Attachment 1 to report 1535154

Renewable Energy Assessment for Nelson City

Final Report

Report compiled for Nelson City Council – 26 June 2013

1542305

Renewable Energy Assessment for Nelson City

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1 Executive Summary

The purpose of this report is to identify what renewable energy opportunities exist within Nelson City Council's jurisdiction and outline the potential for these opportunities to be realised. This report will be used to inform the Nelson Development Strategy and Nelson City Council's work to give effect to the National Policy Statement for Renewable Electricity Generation.

1.1 Energy Demand, Supply and Cost

Nelson City currently consumes 4.1 PJ of energy per annum, which includes 1.2 PJ (340 GWh) of electricity from the National Grid and half in the form of transport fuels. Existing embedded renewable generation consists of thirty four 1.7 kW to 11kW rooftop solar photovoltaic (PV) systems and a 90kW micro hydro plant on the water treatment plant.

Nelson City's energy use per head of population is similar to the national average but renewable energy makes up a significantly lower proportion of the total city usage; at 29% compared with the national average of 43%.

In assessing the likelihood of future development of renewable generation in Nelson City it is important to take into account the forward wholesale electricity price in the region and to a lesser extent the retail electricity price. Wholesale electricity prices are currently averaging around $110/MWh in Nelson and projected to rise to between $120 and $142/MWh in real terms by 2030. Any utility scale electricity generation developed in the region will need to have a levelised cost of electricity (LCOE) at or lower than this range to be economically viable.

Average residential retail electricity prices in Nelson are around 24 c/kWh (excl. GST) and commercial prices range from 10c-20 c/kWh depending on the size of the customer. These tariffs are also expected to rise in line with the wholesale rates over the next 20 years. Embedded small-scale renewable energy sources such as rooftop solar PV, solar hot water systems and energy efficiency can be economic when reducing customer load at these high tariffs.

For direct heating, with a demand of 0.8 PJ per annum, woody fuels can be competitive with coal and are typically much cheaper than liquid fossil fuels. Increasing demand for wood fuel for heating can be met from forest resources within the wider upper South Island region.

1.2 Renewable Energy Opportunities

Gross electricity demand in Nelson City is expected to grow from about 340 GWh in 2012 to 405 GWh in the next 25 years – an overall increase of 65 GWh (about 20%). At this growth rate, peak demand is expected to stay within the electrical capacity of the Stoke grid exit point and Nelson Electricity's 33kV network assets. The overall increase could feasibly be met from an increase in electricity generation from outside of the region, however this could result in overall increases in wholesale / retail electricity prices due to increased losses in transmission. These potential price increases can be reduced by improving efficiency in electricity usage and the development of commercially competitive renewable generation within the region.

This demand growth can potentially be met by the following renewable energy sources which may be commercially developed in Nelson City over the next 25 years:

- Residential solar water heating – good solar resource at 4.0 kWh/m^2/day resulting in between 40-50 GWh potential of which up to 12 GWh might be commercially developed at costs of 19-23 c/kWh;
- Residential rooftop solar photovoltaics – 30 GWh potential (in addition to solar water heating) of which 6 to 26 GWh may be commercially developed at costs of 15 - 27c/kWh;

- Commercial-scale rooftop photovoltaics and possibly small-scale <100 kW commercial solar PV arrays – between 65 and 75 GWh of potential of which 2 to 7 GWh may be commercially developed at costs of 12 – 19 c/kWh;
- Niche micro hydro at NCC Maitai Dam (<1 GWh) and biogas plant at WWTP facility (2-6 GWh);
- Embedded energy efficiency through encouraging passive solar design in new housing and retrofitting insulation and double glazing in existing housing stock during refurbishment – 4 to 12 GWh in future energy savings;
- Small-scale wind turbines and run-of-river micro hydro - <1 GWh potential at 30-50 c/kWh may be economic in niche remote rural off-grid scenarios if avoiding an expensive network connection;
- Direct conversion from fossil fuel heating to wood fuel heating - 0.3 - 0.6 PJ of which up to 50% may be commercially viable;
- Niche biodiesel and wood pellet manufacture – approximately 0.1 PJ plus large scale pellet export potential; and
- Substitution of transport fuels with electricity via electric and hybrid-electric vehicles – approximately 2 PJ of transport fuel potential of which 10% (0.2 PJ) may be substituted with 0.04 PJ (11 GWh) of grid electricity in the time frame.

Based on currently available information on the available Nelson City renewable resources and projected technology economics relative to alternative energy sources, the following renewable energy technologies are not expected to be commercially developed in Nelson City in the next 25 years:

- Large scale woody biomass electricity generation / biofuel facilities – nearly 600 kt of biomass in the wider region but much of which is already accounted for in higher value processes such as MDF manufacture;
- Utility scale wind turbines / wind farms – potentially 150 GWh of wind resource but at low average wind speeds <6 m/s, resulting in high costs of wind generation in excess of $150/GWh;
- Wave energy converters / wave farms – potentially 100-150 GWh of wave energy resource but at low wave energy density of <10 kW/m and wave energy converters are at early pre-commercial stage (>$600/MWh);
- Solar PV farms (>500 kW) – solar resource of 4.0 kWh/m^2/day insufficient to make utility scale solar economic in NZ at $310-350/MWh at current equipment costs, possibly reducing to $180-200/MWh in the next 25 years; and
- Next generation liquid biofuels - based on future surplus low grade woody biomass of 0.5m t would be unlikely to be commercial due to insufficient scale and infrastructure (compared to establishing a facility elsewhere in NZ).

However, while the above list is not anticipated to be economic within the timeframe, this may not prevent early developers seeking to consent these facilities well ahead of the anticipated commercial timeframe.

Overall, Nelson City has a total technically feasible renewable energy resource of between 665 GWh – 760 GWh (2.7 PJ) per annum that could be utilised for electricity production. However there are significant commercial barriers that will prevent the development of these resources in the next 25 years. The commercially viable renewable resource that may be developed over the next 25 years could be between 20 GWh and 63 GWh per annum i.e. between 30% and 100% of predicted electricity demand growth to 2036.

There is also technical potential for between 1.1 and 1.4 PJ of heating and transport fuel substitution to renewable energy and electricity sources in Nelson City. Up to 0.4 PJ of substitution to clean woody biomass for heating is likely to be commercially viable in the next 25 years. In the near term the relative affordability of electric vehicles will likely limit initial widespread uptake of this technology. However the emergence of plug-in hybrid vehicles and increasing cost competitiveness could see an increase in fuel substitution in the order of 0.2 PJ (about 20% of personal vehicles) within the 25 year time frame. Note this would increase annual electricity demand in Nelson by around 0.04 PJ (11 GWh).

1.3 Increasing Uptake

NCC already appears to have a progressive policy for encouraging sustainability and renewable energy. However more can be done by Nelson City Council to help facilitate renewable energy development in its district, including:

- Ensuring that the Resource Management Plan is updated to meet the objectives of the National Policy Statement on Renewable Energy Generation 2011 – see Section 6.2;
- Setting clear and achievable goals for renewable energy uptake – see Section 6.3;
- Supporting measures to reduce the costs and barriers to renewable energy development. For example by reducing the associated consenting fees, creating opportunities for economies of scale in the wider region and by influencing Nelson Electricity and Network Tasman to proactively encourage locally embedded generation opportunities;
- Leading by example, by ensuring that renewable energy opportunities within NCC's operations are fully investigated and undertaken if commercially viable;
- Continuing to promote sustainability and public education: collaborating with interested parties such as EECA, Nelson Environment Centre, Tasman District Council and industry associations;
- Encouraging private sector investment in renewable energy supply and technology development within the city; and
- Actioning specific measures to advance current renewable energy opportunities in the Nelson/Tasman Region – see section 6.4.

1.4 National Policy Statement on Renewable Electricity Generation

It should be noted that if all of the commercially viable renewable electricity generation potential were developed within the next 25 years, Nelson City would only meet 10% of its electricity demand (~40 GWh) from local renewable resources and contribute about 0.1% to the national energy target.

It would not be practical to expect Nelson City to generate 90% of its electricity supply from uneconomic renewable resources within its district when there are more economic renewable resources that can be developed in neighbouring regions and transmitted to Nelson at a lower overall cost.

2 Introduction

2.1 Background

The purpose of this report is to identify what renewable energy opportunities exist within Nelson City Council's jurisdiction (as shown in Figure A below) and outline the potential for these opportunities to be realised.

This report will be used to inform the Nelson Development Strategy and Nelson City Council's work to give effect to the National Policy Statement for Renewable Electricity Generation.

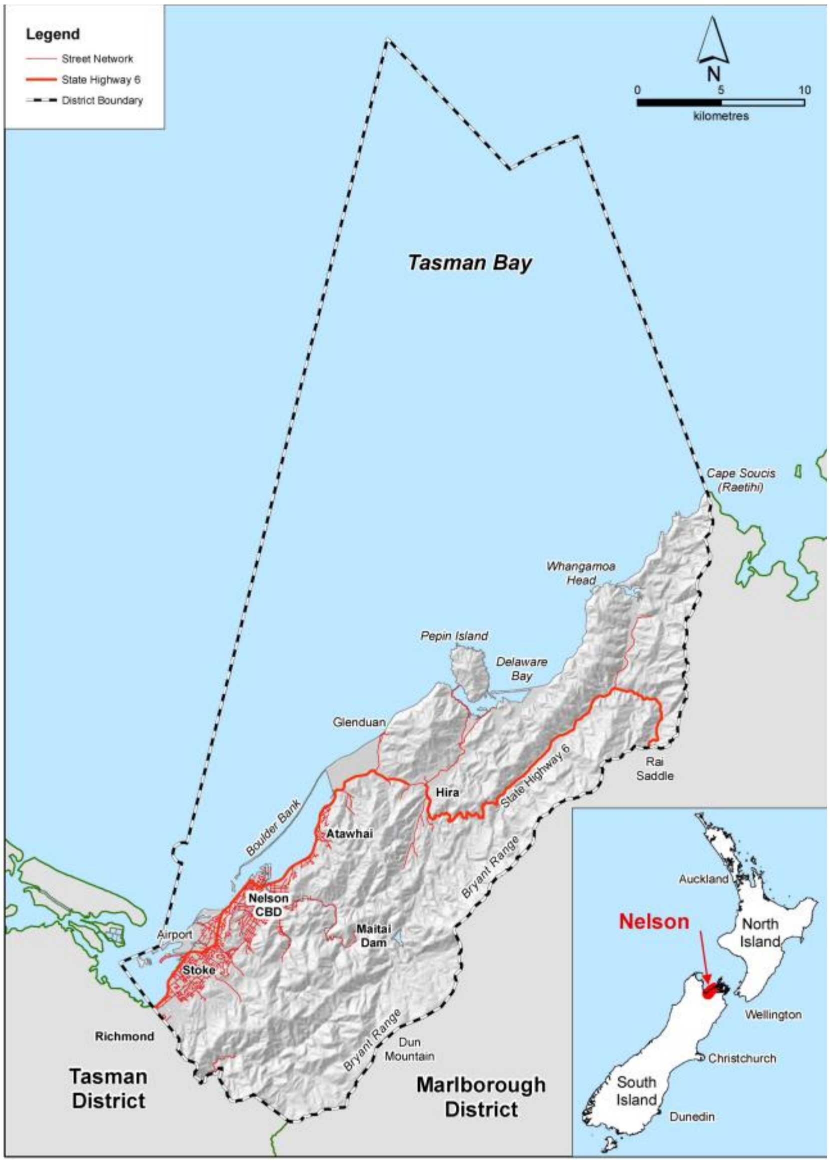


Figure A - Nelson City Council - Area of Responsibility (Nelson City Council, 2008)

2.2 Scope and Objectives

This assessment considers the options for increasing the supply and use of renewable energy in the Nelson City Council's (NCC) territorial area. While the focus is on the Nelson City area, the assessment takes account of the wider regional context.

The assessment is not intended to provide a national perspective and it excludes consideration of demand reduction by reducing consumption (except for opportunities to reduce household heating requirements through passive solar design principles) and improving efficient use of fossil fuels.

The assessment has a 25 year outlook, with a strong 10 year practical focus.

The objectives of the assessment are to:

- Identify the opportunities for renewable energy in Nelson City and outline the potential for these to be realised. The assessment focuses on renewable electricity generation, with a secondary focus on renewable heating and transport biofuels;
- Inform NCC so that it can give effect to the National Policy Statement (NPS) for Renewable Electricity Generation. The NPS for Renewable Electricity Generation's primary objective is to increase the generation of electricity in New Zealand from renewable energy sources from the current level of around 70% to 90% by 2025; and
- Support NCC's long term sustainability strategy, as set out in "Nelson 2060" (Nelson City Council, Feb 2013) and in particular its goal of moving from fossil fuel to renewable energy sources. To support this goal NCC will: use city planning and design to encourage a low carbon economy, creating economic opportunities around renewable energy and lead by example.

2.3 Nelson City Profile

NCC's territorial area has a population of around 43,000 ranking it as New Zealand's 9th most populous city, but with a land area of only 422 square kilometres. NCC is a unitary authority, having the combined responsibilities of local and regional governance and functions.

The city borders on the Tasman District which has a similar population base and includes the town of Richmond. This is located on NCC's boundary and is the region's second-largest urban area with a population of around 13,000 residents.

Nelson City is the economic and business centre of the wider region. The Nelson regional economy is based on seafood, horticulture, tourism and forestry. Port Nelson is the biggest fishing port in Australasia.

