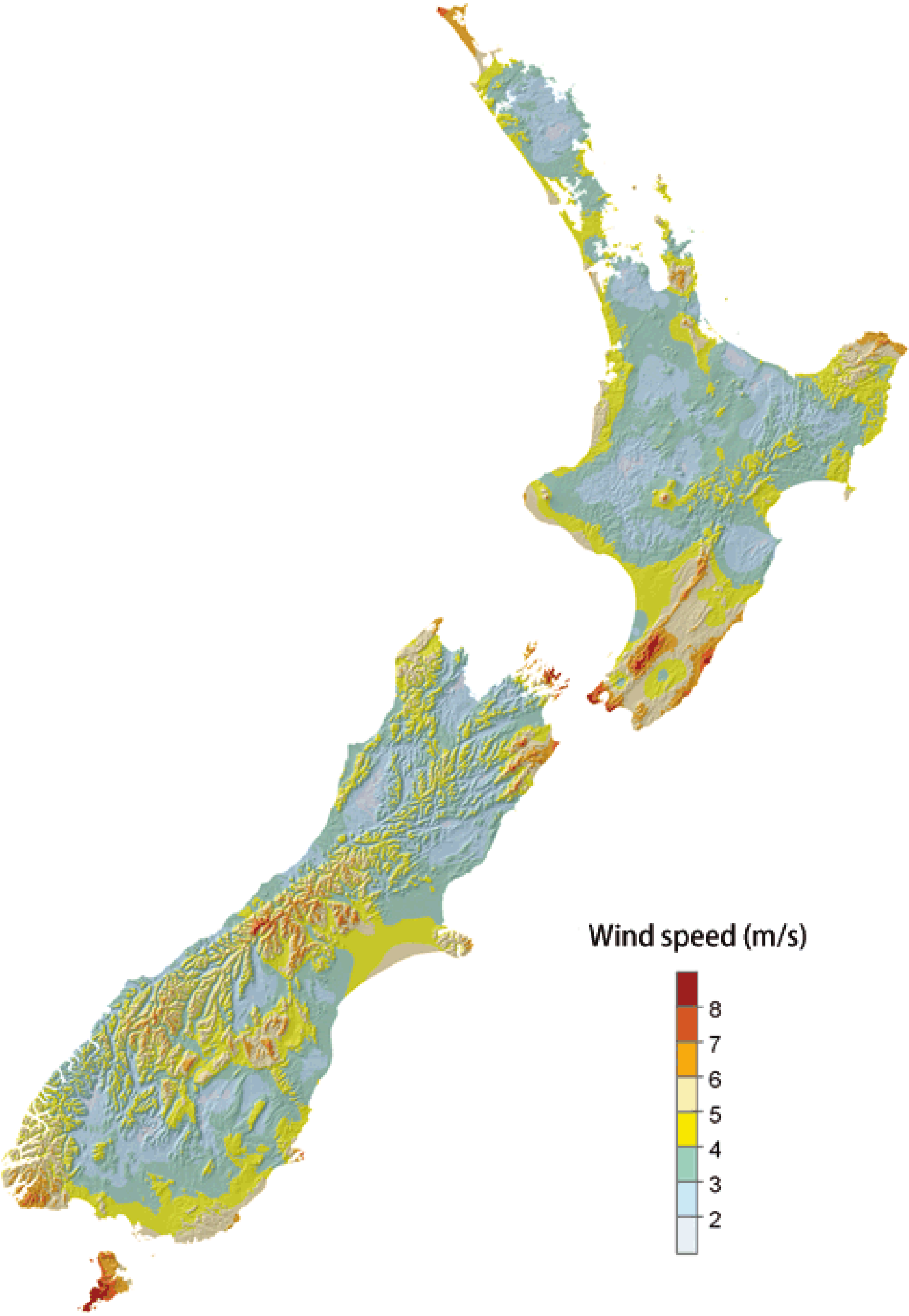
Stewart Island and its approximately 400 permanent residents for example are connected to diesel generators that produce electricity for the island (SIESA, 2011). Similarly, the region around Milford Sound generates electricity from hydroelectric sources and diesel generators (MSI, 2011), with both regions far away from national or local grids. High investment and operational costs as well as power outages from interrupted transmission often are the main obstacles that hold back a grid connection in such cases.

These problems also occur for smaller premises like remote farms, weather stations, lodges, homes or cottages that are distanced from the local grid. Several case studies have shown successful implementations of SMW energy generation systems at isolated locations and even at sites with available grid connection (EECA, 2009b; Watts, 2009).

According to the EECA (2010a) SMWT already work well at wind speeds of about 4.5 m/s. However, others state a much higher average wind speed of around 7 to 8 m/s is required to make SMW generation economical (Leaver et al., 2010). Nevertheless many, mainly coastal or elevated regions in New Zealand have outstanding potential (NIWA, 2011a).

Figure 4 shows the average annual wind speeds in New Zealand. Yet, the annual average wind speed is a critical parameter as it gives no indication about wind quality and quantity. Hydro Tasmania Consulting (2007) states in a study carried out for EECA that “wind speeds vary considerably around the country” and high annual average wind speeds do not necessarily mean a steady wind flow but can have significant wind speed fluctuations.

Figure 4
Overview of average annual wind speed in New Zealand (NIWA, 2011a)



Chapter 4
Turbine Technology, Performance and Operation

4.1 Introduction

Chapter 4 provides an overview of small and micro wind turbine technology and operation. Domestic scale wind turbine technology is described in Section 4.2 while optimal placement of and requirements for SMWT is assessed in Section 4.3, describing important factors for choosing the right on-site turbine location. The installation and operation of standalone and grid-connected SMWT are described in Section 4.4 and 4.5.

4.2 Wind Turbine Technology

4.2.1 Wind Turbine Technology and Design

The two main small and micro scale wind turbine types are horizontal-axis turbines (HAWT) and the vertical-axis turbines (VAWT) (Gipe, 2004). The most commonly used turbine type today is the three bladed HAWT (Mathew, 2006). The two turbine types are compared in Table 3.

Table 3
Comparison of small and micro HAWT and VAWT
(Gipe, 2004; Mathew, 2006; Stankovic et al., 2009)

Turbine	HAWT	VAWT
Picture	 (Source: Southwest Windpower, 2011a)	 (Source: EnergiaPower, 2011)
Axis of rotation	Horizontal	Vertical
Types	Single bladed (with counter weight) Two bladed Three bladed (most common) Multi bladed	Darrieus Rotor (most common among VAWT) Savonius Rotor Cyclo Turbine (Giromill)
Hub/gearbox	Normally on top of the tower	At ground level (bottom of mast)
Min. Hub Height	> 8-10 metres (For turbines > 1kW capacity)	> 8-10 metres (For turbines > 1kW capacity)
Configurations	Upwind turbine (aerodynamically better as they do not have a wind shadow from the tower) Downwind turbine (more flexible in terms of facing the wind)	H shape Delta shape Diamond shape Y shape PHI (oval) shape
Required wind speed at hub height	Areas with 3.5-14 m/sec wind speed (three bladed)	Areas with 5-7 m/sec wind speed
Tower	Tubular, Guyed or Lattice tower	Guyed tubular tower
Blades	Straight airfoil blade(s)	Straight or curved airfoil blades
Advantages	The more blades, the higher the starting power (torque) Generally the highest efficiency (three bladed turbine) High efficiency with even wind flows	Wind from any direction Suitable for more urban areas Most maintenance can be carried out at ground level (bottom of mast) No pitch control of blades necessary

Disadvantages	Has to be oriented towards the wind The more blades the higher the aerodynamic losses Pith control of blades necessary	Some HAWT not self-starting Lower system efficiency Speed control critical Tower support necessary (guy wires)

The turbine hub links the blades in the middle and is mounted on the mast (HAWT) or near the ground (VAWT). Most SMWT hubs contain only a generator and, in most cases, no gearbox. Direct-drive generators enable the turbine to directly transfer the torque to a generator where mechanical power is converted into electricity. Because of constant changes in wind speeds, output voltage and frequency vary. Most small turbines generate alternate current (AC) while micro turbines normally produce low voltage direct current (DC). A synchronous inverter adjusts the power output to required utility voltage frequency (Gipe, 2004; Mathew, 2006):

- Small turbines (> 1 kW) usually generate 230 volt AC that can be directly used in AC application;
- Micro turbines (<1 kW) usually generate 24 or 48 volt DC that needs to be rectified when used for AC application.

4.2.2 Turbine Performance

The performance of SMWT varies with speed and quality of the wind. The higher the wind speed and the less turbulence, the better the energy output will be (Gipe, 2004). To describe the performance of a wind turbine, the following terminology is generally used.

Table 4
Terminology for SMW energy generation (Gipe, 2004; Power-Talk.Net, 2011)

Output (Power and Energy)	Power is described as capacity to do work and is measured in watts (W) Energy is work done over a time period and is measured in kilowatt hours (kWh)
Annual Energy Output (AEO)	Useful parameter to consider a certain turbine in relation to the energy demand (measured in kWh)
Capacity Rating	Maximum power (kW) a turbine can produce; normally much lower in reality
Capacity Factor (η)	Ratio between actual output and rated output over a specific period of time
Installed Capacity	Sum of ratings of installed turbines (e.g. 2 x 1.5kW = 3kW installed capacity)
Start-up Speed	Wind speed required to start the turbine rotor turning (about 2 to 2.5 m/s)
Cut-in speed	Wind speed required by SMWT to start generating power (about 3.5 m/s)
Cut-out speed	Wind speed at which a SMWT shuts down to protect the turbine from damage

The turbine efficiency is defined as the amount of energy that the rotor can extract from the wind Mathew, 2006). When determining the performance of a wind turbine, many different factors have to be considered. Most important are the blade diameter and the wind speed (velocity).

Estimating wind turbine power outputs is a complex task that involves statistical and aerodynamic calculations. Calculating annual power outputs helps to determine expected annual energy outputs and required turbine dimensions to meet the demand. For simplified calculations the following equations can be used for approximate but vague energy output estimations (Reuk.co.uk, 2007):

- **Swept Area:** $A = \pi \times Radius^2$ (or $A = \pi \times \left(\frac{Diameter}{2}\right)^2$)
- **Power Density:** $S = Air\ Density\ (1.23\ \frac{kg}{m^3}) \times \frac{Velocity^3}{1000}$
- **Capacity Rating:** $C = A \times S$
- **Power Output:** $P = C \times \eta\ (with\ \eta = Turbine\ Efficiency\ or\ Turbine\ Efficiency)$
- **Annual Energy Output:** $AEO = P \times 8760\ (hours\ per\ year)$

Table 5 shows the power output for a SMWT at different annual average wind speeds (AAWS). The turbine power at an optimum site has the maximum efficiency or capacity factor of 0.59 (Betz limit), that is the ideal turbine can transform 59% of the energy in the wind into electricity. In reality the capacity factor (CF) normally ranges between 0.1 and 0.4. The CF is also dependent on the prevailing wind, rotor diameter and how good the turbine transforms the energy (Stankovic et al., 2009).

Table 5
Power output for SMWT at different locations in New Zealand

Location	AAWS	Blade Diameter	Blade Swept Area	Power in Wind	Maximum Power Output (Betz limit at 0.59)
Tauranga	4 m/s	1 m	0.79 m^2	0.06 kW	0.03 kW
	4 m/s	2 m	3.14 m^2	0.24 kW	0.14 kW
	4 m/s	3 m	7.07 m^2	0.53 kW	0.31 kW
	4 m/s	4 m	12.57 m^2	0.94 kW	0.56 kW
	4 m/s	5 m	19.63 m^2	1.47 kW	0.87 kW
Invercargill, Wellington City	5 m/s	1 m	0.79 m^2	0.12 kW	0.07 kW
	5 m/s	2 m	3.14 m^2	0.46 kW	0.27 kW
	5 m/s	3 m	7.07 m^2	1.03 kW	0.61 kW
	5 m/s	4 m	12.57 m^2	1.84 kW	1.08 kW
	5 m/s	5 m	19.63 m^2	2.87 kW	1.69 kW
Wellington Airport	7 m/s	1 m	0.79 m^2	0.32 kW	0.19 kW
	7 m/s	2 m	3.14 m^2	1.26 kW	0.74 kW
	7 m/s	3 m	7.07 m^2	2.84 kW	1.67 kW
	7 m/s	4 m	12.57 m^2	5.04 kW	2.98 kW
	7 m/s	5 m	19.63 m2	7.88 kW	4.65 kW

Table 5 provides a simplified calculation of the energy output to show the relationship between blade diameter, wind speed and power output. These cases used a constant wind speed and did not take into account that the wind is not steady. In order to calculate the mean power output of a SMWT, the turbines power curve and the wind speed distribution are required.

Manufacturers' turbine capacity ratings however are mostly based on wind speeds at around 12 – 14 m/s. Wind speeds vary considerably in New Zealand and annual average wind speeds are only indicators for areas with high wind (Hydro Tasmania Consulting, 2007). Turbines generate much less at lower wind speeds and therefore the annual output can be sobering. Wind energy generation is also considered inconsistent as even with abundant wind a high level of fluctuation can occur (Gipe, 2004).

Figure 5
The influence of wind speed and rotor diameter on power output for ideal small wind turbines (at Betz limit)

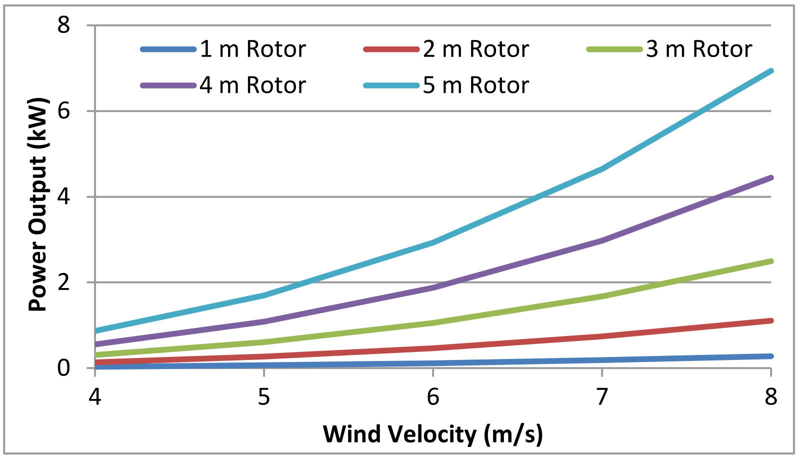


Figure 5 describes the influence of wind velocity and rotor diameter on performance of SMWT. In theory, doubling the blade diameter results in a fourfold of power output as the output increases by a square factor. Doubling the wind speed results in an eightfold of power output as the output increases by a cube factor (Power-Talk.Net, 2011). In practice, SMWT with small diameters have a more linear wind speed-power output relationship (Leaver et al., 2010). This means that the better the wind source and the larger the blade swept area is the higher the output will be. However, regular SMWT can only convert about 10 to 40 percent of the power in the wind into electricity (Reuk.co.uk, 2007).

Theoretically, the more commonly used three bladed HAWT have a higher capacity factor than VAWT or other types of HAWT. Despite their lower efficiency, VAWT are capable of generating more electricity when the wind conditions are turbulent and fast changing (Mathew, 2006).

4.2.3 Maintenance, Operational Lifespan

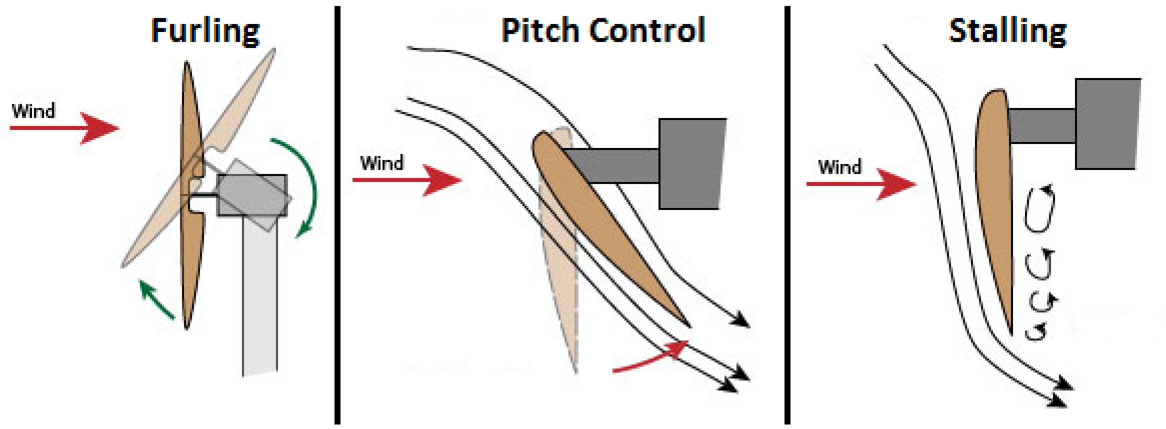
High wind speeds results in higher maintenance costs, especially when the wind turbine is exposed to very high velocities or gusts. The life of a wind turbine is finite and moving parts have to be maintained and replaced on a regular basis to guarantee smooth and uninterrupted generation. The average operational lifespan of a SMWT is given around 120,000 hours. As wind turbines do not constantly work due actual wind conditions, it can be estimated that the normal life cycle of a turbine is approximately 20 years (Gipe, 2004; Green Living Tips, 2011). For standalone systems with battery storage it has to be borne in mind that battery cells need to be replaced every 6 to 12 years (EECA, 2010a).

4.2.4 Damage Prevention and Rotor Control

To prevent damage or high wear in extreme winds or turbulences turbines normally shut down at certain wind velocities. When reaching cut-out (or furling) speeds the following mechanisms are triggered (Figure 6) (Gipe, 2004; Green Rhino Energy, 2011; G. Rogers, pers. comm., 20 June 2011):

- **Furling:** Automatic mechanism that moves the axis out of the wind, decreasing angle of attack and cross sectional area;
- **Pitch control:** Automatic mechanism that decreases angle of attack and cross sectional area;
- **Stalling:** Automatic mechanism that increases the angle of attack and starts stalling;
- **Tilting towers:** SMWT can be manually folded down and out of the wind.

Figure 6
Automatic damage prevention mechanisms (Green Rhino Energy, 2011)



4.2.5 Foundation and Tower Mounting

Normally, concrete foundations are used for SMWT. Each turbine has specific foundation requirements which should be complied with. For a standard turbine (about 2 to 3 kW and 10 to 15 metre tower), manufacturers recommend an about 3 to 5 cubic metre foundation made from steel reinforced concrete to give the structure enough tensile strength. Further, the foundation should be anchored appropriately to the respective soil properties (Gipe, 2004, Bishop, 2010). Southwest Windpower, for example, suggests for their Skystream 3.7 turbine that a 10 metre mast should be mounted on a concrete foundation with an edge length of at least 1.8 and a height of 0.9 metres (about 3 square metres) that is set into the ground (Southwest Windpower, 2011b).

There are three basic forms of towers used for SMWT; tubular, guyed or lattice towers. Freestanding tubular and guyed tubular tower combinations are most common for SMWT. For guyed towers, anchors for the guy cables have to survive the dynamic and static forces acting on wind turbines. The anchors have to be chosen under consideration of soil properties and turbine specifications and appropriately secured in the soil (Gipe, 2004).

4.2.6 Standards for SMW Generation Systems

All SMW energy generation systems have to comply with technical standards listed in Table 6.

Table 6
Technical standards for SMW generation systems (SEANZ, 2009)

General Wind Generation	Standalone Systems (SPS)	Grid-connected Systems
AS/NZS 3000: The Wiring Rules **AS/NZ 3010:** Electrical installations – Generating Sets AS/NZS 1768: Protection from lightning **AS/NZS 1170.2:** Wind loads **NZS 4219:** Seismic resistance specifications	**AS/NZS 4509.1:** SPS – Safety and Installation requirements **AS/NZS 4509.2:** SPS – System design guidelines **AS 4086.2:** Secondary batteries for use with SPS – Installation and maintenance **AS 2676.1 & .2:** Battery installation and maintenance in buildings **AS 3011:** Electrical installations – secondary batteries installed in buildings	**AS 4777.1:** installation of grid-connected energy systems using an inverter **AS 4777.2:** Inverter requirements **AS 4777.3:** Grid protection requirements

Health effects caused by SMWT are minor, if not even negligible. The Australian Government's National Health and Medical Research Council (NHMRC) (2010), for instance, have seen no evidence in adverse health effects from wind turbines and especially not from SMWT. Compliance with noise, electromagnetic interference or flicker standards and appropriate site evaluation, turbine design and technology selection reduce adverse health effects from SMWT to a minimum.

As noise is considered as an effect that can cause irritation of the environment (MfE, 2011a), SMW generation systems normally have to comply with noise standards. The current NZS 6808:2010 was released in 2010 and deals with noise from wind farms; however, it only applies to turbines with a blade swept area greater than 200 square metres. For smaller wind turbines general environmental noise standards apply that are defined in NZS 6801:1999 Acoustic – Measurement of Sound and NZS 6802:1991 Assessment of Environmental Sound (EECA, 2010b). Based on these standards, noise perception seems to be minimal from modern SWT. Experiences recorded by EECA state that turbines only become noisy in high wind speeds. In this case, wind noise itself masks the turbine noise so hardly any wind turbine disturbance is experienced (EECA, 2009a; G. Rogers, pers. comm., 20 June 2011). European studies came to the same conclusion (Hautmann, 2008), while Gipe (2004) argues that turbine noise is generally audible to some degree, but may not be perceived as unpleasant by most.

The compliance with these standards is primarily a responsibility of territorial authorities under the Resource management Act 1991 (see Section 5.2.4). District plans therefore must include rules dealing with the effects of noise. The rules for effects of noise are dependent on the time of the day, the level of sound, the type of sound and the premises location (MfE, 2005).

4.2.7 Environmental Impact of SMWT

The low environmental impact of wind turbines has been widely discussed. As wind generation produces no carbon emissions, wind turbines are carbon neutral after only a short period of time (about 6-12 months) (Green Living Tips, 2011; Stankovic et al., 2009).

Other environmental impacts predominantly focus on visual and noise impacts and are sometimes considered as higher than impacts from fossil fuel generated electricity. Impacts may also include communication effects; effects on habitat of birds and other animals as well as plants during construction and operation; effects on culturally significant; archaeological and historic sites; effects on aviation; land use effects; and public safety (EECA 2004). However, these impacts mainly apply to medium and large scale projects. They are normally no more than minor for SMWT and no research indicates, for example, an exceptional threat for birds (Gipe, 2004). Proper planning can minimise effects while visual and noise impacts can be mitigated appropriately through setback from homes and avoiding environmentally sensitive areas (Green Living Tips, 2011; National Wind, 2011).

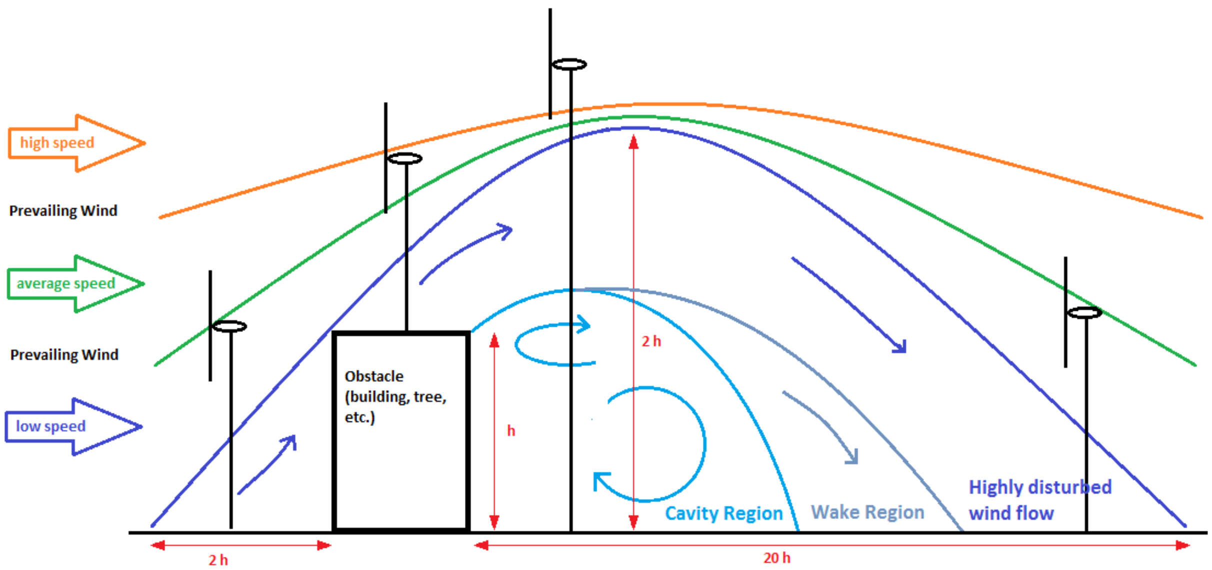
4.3 Turbine Placement and Wind Source Requirements

4.3.1 Wind Flow Disturbance, Wake Interference and Turbulences

Complex aerodynamics analysis is required for determining whether the wind regime is appropriate on a site or not. It is crucial to ensure an optimal turbine choice and placement. High wind speeds do not necessarily go hand in hand with good wind quality. There are other factors such as turbulence, wind shear or local effects that play an important role (Mathew, 2006). A turbine should be placed as far away from buildings, trees or other obstacles as possible and be higher than obstacles in close proximity to avoid turbulence. The higher a turbine and the less turbulence, the more energy it will generate. Mounting a turbine on rooftops can be challenging due to structural strength and high turbulent winds which often results in disappointing performance (Gipe, 2010).

When the wind flow passes obstacles such as buildings, tree plantings, hedges or other structures, a disturbance is caused in the wind flow in front of and behind the obstruction. Disturbed regions can be divided into the cavity region, the wake region and a region of highly disturbed wind flow as indicated in Figure 7 (Gipe, 2004; Mathew, 2006, EECA, 2010a).

Figure 7
Wind disturbance, wake and cavity regions, and turbulences



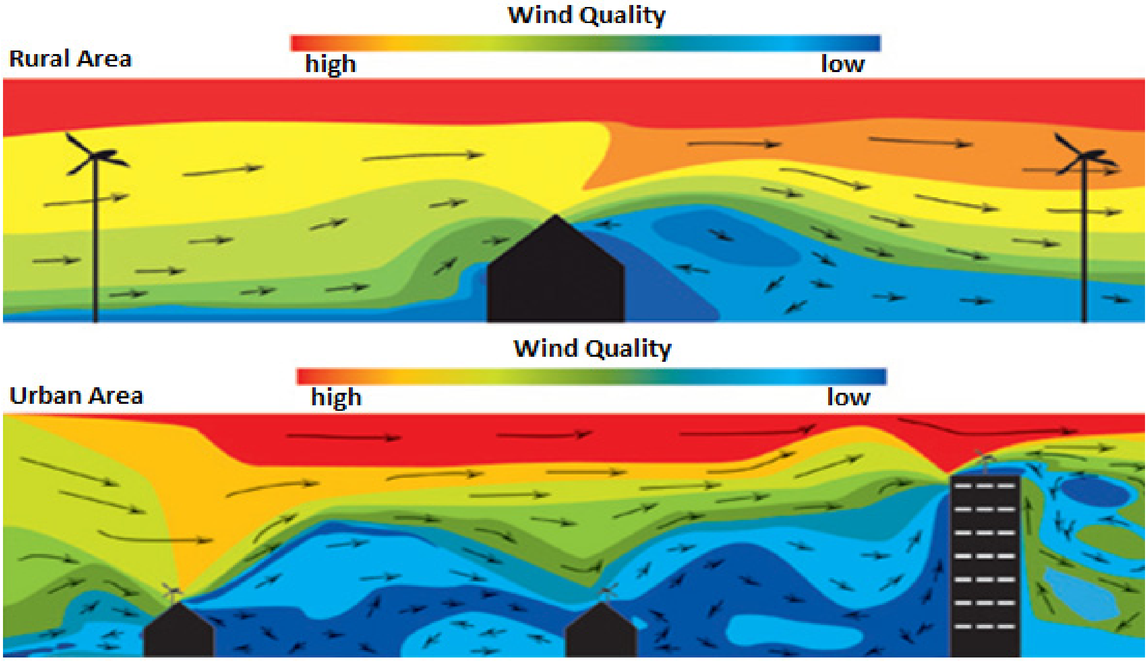
Disturbed regions (blue) normally range from two times the obstacle height before the obstruction and twenty times the obstacle height behind the obstruction. The height of these zones can be up to two times the height of the obstruction (EECA, 2010a). In this zone, the obstacle causes upstream and downstream wind flow that significantly reduces the power of the stream and forces only weak loads on the turbine blades (Mathew, 2006).

4.3.2 Wind Quality – Why Rural Use is More Appropriate

EECA (2010a) and others describe the occurrence of turbulence and wind flow disturbance in urban areas (Gipe, 2004; Stankovic et al., 2009). Figure 8 indicates the disturbed wind flow, wake interference and turbulence caused by the building environment in rural and urban areas.

