BEFORE THE COMMISSIONER ON BEHALF OF THE DUNEDIN CITY COUNCIL

UNDER	the Resource Management Act 1991
IN THE MATTER	an application for resource consent of LUC-2015-469
BY	Blueskin Energy Limited
	Applicant

BRIEF OF EVIDENCE OF SCOTT MATTHEW WILLIS

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May it please the Commissioner:

1. My full name is Scott Matthew Willis. I am the Project Manager for Blueskin Energy Limited and Manager of the Blueskin Resilient Communities Trust. I was previously a Trustee for the Blueskin Resilient Communities Trust ("BRCT") between 2008 and 2010.

Blueskin Resilient Communities Trust

2. Blueskin Resilient Communities Trust ("BRCT") is a Dunedin based non-Governmental organisation and local charity with its office in Blueskin Bay. It was founded in 2008 to create local climate solutions, with the vision: to "facilitate a positive, healthy, secure and resilient future for Blueskin Bay and linked communities and promote sustainable resource use". Seven trustees form its board of governance. The operational team includes myself as manager and two other staff. Many volunteers help us, and experts provide significant pro bono support.

3. Trustees are volunteers from the different Blueskin settlements, representing diverse constituencies. BRCT seeks new Trustees who understand governance, can work as part of a governing team and who have a passion for community initiatives and/or sustainability initiatives.

4. Volunteers help with such things as maintaining the website, distributing flyers around the community, catering for events, creating artwork or assisting wind tower maintenance.

5. Experts provide legal assistance, market analyses, financial planning assistance, wind data analysis and more.

6. BRCT run, manage or catalyse projects that reflect the Trust's values and contribute to building more resilient communities. BRCT provides and stimulates community services, particularly where such services will address need and further BRCT's vision. For example, in 2009 we facilitated a large insulation retrofit programme that reached over 400 homes in just four months. We funded a coordinator position to set up the Waitati Open Orchards group, and funded a coordinator to work with our local schools to develop school gardens.

7. Each year we put on events or expos, conduct research and keep our community informed and involved in all our activities through emails, articles, social media and events. We have been heavily involved in the formation of the Cosy Homes Trust. BRCT currently provides a free energy advice service and a Home Performance Assessment service for the whole city, bulk firewood deliveries to residents, discounted insulation, and encouragement and assistance for local food enterprises, assistance to some biodiversity initiatives through provision of traps to local groups, in addition to our climate action. This year we are running the 'ClimateSafeHouse' project, a project to build a relocatable home for a local resident in fuel poverty.

8. Our research, analysis and submissions give voice to our community's concerns and encourage everyone to get involved in deciding our future.

9. BRCT was formed to strengthen communities in the immediate, mid and long term future. It has an emphasis on energy, food, water and community resilience.

10. BRCT is the sole shareholder of Blueskin Energy Limited.

Background to the Wind Farm

11. In September 2006 a community visioning workshop was held in Waitati, organised by myself and other community volunteers. The workshop was based on the Kinsale Energy Descent Model. The catalyst was a major flood event in April 2006 that had revealed our vulnerability to flooding, isolation and the risk of being cut off from key infrastructure. Residents assessed that the community often acted faster and more effectively than government. Energy was considered an important action area to increase community resilience. The development of a community wind turbine was proposed among many other initiatives. Since that time steps have been taken to realise that vision. A single wind turbine was originally perceived as a practical and realisable project that would enable the settlement of Waitati to generate its own electricity, but did not address the needs of the whole Blueskin area.

12. BRCT was founded in October 2008. It took charge of the suite of existing community energy actions, including facilitating a large insulation retrofit programme worth over $780 000 in partnership with the

Otago Regional Council and EECA. In 2009, BRCT assisted geography students from the University of Otago to collect wind data from 2 sites within the Blueskin area. The evaluation of 3 other sites was also undertaken.

13. In the later half of 2009, BRCT began a feasibility study researching the viability of a single, community owned and managed, grid integrated turbine. This was possible due to Memorandums of Understanding with the local lines network and a turbine supplier. The feasibility study (attached at **Appendix A**) was completed in 2010 and suggested that project viability would likely be assured with 3-5 turbines rather than a single turbine and revealed the strengths and weaknesses of the local network.

14. In 2011 a Memorandum of Understanding was established with Our Wind Ltd (OWL), a subsidiary of a turbine supplier. Community residents helped install a 10 metre wind measuring mast on Porteous Hill (in the Merton/Omimi area) to capture wind data.

15. Between 2011 and 2012 a formal community engagement project was undertaken, with funding support from EECA, the Otago Community Trust and the Waikouaiti Coast Community Board (see below) to seek community views on the development of a small wind cluster of up to four wind turbines. A development of this size would generate more than the existing annual electricity demand of the 1000 households in the Blueskin community.

16. Of those who attended Open Days in Warrington, Waitati and Long Beach as part of the engagement project, most expressed a preference for the proposed Porteous Hill site and only 5% said they didn't want to see turbines at any site in the Blueskin area. Some concerns also raised were:

(a) robustness of wind data and project feasibility;

(b) questions about ethical investment;

(c) questions about community benefit;

(d) concern over Mopanui as a potential site;

(e) concern about risk to birds and health; and

(f) concerns about visual impact.

17. After wind data had been expertly analysed a PledgeMe campaign was launched in late 2012 to raise money for an additional higher 30 metre wind measurement mast to install on Porteous Hill to give additional confidence in data. The PledgeMe funding goal was exceeded thanks to community donations and the mast was installed in February 2013.

18. With data collection underway, BRCT began exploring different development options, learning about the wind industry and the electricity market, securing pro bono assistance, investigating solutions to community concerns, and preparing the business model.

19. After a further three community meetings in 2013 BRCT began the process of establishing a charitable company to develop the project and Blueskin Energy Ltd was established for this purpose on the 16th of December 2013.

20. Land lease negotiations were held through 2014, and in July 2015 a lease was signed between the landowners and BEL providing access to Porteous Hill for the generation of wind power.

21. Throughout 2014-15 the business model was refined, market analyses completed and market negotiations and turbine supplier negotiations undertaken. In parallel, between 2013 and 2015 three expert reports were commissioned to assess Acoustic Impact, Ecological Impact and Landscape Impact, and a roading assessment was completed, while a number of stakeholders were consulted with and/or updated.

Community Engagement

22. Energy work in the community began properly in 2007 with a community energy expo organised by myself and other community volunteers. A second energy expo was organised in late 2008 and BRCT was formed to give structure and a home to the community energy work. At this stage, BRCT took on the suite of energy initiatives.

23. From December 2007 to the present day a monthly column on energy issues and particularly details about the wind farm development has

been published in the Blueskin News. A log of all columns from 2013 is included on the BRCT website[1] and earlier columns can be found on the Waitati Transition Town website[2].

24. From early 2011 a monthly column on the wind development and energy issues has been published in the Rothesay News.

25. The Blueskin Energy Project email list was created out of the first subscriptions to email energy news I began in 2007, but subscriptions grew significantly in 2009 when we began work on the wind project and when we began the insulation retrofit project. It now has 382 subscribers.

26. In 2007 the first independent research projects were undertaken by students and researchers at the University of Otago into attitudes towards small scale wind and other energy issues. Three independent studies (in 2008, 2011 and 2013, included in the full Resource Consent application) were directly related to the proposed wind farm development.

27. Public meetings have been a regular part of this project, particularly leading up to the formal community engagement project and have been documented in the community engagement toolkit report which was included in the Resource Consent application.

28. Between 2011-12 a formal community engagement process was undertaken. Dr Janet Stephenson, Director of the Centre for Sustainability was an external advisor, and the process was led by independent planner Ros Day, supported by planning consultant Andrew Henderson. It involved Open Days, a survey, a leaflet drop to all 1000 households in the Blueskin area, newspaper advertisements, launch of a new website to communicate the project, and advertisements on public noticeboards. This formally structured process, led by experts is thoroughly detailed in the community engagement report and gave BRCT great confidence to proceed with development plans. This work was made possible thanks to support from the Otago Community Trust,

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[1] See: http://www.brct.org.nz/our-projects/blueskin-wind-cluster/

[2] See: http://www.transitiontowns.org.nz/node/1115

the Hikurangi Foundation, the Waikouaiti Coast Community Board and the Department of Internal Affairs.

29. The community engagement project also revealed growing community interest in solar. In 2012 we kicked off our solar project as a result, to facilitate uptake of solar in the Blueskin community. By November 2015, 104.8kW of solar capacity had been installed in Blueskin – a far higher percentage here than in the rest of the OtagoNet network.

30. With a clear community preference for the Porteous Hill site from the community engagement project, further evaluation and preparation was undertaken, and expert opinion sought. In 2013 further community meetings were held to discuss the optimal business structure.

31. In summary, the idea of a single wind turbine for Waitati was put forward in a community visioning workshop in 2006. A feasibility report was completed in 2010. Community debate and discussion throughout 2010 - 2011 led to a proposal to build a small cluster of up to 4 Windflow turbines on Porteous Hill and this concept was presented in the formal engagement work in 2011-12. The community engagement work was followed up with expert assessments, business modelling and project design. Subsequent community meetings related to the design of the development company (and sought information on continued levels of support). Throughout this development period monthly emails on project development were sent out to the email list of 382 people, monthly articles were published in the Blueskin News and from 2011, in the Rothesay News. There were several leaflet drops and many discussions with stakeholders, including the Waikouaiti Coast Community Board, who provided some funding for the community engagement work. By 2014 responsibility for the project development was passed over to Blueskin Energy Ltd who set out to finalise the proposal to apply for a development envelope on Porteous Hill to contain 3 sub-megawatt turbines.

Blueskin Energy Limited

32. Blueskin Energy Limited was incorporated on 16 December 2013. It has 1 shareholder (BRCT) and 3 unremunerated directors on its board. Two of those directors have current or past involvement with BRCT as

trustees, and expertise in the financing and business management sector. The independent director has past CEO experience of a wind farm company and deep involvement in the energy sector. The business and affairs of the Company are carried out in accordance with the company's constitution and resolutions passed by the board. BRCT is the sole shareholder and consequently has the power to appoint directors, [and make changes to Blueskin Energy's constitution], to ensure Blueskin Energy Limited's activities accords with BRCT's purpose.

33. The structure of a charitable company wholly owned by BRCT was chosen for establishing and operating the wind farm on expert advice from Russell McVeagh. Other legal forms considered were: Limited Partnership, Trading Trust and Cooperative Company. Formation of a Charitable Company was identified as the simplest legal form that would ensure there was no unnecessary and undesirable complexity. We wanted a legal form that reduced complex governance, compliance and cost, and would make the structure transparent to any community investors. The formation of a company is relatively simple and it has been provided with a constitution that ensures charitable purpose and BRCT ownership. The company's board are ultimately answerable to BRCT and its Trustees in turn must adhere to the Trust's values[3] reflected in its deed.

34. BEL has a management contract with BRCT for day to day project management and operations of the company. I am the member of BRCT's staff that is engaged via the management contract.

Turbine Model and Development Envelope

35. BEL has applied for a Development Envelope [on a title of 24 hectares of private land for which it has a long term lease agreement]. We have a Memorandum of Understanding with Enercon Ltd to use Enercon turbines in our development however the final contract conditions cannot be finalised until we have secured the Resource Consent and its

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[3] BRCT's six values are: 1) Thriving Together (thriving together well and equitably), 2) Distributing Surplus (Distributing surplus to enrich social and environmental health), 3) Encountering Others (Encountering others in ways that support their wellbeing as well as ours), 4) Consuming Sustainably (Living and consuming sustainably in recognition that all human life and activity occurs within the limitations of planet Earth), 5) Caring (Caring for – maintaining, replenishing and growing – our natural and cultural commons), 6) Investing for the future (Investing our wealth in future generations so that they can live well).

conditions are known. We are considering three different Enercon models: the E44, E48 and E53.

36. We propose to install three wind turbines of one of these types within the development envelope.

37. We have applied for the height of the development envelope to extend to 125 metres, as this aligns with the draft Second Generation District Plan, and provisions for "Wind Generators – Community Scale". However none of the turbines we have to choose between will exceed approximately 87 metres height from ground to blade tip and we would support reducing the envelope in our application to 90 metres.

Financial Matters

38. Should consent be granted, approximately **$5 - $6 million** will need to be raised to finance the project. The business case at present requires BEL to first establish a Limited Liability Partnership (LLP). As the General partner in the LLP BEL will retain management responsibility for the development, with the Limited Partners essentially behaving like a silent partner in a traditional partnership. BEL's value is principally due to the 'sweat equity' invested in getting this project to this stage.

39. Investment into the wind farm will come from a mixture of debt and equity. BEL's 'sweat equity' investment will be contributed as the initial General Partner contribution. A number of Limited Partners will then invest, some of these we anticipate will be institutions, others a consolidation of multiple small investors via an equity crowd-funding platform such as PledgeMe Equity or Kickstarter. Investor interest gives us confidence that project debt will be less than 50%. We already have expressions of interest from institutional investors and many small local investors. However investment commitments will not be given until we have regulatory approval.

40. BEL will remain a whole owned subsidiary of BRCT and as the General Partner, BEL has sole management responsibility for the development. Limited Partners, whether institutions or individuals, simply receive a return on their investment but do not have a say in the running of the business. Community control is maintained through BEL as General Partner with BEL owned by BRCT.

41. The windfarm is projected to return an annual dividend to the BRCT of about $100,000 once the project is fully operational.

42. The dividend returned to BRCT will make it less reliant on grants and donations thus enabling BRCT to become more resilient. Consequently BRCT will then be better able to focus its resources on achieving its purpose and deliver greater service to the community.

43. BRCT concentrates on creating local climate solutions together and engages on projects and initiatives that align with its stated values of: Thriving Together; Distributing Surplus; Encountering Others; Consuming Sustainably; Caring, and; Investing for the future.

Reliability of Wind Resource

44. Expert analysis of our data by Enercon suggests that the wind farm will have a capacity factor of 35%. The capacity factor is ratio of a wind farm's **actual** output over a period of time, to its potential output if it were possible for it to operate at **full capacity** continuously over the same period of time. The average wind farm capacity factor internationally is 24% while the best wind farm sites in NZ are over 40% capacity factor. As a point of comparison the NZ hydro system operates with a capacity factor of about 50%.

45. Wind data reveals low seasonal variation at the Porteous Hill site, which is important for good reliability of supply.

Market for electricity

46. The original vision for a Blueskin windfarm was to sell the electricity within Blueskin communities. It soon became apparent that such an idea was not currently workable given the design of the electricity market in New Zealand. Therefore we decided that becoming a merchant generator who received payment for electricity produced was an alternative mechanism to achieve the community and Trust vision. We are not currently considering becoming an electricity retailer.

47. The electricity will be supplied to either a single local (Dunedin) consumer or many consumers via a long term hedge contract involving an electricity retailer at market price. Concurrent to this development we

are working within the electricity sector as an advocate for a 21st century electricity distribution system that incorporates community scale generation and evolving technologies. We cannot guarantee that regulatory change may allow us to directly supply local consumers by the time the wind farm is commissioned and for this reason we are not pursuing the electricity retail pathway at this time.

48. Business modelling has included all scenarios including the possible closure of Tiwai Point aluminium smelter to test the viability of the project under a variety of conditions. Blueskin Energy Ltd has submitted this Resource Consent application because we are confident of the financial viability of this project under a variety of market conditions within the current market.

Positive Effects

49. The windfarm will have four major positive effects:

    (a) A reduction in the need for non-renewable electricity generation,

    (b) Environmental benefits to the local community,

    (c) Social benefits for local residents,

    (d) Economic [returns directly to investors, in maintaining local employment and in the establishment of new economic opportunities for the local community through BRCT].

50. The turbines will each contribute 800 – 900 kW per hour in optimal conditions to the local supply and will continue to produce electricity even at low wind speeds, decreasing the need for electricity to be supplied through non-renewable sources such as thermal power or from distant electricity generation.

51. It is more efficient to have electricity generation close to consumers to reduce inefficiencies created by long transmission distances. Long transmission increases line losses, which means generation must be enough to offset losses. Such additional generation is inefficient and increases greenhouse gas emissions because thermal generation is currently needed to secure electricity at peak times.

52. New Zealand's electricity demand has been growing steadily and is forecast to continue to grow. The New Zealand government has a target of 90% renewable electricity generation with security of supply by 2025. Meanwhile the timetable set for the closure of Huntly's coal fired power station is causing concern about future security of electricity supply and is leading to demands to retain Huntly open. Locally, 14% of the city of Dunedin's greenhouse gas emissions are caused by the use of electricity generated far outside city boundaries. Analysis by Professor Gerry Carrington shows that the Blueskin wind farm is estimated to reduce Dunedin's greenhouse gas emissions by 966 tonnes per year and is attached at **Appendix B**.

53. The 2011 National Policy Statement on Renewable Electricity Generation says that "*New Zealand must confront two major energy challenges as it meets growing energy demand. The first is to respond to the risks of climate change by reducing greenhouse gas emissions caused by the production and use of energy. The second is to deliver clean, secure, affordable energy while treating the environment responsibly*".

54. The development of a 3 turbine 2.4 – 2.7MW wind farm at Blueskin Bay within city boundaries will increase renewable electricity generation, bring greater security of supply to Dunedin, reduce Dunedin's greenhouse gas emissions and continue the momentum towards a more resilient, distributed electricity network, all while protecting the environment.

55. As previously mentioned the windfarm is expected to cost between $5 and $6 million to construct. A significant portion of this money will circulate through the local economy through the construction process. Furthermore, ongoing maintenance of the site will be required, in order to ensure efficient operation of the turbines. Operating costs are estimated to be approximately $30,000 per year with one local resident employed to provide maintenance services. The company business will continue to be run from Blueskin.

56. Dunedin City's reduction in greenhouse gas emissions as a direct result of the development are only part of the total environmental benefit. Further environmental benefits will be derived from the increase in BRCT

services that will be made available as a result of the development. We anticipate these to include:

(i) Funding additional work on climate safe housing for those in high hazard zones whose homes are at greater risk of inundation. We will help residents in cold, flood prone homes to develop solutions to their current situation including working with partners on new portable housing, and over time, develop partnerships to create community housing options for any necessary relocation. We will also work more intensively with local government on community engagement on climate change issues;

(ii) Maintaining our work on providing energy advice and Home Performance Assessments, and further assistance to the Cosy Homes Trust. In addition, we aim to provide insulation subsidies for those most in need. We expect to not only reduce household greenhouse gas emissions but also reduce power bills, and increase health and wellbeing for residents;

(iii) Assisting with work to build a resilient energy system for Blueskin Bay and other Dunedin communities. We aim to intensify our solar PV assistance, and assist with the introduction of interactive technologies to allow peer to peer transactions in the local network. We expect to build a more resilient system and give people greater control over their electricity use and demand, reducing power bills and reducing greenhouse gas emissions;

(iv) Expanding our work on low carbon transport. We expect to assist the replacement of high emission transport with low carbon options to reduce greenhouse gas emissions, reduce transport costs and improve health and wellbeing. We aim to provide further education and work with businesses to install electric vehicle charging infrastructure and promote local electric bike and EV businesses. We also hope to assist walking groups to improve the local walking and cycling network, and work with public transport advocates to improve access to public transport for residents;

(v) Continuing our work to establish a local food system. We expect to build on our existing support for, and research on, local food, to assist the development of local food enterprises and contribute to the establishment of a local food system. Over time we expect to see a reduction in greenhouse gas emissions as the local food system grows and consumption of distant food is reduced, and an increase in resilience as we reduce supply chains and boost security of supply from our local farms and enterprises;

(vi) Improving our work to improve local biodiversity for biodiversity gain. We expect to increase our supply of traps to local groups and make an annual contribution to an integrated pest control scheme, which we can help develop if needed;

(vii) Enriching our partnership with our local runaka through developing information panels in and around our settlements at vantage points to see the wind farm in locations that also reference the cultural history of our area. We hope to help replenish and grow our cultural commons.

57. In addition to these positive effects, we will seek further community input to help allocate funding for community initiatives that align with the Trust's values of thriving together, consuming sustainably, caring for, maintaining, replenishing and growing our natural and cultural commons, and investing for the future.

Conclusion

58. Community wind for Blueskin was proposed in a community workshop 10 years ago. The realisation of that idea into a viable project has taken 7 years of hard work. It represents countless hours by numerous individuals, groups, organisations and businesses. The turbines will generate annually more than the current annual electricity demand of the

Blueskin community. All the homes in Blueskin Bay will be powered by renewable electricity. Over time, a resilient energy community will be established. The Blueskin Wind Farm is a local community driven initiative. As a ground breaking New Zealand community wind farm project in Dunedin, it will boost the city's profile nationally. I hope that you grant this resource consent to show that clean, community electricity generation is achievable in New Zealand. Let Blueskin Energy Limited and Dunedin be an example to show how small communities can make a big difference.

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Scott Matthew Willis

3 May 2016

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Appendix A

Blueskin Resilient Communities Trust

Final Report to EECA Distributed Generation Fund re Blueskin Power Co-operative Wind Project

April 2010

Public

Final Report to EECA Distributed Generation Fund re Blueskin Power Co-operative Wind Project

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Appendices

Appendix I Discounted Cash Flow Models, Tony Wilson (Polson Higgs)

Appendix II Analysis of Wind Data and Turbine Performance, Solis Norton (OERC)

Appendix III Hodson Hill Report, Deion Campbell (Trustpower) [Alain Laird, Design Power NZ Ltd]

1. Executive Summary

New Zealand has the potential to break with centralised think-big generation projects and build a resilient decentralised national grid while providing householders with the keys to moderate their own energy consumptions patterns. This report sets out the work to date initiated by a community trust (BRCT) in the semi-rural South Island community of Blueskin Bay to establish the feasibility of a community owned turbine.

The Hikurangi Foundation and EECA have supported this feasibility work: BRCT is a recipient of funding from EECAs Distributed Generation Fund and Hikurangi funds the project manager on a fixed term basis. In addition, BRCT has been the recipient of many in-kind donations that have enabled this multi-authored report.

The ideal site for a community turbine involves:

- Choosing a site with maximum wind and minimum requirement for preparation effort
- Creating a symbolic visual reminder of how the community is meeting its consumption needs
- Proximity to the local grid
- An adequate sound perimeter around the turbine or turbine cluster.

These considerations have led to five sites of interest within Blueskin Bay:

1. Mopanui Ridgeline
2. White Road/Doctors Point
3. Mt Kettle
4. Double Hill
5. Omimi/Merton

All sites are close to the intended user population and will enable generation to be delivered via the Waitati Sub-Station. Further work is required to determine the exact infrastructural constraints and no formal contracts with landowners to allow development have yet been established.

We have modelled three types of wind turbines: NEG Micon, (750kW), Vestas V52 (850kW), and the locally manufactured WindFlow 500 (500kW).

A 15 and 20 year discounted cash flow model to estimate the expected rate of return on the project has been prepared. The model is based on a single turbine project, but can be used to model multi-turbine projects equally well.

The model rests on a number of key assumptions relating to:

- The price received for electricity generated
- The installed cost of the facility
- The wind profile (mean wind speed and curve shape) of a site, and associated energy production
- The annual operating costs of the facility

The starting point for this study was the vision of a single, community owned and managed, grid integrated 500KW turbine, supplying the local community with its energy needs and distributing benefits to the community on an equitable basis.

Feasibility work has determined that:

1. Several Blueskin sites appear likely to have a good wind resource for a wind turbine (further site specific testing required);

2. The financial viability of the Windflow 500 (our initial preference) is very sensitive to mean wind speed and Micon 750 (750kW) and Vestas V52 (850kW) models that generate well in the lower wind speed bracket will be better suited to the short-listed Blueskin Bay sites;

3. Entering the electricity market will require a partnership with a generation company;

4. Joint development in a wind cluster of approximately 3 turbines will increase the financial viability and provide expertise;

5. Either a co-operative company, or a limited liability company can provide effective legal governance for community ownership of a turbine and equitable distribution of returns

6. There is enough information at hand to proceed to final feasibility work and take steps towards development.

The feasibility study has demonstrated that using lower cost second hand turbines with a broader power curve more suited to the wind profile at tested sites ensure basic financial viability, subject to confirmation with more precise data.

In the scenario of a Joint Development operation, with the security of a fixed price return and shared development costs, and assuming a windspeed of 7.6 m/s, with second hand NEG Micon (750 kW) turbine costing $1, 240 000, the anticipated internal rate of return on the investment is projected to be in the order of 10% per annum.

The next logical steps are for BRCT to:

1. Report results to the Blueskin community and assess community preferences for development

2. Engage in Joint Development discussion with generator

3. Seek Project Development funding

4. Conduct rigorous site assessment, confirm preferences and secure landowner contract

5. Establish the community ownership and management structure

6. In depth consultation and resource consent application

7. Raise funds for purchase of the turbine

The challenges remaining are mainly financial: we will require further funding to ensure the final feasibility work can be completed and steps to development taken, with all the associated costs of site testing, consultation, legal work (contracts, co-operative/company formulation, prospectus) and fundraising costs to enable purchase of a single turbine as part of a small cluster development.

This report also provides information to enable other communities to consider developing a renewable generation project. It suggests removing some policy constraints and providing policy incentives to stimulate the development of local energy systems using proven technologies to build a resilient national electricity grid. Innovative leadership at all levels (community, research, business, local and central government) is the key to achieving a strong, integrated local energy future for New Zealand.

Nicolas Cullen and Geog380 installing Automatic Weather Station 1 on Mopanui Ridgeline above Blueskin Bay, May 2009. *Carl Scott/WEP stockphoto, 2009*

2. Acknowledgements

This report is a rich collaborative effort. Without the support of a substantial army of volunteers and donations of time and expertise by friends of the project, the Waitati Energy Project (Blueskin Power) would have had barely enough energy to power an eco-bulb.

Indeed, many collaborators have offered so much to this project that it is hard to know where to begin.

But without Janet Stephenson's support, enthusiasm and mentoring first as Otago Energy Research Centre (OERC) convenor and later as collaborator, it is unlikely we would ever have seriously raised our eyes to turbine height. Janet's PLAN438 class of 2007 worked on "visioning a resilient community" and her student Matthew Hoffman conducted some valuable qualitative work on "Community attitudes towards distributed generation and renewable energy" in 2007. Janet has continued to assist this project in many different ways, mentoring, facilitating, advising and contributing with great modesty and generosity.

Nicolas Cullen really opened the door to the turbine project when early in 2009 he set his GEOG380 class a task to work on wind measurements in Waitati. Nicolas's support has opened a whole array of possibilities, with MSc student Alice Bowden now working on the Waitati wind profile. Alice's continued data collection from existing monitoring has been of great assistance.

Seth Gorrie took his initial GEOG380 enthusiasm and continued to forge increasingly valuable contributions on top of other academic obligations and through his OERC summer internship. Seth has brought a unique set of skills, passion and energy and valuable contributions not just to this report but to our wider community as well.

Solis Norton, the voracious 'number cruncher' (and OERC Administrator) has brought his talents to bear on some of the sharper points of this report, helping immeasurably to interpret data and enrich it with analysis.

Rosalind Day, Planning Consultant, has generously provided assistance and expertise and demonstrated a deep sensitivity and understanding of the project parameters and our work together is only just beginning!

Others in the OERC network and Otago University have all played a part. Bob Lloyd, Rob Lawson and Rachel Spronken-Smith have all contributed to the puzzle. The OERC generally has been extremely supportive, notably in 2009 providing a facilitated community turbine workshop led by Paul Stephenson of Synergia – many thanks to Paul as well.