Nelson has one of the sunniest climates of all major New Zealand centres, with an annual average total of over 2,400 hours of sunshine. It is also sheltered from prevailing winds.

2.4 Approach

The following assessment methodology has been used:

- Characterisation of existing energy supply and use in Nelson City and the anticipated future costs based on MBIE forecasts, regional influences and the authors' collective expertise in the energy sector;
- Characterisation of other non-financial influences on future options for energy supply in the city;
- Characterisation of primary renewable resources in the NCC region or nearby;
- For each renewable energy option, characterisation of the technology, its maturity and risks, potential scale options, current and future economics, and special considerations;
- Assessment of the merit order for options to maintain and increase renewable energy supply in the area and their relative economic sensitivities; and
- Identification of ways for NCC to encourage and facilitate increased renewable energy supply.

2.5 Information Sources

The assessment relies on previously published detailed assessments for energy demand and renewable energy opportunities in the Nelson / Tasman Region and/or nationally, providing local context and analysis from the authors' own knowledge and experience in the renewable development industry.. References are provided for the important sources of background information.

Resource size and quality estimates are of first order indications of magnitude and should not be relied upon for commercial purposes, likewise energy demand and electricity price projections. Potential renewable energy developers seeking to establish projects in the region are encouraged to undertake site specific measurements and seek independent advice on future electricity demand and price projections.

All costs in this report are indicative and GST exclusive. Actual costs can vary significantly due to economic conditions, point of use and demand pattern. Future costs are in $2013, i.e. real, ignoring underlying inflation.

3 Review of Drivers

3.1 Current Energy Demand in the Region

3.1.1 Electricity Demand

Nelson City is supplied by two distribution companies: Nelson Electricity and Network Tasman. Nelson Electricity's network supplies Nelson's central business district and is connected to the National Grid at Transpower's 33kV Stoke grid exit point (GXP).

Network Tasman also supplies the urban and rural areas of Nelson City from the Stoke GXP at its Founders, Annesbrook and Songer St zone substations. However it also supplies the Richmond, Hope and Appleby areas of Tasman district from the same GXP (Network Tasman Ltd, 2012).

The total annual electricity demand at Stoke increased from 535 GWh in 2000 to 632 GWh in 2007, but subsequently dropped by about 10% in the following years before recovering to 625 GWh in 2012. (Electricity Authority, 2013).

Based on Network Tasman's peak demand information at each of its zone substations, it is estimated that Nelson City takes about 54.5% of the electricity supply i.e. 340 GWh per annum in 2012.

3.1.2 Total Energy Demand

Nelson City's current energy usage and greenhouse gas (GHG) emissions are estimated to be as follows:

Consumer energy type	Current annual usage[1]	GHG emission factor	Total GHG emissions (per annum)	Source of estimate
Electricity from Grid[2]	340,000 MWh 1.2 PJ	143 $kgCO_2e/MWh$ 40 $ktCO_2e/PJ$	49 $ktCO_2e$	Network Tasman and Ministry for Environment (MfE)
Embedded Renewable Gen.	167 MWh 0.001 PJ	0 $ktCO_2e/PJ$	0 $ktCO_2e$	Solar PV: Network Tasman, Nelson Electricity, Hydro: NCC
Transport fuels[3]	56m litres 2.1 PJ	2.5 $kgCO_2e/l$ 68 $ktCO_2e/PJ$	141 $ktCO_2e$	NCC data: 360mV km/y plus 30% off road usage assumed Assume 12 litres/100 km average
Energy for direct heat				
Coal	0.2 PJ	92 $ktCO_2e/PJ$	20 $ktCO_2e$	NCC data and estimates from users
Diesel/Fuel Oil	0.2 PJ	70 $ktCO_2e/PJ$	16 $ktCO_2e$	NCC data and estimates from users
LPG	0.1 PJ	60 $ktCO_2e/PJ$	6 $ktCO_2e$	prorated from MED data
Solar Water Heating	0.003 PJ	0 $ktCO_2e/PJ$	0 $ktCO_2e$	NCC Consents data for past four years
Bioenergy	0.3 PJ	1.4 $ktCO_2e/PJ$	0.4 $ktCO_2e$	Allowing for 24,000t/y
Total[4]	**4.1 PJ**		**233 $ktCO_2e$**	

Notes:

1. Based on best available information or pro-rated based on national averages
2. Electricity supplied from the Grid is approximately 75% from renewable energy supply (hydro, geothermal, wind and biomass) but this varies from year to year.
3. Excludes shipping and aircraft fuel.
4. Excludes indirect and embodied emissions. Includes diesel use in stationary engines

Based on these estimates, Nelson City's energy use per head of population is similar to the national average but renewable energy makes up a significantly lower proportion of the total city usage; at 29% compared with the national average of 43% (MBIE, 2012).

The current energy use and GHG emissions balances are illustrated below:

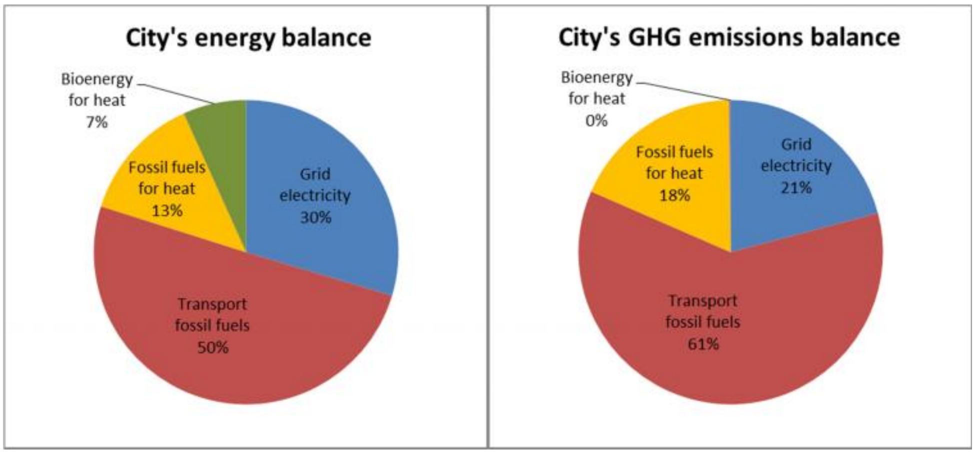


Figure B – Nelson City Energy and GHG Emissions Balance

3.1.3 Future Growth

Nelson Electricity's peak load is forecast to grow from 33 MVA to just above 40 MVA in the next 20 years, at a rate of about 1% per annum – this is expected to be well within the 50 MVA capacity of its 33kV network. Network Tasman's peak demand growth is around 2% per annum for the next ten years – noting that the Tasman District has greater area for population and industry growth than Nelson City. The Council estimates that Nelson City will increase from about 19,200 households in 2011 to around 23,050 households in 2036 (a growth rate of about 0.8% per annum).

This report estimates that annual electricity demand growth at the Stoke GXP will be around 1.3% per annum - based on a growth rate of about 2% per annum in the Tasman District and 0.8% per annum in Nelson City (limited by household growth rate). Assuming no significant embedded generation is built in this period, Nelson City's annual electricity demand could grow from around 340 GWh in 2012 to about 405 GWh by 2036. This also does not assume any end use improvement in electricity efficiency and should be seen as a maximum growth scenario.

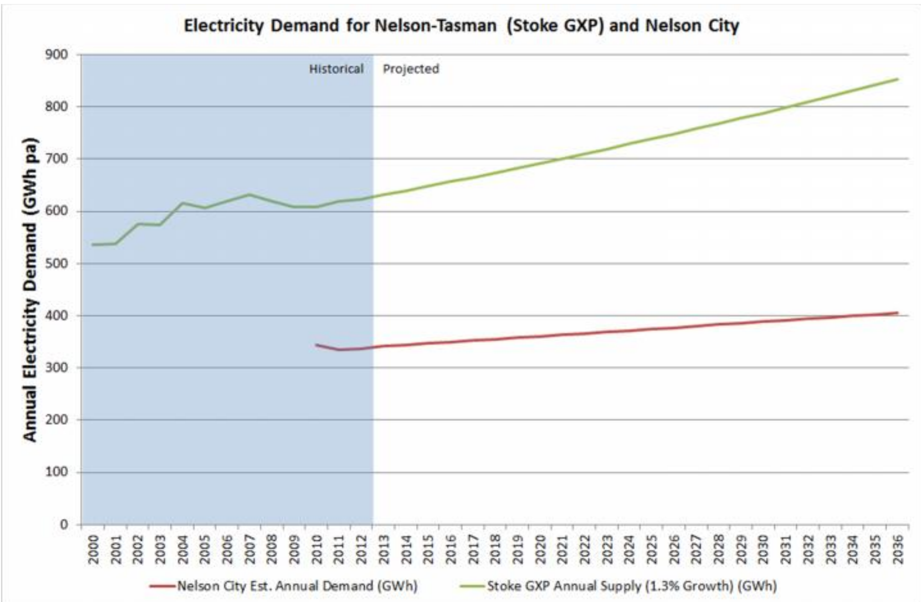


Figure C - Historical and Projected Electricity Demand for Stoke GXP and Nelson City

Embedded distributed generation such as rooftop solar photovoltaics, energy efficiency improvements to existing and new buildings (including use of passive solar design) and solar hot water heating could have significant impact on this future electricity growth and are discussed further in the next section.

Energy demand for transport fuels and heating is also expected to increase broadly in line with household growth, resulting in a 10% to 20% increase by 2036. During this period, there is also likely to be some conversion from liquid fuels to electric vehicles which could add to the electricity demand projections above.

3.2 Current Energy Supply in the Region

3.2.1 Renewable Generation

As at September 2012, there were no existing small to large scale renewable (or thermal) power stations in Nelson City. (Electricity Authority, 2012)

In the wider Nelson / Marlborough region there are seven small to medium sized hydro power stations and two small scale wind farms, generating a total of 262 GWh per annum on average. About 72% of this energy is supplied by TrustPower's 32MW Cobb hydro scheme. The two small wind farms (Weld Cone and Lulworth) were built on the east coast of the Marlborough region by Energy3 in 2010 and 2011, consisting of second hand wind 250 kW wind turbines imported from Denmark (New Zealand Wind Energy Association, 2011).

Network Tasman currently has 21 solar photovoltaic (PV) installations connected to their network within Nelson City with a total capacity of 93.6kWp (Hendrickson, 2013) – the largest of which is the 11kWp system installed at Nelson Airport. Nelson Electricity has 13 embedded PV installations totalling 37kWp (Nelson Electricity Ltd, 2013). The total estimated annual generation from these PV systems is about 164 MWh – approximately 0.05% of total electricity demand in Nelson City.

Figure D - 11 kW Solar PV Array at Nelson Airport

Both companies anticipate continued growth of embedded solar photovoltaic systems in their networks - which will slow the growth of energy consumption but is not expected to have a significant impact on network peak demand (which generally occurs in winter evenings).

A small 90kW hydro generator is installed on Nelson City Council's water supply pipe from Roding waterworks at the Water Treatment Plant, supplying an estimated 3 MWh p.a.

Based on NCC building consent records, in the past four years 447 solar hot water systems have been installed in Nelson City. Based on an average system size it is estimated that these reduce Nelson City's electricity demand by about 970 MWh per annum.

3.2.2 Transport Fuels

Transport fuels used in the region include diesel, petrol and Liquefied Petroleum Gas (LPG) supplies. Diesel and petrol is normally shipped to Nelson port from the Marsden Point Refinery. LPG is shipped, railed or trucked from Taranaki sources or, at times, is from imported supply.

Current indicative retail prices are as follows:

Fuel	GCV	Energy price	Sales tax	Total pump price[1]	
Diesel	38MJ/l	132c/l	0.4c/l	132c/l	$35/GJ
Petrol	35MJ/l	130c/l	61c/l	191c/l	$54/GJ
LPG	27MJ/l	114c/l	10.4c/l	124c/l	$42/GJ

Notes

1. Prices exclude GST. RUC for diesel vehicles excluded.

The price of transport fuels is driven largely by the international crude oil price and the NZ currency exchange rate. Both of these are volatile and cyclic and long term price forecasting is speculative. However it is inevitable that the cost of liquid transport fuels will rise faster than inflation. It is a global commodity that is increasingly expensive and energy intensive to extract, and it is being extracted at an unsustainable rate. Future oil shocks similar to several that have occurred in recent decades are also likely to be repeated.

There is very little production of biofuels in NZ. Gull blends small volumes of ethanol into petrol and biodiesel is produced by several niche businesses. The biodiesel industry was supported by a grants scheme operated from June 2009 until June 2012. This provided a grant of 42 c/litre biodiesel, but the scheme has now ended.

3.2.3 Heating

For heating, apart from electricity, the other important sources of primary energy in the Nelson /Tasman Region are sub-bituminous coal, diesel/fuel oil, LPG, biomass, and landfill gas (LFG).

For the fuels where markets prices are in the public domain, the typical costs of the fuel and delivered heat (fuel cost only) are as follows.

Primary energy	Current price[1]	Conversion efficiency[2]	Delivered heat cost[3]
Electricity - residential	$67/GJ	100%	$67/GJ
Electricity + heat pump	$67/GJ	400%	$17/GJ
Coal – industrial commercial scale	$8/GJ	75%	$11/GJ
Diesel – all segments	$35/GJ	80%	$44/GJ
LPG – bulk supply excluding delivery	$36/GJ	80%	$45/GJ
Wood chip fuel (seasoned) – bulk supply[4]	$11/GJ	70%	$16/GJ
Wood pellets – 20kg bags	$27/GJ	80%	$34/GJ

Notes

1. Retail prices excluding GST
2. Average gross efficiencies for modern best of class appliance
3. Fuel cost only, excluding non-fuel operating costs and capital plant cost
4. Assumed 30% moisture content (wet basis). Domestic firewood is excluded as price and conversion efficiency is highly variable.