When the prevailing wind flow hits obstacles such as buildings, trees or other barriers, turbulence behind and before the obstacles occurs. In Figure 8 blue and green regions provide for a much lower wind quality than the yellow, orange and red regions. The cavity and wake interferences provide very little wind quality (blue) (EECA, 2010a).

Figure 8
Wind flow disturbance and turbulences in rural and urban areas (EECA, 2010a)



The energy output from wind energy generation systems is highly dependent on the wind quality and quantity, which is determined by high velocity and little or no turbulence. Ground levels normally provide a very low wind quality while regions of 10 metres and above are considered as a minimum height for wind energy generation (Stankovic et al., 2009). Gipe (2010) argues that urban areas are not suitable for domestic wind turbines. Urban areas with a higher building and structure density clearly show lower wind speeds, more turbulence and higher cavity and wake interference; not at all an adequate wind quality for SMWT. The cavity and wake interferences accumulate between buildings in close proximity and provide low and disturbed wind speeds. Consequently, to avoid low wind quality, the hub height of a wind turbine has to be increased to access the regions with higher wind quality and less interference (EECA, 2010a; Stankovic et al., 2009).

Figure 9
Wind shear above flat and rough surface

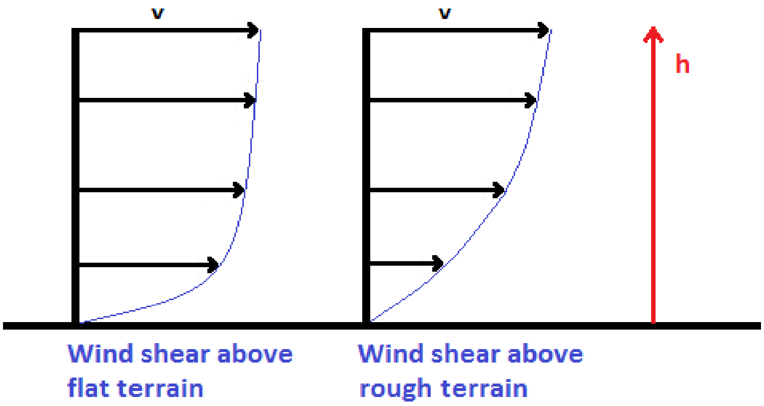


Figure 9 describes the wind shear above flat (e.g. fields) and rough (e.g. forest, urban areas) surfaces. Turbines that are mounted on high masts and on flat surface areas are likely perform better (SWIIS Consortium, 2007). For wind assessments the height of the measurement is important when determining the approximate AEO. Wind monitoring undertaken in lower wind regions will not display the actual AEO that a SMWT can achieve in higher regions. The wind monitoring should be carried out in the same height of the proposed turbine mast. Placing the hub on a higher mast (e.g. 15 metres) will result in better performance and increase the generation rate; for a hub height increase from 10 to 15 metres an approximately 7-8% increase in energy output can be expected (Leaver et al., 2010). Placing the hub lower will most likely decrease the power output, unless the correctly conducted wind monitoring has proven the opposite.

As a logical result, areas with low population and dwelling density are more suitable for wind energy generation, especially when systems with SMWT are used. SMWT have a lower mast height and need a relatively undisturbed wind flow. This is best achieved in areas (EECA, 2010a):

- With uninterrupted wind flows down from mountain ranges, through valleys, over passes, on ridgelines, hilltops or high plains and in coastal areas;
- With stable and even wind flow, uninterrupted and avoiding turbulence;
- Where a higher hub height is possible when considering the respective planning provisions;
- With a smooth surrounding environment and with little vegetation and barriers.

This does not mean that SMWT systems should be exclusively erected in rural areas. Careful turbine placement on semi-rural or urban sites with a large enough plot area can decrease the effects of disturbed regions, wake interference and turbulences (SKM, 2006; Stankovic et al., 2009). However, it may be very difficult to achieve good results (Gipe, 2010) and it involves more detailed wind source assessments, more careful planning and will most likely increase the planning costs for a SMWT.

4.3.3 Wind Monitoring

Wind speed measurement and monitoring (this includes the directions of the prevailing wind) and the analysis of the acquired data are crucial for a turbine's performance and on-site AEO estimations. There are many ways of assessing on-site wind speed and direction. Compliance with standards is recommended when monitoring wind resources (Gipe, 2004).

The International Electrotechnical Commission (IEC) released the most recent version of their international wind turbine power performance testing standard in 2005. The IEC 61400-12 standard describes measuring procedures that specify the assessment of small wind turbine performances and indicates whether the manufacturers' data are correct. On basis of the standardised test results, wind turbines can be compared appropriately. Instruments for testing should be mounted on a mast at the same location and height as the prospective wind turbine. The required instruments include a primary anemometer, a reference anemometer, a wind vane, an air pressure transducer, a shielded air temperature sensor, a rain indicator and a data logger. The data measurement has to include the mean wind speed and its standard deviation as well as minimum and maximum wind speed in one second cycles (1Hz). The output includes one minute data sets and binned ten minute data sets per 0.5m/s. The measurement range should range from 1m/s below cut-in speed to 14 m/s (Smith, 2009).

4.4 Standalone (Off-grid) Systems

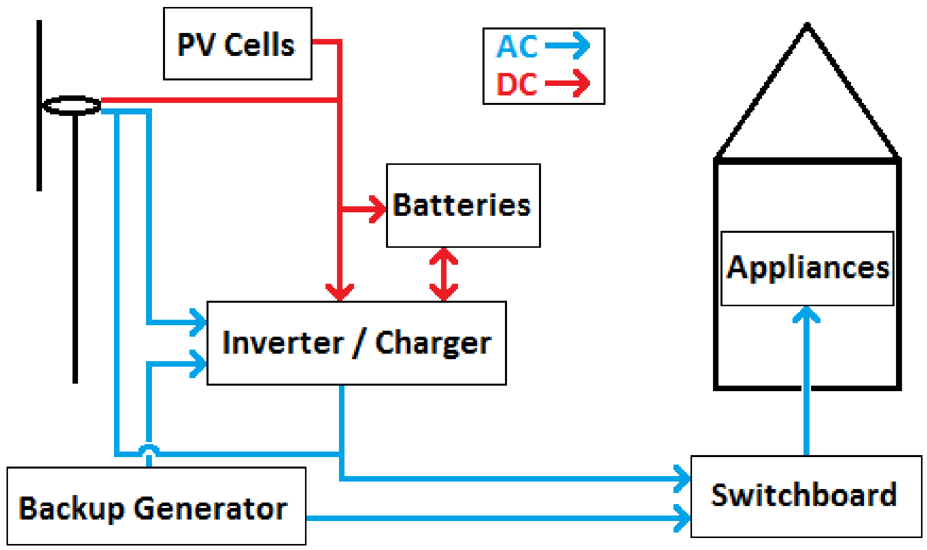
Typical larger off-grid electricity generation systems are located on Stewart Island or in Milford Sound are not connected to the national or a local grid. The required electricity is generated on site and simultaneously used by the connected users and appliances or stored in battery banks. Generally, all electricity generated is used on site and within the system. Nonetheless, to ensure uninterrupted energy supply in off-grid systems, backup systems (e.g. backup generator or battery storage) needs to be in place (Gipe, 2004; EECA, 2010a).

Before choosing to install a standalone system the costs should be evaluated against a grid-connection. The cost of connection, which increases with the distance to the nearest network connection point, can be dropped with a standalone application. On-site electricity supply is likely to be more reliable than a connection to a distant local grid. However, backup generators and/or battery storage have to be in place ensuring a constant energy supply. This and more generous dimensioning of the system will increase the total installation costs. System installation and maintenance costs have to be determined to see if an off-grid application is viable. Especially remote premises might benefit from a standalone system as the costs for a grid connection can be tremendously high with up to $ 25,000 per kilometre (which often includes the installation of a transformer). In some cases the connection costs can range between $ 30,000 and $ 50,000 per kilometre (SEANZ, 2011b; EECA, 2010a).

4.4.1 SMWT Off-grid Application

A standalone system's switch circuit is shown in Figure 10.

Figure 10
Standalone small scale wind energy generation system



For standalone application, battery storage, generators and/or another kind of renewable generation systems (e.g. PV panels) are generally used to back up a SMWT (Gipe, 2004; EECA, 2010a):

- For micro turbines, generated low voltage DC (red) electricity can be rectified into 230 volts AC or directly stored in batteries.

- For small turbines, generated AC (blue) electricity can be directly used in home appliances or to directly charge batteries (via a charger) when more electricity is generated than consumed.
- During periods of poor wind quality and/or a high energy demand, AC generating backup systems (e.g. from a diesel) meet the demand and charge batteries.
- During periods of high generation rates and full batteries, the load has to be “dumped” (e.g. by supplying the hot water cylinder).

4.4.2 Dimensioning of Standalone Systems

It is important for standalone systems to find the appropriate system size and capacity to provide for the required energy output. Before choosing the dimension of the standalone system it has to be clear whether the system size should be adapted to the energy demand or the energy demand should be decreased to adapt to a smaller dimensioned system (this normally means a change of life style to some degree). When choosing to decrease the energy demand, two major features are (EECA, 2010a):

- **Reduced energy demand and alternative energy sources:**
  This involves measures to lower the energy demand and can include substituting electrical heaters with log burners, the use of gas stoves and/or solar water heating systems.
- **Reduced peak load, the maximum energy demand during a day:**
  Avoiding running energy intensive appliances at the same time (e.g. oven and dish washer) or efficient use of light and heating decreases the peak demand.

Successfully operating a standalone system involves finding the right balance between energy demand and system dimension. On the basis of the monthly and daily consumption and with help of on-site wind assessments the system size can be planned appropriately. Analysing monthly energy bills from several years indicate an average consumption. Further, energy audits can help to determine the required energy demand and to adjust the system (i.e. turbine capacity, backup system, other means of renewable generation, battery storage, etc.) to one’s own needs. It further reveals energy saving potentials and options to substitute conventional with more environmentally friendly alternative energy sources (EECA, 2010a).

4.5 Grid-connected Systems

Grid-connected SMW generation systems are more complex than the standalone application as the generation systems are connected to a local distributer’s grid where electricity can be imported and exported, depending on the turbine’s performance. Excess electricity is sold to retailers; energy shortage is balanced with electricity import from a retailer. It is also possible to sell the surplus electricity to the wholesale spot market which is highly time-consuming and hard to plan as generation rates vary with the wind quality and quantity. The appropriate dimensioning ensuring constant energy supply plays a minor role for grid-connected systems as their electricity shortage is met by the local grid. When planned properly, the general benefits of grid-connected renewable DG systems are reduction of greenhouse gas emissions, lower energy bills and facilitating surplus electricity by selling it back to retailers (EECA, 2011a: SEANZ, 2011c).

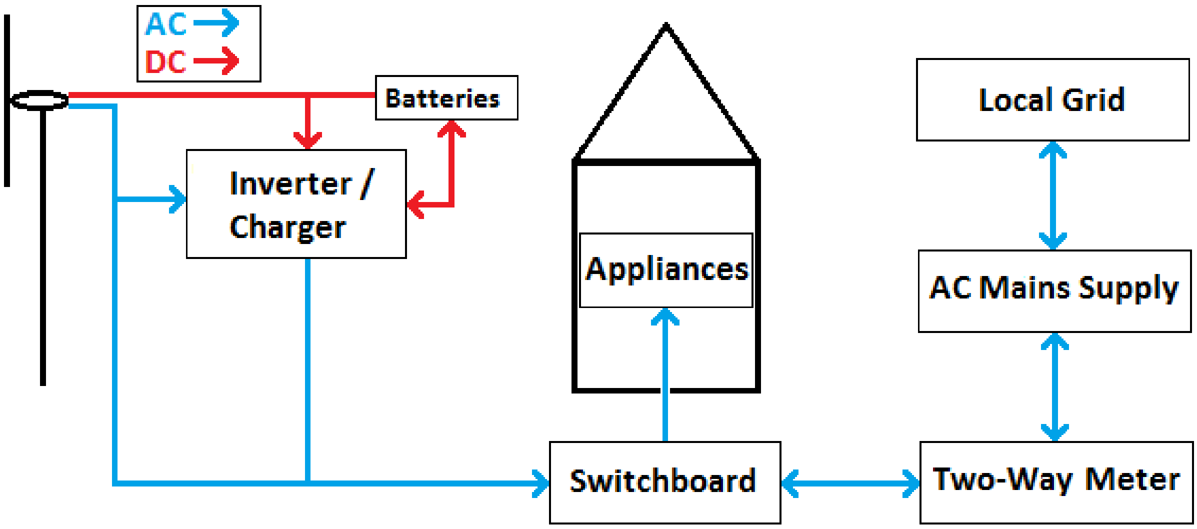
4.5.1 Grid-connected Application

The switch circuit for a standalone generation system is illustrated in Figure 11. Surplus electricity can either be exported to the grid or stored in an optional battery bank and used when the turbine doesn’t generate enough to meet the demand (Gipe, 2004; G. Rogers, pers. comm., 20 June 2011):

- For micro turbines, generated low voltage DC (red) electricity can directly be stored in batteries. It can also be rectified and stepped up into 230 volts AC (associated with voltage losses).
- For small turbines, generated AC (blue) electricity can directly be used in home appliances or for charging batteries (via a charger) when more electricity is generated than consumed.
- Batteries can also be charged and maintained with night electricity rates and used during the day when normally higher rates apply.

- During periods of poor wind quality and/or a high energy demand, AC can be imported from the local grid via the AC mains supply.

Figure 11
Grid-connected small scale wind energy generation system



To meter the electricity imports from and exports to the local grid, two-way meters (also called import/export or smart meters) are used. A two-way meter records both, the amount of electricity that is fed into the grid and the amount that is obtained from the distributer via the AC mains supply. This technology allows charging electricity export against imports on the electricity bill. The system has to be approved by the retailer the buy-back agreement was arranged with. Net-metering, where electricity exports are directly subtracted from the imported electricity within the meter is prohibited in New Zealand, even though it is applied in other countries. Both import and export flow from a distributed generator must be measured separately and are normally charged separately on the monthly electricity bill (SEANZ, 2011d).

4.5.2 Connection to the Local Grid

To connect a DG system to a local grid the following persons are involved (SEANZ, 2011d):
- The **System Owner** or person intending to connect a DG system to the local grid;
- The **Distributer** that operates and manages the local electricity grid (see Appendix A.1 for a map of distributer supply areas);
- The **Electricity Retailer** that supplies the premises and will buy-back the surplus generated electricity (see Appendix A.1 for a list of retailers and areas they supply);
- **Metering Service Company** that installs and maintains the import/export meters.

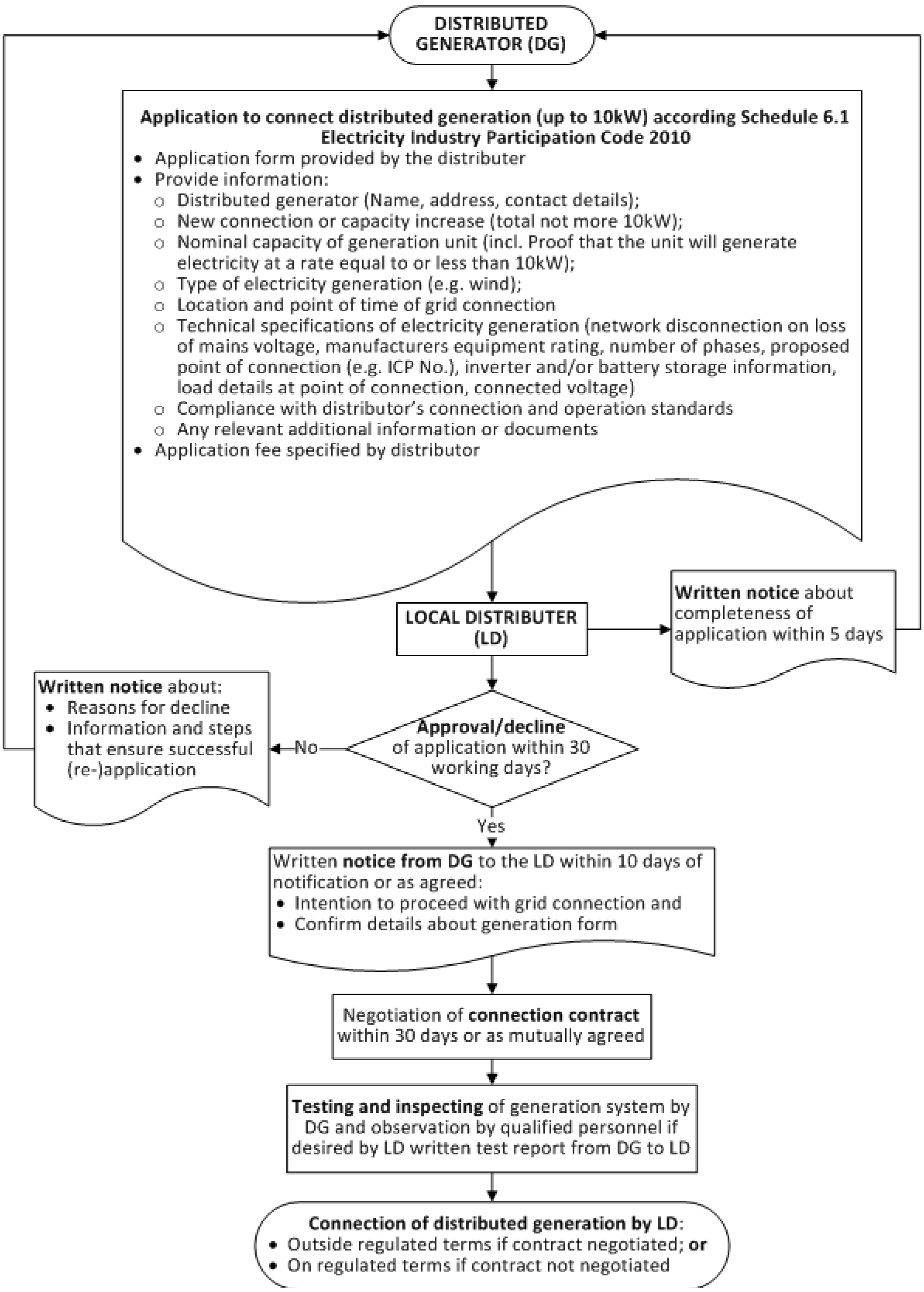
The costs for a grid-connection are borne by the system owner. The fees a distributer charges may vary but there is a maximum charge for systems with a capacity rating of 10kW and less according to Schedule 6.5 of the Electricity Industry Participation Code 2010. The maximum charges for a DG system with 10kW or less are:
- $200 application fee for DG system (with up to 10 kW rated/installed capacity);
- $50 fee for observation of testing and inspection of DG system.

Standards for the grid-connection, wiring and electrical installations have to be complied with at all times (see Table 6 in Section 4.2.6). Hereby, especially the AS 4777 series and standards AS/NZS 3000 and AS/NZ 3010 are relevant. Further, the distributer can imply local electricity network standards that the system has to be in compliance with. These standards are publicly available on the distributers' websites (EECA, 2010a).

In New Zealand, metering service companies are generally owned by retailers or distributers. However, in a normal case the retailer provides the system owner with a two-way meter and may charge for the use of it. When a grid-connection causes additional costs for the network (e.g. power line extension or installation of an additional transformer), this costs may be charged at the expense of the system owner. However, when a property is already connected to the local grid, then additional connection charges are unusual (EECA, 2010a).

The process to connect a DG system to a local distributer's electricity network follows Schedule 6.1 of the Electricity Industry Participation Code 2010 and is described in the flowchart in Figure 12.

Figure 12
Grid connection process according to Schedule 6.1 of the Electricity Industry Participation Code 2010



4.5.3 Electricity Export and Buy-back Arrangements

It is possible to export surplus electricity back into the local grids when more energy is generated than actually needed on-site. Before electricity can be exported, a buy-back (or off-take) agreement has to be arranged with a retailer that operates in the area where the SMWT is located. These agreements include (Level, 2011):

- Details about the electricity flow from the property into the local grid and from the local grid to the property;
- How the electricity flow will be metered;
- Reimbursement price for electricity fed back into the local grid.

In New Zealand, not all electricity retailers offer buy-back arrangements. As opposed to other countries like Germany (Renewable Energy Sources Act – EEG 2009), the UK (Energy Act 2008) or Australia (Electricity Feed-in (Renewable Energy Premium) Act 2008), New Zealand's electricity retailers are not legally bound to offer buy-back rates for distributed renewable generation (EECA, 2010a). This means that feed-in tariffs (FiT) as such do not exist in New Zealand. Most contracts are drawn up on month-by-month basis and retailers reserve the right to cancel or change buy-back rates and conditions anytime, but generally after providing at least a one month notice prior to changing terms and conditions (Email comm. with electricity retailers, 3 to 31 May 2011).

The retailer's supply areas and offered buy-back rates are summarised in Appendix A.1. Mainly nationwide retailers that are also bulk electricity generators offer off-take agreements, i.e. contracts that guarantee a buy-back of a certain amount of generated electricity for a predetermined price per kWh and over an indented period of time. Retailers offering buy-back rates can determine their terms and conditions that apply. Therefore the buy-back price range for a kWh is considerably lower compared to countries that have passed legislation guaranteeing a premium rate paid by retailers to producers of renewable energy. In New Zealand the buy-back rates vary from a few cents/kWh to a one-to-one buy-back (i.e. the same prices that the generator pays to import a kWh). Retailers may also apply surplus charges for metering, transmission, distribution, administration and/or billing, i.e. additional line user charges are added to the monthly power bill.

4.6 Turbine Technology, Performance and Operation Summary

This chapter has shown that a wide variety of turbines can be applied in an even wider range of systems. Summarising this chapter, it can be said that:

- Every system is different and appropriate planning and dimensioning is essential to guarantee a good performance.
- It has to be clear what kind of system application is desired; standalone, grid-connected or hybrid application.
- Critical factors include on-site wind monitoring over an adequate period of time (at least one year), finding the right on-site location to avoid turbulences and choosing the right turbine under consideration of the previous findings. Hereby, standards should be applied.
- Additional costs have to be considered when choosing to invest in a wind turbine. These include foundation costs, freight, electric wiring costs, and costs for backup systems when an off-grid application is desired. Further, maintenance costs over the operational lifespan have to be considered. They are dependent on the turbine's performance.
- Connecting the DG system to a local grid is not as problematic as it might seem and when a grid connection is already available, a small charge and the installation of a two-way meter is all that has to be done to connect the system to the grid. When exporting surplus generation to the grid, a buy-back arrangement has to be made with an electricity retailer. At the time of writing, the best option is the one-to-one off-take agreement offered by Meridian Energy.

Chapter 5
Legal Aspects of Small and Micro Scale Wind Turbines

5.1 Introduction

Chapter 5 deals with legal aspects of small and micro scale wind energy generation. Section 5.2 provides a summary of resource management planning in New Zealand while special attention is drawn to the new National Policy Statement for Renewable Electricity Generation 2011. The different spatial planning processes involved to obtain, if necessary, a resource consent are described in Section 5.3. Section 5.4 deals with building consents. Further legal aspects that distributed generators have to consider when developing SMW energy generation systems and connecting it to the local grid are described Section 5.5. It reveals the different statutes, authorities, regulations and codes that play a role for distributed electricity generation, transmission and trading.

5.2 New Zealand's Planning Framework

5.2.1 Effects-based Planning under the Resource Management Act (RMA) 1991

Unlike most other countries, New Zealand uses a neoliberal effects-based planning approach. Spatial planning in New Zealand manages natural and physical resources by limiting the effects of an activity to a degree where sustainable management of natural and physical resources can still be promoted. This approach enables market decisions about the most suitable resource use instead of a top down regulation of activities (Makgill and Rennie, 2010).

The Resource Management Act (RMA) 1991 is New Zealand's main environmental legislation and provides a planning framework to "promote the sustainable management of [New Zealand's] natural and physical resources", as stated in the purpose of the Act under Section 5 (MfE 2011a).

The consolidation of spatial planning in New Zealand under the RMA 1991 plays an important role for small and micro scale wind energy generation. In Part 2 of the Act, the principles are described to achieve the purpose of the RMA 1991. Section 7 "Other matters" states that "in relation to managing the use, development, and protection of natural and physical resources" decision makers shall have particular regard to:

- (b) The efficient use and development of natural and physical resources;
- (ba) The efficiency of the end use of energy;
- (i) The effects of climate change;
- (j) The benefits to be derived from the use and development of renewable energy.

The legislative provisions are further supported in case law. One important case that strengthens the development of renewable energy use is Genesis Power Limited v Franklin District Council (2005) NZRMA 541 which states that the use of renewable energy should be preferred over conventional generation forms.

All land use activities (wind electricity generation is considered as a form of land use as it involves erection of structures) must comply with the RMA 1991. Every activity in relation to wind energy projects, from micro scale to large scale, is classified in provisions of the relevant regional and district plans as a permitted, controlled, restricted discretionary, discretionary, non-complying or prohibited activity, while the effects of a proposed activity determine how the activity is classified. When the effects of an activity are permitted, no resource consent is required; when the effects are, to some degree, under the consent authority's discretion, then a resource consent is needed (EDS, 2011a).

5.2.2 The National Policy Statement for Renewable Electricity Generation 2011

The National Policy Statement for Renewable Electricity Generation 2011 (NPSREG) was prepared under the RMA 1991 and sets out objectives and policies to promote sustainable management of renewable electricity generation in New Zealand. Its objective is "to recognise the national significance of renewable electricity generation" and to promote the development of new and existing renewable energy generation systems. The NPSREG was notified in the Gazette on 14 April 2011, became effective on 13 May 2011 and from this date became legally binding for regional and territorial authorities.

Important policies for SMW energy generation are Policy E3 and Policy F1:

- **Policy E3** states that "regional policy statements and regional and district plans shall include objectives, policies, and methods (including rules within plans) to provide for the development, operation, maintenance and upgrading of new and existing wind energy generation activities to the extent applicable to the region or district."
- **Policy F** states that "regional policy statements and regional and district plans shall include objectives, policies, and methods (including rules within plans) to provide for the development, operation, maintenance and upgrading of small and community-scale distributed renewable electricity generation from any renewable energy source to the extent applicable to the region or district."

Before the notification of the NPSREG local governments did not have to specifically address renewable energy generation in their plans and gaining resource consent from a consent authority (CA) often resulted in a costly and time intensive process, especially when local opposition was great. For many potential investors in SMW generation this has been one of the main obstacles (Barry and Chapman, 2009).

Now, regional and territorial authorities are legally bound to address renewable generation and in particular distributed generation. They have to include the NPSREG objectives and policies into regional and district plans as stated in Section 55 of the RMA 1991. Policy F explicitly mentions small distributed renewable electricity generation to be enabled by Regional Policy Statements and regional and district plans. Regional and territorial authorities have to incorporate the NPSREG into their policy statements and plans within 24 months (by 12 May 2013).

From now on plans could include distributed renewable energy generation up to a certain capacity as a permitted or controlled activity and make the consenting process for SMWT easier which would, according to Barry and Chapman (2009) attract more potential generators. For SMWT this means that, for example, the erection of masts for mounting the turbine in an economical height could be a permitted activity under the RMA 1991 and that noise emissions from the turbines are permitted up to a particular level at a certain distance from the turbine.

Another not as permissive but more enabling approach to some degree would be the classification of SMWT as controlled activity. On application, a resource consent has to be granted and the consent authority could impose conditions on the consent. The restrictions would only be for matters over which relevant plans or national environmental standards give the consent authority control over. However, what this means for SMWT and how the different regional and territorial authorities are going to incorporate the NPSREG into their statutory plans has to be awaited.

5.2.3 Other Statutory Planning Instruments Relevant for SMWT

- **Regional Policy Statements**
  Regional Policy Statements (RPS) are prepared under Section 63 of the RMA and provide an overview of how regional councils deal with resource management issues under the RMA 1991 and identify a region's policies and methods to manage their natural and physical resources (EDS, 2011b).
- **Regional and District Plans**
  Regional plans are prepared under Section 63 and district plans under Section 73 of the RMA 1991. These plans are statutory planning instruments and assist regional and territorial authorities carrying out their functions under the RMA 1991. Regional and district plans both have to give effect to National and Regional Policy Statements. Both plans contain provisions for governing the region or district respectively and must state (EDS, 2011c):

- Objectives for the region or district;
- Policies to implement the objectives; and
- Rules to implement the policies.

5.2.4 Responsibilities of Regional and Territorial Authorities and the Environment Court

The preparation of statutory regional and district plans falls under the jurisdiction of regional and territorial authorities. Regional, district (or city) or unitary councils also have the decision making power regarding resource consent applications.

In terms of SMW energy generation, only territorial authorities (or district and city councils) are relevant as they deal with the effects of land use activities (Section 31(1)(a) of the RMA 1991) and the effects of noise (Section 31(1)(d)). It can be considered unlikely that regional plans will have to be taken into account for most SMW projects unless the site of a proposed SMWT is located in any coastal marine area (Section 30(1)(d)), in any bed of a water body (Section 30(1)(g)) or a rule in a plan states the conservation of soil in the area where a SMWT is intended to be built (Section 30(1)(c)(i)). The same applies for hazard areas (e.g. flood areas).