In the energy industry we've had generous assistance from a host of companies and individuals. Mark Nelson and Greg Sise of Energy Link, have been extremely generous with time and advice, making the seemingly impenetrable electricity market comprehensible to the full Blueskin Power contribution team and individuals. Terry Jones of PowerNet in addition to his report contributions has provided key advice and support. Peter Dowling of Pioneer Generation has been very generous with time, information and experience in developing small scale embedded wind generation,

while Ken Humphrey of Energy 3 has been supportive, generous with information and very helpful. From WindFlow Technology Limited, Lindsay Leitch and Nick Bowmar have offered much support and their experience, particularly as it relates to the WindFlow 500, and we're also very grateful to Deion Campbell of Trustpower for the timely provision of valuable local wind data and analysis. Bill Currie and Wayne O'Hara of Powerhouse Wind are demonstrating what can be achieved with a will and wind in our own community right now, while Ken Mitchell of Network Waitaki has offered advice on another community/company initiative.

At the local government level we've been well supported by Neville Auton, DCC Energy Manager and offered helpful advice by Doug Spittle, senior DCC planner.
The Energy Efficiency and Conservation Authority (EECA), and Joseph Mayhew in particular, have been critically supportive with funding, but also supportive in terms of advice and suggestions. Without EECA funding support this report would simply not have been possible. Jeanette Fitzsimons in her role as the Greens co-leader was instrumental in consolidating and focussing community passion, and in sustaining it in subsequent visits.

In the wider community we've been assisted by Nick Holmes in recording events, by Glen Saunders (previously of Harbour Wind), and Alan Robb, consultant for advice. In the philanthropic community support from the Hikurangi Foundation and Liana Stupples has been critical, not only in supplying a key wage, but also in building effective capacity and big-hearted mentoring.

Waitati Energy Project volunteer input and community support has been fundamental to this whole project, and manifest in various ways. Graham and Marie Bennett, Bob and Viv Adams and Sarah Rennie and Joy Rudland have all been generous with turbine site testing offers. Hagen Brueggerman has provided not only valuable local wind analysis but also extensive local energy and network experience. Other WEP volunteers – Carl Scott, Leone Rousselot, Geraldine Tait, Ross Johnston, John Salter, Derek Onley, Rosemary Penwarden, Lindsay Graham, Sue Hensley and many others, have really kept things running, from IT assistance, fencing and photos to helping organising meetings and cups of tea, to solar (PV) complementation and just about everything else.

Finally, my colleagues, Tony Wilson and Phillip Broughton of Polson Higgs, Mark Dickson, Geraldine Tait, Chris Young and Antony Deaker of Blueskin Resilient Communities Trust, and Lynn Robberts of the BRCT office: we've all taken this journey together and without the wonderful support I've received from my partner Jenna Packer I'd have run out of energy long ago!

Scott Willis

3. Editors' Introduction

This Report presents the results of a feasibility study into the development of a grid embedded community owned wind turbine (proposed distributed generation project, or PDGP).

This is a multi-authored report, with contributions from the following sources:

Blueskin Resilient Communities Trust:	Scott Willis
Polson Higgs:	Tony Wilson
University of Otago:	Seth Gorrie Solis Norton Janet Stephenson Ros Day
PowerNet:	Terry Jones

Advice and assistance has also been provided by Greg Sise, Energy Link Limited, Peter Dowling, Pioneer Generation Limited, and Nicolas Cullen with M.Sc. student Alice Bowden, Otago University, and others as detailed in the Acknowledgements.

Feasibility and development of this community RG project requires an integrated approach. The Blueskin Resilient Communities Trust (BRCT) is both the developer and also an end-user in an inhabited landscape and to ensure we are able to make the best site selection we must also ensure we are meeting the needs of our community in order to have access to sites and to develop the most suitable model.

In setting out the progress so far, we describe the process and provide a roadmap for future development. In this report we have provided a robust estimation of generation potential, along with an estimation of financial viability. We provide a discussion on the replicability of the PDGP and key up-to-date information on the technologies and wind resources, along with information on the actual parties, the resource consent process, clear estimates of grid connection costs, and any risk assessments,

We are confident that our approach to the project will help develop a model and blueprint for other such initiatives. The timing too seems perfect. There is a growing sense of urgency, not just in our own community, but around the world, to tackle the predicament of climate change and energy security. Our opportunity is to develop a New Zealand appropriate model for community development of renewable generation, and to live the model in practice.

Scott Willis
Blueskin Resilient Communities Trust

Tony Wilson
Polson Higgs

4. History and Background

Extensive flooding in 2006 demonstrated two main things to the Waitati community:

1. Our vulnerability to extreme events beyond our control (such as Climate Change related weather events), and

2. Our resourcefulness and ability to make things happen ourselves.

From that point on we began planning in a co-ordinated way, around how to make our community more resilient to shocks and more autonomous, or more able to adapt and manage the unexpected.

We've held community forums around wind energy, adapting to and mitigating Climate Change and Peak Oil, managing energy prices, forms of alternative energy and many others on the subject of energy in general. The idea of a community wind turbine has been a recurrent community theme at all these forums.

The Waitati Energy Project was launched in 2007 and has conducted extremely successful energy literacy events, planning sessions and extensive insulation retrofitting both within the immediate Waitati community, and the wider Blueskin community and also well beyond. In early 2009 an offer from Nicolas Cullen (Climatologist at the University of Otago) established a research opportunity looking at the technical feasibility for wind powered renewable generation. We were already doing pre-feasibility work on two other community scale energy generation ideas and this research offer kicked off the wind research (what has become 'Blueskin Power'). By September 2009 we knew that we had the potential to generate electricity from wind turbines from the technical data collected and had initiated a number of key relationships around this potential. We applied to the Energy Efficiency and Conservation Authority's Distributed Generation fund in October 2009 for funding to elaborate our feasibility work, and were successful.

Our community-led initiative only cautiously began investigating distributed generation. We concentrated initially on promoting energy awareness and developing community energy efficiency and reduction in energy demand. Our success in these areas and emerging expertise has given us the confidence to develop this PDGP, aware of how consumption and production are integrated and of the necessity to reform, or make explicit, the link between them. In the process we've discovered that we are not alone: all around New Zealand community groups are making small steps towards greater energy security. The November 2009 loss of Meridian Energy's resource consent application for the 630 Megawatt Project Hayes development perhaps signals an opportunity for appropriate scale community-led wind development. The commissioning of Pioneer Generation's 3 Horseshoe Bend turbines in December 2009 and the success of Pioneer Generation's Mount Stuart resource consent application in January 2010 bears witness to this possibility.

Meanwhile the Energy Efficiency and Conservation Authority, set up by the New Zealand Government "to encourage, support and promote energy efficiency, energy conservation, and the use of renewable sources of energy", is the only real government led support for distributed generation. EECA's support is material and important, as is it's support for Resource Consents for renewable generation projects.

Yet even considering the feasibility funding supplied by EECA, small scale distributed generation projects in New Zealand have not merited enough attention thus far in the form of enabling policy to make a perceptible and sustainable difference to New Zealand's energy landscape. While this situation may yet change, essentially all small-scale development has operated in a policy vacuum, relying on entrepreneurial developers and often involving a sizable degree of risk. Risk, in the small-scale distributed generation model, is primarily found the in the virtual infrastructure of the electricity market.

We nevertheless must contend with what is, not what might be, and as such we work within and around the constraints, while being acutely aware of the potential for enhancing the current energy market to ensure a more sustainable and resilient national grid network incorporating embedded generation close to consumers.

NEG Micon turbines at Pioneer Generation's Horseshoe Bend site, Central Otago.
Nick Holmes/saltwaterimages, 2010

5. Relationships

BRCT is a small community group with a clear vision and passion for supporting sustainability initiatives in the Blueskin Bay area. We recognise, however, that we do not have all the resources or expertise needed to successfully develop and operate a wind turbine project without external assistance. Part of the project to date has involved building relationships with a wide range of external experts who can provide the assistance we need. We are equally mindful that some of our collaborators on this project are also potentially commercial competitors with one another. To ensure that we respect and provide security for our partners and collaborators we have been active in developing appropriate Memorandum of Understandings, Confidentiality Agreements, and informal agreements and maintain a high degree of professionalism in our relationships. External parties and their relationship to the project are shown in the following table:

Entity	Role
Blueskin Bay community	Project initiator and host
University of Otago	Independent research and analysis, mentoring, assistance
Polson Higgs	Contracted business advisors
Pioneer Generation	Industry mentor, potential joint-development partner
EnergyLink	Project advisors, provision of electricity price data
Dunedin City Council	Local authority
WindFlow Technology Ltd	Site and capacity assessment, technical advisors, potential partner
Energy3	Site and capacity assessment, technical advisors, possible partner
PowerNet	Grid manager, industry mentor and sponsor
Rosalind Day Planning	Planning consultancy and advice
Powerhouse Wind	Industry partner
Trustpower Limited (Deion Campbell)	Industry, providing assistance

6. Site Selection

6.1 Wind Data/Technical Data.

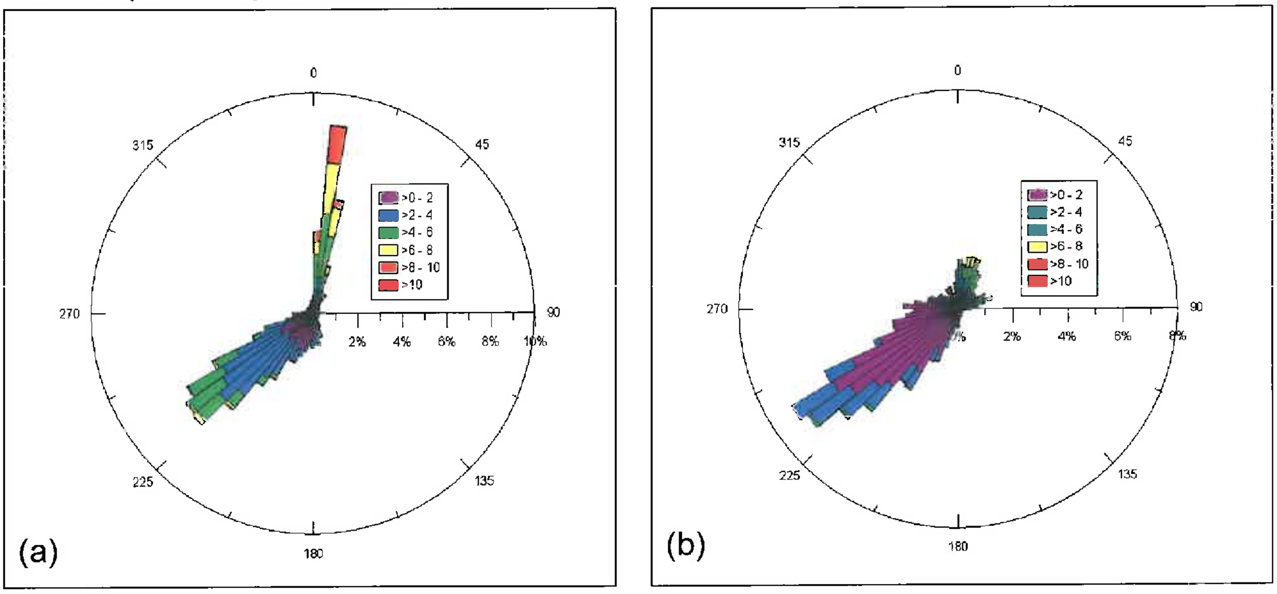
In May 2009 Nicolas Cullen's GEOG380 class set up their first Automatic Weather Station (AWS) in the Blueskin Bay area, on the Mopanui Ridgeline. This was followed the next month with a second AWS on a farm off Double Hill Road, overlooking Blueskin Bay. These two AWSs and subsequent work completed by the GEOG380 class, and independently by Seth Gorrie of the Otago Energy Research Centre, form the initial basis for individual site investigation. Although limited in scope (AWSs are on 3 metre towers on less that ideal sites), information collected has enabled comparison with National Institute for Water and Atmosphere (NIWA) testing stations, notably at Taiaroa Head, see Appendix II.

The magnitude and direction of wind speed at Site 1 and 2 are indicated by Figure 1(a) and (b). The predominating wind directions for both locations are north-north-east (NNE), south-west (SW) and west-south-west (WSW).

The NNE wind measured at Site 1 is comprised of mainly wind speeds greater than 4m.s with wind speeds between 8 and 10m.s occurring approximately 8% of the total sampling period. In contrast the SW and WSW component at Site 1 consist mainly of wind speeds between 0 and 6m.s with wind speeds of 6 to 8m.s only occurring approximately 6% of the time.

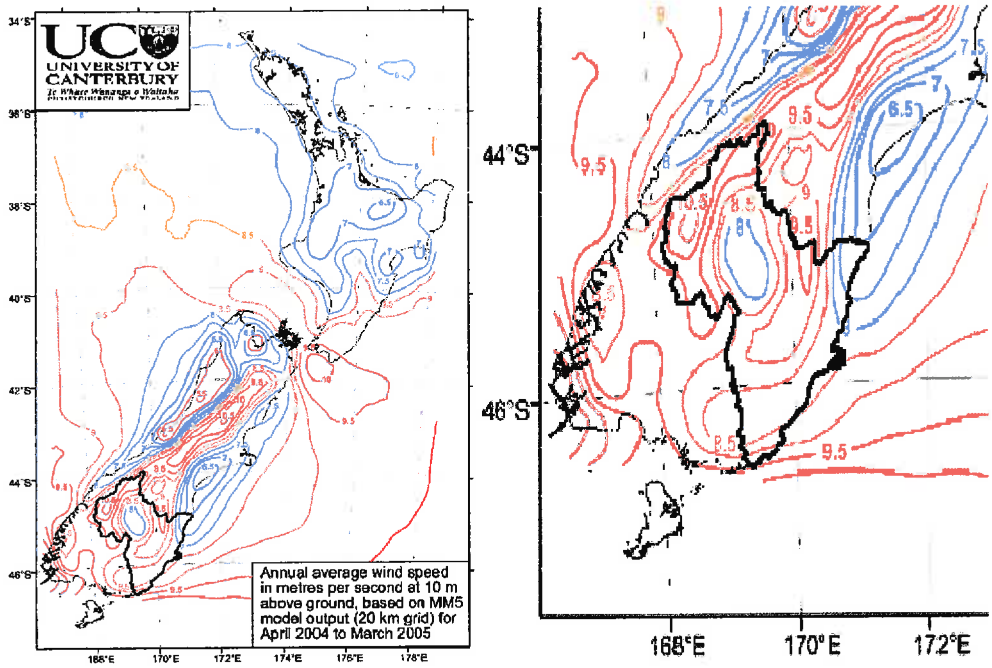
The SW wind measured at Site 2 is made up of frequently low wind speeds between 0 and 4m.s. The frequency of low south-westerly winds varies from about 4 to 7%. In addition, the NNE wind component is comprised of higher wind speeds than that measured towards the SW of up to 8m.s. However, these higher wind speeds occur less than 2% of the total sampling time period.

Figure 1 (a) Windrose diagram 15 min data for Site 1 and 1 (b) Windrose diagram 15 min data for Site 2 (2 metres per second bins).



Alice Bowden, Nicolas Cullen's MSc student, has maintained the two original sites and has continued to supply raw data to enable comparative analysis. Alice will use a modelling programme called TAPM to estimate the wind field of Waitati, and use the AWS field measurements to validate the model. This modelling and measurement campaign will then be placed within a longer temporal context through statistical comparisons with NIWA data from Taiaroa Head. This research aims to assist in determining whether the local wind climate of Waitati is suitable for the installation and long-term use of a wind turbine. Installation of a 10 metre tower by the University of Otago has been delayed by new Resource Consent issues around research that have only recently been resolved.

Figure 2. Model of average annual wind speed in metres per second for 10 metres above ground from April 2004 to March 2005 for all of New Zealand. (b) Model average annual wind speeds over the lower South Island of New Zealand with the Otago Region outlined (Canterprise, 2005).



Independent assessment of NIWA data from testing sites in the vicinity of Waitati by two sources, firstly Lindsay Leitch, Wind Resource Analyst at Windflow Technology Limited, and secondly, Solis Norton, Otago Energy Research Centre shows measured wind speeds of 6 - 10 m/s in exposed locations around the Waitati / Blueskin Bay area, but it must be remembered that wind speed is influenced by the height above ground level (AGL) at which wind speed measurements are taken.

Provision of wind data recorded at Hodson Hill and Hodson Hill data analysis by Deion Campbell of TrustPower's Generation Division has enabled the comparison of Waitati data with another independent wind analysis and assisted with the development of a richer wind field profile for the Blueskin Bay area. See Appendix III 'Dunedin Electricity Report'.

Figure 3. Topographic Map of Hodson Hill (Blueskin Bay is to the North-West).

Current testing of Powerhouse Wind's 'Thinair' single blade turbine prototype (at Don's Creek above Waitati) will provide corroboration of the local wind field once the prototype can be run continuously and it is anticipated that Alice Bowden's MSc project will provide a rich meso-level appraisal of wind potential.

Further site specific testing would enable deeper quality data and our ideal scenario would be to gain access to two 30 metre towers to allow accurate site specific testing over a 12 - 24 month period, however it may be the case that integration of the existing data sets with the addition of 10 metre tower AWS data will provide enough certainty of wind resource to proceed at an earlier date. We will seek further expert assistance to determine exactly what our testing regime will need to involve before moving to development. See section 7. Generation Capacity for greater detail.

6.2 Potential Sites.

At least four important considerations have been identified in selection of an ideal site for a community turbine.

1. The fundamental consideration is to choose a site with maximum wind and minimum requirement for preparation effort.

2. The second consideration is visibility. Informal expressions of the desirability of having a constant visual reminder of how we are meeting our consumption needs have led us to pursue sites that will be visible either from within Waitati or within the Blueskin Bay area.

3. The third consideration is proximity to the local grid

4. The fourth consideration is the importance of an adequate sound perimeter around the PDGP.

A minor challenge arises in that at this stage as feasibility elements have altered, and both prior to community consultation and without a formal relationship with a joint development partner, we cannot know the exact number of turbines that will constitute the PDGP. Our working assumption is that one turbine ('go it alone') will no longer be viable, while between three and five turbines of a generic 750 kW scale at one or more sites will potentially provide the incentive for a joint development agreement and may prove acceptable to our community as an enabling compromise to ensure the successful development of a community turbine.

These considerations have led to initial Memorandums of Understandings (MoUs) with landowners for testing purposes and have directed our site search. Currently we have five sites identified as of interest, all within the Blueskin Bay area. There are:

1. Mopanui Ridgeline
2. White Road/Doctors Point
3. Mt Kettle
4. Double Hill
5. Omimi/Merton

Not all sites have the same status however. Mopanui Ridgeline currently has an AWS located in proximity to the improved location where we hope soon to establish a 10 metre tower through an MoU with the supportive landowners. White Road/Doctors Point used to accommodate a New Zealand Navy trig station and we are in the process of establishing an MoU with supportive landowners to allow testing at this site. Mt Kettle is Dunedin City Council land and we will need to proceed through a simple resource consent process to begin testing at this site. Double Hill is at the end of a single phase (two wires) 11,000 volt distribution power line, and is in proximity to a dwelling so would only be of interest for a smaller turbine if generation came from turbines interspersed around the local network. We are ready to establish an MoU with supportive landowners to allow testing at this site. The Omimi/Merton area holds great interest particularly for a multi-turbine development as it is close to the 33kV line to the Waitati Sub-Station, however we have not yet engaged with landowners in this area.

Another site we have considered is Weatherston Hill which presents similar opportunities but greater challenges to those cited above.

All sites are close to the intended user populations and will enable generation to be delivered via the Waitati Sub-Station. Further work is required however to determine the exact infrastructural constraints on final siting (see '8 Infrastructure Requirements and Implications', especially Figure 1).

Figure 4. Macro view of the general sites within the Blueskin Bay area. Otago Harbour is at the bottom right of the image.

Figure 5: Satellite image of Omimi/Merton with the site of interest outlined.

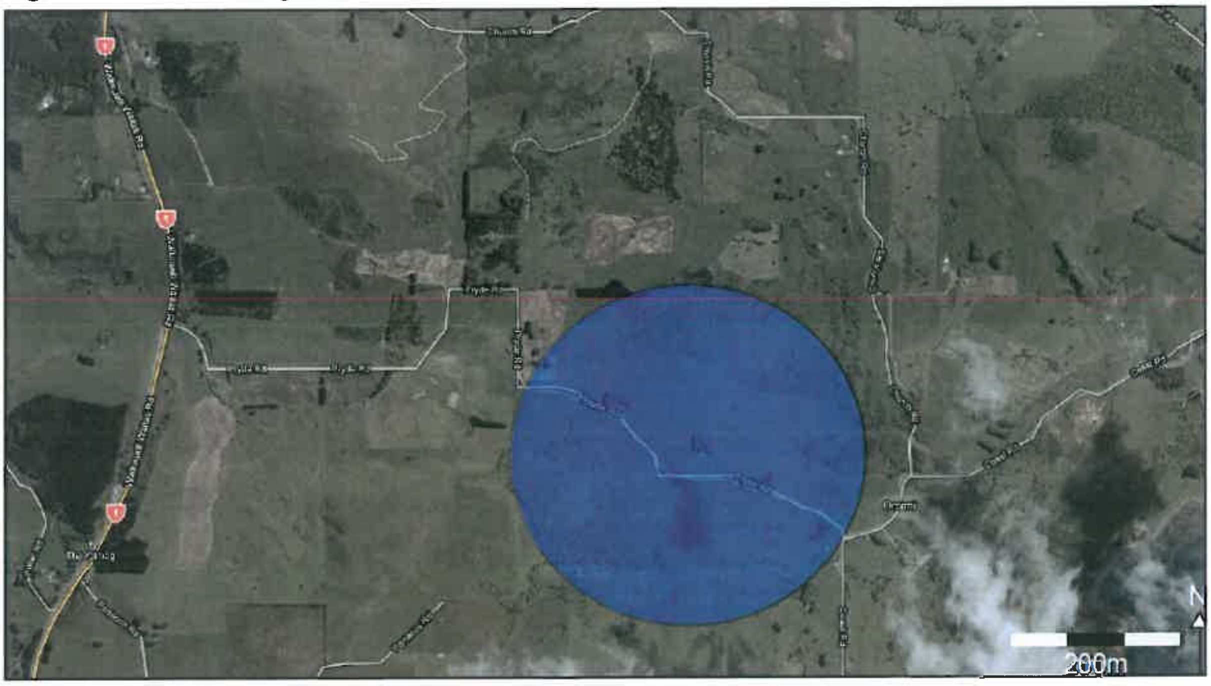


Figure 6: Satellite image of White Road/Doctors Point with the site of interest outlined.

Figure 7: Satellite image of the Mopanui Ridgeline with the site of interest outlined. In addition the first Automatic Weather Station (AWS) established in May, 2009 is also denoted.

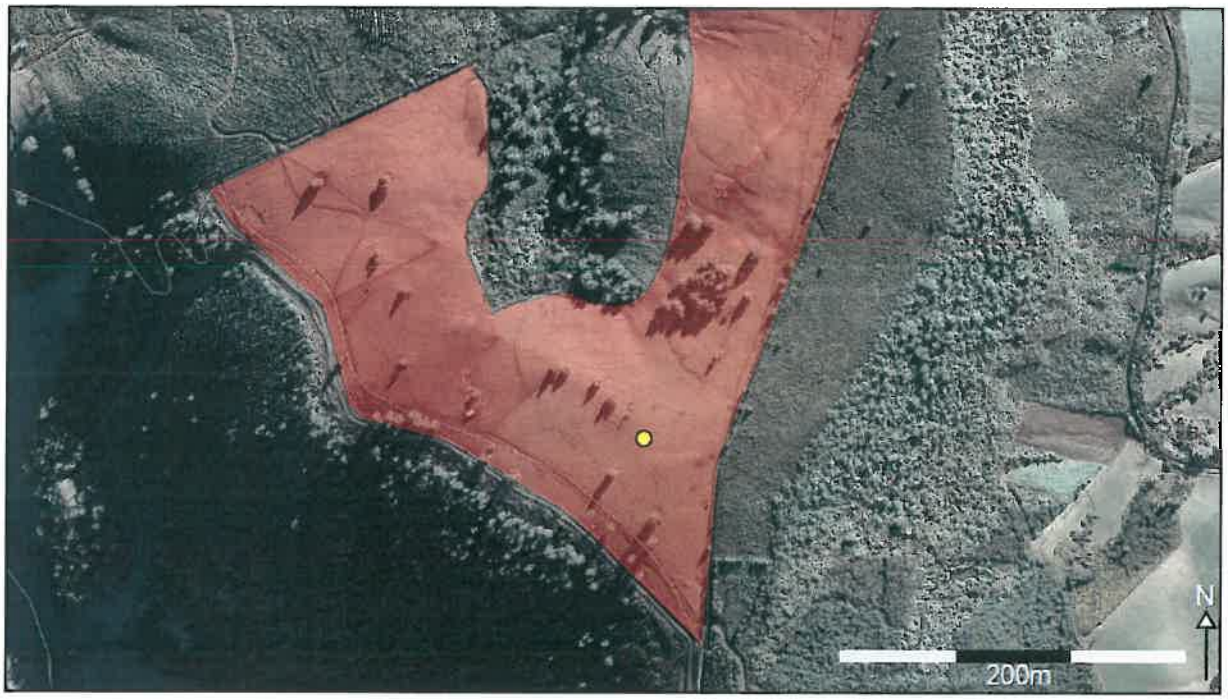


Figure 8: Satellite image of Mt. Kettle above Cedar Creek with the site of interest outlined.