Coal is normally sourced from the West Coast, and its usage in Nelson City is estimated to be approximately 12,000 tonnes per year (NCC Consents). Coal combustion is only permitted in specific industrial and commercial applications covered by resource consents. The largest users are the Nelson Hospital, South Pine and the Stoke Brewery.

Diesel, Fuel Oil and LPG are sourced from transport fuel suppliers. Diesel/Fuel for heating is used mainly in small industrial and commercial applications. ENZA Foods and Sealords are the largest users. LPG is also used for domestic heating and cooking.

In total, approximately 24,000 t/y biomass for bioenergy is used in Nelson City, with significantly more used in the Tasman District. Most of this is generated by local wood processors from wood processing and directly used on their own sites as boiler fuel. The major biomass users are the Nelson Pine MDF and LVL mill, the CHH Eaves Valley Sawmill (both in the Tasman District), Waimea Sawmill and South Pine Sawmills. The balance of approximately 8,000 t/y solid wood is used in domestic wood fires.

Wood pellets for domestic and small commercial scale heating are manufactured locally (in Tasman District) by AZ Wood. These are also distributed throughout New Zealand.

LFG from the York Valley landfill is used for heating at the Nelson Hospital. Approximately 30,000 GJ/y LFG is used with the balance of heat for the hospital supplied by coal boilers.

3.3 Security of Supply

Security of energy supply issues facing Nelson City are similar to many parts of New Zealand.

For Nelson, the major risks include:

Risks	Potential impacts	Mitigation through Renewable Energy uptake
Transport Fuels		
Crude oil price shocks due to international crude oil market supply/demand imbalances	Large transport fuel cost increases may cause serious long term detrimental economic and social impacts	Reduce dependence on liquid fossil fuels. Note however that biofuels are likely to be priced at the avoided costs of fossil fuel alternatives. See section 4.6
Oil supply interruption. For example due to temporary disruption to imports, the operation of Marsden Point Refinery or Nelson Port	Short term supply disruption	
Electricity		
Electricity price shock: for example caused by a dry year	Temporary large cost rises possible.	Increase use of regional distributed renewable energy alternatives such as solar, wind and hydro power generation can reduce price volatility, but limited ability to maintain power supply during outage e.g. solar PV systems must disconnect from grid when power supply is lost.
Natural disaster interrupting NZ supply chain: for example earthquake damaging individual hydro power plants or transmission lines	Load shedding or complete loss of supply. Disruption to supply should be limited to relatively short term period	
Short term loss of one or more transmission lines supplying the Upper SI region due to weather, slip or system fault	Load shedding or complete loss of supply. Disruption to supply should be limited to relatively short term period	Depends on availability of "firm" renewables in the region and extent of power outage.
Heating		
Oil price shocks	Use of Diesel, fuel oil and LPG may become uneconomic.	Convert to locally available biomass fuels

Having additional renewable generation established within Nelson City and the wider Nelson / Tasman Region would have a number of beneficial effects, particularly in reducing average line losses and electricity wholesale prices in the region. However, the role that renewable generation can take in improving security of supply is limited by the variability of the renewable energy source. The loss of a power line supplying the region might occur when the sun is shining or the wind is blowing, but it may not. Without significant storage (such as a hydro dam or biomass storage), the development of renewable generation in the region will not provide significant benefits for security of supply.

3.4 Long Run Cost of Electricity

The delivered cost of electricity for residential customers in Nelson is currently around 24 cents/kWh (typical household excluding GST and including prompt payment discount). Larger commercial and industrial customers may pay significantly less, depending on their scale of usage, load profile, the time of use and location on the network.

The residential cost of electricity in Nelson has four main components, namely wholesale electricity costs, transmission charges, network charges and retail / metering costs as illustrated below and discussed in the following sub-sections.

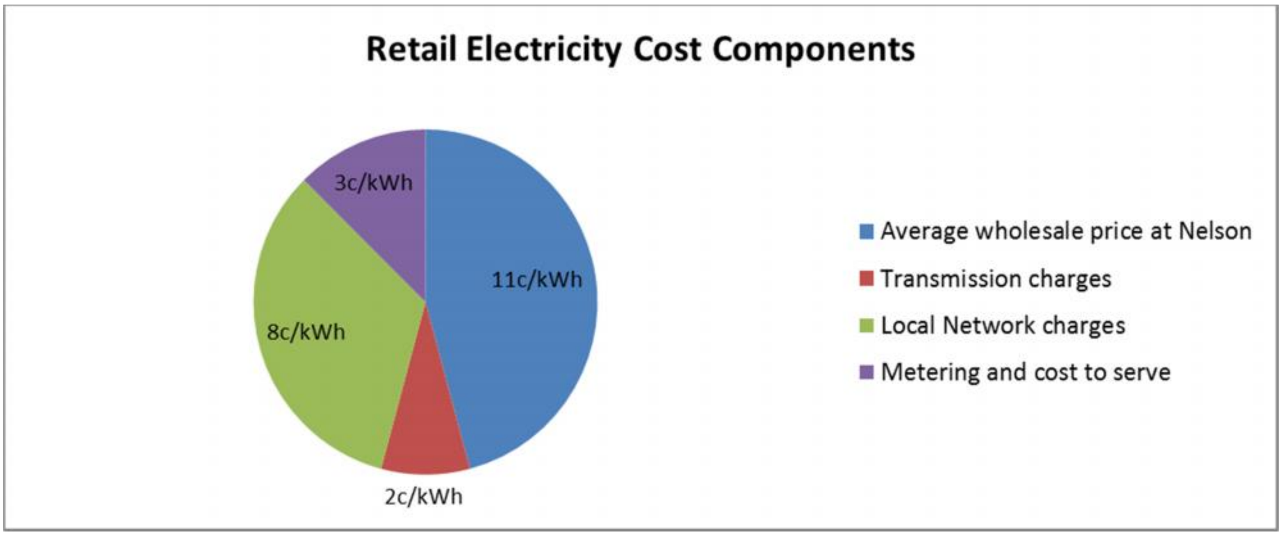


Figure E – Retail Electricity Cost Components

3.4.1.1 Wholesale Electricity Costs

Wholesale electricity prices are affected by both spot market and hedge costs, which are currently averaging around 11 c/kWh ($110/MWh) at Nelson. This cost is expected to rise in real terms (i.e. above the inflation rate) on average between 0.5% and 1.5% per year. The rate of increase will be most influenced by demand growth and the need for more expensive generation, domestic natural gas costs, GHG emission costs and the NZ currency exchange rate.

The Ministry of Business, Innovation and Employment (MBIE, 2011) produce forecasts for the average wholesale electricity price ($2010) at Haywards based on a range of scenarios. For Nelson the wholesale price (ignoring variations depending on the time of use) is typically approximately 24% higher (than MBIE's model) allowing for the Nelson grid location factor, inflation since 2010 and hedge risk margin.

Hedged wholesale prices at Nelson can therefore be forecast using the MBIE reference, highest path (low GDP) and lowest path (low currency) scenarios as shown below.

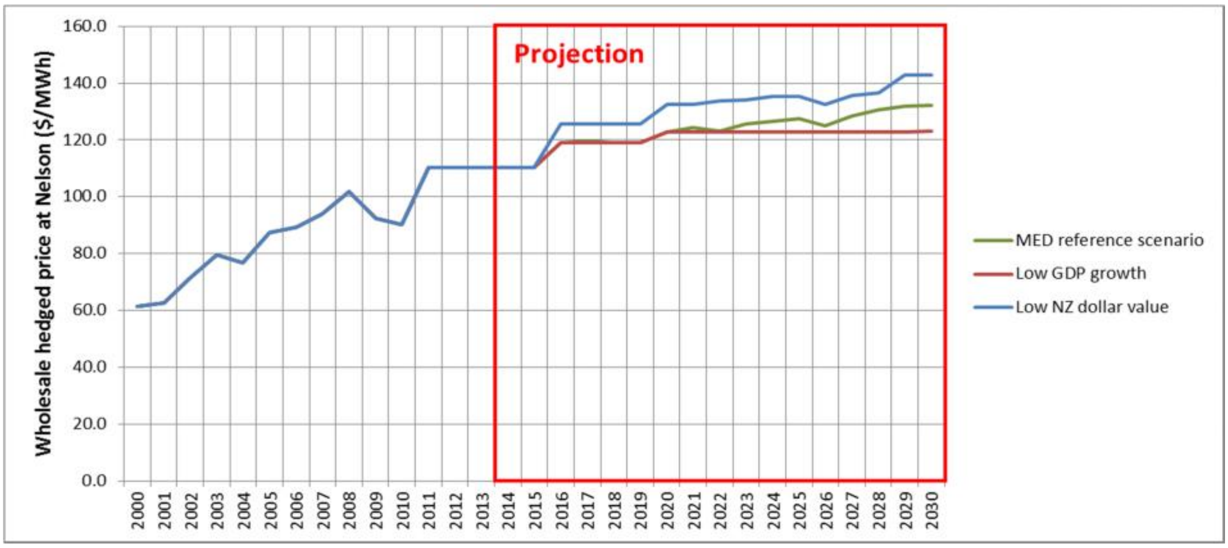


Figure F - Historical and Projected Wholesale Electricity Prices at Nelson

In the shorter term, the electricity price will be influenced year to year by hydrology and the economic growth cycle. Currently economic conditions (low demand growth and over build of generation) suggest prices are likely to be weaker than forecast for the next few years. Beyond that, renewed energy scarcity could resume.

3.4.1.2 Transmission Charges

Transmission charges relate to the National Grid owned by Transpower, and are currently averaging around 2 c/kWh. They are expected to rise in real terms to around 3 c/kWh once recent major Grid upgrades are completed. Once these upgrades are priced into the market, the real cost of transmission should then remain relatively stable because Transpower is a regulated monopoly.

3.4.1.3 Network Charges

Network charges relate to the distribution lines owned by the local network company (i.e. Nelson Electricity and Network Tasman), and are typically in the order of 8 c/kWh for residential users. These costs are also regulated by the Commerce Commission and, in real terms, should also remain relatively stable.

3.4.1.4 Retail / Metering

Retail and metering costs relate to the electricity retailers margin and costs of meter reading, and are in the order of 3 c/kWh for residential users.

4 Renewable Energy Potential in Nelson

4.1 Generic Barriers to Renewable Energy

Barriers that are specific to different types of renewable energy are discussed in the relevant sections below. However there are a number of generic barriers that impact renewable energy supply to a greater or lesser extent. These include:

- Capital cost – renewable projects have a higher upfront capital cost per MW than conventional thermal generation. This increases the risk profile of renewable projects compared to thermal despite the fact that their operating costs are normally a lot lower.
- Certainty around resource potential – to have confidence in the expected annual output from the project, long term quality site-specific data needs to be collected on the resource (e.g. wind speed, solar irradiation, river flows, biomass quantity and specific energy).
- Variability of output –renewable resources such as wind, solar and run-of-river hydro are variable over various time scales, resulting in variable generation outputs from year to year, month to month and in real-time dispatch. This variability can create challenges for integrating renewable resources into local networks and also creates additional uncertainty around project revenues.
- Location relative to load and transmission network – good quality renewable resources are often located distant from where the electricity is used, requiring the construction of transmission lines to connect the renewable generation to the nearest network connection point of sufficient capacity. Depending on the size of the generation facility, the transmission lines may be 11kV or 33kV (connecting into the local lines company lines) or need to be as large as 110kV or 220kV to connect to Transpower's grid. The challenges for the generation developer therefore include finding a suitable line route, negotiating easements with additional land owners and consenting of the transmission line.
- Revenue certainty – there is limited ability for developers to secure competitive long term power purchase agreements from retailers for intermittent renewable generation and reduce their exposure to wholesale price volatility.
- Variability of retail feed in tariffs for embedded generation – there is a wide range of rates that retailers are willing to pay for any electricity that is fed back into the grid by customers with on-site generation. These feed-in rates are generally a lot lower than the offtake rates that customers pay for electricity drawn from the grid (which includes variabilised charges for transmission and distribution). This means that distributed generation is most economic if it sized so that it results in a reduction in load at the offtake rate (particularly at residential tariffs which are higher than commercial tariffs).

4.2 Wind

4.2.1 Technology Review

4.2.1.1 Utility Scale Wind Turbines

Wind turbines are a mature renewable energy technology. Utility scale wind turbines have undergone considerable development and market growth since the early 1980s. At around this time, the industry had converged on the 3-bladed horizontal-axis upwind design that is most commonly used in wind farms today[1]. Over the course of 30 years utility scale land-based wind turbines have grown from 25 kW turbines with 10m diameter rotors to 3MW turbines with 112m diameter rotors, and the worldwide wind energy market has grown from less than 10MW in 1980 to 282,000 MW in 2012. (Global Wind Energy Council, 2013)

New Zealand's utility scale wind development history has followed a similar growth pattern, starting with the 225kW Brooklyn turbine installed in Wellington in 1993 as a research project by ECNZ. This was followed by the Hau Nui wind farm developed by Scan Power in the Wairarapa in 1996, comprising of seven 550kW turbines. By 2013, New Zealand has 13 wind farms (and 3 standalone wind turbines) totalling 623MW contributing 4% of the country's annual electricity demand. (New Zealand Wind Energy Association, 2013)

Figure G - Three of the 2.3MW Wind Turbines at West Wind, Wellington

While the size of wind turbines has grown with materials and manufacturing advances, the power conversion technologies have improved over recent years as well. Many wind turbine manufacturers are moving from gear boxes to direct drive machines to reduce complexity and improve reliability. Likewise the power off take of wind turbines have evolved from fixed speed controlled turbines with squirrel cage induction generators to variable speed turbines with full-scale power converter. This improves the integration of wind farms into the National Grid and wind farms based on this technology can provide voltage support to the system even when the wind is not blowing.