In case of disputes or appeals to council decisions about resource consent applications or resource consent conditions the Environment Court has jurisdiction over these matters. The Environment Court can hear matters under the RMA 1991 and make decisions that can only be further appealed to the High Court on questions of law (Section 120 and 121).

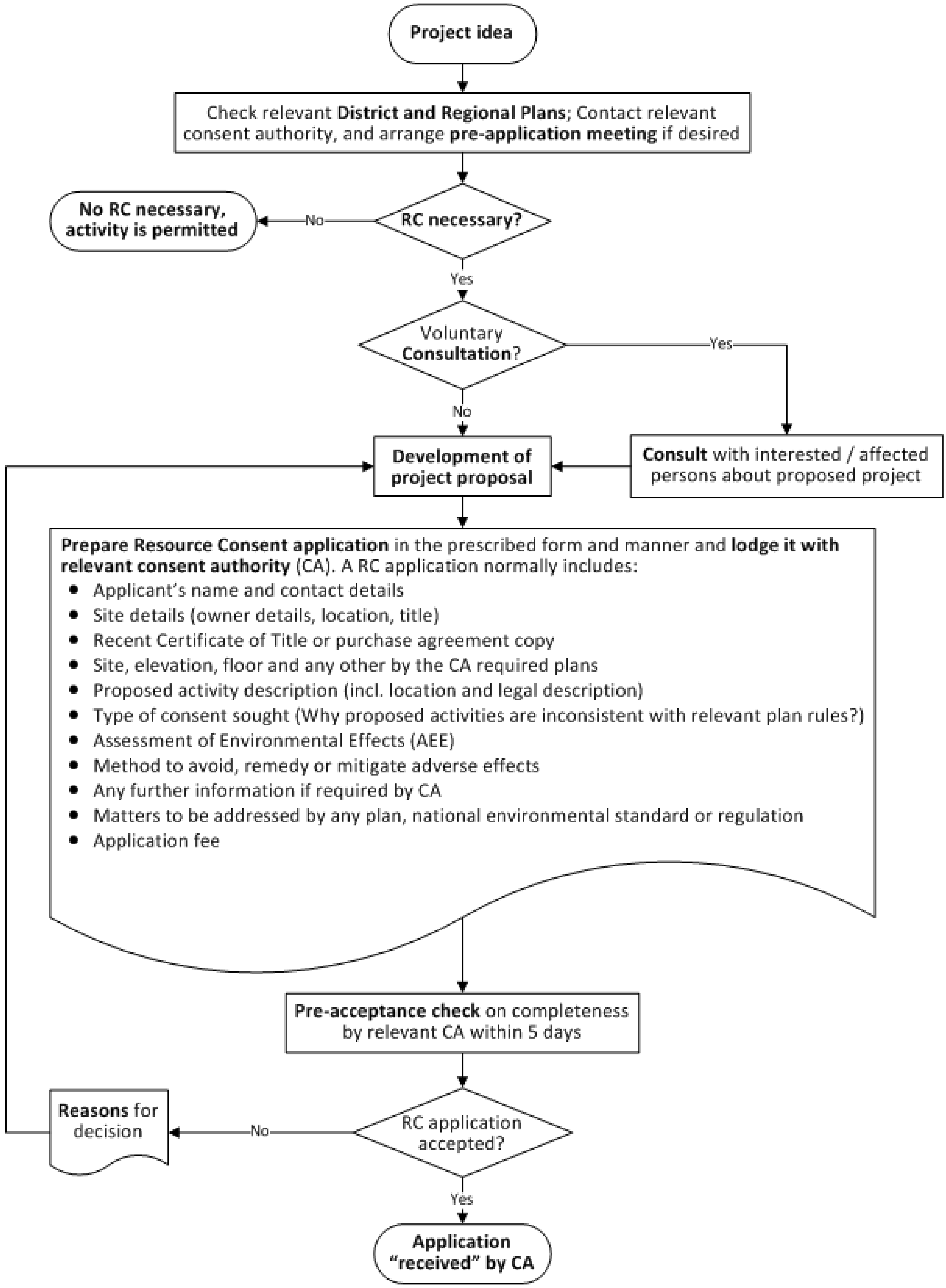
5.3 Resource Consents

5.3.1 Resource Consent Application Process

As described above, all land use activities are regulated by district (or city) councils and have to comply with policies and rules set out in the relevant plans. When an effect of an activity is classified as controlled, restricted discretionary, discretionary, non-complying, resource consent must be obtained in accordance with the prescribed application processes set by the CA (EDS, 2011a).

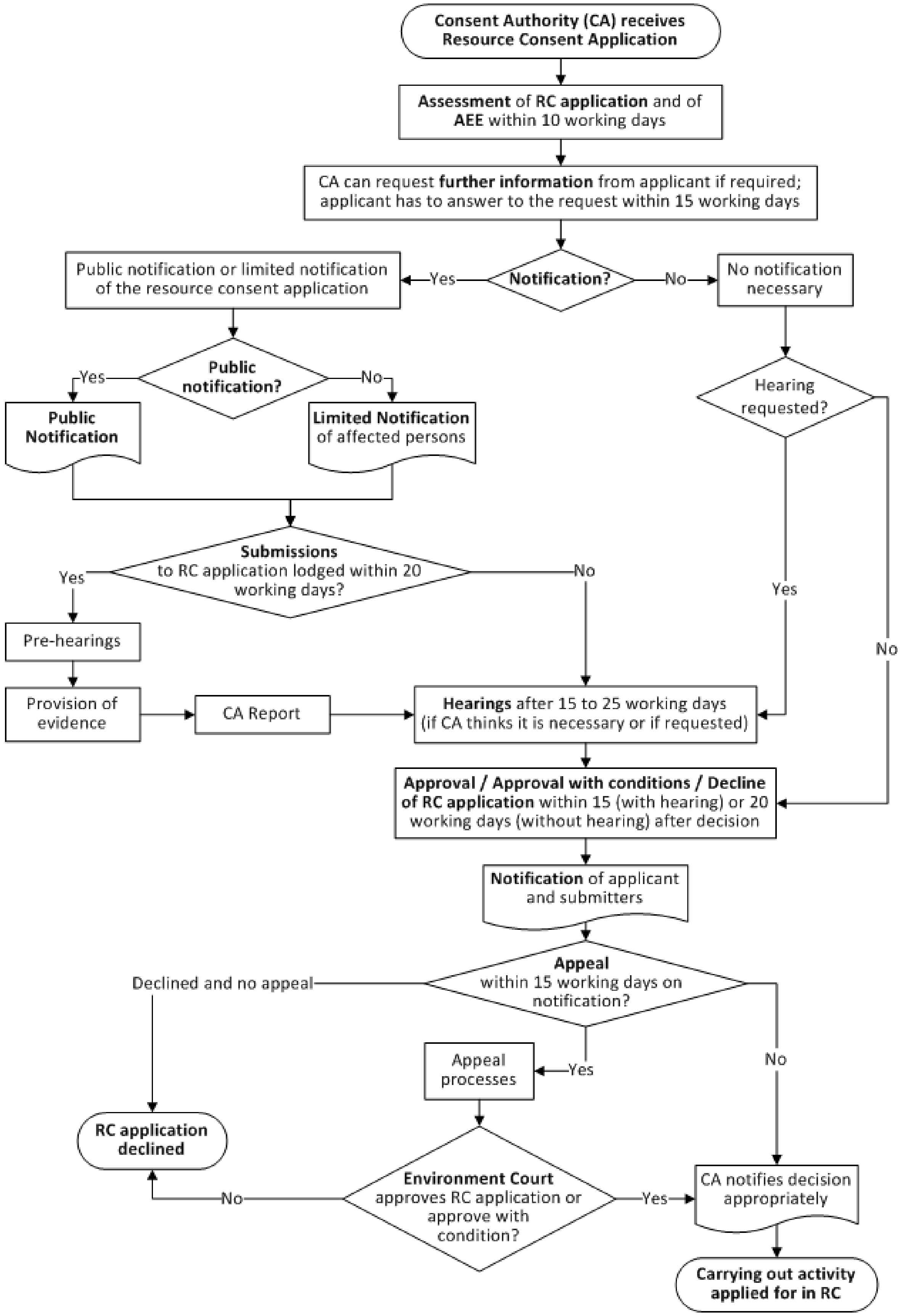
The flowchart in Figure 13 describes the process for lodging resource consent applications according Part 6 of the RMA 1991. All persons applying for a resource consent have to follow this process. The requirements may vary between the different consent authorities. Therefore it is important to check the relevant plans and determine what kind of resource consent has to be obtained to carry out the proposed activity. A SMWT generally only requires a land use consent when exceeding the permitted building or structure height, noise emissions limits, vibration limits, the distance to the property boundary or when earthworks for the foundation are required (SMWT normally require a solid steel-reinforced concrete foundation).

Figure 13
Resource consent application process according to Part 6 of the RMA 1991



Once the consent authority has received the resource consent application, further assessment and decision making processes will be triggered. The process consent authorities go through is described in Figure 14.

Figure 14
Processing of resource consent Applications by the consent authority according to Part 6 of the RMA 1991



5.3.2 Resource Consent and Process Costs

Applying for a resource consent involves council costs that have to be borne by the applicant. Normally charges include a fixed fee for the resource consent application plus processing costs for extra time and work (e.g. hourly planner or consent manager costs). Generally costs thereby incurred are (MfE, 2011b):

- Limited Notified (NZ$ 1,000 – several thousand dollars plus costs for extra time and work);
- Non-notified (NZ$ 700 – 1,500 plus costs for extra time and work);
- Pre-application meeting fees (NZ$ 0 – 150 plus costs for extra time and work);
- Other certificates and further costs (NZ$ 500 – 1,000 plus/or costs for extra time and work);
- Hourly rates for planners, consent manager, etc. and rates for travel
- E.g. Certificate of Compliance, Certificate of Existing Use;
- Change, review or cancellation of resource consent conditions;
- Appeal a CA's decision to the Environment Court involves (NZ$511.10).

Resource consent and process fees vary from council to council. The displayed fee range is an indicator, fees are likely to be higher or lower and subject to annual change. However, the indicated costs reveal that obtaining a resource consent for a SMWT can be a costly matter for a private person.

5.3.3 Assessment of Environmental Effects

When the effects of the installation of a SMWT are not classified as a permitted activity by a relevant regional or district plan, a resource consent must be obtained. An integral part of a resource consent application is to carry out an assessment of environmental effects (AEE) to determine the effects of the proposed activity. Different AEE requirements apply for each classification of the proposed activity (MfE, 2006):

- **Controlled:** AEE only has to address the adverse effects stated in the council's plan;
- **Restricted discretionary:** AEE only has to address the adverse effects stated in the council's plan;
- **Discretionary:** AEE has to determine the degree of impact from all adverse effects;
- **Non-complying:** AEE has to determine the degree of impact from all adverse effects as they may have a significant impact on the environment.

Section 88(2)(b) of the RMA 1991 requires every resource consent application to provide an AEE. It has to be prepared in accordance with Schedule 4 of the RMA 1991. An AEE for installing a SMWT should include (but does not have to when stated otherwise in the council's plan):

- Description of the proposed activity;
- Assessment of the proposed activity's actual and potential adverse effects;
- Possible alternatives (location or methods) when any significant adverse effects are likely;
- Assessment of risks to the environment from use of hazardous substances and installations;
- Avoidance, remedy or mitigation measures to prevent actual or potential adverse effects;
- Identification of affected persons, conducted consultation and response to their views;
- If controlling or monitoring of effects is required, what will be controlled or monitored and how it will be conducted.

Further matters that an AEE for SMWT should consider include:

- Any effects on neighbourhood and wider community (including cultural and socio-economic effects);
- Any physical and visual effects on site and landscape;
- Any effects on ecosystems and natural habitats in the surrounding area;
- Any effects that have aesthetic, recreational, scientific, historical, spiritual, or cultural, or other special value on natural and physical resources for present or future generations;
- Any noise emission that is unreasonable.

For potential SMW generators it is often difficult to identify actual and potential adverse effects and to determine whether those effects are classified as minor, more than minor, major, significant or critical. In this case, expert advice may be obtained to help with the AEE or to lodge the entire resource consent application which is likely to increase the project costs.

5.3.4 Non-notified vs. Limited Notified Resource Consent Applications

RC applications include an AEE which identifies effects on the environment. This includes effects on adjacent site owners or occupants. However, before applying for a resource consent, written approval from potentially affected persons or order holders (i.e. adjacent neighbours) should be obtained to avoid potential conflicts. The consent authority determines whether a person or an order holder is affected in accordance with Section 95B(2) and (3) of the RMA 1991. Limited notification criteria are:

- When no person suffers more than minor effects, then the RC application is non-notified;
- When approval is obtained from all persons that are affected more than minor, then the RC application is non-notified;
- When one or more persons are affected more than minor and they have not given their approval, then a limited notification to these persons is necessary.

5.4 Building Consents

The Building Act 2004 (under Section 8) regulates the installation of permanent structures, including electrical systems that are attached to the described structures. Hence, installing a wind on any structure requires a building consent. The consenting process is normally straightforward and involves only a few simple steps. On the other hand, more complex projects require a higher degree of planning and compliance of all work with health, safety and durability performance standards in the Building Code (DHB, 2011).

Consulting the local consent authority (territorial authority) is advisable. The process of obtaining a building consent is as followed (DHB, 2011):

1. **Early Consultation and Pre-application for a Project Information Memorandum**
   An early consultation with the building consent authority and a pre-application for a project information memorandum (PIM) is advisable in the early project design stage but not mandatory. PIM applications are lodged with relevant territorial authority and can be made prior to applying for the building consent in order to scope out the site. A PIM identifies the requirement of a resource consent, whether any other legislation has to be considered (e.g. heritage status), special site features, surface and waste water details, and whether a development contribution fee has to be paid. It helps to determine whether RMA planning issues are associated with the proposed project.
   When no pre-application for a PIM has been lodged, then a building consent application automatically includes an application for a PIM.
2. **Building Consent Application**
   The building consent application is lodged with the relevant building consent authority. They have to include relevant and detailed building and site plans and specifications that demonstrate compliance with the Building Code, and other required details (e.g. certificate of property title). A qualified professional should be engaged into the application process. Further, a building consent application fee has to be paid.
3. **Alterations or Variations**
   If project alterations or variations have to be made, amendments to the building consent are required. Otherwise, work does not comply with the approved building consent and no compliance certificate can be issued.
4. **Timeframe of Issuing a Building Consent**
   Within 20 working days, a CA decides about an application and issues the building consent when all requirements of the Building Code are met.
5. **Compulsory Final and Interims Inspections**

The consent authority must be informed about the start of the project in order to organise inspections during the construction and a compulsory final inspection for a code compliance certificate (CCC).

5.5 Other Legal Aspects of Distributed SMW Generation

5.5.1 Electricity Generation and Transmission from Grid Connected Systems and Electricity

When connecting a distributed generation system to a local utility network, the following statutes, authorities, regulations and codes that play a major role for electricity generation, transmission and trading. To connect a SMWT to a local grid, generators have to comply with the different legal statutes, regulations, codes and processes involved.

- **Electricity Act 1992 and the Electricity Commission**
  Under the Electricity Act 1992 the Electricity Commission was formed to provide for the purpose of the Act under Section 1A(a). The Electricity Commission was required to "provide for the regulation, supply, and use of electricity in New Zealand".
- **Electricity Industry Act 2010**
  In 2010 most parts of the Electricity Act 1992 were repealed by the Electricity Industry Act 2010. The Electricity Industry Act 2010 became effective on 5 October 2010. It was introduced with the purpose to "provide a framework for the regulation of the electricity industry" (Section 4). Grid connected distributed electricity generators have to comply with requirements set under the Electricity Industry Act 2010 and the Electricity Industry Participation Code 2010 in matters of preparation for selling of, offering of, and reporting on generated electricity (EA, 2010).
- **Electricity Authority**
  The Electricity Commission was dismissed on 31 October 2010, and the Electricity Authority (EA) was established under Section 12 of the Electricity Industry Act 2010. The EA's objective are to "promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers" as outlined in Section 15 of the Act. The EA oversees the electricity market and ensures its effective operation and the balance between supply and demand. The EA further maintains and assures compliance with electricity codes and regulations (EA, 2011). Grid connected distributed generators participating in the electricity market have to comply with the codes and regulations while the EA ensures that the electricity input does not deteriorate the power quality of the grid (e.g. frequency) (Transpower, 2011a).
- **Electricity Industry Participation Code 2010**
  The grid connection of distributed electricity generators is described in Part 6 of the Electricity Industry Participation Code 2010 which has replaced the Electricity Governance (Connection of Distributed Generation) Regulations 2007. The connection and other processes for distributed electricity generation systems up to 10 kW in total are specified in Schedule 6.1 to 6.5 of this Code (see Figure 12 in Section 4.5.2).

5.5.2 Information, Promotion, Subsidies and Incentives

There are a number of legislative provisions and authorities dealing with different aspects related to distributed electricity generation. Besides the RMA 1991 and the authorities described in Section 5.5.1, all distributed generators should know the different responsibilities of the following:

- **Energy Efficiency and Conservation Act 2000**
  The purpose of the Energy Efficiency and Conservation Act 2000 (EEC) is to promote energy efficiency, energy conservation, and the use of renewable sources of energy in New Zealand. The Minister is responsible to develop policies for the use of renewable energies, increase the public awareness, promote practices and technologies, conduct research, monitor and review and publish information about renewable energy use (Section 7 of the EEC Act 2000).
- **Energy Efficiency and Conservation Authority**
  The Energy Efficiency and Conservation Authority (EECA) promotes the use of renewable energy sources in New Zealand and is also engaged in reducing compliance barriers. It provides

independent information and raises the awareness of distributed generation benefits (EECA, 2011b).

- **Regional and Territorial Authorities under the NPSREG**
  The release of the NPSREG imposes upon regional and territorial authorities under Policy G to investigate, identify and assess potential sites and renewable electricity generation and include these in the relevant plan's objectives, policies and methods. This can be seen as research and monitoring to provide information for existing and future generators. How this will be implemented by the different authorities is yet to be revealed.
- **Funding, Subsidies and Incentives**
  At the moment of writing, no forms of funding, subsidies or incentives for domestic SMW electricity generation were available. An EECA funding scheme under the Distributed Generation (DG) Fund was available for a short time in 2008 and 2009 to promote small scale distributed generation feasibility projects in New Zealand (EECA, 2011c). However, the funding scheme is no longer available which leaves capital investment costs for SMWT a financial risk. This remains one of the major obstacles as no government incentives are available that make SMW generation attractive for the private investor.

  With the release of the NPSREG the government decided on a central government led approach and leaves it up to the regional and territorial authorities to promote SMW generation. The government's position towards special loan schemes, subsidies or other incentives for distributed generation remains negative and was strengthened by former Energy Minister Gerry Brownlee's statement that incentives such as feed-in tariffs will not be introduced under the current government (White, 2011).

5.6 Legal Aspects Summary

Barry et al. (2009) stated that the complicated planning procedures in New Zealand are one of the main barriers for investors for SMW generation systems. The findings of this chapter are:

- For domestic wind energy projects, most spatial planning procedures themselves are fairly straightforward and obtaining a resource consent for small and micro wind turbines does not seem to bear many difficulties.
- However, as resource consents are still required in many cases, the whole planning process becomes significantly more time and cost intensive. Application fees of often several thousand dollars and the requirement to include an AEE in a resource consent application increases project costs. Further, connecting a SMWT to the local power grid involves other requirements, costs and knowledge that are often not available or hard to obtain for private investors without involving consulting or assisting services.
- Even though the New Zealand government clearly stated their support for renewable energy sources in their NPSREG 2011, overall policy and planning processes still are far from being integrated and straightforward. Too many different authorities are involved and a wide knowledge base is required to be able to deal with the relevant governmental bodies, legislation, legal frameworks, statutory planning instruments, technical requirements, codes and regulations. One overarching statute like in many other countries would improve the integration of renewable energy generation and give more guidance in spatial and other planning matters.
- In combination with the lack of government subsidies, funding schemes or special loans there are no economic incentives available at the moment.
- Now that regional and territorial authorities are forced to give effect to the NPSREG objective and policies, it has to be awaited how the consent authorities will deal with the integration of small and micro scale distributed renewable generation.

Chapter 6
Case Studies

6.1 Introduction

Chapter 6 outlines two case studies to identify a hands-on planning and implementation process overview of SMW generation projects. Preparation and first steps are described in Section 6.2. During the decision making process for system choice and dimensioning in Section 6.3 analysis of wind speed data from 2008 to 2010 and calculations of the performance of the evaluated turbines are carried out. Sections 6.4 and 6.5 describe case studies on two different sites, one in the Selwyn District in the South Island and one in the Western Bay of Plenty District in the North Island. The SMWT approximate annual energy output is calculated for each evaluated turbine on both sites.

6.2 Project Preparation

6.2.1 System Choice

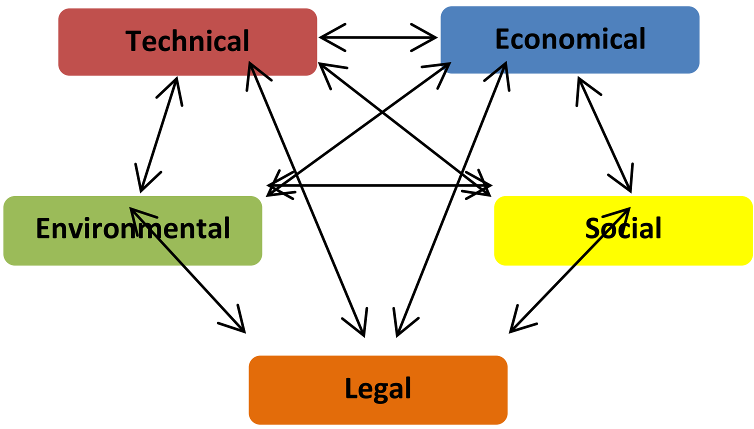
Choosing the appropriate SMW generation system is anything but easy. It involves the consideration of many different factors including technical, legal, economical, ecological and social aspects. Each aspect is weighted differently depending on the project. It is hard, if not impossible, to come up with one model that can be applied for all different situations as the different factors influence each other.

Figure 15 describes the interactions between planning aspects. A few examples are:

- Wind as an environmental factor can influence the technology that is used or the economic aspects of a wind turbine.
- Legal limitations influence the technical and economic factors, but also can have influence on social aspects like disputes between neighbours when a resource consent is granted against their will.
- Economic aspects may influence social aspects, such as having another source of income when surplus electricity is sold back to a retailer, or they can influence environmental aspects such as bird habitat.
- Legal aspects (e.g. resource consent) influence the system size and economic viability.

These interactions are sometimes hard to predict and there is no standard case that applies for all projects. Before commencing a project, some precaution should therefore be taken. One has to be certain about the decisions to be made and to determine the choice of the right system to minimise complications.

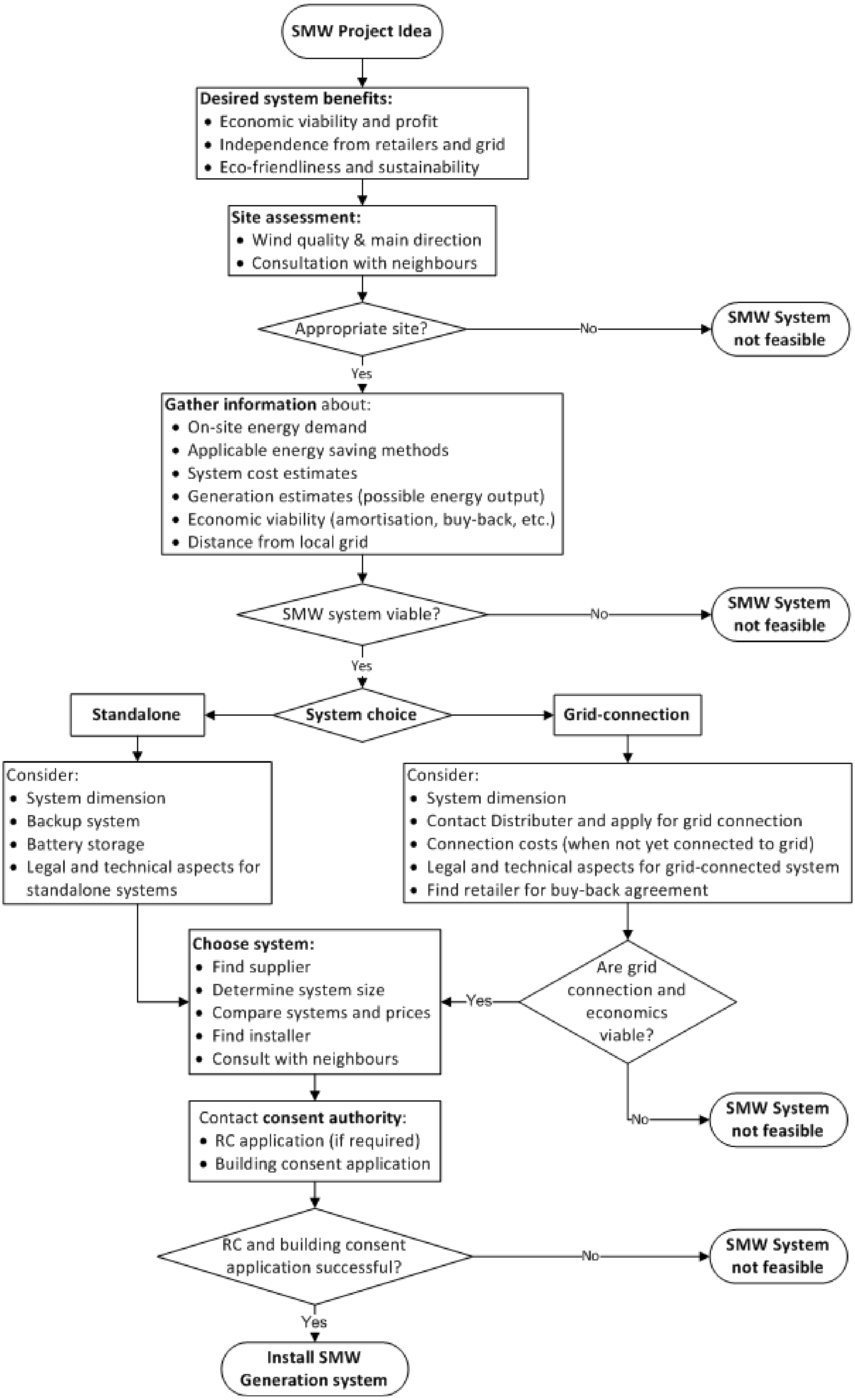
Figure 15
The interaction of different planning aspects for SMW generation projects



6.2.2 Decision Making Process

The following flowchart (see Figure 16) describes the decision making process that should be considered when investigating the possibilities for SMW generation systems.

Figure 16
Decision making process for SMW generation projects



6.3 Wind Turbine Choice and Performance

6.3.1 Wind Data Source and Assessment Methods

Gipe (2004) argues that accurate on-site wind source evaluation is crucial to give an accurate prediction of a SMWT's performance. Precise data can only be gained through appropriate and often costly monitoring of the wind resource over an adequate period of time, preferably over at least one year. Global weather patterns (e.g. El Nino years) should be accounted for by comparing the results to nearby weather stations' historical average measurements. This and the siting in the best possible on-site wind region will promote the best generation rates. Poor placement and wrong wind source monitoring can result in disappointing generation rates and a much longer return on investment.

Due to financial limitations of the research budget, an actual measurement of the wind source on each case study site was not feasible. The wind data used in the case studies was collected and archived by the National Institute of Water & Atmospheric Research (NIWA) and can be retrieved from the National Climate Database (CliFlo) at no charge. The weather stations chosen are the ones in closest proximity to the respective case study sites. Though, as the weather stations are some kilometres away from the case study sites, changes in wind quality and quantity can be expected. The used wind data will give some indication of approximate generation rates on the respective case study sites but, as mentioned above, to predict more accurate generation rates on-site wind monitoring is inevitable as wind is influenced by local aerodynamic and climatic factors. The weather stations used for wind data analysis are described in Appendix B.

Both wind data measurements are monitored surface wind speeds, carried out with an anemometer at 10 metres height above the ground which is considered by many manufacturers as a minimum height for good quality wind source to generate electricity with wind turbines. Wind data were not measured according international standard IEC 61400-12 (Power Performance Measurements of Electricity Producing Wind Turbines). The wind data analysis indicates steady annual average wind speed over three years in both cases. Annually wind speeds varied nominally and no significant change from 2008 to 2010 is recognisable. A median of wind speeds over the last 3 years is used to calculate the energy output in case study.

However, using annual average wind speeds does not necessarily indicate the velocity the SMWT is operating at. Normally, cut-in wind speeds for SMWT lies at around 3.5 m/s. Wind speeds below this are not capable of generating electricity, hence all average wind speeds have to be eyeballed critically. As an example, an annual average wind speed of 4.5 m/s does not mean that the turbine generates electricity all year round. It is very likely that the turbine actually only generates electricity during half of the year as wind speeds are lower than 3.5 m/s during that time.