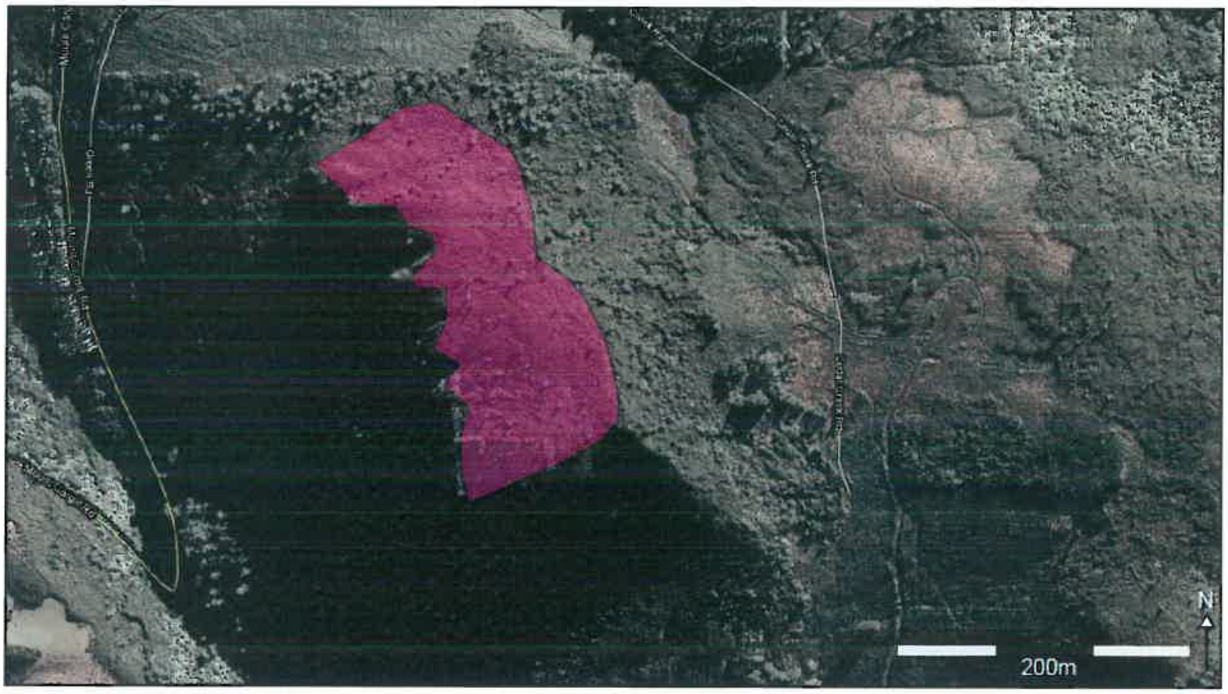
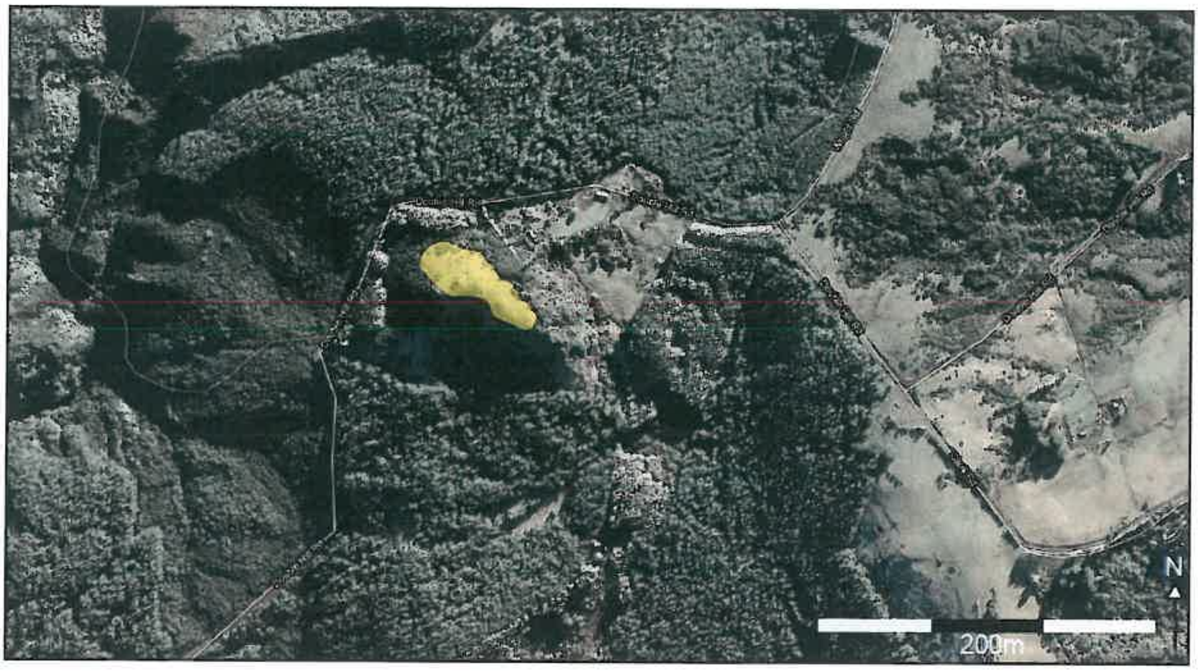


Figure 9: Satellite image of Double Hill with the site of interest outlined.



6.3 Planning Constraints.

The proposed site areas for the turbines all fall within the Rural Zone of the Dunedin City District Plan. The selected sites are also within Landscape Management Areas, specifically including the North Coast Coastal Landscape Preservation Area and the Flagstaff/Mt Cargill Landscape Conservation Area. Wind turbines are not specifically provided for or anticipated by the District Plan and therefore, subject to the confirmation of preferred site locations, application for wind turbines is likely to trigger the need for resource consent as a non-complying land-use activity.

Key assessment areas and considerations for Council are expected to relate to:

- visibility and effects on views from public viewpoints
- the extent to which any adverse effects on the landscape can be managed
- the extent to which the activity impacts on important landscape features, and whether it is compatible with surrounding landscape settings etc
- impacts on rural amenity, existing rural activities, views from public viewpoints etc

Subject to confirmation through community consultation however is an assumed community preference for visual reference to a community owned renewable generation asset (turbine). Community preferences will form an important component of an eventual resource consent application, and will be arrived at by community consultation undertaken prior to the formal consenting process.

6.4 Social/Cultural Issues.

Choosing of a site for the turbine/s is not just a matter of selecting a site with the best wind generation potential. Community acceptance of the turbine will depend a great deal on how suitable the community feels the site is, and this will affect the level of support or opposition, which will then be reflected in submissions during the resource consent process. As part of the site selection process, therefore, it is important to also understand what qualities of the optional sites are important to the community, and how these qualities might be affected by the development. This is particularly the case as the turbine/s will be relatively close to the community, and the community will need to feel comfortable that it 'owns' them.

Research in New Zealand and internationally makes it clear that while people value the visual aspects of landscape (e.g. its aesthetic qualities) there are many non-tangible qualities that are also highly important, such as the stories, histories, spirituality and genealogies associated with places. If this project is to proceed with the support of the community, we feel it is important to discover what is important to the community about each of the optional sites. Accordingly we aim to carry out a survey, with the assistance of researchers at the Otago Energy Research Centre, into qualities of the optional sites as perceived by community members, and to use this information to assist in site selection and project design.

Lindsay Leitch (WindFlow Technology Limited Wind Resource Analyst), with Seth Gorrie, Lydia Perkins and Alice Bowden (Otago University), on Double Hill, Blueskin Bay. *Scott Willis/WEP stockphoto, 2009*

7. Wind Turbine Selection

7.1 New Turbines

Increasingly turbine manufacturers are investing in the development of larger turbines generally, though with some exceptions. New turbines are attractive in that they come with manufacturers guarantees and the up to date technology. They are costly as a consequence.

An eco-social focus had been expressed by wind generation proponents in our community to invest in a New Zealand made, appropriate scale turbine. Not only was there an openly expressed desire to support entreneurial New Zealand industry and technology in an ambitious expression of 'Buy NZ made', but there was also a pragmatic desire to find an appropriate technology whose technical challenges could be met by appropriately trained technical experts. As a consequence, we began discussions with Christchurch based WindFlow Technology Limited, with the intention to invest in a new turbine.

7.2 WindFlow 500 Turbine

The WindFlow 500 turbine is a two-bladed, 500 kW wind turbine, incorporating several innovative features and offers synchronous power generation alongside a relative ease of installation and grid connection, manufactured by WindFlow Technology Limited. It has a generation history in the Te Rere Hau wind farm near Palmerston North and is likely to gain further 'exposure' at the proposed Long Gully Wind Farm near Wellington (south of the Brooklyn wind turbine). The WindFlow 500 turbine is particularly well suited to high wind sites, and becomes most economic at high average wind speeds. However our investigations so far have shown a more marginal wind resource than either of the existing sites where WindFlow 500 turbines are currently deployed (Te Rere Hau and Geddes Pass), which in consultation with other Distributed Generation developers suggests that consideration of turbines with a greater generation range will be necessary to establish final feasibility.

7.3 Second Hand turbines and procurement

As a consequence both of site consideration and market consideration (the mechanism by which community owned generation will work within the local grid necessarily implies engagement in the electricity market), and as we seek a modest economic return on investment (as opposed to simply building generation as a value in itself), we need to secure modest cost, certain-return generation. The second hand turbine market offers a range and value that may be enabling factors in establishing the viability of our commnity owned wind turbine project. We have therefore also sought to assertain whether any other turbines would work for our conditions and be servicable with the available New Zealand expertise. This has led to a broader appraisal of options and possibilities to source the most appropriate wind turbine for our purposes.

See Figure 13 below for turbine power curves.

The availability of second hand turbines presents opportunities for small wind cluster developments as they reduce the installed (upfront) cost substantially while offering a reasonably rapid return on investment. Second hand turbines have become available as European wind farms install greater generation capacity on the same footprint, effectively replacing mid scale machines (in the vicinity of 1 MW and below) with larger machines (3 – 5 MW).

While the availability of second hand turbines may be the key that enables community development of, or participation in, a wind cluster, there are also issues associated with the opportunity:

- Second hand turbines will frequently not be covered by manufacturers' warranties, and will incur some refurbishment costs.
- Larger second hand turbines (in the 500kW range and above) incur substantial shipping costs that must be factored into price.

Both Pioneer Generation and Energy 3 have up-to-date and ongoing experience in the second hand turbine market. The second hand market in turbines is dynamic and difficult to predict with confidence and our opinion is that the most reliable sources of advice and information on turbine availability for New Zealand projects will come from local companies engaged in the market.

Given the singularity of this PDGP for the developers/end-users (community owned) and its likely budget, the question of expertise in the selection of a second-hand turbine is fundamental. We do not possess this expertise in our community and we envisage two options to enable development of our project:

1. Engagement of consultants/advisors and purchasing agents (such as Energy 3)

2. Joint Development in conjunction with an experienced and resourced partner with experience in the second-hand turbine market (such as Pioneer Generation)

Energy 3 is a small South Island Wind Farm developer and Project Contractor for wind projects, and as such has expertise in small-scale wind developments using second hand turbines, and would likely be an important partner to this PDGP should the option to 'go it alone' be selected by the community (and assuming viability could be established)

However as set out below, our investigations indicate that the Joint Development model presents an opportunity to overcome many of the more difficult challenges within the current policy context we are presented with in a 'go it alone' approach. As a consequence, we have entered preliminary discussions with small-scale community owned generation company Pioneer Generation who have a growing experience in wind cluster development.

This strategic possibility has led directly to a focus on two other turbines: the NEG Micon (750 kW) and the Vestas V52 (850 kW) for modelling purposes. We are also aware of Pioneer's current appraisal of a range of second hand turbines in the 500kW range for another small wind farm development.

If Joint-Development is the development route selected by the community, it would make sense to combine interests with the development partner in the selection of turbines (for financial advantage in bulk purchase; for technical simplicity in relation to refurbishment and ongoing maintenance; for resource consent ease in presenting one 'turbine package' rather than hodgepodge of different turbines making up a cluster). We are not yet at this stage.

7.4 Modelling Assumptions

For modelling purposes we have used the model of turbine installed at Pioneer Generation's Horseshoe Bend site (NEG Micon, 750kW) as well as a similar (though slightly larger) capacity turbine (Vestas V52, 850kW), and our initial WindFlow 500 choice as comparison.

A single turbine in any procurement scenario will have different upfront costs. Costs are associated with:

1. Market demand (until recently Vestas were in great demand in Eastern Europe, pushing second-hand prices up considerably)
2. Availability
3. Bulk shipping costs
4. Whether it is a 'stand alone' purchase or one of several (bulk purchase)

Similarly, installation costs vary between the 'go-it-alone' single turbine scenario and the joint development scenario, with a clear indication of the cost benefits of installation as part of a cluster.

To maximise power output it is crucial to match turbine performance with the wind profile at any given site. Blueskin Bay has a unique ability to capture both valley winds and sea breezes and in general wind speeds here seldom exceed 25m/s. In this situation preference should be given to turbines with a low cut-in speed since all three of the turbines we consider cut-out at 25m/s or 30m/s. The particular wind characteristics of Blueskin Bay have led to preliminary assessment of two second hand turbines options.

7.5 NEG Micon 750kW

The MICON NM 48/750 has a nominal output of 750kW, a nominal wind speed of 16m/s and a cut in speed of 4m/s, cut out speed of 25m/s, a rotor diameter of 48.2m and a swept area of 1824m^{2}.

7.6 Vestas V52/850kW

The Vestas tubine has a nominal output of 850kW, a nominal wind speed of 16m/s and a cut in speed of 4m/s, cut out speed of 25m/s, a rotor diameter of 52m and a swept area of 2124m2.

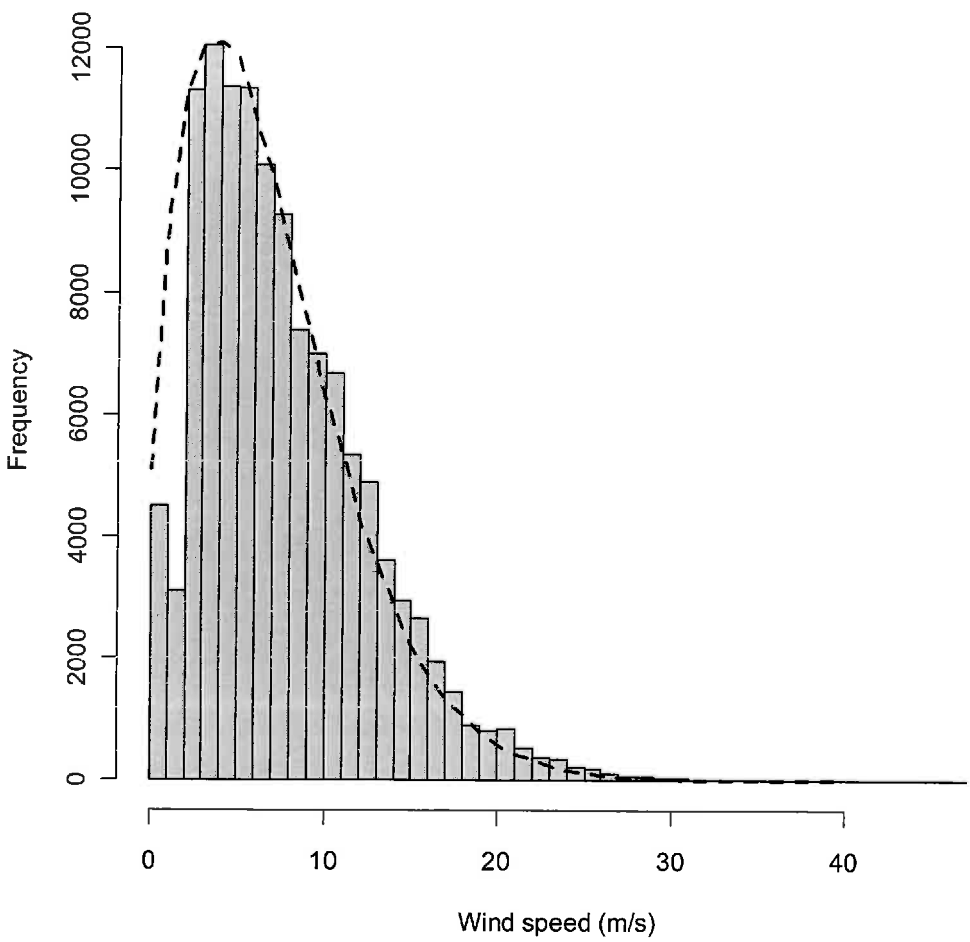
We have modelled the above turbines to enable a realistic assessment of the opportunities available to us. However, under the development scenario with a joint-development partner we will be committed to working with a partner who has greater expertise in the second hand turbine market, and any resource consent application will likely proceed with a single turbine make for simplicity sake. Turbine choice therefore will be made subsequent to a joint development agreement and in the development phase, after resource consent has been granted.

8. Generation Capacity

The capacity of a turbine to generate electricity is dependent on the wind profile and turbine characteristics. In this section the analysis of wind profiles is described, then the power curves for the three turbines, and finally an estimate is made of electricity generated by each of the turbines. Estimates were considered conservative and there are important assumptions underlying them which are included in the appendix.

In this report, data or previous reports describing wind activity at eight sites around Waitati were studied. The sites nearest to Waitati monitored by the GEOG 380 students were not considered very exposed and consequently had low average wind speeds. Because of this, focus was directed to other exposed sites for which data was publicly available from the NIWA CliFlo data base. From this database wind profiles were generated for four sites; Aramoana, Swampy Summit, Taiaroa Head and Mount Cargill.

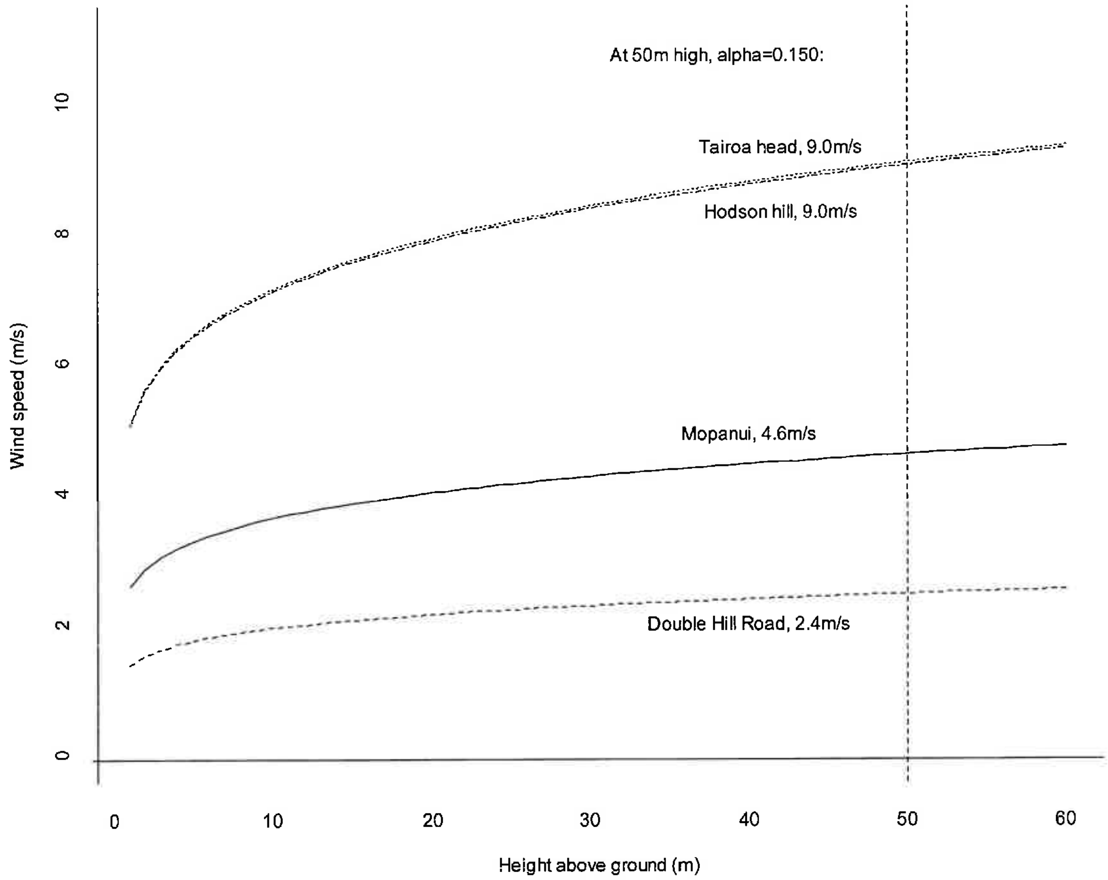
Figure 11 Taiaroa Head (9m AGL) Example Wind speed Distribution



The wind speed at 9m AGL for Taiaroa head and a close fit using the Weibull distribution (dashed line) is shown above as an example of a wind profile.

Wind activity at the 50m above ground level, the assumed hub height of a turbine, was predicted from these wind profiles using the wind profile power law. The general effect of this was to increase the average wind speed as shown for the four locations in the figure below.

Figure 12. Predicted average wind speed at 50m above ground level for four sites near Waitati

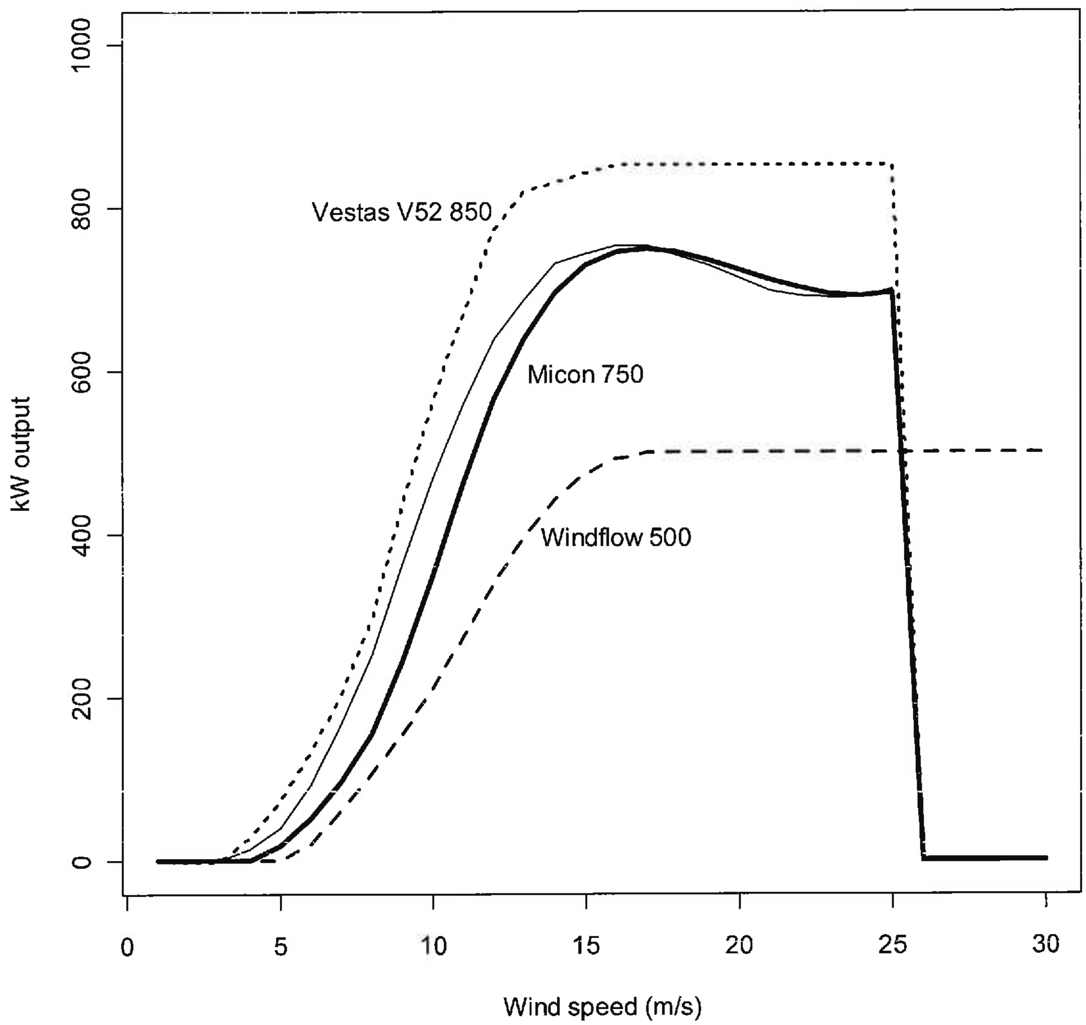


The proportion of hours per year at each wind speed (in 1m/s increments) was determined in the range from 1 – 30m/s.

Power curves for the three turbines were obtained. The power curve for the Windflow 500 was supplied by the manufacturers. For the Micon 750kW turbine, two power curves were compared, one from the Micon promotional brochure and a second from a feasibility study of this turbine in Sri Lanka by Swedish engineering students (Berg et al. 2008). The more conservative of the two Micon curves was used in this study.

The power curve for the Vestas 850kW turbine was taken from the Vestas promotional brochure, available from the web.

Figure 13. Power curve for NEG MICON NM 48/750 wind turbine from MICON technical brochure (thin line) and Berg et al. (2008) (thick line), the Vestas V52 850 (dotted line) and the Windflow 500 (dashed line)



Turbine electricity output was calculated by multiplying the output at a given wind speed increment (taken from the turbine power curve) by the number of hours per year that the wind was blowing at this speed.

The estimates were made in this study for the Micon 750 turbine for each of the four sites and compared with an estimate from the Renewable Energy UK website which has a facility for estimating turbine output, and an estimate for a generic 750kW turbine on a hill near Waitati by Laird (1988).

Table 1. Summary of estimated annual electricity output (GWh) for the Micon turbine for sites near Waitati

Site	Annual output (GWh)	Annual output (GWh) assuming 94% efficiency
Taiaroa head (Berg et al. data)	2.75	2.60
Taiaroa head (website calculation)	5.33	
Hodson hill, typical 750kW turbine (Laird, 1998)	2.97	2.97
Aramoana ridge 1	2.62	2.46
Swampy Summit	2.87	2.70
Mount Cargill	3.40	3.20

Depending on its location, the prediction is that a 750kw turbine would make in the range of 2.4 – 2.7GWh of electricity per year. The prediction is less than the estimate by Laird (1988) of 2.97GWh and much less than the 5.33GWh estimated by the Renewable Energy UK web site.

Three locations considered typical of where a turbine would be located were used to compare the output of the three different turbine types, assuming 94% efficiency and the results are presented in the table below. Not surprisingly the largest turbine is predicted to produce the greatest amount of electricity. The trend was for the 500kW and 750kW turbines to produce about 50% and 75% of the 850kW output respectively.

Table 2. Comparison of annual output (GWh) for three turbine types at selected sites near Waitati assuming 94% efficiency

	Annual output (GWh) assuming 94% efficiency		
Site	Micon 750	Vestas 850	Windflow 500
Taiaroa head	2.59	3.51	1.69
Aramoana ridge 1	2.46	3.40	1.55
Swampy Summit	2.70	3.66	1.73

In conclusion, the electricity generated by a community turbine for Waitati will depend on its size and location. Several preliminary estimates are provided here for three different types of turbine at three relevant locations. These estimates can be refined in future based on the final site and turbine performance characteristics.

9. Infrastructure Requirements and Implications

9.1 Infrastructure Requirements

As parameters for this PDGP have evolved, so have the infrastructural requirements. The existing local grid can incorporate a single Windflow 500 turbine as per the initial conception, however network managers will need to look more closely at clusters of larger machines. The potential site between Porteous and Pryde Roads and 33 kV connection to the network may provide a simple and elegant answer to a larger generation cluster.

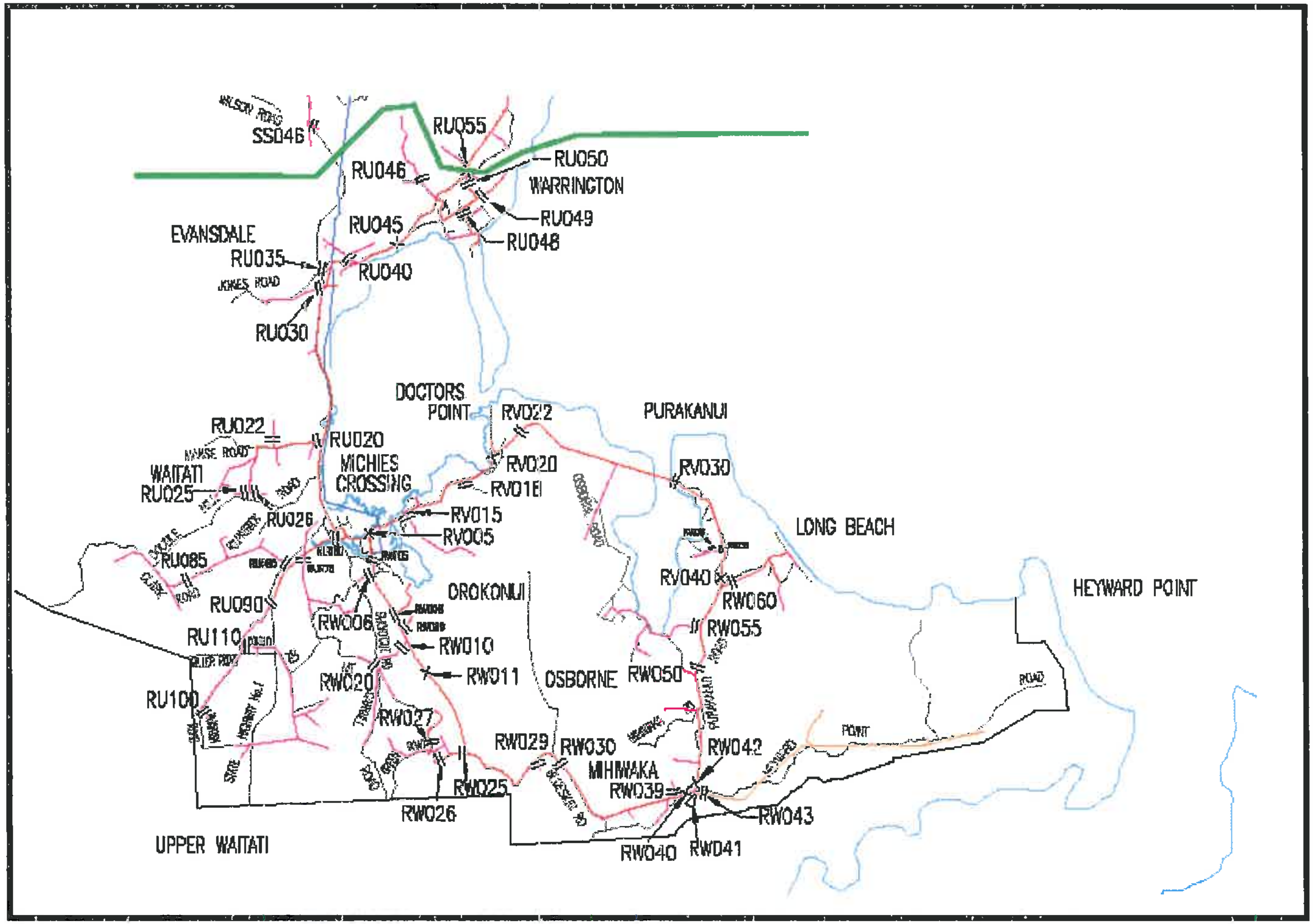
The electrical distribution system around Waitati consists of a main 33,000 Volt sub transmission line bringing power from Palmerston, through Waikouaiti and on to Waitati. At the Waitati zone substation there is a single transformer to reduce the voltage to 11,000 Volts for distribution around the local Waitati area. This transformer automatically adjusts the voltage to hold it at 11,000 Volts and has a capacity to transform 2,500 kW of energy. From the Waitati zone substation there are three 11,000 Volt feeders going to: (1) Waitati and Warrington, (2) Doctors Point Road and on to Purakanui and (3) Heywards Point via Shortcut and Blueskin Roads. Along these feeders there are smaller transformers to finally reduce the voltage to 230 Volts for use in the houses and businesses.