[1] Other wind turbine designs are still being developed and utilised such as New Zealand's two-bladed Wind Flow 500kW turbine, as well as various vertical axis designs. However their share of the global wind turbine market is very small.

4.2.1.2 Wind Farm Characteristics

Wind farms are based on a number of wind turbines connected to a common grid connection point. Some key characteristics of wind farms include:

Location	Wind turbines are best located on the top of smooth hills or ridgelines to maximise the speed up effect on wind. Cliff tops are not suitable sites as these create turbulence which increases the wear and tear on wind turbines.
Spacing	Wind turbines need to be spaced out to reduce wake effects from upwind turbines from those downstream. Spacing between turbines is typically 6 to 10 times the rotor diameter e.g. 500 to 800m for large wind turbines
Site Roads	Earlier wind farms required the construction of 10m wide roads on site due to the track width of the large cranes required for erecting turbines. With the development of narrow track cranes, on site road widths now vary between 4.5m and 6m.
Transformers	Some wind turbines have medium voltage transformers in the tower or the nacelle of the wind turbine. Others require that the transformer and its associated switchgear are sited outside the wind turbine, typically in a unitised substation
Substation	The power from each wind turbine is collected via medium voltage cables laid along the site roads back to an on-site substation. At this point there is typically one or two high voltage transformers and associated switchgear to connect the wind farm to the electricity network.
Transmission	New overhead high voltage transmission lines may need to be built to connect the substation to the nearest network connection point. The voltage depends on the size of the wind farm – wind farms up to 60 MW may connect at 33kV or 66kV, whereas wind farms of 100MW or more require 110kV or 220kV lines. These lines are typically built and owned by the local lines company or Transpower according to national standards and under a long term lease with the wind farm.
Noise	Modern wind turbines are quiet when they operate – however they must comply with strict resource consent conditions to ensure that while wind turbines may be audible at times, the level of sound heard at a nearby house must not be out of place with other sounds in the environment. NZ Standard NZS6808:2010 sets out the recommended noise limits from wind farms and is expected to be the basis of newly consented wind farms in NZ (New Zealand Wind Energy Association, 2010). Because there are a number of site specific and technology factors that govern the level of wind farm sound, there is no specified minimum set back distance from neighbouring houses. Depending on the site this set back may be around 700m to 1km.

4.2.1.3 Distributed Generation Scale Wind Turbines

Small scale wind turbines typically range from 1kW to 20kW and like utility-scale wind turbines, the most common design is the 3 bladed horizontal axis wind turbine. However, there are a number of on-going innovations in the design of small scale wind turbines, including the one-bladed 2kW Thinair wind turbine being developed by Powerhouse Wind in Dunedin.

Small scale wind turbines need to be elevated and tower heights can be between 10m and 20m. Rotor dimensions vary in size from about 3.5m diameter for a 2kW wind turbine to 12m diameter for a 20kW wind turbine.

Figure H – 1.8kW Skystream Wind Turbine Being Installed

Because they are lower to the ground than utility scale turbines, small scale wind turbines experience lower average wind speeds, and therefore have a lower capacity factor (typically 20 – 30%). The turbines also spin much faster than large scale turbines which results in higher pitched aerodynamic noise.

4.2.2 Economics of Wind

The primary drivers of the economics of wind farms in a New Zealand context are discussed below.

4.2.2.1 Wind Speed

The energy generated from wind turbines is proportional to the cubic power of wind speed and the swept area of the blades, as per the following equation.

$$P_{Wind} = \frac{1}{2}\rho A v^3 C_p$$

Where ρ is the air density in kg/m^3, A is the swept area (πr^2) of the blades in m^2, v is the wind speed (m/s) at hub height and C_p is the power coefficient (typically between 0.35 and 0.45 at rated output). (RWE npower renewables, 2012)

The power coefficient is not a constant and varies with respect to the tip speed ratio (the blade tip speed divided by the wind speed). Wind turbines therefore have a power curve similar to the one shown below with a cut in speed of around 3 to 3.5 m/s, with power output increasing according to the equation above until the rated output speed of the turbine is reached after which the power output from the turbine remains constant until wind speed reaches the cut-out speed (typically around 25 m/s).

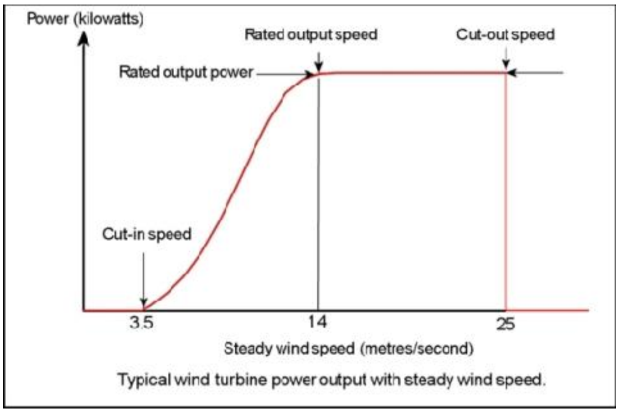


Figure I - Typical Power Curve for a Wind Turbine

Therefore the mean wind speed at hub height[2] over the course of a year is critical to the power generated from a wind turbine. The lower the mean wind speed, the more time the wind turbine is operating at a fraction of its rated power, greatly decreasing the electricity and revenue generated from the turbine.

As mean wind speeds vary significantly around the world, wind turbine manufacturers develop different classes of wind turbines with power curves optimised to different wind regimes. The average wind speeds that each of these IEC classes are designed for are as follows:

- Class I (High wind) – 10 m/s
- Class II (Medium wind) – 8.5 m/s
- Class III (Low wind) – 7.5 m/s

Wind turbines optimised for lower wind speeds typically have longer blade lengths and higher hub heights. For example, the wind turbines installed at West Wind (Class Ia wind farm) are rated at 2.3MW and have a rotor diameter of 82m and hub height of 68m, whereas the wind turbines at Te Uku wind farm (Class II wind farm) are also rated at 2.3MW but have a rotor diameter of 101m and hub height of 80m.

New Zealand is characterised by high quality wind resources compared to most other countries around the world. Most of the wind farms that have been constructed to date in New Zealand have been in Class I wind speed sites (i.e. Manawatu, Wairarapa and Wellington regions) reflecting the importance of wind speed on wind farm economics. The capacity factors of wind farms developed in these wind resources have capacity factors of between 42% and 48%.

The Te Uku wind farm near Raglan is the first to be built out of a large number of Class II wind farms that have been consented or are in the development process. New Zealand Class II sites are expected to have capacity factors of between 35% and 43% depending on the average wind speed and the turbine selected for the site.

4.2.2.2 Capital Cost

The overall capital cost of a wind farm is the other key determinant of the economics of a wind farm. This is affected by a number of factors, including:

- Wind turbine costs – about 70% of the capital cost of a wind farm and impacted by macroeconomic factors (e.g. international turbine demand vs. supply, steel prices, exchange rate) and site specific factors (wind speed class, turbulence, distance from suitable port);
- Civil and foundation costs – New Zealand wind farms are generally on elevated sites and civil costs are determined by ground conditions, steepness of slopes (for onsite roads) and road access to the site (ability to transport oversized components to site without having to widen roads or bridges);
- Transmission – good wind farm sites can be distant from a transmission system of sufficient capacity to accommodate the connection of a wind farm, requiring the construction of many kilometres of high voltage power lines across private land. The cost of these lines and the electrical equipment (transformers, switchgear etc) required to connect the wind farm to the grid are also affected by macroeconomic factors.

Depending on the site, New Zealand wind farm capital costs range from between $2 m/MW and $3.2 m/MW. (Deloitte, 2011). Small scale wind turbine prices range from $10,000 to $15,000 per kW of rated capacity including installation (i.e. five times that of large scale wind farms per kW). (EECA, 2009)

Wind turbine costs will continue to reduce over time as global demand for wind turbines is growing at a rate of around 40 GW per annum, and Chinese wind turbine manufacturers emerge to compete with the dominant European

[2] Hub height varies depending on the size of the turbine. Modern multi-MW wind turbines have hub heights of 70m to 80m off the ground, sub-MW turbines have hub heights of 30m to 50m. Due to friction effects of the terrain on wind flows, the average wind speed generally increases with respect to height above the ground.

manufacturers such as Vestas and Siemens (CleanTechnica, 2012). Wind power costs are expected to fall by a further 12% over the next five years. (New Zealand Wind Energy Association, 2012)

4.2.2.3 Operating Cost

Wind farms have no fuel cost but have the following on-going operating costs:

- Land rental – most wind farms are developed on privately owned land (e.g. farms, ex-forestry land) with easements and associated annual rental fees. The nature of these fees can vary from site to site (e.g. minimum rents, rents linked to annual output and/or electricity market prices) and due to the level of competition by wind developers for good wind sites these rents have generally increased over the years.
- Service, maintenance and repair costs – these are affected by the wind conditions of the site (e.g. turbulence), the technology incorporated in the turbines (e.g. gearboxes vs. direct drive), the cost of long term O&M contracts from the wind turbine suppliers, the size of the wind farm and the number of the wind turbines per MW[3]. Repair costs are generally low early in the life of the wind farm (especially if covered under warranty) and increase over the wind farm's lifetime.
- Transmission charges – sometimes the transmission connection is paid for by the local network company or Transpower and recovered under an annual charge to the wind farm owner. Large wind farms in the South Island also incur HVDC charges which impose an additional cost of up to $10/MWh compared to wind farms in the North Island. (Meridian Energy, 2006).
- Insurance and management overheads.

Depending on the above factors, operating costs for NZ wind farms vary from $10/MWh to $22/MWh. (Deloitte, 2011)

4.2.2.4 Levelised Cost of Energy

Based on the drivers above, the LCOE of large scale wind farms in New Zealand range from $80 - 95/MWh for Class I sites and $90 - $105/MWh for Class II sites. (Deloitte, 2011) (Meridian Energy, 2006)

These LCOE ranges mean that Class I and Class II wind farms are expected to be increasingly economic against other forms of renewable and thermal generation in New Zealand over the next decade, especially if wind turbine prices continue to improve.

The LCOE ranges for small scale wind vary from $250/MWh (or 25c/kWh) for 20kW wind turbines in good wind conditions to over $500/MWh for 2kW wind turbines in lower wind conditions[4]. (Meridian Energy, 2006).

4.2.3 Wind Resource in Nelson

Nelson City is relatively sheltered from the prevailing westerly winds compared to other coastal areas of New Zealand. High level wind mapping undertaken by NIWA (see Appendix A) shows that average wind speeds in Nelson City are between 4 – 6 m/s, which would be categorised as IEC Class III or below. The energy density from wind is around 2 W/m^2 compared to areas such as Wellington where it is in excess of 9 W/m^2. (NIWA et al., 2009)

Class III wind turbines are now being developed by wind turbine manufacturers to optimise performance at low wind speeds – such as the Vestas V126-3MW (126m diameter rotor) which can produce 10-20% more energy in Class III winds compared to the Vestas V112-3MW (Class II machine) in the same wind conditions (Vestas, 2012). However, they will always be more costly (due to size) and less productive than Class I and II wind farms, which means their LCOE will always be higher and will be uneconomic until such time as New Zealand runs out of Class I and II wind speed sites to develop.

[3] Wind farms utilising larger turbines have less gearboxes etc to maintain than those utilising small turbines for the same capacity wind farm
[4] At 6% discount rate, 25 year turbine life and 25-30% capacity factor range.

The large number of Class I and Class II wind sites currently under investigation along the west and east coasts of the North Island and east coast of the South Island, are sufficient to contribute up to 20% of New Zealand's electricity demand by 2030 (New Zealand Wind Energy Association, 2012).

It is therefore highly unlikely that wind farm developers will develop utility scale wind farms in the limited elevated space available in Nelson City in the next 25 years.

Small scale wind turbines can be installed "behind the load" so they have the effect of reducing the electricity offtake (at the full retail tariff), rather than injecting into the grid. However, the LCOE range for small scale wind indicated above are much higher than commercial and residential electricity tariffs, so installing small scale wind does not stack up economically except potentially in off grid applications with battery backup systems where the owner is avoiding significant upfront network connection costs.

4.2.4 Potential Electricity Generation from Wind

The Nelson City land area is 422 km^2. Without taking into account economics, existing land usage and potential environmental limitations, there is about 2% of elevated land area that is potentially technically viable for wind generation (excluding Department of Conservation protected areas). Based on NIWA's energy density for Nelson of approximately 2 W/m^2 would indicate an average annual wind energy potential of about 150 GWh (0.5 PJ pa). Based on a Vestas V126-3MW machine, this would indicate the potential for up to 19 wind turbines, spread across 14km of ridgelines (at 750m spacing).