6.3.2 Wind Speed Distribution

To calculate the on-site performance of a wind turbine, the site's wind speed distribution is necessary. The power output of wind turbines varies at different wind speeds. Therefore the so-called wind speed distribution, the occurrence of wind speeds over a specific period of time (at least one year), is used to determine at which speeds the wind blows most over a year (Gipe, 2004).

When actual, gapless hourly wind speed measurements for a particular site are available, it is more accurate using these data. Otherwise, Weibull or Rayleigh distributions are statistical calculation of continuous probability distributions and often used to calculate probability of wind speeds, i.e. assessing the time that wind units (e.g. hours per year) occur at certain velocities. The equations are then plotted and a distribution curve indicates the percentage of each wind speed's probability. For SMWT the common wind speed range from 0 to 20 or 25 m/s and is usually broken down in 1 m/s bins (Gipe, 2004).

NIWA wind data of the two sites was analysed in Excel and the annual wind speed distribution (hours per year the wind prevails at a certain velocity) for the years 2008, 2009 and 2010 was determined.

The wind speed distribution is similar for both case study sites. Most time of the measurements, winds were blowing with speeds between 1 and 7 m/s:

Figure 17 shows the wind speed distribution between 2008 and 2010 of the Selwyn case study.

Figure 17
Wind speed distribution at Broadfield weather station between 2008 and 2010

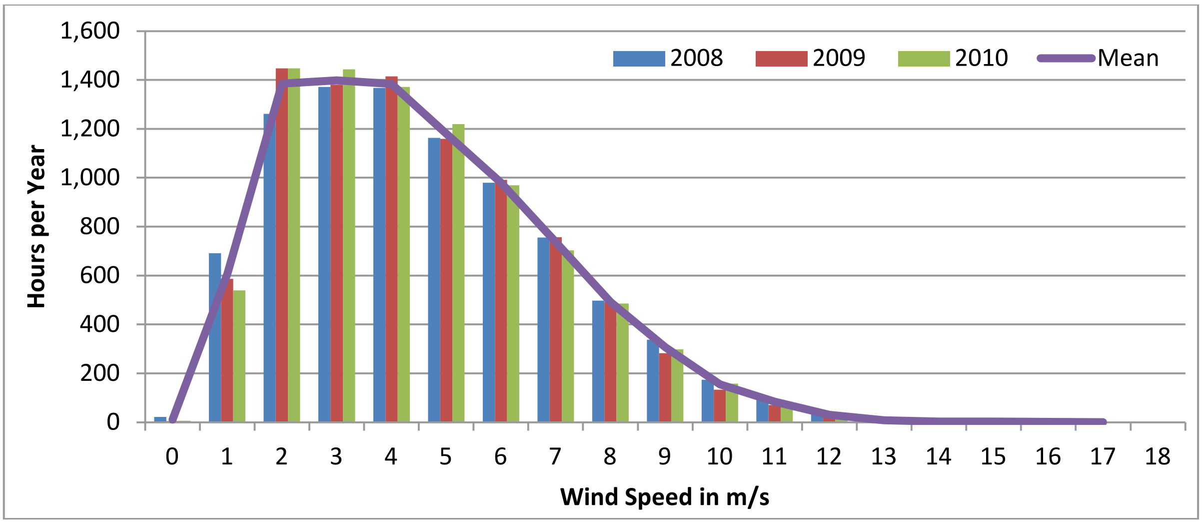
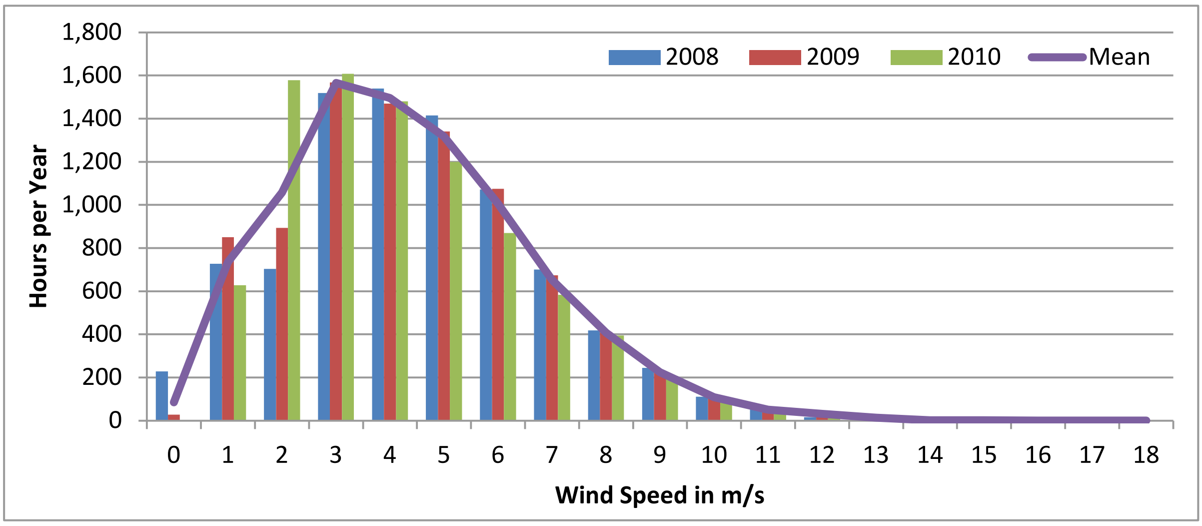


Figure 18 shows the wind speed distribution between 2008 and 2010 for the WBoP case study. Some inconsistency is noticeable at wind speeds between 0 and 2 m/s which may be due to a change in data acquisition in 2010.

Figure 18
Wind speed distribution at Tauranga Aero weather station between 2008 and 2010



6.3.3 Evaluated Small and Micro Wind Turbines

The turbines were chosen based on rated capacity and their availability on the New Zealand market. All prices are approximated and converted into NZ$. They include turbine and mast; no additional costs are regarded at this stage. Additional costs can account for an extra 25 to over 80 percent, depending on foundation works, resource consents, freight and other costs.

Three categories of domestic sized turbines each were chosen to determine the different AEO on the two case study sites. Table 7 gives an overview of the evaluated wind turbines:

- **Category 1:** Small and micro wind turbines with a rated capacity of less than 2.5 kW; this category includes 5 MG-4540 turbines with an installed capacity of 2.5 kW;
- **Category 2:** small wind turbines with a rated capacity of 2.6 to 6 kW;
- **Category 3:** Small wind turbines with a rated capacity of 10 kW.

Table 7
Evaluated wind turbine categories
(Data and picture source: www.allsmallwindturbines.com and manufacturers' websites)

Category 1: Wind Turbines with < 2.5 kW				
Manufacturer	**Powertech**	**Gusto Energy**	**Southwest Wind Power**	**Proven**
Turbine	**5 x MG-4540**	**Gusto 2.0**	**Skystream 3.7**	**Proven 7**
Picture				
Blade diameter	2.5 m	3.2 m	3.72 m	3.5 m
Tower height	6 m	13 m	10.2 – 23 m	6.5 m – 11 m
Rated capacity	2.5 kW (5 x 0.5 kW)	1.9 kW	2.4 kW	2.5 kW
Costs (incl. mast)	$ 6,000	$ 25,000	$ 20,000	$ 25,000

Category 2: Wind Turbines with 2.6 – 6 kW			
Manufacturer	**Fortis Wind Energy**	**Proven Energy**	**Southwest Wind Power**
Turbine	**Montana**	**Proven 11**	**Whisper 500**
Picture			
Blade diameter	5 m	5.5 m	4.5 m (two-bladed)
Tower height	12 – 18 m	9 m – 21 m	9 m – 15 m
Rated capacity	5 kW	5.2 kW	3 kW
Costs (incl. mast)	$ 25,000	$ 39,000	$ 25,000

Category 3: Wind Turbines with 10 kW		
Manufacturer	**Fortis Wind Energy**	**Bergey Windpower**
Turbine	**Alize**	**Excel**
Picture		
Blade diameter	7m	7m
Tower height	18 – 36 m	12 – 49 m
Rated capacity	10 kW	10 kW
Costs (incl. mast)	$ 56,000	$ 56,000

6.3.4 Turbine Performance Calculation

To calculate turbine performances, the wind speed distribution in combination with the power output curve of the evaluated wind turbines are used to determine an approximate annual energy output. The turbines' capacity factors are based on manufacturer data and were received from wind turbine reviews and tests on the Better Generation website, an internet portal for wind turbine reviews (Better Generation, 2011). For Fortis Wind Energy's "Montana" wind turbine, the power output estimation was based on the manufacturer's power output curve (Fortis Wind Energy, 2011).

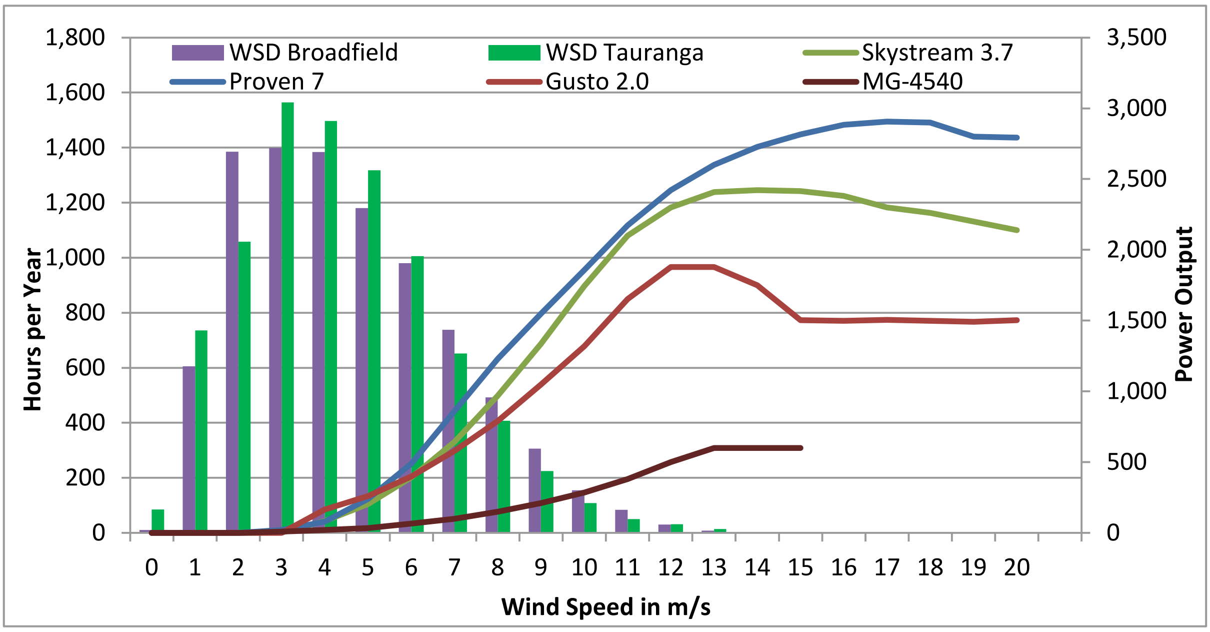
The following AEO calculation methods were used. An example is provided in Appendix C:

- To calculate the power in the wind:
  $\boldsymbol{P_{Wind} = 0.5 \times Swept\ Area \times Air\ Density \times Velocity^3}$
- To calculate the turbine power output:
  $\boldsymbol{P_{Turbine} = P_{Wind} \times \eta\ (turbine\ efficiency\ (CF)\ at\ relevant\ velocity)}$
- To calculate the expected energy output at a specific wind speed:
  $\boldsymbol{E_v = P_{Turbine} \times hours\ (at\ relevant\ velocity)}$
- To calculate the annual energy output:
  $\boldsymbol{AEO = E_{1\,m/s} + E_{2\,m/s} + \ldots + E_n\ m/s}$
- Example for the calculation of the energy output of a Skystream 3.7 at 5 m/s; a CF of 24.3% at 5 m/s; and 1181 hours of 5.5 m/s per year (based on manufacturer data and NIWA wind data):
  - $\boldsymbol{P_{Wind}} = 0.5 \times (3.7\ m)^2 \times 1.23\ kg/m3 \times (5.5 m/s)^3 = \mathbf{1401\ W}$
  - $\boldsymbol{P_{Turbine}} = 1400\ W \times 0.243 = \mathbf{340.4\ W}$
  - $\boldsymbol{E_{5\,m/s}} = 340.4\ W \times 1181\ h = 40{,}1997\ Wh = \mathbf{402\ kWh}$

6.3.5 Wind Turbine Performances

The performance of a wind turbine is expressed in a power output curve that shows the turbine's power output at various wind speeds. In Figure 19, power output curves of three SMWT with a capacity smaller than 2.5 kW are compared and contrasted against the wind speed distribution.

Figure 19
Power output curves (<2.5 kW) in comparison to annual wind speed distribution at Broadfield and Tauranga Airport weather stations



In Figure 20, power output curves of three SMWT with a capacity between 2.6kW and 6kW are compared and contrasted against the wind speed distribution.

Figure 20
Power output curves (2.6 – 6 kW) in comparison to annual wind speed distribution at Broadfield and Tauranga Airport weather stations

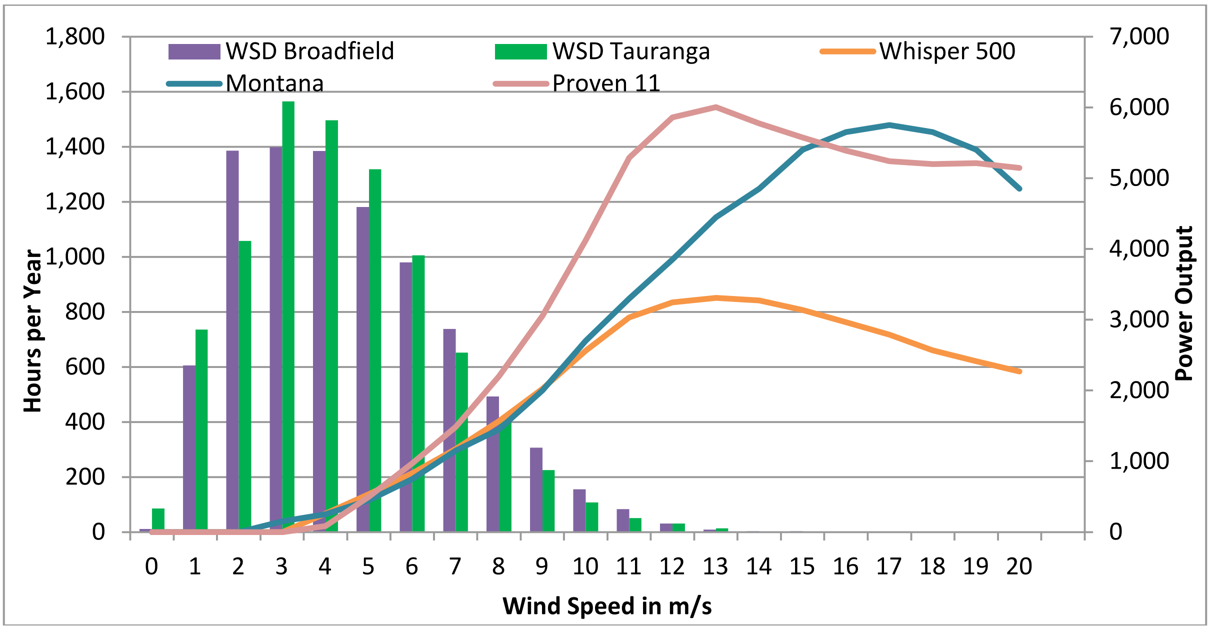
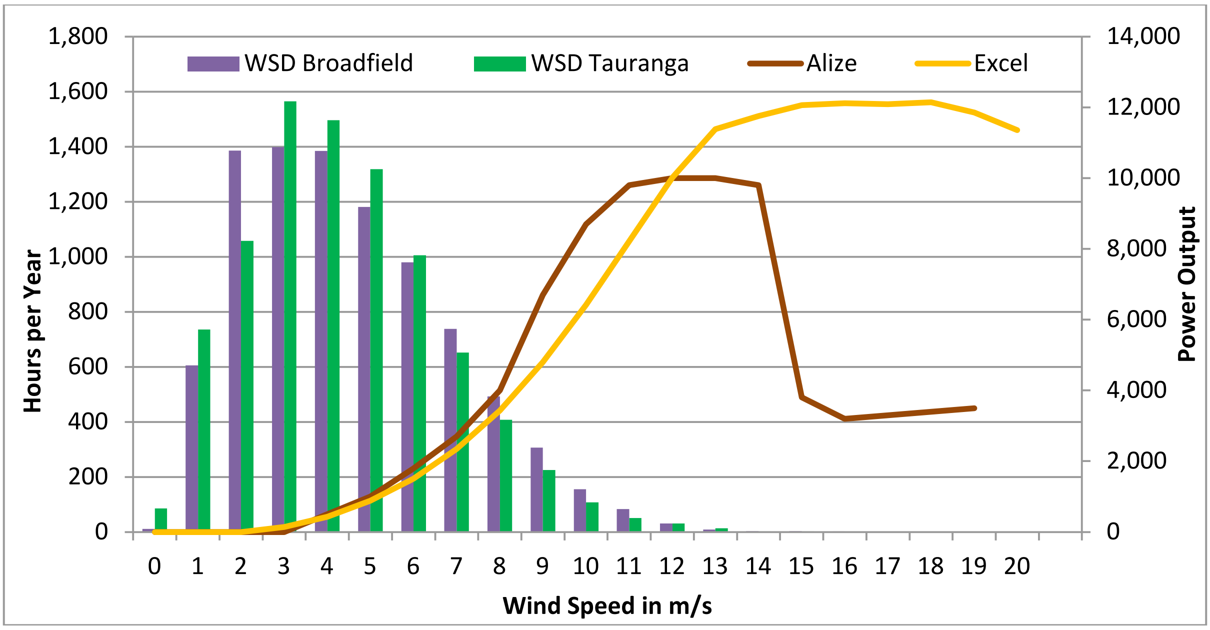


Figure 21
Power output curves (10 kW) in comparison to annual wind speed distribution at Broadfield and Tauranga Airport weather stations



In Figure 21, power output curves of two SMWT with a capacity of 10 kW are compared and contrasted against the wind speed distribution.

Further options are installing two or three 1 to 1.5 kW turbines, e.g. three Southwest Wind Power Whisper 200 (1 kW), three Bergey XL.1 (1 kW) or two Fortis Wind Energy Passaat (1.4 kW) to get an installed capacity of 3 kW. When more installed capacity is required, other SMWT can be paired, although, installation costs should always be offset against costs for a larger turbine with the same capacity as economies of scale apply and larger turbines tend to perform better. Alternatively it is possible to install five micro wind turbines with 0.5 kW. Five of these turbines have an installed capacity of 2.5 kW. Unfortunately, the manufacturer's data could be obtained for only one micro wind turbine with 0.5 kW capacity that is available on the New Zealand market, the Powertech MG-4540 but the available manufacturer's data was limited and is only used as a reference purposes. Further, the Mg-4540 generates 24 volt DC while all other turbines generate 230 to 240 volt AC.

6.3.6 Additional Costs

Additional costs have to be calculated separately for every wind energy project as they vary (i.e. different foundation requirements, resource and building consent costs, freight, etc.). Freight costs, for example, are for a turbine transport in a twenty foot container from closest port to construction site. Otherwise, freight costs will further increase. Further, standalone systems need battery storage and backup systems that have to be installed in addition.

In general, most additional costs are not clearly stated by manufacturers and installers. This means that right from the beginning costs are often hidden and lack transparency to investors, which can be conceived as a major investment risk. When these costs remain non-transparent potential investors bay end up discouraged and deterred.

An example of additional costs is listed in Table 8. The example shows that these costs can play a significant role for the initial capital investment. When a resource consent is required and when most works are carried out by a contractor, then these costs can account for over 80 percent of the wind turbine costs (incl. mast).

Table 8
Example of approximate additional cost comparison for both case studies

Case study site	Selwyn District	WBoP District
Foundation works[1]:		
Steel-reinforced concrete foundation (Contractor):	$ 4,000	$ 4,000
Steel-reinforced concrete foundation (DIY):		
Concrete and steel reinforcement	$ 1,500	$ 1,500
Excavator (rental and transport costs)[2]	$ 900	$ 900
Planning costs:		
Resource Consents (consent & planner costs)[3]	-[4]	$ 2,500
Building consent	$ 1,500	$ 2,000
Freight costs (domestic)[5]	$ 300	$ 300
Installation works:		
Wiring approx. 100 meters ($ 20/meter)	$ 2,000	$ 2,000
Excavator for drench for cable-laying	$ 500	$ 500
Battery bank (15 kWh)[6]	$ 5,000	$ 5,000
Grid connection	$ 250	$ 250
TOTAL ADDITIONAL COSTS	**$ 6,950 to $ 13,550**	**$ 9,950 to $ 16,550**
Turbine costs (e.g. Skystream 3.7 or Gusto 2.0)	$ 20,000	$20,000
TOTAL	$ 26,950 to $ 33,550	$ 29,950 to $ 36,550
Percentage of turbine costs	35 % to 68%	50 % to 83%

1 For a 2.5 kW turbine with a 10 metre mast an about 4 to 5 m^3 steel-reinforced concrete foundation is required. Larger turbines require a foundation with bigger dimensions (G. Rogers, pers. comm., 20 June 2011).
2 Assumption: Excavator costs $ 120 per hour, plus transport to and from site.
3 Assumptions: Non-notified resource consent, approx. 6-8 hours of consent manager and planner costs and travel costs, initial pre-application meeting, etc.; more costs apply when the resource consent is limited notified and more planner time, hearings, etc. is required.
4 No costs apply when no resource consent is needed as for a SMWT with a mast height of 25m or less and no electricity exports (see Section 6.4.3).
5 Domestic freight costs; no custom and MAF costs included; for internat. Freight higher costs apply (J-P. Thull, pers. comm., 28 June, 2011).
6 Battery bank when desired; assumption: costs for battery with 15 kWh incl. wiring, inverter and storage.

6.3.7 Reference Site – Wellington Airport

Wellington is known as a city with an excellent wind resource, and the two large Meridian Energy wind farm developments in close proximity to the city confirm this statement on the Wellington City Council's website (WCC, 2011). The New Zealand Wind Energy Association (NZWEA) also states that strong winds in and around Wellington allowed Brooklyn wind turbine to achieve a generation record in its class (NZWEA, 2011b).

Therefore, as a reference site with excellent wind resources and an average annual wind speed of 6.8 m/s, the wind data from Wellington Airport was analysed. The mean annual energy output (2008 – 2010) of the 9 evaluated turbines was calculated for comparison purposes (shown in Table 9).

Table 9
Turbine performance on a reference site (Wellington Airport)

Turbine	Rated capacity	Mean AEO	On-site Capacity Factor	Annual earnings (at 21.5 cent/kWh)
MG-4540	0.5 kW 5 x 0.5 kW	5 x 1,483 kWh 7,414 kWh	0.338	$ 319 $ 1,594
Gusto 2.0	1.9 kW	6,621 kWh	0.398	$ 1,424
Skystream 3.7	2.4 kW	8,198 kWh	0.39	$ 1,763
Proven 7	2.5 kW	9,037 kWh	0.425	$ 1,943
Whisper 500	3 kW	12,567 kWh	0.478	$ 2,702
Montana	5 kW	14,107 kWh	0.322	$ 3,033
Proven 11	5.2 kW	19,585 kWh	0.43	$ 4,211
Excel	10 kW	33,123 kWh	0.379	$ 7,121
Alize	10 kW	35,766 kWh	0.408	$ 7,690

Table 9 indicates capacity factors between 0.3 and 0.4, which is much higher in comparison to sites with poorer wind resources (e.g. SMWT on a site with 4 m/s annual average wind speed may achieve capacity factors between 1 and 1.5). Inexplicably the capacity factor of the Whisper 500 is exceptionally high and might be the result of inaccurate manufacturer's data. This shows that independent tests should be taken into account.

6.4 Case Study – Selwyn District

6.4.1 Case Study Site Characteristics

The chosen case study site in the Selwyn District is a rural property opposite the Upper Selwyn Huts at the end of Selwyn Lake Road. The address is 50 Selwyn Lake Rd, Leeston, 7683 (see Appendix D.1.1 for a map and aerial pictures) with site coordinates of latitude -43.71239 and longitude 172.43297. The property lies within the rural zone of the Selwyn District.

The land is divided into three blocks, a northern block with 18 hectares (Block 1), a southern block with approximately 10 hectares (Block 2) and small block (Block 3) which lies between Block 1 and 2. The site has an elevation of approximately 3 metres above sea level; its surface is grassy and flat. The site is located adjacent to the western bank of the Selwyn River. Higher trees grow along the eastern perimeter along the river banks and along the northern and southern boundaries shelter belts are planted. Towards the west, adjoined paddocks are separated by a farm track and no trees or shelterbelts are planted along this boundary. The site is connected to the local grid which is operated by Orion. The proposed turbine placement is in the middle of Block 1 near a small hedgerow, ensuring enough distance to the Selwyn River.

The wind data for the case study site is retrieved from Broadfield weather station and is analysed in Table 10.

Table 10
Broadfield weather station wind data overview over the last 3 years
(Data source: NIWA, 2011b)

Measurements at Broadfield weather station	2008	2009	2010
Total hourly measurements per year	8,782	8,760	8,758
Measurements over 3.5 m/s (cut-in speed)	4,859	4,773	4,771
Days with wind speed over 3.5 m/s (illustrative)	203 days	199 days	199 days
Annual average wind speed	4.15 m/s	4.06m/s	4.07m/s
Annual % of wind speed over 3.5 m/s (cut-in wind speed)	55.3%	54.5%	54.5%
Annual % with wind speed above 8 m/s (strong wind)	8.2%	6.5%	7.2%
Annual % with wind speed at capacity rating (>12 m/s)	0.3%	0.1%	0.2%
Main wind directions	NE & SW	NE & SW	NE & SW
Strongest prevailing winds	NE	NE	NE

6.4.2 System Choice

The desired wind energy generation system is a grid-connected wind turbine that is capable of meeting the on-site electricity demand for a dwelling with four people. Generated electricity is mainly used on site and surplus electricity will be exported to the local grid. The main purpose of the distributed generation system is to be independent from retailers as well as local and national grids.

The owner claims that the annual on-site energy demand will most likely be between 4,000 and 5,000 kWh. The system dimension should yield at a minimum annual energy output of 4,300 kWh. Surplus generation will be exported to the local distribution grid operated by Orion. It is assumed that one kWh is "worth" 21.5 cent (excl. GST) (Meridian one-to-one buy-back rate). Table 11 compares the AEO yield, the capacity factors and the expected annual earnings (from electricity export or for saved electricity imports) (excl. GST) of the evaluated turbines.

Table 11
Turbine performances on the Selwyn case study site

Turbine	Rated capacity	Mean AEO	On-site Capacity Factor	Annual earnings (at 21.5 cent/kWh)
MG-4540	0.5 kW 5 x 0.5 kW	5 x 458 2,291 kWh	0.100	5 x $ 99 $ 493
Gusto 2.0	1.9 kW	2,492 kWh	0.150	$ 536
Skystream 3.7	2.4 kW	2,657 kWh	0.126	$ 571
Proven 7	2.5 kW	3,201 kWh	0.146	$ 688
Whisper 500	3 kW	4,866 kWh	0.185	$ 1,046
Montana	5 kW	4,884 kWh	0.111	$ 1,050
Proven 11	5.2 kW	6,124 kWh	0.134	$ 1,317
Excel	10 kW	10,363 kWh	0.140	$ 2,228
Alize	10 kW	12,251 kWh	0.118	$ 2,634

6.4.3 Selwyn District Plan Provisions

The operative version of the Selwyn District Plan (SDP) became partially effective on 10 June 2008. Some parts are yet operative as it is in the plan review process and submissions, hearings and appeals may change proposed rules.

Wind turbines are not clearly defined and not explicitly mentioned in the Selwyn District Plan (SDP). Under Part D Definitions, utilities include "the use of any structure, building or land for [...] the generation, transformation and/or transmission of energy". Utility structures include equipment such as masts, poles or pylons that support utilities. Utility structures are excluded from the definition of a building; therefore specific rules apply for utilities. This suggests that wind turbines, no matter what size, are classified as utilities or utility structures respectively.

The described case study site is a rural property adjacent the Selwyn River opposite the Upper Selwyn Huts settlement. According to the latest planning maps, it is situated in the rural zone of the Selwyn District. Therefore only objectives, policies and rules for this zone and rules that are relevant for all zones apply. Further the area the property is located in is classified as "Lower Plains Flood Area" which means that additional rules for this particular zone apply.