The plan below (Fig 14) shows the area supplied from OtagoNet's Waitati substation. The dark blue line is the 33,000 volt sub-transmission line from Transpower's Palmerston substation leading to the Waitati substation. The green line marks the (usual) boundary between Waitati's and Merton's substation supply area (Merton substation is located near Hawksbury Estate).

Three 11,000 volt distribution feeders from Waitati going to the following areas are identified by code in (brackets), i.e.: Warrington (RU), Doctors Point (RV) and Heyward Point (RW). Each feeder can be traced by the isolation point numbers which start with the feeder codes. For example RV040 is a switch near Purakanui, and marks the point where the ends of the Doctors Point and Heywards Point feeders meet. RV040 is usually open so the two feeders are independent. Similarly RO055 is normally open to keep Waitati and Merton substations independent.

Red, pink & orange lines are 11,000 volt distribution power lines; red lines are three phase (three wires), pink lines are single phase (two wires), and orange lines are single wire earth return lines.

Fig 14 Waitati 11 kV Switching Diagram – with switches and fuses and limit of the lines fed from the Waitati zone substation

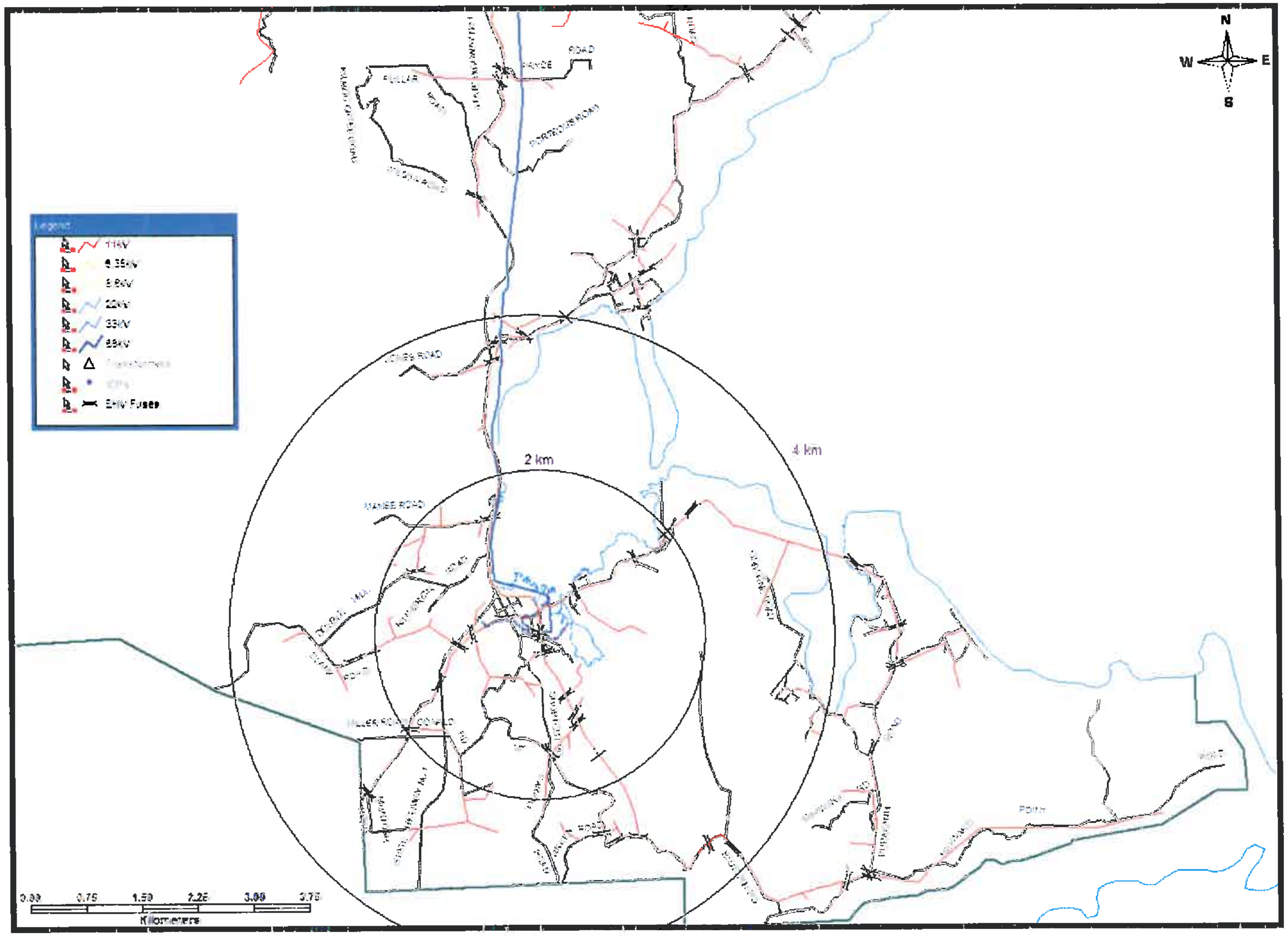


Wind turbines come in varying sizes and it is likely to be more economical to cluster a number of them on one site to share other infrastructure costs like access roads, control buildings, the electrical connection to the network and resource consents. It is most economical to connect a wind turbine or cluster to an existing 11,000 Volt line and to minimise the length of new or reinforced line required. Each turbine will have its own transformer to step up its generating voltage to 11,000 Volts and will likely be connected by underground cable to the end of the overhead line at a suitable point. A connection to the local 11,000 Volt lines should also minimise the expense of the metering and protection and will ensure that the power generated goes to the local community. However there will be limitations to the size or number of clustered turbines that can be connected without compromising the voltage and quality of supply experienced by the local houses also connected to the same 11,000 Volt lines.

Figure 15 below is the local Waitati electrical network diagram showing the 11,000 Volt distribution lines in red and the 33,000 sub transmission line in blue. The distance rings are 2km and 4km out from the Waitati zone substation to show the approximate radial length of 11,000 Volt line from the zone substation. This will give a geographical indication of the network's ability to connect large wind turbines or clusters. For assessing the potential sites for wind turbine size it can be assumed that within the 2km radius generation of up to the zone substation transformer capacity of 2,500 kW could be connected to the 11,000 Volt lines. Between 2 and 4 km the limit would be less than 2,000 kW and beyond 4 km it is unlikely that more than 1,000 kW of wind turbines could be connected to the existing 11,000 Volt lines. The actual limitation would need to be modelled more accurately and will depend on the turbine type and its control system as well as the line length and size.

To generate more than the above amounts would normally require a higher connection voltage of 33,000 Volts or replacement of the existing 11,000 Volt lines with much heavier wires. There is however an option to connect a larger wind turbine or cluster directly to the 33,000 Volt line between Waikouaiti and Waitati, see the blue line on figure 1 below. A connection to this line could take up to 5,000 kW of wind turbine energy with most of the power flowing on to Waitati and any surplus flowing back towards Waikouaiti at times of low load or high generation. Connecting to this existing line at 33,000 Volts may not be a great deal more expensive than a 11,000 Volt connection and will certainly be cheaper per kW for the larger installation. A 33,000 Volt connection has the advantage for the distribution network and local customers, as the fluctuations in the wind turbine output power will have a reduced effect on the voltage at each house in Waitati, which would otherwise limit the size of the wind turbine on the 11,000 volt lines.

Fig 15 Waitati 11 kV & 33 kV lines and Distance from Waitati Substation



9.2 Implications for the Local Grid

The OtagoNet electricity network has the greatest line length per customer of all the electricity networks companies in New Zealand, mainly because of the Otago geography with many long valleys, obstructing hills and generally small population numbers in the widely spaced rural towns (Dunedin city is not included in OtagoNet). Because of the long and light electrical lines there are considerable costs per customer to maintain and improve the network and quality of supply, resulting in some of the highest line charges in the country.

With truly distributed generation, where local loads are matched and fed by local generation, there is the opportunity to reduce the need for line reinforcement as loads grow and greater reliability is demanded. Electrical losses in transmitting power large distances from remote generators would also be reduced by local generation, with a reduction in the energy delivery cost. The network may eventually only be required to balance the power flows and provide a small back up when some of the generators are not working.

The ultimate distributed generation model would have a mix of energy sources to ensure a constant input of energy to match the loads and reduce the overall reliance on the network to provide the backup or peak power. With reduced peak power flows the need for expensive line upgrades is removed, ultimately resulting in lower network costs. The wind turbines proposed for Waitati will be the start of this process, but being the first and a single installation their output will be variable and while not supported by other diverse generation there is unlikely to be any reduction in the network costs. A larger number of smaller and more diverse generators would be required to achieve measurable benefits for the distribution network, in the mean time the network still has to be maintained to provide a reliable electricity supply to the area.

10. Financial Viability

We have prepared a 15 and 20 year discounted cash flow model to estimate the expected rate of return on the project. The model is based on a single turbine project, but can be used to model multi-turbine projects equally well.

The model takes into account the current corporate tax rate, depreciation rates for wind turbines and depreciation tax shields. Straight line and diminishing return depreciation scenarios are modelled, although there is no material difference between the expected rates or return under each of these scenarios.

The model rests on a number of key assumptions relating to:

- The price received for electricity generated
- The installed cost of the facility
- The wind profile (mean wind speed and curve shape) of a site, and associated energy production
- The annual operating costs of the facility

Sensitivity analysis around these assumptions has also been undertaken

Revenue projections are based on the current wholesale price of electricity and projected real changes in wholesale electricity prices from 2010 to 2030, using a projection model prepared by the Ministry of Economic Development. Efforts were made to predict real changes in wholesale electricity prices based on a statistical analysis of wholesale prices over the last decade from data publicly available from the Electricity Commission and from data provided by Energy Link (see Appendix II). The results of this analysis clearly demonstrated that prices could not be predicted with any degree of certainty. Consequently, the predict scenarios provided in the model from the Ministry of Economic Development were considered the most cost effective available.

Models have been prepared based on projected output from the Windflow 500, Micon 750 and Vestas V52 850 turbines. It must be noted that, at this stage of the project, the purchase, transport and installation costs of these turbines are not known with any precision and these cost elements are indicative at best. The purpose of building the models has not been to definitively establish the expected rate of return of investing in a PDGP, but rather to create a framework for testing financial viability and return on investment as firmer financial data becomes available.

Taking the Windflow 500 turbine as an example, if a total cost of purchasing and installing the turbine and connecting it to the local grid is $1.4 million dollars, the sale price of electricity generated is 9c/kWh and the mean wind speed at the installation site is 7.6 m/s, then the projected real Internal Rate of Return (IRR) on the investment would be a very modest 2.3% (NPV = -$69,000). If, however, the mean wind speed is 8.8 m/s, the projected IRR increases to 5.1%, and at 10.57m/s it rises to 8.7%. Clearly, the financial viability of the Windflow 500 is very sensitive to mean wind speed. As the following sensitivity analysis shows, it is also sensitive to operating costs and electricity prices.

Windflow 500 Scenario Analysis

Wind Speed	NPV
Taiaroa Head: 7.6m/s, Weibull K=1.55	**-$69,942**
Aramoana ridge 1: 8.8m/s, Weibull K=2.1	$302,679
Mount Cargill: 10.57m/s, Weibull K=2	$841,002
Swampy Summit: 10.7m/s, Weibull K=2	$875,507

Annual O&M Expense	NPV
$5,000	$98,166
$10,000	$42,435
$15,000	-$13,675
$20,000	**-$69,942**
$25,000	-$126,476
$30,000	-$183,408
$35,000	-$240,671
$40,000	-$298,333
$45,000	-$356,458

Initial Electricity Price	NPV
$0.070	-$360,261
$0.075	-$286,674
$0.080	-$213,817
$0.085	-$141,605
$0.090	**-$69,942**
$0.095	$1,275
$0.100	$72,157
$0.105	$142,750
$0.110	$212,966
$0.300	$2,800,891

In contrast, if the total cost of purchasing and installing a second hand Micon 750 turbine and connecting it to the local grid is $1.24 million dollars[1] then, holding other input factors constant, the IRRs for mean wind speeds of 7.6 m/s, 8.8 m/s and 10.57 m/s are projected to be 10.0%, 14.6% and 18.5% respectively. These much higher IRRs are achievable because the Micon 750 produces about 50% more output at a given wind speed than the Windflow 500 and has a broader power curve more suited to the wind profile at tested sites. The projected returns from the (second hand) Micon are, however, partially lowered because they are modelled on a 15 year life rather than the 20 year life of the Windflow.

Micon 750 Scenario Analysis

Wind Speed	NPV
Taiaroa Head: 7.6m/s, Weibull K=1.55	**$698,438**
Aramoana ridge 1: 8.8m/s, Weibull K=2.1	$1,228,730
Mount Cargill: 10.57m/s, Weibull K=2	$1,724,699
Swampy Summit: 10.7m/s, Weibull K=2	$1,753,965

Annual O&M Expense	NPV
$5,000	$827,703
$10,000	$784,702
$15,000	$741,678
$20,000	**$698,438**
$25,000	$655,198
$30,000	$611,958
$35,000	$568,718
$40,000	$525,394
$45,000	$481,888

Initial Electricity Price	NPV
$0.070	$293,626
$0.075	$395,304
$0.080	$496,675
$0.085	$597,638
$0.090	**$698,438**
$0.095	$798,991
$0.100	$899,281
$0.105	$999,266
$0.110	$1,098,035
$0.300	$4,846,811

Similarly, the projected IRRs for a Vestas 850 at mean wind speeds of 7.6 m/s, 8.8 m/s and 10.57 m/s are 10.4%, 15.1% and 18.9% respectively. This is based on a total cost of purchase and installation of $1.42 million and a turbine life of 15 years.[2]

1 Estimate based on purchase price $480,000, dismantling $60,000 and shipping $200,000
2 Estimate based on purchase price $660,000, dismantling $60,000 and shipping $200000

Vestas 850 Scenario Analysis

Wind Speed	NPV
Taiaroa Head: 7.6m/s, Weibull K=1.55	**$795,603**
Aramoana ridge 1: 8.8m/s, Weibull K=2.1	$1,376,583
Mount Cargill: 10.57m/s, Weibull K=2	$1,900,814
Swampy Summit: 10.7m/s, Weibull K=2	$1,931,530

Annual O&M Expense	NPV
$5,000	$917,722
$10,000	$877,015
$15,000	$836,309
$20,000	**$795,603**
$25,000	$754,897
$30,000	$714,055
$35,000	$673,109
$40,000	$632,164
$45,000	$591,218

Initial Electricity Price	NPV
$0.070	$341,796
$0.075	$455,794
$0.080	$569,322
$0.085	$682,634
$0.090	**$795,603**
$0.095	$908,303
$0.100	$1,020,379
$0.105	$1,131,151
$0.110	$1,241,885
$0.300	**$5,449,789**

10.1 Feed-In-tariff Scenario

In addition, the model can be used to test the viability of a PDGP if government incentives such as feed-in-tariffs are implemented to encourage smaller scale community based wind farms. For example, in the above scenario analyses, we have included an electricity price scenario based on a feed-in-tariff of 30c/kWh. Under this scenario, a single turbine facility is projected to be highly profitable (and attractive to potential investors). Even at a models mean wind speed of 7.6 m/s, the projected with IRRs for the Windflow 500, Micon 750 and Vestas 850 are 19.4%, 39.3% and 41.1% respectively. Please note, we have used figures directly from an existing local feed-in tariff agreement between a major generator/retailer and a single household and extrapolated this agreement to the community turbine proposal for modelling purposes.

11. Operational Models

Our investigations to date have identified two operational models that we believe are worth exploring in more detail. The first involves a "go it alone" approach whereby the community co-operative develops and operates a single turbine facility, including managing the sale of output into the wholesale electricity market. The second involves forming a joint development operation with a partner who has experience and expertise in wind turbine operation as well as the wholesale electricity market.

11.1 Go it Alone Model

The first model had been our initial preference as it fits most comfortably with our vision of a community owned and controlled distributed generation facility. However, we recognise that there are a range of difficulties with this model that make its viability questionable. These include:

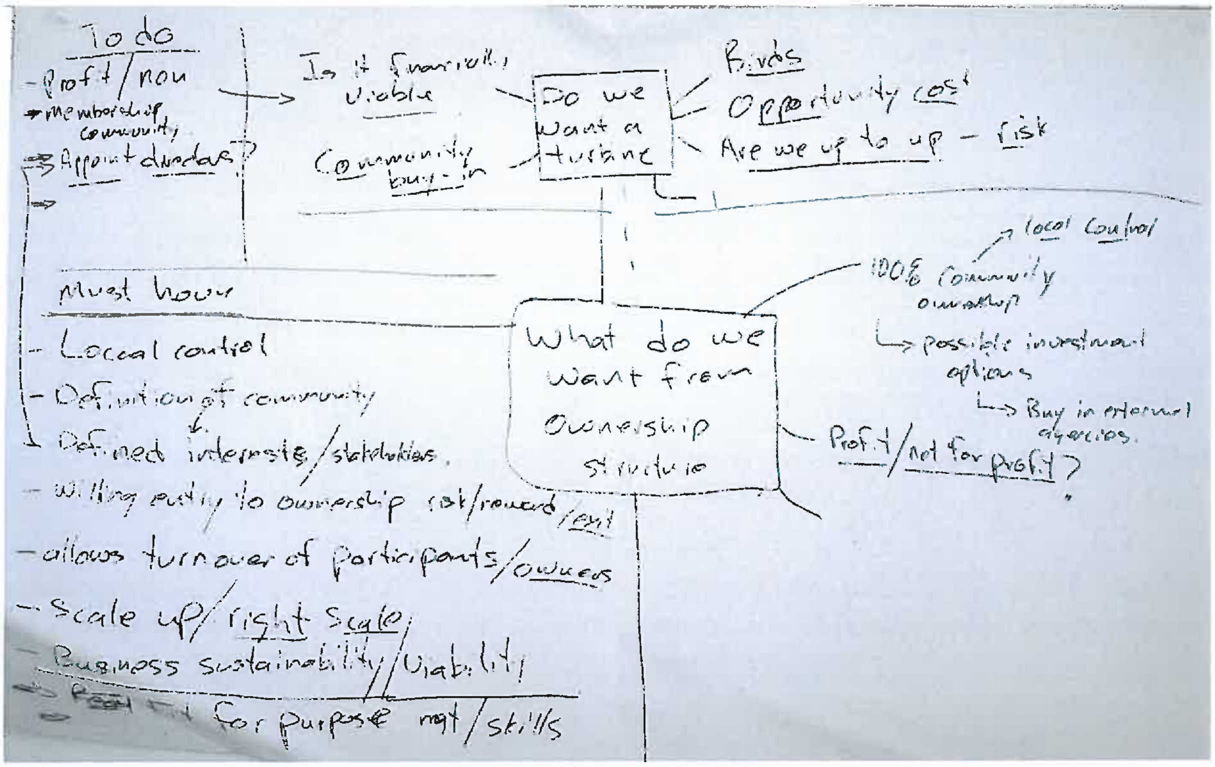
- Infrastructure costs – there are high (per unit) infrastructure costs associated with a single turbine facility
- Volatility risk – there is a high level of risk associated with volatility of electricity prices in the spot market and the output of a single turbine facility
- Expertise and systems – the development and operation of a wind turbine facility entails a level of expertise and management systems that the BRCT does not possess and would need to be secured from external parties.

11.2 Joint Development Model

The second model, a JD approach, has the potential to successfully address the difficulties associated with a "go it alone" model. Key features of the JD model are:

- Instead of developing a single turbine operation, a small wind cluster with, say, three or more turbines is developed.
- One of these turbines is owned by the community co-operative and the remainder are owned by the JD partner.
- Each turbine owner is responsible for the cost of constructing and maintaining the turbine(s) they own and each receives the revenue for the sale of electricity generated by the turbine(s). Hence, the output of each turbine is metered separately to allow revenue to be split between owners.
- Each JD partner pays a share of the costs of developing shared infrastructure associated with the development (eg, access, site preparation, metering, cabling upgrades and connection to the local network etc)
- The revenue from each JD partner is top sliced to pay for any shared operational costs in proportion to the number of turbines they own.

- Ideally, one of the JD partners is a generator who is capable of managing the process of selling the output of the wind cluster on the wholesale electricity market.



2009 Synergia Workshop, storyboard of workshop turbine ownership discussion. *Nick Holmes/saltwaterimages, 2009*

12. Ownership and Governance Models

We have a preference for a community co-operative ownership and governance model adapted from similar models developed in Denmark. The Danes have a long history of co-operative ownership of wind turbine generation facilities that provide examples of successful models that could be adapted to New Zealand. Danish co-operatives often take the legal form of partnerships, but operate under rules that resemble those of a co-operative. This could also be the case in New Zealand.

The most suitable alternative to a co-operative structure would be the formation of a limited liability company. A company would provide the simplest and most flexible option as it would eliminate the need to create a transactional relationship between shareholder and the company.

12.1 Ownership

The essence of a company or co-operative model is that a fixed number of shares are issued to raise the capital needed to build the facility. The total value of the issued shares is sufficient to meet the estimated capital requirements for the project.

Rules and arrangements will need to be established to address a number of issues associated with this approach including:

Eligibility: Rules will need to be established to determine who is eligible to purchase shares in the company/co-operative and how many shares each member is able to purchase. This could entail restricting the right to purchase shares to residents in a defined geographical area (eg a network area or the Blueskin Bay area). In a co-operative model, shareholders will also have to commit to purchasing electricity from a retailer nominated by the co-operative (see section 11.2 below).

Trading shares: Rules will need to be established on how shares are able to be traded and the process for establishing the value of traded shares. Any such rules will need to be consistent with eligibility rules.

Distribution of profits: Rules will need to be established on how profits or rebates will be distributed to members.

Other operational risks: Rules may be needed that require the company or co-operative to carry adequate insurance against major risk events.

Under-subscription: Contingencies must be established to deal with the possibility that there is insufficient support in the local community initially to raise the capital required for the development. If this occurs, options include:

- Extending the time available to raise the required capital
- Loosening the eligibility criteria so that ownership is not restricted to residents within a defined community, or allowing residents in the community to own more shares than originally provided for (ie. Allow unequal share holdings).

- Opening membership to other types of entities (eg, electricity generators, local authorities, other corporate entities)

It may also be possible to come to an arrangement with a JD partner for them to underwrite the issuing of shares to the community, so that they assume ownership of any unsubscribed shares, at least in the short term until a higher level of community ownership can be achieved. This may be an attractive arrangement to a JD partner if it expedites the construction of the development.

Financing: One of the barriers to raising the required capital may be that there are community members who wish to purchase shares in the co-operative, but lack the funds to do so. An underwriting arrangement with a JD partner may reduce this barrier.

12.2 Transacting Shareholders

Co-operative structures require transacting shareholders - shareholders who supply goods or services to the co-operative or purchase or use goods and services provided by the co-operative. In order to register as a co-operative, the directors must complete a statutory declaration that the company will be a co-operative within the meaning of the Co-operative Companies Act 1996, and this includes having a transactional relationship with shareholders.

Based on advice received from Alan Robb, an independent expert on co-operatives, we believe we can satisfy the requirements for a co-operative using the following process.

- The members subscribe capital (according to a formula to be decided upon).
- That capital - plus any borrowings - is used to construct a facility.
- As long as the members are then supplied with electricity from the facility they are transacting shareholders who are using the services the co-operative supplies.

As we are not proposing that the co-operative runs a retail operation, to create a transactional relationship with members, the co-operative will need to arrange to sell its output to one of the main electricity companies and members will need to agree to buy all their electricity from that company through the co-operative. In this way, the amount received for the power generated by the co-operative could be rebated to members in proportion to the amount of power they buy from the co-operative.

12.3 Governance

Governance is provided via a Board of Directors that is elected by shareholders. This Board may contain co-operative members but may also contain independent directors with specialist expertise useful to the company or co-operative. Typically, in a co-operative situation, when electing the Board or voting on matters of major importance, shareholders have one vote each, rather than in proportion to the number of shares they hold. In a company structure, shareholders typically have one vote per share, although different classes of shares could be created that do or do not carry voting rights

Further community consultation will need to be undertaken to establish a structure and associated rules relating to ownership and governance that are acceptable to potential members.

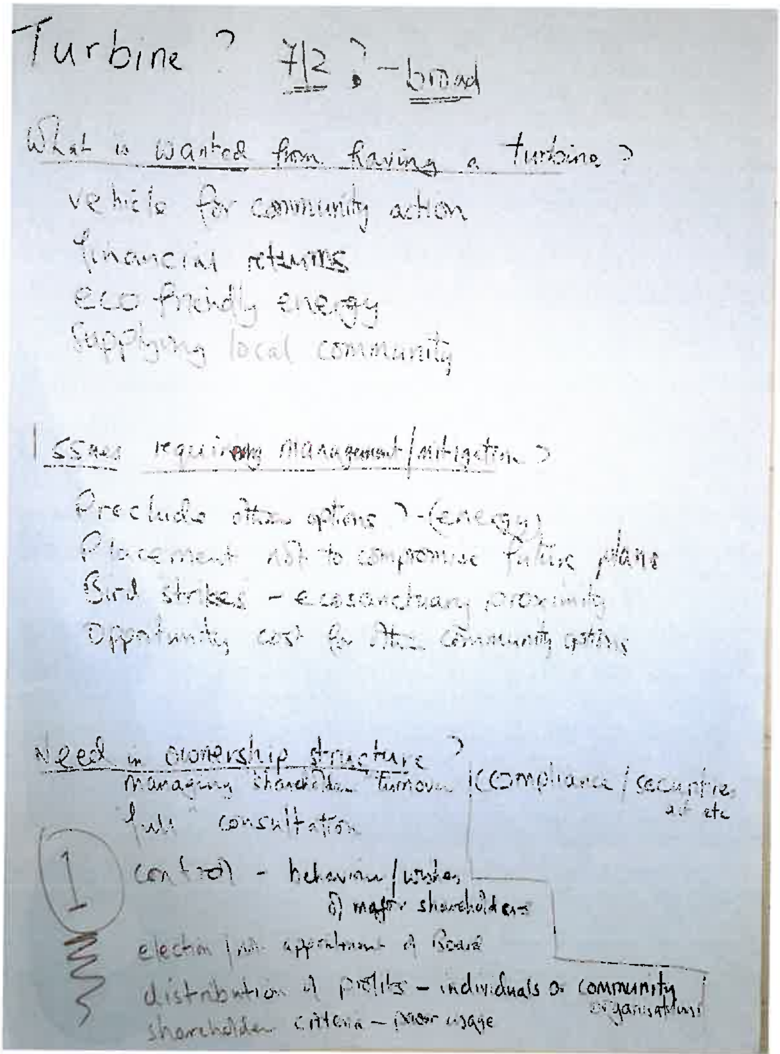
2010 Waitati Energy Project field trip to Horseshoe Bend. Peter Dowling, Chief Executive of Pioneer Generation, explains the Horseshoe Bend project.