However, given the economic and technical issues discussed above, it is not anticipated that a commercial wind farm or wind farms will be established in Nelson City in the next 25 years. If any wind generation is established in that period it is most likely to be limited to a few small scale wind turbines for off grid purposes.

4.2.5 Viability/Barriers to Development

The primary barriers to development of large scale wind in Nelson City are as follows:

- Low average wind speeds compared to the rest of the country, putting wind energy in Nelson well down the economic merit order for renewable generation;
- Limited suitable elevated land not currently being used for forestry.

The above is based on high level wind modelling undertaken by NIWA. There may be ridge lines that are exposed to higher wind speeds than estimated. To determine this would require the establishment of wind monitoring masts – firstly at 10m over a period of a year or more, then at hub height (e.g. 70-80 m) should any promising sites be found. If the NCC wished to attract wind developers to the region it might consider incentives to encourage them to establish 10m masts to begin the data collection process, or establish its own masts.

4.3 Solar

4.3.1 Technology Review

4.3.1.1 Solar Water Heating Systems

Solar hot water (SHW) systems involve harnessing the energy from the sun to heat up water which is then stored in an insulated hot water tank, significantly reducing the requirement for electricity or gas to heat up the water. The components of a SHW system typically include:

- Solar hot water collectors – either flat panels or evacuated tubes located on the roof;
- Hot water tank – either located on the roof or on the ground (split system);
- Pump and heating loop – required in split systems to circulate water from the cylinder to the collector on the roof, to be heated up and returned to the cylinder[5]. Thermo-siphon systems are more efficient in this regard as they utilise natural convection flow, but these require that the storage cylinder be located above the collector panel outside on the roof or inside the roof structure; (NIWA et al., 2009)
- Controller / Timer – designed to ensure hot water remains above a minimum temperature level by triggering an electric or gas boost either when temperatures fall below a set level, or at a specific time of day.

Figure J - Example of Flat Panel and Evacuated Tube SHW Systems

A well designed and appropriately sized SHW system in a good solar environment like Nelson should generate 100% of a household's hot water requirements in summer, but can drop down to as low as 50% during winter. Overall this can reduce household water heating bills by up to 75% (Righthouse, 2013). About 29% of a household's electricity usage is for hot water heating (i.e. 2,900 kWh per annum) so a SHW system can reduce electricity usage by about 2,200 kWh per annum in an average house (BRANZ, 2010).

Given the different SHW system approaches available, the cost of installation for a SHW system can vary widely. Complete systems, including the storage cylinder and installation, start at around $5,000 and depending on quality and size can be as much as $10,000. Retrofitting a solar collector to an existing hot water cylinder can cost as little as $3,000 but depends on the location and type of cylinder. It also requires a building consent (up to $500 depending on the council) to be obtained, due to the additional loading on the roof structure and as these systems potentially interact with drinking water supplies (Righthouse, 2013). Nelson City Council has offered free building consents for solar hot water heaters since 2008.

As part of the Government's Warm Up NZ: Heat Smart programme, EECA subsidies of up to $1,000 were previously available to support the installation of SHW systems on eligible homes. However in the 2012 Budget, these subsidies were discontinued in favour of an information-based programme. (EECA, 2012)

[5] Closed loop systems circulate a heat conducting fluid (typically glycol) in a closed loop from the collector to the cylinder, with the heated fluid heating the water in the cylinder through a heat exchange system. This is more expensive than an open loop system, but has benefits of frost protection in colder climates.

Larger SHW systems are also available for commercial purposes (e.g. public pool heating). In Nelson, the CityFitness gym has installed 32 SHW collector panels utilising a glycol closed-loop with four 1000 litre cylinders and a gas booster to provide hot water for the gym showers and taps (Nelson City Fitness, 2013). Likewise in 2010, the Nelson YHA installed a 117m^2 solar water heating system with gas back up on the northern roof of the hostel.

4.3.1.2 Passive Solar Design

Passive solar construction is a building design philosophy that seeks to maximise the utilisation of free energy and light from the sun to provide warmth and light in buildings during the day. Done well it can result in significant energy savings, reduce dampness and condensation and provide a comfortable living or working environment, with consequential benefits for health and well-being.

There are a number of elements which need to be considered holistically, including the site's microclimate, orientation, landscaping, external shading and the design of the building's windows, room layout, thermal storage and insulation (EECA EnergyWise Renewables, 2007). Some the key design principles include:

- **Site planning and orientation** – ideally the site will have a northerly aspect and the house elongated along the west-east axis, with winter sun unobstructed and summer sun restricted by exterior shading. Main living areas should be on the north side of the house, with rooms used in the morning orientated the east and those occupied in the evening to the west. Lesser used rooms such as storage, laundry, bathrooms and garages should be on the south.
- **Collecting solar heat** – the key mechanism for allowing solar heat into a building is through its windows. Generally glazing on the north should be larger, with a minimum of glazing on the south side of the building. Windows on the east side of the building can generally be larger than those on the west, to help with warming the house in the morning and minimising overheating in the afternoon. However, it is a careful balancing act between the amount of solar heat allowed into the building through glazing and the amount of thermal mass available to absorb that heat.
- **Storing solar heat** – materials such as concrete, terracotta or ceramic tiles can absorb heat during the day when exposed to direct sunlight, and then release that stored heat at night when the internal temperature drops. This means that flooring utilising these materials are best located in the northern side of the building and textile floor coverings should be restricted to parts of the building that are not used for thermal storage.
- **Conserving solar heat** – insulation reduces the loss of interior heat in the winter and heat gain in the summer. Insulation rated appropriately for the region (Nelson is Zone 3) should be correctly installed under floors, in the ceiling and wall cavities. The use of double glazing (mandatory in Zone 3 since October 2007) reduces heat loss in winter from windows by nearly 50% and heat gain in summer by 10% - as well as having other benefits such as eliminating condensation and noise intrusion[6]. Heavy curtains (preferably thermal lined) are another effective mechanism for insulating windows.
- **Avoiding overheating** –the windows that provide so much useful heat in the winter can generate excessive heat in summer. Designing the building with appropriately sized eaves reduces direct sun in the summer and allows more in during winter, as the sun is lower in the northern sky during winter. Also external plantings such as deciduous trees can have a similar shading effect, although bare trees can shade 20-40% of the sun in winter[7]. Good ventilation can be achieved with doors, windows or roof vents open in the direction of the prevailing summer breeze and another opening on the opposite side of the house to bring cooling breezes through the house.

[6] . The heat loss savings of double glazing over single glazing in standard aluminium frames is 40% (for window areas only, not the whole house heat loss).

[7] It should be noted that planting can cause potential over-shading and conflict with solar gain. The south west corner of the house is the best place to plant in Nelson.

The effectiveness and cost of passive solar heating is highly variable given the range of factors that need to be balanced. Anecdotally there can be a number of challenges in adhering to passive solar design principles as these can come into conflict with aesthetic or other considerations. For example, the desire to have living rooms and entertaining on the south side of the house with large windows due to southern coastal views. Inevitably compromises between energy efficiency and these factors are made and the potential energy savings benefits are reduced.

The passive solar fraction (PSF) is a measure of the percentage of the building's heat load met by passive solar heating i.e. the potential reduction in heating from electricity, gas or biomass sources. Reported PSF figures range from 5-25% for modest systems, 40% for highly optimised systems and up to 75% for very intense systems.

About 34% of average household energy consumption in New Zealand is for space heating - about 3,400 kWh per annum (BRANZ, 2010). A well designed new house in Nelson utilising passive solar design principles above, without incorporating excessively costly design features (e.g. triple glazing) is likely to have a PSF of around 30%, reducing heating energy by around 1,000 kWh pa (or 10% of average household energy requirements). This is consistent with a study undertaken by Sustainable Energy Authority of Ireland that estimated typical energy savings from passive solar houses of between 8 and 10% (SEAI, 1997).

4.3.1.3 Solar Photovoltaic Modules

Solar photovoltaic (PV) modules convert solar radiation into direct current (DC) electricity using semiconductors that exhibit the photovoltaic effect[8]. The DC electricity produced in an individual module is then combined with the output of other modules connected in parallel to an inverter which converts the electricity into alternating current (AC) before being stepped up in voltage and connected to the grid.

The main solar PV technologies include:

- **Crystalline silicon** – the most common and mature form of PV, available in either monocrystalline or polycrystalline form. Monocrystalline is a dark black colour, is more expensive due to the manufacturing process but has high efficiencies[9] – ranging from 16.9% to 20.4%. Polycrystalline is typically light to dark blue with a non-uniform appearance, is lower in cost and has lower module efficiencies – ranging from 15% to 16%.
- **Thin film** – these technologies reduce the amount of semi-conductor material required in creating the solar cell and are typically sandwiched between two panes of glass to create a solar module. There are a number of thin-film technologies available: cadmium telluride (CdTe), amorphous silicon (a-Si), copper indium (gallium) diselenide (CIGS / CIS). The manufacturing process for thin film is lower than crystalline silicon reducing the cost per Watt, however module efficiencies are much lower; from 7-9.5% for a-Si, up to 13% for CIS and up to 14.4% for CdTe.
- **Other third generation** - there are many emerging new materials under development to create the photovoltaic effect, such as light absorbing dyes, flexible polymers and organic/synthetic polymers.

[8] The photovoltaic effect is the creation of voltage or a corresponding electric current in a material, upon its exposure to light
[9] The module efficiency is a measure of how much of the solar energy is converted into electricity. The higher the efficiency, the lower the surface area required to be covered with solar modules to generate the same output.

Figure K - Types of Solar PV Modules (Monocrystalline Si, Polycrystalline Si and CIS)

Each of the PV technologies have different performance characteristics and cost versus efficiency trade-offs. For example CIS solar modules are more efficient than silicon in overcast conditions, and CdTe are more efficient in higher temperatures.

Solar photovoltaic technology is a mature and proven technology and in the past ten years has undergone considerable improvement in costs and efficiency. Global markets for PV have grown from 1 GW installed in 2004 to nearly 31 GW installed in 2012, with a total of 100 GW of solar PV installed worldwide reached in February 2013 (Renewable Energy World, 2013).

Solar PV is extremely scalable – i.e. solar PV systems can be sized to suit residential usage (typically 2-5kW), commercial (10 – 100kW), industrial (100 kW to 1MW) to utility scale (500kW to 500 MW). Residential to industrial scale PV is typically installed on rooftops and sized to generate a portion of the building load. Utility scale PV systems are most often designed as solar farms (i.e. built in array structures on land) and connect into the grid like other renewable power stations. The different types of system are discussed below.

4.3.1.4 Rooftop Solar

Rooftop solar PV systems are commonplace around the world and generally consist of solar modules installed on roofs either directly on rails or on pitched frames (particularly on flat roofs). Each of the modules is connected together with DC cables which are collected back to a central point where one or more inverters are located.

Figure L - Rooftop PV System Examples - Commercial, Residential and University of Queensland 1.2MW[10]

Solar PV panels perform best when receiving direct sunlight. The angle of sun moves from east to west during each day, and is higher in the sky during summer and lower in winter. This means that solar PV panels that are fixed in position will achieve up to 71% of the annual output that could be achieved by solar panels that are mounted on a 2-axis tracker (Landau, 2012).

To achieve the optimal daily generation with fixed rooftop solar panels, accounting for the east to west movement, solar panels should be facing true north (in the Southern Hemisphere). The optimal tilt to account for seasonal movement depends on whether the system is being designed for maximum annual generation or for more generation in the winter or summer. The shallower the tilt, generation will be greater in the summer to the detriment of winter generation - the steeper the tilt, the reverse will be true. The overall annual generation will be less in either case, but if the site has variable time of day / time of year electricity tariffs, it may be more economical to sacrifice overall annual generation to maximise generation during high price periods.

To maximise annual generation for a fixed system, there are a number of rules of thumb – some solar calculators advise tilting at the angle of latitude i.e. 41^{o} in Nelson. A formula from Macs Lab improves on this which advises that if latitude is between 25^{o} and 50^{o} to tilt the solar panels at 0.76 times the latitude plus 3.1^{o} (Landau, 2012). For Nelson this would suggest 34^{o} is the optimum angle. In the absence of solar modelling tools, this is a reasonable approach – however, it is advisable to use solar modelling software such as PVSyst or the freely available SMA Sunny Design – the latter shows that optimal generation in Nelson occurs at a tilt between 28^{o} and 30^{o}.

While this is useful information, for many residences and buildings with sloping roofs, the orientation and tilt is more likely to be determined by the pitch and orientation of the roof. If the orientation of the roof is not true north then overall generation will be reduced, and generation will be greater in the morning for roofs that are more easterly facing and greater in the afternoon for roofs that are more westerly facing. The other important consideration is whether there are neighbouring buildings, trees or hills that will cast shadows on the solar panels during the day.

[10] Courtesy of http://solardawn.com.au/e-newsletter/investing-in-research-and-development-for-global-benefit/

Costs of rooftop PV systems vary based on:

- **Size of system** – economies of scale can come into play in pricing of modules and inverters. Systems greater than 10kW generally incur modest charges from network companies to undertake studies to confirm that the system is compatible with the network without required additional reinforcing;
- **Type and source of PV modules** – i.e. crystalline silicon vs. thin film, European vs. Chinese manufacturers. In the past 3 years, with massive growth of world solar markets and solar module manufacturing in China, solar module prices have dropped from over $US2/W to under $US1/W;
- **Inverters** – like PV modules these have continued to improve in cost and efficiency, and prices depend on country of origin and functionality (e.g. inclusion of Wi-Fi and web-based monitoring);
- **Rooftop mounting configuration** – tilted mounting systems are more expensive than mounting rails for standard tin roofs. The distributed weight of the solar modules (typically 18-20kg per module) also needs to be considered with respect to the capability of the current roof to support the additional load.