The relevant rules for erecting a SMWT in the Rural Zone in the Selwyn District and the Lower Plains Flood Area are outlined in Appendix D.1.2. The resource consent application forms can be obtained from the relevant consent authority. On the SDC website one general resource consent application form is available and a special AEE form is not provided for. For erecting a SMWT with a mast height not exceeding 25 metres, the effects of activities in Table 12 are classified as followed:

Table 12
SDP activity classification for erecting a SMWT in the Selwyn District

Rule	Activity description	Compliance	RC
1.3.1.1	Building platform for utility structure does not alter or impede existing land drainage patterns.	Permitted	No
1.3.1.2	Earthworks do not raise the mean average level of the land.	Permitted	No
1.6.1.1	Earthworks will have a setback of more than 20 metres from the edge of the Selwyn River.	Permitted	No
1.6.1.2	Earthworks volume will be less than 5000 m^3	Permitted	No
5.1.2.4	As electricity generation for on-site use is the main purpose of the utility structure, it is considered that the activity complies with the plan rule as long as no electricity is exported to the local (or national) grid. All on-site generated electricity must be consumed within the property boundaries.	Permitted	No
5.1.2.4	When electricity is fed in the grid, then the activity becomes restricted discretionary.	Restricted Discretionary	Yes
5.3.1.1	Utility structure (wind turbine) height will be less than 25 metres; Note: When installing an Alize or Excel on a tower higher than 25 metres then the activity is a restricted discretionary activity under Rule 5.3.2.	Permitted	No
5.3.1.2	Utility structure (wind turbine) mast will be less than 0.5 metres in diameter at a height of 6 metres and above.	Permitted	No
5.3.4	When installing category 3 the tower diameter might exceed 0.5 metres in 6 metres height and above then the activity is a discretionary activity, especially when a lattice tower is used.	Discretionary	Yes
5.8.1	Utility structure (wind turbine) will not diverts or displace any floodwater, or obstructs or alters the existing drainage pattern of the land.	Permitted	No
5.13.2.3	Utility structure (wind turbine) will have a setback of more than 10 metres from the Selwyn River.	Permitted	No
9.16.1	Noise levels from the utility structure at the notional boundary of any dwelling will most likely not exceed noise limits.	Permitted	No
9.17.1.2	Vibration from the utility structure is considered minor and will most likely comply with NZS 2631:1985-89.1-3.	Permitted	No
9.21.1	No clearance of indigenous vegetation.	Permitted	No

A resource consent only needs to be obtained when the electricity generated is exported to the local grid, when masts exceed 25 metres in height or when the mast diameter goes beyond the prescribed dimensions. When all generated electricity is used on-site and surplus generation is stored in battery banks, no resource consent is needed to build, install and maintain a SMWT. An exception would be when one of the two evaluated 10 kW turbines (Alize and Excel) is installed. Their mast height (available from 12 to 49 metres) and diameter might exceed the permitted standards. When a grid connection is existent it is advisable that all on-site generated the electricity is used or stored in battery banks without exporting it to the local grid. Then, the erection of a SMWT is a permitted activity and a grid connection can then only be used for electricity import.

6.5 Case Study – Western Bay of Plenty

6.5.1 Case Study Site Characteristics

The chosen rural case study site in the Western Bay of Plenty District is located on the Old Highway in Whakamarama. The address is 232 Old Highway, Whakamarama, 3176 (see Appendix D.2.1 for planning maps and aerial pictures) with site coordinates of latitude -37.672454 and longitude 176.005608. The property lies within the Rural G zone of the Western Bay of Plenty District.

The site has an elevation of between 36 and 62 metres above sea level. One dwelling is located on the northern property boundary located on a hilltop, and from there the property is sloping towards the east, south and west. Higher trees grow along the north-western property boundary. To the north of the dwelling it adjoins a property without any dwellings on it. To the north-east, the adjacent property contains one dwelling. Large bushes reaching a height of approximately 8 metres are located north-east of the dwelling on the northern property boundary. The property is connected to the local grid, operated by Powerco. The proposed turbine placement is behind a small garden shed, approximately 20 metres north-west of the dwelling near the northern property boundary.
The wind data for the case study site is retrieved from Tauranga Aero weather station and is analysed in Table 13.

Table 13
Tauranga Aero weather station wind data overview over the last 3 years
(Data source: NIWA, 2011b)

Measurements at Tauranga Aero weather station	2008	2009	2010
Total hourly measurements per year	8,759	8,756	8,750
Measurements over 3.5 m/s (cut-in speed)	4,863	4,691	4,309
Days with wind speed over 3.5 m/s (illustrative)	203 days	195 days	180 days
Annual average wind speed	3.9 m/s	3.9 m/s	3.8 m/s
Annual % of wind speed over 3.5 m/s	55.5%	53.6%	49.3%
Annual % with wind speed above 8 m/s	5%	5.2%	4.9%
Annual % with wind speed at capacity rating (>12 m/s)	0.1%	0.3%	0.2%
Main wind directions	W, SW & NE	W, SW & NE	W, SW & NE
Strongest prevailing winds	W & SW	W & SW	W & SW

6.5.2 System Choice

The desired wind energy generation system is a grid-connected wind turbine with a rotor diameter that does not exceed 5 metres. One turbine is preferred over two or more; though, the cheapest option in relation to the best generation rate is desired and therefore the erection of multiple smaller wind turbines instead of one with greater capacity may be an option for the decision making. A standalone system is not desired but might be an option for a site that is not grid connected and where a connection to the nearest ICP would be economically not viable.

The owner claims that the annual on-site energy demand will most likely not exceed 4500kWh. On a normal summer day he claims not to use more than 6-7kWh/day which can reach about 12kWh/day in winter. Therefore, the system dimension should yield at a minimum annual energy output of 2200 kWh and a maximum of 4500 kWh. Surplus generation will be exported to the local distribution grid operated by Powerco. It is assumed that 1 kWh is "worth" 21.5 cent (excl. GST) (Meridian one-to-one buy-back rate). Table 14 compares the AEO yield, capacity factors and expected annual revenue (from electricity export or for saved electricity imports) (excl. GST) of the evaluated turbines.

Table 14
Turbine performances on the Western Bay of Plenty case study site

Turbine	Rated capacity	Mean AEO	On-site Capacity Factor	Annual revenue (at 21.5 cent/kWh)
MG-4540	0.5 kW 5 x 0.5 kW	5 x 407 kWh 2,033 kWh	0.090	5 x $ 87 $ 437
Gusto 2.0	1.9 kW	2,244 kWh	0.135	$ 482
Skystream 3.7	2.4 kW	2,314 kWh	0.110	$ 498
Proven 7	2.5 kW	2,802 kWh	0.128	$ 602
Whisper 500	3 kW	4,381 kWh	0.167	$ 942
Montana	5 kW	4,406 kWh	0.101	$ 947
Proven 11	5.2 kW	5,315 kWh	0.117	$ 1,143
Excel	10 kW	9,166 kWh	0.105	$ 1,971
Alize	10 kW	10,687 kWh	0.122	$ 2,298

6.5.3 Western Bay of Plenty District Plan Provisions

The operative version of the Western Bay of Plenty District Plan (WBoP DP) became effective in July 2002. A new version is proposed but has not yet been notified as it is in the plan review process and submissions, hearings and appeals may change proposed rules.

The operative DP does not explicitly mention distributed generation or wind energy generation activities. Wind turbines are generally classified as discretionary activity. Specific details about turbine height or size are not mentioned which raises the question whether all turbines, no matter what hub height or size, are to be treated equally. Buildings include any mast higher than 7 metres above the point of attachment or its base support, which concludes that SMWT on masts with more than 7 high metres are likely to be classified as building.

The proposed WBoP DP defines electricity generation as "Infrastructure and Network Utilities". However, this version is not operative yet and is irrelevant for this particular case study. Nevertheless, once operative, the proposed plan identifies standalone wind energy generation systems as permitted activity. Grid-connected (bulk) SMWT seem to be subject to the Council's discretion. Upon information request, the WBoP DC states that bulk generation is defined larger facilities or a series of turbines considered for bulk electricity supply. Domestic scale wind turbines for the mainly private on-site supply with or without grid connection remain a permitted activity under the proposed rules. Despite domestic scale wind generation systems being permitted under the proposed plan, they have to comply with other underlying rural performance standards such as height, yards and noise emission. While the SMWT remains the main supply system, backup generators would possibly be classified as integral components of the wind generation system but are also a subject to the council's discretion as they are not clearly identified in the proposed plan. It seems that the only case that would not require a resource consent is when the SMWT is operated as a residential size system for mainly on-site supply, where only backup systems described as permitted in the proposed plan are used, and the SMW generation system complies with all other relevant performance standards in the proposed plan (such as height, yards, etc.).

The described case study site is a rural property on the Old Highway in Whakamarama near Tauranga. According to the latest planning maps, it is situated in the Rural G Zone of the. Therefore only objectives, policies and rules for this zone and rules relevant for all zones apply.

The relevant rules for erecting a SMWT in the Rural G Zone in the Western Bay of Plenty District are outlined in Appendix D.2.2. The resource consent application forms can be obtained from the relevant consent authority. The WBoP DC website provides application forms for "Land Use Consent – Performance Standards" regarding height and yards, and for "Land Use Consent – Discretionary and Non-Complying Applications Notified or Non-Notified" regarding all other performance standards the effects of the proposed activity do not comply with. An AEE for the relevant activity has to be included in the respective application form. For erecting a SMWT, the effects of activities in Table 15 are classified as followed:

Table 15
Operative WBoP DP activity classification for erecting a SMWT in the WBoP District

Rule	Activity description	Compliance	RC
2.3.5 (a)	Building (wind turbine) height will be more than 9 metres;	Discretionary	Yes
2.3.5 (c) (iii)	The turbine will be located within 5 metres from the northern property boundary	Discretionary	Yes
9.3.3.	Earthworks will be carried out for the turbine foundation	Discretionary	Yes
9.3.5 (iv)	Earthworks will have no impact natural habitats and ecosystems	Permitted	No
13.2.3.2 (ii)	Noise levels from the utility structure at the notional boundary of any dwelling will most likely not exceed noise limits as neighbouring property to the north is uninhabited and the adjacent dwelling on the neighbouring property to the north-west is blocked by hedgerows and trees. It is unlikely that the sound emissions exceed the permitted limits.	Permitted	No
13.2.4 (b)	No significant vibration from the wind turbine is expected	Permitted	No
17.3.1 (w)	Windmills and wind power generators classified as Discretionary Activity	Discretionary	Yes
17.3.3.1 (a)	Landscape planting 3 metres around the perimeter of the wind turbine will be developed and maintained	Permitted	No
17.3.3.5	The wind turbine will not exceed height restrictions in the Tauranga Airport Approach Path	Permitted	No

As indicated in the above table four activities are classified as discretionary in the operative WBoP DP and the council will decide whether effects on the environment are more than minor. The RC application must contain these four activities. An AEE has to determine the degree of impact from all adverse effects and whether these effects are minor or more than minor. After considering the effects, the council may grant the resource consent application, grant it with conditions or decline it.

6.6 Case Study Findings Summary

The conducted case studies show that the following aspects are of importance:

- The preparation phase for small and micro wind energy systems is important to get an overview of what is possible and what is not feasible on the preferred site. The desired benefits should be clear beforehand, i.e. whether economic viability, eco-friendliness and sustainability, independence from the grid and retailers or other non-monetary gain is strived for.
- The Selwyn case study site enjoys a slightly better wind resource (4.1 m/s annual average wind speed) than the Western Bay of Plenty site (3.9 m/s), even though the generation performance assessment indicate only minor differences in performance. On both sites, higher wind speeds (8 m/s and more), at which the turbines yield a higher power output, are relatively sparse.
- The two respective consent authorities deal with SMWT in a different way:
  - Selwyn DP has more supportive plan rules for dealing with SMWT. Only systems that export electricity to the grid and turbines with masts exceeding the prescribed height (25 metres) or diameter are classified as restricted discretionary or discretionary respectively.
  - Western Bay of Plenty DC is more restrictive. It classifies all SMWT as discretionary activities under the operative plan; even micro turbines with less than 1 kW require a resource

consent. The proposed plan is slightly more enabling but still prohibitive. It permits SMWT for mainly on-site electricity use while other performance standards still apply.

- The evaluated wind turbines' performances varied on the different sites. Generally, the larger turbines performed better than smaller ones due to the economies of scale effect of wind energy generation (larger turbines are capable of generating proportionally more energy – see Section 4.2.2).
- Table 16 shows a critical performance comparison of the nine evaluated turbines.

Table 16
Performance comparison of evaluated turbines

	Turbine	Rating	Cost/kW	Positive properties	Negative properties
Category 1	**5 x MG-4540**	2.5 kW	2,400 $/kW	Low investment costs per kW; good performance for price	For 2.5 kW five turbines and masts required; lowest CF; five turbines harder to operate simultaneously; 24V DC output needs to be rectified and stepped up to be used in home appliances; turbine quality questionable
	Gusto 2.0	1.9 kW	13,158 $/kW	Performs well at lower wind speeds (< 6 m/s); generates almost as much as a Skystream 3.7; Performs well for size; High CF; made in New Zealand	High investment costs per kW
	Skystream 3.7	2.4 kW	8,333 $/kW	Performs well at good wind speeds (> 5 m/s); average overall performance; well-known and widely installed	High investment costs per kW
	Proven 7	2.5 kW	10,000 $/kW	Good performance in Category 1; very efficient at wind speeds > 5 m/s	High investment costs per kW; performs worse compared to Montana for the same price
Category 2	**Whisper 500**	3 kW	8,333 $/kW	Best performance in Category 2 when considering the smaller size high investment costs per kW; high CF, esp. at low wind speeds;	Performs worst in Category 2 at high wind speeds (> 10 m/s)
	Montana	5 kW	5,000 $/kW	Low investment costs per kW; good CF	Performs only better than Whisper at high wind speeds;
	Proven 11	5.2 kW	7,500 $/kW	Good CF; highest AEO in Category 2; efficient at wind speeds > 5 m/s	High investment costs;
Category 3	**Excel**	10 kW	5,600 $/kW	Low investment costs per kW; economies of scale; yields around 10,000 kW per year on sites with average wind speed of 4 m/s; suitable high energy demand (e.g. for farm application)	Performs worse than Alize as lower CF at wind speeds up to 12 m/s; high overall capital investment; fairly big turbine for domestic use; RC may be harder to obtain
	Alize	10 kW	5,600 $/kW	Low investment costs per kW; Performs better than Excel as better CF at lower wind speeds; economies of scale; yields around 10,000 kW per year on sites with average wind speed of 4 m/s; suitable for high energy demand (e.g. for farm application)	High overall capital investment; fairly big turbine for domestic use; RC may be harder to obtain

Chapter 7
Critical Analysis of Planning Processes

7.1 Introduction

This chapter evaluates technical planning aspects (Section 7.2), resource management planning processes (Section 7.3) and economic aspects (Section 7.4) of small and micro wind turbines for residential use. Conducted case studies are analysed in Section 7.5. To set the perspective for the discussion in Chapter 8, results of other case studies in New Zealand and other countries are described in Section 7.6.

7.2 Technical Planning Aspects

7.2.1 On-site Wind Resource Requirements

The evaluation of different small and micro wind turbines available in New Zealand and the determination of their performance on two case study sites and one reference site revealed the importance of a good on-site wind resource and accurate wind monitoring over an appropriate period of time (this includes the directions of the prevailing wind). Proper analysis of the acquired data is crucial for the turbines performance and on-site AEO estimations.

There are many ways of assessing on-site wind speed and direction. “Home weather stations” sitting on a two metre high pole or on a fence in someone’s backyard will not deliver accurate and useful wind data, because they are located too low and in an area with highly turbulent winds. In every case, standards (like the IEC 61400-12) should be applied for wind speed monitoring and data analysis to receive useful results.

For the two conducted case studies and for the reference site at Wellington Airport, wind data obtained from the National Institute of Water & Atmospheric Research (NIWA) was used. The NIWA measurements were not carried out under consideration of the IEC 61400-12 standard. The points of wind data measurement were 10.0 km linear distance to the Selwyn case study site and 16.7 km linear distance to the WBoP case study site. A UK study states that inappropriate wind data can cause incorrect predictions with error ranges of up to +/- 25% (Encraft, 2009). However, this was the only gapless data available for the assessed case study sites.

As already discussed, wind quality and quantity can change dramatically within a small distance and surrounding features can have a big influence. For example valleys down from a hill or mountain saddle as well as hilltops can have much better wind quality and quantity than other areas in close proximity. Measurement accuracy is a highly important factor when determining whether a SMWT can perform well enough on a specific site and generate enough electricity or whether other means of electricity supply should be considered. Further, avoidance of turbulences will increase the AEO. To maximise the turbine’s life expectancy (which is dependent on steady wind flows and decreases with turbulences and gusts), turbulent regions (e.g. on rooftops or in close proximity to larger obstacles) and regions with high gusts should be avoided.

Leaver et al. (2010) and Cace et al. (2007) both described minimum annual on-site wind speeds and suggested it should not fall below 5.5 m/s. The case study evaluation comes to the same conclusion. To receive a decent generation rate, average annual wind speeds of 6 m/s or more on a particular site should be strived for. The annual energy generation for both case study sites is relatively small. The installation of SMWT is likely to be only economical when the costs for connecting the premises to the nearest grid connection point exceeds the installation and maintenance costs of a wind turbine, or when eco-friendly and self-sufficient electricity generation is desired.

7.2.2 Annual Energy Output Calculation

When determining a turbine's potential AEO, it is important not to rely on generalised calculations using mean wind speeds as capacity factors are turbine and wind speed specific. Mean wind speeds can give an indication whether a site is windy or not, but tell very little about the actual wind resource. Rough calculations using mean wind speeds and approximated capacity factors can give an indication but are likely to be highly inaccurate, especially when taking into account a turbine's cut-in wind speed and power output curve. Some turbines may be more efficient than others at a specific wind speed but in return have a lower generation rate at a higher velocity. Using the wind speed distribution and the actual power output at various on-site velocities gives more accurate energy output estimation.

Online energy output calculators are easy-to-use tools for estimating the AEO. Websites like www.smallwindindustry.org offer energy output calculators that help to estimate (with help of a Weibull distribution) the AEO when only limited information is given but power curves, mean wind speed and some other turbine data are still required. Conversely, most other online calculators delivered only rough estimations as they use the annual average wind speed and do not take into account wind speed distribution. The input in these calculators besides annual average wind speeds generally includes rotor diameter, cut-in wind speed, cut-out wind speed and a capacity factor. While the capacity factors are specific to turbines and certain on-site wind speeds it is hard to be estimated without measuring. The same SMWT, for example, will have a different capacity factor in relation to wind speed. Online calculators should only be used for rough estimates. In most cases, outcomes were far off from the actual generation rates calculated with the wind speed distribution and the power output curves in the case studies.

7.2.3 Reliability of Manufacturers' Data

While researching available small and micro wind turbines for the two case study sites, manufacturers often gave energy output estimations at a certain annual average wind speed. These estimations are sometimes related to wind speeds of 5.5 m/s and some were also subject to the rated capacity at 12 or 13 m/s. Wind turbines are often branded as highly efficient and eco-friendly technology by manufacturers. Though, much (usable) technical information is often not provided and actual performance, especially for less quality wind regimes is often undisclosed.

Gipe (2004) also argues that manufacturer calculations often are inconsistent, unreliable and misleading for most non-experts. It is seldom stated whether the wind speed distribution was considered for manufacturers' test sites or whether it is just a broad-brush calculation giving little consideration to local wind speed distribution and surrounding. Stating an AEO of up to 8000 kWh per year without mentioning at which wind speeds this energy output can be expected seems to be whitewashing the fact that small and micro wind turbines in particular need consistent and strong prevailing winds to generate electricity on an economical scale. This is related to smaller blade swept area and the and lower mast heights of SMWT. Figure 5 (Section 4.2.2) showed the economy of scale effect of wind energy generation. The higher the turbine is mounted, the better the wind quality gets. By doubling the wind speed, the turbine's power output increases by a cube factor. Doubling the rotor diameter (and therefore the blade swept area) increases the power output by a square factor. For this reason, on-site wind speeds and the appropriate turbine size should always be borne in mind when comparing manufacturer data. Manufacturer's daily, monthly and yearly energy output estimations should always be eyeballed critically and individual calculations, either with the actual on-site wind data or with the help of Weibull or Rayleigh distributions should be conducted. Gipe (2010) suggests that especially for urban areas, manufacturer data are highly inaccurate and project installers often try to whitewash turbines that are obviously inefficiently and wrongly placed. They predict excellent performances at wind speeds of 7 m/s or more which is highly unlikely for most urban areas due to turbulences and large regions of disturbed wind flow.

7.2.4 Siting and Turbine Choice

Wind quality and quantity are crucial factors for a reasonable generation rate. Turbine placement, hub height and the appropriate technology choice are important aspects that determine the turbine's performance. The location of the wind turbine has to be carefully chosen to avoid turbulent, inconsistent and slow winds. Buildings, trees, shelter belts and other obstacles can dramatically influence the wind flow and decrease its quality. By increasing the mast height and the distance to potential obstacles, an increase of energy output can be expected. Generally rural or semi-rural areas with no high obstacles in close proximity are most suitable. Urban areas and rooftop application should be avoided.

Some turbines have a better power output at lower wind speeds, while others might generate more at a higher velocity. This shows that another important aspect is to choose the right turbine for the existing conditions. Analysing power output curves and comparing them to wind speed distribution to determine the expected AEO will give a performance indication. Comparing a Gusto 2.0 (1.9 kW) and Skystream 3.7 (2.4 kW) in case studies shows that the Gusto comes close to the Skystream's performance. The same applies for the Whisper 500 (3 kW) and Montana (5 kW).

7.3 Resource Management Planning Aspects

7.3.1 Consent Authorities and Inconsistency of Plan Provisions

New Zealand has 67 territorial authorities (including 6 unitary councils) that deal with effects of land use and noise. 16 regional councils (including 6 unitary councils) are responsible among other things for the coastal marine area, water quality and quantity and effects of air, water and land pollution related activities. Every region and district (or city) has its own statutory planning regulations. There is no uniform application of erecting a wind turbine, no matter what size the turbine has or how many turbines are subject to be installed.

Investors should be aware of what requirements and processes are involved in erecting a SMWT; resource consents, building consents, the grid connection process and buy-back arrangements with electricity retailers all require some degree of knowledge. It can be argued that all the planning could be outsourced to someone who offers the wind turbine in a package that includes all, the planning process, consenting, installation and maintenance. However, this service is likely to be more costly and might also be not transparent enough for the customer to actually influence some decisions.

7.3.2 Legislative measures and the National Policy Statement for Renewable Energy Generation

One common way of dealing with the matter does not exist; each project is different as already discussed. Unlike in other countries that have implemented overarching legislative frameworks for renewable energy generation and mechanisms to promote and fund such projects, New Zealand has not done much to encourage distributed generation from renewable resources. The neo liberal planning framework in New Zealand still hasn't come up with straightforward and consistent planning processes, e.g. by introducing an enabling legislation. A separate act of parliament, dealing with renewable energy generation could be one option for a government led approach.

With the introduction of the now effective National Policy Statement for Renewable Energy Generation 2011 (NPSREG), some guidance is given for local authorities in relation to renewable energy generation. Still, the NPSREG does not promote one common approach; it only forces local authorities to incorporate the policies and objective of the NPS, but consent authorities will still have discretion over how they implement this statutory document into their plans.

7.4 Economic Aspects

7.4.1 Economic Viability

In many cases it seems that economic return only comes second or third after self-sufficiency and independence from the local grid. Showing commitment to eco-friendly, sustainable and independent electricity generation may be one of the main incentives at the moment. This is likely to be due to critical economic viability and existing investment risks (i.e. high turbine costs, no conclusive and consistent enabling legislation or plan provisions and the lack of feed-in tariffs, which is one of the main incentives in other countries) (S. Jarvis, personal communication, 17 June 2011; G. Rogers, pers. comm., 20 June 2011).

Gipe (2004) states that only vague cost-benefit prognosis for domestic wind turbines are possible. One simple way to estimate the economic viability of wind turbines does not exist as many uncertain variables are involved. These include inflation and interest rates, the turbine's AEO, buy-back rates and the desired payback of the turbine. Most investors want to see a fast payback but do not consider that a wind turbine should be seen as medium or long-term investments (20 year lifespan) that create its biggest return on investment only after the payback of the initial installation costs. When economic viability and fast amortisation is desired, the turbine performance has to be offset against electricity imports from the grid which is dependent on many different factors:

- For grid-connected systems this means it is not necessarily vital to meet the entire on-site electricity demand in order to be beneficial. However, with buy-back rates lower than the bulk electricity price, the export of surplus electricity cannot be considered as economic.
- For off-grid application the entire on-site electricity load has to be met by the system. Standalone systems are dependent on many variables and how the system works as a whole as they often require other means of electricity generation besides the wind turbine.
- On top of acquisition and installation costs, the fees for potential resource consents, building consents, grid connection, battery bank costs, backup system costs, interest rates on loans, insurance and further planning and implementation costs have to be considered.
- Interest rates on bank loans (to finance the wind turbine) increase the total costs. Immediately paying the wind turbine (when sufficient funds are available) on the other hand prevents the investment sum from earning interest while invested with a bank or in funds. Another option is to increase the home mortgage to finance the turbine.
- The right insurance choice is helpful to eliminate or decrease investment risks, e.g. when the wind turbine is subject to acts of nature beyond control before the investment has redeemed itself

7.4.2 Simple Economic Analysis Tools

The following economic evaluation methods give a general indication on economic performances of domestic wind turbines. Interest rates, inflation, real time value of money and other economic factors are not recognised by these methods. Examples are provided in Appendix E.1 (Gipe, 2004; Investorpedia, 2011):

- **Cost of Energy (COE) Method**
  This method calculates the approximate cost per kWh that can be compared to conventional electricity generation costs. The COE is compared to the actual electricity price retailers charge (at the time of writing, the average residential electricity price was 21.5 cents/kWh excl. GST (MED, 2011a)).
  $$COE = \frac{Total\ Lifetime\ Capital\ Investment + Interest\ Rates}{Expected\ Lifetime\ Energy\ Output\ (kWh)}$$
- **Payback Method**
  This method determines whether the investment pays for itself, in other words, whether the wind turbine generates enough electricity to pay back the initial investment within a certain amount of time (i.e. turbine lifetime). Does this period exceed the expected turbine lifespan

then the turbine is not an economic alternative. When the period is shorter, the turbine payback lies within an economic margin.

$$Payback = \frac{Total\ Lifetime\ Capital\ Investment}{Annual\ Savings\ or\ Revenue}$$

- **Return on Investment (ROI)**
  The ROI is defined as measurement of investment performance that indicates how efficient or profitable an investment is. The efficiency of different investments can be compared. Conversely, the results can be modified to get specific outcomes that suit different situations. Results may vary by including or not including different costs.

$$ROI = \frac{Lifetime\ Savings\ or\ Revenue\ -\ Total\ Lifetime\ Capital\ Investment}{Total\ Lifetime\ Capital\ Investment}$$

7.4.3 Cash Flow Determination for SMW Generation Projects

The above described methods may be simple to apply but they are also delusive. Gipe (2004) describes the annual cash flow over a longer period of time (e.g. turbine lifetime) as the only valid way to determine whether the investment is worthwhile and whether the costs break even within a turbine's lifetime. It is the only analytical method that incorporates all costs (interest rates, costs, profit, annual inflation and nominal electricity price increase) in the form of assumptions into the financial performance of a wind energy generation system.

A discounted cash flow analysis helps to evaluate long term investments allowing for the time value of the money. Hereby the net present value (NPV), as a sum of present cash flow values, indicates how much an investment is worth over a certain time period (e.g. 20 years as the average lifetime of a small wind turbine). The discounted cash flow is determined with a discount rate, indicating the rate that the required capital investment could return when invested on the capital market. A positive NPV adds value to an investment while a negative NPV indicates that it would be more worthwhile to invest the money into another venture as it deducts money from a financial capital instead of adding value to it. (C. Andersen, pers. comm., 25 June 2011).

When the NPV over a certain period of time is close to zero, then other criteria or benefits should be taken into account. If, for example, a small wind turbine adds non-monetary value in the form of eco-friendly and sustainable electricity generation, then a NPV of zero or even a slightly negative NPV could still mean that the renewable energy generation system adds (non-monetary) value. When no other benefit is visible, then alternative investments with a NPV greater than 0 would add more value to a person's or company's capital.

A cash flow analysis example is presented in Appendix E.2. As every wind energy project is different and each turbine has specific requirements (mast height, foundation, noise emissions, etc.), it has to be noted that none of the cash flow analysis accounted for consenting, planning and other additional costs (foundation works, freight, electric wiring, etc.) in order to show the evaluated turbines' on-site financial performances. When a resource consent is required, the initial investment costs are likely to increase by several thousand dollars. On top of that freight costs often apply. Tax credits, grants, subsidies or other incentives for distributed wind energy generation do not exist in New Zealand; hence total installation costs per se cannot be reduced. The electricity price assumptions are based on the average nominal kWh-price increase over the last 5 years. According to New Zealand Treasury (2011) a discount rate of currently 8 percent is used for the discounted cash flow analysis.

7.5 Case Study Evaluation

7.5.1 Selwyn Case Study

For most of the wind turbines a resource consent is not necessary unless the system feeds electricity into the grid or fails compliance with one of the performance standards set in the relevant plan rules (e.g. max. structure height of 25 metres). The costs for obtaining a resource consent for a domestic wind turbine are dependent on the respective effects the activity causes and on hourly rates charged by the consent authority. Building consents are usually easy to apply for and are generally needed for the erection of a SMWT. All relevant consenting costs are summarised in Appendix D.1.3.