Nick Holmes/saltwaterimages, 2010

13. Consultation, Planning and Resource Consents

13.1 Relevant Planning Considerations

As part of the WEP (Blueskin Power) project, the Blueskin Resilient Communities Trust (BRCT) is exploring the relevant planning considerations in relation to any future resource consent application for the construction and use of wind turbines on selected sites in the Blueskin Bay and Waitati areas of Dunedin City.



2009 Synergia Workshop, storyboard of workshop turbine desireabiity discussion. ***Nick Holmes/saltwaterimages, 2009***

As previously indicated, the proposed site areas for the turbines all fall within the Rural Zone of the Dunedin City District Plan. An application for wind turbines is expected to require a resource consent for a non-complying land-use activity.

The Dunedin City Council are expected to require appraisal and evaluation on such things as:

- The visibility of any structures, assessed from different vantage points
- How any potential adverse effects on the landscape can be managed
- Any impacts of the turbine project on important landscape features, and whether a single or several turbines are compatible with the surrounding landscape
- The impacts on the rural amenity, and on existing rural activities, including views from public viewpoints

Rosalind Day, Planning Consultant, recommends that BRCT (or a specific legal body established to manage project development) undertake pre-application consultation with the City Council as soon as is practicable to identify any potential issues and difficulties and to obtain an indication on how the application may proceed through the consent process.

13.2 Community Engagement Strategy

The WEP (Blueskin Power) Project involves a number of distinct planning phases and as such requires a robust structure and framework by which to engage the local community throughout the process, key stakeholders and the Dunedin City Council.

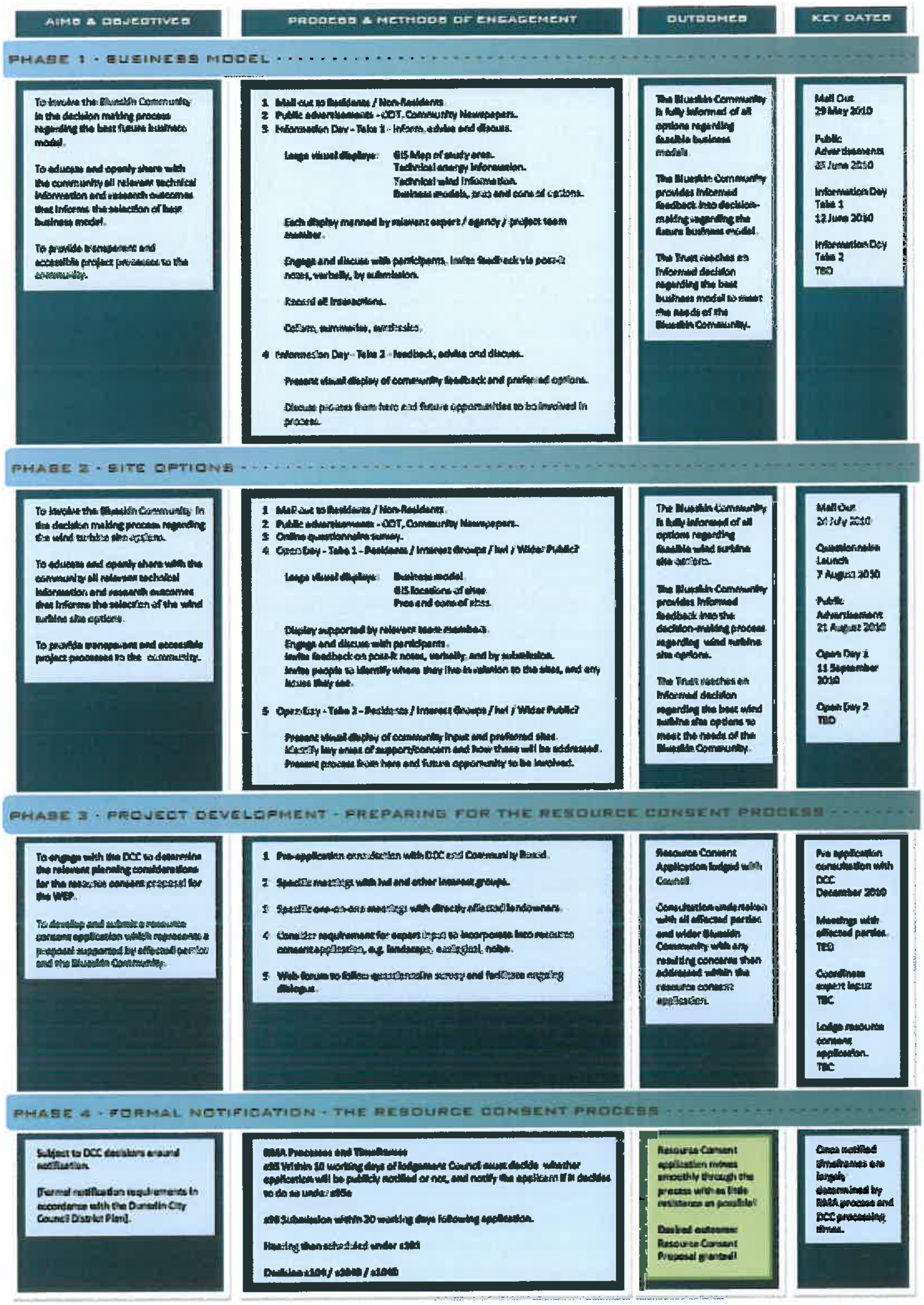
A draft engagement strategy is presented in Figure 16 below.

The strategy outlines four distinct phases and associated methods of engagement, desired outcomes and key dates.

It is critical to meaningfully engage the Blueskin Community with decisions around the preferred business model and site options for the wind turbines. The attached strategy suggests a process and methods to achieve this in Phases 1 and 2. These constitute important stages in the Roadmap to Development for the community turbine.

It is equally important for BRCT to be anticipating any potential resource consent matters in relation to the proposed turbine sites, and to also manage the relationship with the Dunedin City Council via liaison and dialogue early on the process. The following strategy diagram sets out a process to formally achieve this and indicates key planning considerations in Phases 3 and 4.

Figure 16 Engagement Strategy



14. Contractual Agreements

In the latter part of the feasibility stage, and on the cusp of the development stage, we anticipate achieving greater formality in contractual agreements than is presently the case.

Current contracts with EECA and Polson Higgs Business Advisors concern the delivery of this feasibility study. Agreements with the University of Otago are intended to ensure academic IP exectations are maintained and community needs are respected. MoUs with landowners provide the basis for site testing and initial relationships should any site become a firm favourite. The MoUs with Rosalind Day and PowerNet ensure respect of each parties' needs while maintaining goodwill in this early stage. The confidentiality agreement with WindFlow Technology is intended to ensure no commercially sensitive information enters the public domain without both parties' agreement.

Formalisation of existing contractual agreements or establishment of new contractual agreements particularly with industry partners will become necessary as we move out of the feasibility stage and into development. Formal or semi-formal partners and their contract status are shown in the following table:

Partner	Contract Status
Marie and Graham Bennett, landowners	Existing MoU, with updated MoU pending
Sarah Rennie and Joy Rudland, landowners	No contract at this stage
Bob and Viv Adams, landowners	MoU under preparation
Dunedin City Council	No contract at this stage
Alice Bowden, University of Otago	Existing MoU
Otago Energy Research Agreement	Existing MoU
Rosalind Day, Planning Consultant	Existing MoU
Polson Higgs	Contract to deliver EECA report with BRCT fulfilled (19th April 2010)
PowerNet, Regional Grid Managers	Existing MoU
WindFlow Technology Ltd	Confidentiality Agreement
Pioneer Generation, Generation Company	MoU under development, Joint Development Contract being considered
EECA	Contract to deliver feasibility report, due 19th April 2010

15. Roadmap to Development

The investigation to made has made good progress in creating an understanding of the potential to develop a community owned sustainable generation facility in the Blueskin Bay area.

Early feasibility analysis suggests that there is a viable wind resource in the area and that there are industry partners who can assist in the complex process of developing and operating such a facility. There remain, however, a large number of steps to be taken before such a vision can become a reality. While the following roadmap will undoubtedly be subject to change, we envisage the major future steps to include:

- Presenting the findings to date back to the community for their consideration and mandate to proceed further
- Exploring a joint development option with potential partners such as Pioneer Generation
- Continuing to gather more accurate data on the wind resource characteristics at selected site
- Refining the financial modelling using more accurate financial and wind resource data to establish the relative viability of different possibly configurations that will vary according to the following parameters:
  - Site (wind resource profile), cost of access
  - Turbine type – purchase, installation and operational costs, output
  - Operation type - go it alone v joint development
  - Number of turbines
- Establishing a preferred operational and ownership structure
- Securing access to sites from land owners with contractual agreement
- Raising funding for the venture – grants, investment capital, loan finance
- Community consultation and resource consent process
- Construction and operation of the facility

It will not be possible to proceed down this path without further seed funding that can take the project to the point where there is sufficient certainty and clarity to "go to the market" to raise capital to proceed with the venture. Notwithstanding the essential funding provided by EECA, to date the project has relied heavily upon the voluntary input and good will from a large range of individuals and organisations. While that good will remains, it cannot be relied upon to provided all the resource needed to take the project to the point where investment capital can be obtained from the local community and other sources.

16. Replicability of the Proposed Distributed Generation Project (PDGP)

16.1 Our specific situation

At the inception of the Waitati Energy Project (WEP) in 2007, the obstacles to establishing a community owned wind turbine were only hazily appreciated. And if passion was all that in needed to build a wind turbine, we'd have had constructed one already. Intuitively, pragmatically, and on the resource base of volunteer time however, the WEP's first strategies were to engage with the 'black box' of energy consumption: changing energy behaviour, or otherwise described as increasing 'energy literacy'. Being 'in' and 'of' the community this approach paid dividends throughout 2008, reflected in a survey of household energy use conducted by the University of Otago towards the end of 2008. Informal discussions with a range of supporters on the potential to establish community generation in conjunction with energy efficiency and conservation strategies continued through this time, until early 2009, with several possibilities being explored (pre-feasibility).

By early 2009 a substantial body of work had been achieved by the WEP and the WEP co-ordinator had moved from being a volunteer (October 2007 – November 2008) to a paid employee of the Blueskin Resilient Communities Trust. On the basis of the history of community accomplishments and ongoing energy action (notably being the public face of a $780 000 EECA insulation retrofit pilot in early 2009), the WEP co-ordinator's job was first consolidated with further funding, and then expanded through sponsorship offered by the Hikurangi Foundation.

Shortly prior to Hikurangi's sponsorship, a research offer from the University of Otago opened the door to examining the feasibility of a local wind turbine (wind measurements), and the WEP's turbine initiative began (what has become 'Blueskin Power').

16.2 'Community' owned Distributed Generation?

Each community will inevitably follow its own trajectory towards local embedded generation at least in the early stages. However one particular element we believe is the key to understanding how community owned distributed generation projects are likely to unfold, and that is self-evidently 'community'.

From the beginning, the WEP responded to enthusiasm from community members towards developing greater energy resilience. Yet it is a great step from enthusiasm to the structure and mechanisms necessary to a Proposed Distributed Generation Project (PDGP). How can we identify our community, ensure support and commitment to what will inevitably be a substantial task?

We began with 'assuming' a geographical community, backed up by an extensive subscriber email list from within that community, and vigorous participation in meetings (passion). That has evolved into a wider geographical community, loosely united under such identity banners as 'Blueskin Bay residents', 'Transition Town' and 'local WEP supporters', and more mechanically connected by a precise section of the local grid distinguished by the Waitati sub-station. This is a community of local individuals and households.

Another obvious functional community example from our perspective is the Pioneer Generation example, a small South Island generation company and electricity wholesaler "100% owned by a charitable trust, Central Lakes Trust. Beneficiaries of the trust are the ratepayers of the old Central Electric franchise area". Pioneer Generation is we believe a singular example and the result of key decisions made by the then Central Electric Ltd in 1999 at a strategic moment in the market orientated restructuring of New Zealand energy sector (the Electricity Industry Reform Act 1998 obliged power companies to divest either their energy or their lines business). Community capture of this nature (of existing generation assets) are unlikely to be repeatable in our opinion.

Our attempt to build and own a new community generation project is not the only attempt. Harbour Wind, on Banks Peninsula for example has a parallel goal and is community-led.

16.3 General steps in our process and Timeline

In the table below we have attempted to distil the specific elements that have enabled our success to this point:

Step	Effect
Formation of a broad based energy group within community	Consensus as process and integrated thinking incorporated into the initial structure
Energy Literacy events	Increasing awareness of energy issues within the wider community
Establishing key relationships	Anchor initiative in objective external structures
Local Publications	Energy issues maintained in the public eye and possibility of informal public forums enabled (informal networks)
Discussions with grid managers	Establishment of a crucial working relationship
Discussions with landowners	Initial site prospecting begun
Formation of legal body	Professionalisation of initiative through legal bodies
Employment of Staff	Ability to secure strategic outcomes to clear timeline
Regular community meetings	Ongoing informal community consultation
Approaches to development partners	Expert assistance in elaboration of initiative (feasibility)
Community wind turbine strategy workshop	Richer, deeper community engagement and input
Development of project feasibility	Provides footing and roadmap to begin development

Below we set out key moments/actions that have led us to the cusp of development.

Timeline

2006

- Community workshop on strategic visioning (with Sue Kedgeley)

2007

- Community core established (volunteers)
- MoU with Otago Energy Research Centre established
- Energy Expo held
- Otago University PLAN 438 students undertake community planning project
- 12 month strategic plan developed
- Monthly community column established

2008

- First key relationships established (Otago Energy Research Centre, Powerhouse Wind, Energy Efficiency and Conservation Authority)
- SMF Funding application (declined)
- Public meeting with Jeanette Fitzsimons
- Community Initiative: Home Energy Rating Scheme Audits, for 21 community households (sponsored by EECA)
- Website established (www.transitiontowns.org.nz/waitati)
- Sponsored Energy Information Event for community
- 2008 Energy Expo
- Student study into community attitudes to small wind
- Household Energy Use Survey conducted by Otago University
- Formation of Charitable Trust (October)
- Employment of Waitati Energy Project Co-ordinator (December)
- Strategic plan assessed, next 12 month strategic plan developed

2009

- Facilitation of Powerhouse Wind turbine prototype testing at household site in community
- SMF Funding application (declined)
- EECA sponsorship of community insulation initiative (WEP Retrofit Rollout, 2009)
- First landowner contract signed
- Otago University GEOG380 students undertake initial site testing
- Key worker funding secured for 12 months (Hikurangi Foundation)
- Otago University MSc student undertakes rich wind profile assessment
- Contracts established with WindFlow Technology (turbine manufacturers), PowerNet Ltd (Grid managers), OU MSc student, Planning Consultant
- Synergia workshop on community turbine (sponsored by OERC)
- EECA funding of feasibility report
- Contract with Polson Higgs Business Advisors to deliver report

2010

- Strategic plan assessed, next 12 month strategic plan initiated
- New industry relationships established (Pioneer Generation, Energy Link, Trustpower)
- Community field-trip to Pioneer Generation's Horseshoe Bend operational turbine site
- Completion of feasibility report for EECA (19th April 2010)

16.4 Replicability

Replication of this PDGP should indeed be possible. Our example however exposes a dilemma we and any other community seeking to recreate our example face. There is no supportive policy environment in New Zealand for this type of initiative. A regulated feed-in tariff does not exist, which in turn ensures all real power as well as electrical power essentially remains with the five major electricity generators in New Zealand: Meridian Energy, Contact Energy, Genesis Energy, Mighty River Power and TrustPower. These five dominate and in practice (and in absence of government regulation in favour of distributed generation) control generation.

Our solution in this restrictive context will be to sell our energy through another party at reduced rates. We will be obliged to negotiate from a position of relative powerlessness, however we do have one ace up our sleeve: our hearts and minds and our landscape combined. This full report provides an example that can be adapted to different specific situations and below is given a summary of the 5 key elements we believe are necessary to replicate this project within current constraints:

1. A core passionate and dedicated steering group with broad community support and clear target community
2. External mentors and assistance
3. Funding
4. Good working relationship with key industry: grid managers and industry partner to enable secure returns from electricity market participation
5. Contract with Joint-Development partner

Obviously the most crucial element that would enable the replication of this PDGP is establishing the quantity and quality of energy asset potentially available. Within the current policy context however, a strong community drive is also a crucial ingredient. Community ownership implies a different emphasis than other renewable generation projects and must necessarily involve broader considerations than whether there is enough wind resource available.

17. Discussion of Barriers and Policy Constraints

17.1 Market Reform

2010 has witnessed a 'step-change' in wholesale electricity prices, with spot prices rising from abruptly from around $50/MWh to around $100 - $120/MWh at one point, while the southward flow in early 2010 on the Cook Strait link was greater than past trends, given that electricity storage (hydro lakes) are in the South Island. Now that South Island storage is being spilled, spot prices have dropped to around $70 - $80 a MWh, but may not reflect the full reality of generation.

There seems little doubt that this market change was linked to Meridian Energy, although no-one outside of Meridian seems to know what the strategy of holding back generation (only releasing minimal flow from the hydro lakes) was targetting.

It seems likely however that the market change is somehow linked to the Ministerial Review reforms, such as: hedge market developments to bring retail prices down; establishing a floor for the spot price as a way of reducing the number of conservation campaigns; a retail compensation scheme (consumers compensated if there is a requirement for a conservation campaign); encouragement of new generation through a rise in average electricity pricing; and of course, replacement of the Electricity Commission with a new Electricity Authority. Is it possible the government is receiving signals from the big five generators to proceed carefully with reform?

The reforms, particularly the objective of replacing the Electricity Commission with the Electricity Authority are intended by the Government to bring greater stability for consumers through market mechanisms such as competition, while hoping for reliable supply and better operation of the electricity market. The Electricity Authority's focus will be as market enabler, overseer and rule maker. However 2010 has proven to be a particularly volatile year thus far and change and uncertainty do not tend to lead to stability. Looking ahead, the carbon tax after 2010 will certainly have electricity market implications, which the new Electricity Authority will be expected to moderate.

17.2 Distributed Generation and the Current Market

An embedded community owned wind turbine can theoretcially secure a fixed return under current conditions if it sells into the hedge market (and could find a buyer). However this market is not designed for small scale generation and it is improbable that a community body managing a community wind turbine could guarantee a fixed supply to ensure a fixed price, even if it was in a situation to manage the risk.

As a consequence then, some, or all of the generation from the community wind turbine would likely be sold on the spot market, with its high volitility in prices. This again presents extreme risk that makes it unlikely any community organisation would be willing or able to manage.

17.3 Facilitation of Embedded Distributed Generation

The solution explored in this report has been to join forces with a generation company to allow secure income from variable generation. There are many costs to this model, and many hoops for a community oraganisation to jump through. Essentially we are trying to enter a market designed to facilitate the participation of big generators with 'Think Big' generation projects, not small localised generation with appropriate scale generation close to it's intended users.

It is ironic that our community is generally very aware of the potential of current technologies to provide greater local energy security and greater resilience in the national grid, while the regulatory bodies seem largely trapped in a 1970's infrastructural model. Our (nationally) abundant renewable energy sources are ideally suited to decentralised generation, close to consumers, yet policy continues to favour large, remote generation projects, requiring further reinforcement of the grid.

Government regulated feed-in tariffs, as in other countries, to encourage distributed generation would reduce the need for large new remote power stations, and would be the enabling element that is currently missing from the electricity market.

We are attempting via the only viable way we have identified to model and hopefully build local embedded renewable generation, in the form of wind generation (2-3,000 kW of wind generation may supply the community energy needs of the 700+ electricity customers in Blueskin Bay area). However desirable that is, it still requires the entire network to transmit it around, take away the excess power and supply power when the wind stops. An even more elegant solution would be to install as much household level generation as possible (photovoltaic panels for the most part in our residential areas), to reduce the amount of expensive energy delivered to each house and to reduce the cost of lines charges as the need for the network reinforcement would be substantially if not completely reduced. A combination of community scale wind and household scale generation would give us the greatest energy security possible.

Current barriers to the reproduction of our attempt around the country are:

1. Absence of a feed-in tariff
2. Absence of an 'off-the-shelf' community ownership model

This report has begun the development of a model and blueprint for other such initiatives, however we are now aware that as a blueprint ourselves we will need substantial funding to allow our model to proceed to development.

Alternatively, the government may choose to proceed with policy reform as part of the review of the market that will enable a modern, resilient national grid by prioritizing local energy. The Parliamentary Commissioner for the Environment suggests ways in which the Ministers of Energy and Commerce identify barriers to the uptake of local energy and develop policies to:

- Ensure that there are no market barriers preventing the sale of surplus electricity produced by local energy systems
- Create pricing conditions that reflect the true value of local energy

- Guarantee access to the wider grid for end-users with on-grid local energy systems [...]
- Address the effect of line and connection charges on the financial viability of on-grid connection systems
- Address the barriers facing lines companies wanting to be involved in local energy (which is different from lines companies being involved in larger-scale distributed generation)
- Develop measures that encourage the uptake of smart/advanced meters that support local energy systems [...]3

Micro (household scale) and meso level (community scale) local energy complement each other perfectly, and it is just these types of policy recommendations which, if implemented, would break many of the constraints and ensure this type of initiative was replicated around the country, with even greater decentralisation, giving our children the tools to build a more resilient future.

Waitati and Warrington School children learn about the Waitati Energy Project and wind testing above Blueskin Bay from Seth Gorrie. *WEP stockphoto, 2009.*

[3] PCE (2006), *'7.3.5 A place in the market for local energy (issue six), pp.95-96.* In "Get smart, think small: Local energy systems for New Zealand". Parliamentary Commissioner for the Environment : Wellington,

18. Responsibility

This is a multi-authored report made possible through generous contributions. Any faults or inconsistencies are the responsibility however of the editors.

This report has been commissioned by the Energy Efficiency and Conservation Authority and is additionally supported by Hikurangi Foundation funding.

Scott Willis and Tony Wilson

Appendix I

Windflow 500

[Subject to Confidentiality Agreement]

Micon 750

Input Data		
Corporate Tax Rate	30.00%	
Nominal Cost of Debt	9.00%	
Expected Inflation Rate	3.00%	
Risk-Free Rate	5.94%	
Market Risk Premium	7.50%	
Target Debt Ratio	0.00%	
Beta	0.00	
Mean Wind Speed	7.6	m/s
Weibull K	1.6	
Efficiency	94.0%	
Lifetime of Turbine	15	years
Turbine Cost	$740,000	
Installation Cost	$300,000	
Connection Cost	$200,000	
Depreciation Rate	16.20%	
Annual Operating Expense	$20,000	/year
Annual Maintenance Expense	$0	/year
Landowner Royalties	$0	/year
Initial Electricity Price	$0.090	/kWh
Value of Carbon Credits	$0	/kWh

(1) See Annual Energy Production Model (sheet 2)
(2) See Depreciation Schedule (sheet 2)

WACC	
Nominal Cost of Equity	5.94%
Nominal Weighted Average Cost of Capital	5.94%
Real Weighted Average Cost of Capital	2.85%

Annual Energy Production	
Annual Energy Production (1)	2,129,607 kWh

Cost of Energy Production	
Investment	$1,240,000
Annualised Cost of Capital	$75,294 /year
Annual Operating Cash Flow	$171,665 /year
NPV of Depreciation Tax Shield (2)	$331,608
Cost of Energy Production	$0.069 /kWh
Net Present Value of Investment	$698,438
Internal Rate of Return	9.98%

Assumptions

* Annual operating expense of $20,000 taken from BRCT proposal to the Distributed Generation Fund. Any unscheduled maintenance required after the two year warranty period may add to this estimate

* Initial electricity price estimated at 9c/kWh, future prices based on MED projections

* All values are assumed to be in real (current dollar) terms, so the real WACC is used as the appropriate discount rate. All funding is assumed to come from the community at the risk-free rate

* Tax rate of 30% is assumed to be constant over the life of the project

* Salvage value at the end of the project is assumed to be zero

* Shareholder continuity (no more than 51% of shareholders change) is assumed to allow losses to be carried forward

Vestas V52 850

Input Data		
Corporate Tax Rate	30.00%	
Nominal Cost of Debt	9.00%	
Expected Inflation Rate	3.00%	
Risk-Free Rate	5.94%	
Market Risk Premium	7.50%	
Target Debt Ratio	0.00%	
Beta	0.00	
Mean Wind Speed	7.6	m/s
Weibull K	1.6	
Efficiency	94.0%	
Lifetime of Turbine	15	years
Turbine Cost	$920,000	
Installation Cost	$300,000	
Connection Cost	$200,000	
Depreciation Rate	16.20%	
Annual Operating Expense	$20,000	/year
Annual Maintenance Expense	$0	/year
Landowner Royalties	$0	/year
Initial Electricity Price	$0.090	/kWh
Value of Carbon Credits	$0	/kWh

(1) See Annual Energy Production Model (sheet 2)
(2) See Depreciation Schedule (sheet 2)

WACC	
Nominal Cost of Equity	5.94%
Nominal Weighted Average Cost of Capital	5.94%
Real Weighted Average Cost of Capital	2.85%

Annual Energy Production	
Annual Energy Production (1)	2,555,619 kWh

Cost of Energy Production	
Investment	$1,420,000
Annualised Cost of Capital	$86,027 /year
Annual Operating Cash Flow	$210,006 /year
NPV of Depreciation Tax Shield (2)	$382,112
Cost of Energy Production	$0.066 /kWh
Net Present Value of Investment	$795,603
Internal Rate of Return	10.43%

Assumptions

* Annual operating expense of $20,000 taken from BRCT proposal to the Distributed Generation Fund. Any unscheduled maintenance required after the two year warranty period may add to this estimate

* Initial electricity price estimated at 9c/kWh, future prices based on MED projections

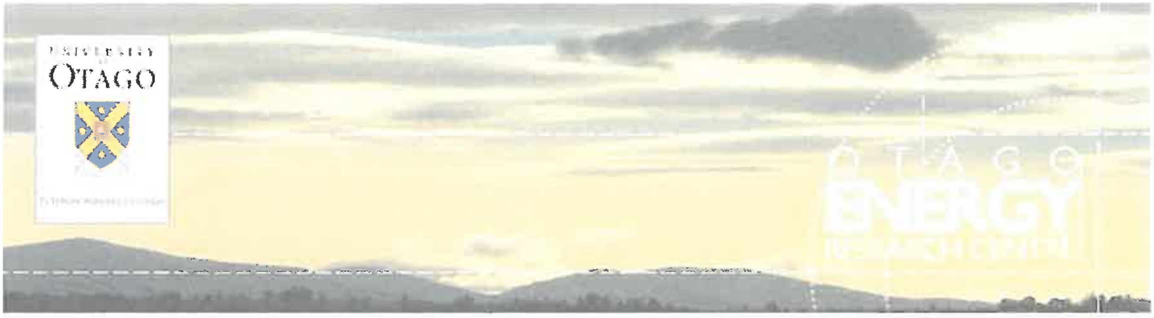
* All values are assumed to be in real (current dollar) terms, so the real WACC is used as the appropriate discount rate. All funding is assumed to come from the community at the risk-free rate

* Tax rate of 30% is assumed to be constant over the life of the project

* Salvage value at the end of the project is assumed to be zero

* Shareholder continuity (no more than 51% of shareholders change) is assumed to allow losses to be carried forward

Appendix II



Summary

In this study wind data from locations close to Waitati have been analysed to gain an understanding of the wind profiles in this area. The annual electricity output of three wind turbines, the Windflow 500 (500kW), Micon NM 48/750 (750kW) and Vestas V52-850 (850kW) were predicted at three locations near Waitati.