Depending on supplier, grid-connected residential 3kW solar PV systems (complete with installation) are now available in New Zealand from between $10,700 and $13,500 including GST ($3.10 to $3.90/W excluding GST), with solar PV modules comprising 35-50% of the overall cost.

A 95kW rooftop PV system proposed for the Palmerston North City Council is expected to cost $240,000 ($2.50/W excl. GST) (Manawatu Standard, 2013).

With continued cost reductions in the cost of solar modules internationally this will continue to flow through to New Zealand pricing, and residential system prices of around NZ $2/W may be possible within the next five years (The Guardian, 2013). This is a marked improvement over the costs of PV of between $13 – 20/W reported in the 2006 Tasman Renewable Energy Assessment report (Sinclair Knight Merz, 2006).

4.3.1.5 Solar Farms

Solar PV farms differ from rooftop solar in that they are typically situated on unutilised low grade land and are usually (but not always) designed to export power directly into the grid like a conventional power station, rather than supply a local load.

Some of the key differences between solar farms and rooftop solar systems include:

- **Scale** – solar farms can range from 500 kW to 1MW to 10MW to 100MW+ depending on land available and the capacity of the transmission system that they are connecting into;
- **Mounting** – the solar modules are typically fixed in long arrays of solar frames which are either mounted on piles driven/screwed into the ground or on concrete foundations. The mounting systems may also involve automated single-axis (i.e. daily sun tracking) or dual-axis (i.e. daily / seasonal sun tracking) tracking systems;
- **Inverters** – like large commercial/industrial rooftop PV systems, smaller solar farms typically combine the output of module “strings” to distributed small scale inverters (up to 20kW capacity) whereas larger solar farms combine the output of many strings to large central inverters (500kW to 1.5MW each);
- **Grid connection** – the larger size necessitates high voltage connections to the grid with associated transformers, switchgear, protection, SCADA and control systems. They are also treated as power stations within the rules and regulations of the relevant electricity market i.e. rules around grid compliance, operation and market offers.

Figure M - Examples of Solar Farm Mounting Systems – Fixed (Concrete Slab)[11], Single Axis Tracker[12] and Dual Axis Tracker[13]

Depending on the type of modules used, row spacing and mounting system, solar farms typically require between 2 Ha and 3 Ha of land per MW – with dual-axis tracking systems requiring the greatest amount of land. Ideally land is flat as possible to reduce civil costs, but solar farms can be built on moderate slopes up to about 10% gradient (less for single axis tracking systems).

Due to their ground coverage ratios solar farms are not normally built on productive agricultural land. In countries such as the US and Australia where large solar farms are being installed, the land being used is typically desert or low value degraded / marginal agricultural land. Weed and grass control is still usually required between rows of solar panels, and some solar farm operators contract with local sheep farmers to graze their sites – a mutually beneficial arrangement.

Figure N - Sheep Grazing at CalRENEW-1 Solar Farm (Meridian Energy USA, 2013)

Maintenance requirements for solar farms are very low relative to other power stations and typically consist of panel washing, ground maintenance and annual inspections / maintenance of electrical equipment. Solar farms with trackers have higher maintenance costs associated with the electro-mechanical tracking systems.

The costs of solar farms depend on the scale and location, transmission connection and mounting system and can range from between $US2m and 4m per MW ($NZ 2.5 – 5m per MW). Over the next ten years with on-going cost and efficiency improvements in PV modules, installation techniques and balance of plant it is estimated that the cost for utility scale solar farms could reduce to $US1.44m ($NZ 1.8m) (Bloomberg New Energy Finance, 2012).

Depending on the location the annual average capacity factor of fixed mount solar farms can range from between 15% and 23% (highly dependent on solar insolation levels and ambient temperatures). Single axis tracking systems can increase capacity factor by around 3% and dual axis by a further 2%. The additional revenue gained from tracking needs to be weighed up against the additional capital and maintenance costs, and land constraints (since tracking systems require more land per MW than fixed systems).

[11] 1.25MW Maama Mai Solar Farm, Tonga built by Meridian, Courtesy of http://www.meridianenergy.co.nz/what-we-do/our-power-stations/solar/maama-mai/

[12] Courtesy of Screwpile Technologies, Australia, http://www.screwpile.com.au/app_images/249Solar%20Farm%201.jpg

[13] Kings Mountain solar farm, North Carolina, Courtesy of http://biofuelschat.com/topics/solar-farm-opens-kings-mountain

4.3.1.6 Concentrated Solar Power

Concentrated Solar Power (CSP) refers to technologies that focus solar irradiation onto a focal point using mirrors. Within CSP, there are two technology categories, Concentrated Solar Thermal (CST) and Concentrated Photovoltaic (CPV).

- CST involves concentrating solar energy to heat a fluid (typically oil), which in turn is used to create steam and drive a traditional steam turbine. There are three main concentrated solar thermal technologies: Parabolic Trough, Heliostat (or Power Tower) and Linear Fresnel Reflectors
- CPV utilises mirrors to concentrate light on to a small high efficiency PV module or cell.

The vast majority of CSP projects installed globally are using a CST technology. However, while solar thermal has a number of potential advantages relative to solar PV farms such as the ability to store energy, the risks and costs are much higher and in a number of cases in the US developers have cancelled plans for a large solar thermal facility in favour of a large PV farm.

Unlike conventional PV, CSP requires uninterrupted direct sunlight to operate and is best suited to high insolation desert environments. With New Zealand's lower insolation levels and cloud cover, CSP is not considered a viable future technology for the country, and given Nelson City's limited flat land area is highly unlikely to feature in the next 25-30 years.

Figure O - CSP Technologies – Power Tower with Heliostat Mirrors[14], Linear Fresnel Reflector[15], Concentrated PV[16]

4.3.2 Solar Resource in Nelson

Nelson is well known for its solar resource and typically has the highest annual number of clear sky days in the country. This does not however necessarily equate to the highest insolation (kWh per square metre per day) as its lower latitude results in less annual daylight hours and a lower angle of solar incidence than Northland.

As shown in Appendix A, the solar power density or global irradiance (tilted to degrees of latitude) in Nelson City is >170 W/m^2 (4.08 kWh/m^2/day) (NIWA et al., 2009). Other long term estimates of Nelson's global radiation levels on the horizontal plane range from between 4.0 kWh/m^2/day (RETScreen International, 2013) and 4.06 kWh/m^2/day (Meteonorm, 2013). As can be seen in the Meteonorm graph below, Nelson receives around 5 times the solar energy in peak summer months than it does in mid-winter.

[14] Courtesy of http://inhabitat.com/the-las-vegas-strip-could-soon-be-powered-by-a-solar-tower/
[15] Courtesy of http://shaikmohasin.wordpress.com/2012/02/
[16] Courtesy of http://newenergyportal.wordpress.com/category/solar-energy/

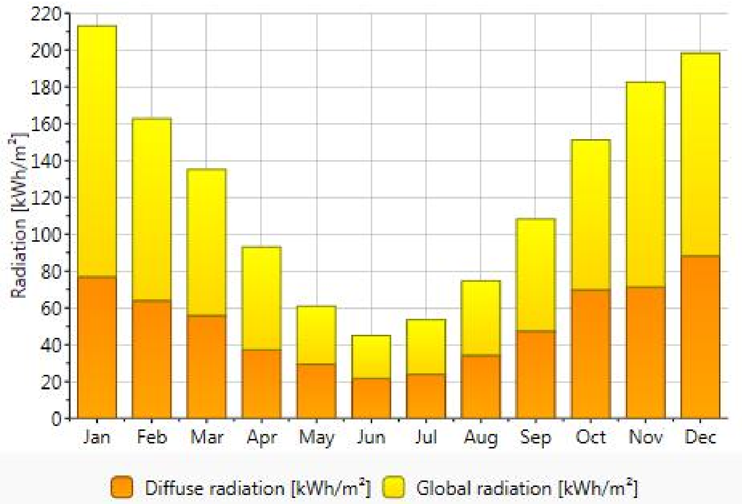


Figure P - Nelson Monthly Solar Diffuse and Global Radiation[17] (Meteonorm, 2013)

A comparison of daily average global radiation figures for Nelson relative to other locations is shown in the table below:

Location	Daily Global Radiation ($kWh/m^2/day$)
Nelson, NZ	4.06
Auckland, NZ	4.25
Napier, NZ	4.20
Christchurch, NZ	3.72
Invercargill, NZ	3.39
Melbourne, VIC, Australia	4.19
Sydney, NSW, Australia	4.59
Brisbane, QLD, Australia	5.25
Darwin, NT, Australia	5.54
Tongatapu, Tonga	4.64

While the solar resource in Nelson and wider New Zealand looks relative modest compared to Australia, it should be noted that Germany, which has over 22GW of solar PV installed, has global solar radiation levels of between 2.86 and 3.08 $kWh/m^2/day$. Also because higher ambient temperatures reduce the efficiency of photovoltaic conversion of solar energy into electricity, the difference between in global radiation between Auckland and Nelson does not translate directly to difference in electrical output as the latter has average ambient temperatures of around 2°C lower than Auckland.

A fixed PV system installed in Nelson (at an optimal tilt and orientation) will have an average annual capacity factor of between 14 and 15%. For example, the 10.4kW system on the NIWA building in Nelson generates an estimated 13.2 MWh per annum which is a capacity factor of 14.5% (PowerSmart Solar, 2012).

4.3.3 Economics of Solar

4.3.3.1 Solar Hot Water

The economics of solar hot water for residential consumers is driven by four main factors:

- Cost of the system;
- Homeowner's cost of borrowing;

[17] Global radiation is the total amount of solar energy falling on a horizontal surface. Diffuse radiation is the proportion of global radiation that falls on a horizontal surface from all parts of the sky apart from the direct sun, and is usually highest during cloudy conditions and lowest during clear sky days.

- Amount of customer electrical load is reduced;
- Electricity tariff.

Assuming an average home in Nelson, a SWH system would reduce annual electricity usage by 2,175 kWh, saving about $450 per annum (based on a controlled tariff of 20.6c/kWh including GST). It should be noted that in Nelson hot water cylinders are often connected to a separate meter and incur lower variable charges than the rest of the household supply because the electricity supply to the cylinder can be controlled by the lines company (hence the savings from SWH are not as high as one might expect)[18].

At a long term lending rate of 6% and assuming electricity tariffs rise at the rate of inflation over the long term, the rates of return for different cost SWH systems are as follows:

System Cost[1] (incl. GST)	System Cost ($/kWh)	IRR at 20.6 c/kWh	Simple Payback	Disc. Payback (@ 6% DCF)	Breakeven Tariff (incl. GST)
$5,000	$2.30	6.6%	13 yrs	23 yrs	19.8 c/kWh
$6,000	$2.75	4.8%	16 yrs	>25 yrs	22.8 c/kWh
$7,500	$3.45	2.9%	19 yrs	>25 yrs	27.2 c/kWh
$10,000	$4.60	0.6%	24 yrs	>25 yrs	34.7 c/kWh

Notes:

1. Assumes hot water system is saving the same amount of electricity in each case and the cost difference is due to site specific factors e.g. new hot water cylinder required, more pipework. In some cases a SWH system costing $10,000 might be designed for a higher water heating load and save more electricity than the example above. It is important to look at the system cost over expected annual savings ($/MWh) when comparing to the above table, rather than system cost alone.

The above shows that for an average sized SWH system if the installed cost is $2.75/kWh or less then it may make financial sense for the home owner to invest in solar hot water heating by extending their home loan or investing savings (a 5-6% after tax return is substantially better than current interest rates less tax).

Kiwibank is currently providing Sustainable Energy Loans to customers who have a mortgage with the bank, which enable them to add the cost of a solar hot water or PV system to their home loan without charging a top up fee. For customers borrowing over $5,000 for a system, Kiwibank will also pay $800 on the loan at the end of the first year, and $400 for each of the subsequent three years – to a total of $2,000 (Kiwibank, 2013). This improves the rate of return by 2.4% and significantly improves the payback periods.

The Nelson City Council currently waives the council consent fee for a solar hot water system. Other councils charge for a building consent (sometimes partially subsidised) ranging from $220 to $600. The value of a $500 consent fee being waived is an improvement in rate of return by about 0.5% and reduction of payback period by about a year.

For larger commercial solar hot water systems such as the one installed at the CityFitness Gym in Nelson, the costs and benefits are specific to the heating requirements of the commercial building. Larger systems should have improved economies of scale – however the variable electricity tariffs for larger customers can range from about 9 c/kWh[19] to 20c/kWh (excluding GST), so for a system that costs, say, $2,000/MWh (excluding GST), the IRR can range from about 2% for the low tariff to 9% for the higher tariff.

[18] There has also been a problem, both locally and nationally, where installers of SWH systems have changed the supplementary water heating element from the cheaper ripple controlled economy electricity supply, to the dearer uncontrolled "Anytime" supply. This costs customers roughly 29% more for any non-solar energy top up than it should, plus supply companies lose load control ability.

[19] For large commercial and industrial customers, the lines component is either a fixed daily or kW capacity based charge, hence a significantly lower per kWh tariff applies compared to smaller commercial and residential customers where the network charges are apportioned based on kWh usage.