As the site is connected to the local grid, a standalone system should only be considered when total independence from the market is preferred. Regardless, the system is desired to meet the on-site electricity demand in order to be as much independent from the grid as possible. As the turbine should be capable of meeting most of the electricity demand, an AEO of at least 4,300 kWh per year should be strived for. Given this, two turbines seem to be right for the case study site. The Montana and the Whisper 500 generate enough electricity on-site to meet the annual demand; both turbines generate approximately 4,800 kWh per year. Installing a smaller system only becomes viable with a decreased energy demand and smart system operation (i.e. energy saving methods, gas or solar hot water, and when there is no wind, charging the batteries over night for a night-rate).

Table 17 gives an overview of the evaluated turbines' economic performances.

Table 17
Comparison of economic analysis methods for Selwyn case study

Turbine	Turbine Costs	AEO	COE	Payback after	ROI	Pos. Net Cash Flow after	NPV of investment over 20 years
MG-4540 (5x)	$ 6,000	2,291 kWh	0.15 $/kWh	12.2 years	0.42	11 years	$ 496
Gusto 2.0	$ 25,000	2,492 kWh	0.42 $/kWh	39.2 years	-0.49	28 years	$ -18,629
Skystream 3.7	$ 20,000	2,657 kWh	0.40 $/kWh	35.0 years	-0.46	24 years	$ -12,957
Proven 7	$ 25,000	3,201 kWh	0.41 $/kWh	36.3 years	-0.48	24 years	$ -16.549
Whisper 500	$ 25,000	4,866 kWh	0.28 $/kWh	23.9 years	-0.22	19 years	$ -11,664
Montana	$ 25,000	4,884 kWh	0.28 $/kWh	23.8 years	-0.22	18 years	$ -11,611
Proven 11	$ 39,000	6,124 kWh	0.34 $/kWh	29.6 years	-0.36	21 years	$ -22,500
Excel	$ 56,000	10,363 kWh	0.29 $/kWh	25.1 years	-0.26	19 years	$ -27,703
Alize	$ 56,000	12,251 kWh	0.25 $/kWh	21.3 years	-0.13	17 years	$ -22,163

At given costs and electricity prices, it is unlikely that installing a wind energy generation system is financially viable within its lifetime. Apart from the five MG-4540 with a breakeven after 11 years, none of the evaluated turbines perform well enough to break even within an adequate time period. The five MG-4540 turbines are the only investment option that has a positive NPV over an investment period of 20 years.

Although some turbine manufacturers promise high generation rates at lower wind speeds, the best performance is delivered by the cheapest among the available options. The five MG-4540 generate almost as much as other turbines (Skystream 3.7 or Gusto 2.0) and an installation of a six or more of the same turbines would still prove to be more economical. Apart from that, none the other eight turbines return profit within their lifetime while the larger turbines have a better economic performance. This is likely due to the better cost-performance ratio (four to five times higher AEO at roughly three times the cost).

On the Selwyn case study site, domestic wind energy generation appears to be uneconomical and other distributed renewable generation methods might yield a better economic performance. Standalone and grid-connected applications are both technically feasible but an investment in both system types will be highly uneconomical. Investing in other technologies or even continuing to import electricity from the grid (and investing the capital with a bank) remain cheaper options. Nevertheless, when a grid-independent system is desired, it can be realised in combination with e.g. solar hot water and PV cells and battery storage. The higher cost of such a system has to be taken into account.

7.5.2 Western Bay of Plenty Case Study

For all wind turbines a resource consent is necessary as all activities associated with both, grid-connected and off-grid application fail to comply with most performance standards set in the relevant plan rules[7]. The costs for obtaining a resource consent for a domestic wind turbine are dependent on the respective effects the activity causes, the costs for an AEE and the costs estimated for hourly rates. Building consents are usually easy to apply for and are generally needed for the erection of a SMWT. All relevant consenting costs are summarised in Appendix D.2.3.

As the site is connected to the local grid, a standalone system should only be considered when total independence from the market is desired. The installation costs of a suitable wind turbine system, battery bank and preferably some sort of backup (e.g. PV arrays and a diesel generator) will by far exceed the costs of importing electricity, particularly when annual price increase and inflation are considered.

The desired system is a grid-connecter turbine with no more than 5 kW installed capacity. The system is desired to meet the on-site electricity demand and export surplus generation into the local grid. As a minimum energy demand, 6 kWh per day was set and a maximum of 12 kWh per day which is considered as sufficient to sustain a day with high demand. This results in an annual energy demand between approximately 2,250 and 4,400 kWh with a median of about 3325 kWh per year. Based on this, the Proven 7 seems to be the turbine that meets the demand the best. For the same price, a Montana or a Whisper 500 could be installed; yielding 1,600 kWh more per year and surplus generation could be sold to a retailer. Installing a smaller system (e.g. a Gusto 2.0 or 5 MG-4650 turbines) means that the energy demand can only be met with smart system maintenance (i.e. energy saving methods and reducing peak loads). As Meridian Energy offers a one-to-one buy-back rate it technically does not matter when the energy is generated as the total AEO will be off-set against the imports.

Table 18 gives an overview of the evaluated turbines' economic performances.

Table 18
Comparison of economic analysis methods for Western Bay of Plenty case study

Turbine	Turbine Costs	AEO	COE	Payback after	ROI	Pos. cum. Net Cash Flow after	NPV of investment over 20 years
MG-4540 (5x)	$ 6,000	2,033 kWh	0.17 $/kWh	15.6 years	0.28	12 years	$ -261
Gusto 2.0	$ 25,000	2,244 kWh	0.47 $/kWh	43.3 years	-0.54	30 years	$ -14,169
Skystream 3.7	$ 20,000	2,314 kWh	0.45 $/kWh	42.1 years	-0.52	26 years	$ -13,963
Proven 7	$ 25,000	2,802 kWh	0.47 $/kWh	43.4 years	-0.54	26 years	$ -17,720
Whisper 500	$ 25,000	4,381 kWh	0.31 $/kWh	28.4 years	-0.30	20 years	$ -13,087
Montana	$ 25,000	4,406 kWh	0.30 $/kWh	28.3 years	-0.29	20 years	$ -13,014
Proven 11	$ 39,000	5,315 kWh	0.39 $/kWh	36.0 years	-0.44	23 years	$ -24,873
Excel	$ 56,000	9,166 kWh	0.33 $/kWh	30.3 years	-0.34	21 years	$ -31,215
Alize	$ 56,000	10,687 kWh	0.28 $/kWh	26.2 years	-0.24	19 years	$ -26,752

The results are similar to the Selwyn case study; only the five MG-4540 of all evaluated turbines will be profitable within their lifetime. Here, all turbines have a negative NPV over an investment period of 20 years. In general, the same conclusions as for the Selwyn case study apply.
This site has a slightly worse wind resource and with SMWT no economic benefit is achievable. On-site wind energy generation is considered uneconomical and other renewable energy systems might yield a better economic performance.

7 The provisions of the proposed district plan regarding wind turbines are different; height, yard and other performance standards remain non-complying with the relevant rules.

7.5.3 Wellington Airport Reference Site

In better wind regimes domestic wind turbines can perform tremendously better. Most turbines achieve a positive cash flow between 11 and 15 years which lies within the turbines' lifetime. Table 19 gives an overview of the evaluated turbines' economic performances.

Table 19
Comparison of economic analysis methods for the Wellington Airport reference site

Turbine	Turbine Costs	AEO	COE	Payback after	ROI	Pos. cum. Net Cash Flow after	NPV of investment over 20 years
MG-4540 (5x)	$ 6,000	7,414 kWh	0.06 $/kWh	5.6 years	2.56	4 years	$ 15,526
Gusto 2.0	$ 25,000	6,621 kWh	0.17 $/kWh	15.9 years	0.26	15 years	$ -6,515
Skystream 3.7	$ 20,000	8,198 kWh	0.14 $/kWh	13.2 years	0.51	10 years	$ 3,300
Proven 7	$ 25,000	9,037 kWh	0.16 $/kWh	14.7 years	0.36	12 years	$ 573
Whisper 500	$ 25,000	12,567 kWh	0.12 $/kWh	11.1 years	0.80	9 years	$ 10,930
Montana	$ 25,000	14,107 kWh	0.11 $/kWh	10.1 years	0.98	8 years	$ 15,448
Proven 11	$ 39,000	19,585 kWh	0.12 $/kWh	11.1 years	0.80	9 years	$ 16,996
Excel	$ 56,000	33,123 kWh	0.10 $/kWh	9.7 years	1.06	8 years	$ 39,073
Alize	$ 56,000	35,766 kWh	0.10 $/kWh	9.1 years	1.19	8 years	$ 46,828

On the Wellington reference site, the five MG-4540 achieve the fastest payback and even though they have the lowest AEO, they generate sufficient electricity to supply the demands of an average residential home in New Zealand. All turbines break even within their lifetime and the only turbine that has a negative NPV over an investment period on 20 years is the Gusto 2.0. All other evaluated turbines are worthy investments and add value to a renewable energy generation project.

7.5.4 Sensitivity Test of Cash Flow Inputs

Assumptions for the cash flow analysis are based on wind data, a turbine's AEO, the investment costs, current discount rate, and the best currently available buy-back rate. To test the outcomes for the case of wrong or inaccurate assumptions the sensitivity of the inputs is listed below. Only those inputs described are altered while all other inputs are set as under the assumptions used for the cash flow analysis for sites with average (e.g. annual average wind speed of 4.0 m/s) and good (e.g. annual average wind speed of 6 m/s and more) wind resources. The i.e. discount rate: 8%; buy-back-rate: 21.5 cent/kWh; respective investment sum of assessed turbines).

The AEO of a domestic wind turbine is a major factor that determines the economic viability. For an identical investment sum, a higher AEO results in higher revenue and shorter profit returns. Calculated AEO are tested for plus/minus 25 percent (see Encraft study described in Section 7.2.1) in the case of turbine failure or wind speeds beyond cut-out (e.g. extreme gusts and gale winds):

- On sites with average wind resources a 25 percent lower AEO, at least doubles the period in which the cash flow turns positive.
- On sites with good wind resources a 25 percent higher AEO, the period in which the cash flow turns positive increases by about 40 to 60 percent.

The current buy-back rate of 21.5 cent/kWh is tested for a reimbursement of 5 cent/kWh (as from e.g. Genesis Energy) and for 40 and 60 cent/kWh (as for potential FiT). The buy-back rates have a significant effect on the revenue from domestic wind turbines:

- A rate of 5 cent/kWh in all cases reflects extremely long amortisation period with positive net cash flows only after multiple decades and deep red NPV over 20 years even for sites with good wind resources. Most turbines return no or hardly any annual revenue within 20 years.
- A buy-back rate of 60 cent/kWh produces a positive NPV for almost all evaluated turbines on all sites. For sites with good wind resources, 40 cents/kWh already drops the amortisation period dramatically (within 10 years), but is not sufficient for sites with an average wind resource.

The investment sum is tested for acquisition and installation costs that would generate a positive NPV within the turbine's lifespan. For the average SMW system costs the following applies:

- On sites with average wind resources:
    - For category 1 turbines total initial capital investment should be no more than $ 6,000;
    - For category 2 turbines total initial capital investment should be no more than $ 12,500;
    - For category 3 turbines total initial capital investment should be no more than $ 25,000.
- On sites with good wind resources:
    - For category 1 total initial capital investment should be no more than $ 18,000;
    - For category 2 total initial capital investment should be no more than $ 35,000;
    - For category 3 turbines total initial capital investment should be no more than $ 80,000.

7.5.5 Case Study Evaluation Summary and Conclusion

The critical analysis of the conducted case studies revealed that:

- Finding the right turbine and placing in the right spot is anything but easy. The conducted wind data analysis and turbine performance assessment revealed that:
    - Both sites are not perfectly suitable for wind energy generation on a small scale. Available wind resources, especially in lower regions at around 10 metres, are hardly sufficient for generating a decent annual energy output;
    - Larger turbines are capable of generating a higher AEO at a lower per kilowatt installation cost. In addition, larger turbines are normally mounted on higher poles which increase the wind quality and quantity and are likely to result in better performance and a higher AEO.
- The case studies revealed the different approaches that local authorities take in matters of wind energy generation on a small or micro scale. The case studies revealed that:
    - Selwyn DC has a more enabling process to deal with wind energy generation. The only barrier for SMW generation systems is that electricity export is a discretionary activity under the Selwyn DP and requires a resource consent;
    - Western Bay of Plenty DC has more prohibitive operative plan provisions. Wind turbines are classified as a discretionary activity while height, yards and other standards apply in addition;
    - The proposed WBoP DP deals with small scale wind energy generation in a slightly more enabling way. However, while electricity generation for on-site energy use is permitted, height restrictions remain problematic and a resource consent still seems to be inevitable.
- The economic analysis showed that in most cases an investment will not return profit within the lifetime of a domestic wind turbine. For the Western Bay of Plenty case study site, the results are even more sobering than for the Selwyn case study site:
    - For the both case studies, nearly all turbines had a negative NPV over a period of 20 years.
    - Capital investment with a bank and importing electricity from the grid is the more beneficial alternative when monetary gains are most important.
    - Under the given circumstances (no economic incentives, no FiT, high turbine and additional costs), capital investment would have to be a quarter to a half of the actual turbine and additional costs to achieve positive cash flow within a turbine's lifetime.
    - The current best buy-back rate is only sufficient for sites with exceptional wind resources. For sites with less wind, only a guaranteed long-term buy-back rate of at least 0.60 $/kWh would return profit within the lifetime of a domestic wind turbine.
    - The Wellington case study site shows that with good wind conditions the economic benefit and the generation (AEO) look far more attractive. The AEO is about three times higher than on the two case study sites. Evaluated turbines are more economic and capable of returning profit within their lifetimes. Most turbines achieve positive NPV over 20 years.

7.6 Evaluation of Other Case Studies

7.6.1 Limited Availability of Research and Case Studies

There is not much literature regarding experiences with small or micro scale wind turbines in New Zealand. Some case studies are described on the EECA website but no critical reports or articles were available. This section gives an overview of New Zealand and overseas case studies and reports.

7.6.2 Examples from New Zealand

- **Taurikura Lodge In Motukarara** (EECA, 2009a; S. Jarvis, pers. comm., 17 June 2011)
  - Turbines: Two grid connected Southwest Wind Power Skystream 3.7 (2.4 kW each); height, 10 metres; blade diameter: 3.7 metres;
  - Location: Motukarara Valley, Banks Peninsula, New Zealand;
  - Performance: Monthly energy output up to 2,100 kWh on top of energy consumed by the premises; hardly any electricity imports;
  - System features: Energy exported to the local Grid (Orion Network) and sold to Meridian Energy at a one-to-one buy-back rate;
  - Evaluation: Excellent performance due to siting (at the bottom of a valley where strong winds are being funnelled down from the north and south). The project included increase of energy efficiency (e.g. more efficient water heating, efficient log burners, etc.) and a reduction of the electricity demand (e.g. energy saving light bulbs). A resource consent was required as electricity is exported.

- **Lincoln New World Supermarket** (S. Jarvis, pers. comm., 17 June 2011; G. Rogers, pers. comm., 20 June 2011)
  - Turbines: Two grid connected Southwest Wind Power Skystream 3.7 (2.4 kW each); height, 10 metres; blade diameter: 3.7 metres;
  - Location: Lincoln New World parking lot, Lincoln, New Zealand;
  - Performance: No available data; however, it is expected that the turbines do not perform well;
  - System features: Energy exported to the local Grid (Orion Network) and sold to Meridian Energy at a one-to-one buy-back rate;
  - Evaluation: Wrong turbine placement and low mast height influence the turbines performance. Lincoln does not have adequate wind resources. The turbine cannot be considered to be operating effectively. On the other hand, this approach is supposed to be a best practice model for sustainable building and shows commitment to renewable energy generation and eco-friendly business operation. It is a best practice project for environmental sustainable supermarkets in New Zealand, including eco-friendly materials, recycling and energy saving methods.

- **Hybrid System, Selwyn District** (G. Rogers, pers. comm., 20 June 2011)
  - Turbine: Aeromax Lakota 1 kW; 20 metre high guyed mast with hinge in the middle to tilt the turbine for maintenance and in too high wind speeds; blade diameter: 2 metres;
  - Location: Rural property near Rolleston, Selwyn District, New Zealand;
  - System Features: Hybrid system (upgrade of an solar PV system); grid-connected only for electricity imports; no exports; system facilitates surplus generation to charge a battery bank;
  - Performance: Not yet available as turbine still under construction;
  - Evaluation: The main purpose of this project is not to be more economical (importing electricity from the grid is likely to be cheaper), but to be more eco-friendly as well as independent from power outages and natural hazards (such as earthquakes, flooding, etc.). The battery bank and its maintenance is one crucial, if not the most important factor of the whole generation system as under- or overcharging has to be avoided to ensure an adequate battery lifetime. Further a smart system design and energy saving methods should go hand in hand with every renewable generation system. Rogers also emphasised that domestic wind turbines should only be put in places where an adequate wind resource is available. He recommends that turbines should be placed a minimum of 10 metres above any surrounding obstacles (trees, houses, etc.) within a 100 metre radius of the turbine as wind quantity and quality improves dramatically with every meter of clear wind flow. The 1 kW turbine did not require a resource consent as the electricity is used on site. When no wind or sun is available over a longer period of time, the battery bank is charged at a night power rate and used during the day when the electricity price is higher.
- **Motukiekie Island holiday home** (EECA, 2009b; Watts, 2009)

- Turbine: Southwest Wind Power Whisper 200 with 0.9 kW;
- Location: Motukiekie Island, Bay of Islands, New Zealand;
- System features: Off-grid application; total system capacity is 8.42 kW (2.72 kW solar PV system and a 4.8 kW low noise 2 cylinder backup diesel generator); battery bank to store surplus electricity);
- Performance: Solar PV arrays and wind turbine cover main demand; peak demand and battery management met by diesel generator;
- Evaluation: Off-grid renewable DG systems can be highly beneficial for application in remote areas. System is a viable alternative to an expensive grid connection. Instead of solely relying on a fossil fuel system, the combined use of renewable energy sources can be a worthwhile alternative.

- **Southbridge Wind Turbine** (Energy3, 2011)

  - Turbine: 100 kW turbine (classified as medium size or community scale wind turbine); height: 42 metres; blade diameter: 20 metres;
  - Location: Near Rakaia River mouth, Southbridge, New Zealand;
  - Operated by Meridian energy;
  - Performance: AEO of app. 200,000 kWh, enough electricity for 26 households with an average energy demand of 7,700
  - Evaluation: Good example that proper planning, turbine placement and exposure to abundant winds are critical success factors.

7.6.3 Examples from Overseas

- **A farm in the south of France** (SWIIS Consortium, 2004)

  - Turbine: Two-bladed 10 kW turbine (installed 1986);
  - Location: Récoumpatot Farm in the Corbières, Languedoc-Roussillon, Aude, Southern France
  - System features: Standalone system; battery bank and a small diesel generator back up the energy demand in low-wind periods;
  - Performance: Average daily energy output of 45 kWh (measured over 16 years); enough to cover 90 percent of the on-site energy demand;
  - Evaluation: Located on a small hill with no surrounding obstacles, the farm has excellent wind resources and an average annual wind speed of 7.5 m/s. When the turbine was installed in 1986 the costs to connect the farm to the utility grid would have included a two kilometre grid extension and a transformer which was not economically viable for the farm owner; 55,000 Euro (NZ$ 97,000) for the wind turbine stood against estimated 75,000 Euro (NZ$ 132,500) for grid connection. The turbine operated thirteen years until its first major maintenance; the battery bank had to be replaced after 15 years. Since installation, the system owner has been very content with the turbine performance. This is a good example where good planning and implementation processes created an alternative approach to an eco-friendly and successful off-grid energy generation system.
- **UK case study on rooftop micro wind turbines** (Gray, 2009; Encraft, 2009)
  - Study description: Assessment of building mounted small and micro wind turbines (up to 1 kW) in urban areas in cities across the UK; conducted by Encraft in 2007 and 2008, an independent renewable energy consulting company in the UK.
  - Performances: Average daily electricity output per wind turbine only 628 Wh, average AEO 630 kWh; average CF of 4.15%;
  - Study findings: The study shows the necessity of wind monitoring and appropriate turbine placement, but also too high expectations. Some turbines operated quite efficiently, others generated the same amount in a year than other, more efficient ones, produced in a day. Noise emissions from efficiently performing wind turbines were experienced and described as disturbing by adjacent neighbours. In general, rooftop turbines do not perform nearly as well as freestanding ones and are not worthwhile.

- **U.S. case studies** (Kandt et al., 2007; NREL, 2011)
  - Study description: Various case studies conducted in the USA evaluating barriers for small wind energy generation.
  - Study findings: The tests conducted in good wind regimes yielded good generation rates. In these tests the larger models in the SMWT class were found to perform better than smaller rated models with 1 or 2 kW which can be affiliated with the economy of scale aspect for wind turbines. Further, the relatively high acquisition costs of small and micro scale wind turbines seem to prevent markets from growing at a faster rate. High raw material costs, especially for alloys such as aluminium used for turbine manufacturing, decreased the manufacturers' profit margins. Investors mainly promoting large-scale projects reduced the interest in small scale technology which left manufacturers also shifting their main focus towards medium to large scale turbines.

7.7 Summary of Critical Analysis of Planning Processes

The analysis and evaluation of the case study findings and the evaluation of articles, studies and reports come to the same conclusion revealing that:

- A site with good wind resources should be chosen to avoid bad overall performance and sobering results. This should always go hand in hand with appropriate wind monitoring and data analysis. Then, it should be determined which turbine works best for the existing conditions.
- An economic analysis in form of a cash flow determination should be conducted beforehand. This is the only reliable economic analysis tool that incorporates all the different economic aspects. When a SMWT is economically not viable, then other means of distributed electricity generation should be considered, unless other non-monetary benefits are more important.
- The cash flow analysis was conducted without taking into account additional costs. When these are considered, turbines on both case studies are likely to be much more uneconomical.
- Additional costs for consenting (resource and building consents can make up $ 6,000 or more), electrical wiring, foundation works or freight may increase the initial capital investment by 25 to over 80 percent. This should always be considered when looking at SMWT prices.
- Both case study sites revealed, that the performance of most turbines is not sufficient to make them economic viable within their lifetime. Especially when additional costs are added, the system becomes highly unviable. In contrast, performances on the reference site with good wind resources resulted in the almost all turbines being efficient and viable.
- Economies of scale effects apply for wind turbines. Larger turbines perform better than their smaller many cases it is more efficient to promote community scale projects.

Chapter 8
Discussion

8.1 Introduction

The discussion in Chapter 8 is based on the literature review and case study findings and segmented in three parts. Section 8.2 critically reflects technical planning aspects of small and micro wind turbines. Section 8.3 looks into resource management planning, while Section 8.4 discusses economic aspects.

8.2 Technical Planning Aspects

8.2.1 Market Limitations

The market for domestic wind turbines is rather small in New Zealand and a limited source of manufacturers and retailers are present. Only a few domestic size turbines are produced here and models from overseas are limited on the New Zealand market. It is possible to import turbines from overseas but freight costs and import taxes increase the acquisition costs. In general turbine prices on the New Zealand market are higher, if not too high without state funding or other incentives, than in other countries where more competition exists. Further, the latest technology may not be available or is limited on the New Zealand market.

New Zealand may have adequate renewable resources, but lacks the local market. Investing in the small scale renewable energy sector in other countries has proven to be a successful measure to promote job creation and boost technology research and development.

8.2.2 More Transparency and Assistance from Governmental Agencies

Domestic wind turbines in New Zealand can only operate efficiently in good wind resources. Unlike the 4.5 m/s annual average wind speed stated by EECA as sufficient, results show that only generate a decent and economical AEO at annual average wind speeds of at least 6 m/s. Better education about the available technology on the market is necessary. Estimating a turbine's AEO on a specific site requires physical and statistical knowledge that many people won't have. It is therefore essential that potential investors receive better education and information.

It is the government's responsibility to promote renewable energy generation and to provide accurate information. An important factor considering the governmental duties is that more information concerning small and micro scale distributed renewable energy generation is required. There is a clear lack of information platforms in New Zealand. EECA provides some information which, appears to be inaccurate and not as qualitative and comprehensive as desired. There is a strong need for information to be more accurate and detailed. This should be provided by the authorities and include independent test centres for small wind turbines, better educational programmes, independent certification of wind turbines to better determine their performance, accurate calculation tools, guidelines for energy output calculation or an easy-to-use national wind database are only a few examples.

8.2.3 More Transparency from the Industry

White- or rather green-washing seems to be a general practice among turbine manufacturers and installation companies. Their marketing campaigns often are misleading for most layman (but understandably – they want to sell their product), providing insufficient information as well as inadequate and poor data. The fact that every wind energy project is different, standardised statements such as "This turbine generates 6,500 kWh per year at an average wind speed of 6 m/s" makes it hard for inexperienced and new market players to see the real technical performance and economic viability of a wind turbine.

Installation companies often seem to hold back information about additional costs for freight, electrical wiring, foundation works and consenting fees. It is often kept a secret, that these costs are often not transparent to investors and may account for up to over 50 percent of the turbine's purchase costs. There is a need for the market to open up and create more trust, help interested investors with more transparent prices and information and work together with small and micro wind turbine interest groups. A lack of transparency leads to less satisfaction with the turbine performance which may result in low recommendations for potential customers.

8.2.4 Critical Technical Success Factors

The literature review and the conducted case studies have shown the different requirements that a turbine needs to operate efficiently. These are:

- The more time the wind speeds exceed 3.5 m/s (cut-in wind speed for most SMWT) the more the turbine operates;
- Prevailing winds should be of high quality and quantity, i.e. uninterrupted flow, no turbulences and wind speeds of 6 m/s and more are best suitable for SMWT; the highest capacity factors are achieved at wind speeds of more than 10 m/s;
- A wind speed distribution that correlates with the turbine's power output curve. A turbine with high capacity factors at lower wind speeds should be chosen over a turbine with a lower CF when placed in wind regimes with higher occurrence of lower wind speeds. Similarly, a turbine with high capacity factors at higher wind speeds should be chosen over a turbine with a lower CF when placed in wind regimes with higher occurrence of higher wind speeds;
- The higher the hub height, the better the AEO yield. An increase in height is the one of the most effective measure to boost a turbine's performance;
- System set-up and maintenance is a crucial factor, especially for standalone application in combination with battery banks and other means of electricity generation.

8.2.5 Grid Connection vs. Standalone Application

The system choice is dependent on many factors. First, it has to be clear what kind of system is desired or, in other words, what the preferred benefits from the system are. The desired size of the wind turbine determines potential generation rates. The larger a turbine, the more it will generate. Size also influences capital investment and other economic factors, such as revenue from feeding electricity back into the grid.

Especially for remote premises, cost of connection (i.e. line extension and in cases a transformer station) are entirely borne by the DG system owner when the grid operator sees no economic viability in the matter. These extra costs can make a grid connection highly uneconomical and an off-grid application may be favourable. Further, installation of small or micro wind turbines should always go hand in hand with energy saving methods and other means of renewable generation to reduce the risk of power loss while avoiding fossil fuel generators. When grid connection is not economically viable, when environmental awareness is high and when a good enough on-site wind resource is available, then standalone renewable distributed energy generation systems are an excellent alternative.

Connection to the local grid is not considered as problematic in most cases. The Electricity Industry Participation Code 2010 provides for the possibility to connect SMWT to the grid in a relatively straightforward way. Surplus generation can be stored in batteries, sold to one of the four nationwide operating retailers that offer off-take agreements or sold on the electricity spot market.

8.2.6 Economies of Scale

For remote farms, holiday homes, batches, weather station, lifestyle blocks, to name a few, even smaller and less economic viable turbines in combination with other renewable generation means and energy saving methods may be a viable alternative to a grid connection or fossil fuel burning generators.

However, economies of scale play a major role when developing wind energy generation systems. Larger turbines have a bigger blade swept area and more kinetic power from the wind can be transformed into electricity. Their increased height lets them operate with a higher efficiency. They have lower installation cost per kilowatt, their amortisation periods are shorter and they generate comparably more energy than their smaller brothers.

In many cases, especially in areas with low only average wind speeds, larger or even community scale wind generation systems may be a better alternative to small or micro scale projects. Successful projects such as the Southbridge wind turbine show that they are capable of generating enough electricity to power small settlements or villages. This example could be easily applied in other locations and situations, for example for farm application where a group of farmers install a 50 or 100 kW turbine instead of investing in multiple smaller turbines. The higher hub and comparably less investment costs are likely to be more beneficial than smaller turbines operating at lower heights.

8.3 Resource Management Planning Aspects and Government Duties

8.3.1 More Transparency and Consistency of Spatial Planning Processes

The spatial planning process has been deemed as a major barrier for small scale wind energy generation. To some degree this is evident as potential investors are usually scared away by extra or latent costs, and time consuming application processes that include submissions or possible hearings.