The average wind speed at a hill top location near Waitati (above Aramoana) was 6.8m/s based on 3642 measurements over 12 months. It was used to estimate the average wind speed at 50m above ground level (AGL), 8.8m/s, through the wind profile law. The Weibull distribution that most closely fit this data had shape and scale parameters of 2.1 and 7.9.

Using the wind profile predicted to occur at 50m AGL and assuming 94% turbine efficiency this study provided a preliminary estimate of annual electricity output of around 1.55, 2.46, and 3.40GWh for the Windflow, Micon, and Vestas turbines respectively. Annual output assuming the turbines were located on Swampy Summit was 1.73, 2.70, and 3.66GWh.

Wholesale electricity price data was obtained from the Electricity Commission and from EnergyLink for the decade prior to 2010. The goal was to analyse this data statistically and to predict the wholesale price twenty years into the future to assist in determining the net present value of a turbine. Statistical analysis showed wholesale prices to be highly variable from year to year and consequently no meaningful predictions of future prices could be made. Predictions of real wholesale price available to the public through the Ministry of Economic Development website have been used by Polson & Higgs in their report.

With the electricity production figures given above for the predicted wind profile 50m AGL at the Aramoana hill top site the Polson & Higgs economic model gives net present values for the Windflow turbine of $302,000, the Micon of $765,000, and the Vestas of $1,207,000. However the prices for purchase and installation remain very coarse estimates at present and the work contained in this study has yet to be reviewed by an expert in the field. Nevertheless, the results of this study indicate that a wind turbine above Waitati may well be economically feasible.

Introduction

Looking ahead to 2030 energy security looms as one of several enormous challenges to be met by the developed world as it struggles to maintain perpetual growth.

No easy path has been identified for the transition to a genuinely sustainable society but it is clear that improving the resilience of communities will be an integral part of it. The resilience of a community to almost any shock would be improved by ensuring it has a secure and adequate supply of energy, for example electricity.

Wind power is an increasingly popular means of generating electricity by virtue of having low emissions, a comparatively low environmental impact and an energy return on investment (EROI) that is competitive at least with other renewable energy alternatives.[2]

The community of Waitati is an established transition town and ensuring energy security is an important step in its ongoing transition to a low energy way of life. A research relationship exists between Waitati and the Otago Energy Research Centre based at the University of Otago and it is through this relationship that we have investigated the feasibility of wind power as an energy source for Waitati and potential revenue earner through the selling of surplus electricity into the national grid.

In this part of the feasibility study wind data collected near Waitati is analysed and combined it with wind turbine performance data to estimate the electricity that could be produced annually. Performance data was then included in the Polson & Higgs economic model as a preliminary guide to the economic attractiveness of installing a wind turbine above Waitati.

Data description

Wind data

Data was available from several sources. Wind data was collected from two sites near Waitati in 2009 and 2010. Additional data came from the publicly accessible NIWA CliFlo database (http://cliflo.niwa.co.nz/). The Taiaroa head weather station provided a very large data set covering 24 years. Up until 2002 data here was generally collected 3 hourly and from 2002 onward it was collected hourly. There was also data available from two sites near Aramoana and a point estimate from the [confidential] report by Alan Laird prepared for Dunedin Electricity in 1998 for wind monitoring at Hodson Hill which is approximately midway between Aramoana and Careys Bay.

Table 1. Wind data description

Site	Agent no.	Network no.	Elevation (m)	Height above ground (m)	Start date	Finish date	data points
Aramoana Ridge 1	5353	I50764	235		April 1981	April 1982	3642
Aramoana Ridge 2	5352	I50763	200		Feb 1982	June 1982	1831
Mount Cargill	5381	I50858	676	190	Oct 1982	April 1983	3631
Swampy summit	35134	I50845	722		Jan 2008	Jan 2010	16441
Taiaroa head	24854	I50772	72 -75	9	Feb 1975	Nov 2009	130073
Mopanui	(GEOG 380)			3.1			
Double hill road	(GEOG 380)			3.3			
Hodson hill					June 1997	June 1998	avg only

Waitati data

Data from Waitati clearly showed that the recording sites were not exposed to large amounts of wind.

Table 2. Predicted average monthly wind speed at the two Waitati test sites obtained

Month	Mopanui	Double Hill road
Jan	1.99	0.25
Feb	2.16	0.35
March	2.26	0.42
April	2.13	0.33
May	2.11	0.32
June	2.27	0.42
July	2.04	0.28
Aug	2.09	0.31
Sept	2.23	0.40
Oct	2.53	0.58
Nov	2.62	0.64
Dec	2.40	0.50
Overall	**2.24**	**0.41**

The estimate by Gorrie was for 2.95m/s for Mopanui and 1.68m/s for Double Hill road, slightly higher than here. Consequently eEmphasis was placed on historical wind data collected from exposed sites near Waitati as it is reasonably clear that a turbine located at either of the Waitati test sites would fail to perform adequately.

Simulation of windspeed

Wind speed increases in a non linear fashion with height above ground level. The wind speed at an unknown height can be estimated from the wind speed at a known height through the wind profile power law:

Wind $\text{speed}_{\text{unknown}}$ = wind $\text{speed}_{\text{known}}$ * $(\text{height}_{\text{unknown}} / \text{height}_{\text{known}})^{\text{alpha}}$

Where alpha is a value relating to the stability of the atmosphere. Under neutral conditions it is approximately 1/7 (0.143). In this study we compared the values of 0.22 recommended as appropriate for New Zealand wind conditions by Bill Currie of Powerhouse Wind Ltd and 0.150 which was midway between the range of values used in the Hodson Hill report by Allan Laird (1998). Focus should probably be directed towards results using the alpha of 0.150 since this value lay midway in the range of values for rural exponent values given at the Meteorological Resource Centre (http://www.webmet.com/met_monitoring/625.HTML). Knowing the average wind speed at a specific height we extrapolate using the wind profile law across a range of heights.

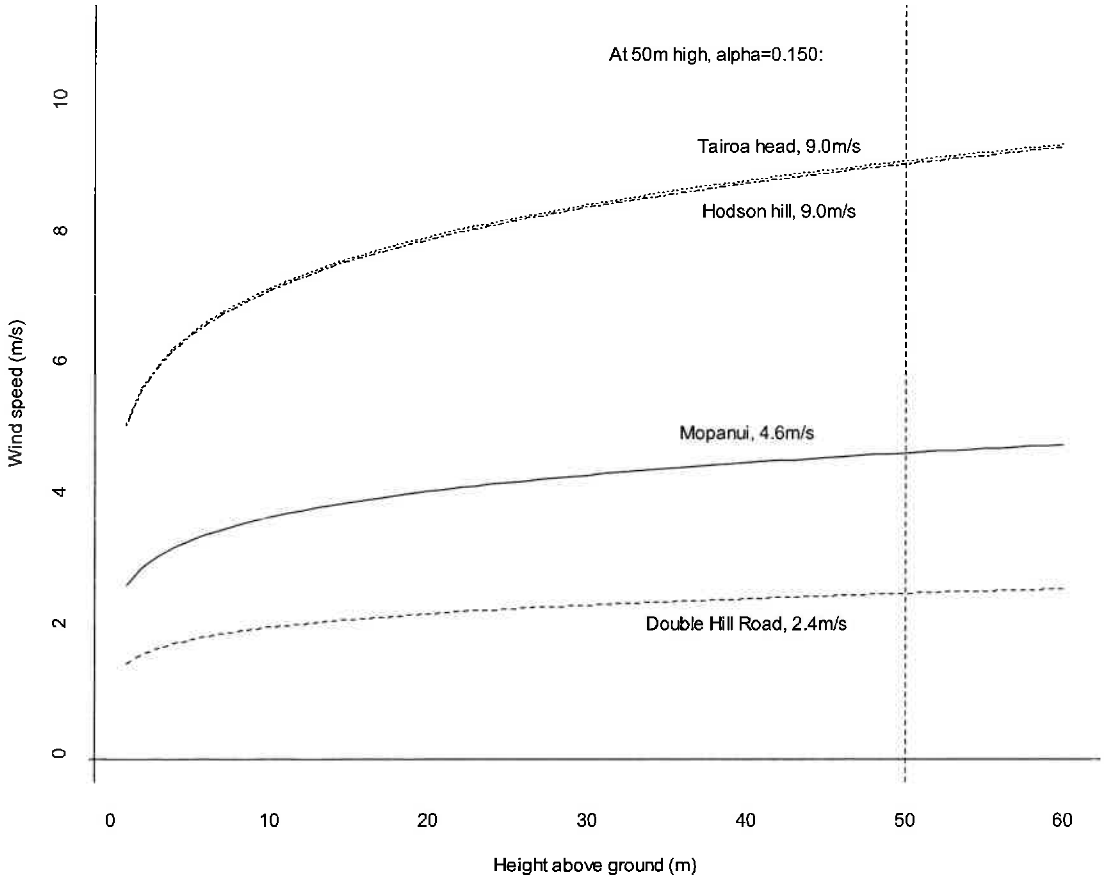


Figure 1. Predicted average wind speed at 50m above ground level for four sites near Waitati

Both the Mopanui and Double hill road locations were not considered exposed to wind activity, so the estimates here may considerably underestimate the true average wind speed.

Turbine power curves

The MICON NM 48/750 was the focus of this study. It has a nominal output of 750kW, a nominal wind speed of 16m/s and a cut in speed of 4m/s, a rotor diameter of 48.2m and a swept area of $1824m^2$. The hub height was assumed to be 50m. Two sources of data were used to create a power curve for this turbine. The first was replicated from the promotional brochure. The second was from a study in 2008 of the feasibility of this turbine at a location in Sri Lanka by mechanical engineering students at the University of Skovde in Sweden.[1]
There was a considerable difference in the two curves. Average turbine output was 18% lower when using the Swedish curve compared to the curve from the Micon company. Berg et al. report that their power output data came from a catalogue, but which one exactly was not clear. In the current study the more conservative set of values was used.
Power curve data was also taken from the promotional brochure for the Vestas V52 850 and from the Polson and Higgs model for the Windflow 500.

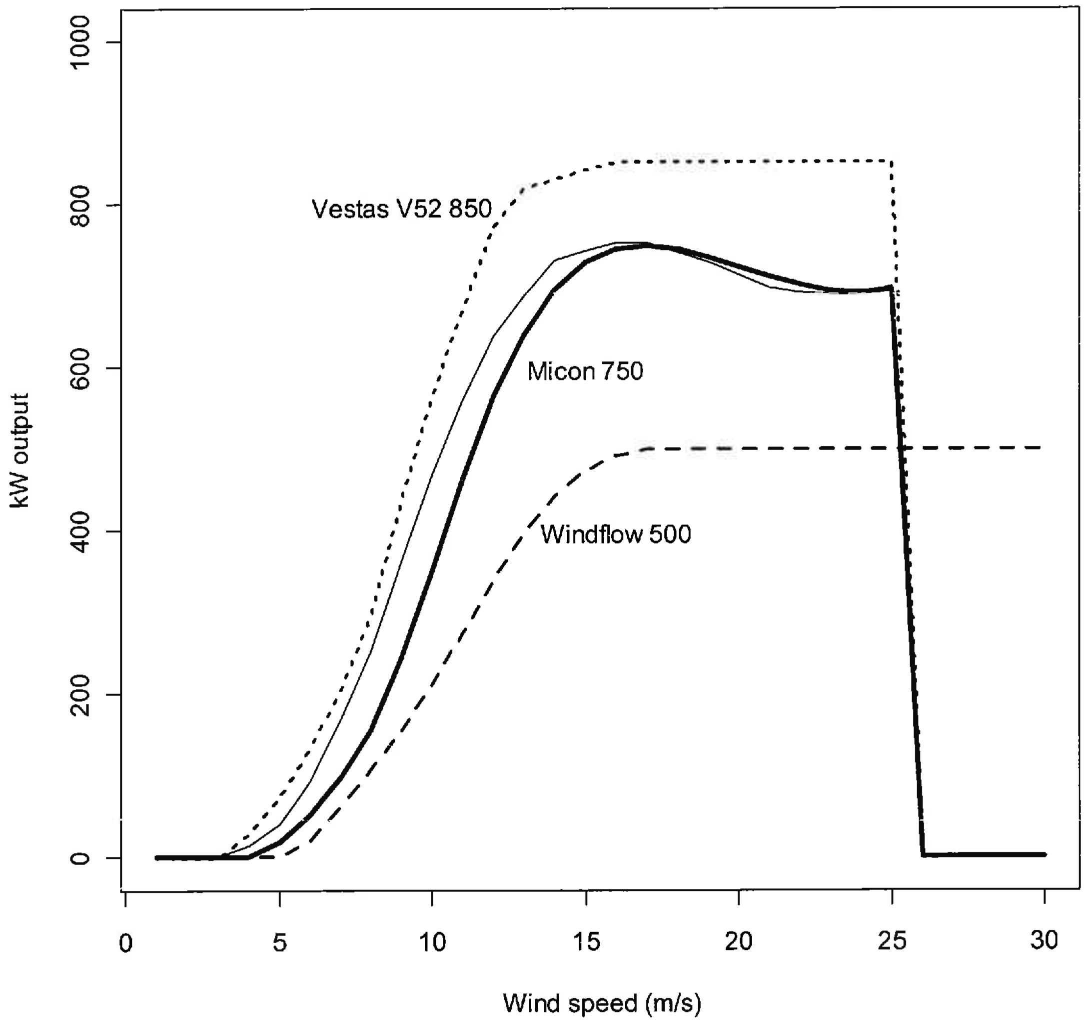


Figure 2. Power curve for NEG MICON NM 48/750 wind turbine from MICON technical brochure (thin line) and Berg et al. (2008) (thick line), the Vestas V52 850 (dotted line) and the Windflow 500 (dashed line)

Both the Vestas and Micon turbines began producing power at 4m/s while the Windflow 500 began at 5m/s. The Vestas had the highest peak output but the Windflow 500 turbine continued to operate in high wind speeds after the other turbines had shut down. The benefit of performance at high wind speeds is minimal in the case of Waitati.

The hub height can be varied to some extent to ensure environmental requirements are met and in the case of the Vesata turbine at least, ranges from 44m to 74m.

For the Vestas turbine, nacelle weight is 22t and the rotor weight is 10t. Tower weight depends on the specifications to which it is built and height, but typically ranges from 45 – 100t.

Table 3. Power curves (kW) for wind turbines

Wind speed	Micon 750 (brochure)	Micon 750 (Berg et al.)	Vestas 850	Windflow 500
1	0	0	0	0
2	0	0	-1	0
3	0	0	0	0
4	14	0	29	0
5	40	20	74	0
6	93	53	134	20
7	169	97	205	63
8	253	155	296	107
9	363	245	437	155
10	469	349	562	211
11	560	462	671	275
12	639	565	773	340
13	689	641	821	396
14	731	696	831	443
15	744	730	842	474
16	753	746	852	492
17	753	750	852	500
18	741	745	852	500
19	730	735	852	500
20	713	723	852	500
21	697	712	852	500
22	691	701	852	500
23	690	694	852	500
24	690	693	852	500
25	700	695	852	500
26	0	0	0	500
27	0	0	0	500
28	0	0	0	500
29	0	0	0	500
30	0	0	0	500

Wind Output

Taiaroa Head

A density histogram of wind speed at Taiaroa head, 9mAGL was created.

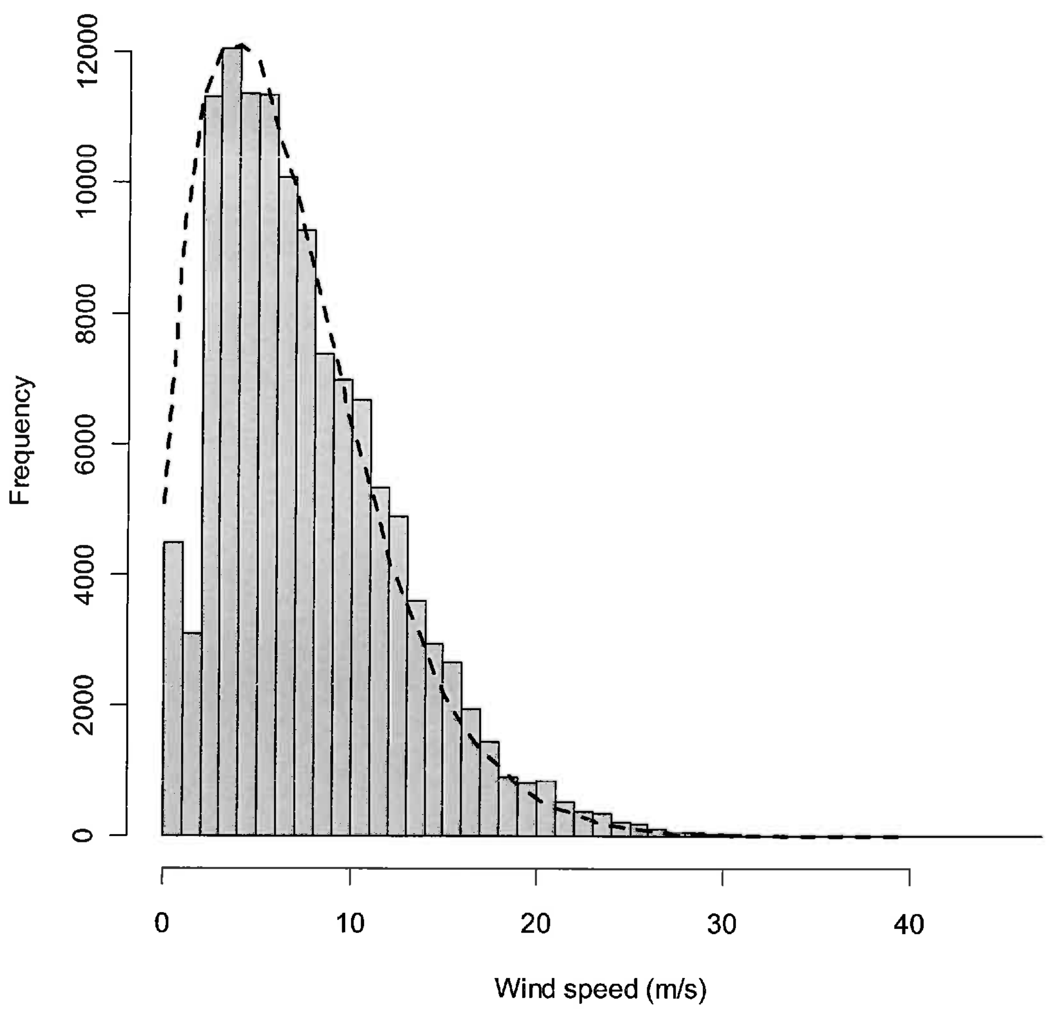


Figure 3. Proportion of wind speed measurements at each wind speed at Taiaroa head (1975 – 2009), 9m AGL and Weibull approximation

There was a slight periodicity evident in the curve of this data after its peak. Extrapolation from this data using the wind profile law and an alpha of 0.150 provided an estimate of wind speed at the hub height of 50m AGL. The Weibull curve used to model this distribution had shape and scale values of 1.55 and 8. The mean wind speed was 7.6m/s.

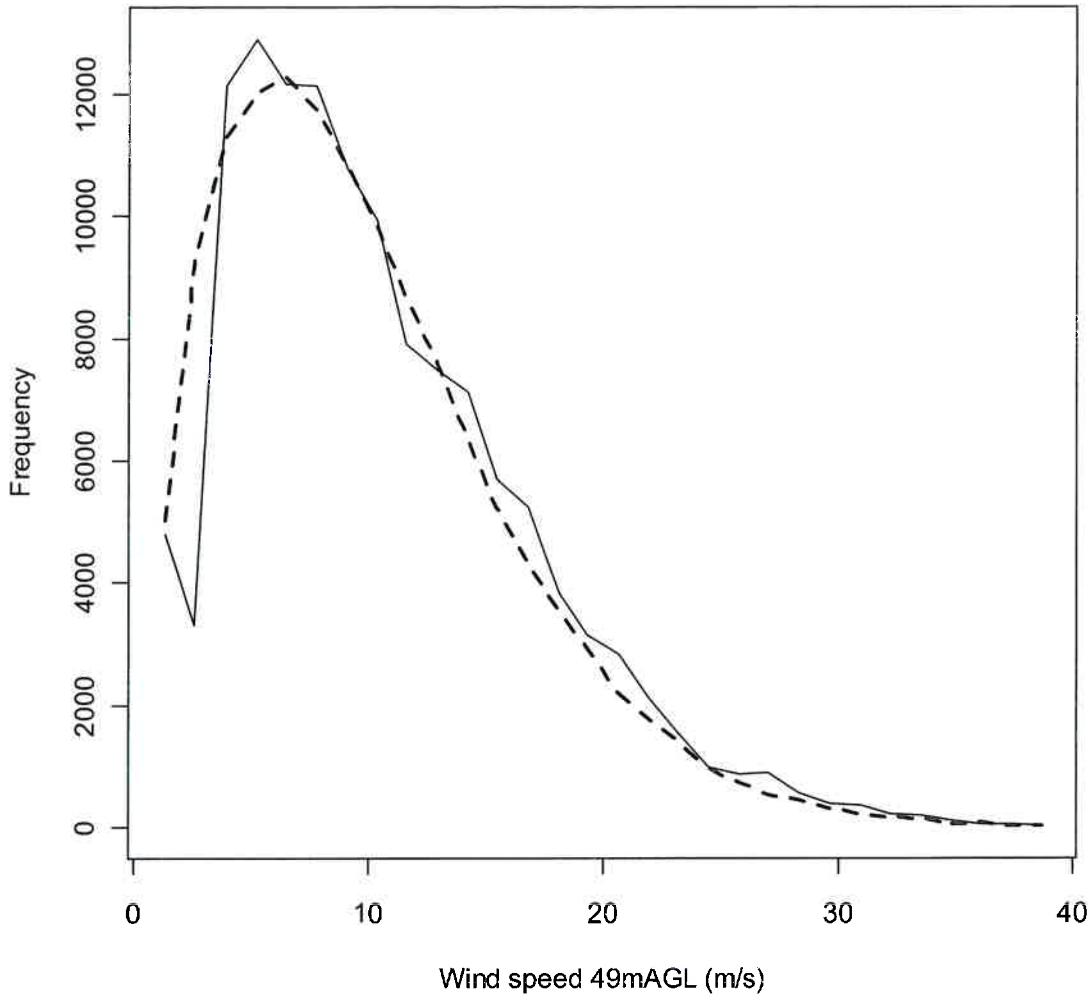


Figure 4. Predicted wind speed at 50m AGL at Taiaroa head (solid line) and Weibull approximation (dashed line)

This distribution was used to determine the proportion of hours in a year that the wind was at various speeds. From this kW output for the turbine could be calculated.

Summing kW output gave an estimate of the annual generation from a Micon turbine of 2.47 GWh of electricity (capacity factor of 38%). The estimate by Laird for a typical 750kW turbine on Hodson hill was 2.97GWh (capacity factor of 45%). A website for calculating power output, Renewable Energy UK, (http://www.reuk.co.uk/Calculate-kWh-Generated-by-Wind-Turbine.htm) which considers the rotor diameter (48.2), average wind speed (9.0), cut-in speed (4m/s), cut-out speed (25m/s), turbine efficiency (40%), and Weibull shape parameter (2) gave an estimate for a of 5.33GWh. The estimate by Laird did not specify the cut out speed of its generic turbine and this could explain some of the difference between our estimates and that report.

Aramoana, ridge 1

Wind data for Aramoana ridge 1 had an average of 6.8m/s, but the anemometer height was not given on the NIWA website. In this study it was assumed to be 9m above ground level and given this assumption average wind speed at 50m AGL was estimated to be 8.8m/s. The shape and scale parameters for the Weibull distribution were 2.1 and 7.9.

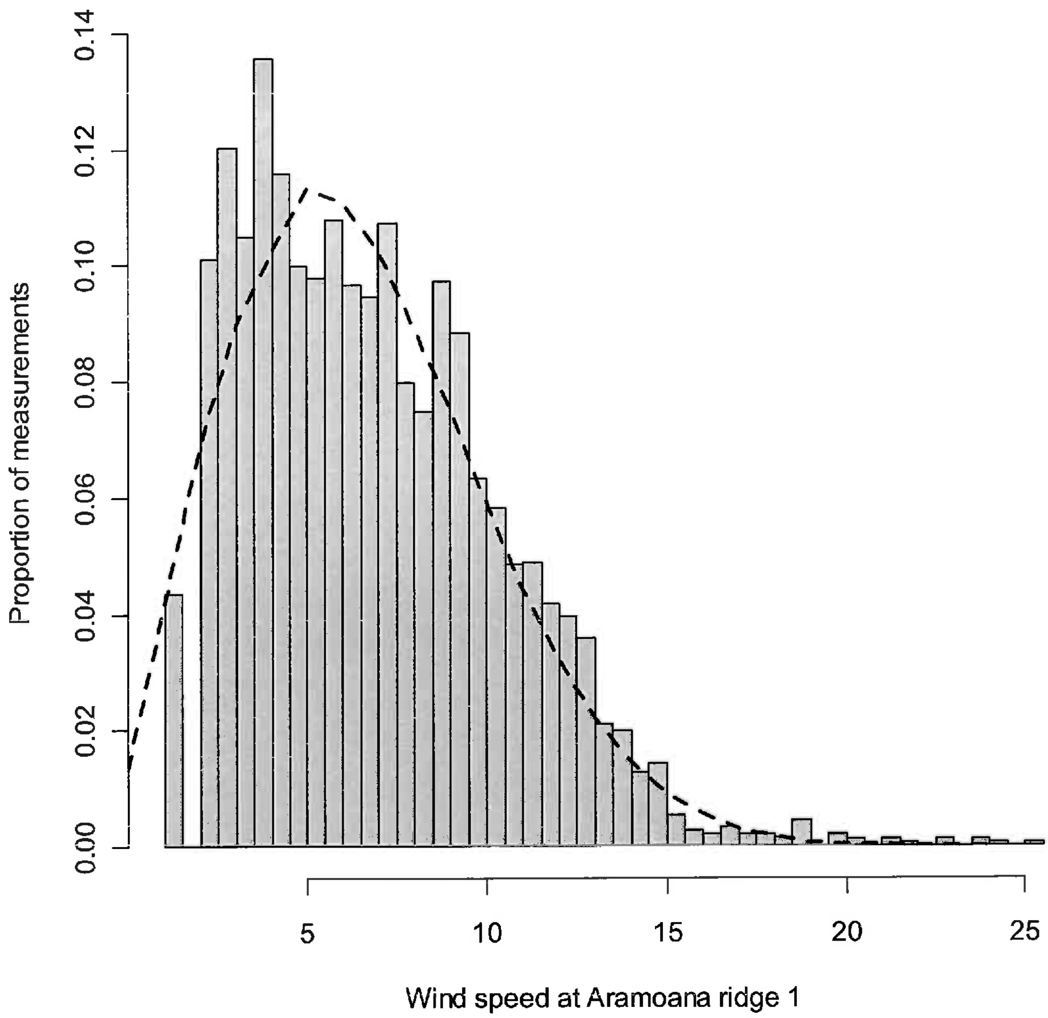


Figure 5. Wind data for Aramoana ridge 1, with Weibull approximation

Mount Cargill

According to the NIWA Cli Flo website the Mount Cargill anemometer was 190m AGL which was quite different from the other data sources. Average wind speed at this location was 10.57m/s when calculated from the raw data and 10.65 when calculated from the Weibull approximation of the raw data. Shape and scale parameters for this distribution were 2 and 12.