4.3.3.2 Rooftop Solar PV

Like rooftop solar hot water, the economics of rooftop PV is dependent on the cost of the system; the owner's borrowing costs; electricity tariff and how much electricity the system can generate given the solar resource and orientation of the system on the roof.

In many overseas countries rooftop solar has seen significant growth due to government subsidies and feed in tariffs. Many of these are being substantially reduced as the solar industry has established itself and the costs of solar have come down. In the space of 3 years, over 1GW of rooftop solar PV has been installed in Australia due to State level feed in tariffs. Successive New Zealand governments have not deemed it necessary to subsidise solar PV due to the country's abundance of low cost renewables.

Not surprisingly the take up of solar PV in New Zealand has been very low historically with only 1.4MW installed at the end of 2004 (NIWA et al., 2009) and mostly associated with off-grid applications in the first instance. However, in recent years pricing of solar PV systems in New Zealand has benefited from the rapid global growth of solar PV and more locally the flow-on pricing effects from the growth of Australia's solar industry.

For grid-connected rooftop solar PV, the primary economic benefit for the customer comes from reducing the household load at the retail price of electricity. However, depending on the size of the system and the profile of the customer's load there may be times when the property becomes a net exporter of power to the grid. New Zealand's electricity governance rules do not allow for net metering (i.e. allowing meters to run backwards) and all distributed generation connected to the grid must have separate import / export meters.

This means that when the output from the solar panels exceeds the site demand, the excess power will be exported to the grid and recorded on the export meter. The export tariff that retailers will pay for exported power varies significantly between retailers[20], but is generally lower than the retail offtake rate, reflecting that this contains variabilised fixed distribution and transmission costs which are not avoided by intermittent distributed generation.

Residential Systems

Given the current residential system pricing of between $3.10/W to $3.80/W excluding GST, the economics of residential rooftop PV in Nelson is given below for a 3kW system, assuming minimal generation is exported to the grid and the consumer's long term cost of borrowing is 6%.

System Cost (incl. GST)	System Cost ($/Wp)	IRR at 27.6 c/kWh	Simple Payback	Disc. Payback (@ 6% DCF)	Breakeven Tariff (incl. GST)
$10,730	$3.58	8.8%	11 yrs	17 yrs	22.0 c/kWh
$12,150	$4.05	7.5%	12 yrs	20 yrs	24.4 c/kWh
$13,400	$4.47	6.4%	14 yrs	24 yrs	26.6 c/kWh

The above shows that at the current range of pricing an optimally sized and oriented rooftop PV system in Nelson is an economic proposition for residential customers. The effect of the $2,000 cash back under the Kiwibank Sustainable Energy Loan would improve the above IRRs by nearly 2% and reduce the breakeven tariffs by up to nearly 3c/kWh. This would enable some export to the grid during the day at a lower export tariff rate while still being a good investment at 6% discount rate (e.g. up to 50% of total output at the lower end of the system costs above, assuming a 12c/kWh feed in tariff and the Kiwibank credits).

In the long run it is possible that the continued reduction in cost and improvement in efficiency of solar modules could result in residential rooftop PV systems costing as little as $2/W (with the module making up about 25% of this cost). At this cost the breakeven tariff for a Nelson based residential PV system would be around 15c/kWh. This would make it an extremely attractive investment for home owners should retail tariffs continue to include per-kWh transmission and

[20] Until late 2012 Meridian Energy had a 1:1 feed-in rate for residential generation equivalent to its offtake rate – however this was a function of their billing system which previously did not have the ability to have two separate tariffs per customer. This has since been rectified and Meridian now offers energy only rates for electricity exported to the grid.

distribution costs. However, it is quite possible that should a high uptake of distributed generation occur, lines companies would need to move to capacity or peak-demand based charging to ensure they were able to recover sufficient revenue to maintain the networks, resulting in a much lower variable offtake charge for residential customers.

Commercial Systems

The economics for commercial roof top PV differs from residential systems in that businesses can claim GST and depreciation on the assets. Also the commercial variable tariffs tend to be a lot lower than residential, particularly for larger businesses as network charges are typically fixed monthly charges based on capacity or peak demand.

The cost of commercial scale rooftop PV systems are likely to be lower than those for residential given economies of scale. Based on the reported Palmerston North City Council 95kW system cost of $240,000 ($2.50/W), the commercial viability of commercial rooftop PV in Nelson at a range of commercial tariffs and at a commercial cost of capital of 9% is given below.

Tariff (excl. GST)	IRR (at $2.50/W)	Breakeven System Cost (at 9% WACC)
9 c/kWh	1.6%	$1.04/W
12 c/kWh	3.9%	$1.42/W
15 c/kWh	5.8%	$1.80/W
18 c/kWh	7.6%	$2.19/W
21 c/kWh	9.2%	$2.57/W

The table above shows that at the current system prices installing rooftop solar is unlikely to be commercial for larger businesses (i.e. those with tariffs which are closer to the wholesale rate). To be fully commercial for businesses in Nelson to install rooftop PV systems, overall system prices would need to fall by around 30 – 50% - noting that PV modules only make up around 40-50% of the total system cost[21].

While this is currently the case, some businesses are choosing to install smaller commercial systems (e.g. 10 kW) for other reasons such as research, brand or sustainability.

4.3.3.3 Solar PV Farms

Utility scale solar farms have different cost structures to commercial roof top systems. Due to their multi MW size, they can benefit from economies of scale for purchasing modules, inverters, racking systems – however, they have significant grid connection costs and civil costs. Additionally as they are on land rather than un-used roof space they will normally need to pay annual land lease fees which will be set on the next best use for the land e.g. subdivision, agriculture etc.

The cost per MW varies by project and region. The 10MW Greenhough River solar farm built in Western Australia in late 2012 was reportedly $A50m (NZ$6.25m/MW) (Power Technology, 2012). This was utilizing low cost CdTe solar modules, driven piles and the latest installation technologies from First Solar – although it is likely to have had relatively high labour costs given the Australian environment and possibly had a higher than usual grid connection cost. The project was supported by State Government grants.

By comparison the installed cost of large scale solar PV farms in the US is reported to be between $US2.10m - 2.40m/MW ($NZ2.6m – 3m/MW) (Bloomberg New Energy Finance, 2012). This reflects significant scale (100MW +) and experience in solar farm construction in that country compared to Australia and NZ.

[21] i.e. if PV modules prices halved the system cost would drop by 20-25%. Other cost components of PV systems, particularly installation and design are much less likely to drop significantly.

Assuming an ideal site exists for a small multi-MW solar farm in Nelson such as unused Airport land the capital cost based on current solar farm equipment costs is likely to be between $3.50m and $4.00m/MW for a fixed mount system. This is consistent with the cost of a 68kW ground mounted array built in Drury by South Auckland Forging Engineering (SAFE) for $270,000 ($3.97/W).

Given Nelson's solar resource (4.08 kWh/m^2/day) and assuming annual operating and maintenance costs of $30,000 per MW, a land lease of around $5,000 per Ha ($10,000 per MW), the LCOE for a utility scale solar farm at the above cost range would be between $310/MWh and $350/MWh.

Bloomberg forecast that solar farm costs could drop to around $US1.44m/MW ($NZ1.80m/MW) in ten years based on current technology cost and efficiency projects (Bloomberg New Energy Finance, 2012). Even at this cost, the LCOE of a fixed array solar farm in Nelson would be around $180/MWh – i.e. not cost competitive with average wholesale electricity prices[22]. A small improvement in LCOE might be gained from using tracking systems; however the additional capital and operating costs will somewhat offset the additional electricity generated.

4.3.4 Energy Potential for Solar

4.3.4.1 Solar Hot Water

In the past four years, consents have been granted for nearly 450 solar hot water systems, nearly half of which were granted in 2010. Assuming these were predominantly residential systems and the remaining 18,790 houses in the district have the technical potential to install SWH systems, then the energy savings potential for residential solar hot water in Nelson City is about 41 GWh per annum increasing to 49 GWh per annum in 25 years.

However, the average rate of install in Nelson is 112 systems per year (0.24 GWh), indicating that if systems continue at the present rate, in 25 years an additional 2,800 SWH systems could be installed in Nelson City, saving 6.1 GWh per annum.

4.3.4.2 Rooftop Solar PV

There are approximately 19,200 houses in the district which currently do not have rooftop solar PV systems installed, and 3,800 additional houses expected to be built in the next 25 years. Assuming a best case scenario that all had suitable roof angles and orientations for solar PV, the theoretical potential for residential rooftop solar PV in Nelson City based on an average 3kW system is 68 GWh per annum increasing to 81 GWh in 25 years. Based on the current installation of 0.13 GWh and compound annual growth rates between 10 and 20%, installed residential capacity in 25 years could be between 6 GWh and 26 GWh.

However it should be noted that SWH and solar PV are likely to be mutually exclusive from an economic point of view. If a house has an SWH system to provide the hot water heating load, then it is more likely that a PV system on the same house will be exporting to the grid during the day time and receiving a lower feed-in-tariff than if it was supplying household loads at the avoided retail offtake rate.

Also, due to the geography of the district, many of the roads run from south-west to north-east and cross-roads from north-west to south-east, with houses oriented in parallel. This means that many houses have roofs oriented to about 40^o east of north, reducing the annual yield by about 3%, or 50^o west of north reducing annual yield by 6%.

Commercial Systems

As at 2006, there were about 5,300 businesses in Nelson City. These vary in size from small-medium commercial enterprises to large meat and seafood processing firms. Many of these businesses are in large factory buildings which could accommodate solar PV systems on their rooftops. No data is available on the number of these buildings in Nelson City or associated rooftop area. Utilising Google Earth we have estimated that Nelson City has approximately

[22] In overseas locations such as California, solar farms with high LCOEs can be economic because their output is aligned with very high summer daytime wholesale prices driven by air conditioning loads and limited peak generating capacity. In NZ we have excess generation in summer due to hydro inflows and peak loads / higher wholesale prices normally occur in winter evenings.

3.6 km^2 of land area utilised by commercial or industrial buildings e.g. CBD, Port Nelson, Nelson Airport, Annesbrook, Wakatu Industrial Estate, ENZA, CHH Packaging and Nelson Hospital. Based on a visual estimate of building coverage percentage for each area and assuming that two-thirds of the northerly facing rooftops can be covered by solar PV panels gives an approximate PV area of 380,000 m^2.

With standard 250W solar PV panels this would give a total potential cumulative installed capacity of 59.2MW with a maximum annual yield of 65 to 75 GWh per annum. This equates to approximately a 10-11kWp PV system for every business in Nelson City. The technically feasible installed capacity will be dependent on a number of factors such as the strength of the commercial building rooftops, and capacity of the network to integrate significant amounts of distributed PV systems. However the commercial considerations above are likely to limit the development of commercial scale rooftop solar to a fraction of the above for the next 25 years. Based on the current installation of 0.03 GWh and compound annual growth rates between 10 and 20%, installed residential capacity in 25 years could be between 1.6 GWh and 7 GWh.

4.3.4.3 Solar PV Farms

A Nelson developer is anecdotally considering the potential for two 5MW solar farms at the Nelson Airport. If these were successfully commercialised in the next 30 years, the annual energy potential could be between 12.7 GWh and 13.1 GWh.

4.3.4.4 Passive Solar Building Design

Nelson City Council estimate that the number of households in Nelson City will increase by 3,810 over the next 25 years (Nelson City Council, 2012). If all of these new houses were designed according to passive solar design principles then the potential energy savings would be in the order of 3.8 GWh (0.014 PJ) per annum.

The existing stock of 19,240 houses in the City is likely to be refurbished by their owners over the next 50 years. Many are likely to have already benefited from the EECA Warm-up subsidy and fitted under-floor and ceiling insulation in the past 5 years (contributing to the slowing of demand growth in the region). However, savings in the order of 8 GWh (0.03PJ) per annum might be possible within 25 years assuming half the existing housing stock is retrofitted with double glazing and wall insulation during renovations[23].

4.3.5 Viability/Barriers to Development

4.3.5.1 Solar Hot Water Heating

Not all houses are going to be suitable for solar hot water heating due to roof structure and direction, neighbouring obstacles (e.g. large buildings, trees or hills) that cut out the sun or the houses are rental properties.

For those that are suitable, the biggest barriers to solar hot water heating are affordability and payback. In many cases, SHW should be a good investment and enabling factors such as the council waiving consent fees and Kiwibank's sustainable energy loan should make it a no-brainer. That said, the payback period for a SWH system is greater than 10 years, which may be longer than people expect to stay in the same house. This should not matter, as the value of the house should be higher with a SWH system, but it is difficult to determine the tangible value of this uplift. This is a difficult rationale for the solar water heating industry to overcome and is a reflection of complex human nature in relation to perception of value – e.g. the same people who might decide not to invest in a SHW system due to payback, might happily pay several thousand dollars for an entertainment system that will be obsolete in 5 years with no payback at all.

Another factor that can be a barrier is the impact of poor publicity and lack of knowledge. Negative perceptions of SWH can be created by poor quality installations, systems not delivering on promised savings and resulting in cold showers, or lack of service. Not all SWH systems are created equal and people can find the choices of systems overwhelming.

[23] Assuming 10% PSF (870 kWh p.a. savings)

4.3.5.2 Rooftop Solar PV

The barriers for rooftop solar PV are very similar to solar hot water heating discussed above.