Analysing the statutory planning provisions of district and regional plans for the case studies as well as reading through other plans and policies have shown that when the effects of SMWT are more than minor and a resource consent is required, it can normally be obtained fairly easy. Some consent authorities have already enabled SMW energy generation in their plan provisions. This process will most likely be driven further as the new National Policy Statement for Renewable Energy Generation 2011 requires regional and territorial authorities to incorporate ways and methods in their plans and policy statements that promote distributed renewable energy generation on small and micro scale.

Speaking to experts and people having installed SMWT on their premises, no one expressed the opinion that the resource consent application process was a real barrier. They were limited more by false manufacturer and installer promises that claimed much higher AEO and economic profitability.

Turbines are most efficient on sites with good wind resources but in general central and local governments should be aiming to encourage rather than hold back private investors from devoting themselves to renewable distributed generation. However, as long as the smallest level of micro turbines with several hundred watts still need a resource consent, wind energy on small and micro scales is far from being feasible and integrated. Especially when SMWT are not highly profitable, then resource consent costs of $ 2,000 or more play a major role in the overall economic efficiency. The installation of a micro turbine is still classified as a discretionary activity by many consent authorities. Initial investment costs for a micro turbine of about $ 1,500 (incl. mast, inverter and small battery bank) increase by over one hundred percent when a resource consent is required. For an investment of, for example, $ 20,000 this means that at least another 10 percent of the investment costs has to be added to the total costs, which significantly influences the economic return. Designing a system in a way to avoid resource consents is not advisable. Complying with permitted height and other restrictions or placing turbines on sites where they are a permitted activity can be counterproductive as the turbine may no longer be located in the best possible wind region.

The main barriers could be removed by introducing legislation that is uniform and consistent for all 67 territorial authorities and 16 regional councils. Further, small wind turbines (e.g. under 10 kW) could be a permitted or at least a controlled activity under the RMA due to their minimal adverse effects. Last but not least, a widely discussed FiT scheme would show the government's commitment to a greener and cleaner electricity generation and to a more sustainable and resilient total energy consumption. The discrepancies of how consent authorities deal with wind turbines need to be changed and one, easy applicable and straightforward legal process should deal with small and micro wind turbines and renewable distributed energy generation in general. How much this will be influenced by the new NPSREG is questionable as it will still be in discretion of the consent authorities to incorporate the statutory planning document into their plans.

8.3.2 More Transparency and Commitment from Government and Policy Makers

In sparsely populated countries like New Zealand with many remote farms, "lifestyle blocks", and even entire villages that are off the national grid, the needs for and advantages of distributed generation are obvious. Generating electricity where it is needed and without grid losses or high capital investment for new electricity lines, might be the way that leads New Zealand towards a more eco-friendly and sustainable energy supply and total energy consumption. Small and micro wind turbines for residential use may not be capable of providing a big share in the New Zealand Energy Strategy's objectives and targets, but promoting SMW energy generation will play a role in showing commitment to resilient and sustainable thinking.

New Zealand's government and policy makers will have to deliver more than the recently released National Policy Statement for Renewable Energy Generation 2011. It clearly is a first step in the right direction but it still does not tap the full potential and leaves many open questions. It does not promote one harmonised way for consent authorities to deal with distributed renewable energy generation. It only provides direction while leaving the discretion over how to implement plan policies and rules up to the relevant council. Other countries have shown that renewable energies have to be boosted by the government to increase their acceptance and to establish them among conventional energy generation. Active promotion and clear supportive statements are therefore further steps to be considered by the central government.

The government claims that FiT are not necessary in a country with a 75 percent renewable share of energy generation. While only 38 percent of the country's total primary energy supply derived from renewable resources, there is still an extensive potential to do better, particularly due to the inevitable fact that fossil fuel prices will continue to rise in the decades to come. Given this, more strategic foresight, even on a small scale, will be worth more than standing still and maintaining the status quo. Of course, large scale projects will contribute to a sustainable and eco-friendly energy sector to a much higher degree. On the other hand, it is clearly a lack of commitment that the government shows with their current attitude towards distributed renewable energy generation.

A reason for the lack of commitment might be that three of the five major electricity generator and retailer companies are state-owned enterprises, meaning that millions of dollars in dividends are distributed into the governments pockets. This raises the question to what degree the government is willed to subsidise FiT and create other economic incentives resulting in lower revenue from their stakes in electricity market assets. With these assets lies an opportunity to promote distributed renewable energy generation. As three of the largest generators/retailers are state-owned, higher buy-back rates and long-term contracts could be offered by those companies without changing the law. This, however, can only happen when the retail sectors of those companies remain state assets.

The potential is great. Other countries have led the way, now New Zealand has to follow. Promoting small scale renewable energy generation and boosting the renewable energy industry will not only result in more investments in this sector but also return more revenue from business taxes. New Zealand has the potential of forming an advanced multi-million dollar industry and creating thousands of new jobs in this sector.

8.4 Economic Aspects

8.4.1 Economic Viability as Critical Success Factors

Economic viability and cost effectiveness are critical success factor for the feasibility of wind energy generation systems. It is simply due to the comparably high acquisition and installation costs and the limited lifespan of SMWT that a quick amortisation period is desirable. The economic analysis of the case studies revealed several factors that influence the economic viability of a domestic wind turbine. These are:

- The definition of benefit;
- Capital investment (acquisition, implementation and spatial planning costs; long-term investments vs. short-term investment with a bank or akin);
- The buy-back arrangement with the retailer;
- The national residential energy price development and inflation.

8.4.2 Definition of Benefit

The benefits from small or micro scale wind energy generation can be of different nature. Some might build a wind turbine out of economic reasons, especially when a good wind resource provides enough financial safety and when amortisation periods are short. On the other hand, others might see the actual benefit in being more independent from the whims of retailers and national or local grid operators. Pursuit of profit, rising fossil fuel prices and the need to invest in utility infrastructure will most likely further increase the real electricity price in future (with inflation taken into account) over the decades to come. This will drive more private interest towards investing in alternative energy generation systems as over time, acquisition, installation and operation costs are likely to decrease.

Commercial wind turbine operators may want to set an example for sustainable energy supply. Increase their environmental credibility might play a role for their marketing campaigns and corporate identity. On the other hand, people living in remote areas without a feasible grid connection might simply offset the costs of a standalone distributed generation system against the often tremendously high costs for connecting their premises to the local or national grid.

8.4.3 Capital Investment

Capital investment plays a major role when determining the economic performance of a wind energy system. Turbine prices vary; generally the larger the turbine, the more costly they become. Especially for standalone applications, backup systems and battery banks have to be added which increases the initial investment sum. Therefore, an increase in acquisition and installation costs should go hand in hand with a higher AEO, otherwise the economic performance of the turbine will lag behind. Some turbines perform worse than others from an economic point of view, even though they have a higher power output which is related to higher investment costs.

Additional costs play a major role for the capital investment. In many cases, 25 to over 80 percent of turbine costs (incl. mast) have to be added. This influences economic viability and overall performance of a system. Hereby, spatial planning fees for resource consents, building consent fees, costs for the construction of a foundation, wiring and long distance freight, all heavily influence the investment costs, while the grid connection fees are minor. One alternative to consider is that money can be saved with DIY (“do it yourself”). When the required knowledge is available, foundation (excavation and concrete works) and the wiring costs (e.g. digging a wire trench) can be reduced dramatically but not everybody has the required expertise. Looking at additional costs, it is surprisingly common for manufacturers and installation companies not to mention that for the installation and operation of SMWT, extra costs of up to 100 percent of the turbine acquisition costs have to be spent.

One surprisingly outcome of the case studies was the assessment of the five micro turbines (MG-4540) with an installed capacity of 2.5 kW that clearly outperformed (on a financial basis) other turbines with similar capacity ratings. This is due to their low acquisition costs. Even when offsetting 50 percent higher per-turbine-costs than used for the case studies against e.g. a Skystream 3.7 or a Gusto 2.0 the economic performance remains better.

The case studies indicated that wind regimes on both sites are not sufficient to compensate a high capital investment. For most turbines, about a third to a half of the actual investment was able to produce adequate revenue. It can be concluded, that for sites with low or average wind quality investment costs are too high and turbines still are too expensive to generate revenue within their lifespan. In good wind regimes (e.g. at Wellington Airport) the turbine performs much better. However, capital investment still is high and turbines generate revenue much later, normally in the second half of their lifespan. It is therefore important to assess each site and evaluate each turbine individually. When site and turbine do not promise an adequate AEO, the capital will return more profit when invested with a bank or in funds.

8.4.4 Buy-back Arrangements

In many other countries, domestic distributed renewable generators have found an additional income from selling electricity to the grid at special rates. Legally established feed-in tariffs (FiT) guarantee long-term buy-back arrangements. At the time of writing FiT did not exist in New Zealand. It may be likely that future governments (potentially a Labour government rather than National) will introduce FiT to promote distributed generation from renewable energy sources on small and micro scale.

The best buy-back arrangement at the time of writing was Meridian Energy's one-to-one off-take offer. Most retailers still reserve the right to change and cancel the contracts at any time. No consistency in the retailers' contracts is kept as each retailer can invoke their own terms and conditions. Some retailers offer buy-back rates of only a few cents per kWh which is not considered as a genuine offer at all. This reveals a major barrier for potential investors as no guaranteed long-term contracts are legally established that would reduce the financial risk of an investment of often several tens of thousands of dollars.

8.4.5 Electricity Price Development

The national electricity price development indicates that the real electricity price increased annually by 3.2 percent, while the inflation rate increased less than the electricity price. It is likely that with an increase of future energy demands and investments in utility and energy generation infrastructure this development will continue in the decades to come.

For small and micro scale wind energy generation this means that they will become more competitive. The cost of energy from a domestic wind turbine in areas with average wind quality on the other hand is still too high to be competitive with conventionally generated electricity. Without governmental subsidies, investment programmes, potential FiT and other measures to promote renewable distributed generation it is unlikely that small and micro scale wind energy generation will become a viable alternative to bulk electricity. For larger wind turbines and regions with good wind resources, the cost of energy already is competitively viable to bulk electricity.

8.5 Discussion Summary

8.5.1 Technical Planning Summary

New Zealand's market is limited. Only small number of manufacturers and installation companies offer SMWT and prices are too high to be a widely competitive alternative to conventional electricity generation. More investment is necessary to establish renewable energies among other forms of distributed generation.

There clearly is a lack of qualitative information and support from governmental agencies. No supportive measures, independent testing and information forums exist so far.

Manufacturer and installer data often is biased, whitewashed and misleading. The industry needs to create more trust, offer more assistance and make their prices more transparent.

One of the big questions is whether a standalone or grid-connected application is more beneficial. As cases differ from each other, there is no generalised answer to this question and each project has to be assessed individually.

The economies of scale should always be borne in mind. Larger turbines are more efficient than smaller ones. Promoting community scale projects can bear more benefits than single small wind turbines. However, each case has to be assessed separately.

8.5.2 Resource Management Planning and Government Duties Summary

The resource management planning process was described to be one of the main barriers. Once having dealt with resource consent applications, most projects seemed to have had no major problems with statutory planning procedures and resource consents, if needed at all. However, resource consents might still be perceived as a major barrier as they may increase planning costs and time intensity, especially for low capital investment for a turbine that still needs a resource consent. Potential project developers may be put off by this.

Adequate resource management planning is essential to avoid problems deriving from resource consent issues. Hereby, consultation with neighbours and/or other potentially affected groups will decrease possible dispute that lead to local opposition.

The NPSREG 2011 will, within the next two years, change statutory plans and policy statements. It legally binds consent authorities to deal with SMWT in a more enabling way.

However, a new piece of legislation dealing with renewable energy generation (like, for example, in Germany or the UK) would bring more benefits than the NPS that only gives guidance for the different consent authorities. It does take a new approach by simplify and unify the way of dealing with renewable energy generation but only tries to encourage consent authorities to implement rules that make the spatial planning process more enabling. In the end, the discretion of how to address and include the NPSREG objectives and policies into regional and district plans still lies with the consent authority.

8.5.3 Economic Viability Summary

For many people the most important factor of a domestic wind turbine is its economic performance. However, other factors may be non-monetary (e.g. eco-friendliness and sustainability, independence from the grid and retailers, etc.) but equally or more important. In general, desired benefits should be clarified beforehand.

A wind turbine that does not generate revenue within its lifespan simply is not economically viable for private investors, unless when the desired benefit is independence from distributers and retailers or setting a statement for eco-friendly and sustainable businesses.

From an economic point of view, wind energy generation systems should return profit within a certain period of time, desirable within the first two thirds of the turbine’s lifespan. Without this return, the capital investment would be more beneficial invested with a bank or in funds that offer a higher rate of return. Economic analysis can show whether a SMWT is economically viable or not.

The rate of return from SMWT is closely linked to initial investment (acquisition, installation and additional initial costs), the generated AEO and the buy-back rate that is offered by retailers. The lower the initial investment and the higher the revenue (high AEO and high buy-back rate) the better is the economic performance which lowers the amortisation period. This can often only be achieved with feed-in tariffs, especially when the technical performance leaves much to be desired. Hereby, additional costs of often 25 to over 80 percent should always be borne in mind.

Increasing electricity prices as well as new and cheaper technologies will decrease the gap between cost of energy from renewable distributed generation systems and conventional bulk electricity generation. This will make SMWT more financially viable on the New Zealand market.

8.6 Areas for Further Research

Areas for further research can include:

- Monitoring how regional and territorial authorities implement the NPSREG 2011 into their plans and how this affects planning process for renewable distributed energy generation in New Zealand. The outcomes can be compared to measures in other countries such as Germany, Denmark, UK, USA and Australia who have passed overarching renewable energy legislation.
- Conducting wind monitoring and wind data analysis on different case study sites and determining differences to the nearest available NIWA weather station data. With appropriate on-site wind date, the economic viability of different turbines can be determined and NIWA weather station data can be compared to own measurements.
- Lincoln University students have an opportunity to reactivate and upgrade the Lincoln University weather station to carry out wind monitoring for the purpose of further research and potential SMWT on campus. This will give Lincoln University a greener and cleaner image by showing their commitment to sustainability and eco-friendliness.
- Establishing a forum for distributed renewable energy generators where experiences, technical, spatial planning and economic aspects and knowledge can be exchanged and discussed between SMWT owners.

Chapter 9
Conclusion and Outlook

9.1 Conclusion

The aim of this dissertation was to assess the feasibility of small and micro wind turbines (SMWT) for residential use in New Zealand and to analyse effectiveness, consistency and straightforwardness of involved processes. Putting up a wind turbine might seem like a fairly simple task but it is anything but straightforward and easy to plan an efficient wind energy generation system, even on a small or micro scale.

The literature review and case study findings indicate:

- For every project, the first question should answer what the desired benefits of a wind energy generation system are. Benefits can be economic, environmental, social or a mix of these. SMWT are only valuable when some benefit can be achieved. When a turbine doesn't pay for itself and also fails to achieve to be more eco-friendly (due to a lack of performance), other generation forms are more suitable.
- Small and micro scale wind energy generation requires a good quality wind resource; only uninterrupted wind flow, no turbulences and wind speeds of 6 m/s and more achieve good results. Further, a turbine's height should be at least 10 metres above ground, but ideally 15 or 20 metres above ground are recommended. On sites with inadequate wind resources, hybrid systems or other means of renewable energy generation (e.g. micro hydro, solar or biomass) are likely to be more suitable.
- Good wind quality and quantity is mainly available in rural and semi-rural settings. Urban application is predestined to be (much) less efficient by many researchers; however, many still whitewash the physical and aerodynamic aspects of urban wind regimes.
- Economies of scale effects apply for wind energy generation and in many cases it is more favourable and efficient to promote community scale projects instead of SMWT. However, for remote off-grid premises distributed renewable energy generation does makes sense and hybrid systems (i.e. a combination with micro-hydro, solar and other means of renewable energy generation) are an excellent alternative to conventional diesel generators.
- Consent authorities deal with wind turbines in a different way; the Selwyn DC providing a by far more enabling book of rules than the Western Bay of Plenty DC. This trend is usual for the neo-liberal planning framework in New Zealand.
- A lack of sufficient information about distributed and small scale renewable energy generation in New Zealand is a problem that has constantly emerged during this study. Incorrect calculations, whitewashed information and the non-existence of a New Zealand wide information exchange platform for distributed generators show a lack of commitment (or competence) from government authorities.
- The lack of integrated, comprehensive and overarching renewable energy legislation and the nonexistence guaranteed electricity buy-back rates (feed-in tariffs), state funding, special loan schemes and other economic incentives deters potential investors and prevents market growth. They have proven to be an effective instrument in many other countries. In New Zealand, electricity buy-back is still widely managed with short-term contracts (often on a monthly basis) and retailers can impose their own contractual conditions. As long as no guaranteed buy-back or monetary benefit is contractually and legally established, the investment risk remains too high for private investors. At the same time, FiT has to be higher than bulk electricity costs.
- White- or rather green-washing seems to be a general practice among turbine manufacturers and installation companies. Installation companies often seem to hold back information about additional costs for freight, electrical wiring, foundation works and consenting fees. That these costs often are not transparent to investors and may account for over 80 percent of the turbine's purchase costs is often kept a secret. This and providing insufficient information as well as inadequate and poor data is misleading for most laymen. Additional or hidden costs

decrease a turbine's economic viability. With 25 to 80 (or more) percent higher capital investment, much longer amortisation periods are to be expected. When these costs are not transparent, private investors will be deterred and their disappointment will play a part in contributing to a rather bad public image.

9.2 Outlook

Wind energy generation has great potential in New Zealand. However, especially on a small and micro scale, much has to be done to promote a more decentralised and distributed energy supply. Decreasing the dependency on bulk generated electricity and on national and local grids seems to be desired by an increasing number of New Zealanders. Governmental actions as well as industry behaviour have to change, market barriers have to be removed and the economic viability of distributed renewable energy generation has to be enhanced. Critical success factors are:

- Examples from other countries have shown that comprehensive, straightforward and integrated renewable energy legislation effectively promotes many forms of renewable distributed energy generation, be it solar, micro hydro, biomass or wind.
- Manufacturers, installation companies, governmental authorities as well as central and local government have to provide higher qualitative information without whitewashing facts.
- Transparent planning and consenting costs, harmonised handling of resource management planning procedures and enabling plan provisions are essential to remove the strongest perceived barrier to small and micro scale wind energy generation. Obtaining a resource consent may account for a cost increase of several thousand dollars. The additional bureaucracy and costs many investors have to grapple with are inappropriate and counterproductive. While even the installation a micro turbine remains a discretionary activity in many council plans, it is questionable how much local and central governments really show their commitment to renewable energies and a sustainable energy supply for New Zealand.
- Policy makers have to take into account that urban wind energy projects are less effective, but simultaneously should not block them out completely. Where urban wind is sufficiently practical, planning and implementation process conditions should be as "simple" as for rural or semi-rural areas.
- Especially for off-grid application in remote areas, central and local governments have to encourage renewable energies.
- Central government claims that FiT are not necessary in a country with a 75 percent renewable share of energy generation. While only 38 percent of the country's total primary energy supply derived from renewable resources, there is still a significant potential to do better. It is well accepted that fossil fuel prices are increasing in the decades to come. More strategic foresight, even on a small scale, will be more proactive than standing still and maintaining the status quo. It is clearly a lack of commitment that the government shows with their current attitude towards distributed renewable energy generation.
- Even though domestic size wind turbines are unlikely to play a significant role in achieving climate policy targets, the government still needs to make a clear statement in favour of small scale renewable energy generation. For them it should be a matter of showing their commitment and leading the way to a sustainable and more eco-friendly energy supply rather than economic viability. Strategic planning is important and public acceptance of more widespread and decentralised renewable energy generation has to be increased. This may take decades but it is essential to start as soon as possible to gain technological advantage (e.g. use of new material and experience with extreme winds) for the future electricity supply of New Zealand's residential, commercial and public sectors.
- Small scale renewable energy generation has the potential to bring New Zealand forward in technology research, development and innovation. Other countries have led the way, now New Zealand has to follow. From a strategic point of view, promoting small scale renewable energy generation and boosting the renewable energy industry will not only result in more investments in this sector but also return more revenue from business taxes. It is capable of forming an advanced multi-million dollar industry, creating thousands of new jobs, increasing technology export and consolidating New Zealand as a sustainable and energy efficient business location.

9.3 Recommendations

9.3.1 Recommendations for Investors

- Increasing on-site energy efficiency should always be the first step.
- Consulting independent experts (planners, technical advisors, accountants, etc.) is advisable when the required expertise is not existent.
- It is important to carry out wind monitoring and "do the math" instead of blindly trusting installation companies and manufacturer data.
- Owners of small wind turbines should create and participate in information platforms, where experiences on planning, technical and economic aspects can be exchanged with other owners and prospective investors. An association of small wind turbine owners would increase the pressure on central and local governments as well as policy makers.
- Combining wind turbines with other means of renewable energy generation (e.g. micro hydro, solar hot water, solar PV, etc.) increases system efficiency, reduces the use of fossil fuels and prevents power outages.
- Economies of scale should always be considered. Building a bigger turbine with a few neighbours or as a community may be much more beneficial (in different aspects) than one or more small turbine.

9.3.2 Recommendations for Governments and Policy Developers

- The spatial planning process urgently needs to be made more transparent and consistent. The NPSREG 2011 is a step in the right direction but not enough.
- In many other countries, overarching legislation and streamlining the involved processes has proven to be an effective measure to promote renewable energy generation on all scales. Central government has to strive for similar measures, passing an act that is modelled on best practice examples from overseas and adjusted to New Zealand's legal, social, environmental and economic requirements.
- Guaranteed Feed-in Tariffs (FiT) have proven to be an effective economic market instrument in many other countries. These incentives demonstrate government commitment and make renewable electricity generation on a small and micro scale more financially viable. Financial assistance (like the EECA scheme for solar water heating) and special load schemes are necessary to decrease the financial risk for potential investors.
- Without FiT, state owned electricity retailers in particular have to show more commitment and offer better conditions for buy-back agreements (e.g. long-term contracts and higher buy-back rates).
- Local governments, when addressing the new NPSREG 2011 in their future plan provisions, have to start harmonising their plan provisions to achieve more consistent planning processes. This has to happen, even without central government putting forward renewable energy legislation.
- Platforms (i.e. internet forums and information hubs led by EECA) for information exchange as well as accurate online tools to determine technical, planning and economical aspects have to be provided free of charge.
- Creating incentives in forms of special loan schemes, subsidies, and guaranteed long-term buy-back rates is required to take away the financial risks for potential investors. This should only apply for projects that are likely to be feasible. Therefore a nationwide database is necessary that lists in detail areas with good wind resources as well as other renewable energy resources such as solar or geothermal potentials.
- Many researchers advocate that "urban wind" projects are unlikely to be as efficient as wind turbines in rural or semi-rural settings. Therefore, government should, above all, support and promote SMWT in rural and semi-urban areas with good wind resources. However, when an urban SMW energy project has the potential to be viable and efficient, then urban application should not be left out.

9.3.3 Recommendations for the Industry

- Whitewashing of turbine performances is counterproductive for the industry. It will not create the necessary trust in technology and potential of small turbines.
- Turbine efficiencies and potential AEO should be additionally measured and stated for lower wind speeds. This needs to be conveyed in a way that laymen can understand the potential performance of a turbine on a site similar to theirs.
- Additional costs should be stated and more transparent. Full packages should be offered with transparent prices.
- It seems that many New Zealanders are interested in small and micro wind turbines for residential use. However, the sector is still fairly small compared to the large scale wind farms that spring up all around New Zealand. Therefore, the industry has to promote and advertise their technology on a broader scale.

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- National Policy Statement for Renewable Electricity Generation 2011
- Resource Management Act 1991
- Selwyn District Plan
- Western Bay of Plenty District Plan

Appendix A
Electricity Distributors and Retailers in New Zealand

A.1 Local Network Operators (Distributors) and Retailer Supply Areas

Figure 22
Local grid operators (distributors) in New Zealand (as of July 2011) (EECA, 2010a)

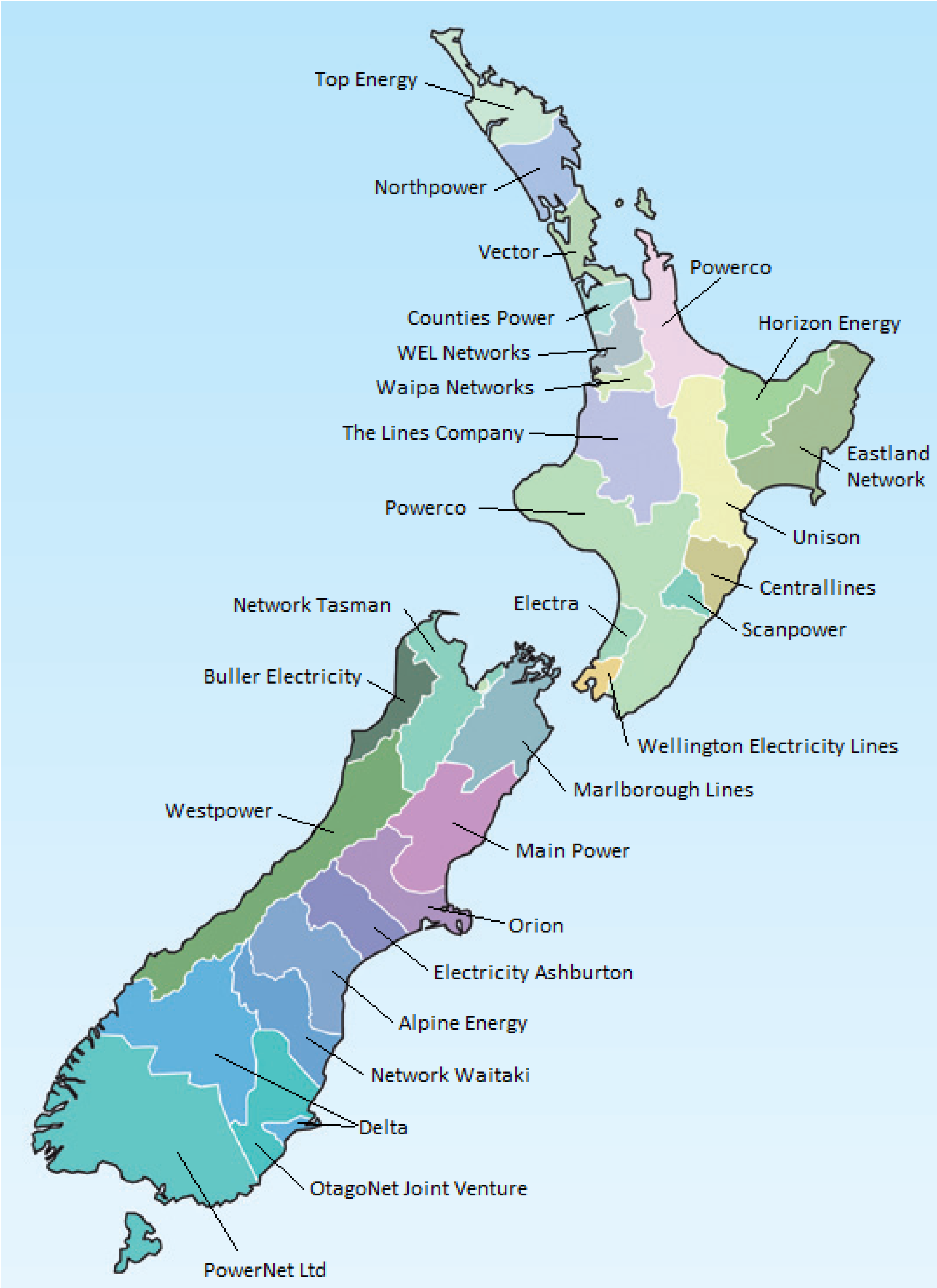


Table 20
Electricity retailers in New Zealand, their supply areas and electricity buy rates as of July 2011 (E-mail comm. with electricity retailers, 3 to 31 May 2011)

Electricity Retailer	**Electricity supply area (as indicated on the respective retailer websites)**	**Offers buy-back rates**	**Buy-back rates**
Bay of Plenty Electricity	Eastern Bay of Plenty	Case by case	Case by case
Bosco Connect	Auckland City	n.a.	n.a.
Contact Energy	Nationwide	Yes	17.285 ct/kWh + GST
Empower	Northland, Auckland, North Shore, Thames Valley, Hamilton/Waikato, Taupo, Rotorua, Tauranga, Manawatu, Wairarapa, Wanganui, Wellington, Christchurch	No	n.a.
Energy Direct NZ	Wanganui, Marton, Bulls, Manawatu, Taranaki	No	n.a.
Energy Online	North Island (excl. Far North, Whangarei, Kaipara, Gisborne, Wairoa)	No	n.a.
Genesis Energy	Nationwide; feed-in only in some regions (see email)	Yes Restricted to the following local networks: United Networks Waitemata & Wellington, Powerco Valley & Western Region Zone A&B, WEL Networks	Dependent on area & tariff[8]: Anytime 5.25-5.95 ct/kWh + GST N/D D 5.66-6.44 ct/kWh + GST N/D N 3.91-4.39 ct/kWh + GST S SD 5.68-5.87 ct/kWh + GST S SN 6.35-7.22 ct/kWh + GST S WD 3.53-3.96 ct/kWh + GST S WN 4.44-4.91 ct/kWh + GST
Just Energy	Many cities across NZ; No rural areas	n.a.	n.a.
King Country Energy	Waitomo, King Country, Ruapehu	n.a.	n.a.
Mercury Energy	Primarily North Island (excl. Hawkes Bay and Gisborne Region, Waitomo, parts of Taupo); South Island (excl. Buller, Tasman, Marlborough, Southland, Queenstown Lakes, Gore)	Case by case	Case by case
Meridian Energy	Nationwide	Yes	1:1 (excl. GST)