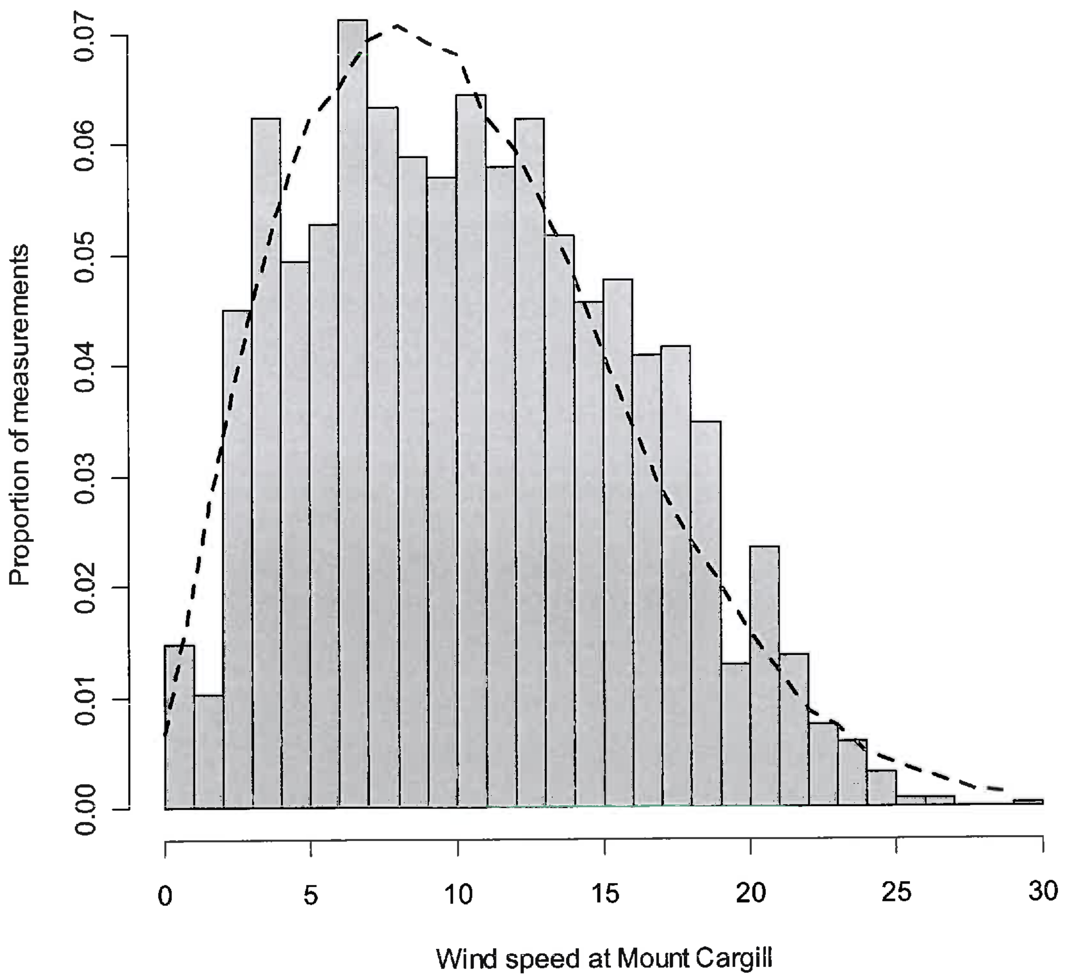


Figure 6. Distribution of wind speed at Mount Cargill at the original recording site and a Weibull approximation of this data (dashed line)

Swampy Summit

The average wind speed at Swampy Summit was 8.3m/s, but the height at which this was recorded was not documented in the NIWA website. If we assumed it was 9m AGL, as at Taiaroa, the average wind speed at 50m AGL was approximated with the wind power law to be 10.7m/s. The shape and scale parameters for the Weibull distribution for this data were 2 and 9.5.

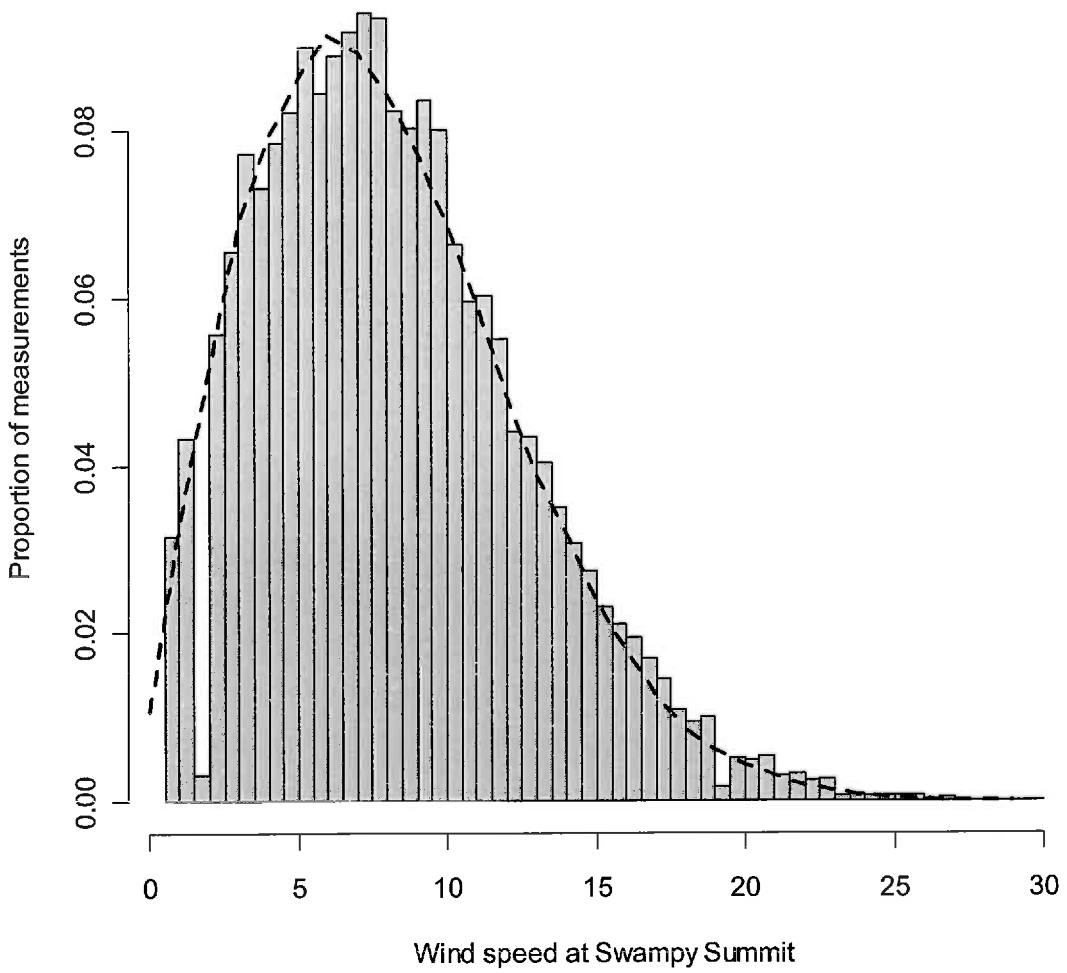


Figure 7. Wind distribution at Swampy Summit and Weibull approximation

The Swampy Summit and Taiaroa head data were most closely modeled with the Weibull distribution.

Summary of wind data for Micon turbine

The wind data described above was extrapolated to 50m AGL and then used to determine the

Table 4. Summary of estimated annual electricity output (GWh) for the Micon turbine for sites near Waitati

Site	Annual output (GWh)	Capacity factor (%)	Annual output (GWh) assuming 94% efficiency
Taiaroa head (Berg et al. data)	2.75	38	2.59
Taiaroa head (website calculation)	5.33	42	2.73
Hodson hill, typical 750kW turbine (Laird, 1998)	2.97	45	2.97
Aramoana ridge 1	2.62	40	2.46
Polson & Higgs model (Weibull for Aramoana ridge 1, 5m AGL)	1.86		
Swampy Summit	2.87	44	2.70
Mount Cargill	3.40	52	3.20

From the results of this study it would appear that a Micon 750kW turbine would produce in the range of 2.3 to 2.7 GWh of electricity per year depending on where it was located.
The estimate from the Polson & Higgs annual energy production model (part of their discounted cash flow model) is made under the assumption of a Weibull curve best fitting Aramoana data collected at an assumed 9m AGL. Under the same assumptions energy output calculated by the method in the current study output was estimated to be 1.16GWh.
Overall, predictions of output in this study appear to be on the conservative side compared with estimates from other sources, particularly the high value obtained from the Renewable Energy UK website.

Table 5. Comparison of annual output (GWh) for three turbine types at selected sites near Waitati assuming 94% efficiency

	Annual output (GWh)		
Site	Micon 750	Vestas 850	Windflow 500
Taiaroa head	2.59	3.51	1.69
Aramoana ridge 1	2.46	3.40	1.55
Swampy Summit	2.70	3.66	1.73

Not surprisingly the largest turbine is predicted to produce the greatest amount of electricity. The trend was for the 500kw and 750kW turbines to produce about 50% and 75% of the 850kW output respectively.

El nino

A cursory examination of the potential for El nino and La nina weather patterns to influence wind turbine performance was conducted. El nino and La nina weather patterns are determined based on the Southern Oscillation Index which is based on the pressure difference between Tahiti and Darwin. El nino is characterized by unusually low pressures and La nina by unusually high pressures.

According to the NIWA website (http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/elnino), El nino conditions occurred in 1982/83, 1986/87, 1991 – 1994, 1997/98, and 2001 – 2003.

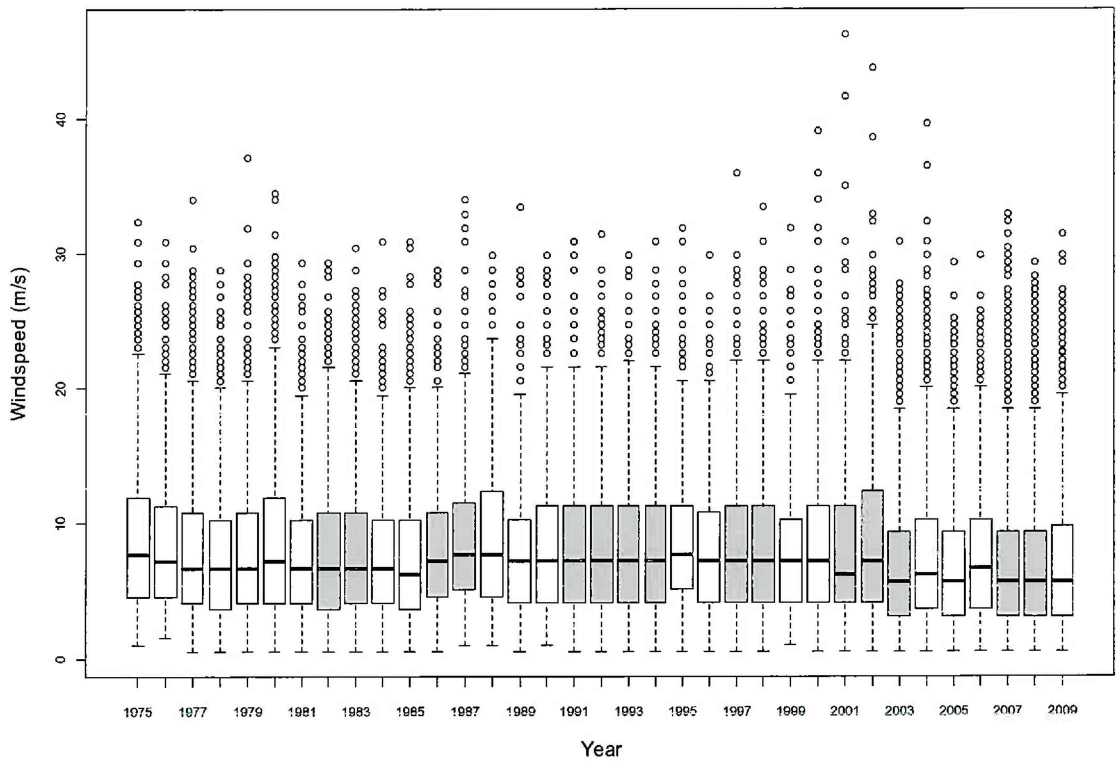


Figure 8. Wind activity during El nino years (gray) compared with other years (white) at Taiaroa head, measured at 9m above ground level

The El nino weather pattern does not have a consistent visibly significant impact on the wind activity at Taiaroa head. Consequently it should not cause any large differences in the electricity generating capacity of wind turbines installed at this site. It is a reasonable assumption that this trend would be consistent across the local area, thus turbines installed near Waitati are unlikely to be affected by the El nino weather pattern.

Electricity price data

Electricity price data was obtained from Energy Link for two nodes (HWB0331 and PAL0331) for the period January 2000 – March 2010. Prices for each half hour trading period were provided, a total of 178959 data points for each node. 14 records were deleted due to missing price data. A further 193 records were deleted for which the price was zero. A single extreme data point of 826.60 was omitted.
Identifiers were created for each year, month, day, and hour.

The distribution of electricity price data was centered around 3-6c/kWh and skewed to the right.

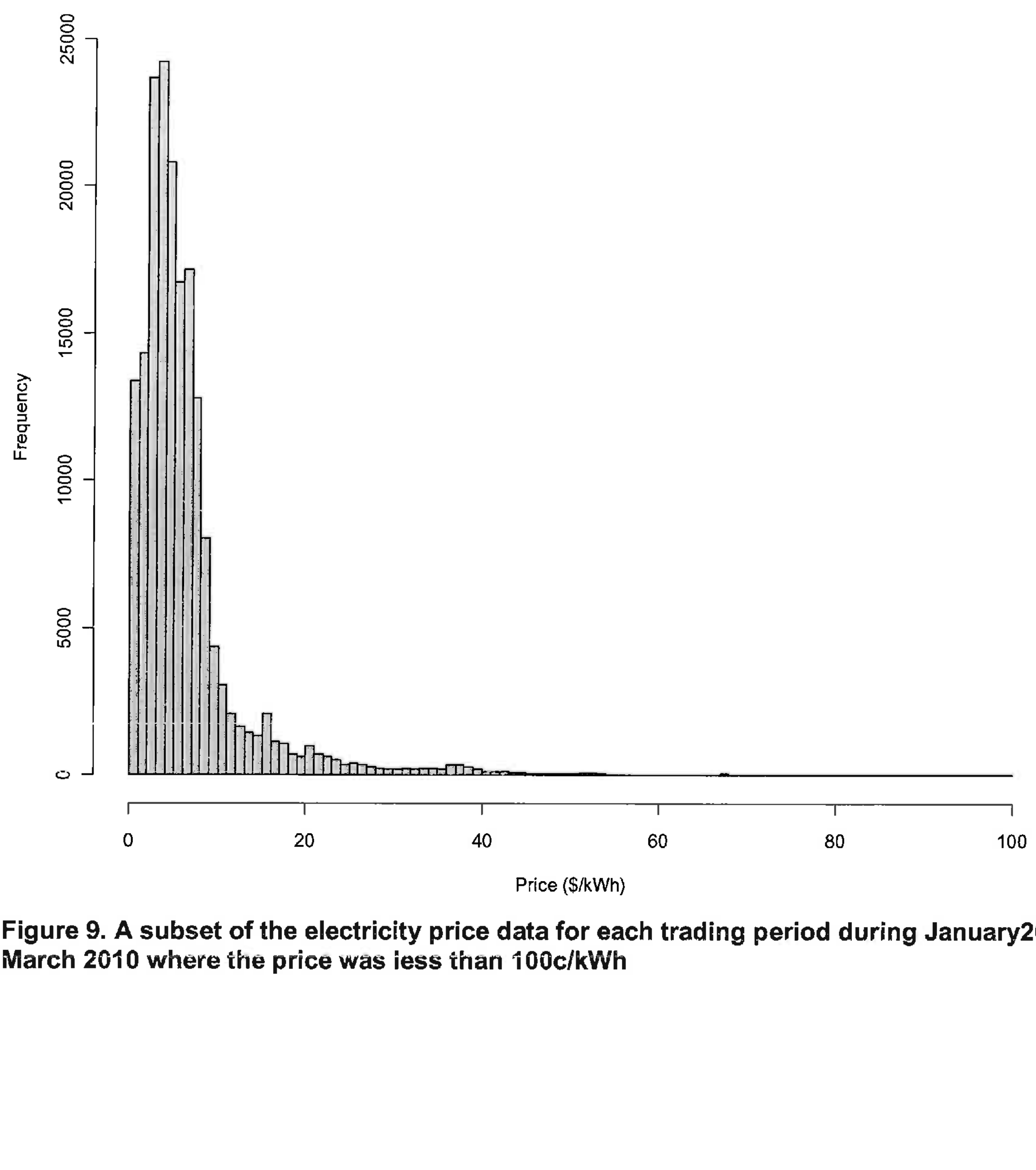


Figure 9. A subset of the electricity price data for each trading period during January2000 – March 2010 where the price was less than 100c/kWh

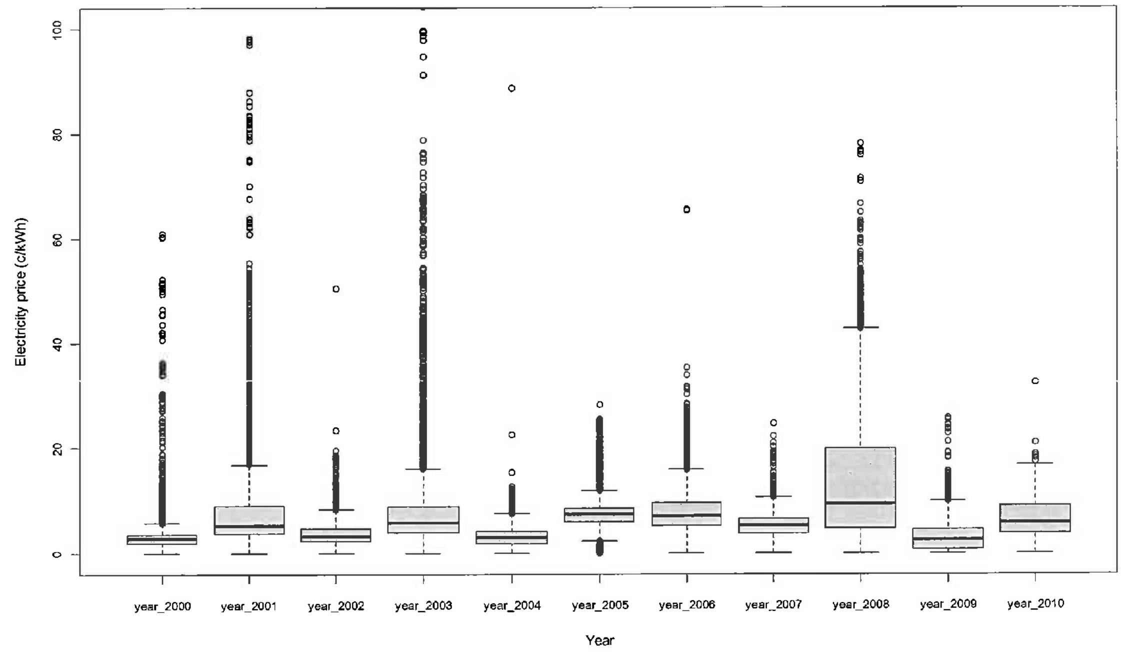


Figure 10. Variation in electricity price by year

There appeared to be a roughly bi-annual oscillation in electricity price and at the monthly scale, prices in winter tended to be higher than prices in summer. Looking at the hourly scale, there

Modeling the price of electricity

To model electricity price data, only prices less than 25c/kWh were considered due to the relative rarity of prices higher than this. This action excluded less than 2.8% of the data.
Three approaches to modeling electricity price were used. In the first, all Trading Period prices were modeled. In the second, Trading Period prices less than 25c/kWh were modeled. In the third, an average price was calculated for each day and these averages were subsequently modeled.
A linear mixed effects model was used which included a random effect to account for correlation in the price data. For models one and two the random accounted for correlation between hourly prices because the most visible trend in the data was at the hourly level. In model three the random effect accounted for correlation between months because a seasonal effect was also evident in the data which would be best accounted for at the monthly level and level of focus had shifted from half-hourly prices to daily prices. Coefficients were determined by maximum likelihood and annual average electricity prices were simulated using model output and Markov Chain Monte Carlo simulation.

Table 6. Annual average electricity price (c/kWh)

Year	Price[1]	95% Error bound	Price[2]	95% Error bound	Price[3]	95% Error bound
2000	3.05	(2.76 ,3.34)	2.91	(2.70 ,3.10)	3.08	(1.73 ,4.44)
2001	8.29	(7.99 ,8.58)	6.73	(6.53 ,6.93)	8.31	(6.95 ,9.66)
2002	3.6	(3.31 ,3.89)	3.62	(3.40 ,3.80)	3.64	(2.29 ,4.99)
2003	8.08	(7.79 ,8.37)	7.08	(6.87 ,7.28)	8.12	(6.76 ,9.48)
2004	2.96	(2.67 ,3.25)	2.97	(2.76 ,3.16)	2.99	(1.63 ,4.35)
2005	7.32	(7.03 ,7.61)	7.31	(7.10 ,7.50)	7.35	(5.99 ,8.71)
2006	8.03	(7.73 ,8.32)	7.93	(7.72 ,8.12)	8.05	(6.7 ,9.4)
2007	5.14	(4.86 ,5.43)	5.16	(4.95 ,5.35)	5.18	(3.82 ,6.53)
2008	13.89	(13.6 ,14.18)	8.82	(8.61 ,9.01)	13.92	(12.56 ,15.28)
2009	2.83	(2.53 ,3.12)	2.84	(2.62 ,3.02)	2.84	(1.48 ,4.2)

Price[1] = raw price data
Price[2] = raw data excluding values above 125c/kWh
Price[3] = model of daily average prices

So what kind of average is appropriate?

The average price received for electricity varies by up to 18% depending on the period across which the average is calculated.

Table 7. Average price (c/kWh) under each of the modeling methods and for varying time periods

Year	Price[1]		Price[2]		Price[3]	
10 year avg (2009 – 2000)	6.32		5.54		6.35	
7 year avg (2009 – 2003)	6.89	1.09	6.02	1.09	6.92	1.09
5 year avg (2009 – 2005)	7.44	1.18	6.41	1.16	7.47	1.18
3 year avg (2009 – 2007)	7.29	1.15	5.61	1.01	7.31	1.15

Price[1] = raw price data
Price[2] = raw data excluding values above 125c/kWh
Price[3] = model of daily average prices

Having studied the data, no simple way of predicting future prices was evident and the alternative of using predictions made in the spreadsheet available from the Ministry of Economic Development website which Polson and Higgs have incorporated in their model makes good sense.

Discussion

It seems likely that the wind profile most likely for a turbine near Waitati would be one similar to the Aramoana or Swampy Summit data.

If we used Aramoana wind data and the Micon turbine parameters in the Polson and Higgs economic model we obtain a net present value for the turbine of $765,000. Using the same wind data the Windflow 500 NPV was $302,000. The Vestas 850 turbine was the most attractive at $1,207,000. However it must be remembered that estimates of the purchase and installation price for the turbines is very coarse at this early stage in the analysis.

Including realistic values for these parameters will almost certainly change the NPV figures substantially. Nevertheless, it is important to note that, given the current understanding, the turbines are not obviously uneconomic. The wholesale price of electricity over the lifespan of the turbine, which is essentially impossible to predict, is a key determinant of this conclusion. It had been a goal of this study to review electricity prices and attempt to predict a price likely to be received for electricity generated in the future. Due to the nature of electricity prices in New Zealand this goal was not achieved. Fortunately predictions of a reputable nature are available from the Ministry of Economic Development website and have been utilized in other parts of this wider study by Polson & Higgs.

During the analysis it was noticed that application of the wind profile power law to large data sets created a peculiar periodicity in the subsequent wind speed distributions which may have influenced our results, although it is not clear whether it would have inflated or deflated our estimates. This could be overcome in future more detailed analyses by using a software product specifically designed for this purpose, or through consultation with wind profile experts.

References

1 Berg J, Furulind J, Hellstrom P: Feasibility study for a wind power project in Sri Lanka, p. 100. University of Skovde, School of Technology and Society, Stockholm, Sweden, 2008

2 Murphy D, Hall C: Year in review-EROI or energy return on (energy) invested. Annals of the New York Academy of Sciences **1185:** 102-118, 2010

Appendix III

DUNEDIN ELECTRICITY
HODSON HILL
WIND MONITORING 12 MONTH REPORT

CONFIDENTIAL

Prepared for

DUNEDIN ELECTRICITY

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APPENDICIES

Appendix A: Energy Calculation for 750kW Wind Turbine

Appendix B: Preliminary Economic Calculations

1. Executive Summary

A full year of wind monitoring has now been completed at the Hodson Hill site for Dunedin Electricity (June 1997-June 1998). This report summarises the results of the wind monitoring, and makes recommendations based upon those measurements.

The average wind speed recorded at the site throughout this period is 8.7 m/s at 40 mAGL (metres Above Ground Level).

The predicted long term wind speed at the site is:

- 8.3 m/s at 40 mAGL
- 8.5 m/s at 50 mAGL[4]

The measured wind direction distribution shows that the prevailing winds are northerly and southwesterly. The relationship of the prevailing wind directions to the main ridgeline (tending east to west) is one of the factors which determines the number of turbines that can be installed at the site. Although the site topography is not exactly perpendicular to either of these wind directions, the site does fit reasonably well with the prevailing winds. Turbines can be spaced closest together if the prevailing winds are perpendicular to the ridgeline ensuring an optimum land usage.

The predicted average wind speed at a turbine hub height of 50 m is not considered high enough to be economic for wind power generation in New Zealand at present when competing in the wholesale electricity market. However, the site might be economic when consideration is given to green power pricing schemes.

The average wind speeds would lead to capacity factors of about 45% for a single typical modern wind turbine. This is considered high according to International Standards. Preliminary economic calculations suggest that the value of energy from a 10 MW wind farm would have to be at least 7 c/kWh for a wind farm to be economically attractive at the site at present. The economics of the site are expected to improve in the future. The timing of the site becoming economically viable will be dictated by various factors. These include improving wind turbine technology, falling wind turbine costs, longer term increases in electricity prices due to the depletion of fossil and gas fuel supplies, carbon charges and green power pricing.

Next Step: DesignPower recommends that monitoring be continued at the Hodson Hill site. A continuous monitoring period is required to allow the following:

- Calculation of the expected long term maximum gust wind speed at the site (2 years of data will be necessary).
- Improve the accuracy of the long term wind speed predictions at the site.