8 Tariffs: Anytime; Day/Night Day (D/N D), Dan/Night Night (D/N N); Seasonal Summer Day (S SD), Seasonal Summer Night (S SN), Seasonal Winter Day (S WD), Seasonal Winter Night (S WN)

Nova Energy	Auckland, Waikato, Bay of Plenty, Taranaki, Manawatu/Horowhenua, Wellington	n.a.	n.a.
Opunake Hydro	General Taranaki region	No	n.a.
Powershop	Auckland, Franklin, Waikato, New Plymouth, Wanganui, Palmerston North, Horowhenua, Kapiti, Wairarapa towns, Wellington, Christchurch, Queenstown Lakes, Dunedin	n.a.	n.a.
Pulse Energy	Urban Areas in: Auckland Central, North and West, Manukau, Counties, Waikato, Thames Valley, Waipa, Hawkes Bay, Taranaki, Hawera/Rangitikei, Wanganui, Manawatu, Wairarapa/Tararua, Kapiti/Horowhenua, Buller, Tasman, Nelson, Marlborough, Westland, Queenstown Lakes, Central Otago; No rural areas	Not for small generators < 100kW	n.a.
Simply Energy	Nationwide; Commercial and industrial customers only (demand > NZ$ 25k)	No	n.a.
Tiny Mighty Power	Thames Valley (Matamata, Morrinsville, Paeroa, Te Aroha), Waipa (Cambridge, Te Awamutu), Wairarapa (Masterton, Carterton, Greytown, Featherston), Marlborough (Blenheim, Picton, Renwick), Waimakariri (Rangiora, Kaiapoi, Oxford)	n.a.	n.a.
TrustPower	Nationwide	Yes	6.5 ct/kWh + GST

Appendix B
Wind Data Acquisition

B.1 Selwyn Case Study Weather Station

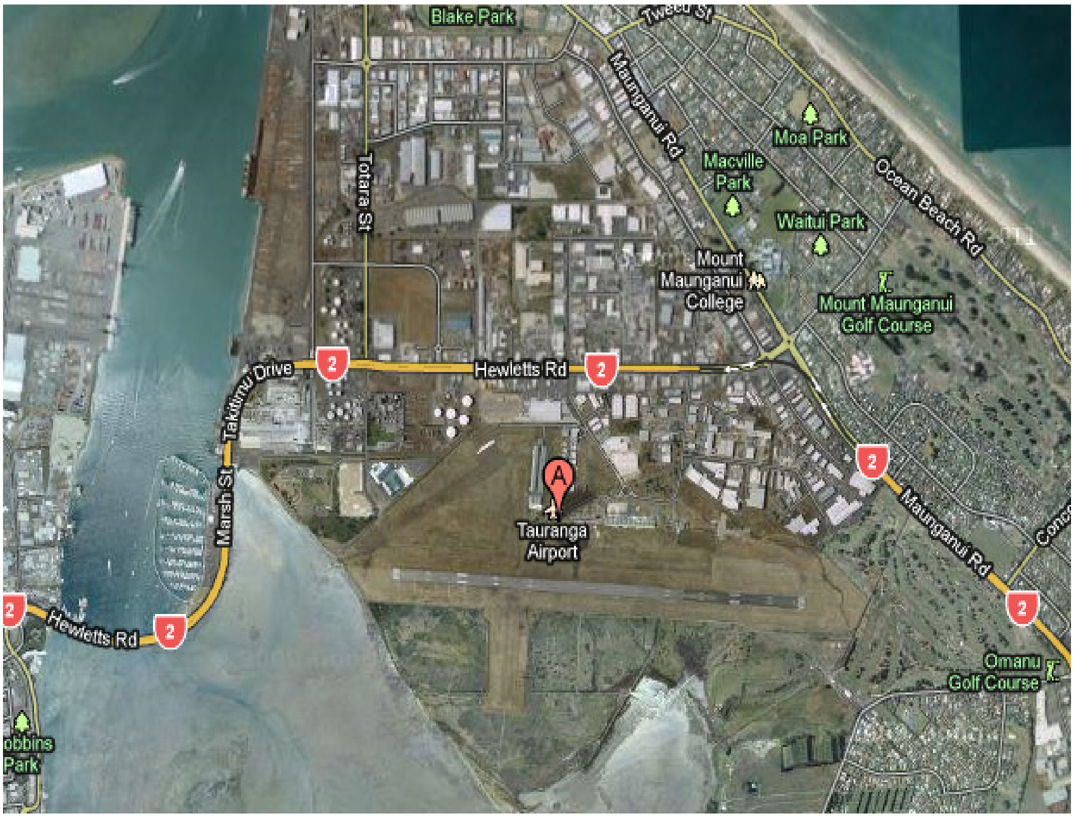
- Broadfield Weather Station operated by Niwa/Plant & Food Research;
- Location: 175 Boundary Road, Lincoln, Canterbury (Latitude -43.62622, Longitude 172.4704);
- Distance to case study site: 10.0 km linear distance;
- Data used from the years 2008, 2009 and 2010;
- Measure period: 1 hour;
- Data completeness: 99.98%;
- Height above mean sea level: 18 metres.

Figure 23
Location of Broadfield Weather Station
(Google Maps, 2011)

B.2 Western Bay of Plenty Weather Station

- Tauranga Aero Automatic Weather Station operated by MetService;
- Distance to case study site: 16.7 km linear distance
- Location: Tauranga Airport (Latitude -37.673 Longitude 176.196);
- Data used from the years 2008, 2009 and 2010
- Measure period: 1 hour (2010), 10 minutes (2008 and 2009);
- Data completeness: 99.8%
- Height above mean sea level: 4 metres

Figure 24
Location of Tauranga Aero Automatic Weather Station (Google Maps, 2011)



Appendix C
Turbine Power and Energy Output Calculation Example

Table 21
Power and energy output calculation example for a Skystream 3.7 on the Selwyn case study site

Energy Output for:	Skystream 3.7 (2.4 kW)				
Location:	Selwyn Case Study				
Wind Data:	Broadfield Weather Station				
Wind Speed in m/s	**Swept Area in m^3**	**Capacity Factor**	**Power Output in W**	**Av. Hours per year**	**Energy Output in kWh**
0.00	10.87	0.00	0	11	0.00
1.00	10.87	0.00	0	606	0.00
2.00	10.87	0.00	0	1385	0.00
3.00	10.87	0.02	3	1399	4.29
4.00	10.87	0.20	84	1384	116.06
5.00	10.87	0.24	203	1181	239.74
6.00	10.87	0.27	391	980	383.49
7.00	10.87	0.28	642	738	474.03
8.00	10.87	0.28	969	492	476.57
9.00	10.87	0.27	1,335	306	409.05
10.00	10.87	0.26	1,745	155	270.44
11.00	10.87	0.24	2,100	84	175.69
12.00	10.87	0.20	2,299	30	69.73
13.00	10.87	0.16	2,409	9	20.88
14.00	10.87	0.13	2,421	3	6.46
15.00	10.87	0.11	2,414	3	6.44
16.00	10.87	0.09	2,382	2	3.97
17.00	10.87	0.07	2,299	0	0.00
18.00	10.87	0.06	2,261	0	0.00
19.00	10.87	0.05	2,201	0	0.00
20.00	10.87	0.04	2,139	0	0.00
			Annual Energy Output		**2,657 kWh**
			Mean Turbine Efficiency (CF)		**12.64%**

Appendix D
Spatial Planning Details

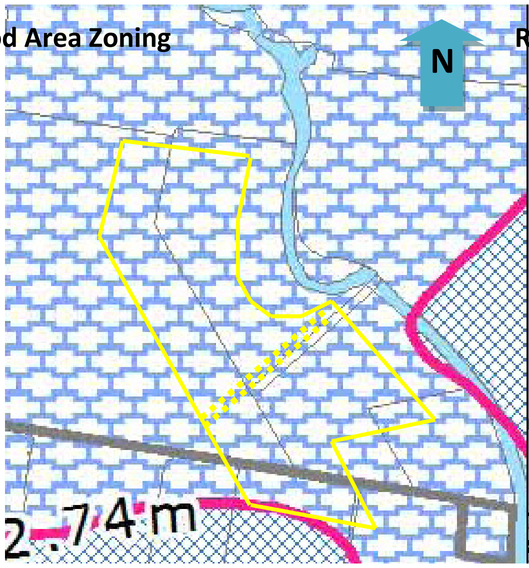
D.1 Selwyn District

D.1.1 Planning Maps and Aerial Property Images

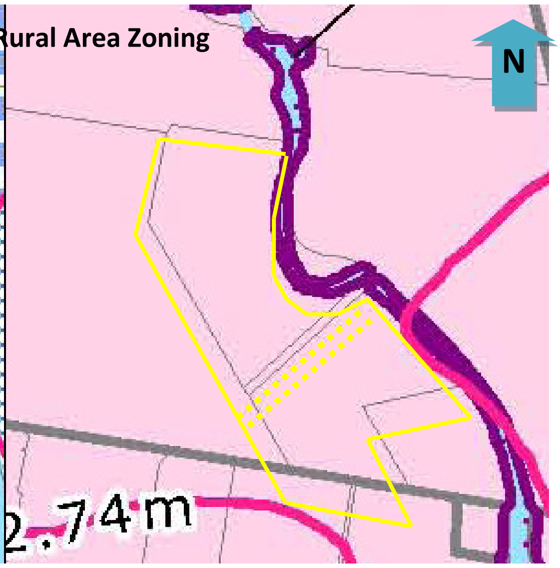
Figure 25
Aerial image of case study site (yellow) in the Selwyn District with desired wind turbine location (red) and dwelling (orange)
(Google Maps, 2011)

Figure 26
Rural planning maps of case study site in the Selwyn District (SDC, 2011a

Flood Area Zoning



Rural Area Zoning



D.1.2 Selwyn District Plan Rules

Table 22
Relevant district plan rules for Utilities/Utility Structures in the Selwyn District

Rural Rules	Rule Description
Rule 1.3.1.1	**Building platforms** The forming of building platforms is a permitted activity as long as the platform does not alter or impede existing land drainage patterns
Rule 1.3.1.2	**Any other earthworks** which do not raise the mean average level of the land subject to the earthworks
Rule 1.6.1.1	**Earthworks** setback from the edge of the Selwyn River Minimum setback distances: 20 metres Note: When setback less than 20 metres then classified as discretionary activity under Rule 1.6.6; Setback for rivers can be reduced to 5 metres but only in accordance with Rule 1.6.1.1(b)
Rule 1.6.1.2	**Earthworks volume** Maximum permitted volume per project: $5000m^3$ See permitted volume for reduced setback for rivers under Rule 1.6.1.1(b)
Rule 5.1.2.4	**Utility provisions** Electricity generation for on-site use is a permitted activity **Note:** Grid-connected electricity generation classified as restricted discretionary
Rule 5.3.1.1	**Height of utility structures** Maximum permitted height: 25 metres Note: Utility structures higher than 25 metres are classified as restricted discretionary activity under Rule 5.3.2 Height is measured from the ground surface to the top of the highest point of the utility structure and includes any attachments
Rule 5.3.1.2	**Pole or mast diameter** Maximum permitted diameter: 0.5 meters at a height of 6 metres and above Note: When diameter exceeds 0.5 metres then Rule 5.3.1.3 applies in combination with recession plans in Appendix 16. When pole or mast diameter exceeding 0.5 metres or not complying with Rule 5.3.1.2 in combination with recession planes in Appendix 16 then classified as discretionary activity under Rule 5.3.4
Rule 5.8.1	**Utility structures in flood areas** Any utility structure is permitted unless it diverts or displaces any floodwater, or obstructs or alters the existing drainage pattern of the land
Rule 5.13.2.3	**Setback from the edge of the Selwyn River** Utility structures minimum setback distances: 10 metres
Rule 9.16.1	**Permitted noise limits in Rural Zone** Noise limits assessed at the notional boundary of any dwelling, rest home, hospital, or classroom in any educational facility. When noise limits are exceeded then classified as discretionary activity under Rule 9.16.2 **Noise Limits:** 7.30am to 8.00pm L_{10} 60dBA L_{max} 85dBA 8.01pm to7.29am L_{10} 45dBA L_{max} 70dBA
Rule 9.17.1.2	**Vibration** Vibration caused by any activity has to comply with NZS 2631:1985-89.1-3. Otherwise the activity is classified as discretionary under Rule 9.17.2

Rule 9.21.1	**Indigenous vegetation** (if applicable) The clearance of indigenous vegetation must not include Threatened and Uncommon Plants (Rules 9.21.1.1) and Significant Plants on the Canterbury Plains (Rule 9.21.1.2), otherwise classified as a non-complying activity under Rule 9.21.4 Clearing of indigenous vegetation will most likely comply with Rules 9.21.1.3 to 9.21.1.6

D.1.3 Selwyn District Council Consenting Costs

Table 23
2011-2012 resource consent fees (incl. GST) in the Selwyn District (SDC, 2011b)

Land use consent description	Fee (incl. GST)
Limited notified RC (fix fee)	$ 2,000
Non-notified RC (fix fee)	$ 1,000
Certificate of compliance (fix fee)	$ 560
Change, Review or Cancellation of Consent Conditions	$ 560; $ 2,000 (for notified RC)
Monitoring (when additional monitoring is required):	
• Basic (desktop)	$ 50 + $145/hour
• Standard (1 inspection)	$ 100 + $145/hour
• Specialised (>1 inspection)	$ 205 + $145/hour
Hearing:	
• 2 Councillors	$ 180.00/hour per panel
• 3 Councillors	$ 260.00/hour per panel
• 2 Councillors and (when External Commissioner is appointed) External Commissioner acting as Chairperson	$ 160.00/hour per panel plus up to $ 180.00/hour for Comm.
• External Commissioner appointed by Council	Max $ 180.00/hour
• External Commissioner at the applicant's request.	At cost
Officer's Time:	
• Planning Manager / Team Leader	$ 155/hour
• Other Planners	$ 145/ hour
• Administration Staff	$ 75/hour
• Engineering - Road, Water & Waste Water, Waste, Reserves, etc.)	$ 90/hour
• Consultants	At cost
• Legal Advice	At cost

Table 24
2011-2012 building consent fees (incl. GST) in the Selwyn District (SDC, 2011b)

Building consent description	Fee (incl. GST)
• General fee for building works with value:	
Less $ 5K	$ 550
$ 5k to $ 15k	$ 680
More $ 15k	$ 1,000
• PIM	$ 200
• Building Administration Staff	$ 60 per hour
• Planner	$ 145 per hour
• Building Officials	$ 138 per hour
• Travelling Time	$ 138 per hour
• Mileage	$ 0.71 per km
• Re-inspection	At cost
• Code Compliance Certificate Fee	Time & cost
• Consultants, Peer Review, Fire Reports, Acoustic Reports, Certificate of Title Order	At cost
• Compliance Schedules / Statement of Fitness issue (including amendments and administration and on-site auditing)	At cost
• Research to provide information relating to building records e.g. Photocopying, postage etc.	Time & cost
• All chargeable work under the Building Act for carrying out Council's responsibility is charged at actual cost	Time & cost

D.2

D.3 Western Bay of Plenty District

D.3.1 Planning Maps and Aerial Property Images

Figure 27
Planning map and areal image of case study site (yellow) in the Western Bay of Plenty District with desired wind turbine location (red) and existing dwelling (orange)
(WBoP DC, 2011b)

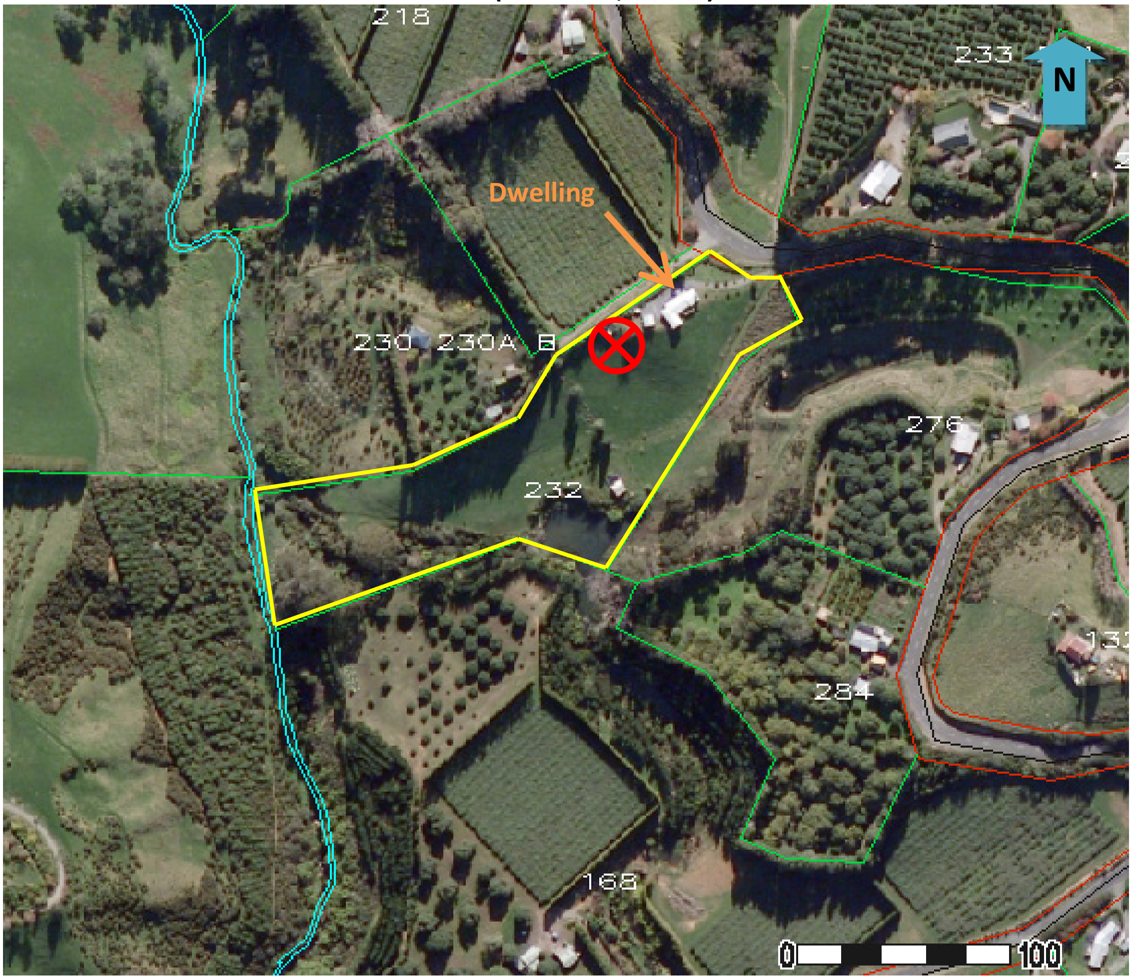
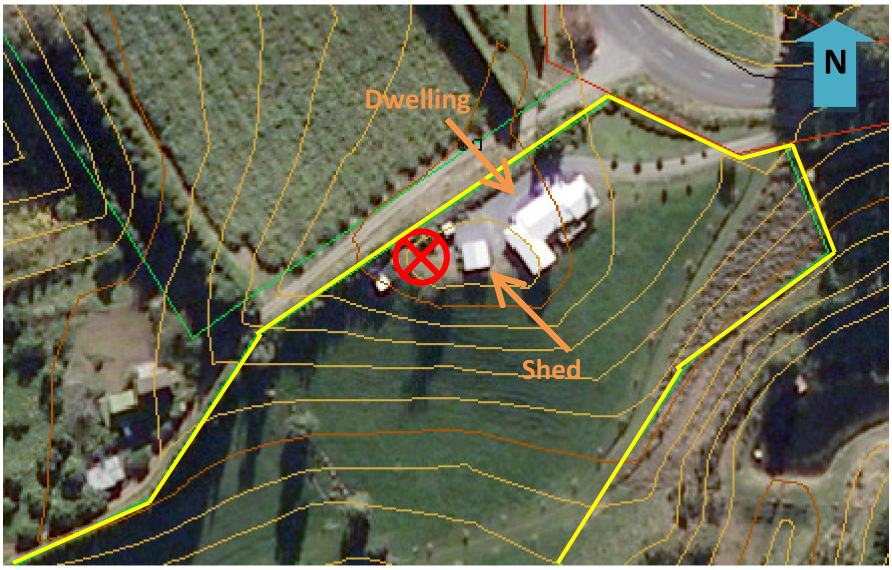


Figure 28
Close-up planning map and areal image with highest point
(WBoP DC, 2011b)



D.3.2 Western Bay of Plenty District Plan Rules

Table 25
Relevant district plan rules (Zone G) for buildings and wind turbines in the WBoP District

Rural Rules	Performance Standard / Rule Description
Rule 2.3.5(a)	**Height of Buildings in Rural Zone** Maximum permitted height: 9 metres
Rule 2.3.5(c)(iii)	**Yards in Rural Zone** Distance from property boundary: Minimum 5 metres Adjoining to State Highways: 10 metres Provided that: a building may be located within and up to a side or rear boundary where the written approval of the owner of the immediately adjoining property to a specified lesser distance is obtained.
Rule 9.3.3.	**Earthworks** Earthworks classified as Discretionary Activity
Rule 9.3.5(iv)	**Criteria for Earthworks** as a Discretionary Activity All earthworks necessary for building platforms, access or the activity shall be such that they create minimal disturbance to natural habitats and ecosystems.
Rule 13.2.3.2(ii)	**Noise Limits in Rural Zone** All activities located within these zones shall be so conducted as to ensure that noise from the site shall not exceed the following noise limits within the stated timeframes at any point within the notional boundary of any dwelling in a Rural zone. **Note:** The notional boundary is defined in NZS 6801:1999 Measurement of Sound as a line, 20 metres from any side of a dwelling, or the legal boundary where this is closer to the dwelling. **Noise limits:** Monday to Saturday 6am to 10pm L_{10} 50dBA L_{max} N/A Sunday 9am to 6pm L_{10} 50dBA L_{max} N/A At all other times and on public holidays L_{10} 40dBA L_{max} 65dBA
Rule 13.2.4(b)	**Vibration** No specific rules to manage vibration; Where significant vibration effects are experienced, Council may deal with the matter as a nuisance under the Health Act.
Rule 17.3.3.1(a)	**Spatial Separation and Privacy** (i) Landscape planting shall be developed and maintained around the perimeter of windmills and/or wind power generators. Landscape planting shall be provided in accordance with Section 13.6.3(b). (ii) All yards minimum 3m
Rule 17.3.3.3	**Criteria for Discretionary Activities** Effects that are considered in the discretion: (a) Visual Effect (b) Noise Effect (e) Social and Heritage Effects (f) Wind Effects (g) Risk Management
Rule 17.3.3.5	**Tauranga Airport Approach Path Protection** Note: Highly unlikely that a SMWT would exceed height restrictions

D.3.3 Western Bay of Plenty District Council Consenting Costs

Table 26
2011-2010 Resource consent fees (incl. GST) in the WBoP District (WBoP, 2011c)

Land use consent description	Minimum fee (incl. GST)
• Public notified RC	$ 2,050
• Limited notified RC	$ 1,550
• Non-notified RC	$ 1,280
• RC that proceed to hearing	Actual & reasonable cost
• Change or cancellation of consent conditions	$ 820
• Lapsing of consent/extension of time	$ 550
• Non-compliance with performance standards/rules	$ 770.00/hour
• Consents Manager	$ 145/hour
• Senior Planner	$ 135/hour
• Senior Development Engineer	$ 135/hour
• Planner	$ 120/hour
• Regulatory Services Team Leader	$ 85/hour
• Consents Officers and Technicians	$ 75/hour
• Compliance Team Leader	$ 85/hour
• Engineering Managers	$ 145/hour
• Group Manager	$ 185/hour
• Vehicles	$ 0.75/km
• Legal Property Officer, Property Officer	$ 66/hour

Table 27
2011-2012 Building consent fees (incl. GST) in the WBoP District (WBoP, 2011c)

Project Value	Application	PIM	BCAAA levy	Plan checking deposit	Council lodgement fee	Inspections
$ 1 to $ 10k	$ 140	$ 97	$ 26	$ 110	$ 373	$ 158.00
$ 10k to $ 20k	$ 240	$ 194	$ 26	$ 220	$ 680	$ 158.00
$ 20k to $ 100k	$ 348	$ 337	$ 26	$ 348	$ 1,059	$ 158.00

Appendix E
Economic Analyses

E.1 Simple Economic Analysis Example

Table 28
Simple economic analysis for a Skystream 3.7 turbine on the three assessed sites

Assumptions: Turbine Lifespan: 20 years Turbine costs: $ 20,000 (incl. mast; excl. additional costs) Maintenance: 0.02 $/kWh Buy-back rate: 21.5 ct/kWh (excl. GST)			
Site	**Selwyn**	**WBoP**	**Wellington**
Acquisition costs	$ 20,000	$ 20,000	$ 20,000
Maintenance costs (at 0.0215 $/kWh)	$ 1,063	$ 926	$ 3,279
Total system costs	$ 21,063	$ 20,926	$ 23,279
AEO (kWh/year)	2,657 kWh/year	2,314 kWh/year	8,198 kWh/year
Expected generation over turbine lifespan (20 years) (kWh)	53,140 kWh	46,280 kWh	163,960 kWh
Approximate annual profit ($/year)	$ 571	$ 498	$ 1,763
Approximate total profit in 20 years	$ 11,425	$ 9,950	$ 35,251
Payback period (years)	36.9 years	42.1 years	13.2 years
COE ($/kWh)	$ 0.40	$ 0.45	$ 0.14
ROI	-0.46	-0.52	0.51

E.2 Cash Flow Example

Table 29
Cash flow example for a Skystream 3.7 on the Selwyn case study site

Cash flow for	**Skystream 3.7**	
Location	**Selwyn Case Study**	
Wind Data	**Broadfield Weather Station**	
Assumptions:		
Installation costs	20,000	NZ $
AEO yield	2,657	kWh/year
Maintenance	0.02	NZ $/kWh
Buy-back rate	0.215	NZ $/kWh
Annual inflation rate (over last 10 years)	2.8%	(RBNZ, 2011)
Annual electricity price increase (Nominal)	6.2%	(MED, 2010b)
Annual electricity price increase (Real)	3.2%	(MED, 2010b)
Insurance	1%	of investment costs
Discount rate	8%	(NZ Treasury, 2011)

Year	Electr. Sale	Mainten.	Insurance	Net Cash Flow	Cumulative Net Cash Flow	Discounted Cumulative Cash Flow
Year 0	-	-	-	-20,000	-20,000	-
Year 1	571	-53	-200	318	-19,682	-18,246
Year 2	607	-55	-206	346	-19,335	-17,971
Year 3	644	-56	-211	377	-18,959	-17,694
Year 4	684	-58	-217	409	-18,549	-17,415
Year 5	727	-59	-223	444	-18,105	-17,136
Year 6	772	-61	-230	481	-17,624	-16,855
Year 7	820	-63	-236	521	-17,104	-16,573
Year 8	870	-64	-243	563	-16,540	-16,292
Year 9	924	-66	-249	609	-15,932	-16,010
Year 10	982	-68	-256	657	-15,275	-15,728
Year 11	1,042	-70	-264	709	-14,566	-15,447
Year 12	1,107	-72	-271	764	-13,802	-15,166
Year 13	1,176	-74	-279	823	-12,979	-14,885
Year 14	1,249	-76	-286	886	-12,092	-14,606
Year 15	1,326	-78	-294	953	-11,139	-14,328
Year 16	1,408	-80	-303	1,025	-10,114	-14,051
Year 17	1,496	-83	-311	1,102	-9,012	-13,775
Year 18	1,588	-85	-320	1,184	-7,828	-13,501
Year 19	1,687	-87	-329	1,271	-6,558	-13,228
Year 20	1,791	-90	-338	1,364	**-5,194**	**-12,957**
Year 21	1,902	-92	-347	1,463	-3,731	-12,688
Year 22	2,020	-95	-357	1,568	-2,163	-12,421
Year 23	2,146	-98	-367	1,681	-482	-12,156
Year 24	2,279	-100	-377	1,801	**1,319**	**-11,893**
Year 25	2,420	-103	-388	1,929	3,248	-11,632
Year 26	2,570	-106	-399	2,065	5,313	-11,373
Year 27	2,729	-109	-410	2,210	7,524	-11,117
Year 28	2,899	-112	-422	2,365	9,889	-10,863
Year 29	3,078	-115	-433	2,530	12,419	-10,612
Year 30	3,269	-118	-445	2,705	15,124	-10,363
Year 30	3,269	-118	-445	2,705	15,124	-10,363