[4] Wind speed measurements were taken at 20.3, 30.2 and 40 mAGL. Modern wind turbines to be installed on this site would probably have hub heights of between 40 and 50 m. The wind speed at 50 mAGL has thus been calculated. For this calculation an approximate wind shear factor, close to the measured value, of 1/7 has been used to scale up the long term predicted wind speed for a height of 50 mAGL. There are uncertainties due to cross correlation and assumed wind shear, and therefore we believe the error range in the wind speed prediction to be ± 0.5 m/s.

- Allow Dunedin Electricity to use the site as a reference for other wind measurements and wind prospecting that they wish to carry out.

DesignPower can continue to check, analyse and archive the collected wind data for a further 12 months (as per a similar arrangement). Data Verification Reports (DVR), as have been done for the first 12 months of monitoring are recommended to ensure high quality data.

2. Introduction

In June 1997 a wind monitoring system was installed at Hodson Hill (Grid ref. NZMS 260 Series I44 272 894). The system includes a NRG 9200P Data Logger, 40 metre (m) tower and sensor equipment (3 Max #40 anemometers and two 200P wind vanes. The anemometers were mounted at heights of 40 m, 30.2 m and 20.3 m. The wind vanes were mounted at heights of 40 m and 30.2 m.

This report summarises the measurements that have been carried out from 4 June 1997 to 4 June 1998.

There was 100% data retrieval. No recorded data has been lost from the Data Logger and all data recorded has been determined as correct and valid.

3.0 Measurement summary

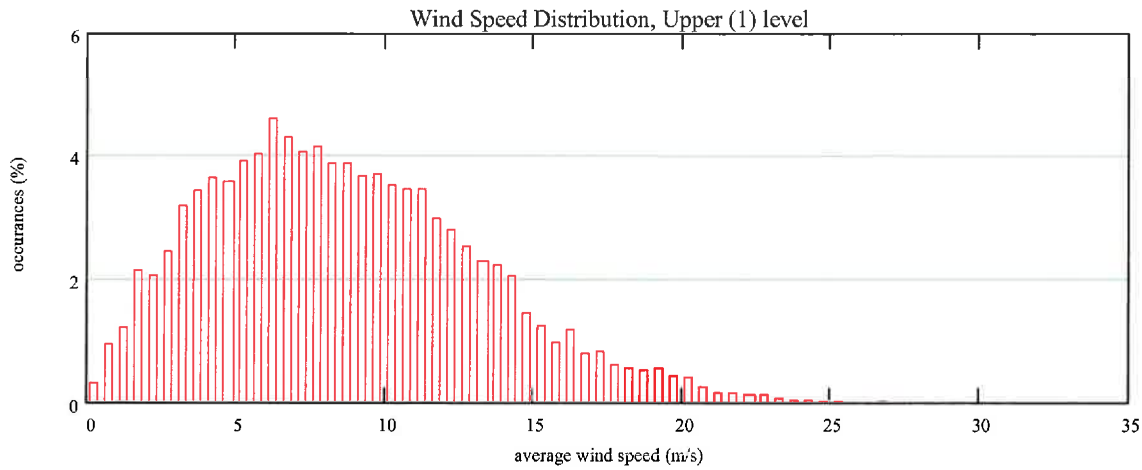
3.1 Measured Average Wind Speed

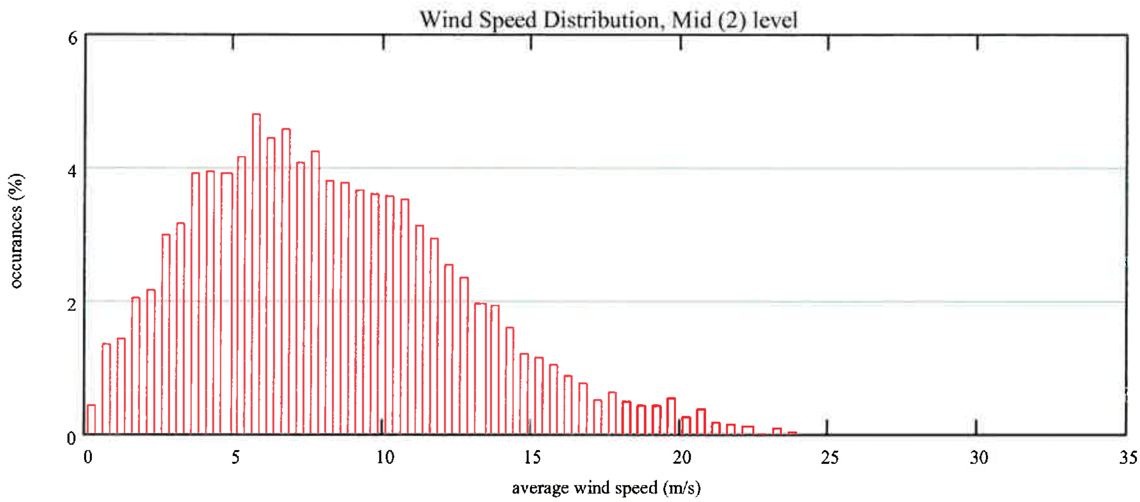
The averages of the measured wind speeds at the site (at the measured heights) are shown in the following table.

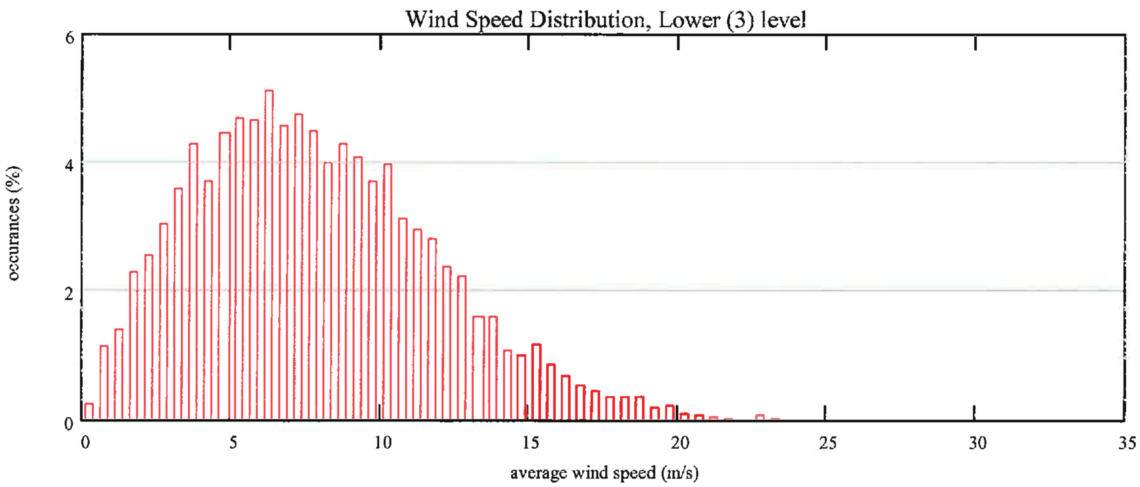
Anemometer Height	Average of Measured Wind Speed (metres per second m/s)
40 m	8.71 m/s
30.2 m	8.37 m/s
20.3 m	7.87 m/s

New default scaling factors (slope and offset) for the Max 40 anemometer sensors have been applied. These scaling factors, recently published by a group of wind power research institutes, have been accepted by the wind energy industry. They are applied in this case as the installed anemometers were uncalibrated i.e. they did not already have individually assigned scaling factors and used the old default scaling.

The measured wind speed distributions for the 12 months of data for each anemometer level are shown in the graphs below.







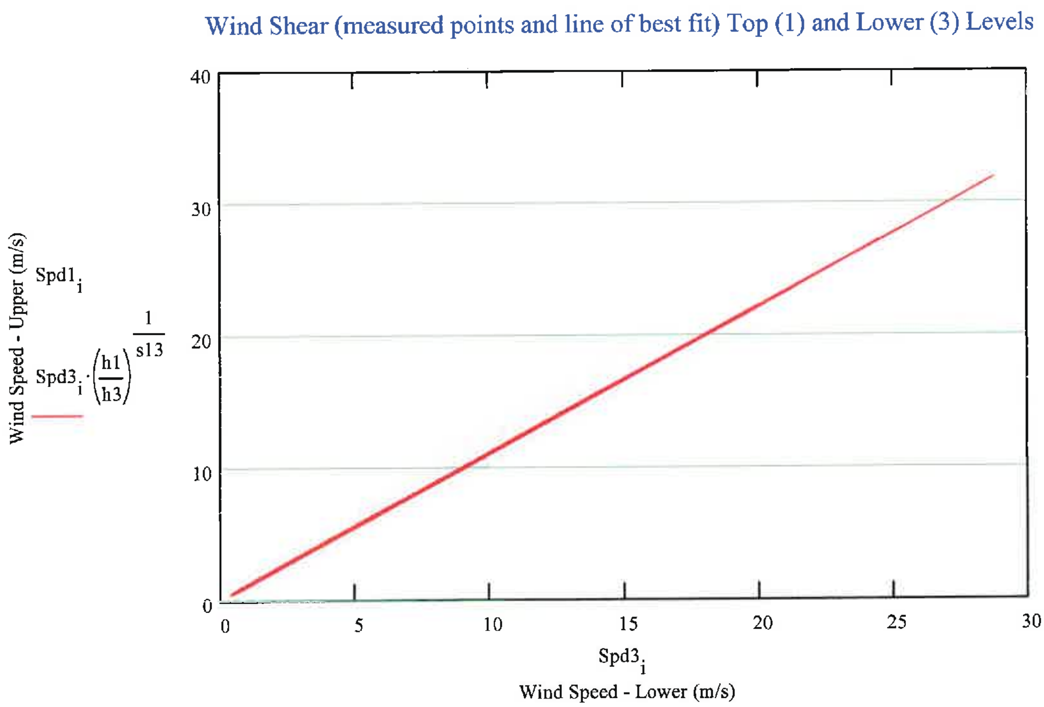
3.2 Wind shear

Wind shear is a measure of how the wind speed increases with height. Smooth airflow over a flat surface gives a wind shear profile that fits an exponential relationship, i.e. the wind speed increases in proportion to the height, raised to the

power of 1/7. Rounded hill tops give wind shear that may not fit an exponential relationship, however the measured relationship between two anemometer heights can be used to extrapolate to higher heights.
The wind shear factor of 1/6.6 from 20.3 m to 40 m is at the higher end of the expected range. Typically wind shear factors in the range of 1/7 to 1/12 would be expected at a site similar to Hodson Hill. This wind shear factor of 1/6.6, means that the wind speed increases slightly more with height than what would typically be expected.
Wind shear factors between the different anemometer heights are shown in the following table.

Anemometer Heights	Wind shear factor
20.3 to 40 m	1/6.6
30.2 to 40m	1/6.5
20.3 to 30.2 m	1/6.9

The graph below shows the relationship between the wind speeds measured at the 20.3 metre and 40 metre anemometers at the Hodson Hill site.



3.3 Measured Turbulence Intensity

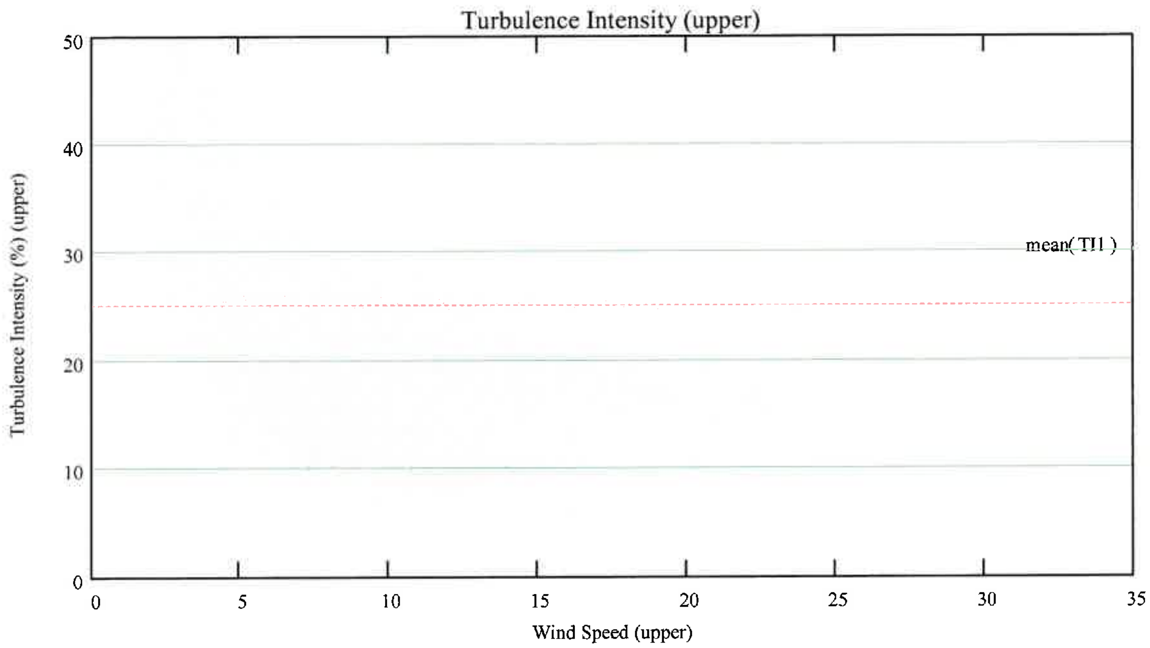
The average turbulence intensities measured at the site are shown in the following table:

Anemometer Height	Average of measured turbulence intensity (%).
40 m	25.2%
30.2 m	26.4%
20.3 m	26.9%

These turbulence intensities shown are considered to be moderate levels of turbulence. As can be seen above, turbulence intensity decreases towards turbine hub height and is assumed to be marginally lower when considering a turbine hub height of say 50 m.

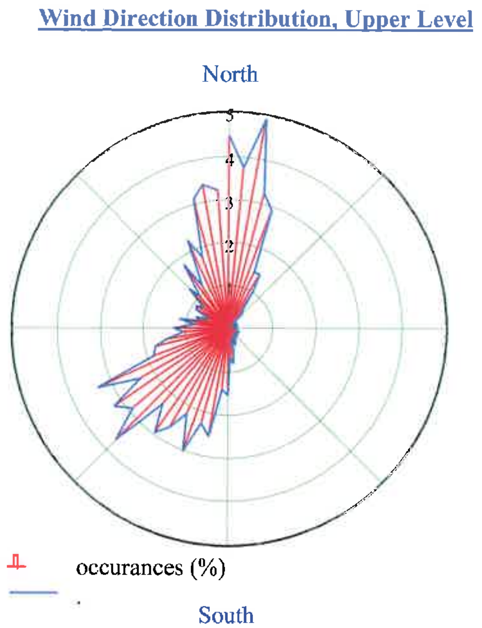
The turbulence intensities for the 40 m anemometer are shown in the following graph.

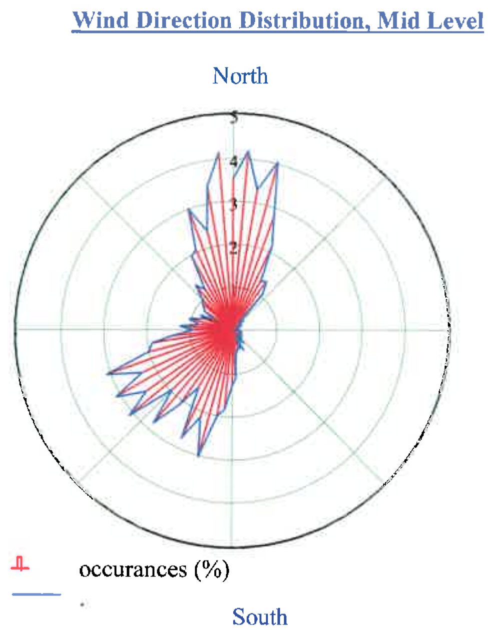
Mean turbulence intensity (upper) mean(TI1) = 25.2 %

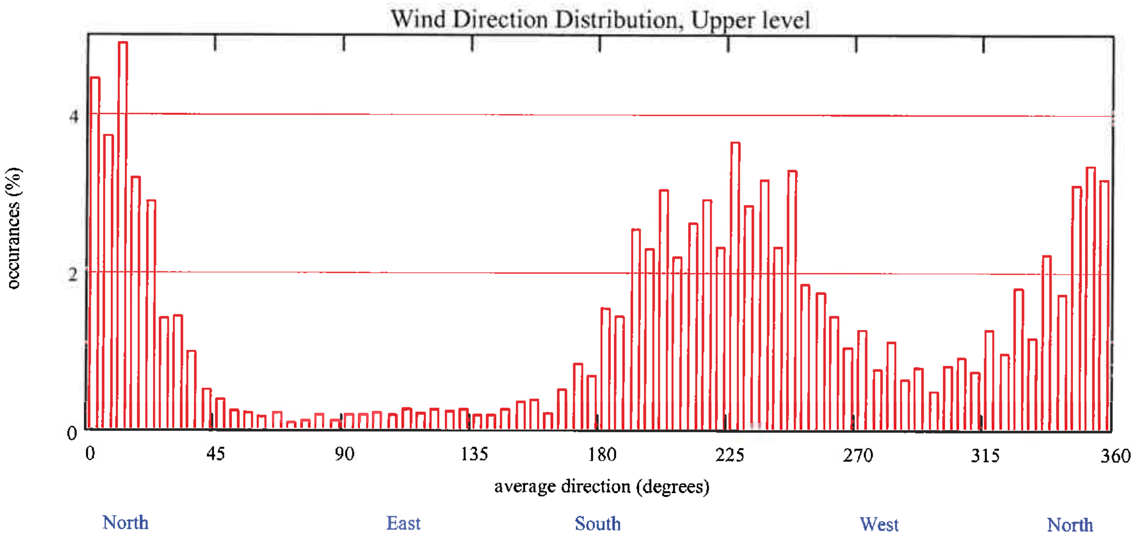


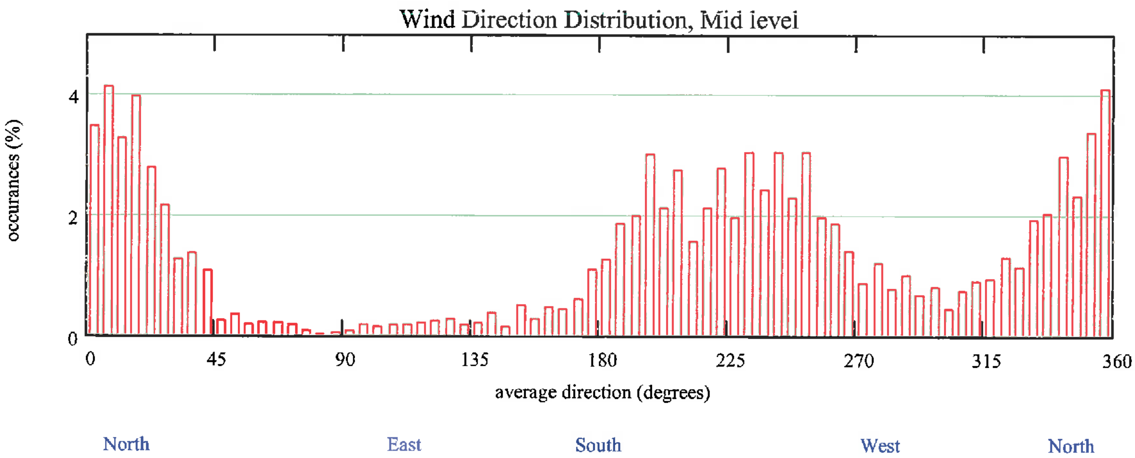
3.4 Wind Direction Distribution

The wind direction distribution measured at the site shows prevailing northerly and southwesterly winds. The prevailing wind directions are reasonably well aligned to the topography at the site. This means that turbines placed along the ridgeline can be more closely spaced (than if the prevailing wind was for example a straight westerly) thus optimising the land usage. The spacing of wind turbines is dictated by the manufacturer's requirements and the orientation of the prevailing wind direction and site topography. The turbines spacing is designed to reduce wake effects, which can adversely affect efficiency and fatigue life. The wind direction distribution at both wind vane heights is shown in the graphs below.


Wind Direction Distribution, Upper Level
North
occurances (%)
South


Wind Direction Distribution, Mid Level
North
occurances (%)
South


Wind Direction Distribution, Upper level
occurances (%)
0
2
4
0
45
90
135
180
225
270
315
360
average direction (degrees)
North
East
South
West
North


Wind Direction Distribution, Mid level
occurances (%)
0
2
4
0
45
90
135
180
225
270
315
360
average direction (degrees)
North
East
South
West
North

4. Predicted Long Term wind speed/Economics

4.1 Predicted Long Term Average Wind Speed

The wind speed information measured at the site has been cross-correlated with wind speed measurements that have been collected by NIWA. The NIWA site used is Tairaroa Head (approximately 6 km east of Hodson Hill), where long term (15 years) wind information is available[5]. This cross correllation takes into account the fact that the last year's measured wind speed average may be high or low when compared to the average for wind speeds at Tairaroa Head over an extended period. The Tairaroa Head data is the best long term data available.

This has resulted in a predicted long term average wind speed at Hodson Hill of 8.3 m/s at 40 mAGL. The correlation coefficient for this calculation is 76%, which indicates a reasonable degree of correlation. Due to this and uncertainties in the reference data and correlation we believe the error range is ± 0.5 m/s.

4.2 Predicted Long Term Average Wind Speed at Hub Height of 50 m

The predicted long term average wind speed has been extrapolated up to a turbine hub height of 50 m. As mentioned previously wind shear factors typically range between 1/7 and 1/12. The wind shear factors across the anemometer heights (at this tower location) are reasonably constant and indicate that it is acceptable to calculate wind speeds at higher levels using the measured wind shear factor of 1/7.
The predicted long term average wind speed at a 50 m hub height at this tower location is calculated to be 8.5 m/s.

4.3 Predicted Energy Generation

Using the predicted long term wind speed at 50 m hub height, the long term wind speed distribution and the power curve of a typical 750 kW wind turbine[6], the predicted energy generation from a single 750 kW turbine is about 2.97 GWh per year, which corresponds to a capacity factor of about 45% (Refer to Appendix A for calculations). At present day prices this would give a cost of energy of approximately 7 c/kWh if a 10 MW wind farm is installed. The preliminary economic calculations use estimated costs for a 10 MW wind farm and include estimated electrical and wake losses for multiple turbines (Refer to Appendix B).

[5] The data from Tairaroa Head is a mixture of hourly and three hourly data. The majority of the wind data at this NIWA site appears to be reliable, however the history of the anemometers and anemometer installation is not available to DesignPower

[6] The average size of wind turbine being installed at wind farms similar to this site has increased to approximately 600 kW. Manufacture of 750 kW turbines is common and therefore this turbine could be considered likely at a future time. Larger turbines (over 1 MW) are available although transportation and installation constraints mean that these are unlikely to be viable at present.

5. Discussion and Conclusions

A full year of wind measurements has been carried out at the Hodson Hill site. The data has been checked each month and Data Verification Reports produced (these are standard DesignPower reports). All data has been assessed as correct and valid.

The year of wind measurements has been cross-correlated with wind speed measurements at Tairaroa Head, where a long term wind speed data set is available. This has resulted in a predicted long term average wind speed at the site of **8.3 m/s** at 40 mAGL. Using a 1/7 wind shear factor (to extrapolate to wind speeds at higher levels) a long term average wind speed of **8.5 m/s at 50 mAGL** has been calculated. Hub heights between 40 and 50 m are likely to be considered for turbines installed at this site in the future.

When this long term average wind speed is combined with the power curve of a single generic 750 kW wind turbine, this gives a **capacity factor of 45%** and an estimated energy production of **2.97 GWh/year** (Refer to Appendix A). The capacity factor of a wind farm will be slightly different (possibly lower) due to electrical and wake/array losses and changing wind speeds at other locations within the site.

From the predicted wind speeds and energy generation a wind farm at this site is not expected to be economic at present. This however does not include consideration given to possible green power pricing schemes. Preliminary economic calculations based on installation of a 10 MW wind farm suggest that the value of energy from the wind farm would have to exceed 7 c/kWh before the wind farm would be economically viable (refer to Appendix B). The economics of the site are expected to improve in the future. The timing of the site becoming economically viable, will be dictated by various factors including improved wind turbine technology, falling wind turbine costs, and eventual long term increases in electricity prices due to the depletion of fossil and gas fuel supplies, carbon charges and green power pricing schemes. It should be noted that wind turbine prices (in $/kW) have fallen consistently over recent years, and are expected to continue to fall.

Next Step: Although the site is not presently economically viable, DesignPower recommends that monitoring be continued at the Hodson Hill site. A continuous monitoring period is required to allow the following:

- Calculation of the expected long term maximum gust wind speed at the site (2 years of data necessary).
- Improve the accuracy of the long term wind speed predictions at the site.
- Allow Dunedin Electricity to use the site as a reference for other wind measurements and wind prospecting that they wish to carry out.

DesignPower can continue to check, analyse and archive the collected wind data for a further 12 months (as per a similar arrangement). Data Verification Reports (DVRs), as have been done for the first 12 months of monitoring are recommended to ensure high quality data.

Appendix B

Campbell Hodgson

To: Scott Willis
Subject: RE: Baseline Energy: back of the envelope question

AuthorsName: Campbell Hodgson

From: Scott Willis [mailto:blueskinenergy@gmail.com]
Sent: Tuesday, 3 May 2016 9:40 a.m.
To: Campbell Hodgson
Subject: Fwd: Baseline Energy: back of the envelope question

Scott Willis
Project Manager
Blueskin Energy Ltd, owned by:
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The latest **Cuppa Tea** by Hugh Campbell considers the impact of the TPPA on Agriculture.

---------- Forwarded message ----------
From: **Gerry Carrington** [redacted]
Date: Wed, Feb 3, 2016 at 2:29 PM
Subject: RE: Baseline Energy: back of the envelope question
To: Scott Willis <blueskinenergy@gmail.com>, Janet Stephenson [redacted]

Hi Scott,

I have used Cle Anne's spreadsheet to look at the effect of Dunedin reducing the amount of electricity drawn from the national grid by 7 GWh per annum and increasing the amount locally generated with zero emissions by the same amount. This means that instead of Dunedin using 613.62 GWh from the grid, we would draw 606.62 GWh. This would reduce the ghg emissions due to electricity generation in Dunedin by 1.14% of current electricity emissions, or 966 tonnes CO2-e. All the assumptions that we applied in the Dunedin Energy Baseline report apply. The total ghg emissions for Dunedin presented in the report are 598638.39 tonnes CO2-e per annum. The effect of the additional wind generation would reduce this by 966 tonnes, as I said, of 0.16%. The percentage of our emissions that are attributable to electricity would drop from 14.15% to 14.01%.

That's probably more numerical info than you want, so you can take your pick what you use.

I hope this helps. Best wishes, Gerry

From: Scott Willis [mailto:blueskinenergy@gmail.com]
Sent: Tuesday, 2 February 2016 11:11 a.m.
To: Janet Stephenson; Gerry Carrington
Subject: Baseline Energy: back of the envelope question

Hi Janet and Gerry,

I have a question for you that you may be able to answer. I would like to have estimation on hand for my evidence at the Resource Consent hearing coming up. It relates to emissions.

Q.

If, as the Baseline Energy Study states, 14% of Dunedin's greenhouse gas emissions come from electricity, what will be the reduction in emissions if the Blueskin Wind Farm is built within Dunedin city? The wind farm will be rated at 2.4MW and will generate on solid energy yield predictions, at least 7GWh per annum.

Is there an easy answer and would you be willing to share it with me? There is a carbon cost to establishing a wind farm, in use of steel, in transport costs and construction costs, etc, but I don't know what that is at present.

Cheers

Scott

Scott Willis
Project Manager

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The latest **Cuppa Tea** by John Kaiser looks at keeping the energy dollar local.