The economics have greatly improved in the past three years to the point where the rate of return for residential PV is similar to solar hot water heating – provided the bulk of the electricity generated by the PV system is utilised by loads in the house at the time it is generated i.e. the household has sufficient daytime loads. For many households this will not be the case, increasing the likelihood that the exported power will be larger and receive a much lower feed in tariff compared to the offtake rate.

In the near term the lack of a 1:1 feed in tariff will be a major barrier, or at least a limiting factor on the size of PV systems installed by people. As the cost of PV systems continue to decline this will become less of an issue. The impact can also be limited with automated load management e.g. use of timers on dishwashers, washing machines or dryers to run during the day while the homeowner is at work.

Another minor barrier that has recently been raised on feed-in-tariffs is that the Inland Revenue may require the homeowner to pass on the GST component paid by the retailer to the IRD – reducing the feed in tariff rate by a further 13%.

4.3.5.3 Solar PV Farms

It is highly unlikely that utility scale PV facilities will be developed in Nelson due to the following barriers:

- Relatively high capital costs and solar energy resource around 30-35% lower than the desert locations in California and Australian deserts where large scale solar farms are being built;
- Solar farms are therefore not expected to be commercially competitive against alternative renewables in NZ for another 15 years (unless average summer daytime prices increase significantly);
- The need for relatively flat land for solar farms, limited flat land area in Nelson City and the high productive value of land for agricultural and subdivision purposes;
- The need for economies of scale (i.e. 10MW or greater) to improve the economics and exacerbating the above land requirements.

Small scale ground mounted solar PV arrays such as the 68kW system installed at the SAFE Engineering site in Drury in 2012 may be possible provided they are installed behind a commercial load e.g. at the Nelson Airport.

4.4 Hydro

4.4.1 Technology Review

Hydro power is the most mature renewable energy source for producing electricity, and has been the backbone of New Zealand's electricity industry since the first hydro-electric plant was built in Reefton in 1888. Today hydro power supplies about 60% of New Zealand's electricity demand.

Hydroelectric power schemes generate electricity from the gravitational energy potential between the power plant's water source and the plant's outflow. The power generated is governed by the following equation:

$$P = \eta\rho Q g h$$

Where η is the efficiency of the turbine, ρ is the density of water (998 kg/m^3), g is gravity (9.81m/s^2), Q is the flow (m^3/s) and h is the net head (height differential between inflow and outflow less frictional losses).

Figure Q below shows a basic schematic of a typical hydroelectric scheme with water being drawn from an upstream reservoir (e.g. dam, lake or head pond), passed through one or more turbines which are connected to electrical generators, and the outflow discharged into the river at a lower level.

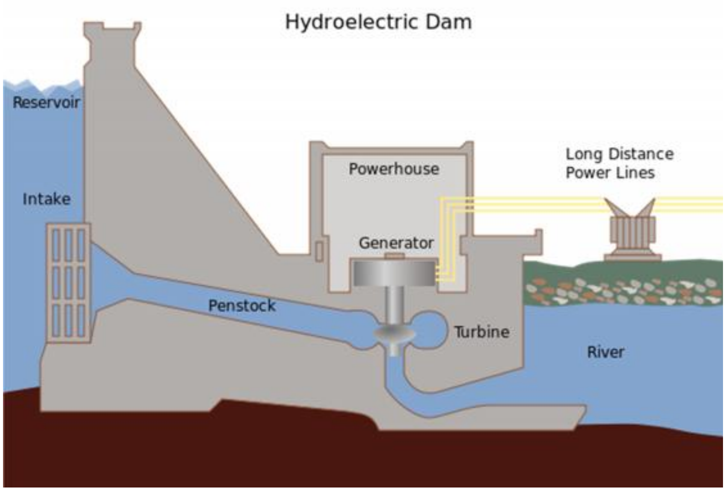


Figure Q - Schematic of Typical Hydroelectric Power Station (Wikipedia, 2007)

There are two main types of hydro power schemes in New Zealand:

- **Conventional dams** – involves building a dam across a river to build a storage reservoir or lake upstream and create the head for the power scheme;
- **Run of River** – involves diversion of water from a river through a pipe or canal to a small head pond which then leads to the hydro plant, with the water being returned to the river downstream.

Depending on their size, dams provide a greater level of water storage and flexibility in hydro power operation, making the plant less vulnerable to short term river flow variability and more valuable from the perspective of the electricity market. However, they do have a greater impact on the environment, requiring large areas of land upstream to be flooded and can have potentially adverse impacts on the pre-existing environment (e.g. constraining fish and eel migration).

Run of river hydro schemes have a lower impact on the existing river, except for the reduction of flows in the stretch of the river between the intake and outflow. Because they have little or no storage, the output from run of river hydro is more variable, reducing the ability of the operator to optimise generation to meet electricity demand peaks. Some run of river schemes are based on a chain of power stations linked by canals or tunnels, with the water from the last power station returning the water to the river, well downstream from the initial intake.

The size of hydro schemes can range from micro hydro (less than 100kW), small (typically up to 10MW) to large (which in a New Zealand context is less than 1000MW[24]).

4.4.2 Economics of Hydro

The cost of hydro power is highly specific to the river resource and the topography. From the equation above the key factors driving economic viability of hydro is the topographical potential to create significant head and river flows (the more consistent the better). The former might be generated by a valley formation which could be dammed to create a lake, a tightly winding river with a steep slope, or a nearby river or sea at a lower level.

A significant portion (e.g. 50-70%) of the overall capital cost of a hydro power station is associated with the civil structures (e.g. tunnels, canals) and earthworks (e.g. dams). This means that hydro has a higher risk profile and time for construction than other renewables such as wind and solar where civil works are a much smaller proportion of the cost. It also means that hydro tends to benefit more from economies of scale.

The sizing of hydro turbines and electrical plant are optimised around the most efficient utilisation of the available water resources based on the overall scheme design. The design of the turbines is dependent on the scheme's specific head and flow regime, and these are manufactured to suit.

Hydro power stations are very long lived assets. The civil works can last in excess of 70 years, with mechanical and electrical plant being refurbished or replaced at around 35 years.

Depending on storage capability and how the scheme has been sized, the capacity factors of hydro schemes can vary between 40% and 70%.

The following graph in Figure R shows the LCOE cost ranges for generic hydro schemes in New Zealand, based on an analysis undertaken in 2006 by Meridian Energy, updated to 2013 dollars (Meridian Energy, 2006).

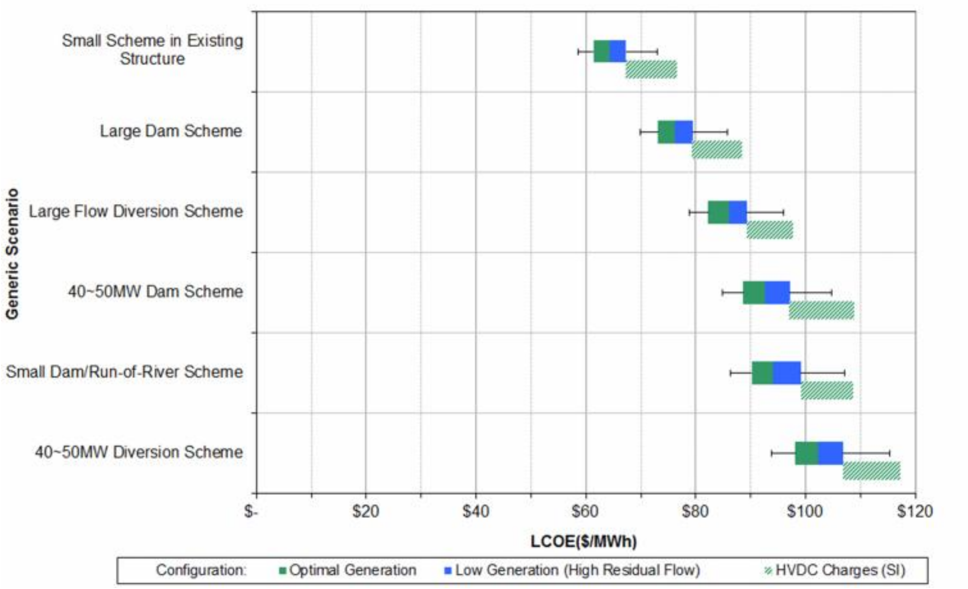


Figure R - Levelised Cost of Energy for Hydro

The key takeaway points are:

- The most economic hydro options are those where existing infrastructure such as a dam already exists ($60-85/MWh);

[24] New Zealand's largest hydro power station is Manapouri which has a peak capacity of 860 MW.

- Larger schemes (100MW+) tend to be more economic ($70 – 105/MWh) than smaller schemes ($85 - $125/MWh) due to economies of scale, particularly those involving storage;
- Hydro schemes built in the South Island have an additional LCOE burden of up to $10/MWh due to Transpower's HVDC pricing regime (although small hydro projects embedded within distribution networks do not face this charge).

Another key point is that over the past 80 years the Government and electricity industry have successfully developed the most economic large hydro projects (the low hanging fruit) to the point where there are few remaining economic hydro projects. Most of these have been fully or partially consented in recent years (e.g. North Bank Hydro, Arnold, Wairau) and some have been unsuccessful either at the consenting stage or put on the shelf (e.g. Mokihinui, Mohaka, Clutha options).

4.4.3 Review of Hydropower Capacity Studies

In 2004, East Harbour Management Services was engaged by the Ministry of Economic Development to review New Zealand's hydroelectricity opportunities where there is a possibility that they might be considered for development within the next 20 years. The report scope was focused on opportunities with a high to medium confidence level of proceeding. (East Harbour Management Services, 2004)

In the Nelson-Marlborough Region the report found that there were 5 potential hydro projects totalling 141 MW (678 GWh per annum) that had a medium to high confidence level. The bulk of this potential was from a 100MW scheme on the Wairau River in Marlborough (a 72 MW scheme has since consented by TrustPower). Three of the other schemes were in the Marlborough region including the Pelorus River, lower Waihopai River and Middle Awatere River.

4.4.3.1 Wairoa Gorge

The fifth scheme in the list was a potential 16MW (70 GWh pa) scheme at the Wairoa Gorge in Tasman District. The scheme would involve damming the Wairoa River immediately downstream of the Lee River confluence to create a 90m head to supply flood mitigation, irrigation water, town water supply, recreational facilities and electricity generation. The project is located within the region supplied by the Stoke GXP, so while the scheme would not be within Nelson City, the power output and associated beneficial impacts on security of supply and wholesale price would benefit Nelson City.

4.4.3.2 Others in the Region

Three other hydro opportunities in the Tasman region were indicated in the East Harbour report – a 39MW scheme in Motueka, 5MW supplement to the Cobb scheme and a 13MW scheme on the Anatoki River. No further information was supplied on these schemes but presumably these had been investigated previously by the old Ministry of Works or NZ Electricity Department. No developer is currently investigating the potential of these schemes and they are not expected to be developed within the 25 year outlook.

4.4.4 Hydro Resources

Nelson City has three main river catchments – the Maitai River catchment, Wakapuaka River catchment and the Whangamoa River catchment. These feed into various streams around the district.

River flows are recorded by the council for the Maitai River at the Forks and Avon Terrace, Wakapuaka at Hira Rd, Roding at Caretakers and Orphanage at Ngawhatu Rd. (Tasman District Council, 2013)

4.4.4.1 Maitai Dam – Nelson City

In 1987, an earth dam was built on the Maitai River to store water and supply potable water to the district. The Maitai dam is 36m high and has a storage volume of 4 million m^3. The scheme is designed to supply a peak demand of 40,000 m^3 per day, and its resource consents require that minimum flows in the Maitai River are 300 litres per second from April to October, and 175 litres per second from November to March. (The Prow, 2009)

4.4.4.2 Waimea Community Dam (Lee River) – Tasman District

Since the East Harbour report was commissioned a partnership (Waimea Water Augmentation Committee) between local industry and Councils was created to develop a 52m high dam within the Lee Valley (approximately 300m upstream of the confluence of Anslow Creek and the Lee River). The scheme would supply irrigation water for 1800 Ha in the Waimea Plains, Wairoa and Wai-iti. The feasibility study has included an assessment by Network Tasman of a 1.2MW hydro plant added to the scheme which would produce about 6.4 GWh pa. (John Cook & Associates et al, 2011)

It is assumed that this project supersedes the Wairoa Gorge proposal and that the two projects are mutually exclusive. As per above, the proposed scheme would likely feed into the Stoke GXP which also supplies Nelson City. However its lesser size would significantly decrease the security of supply and nodal pricing benefits at the GXP.

4.4.4.3 Roding Valley Waterworks – Nelson City

The other water supply to Nelson City and Richmond comes from the Roding Waterworks scheme, built in 1941. The scheme consists of an 11m high dam which supplies a peak demand of 13,000 m^3 per day via a 2.7km pipeline (The Prow, 2008). The storage capacity of the dam has reduced from 40,000m^3 to 3,000m^3 due to build-up of gravel and sand in major floods and the water supply intake has since been moved to below the weir. A small 90kW hydro power generator was installed in 2009 at the Water Treatment Plant to capture some of the energy in the water supply system that otherwise would have been lost through a pressure reducing valve. (Nelson City Council, 2012)

4.4.5 Potential for Hydropower in Nelson

The Maitai Dam appears to be the largest single opportunity for hydro power in Nelson City, given that the storage infrastructure has already been built. In 1990, Citipower undertook a prefeasibility study for a hydro scheme utilising residual flows after town water supply is withdrawn from the dam. The report estimated a potential scheme size of 130 kW generating an annual electricity supply of between 485 MWh and 675 MWh (0.0024 PJ). (Citipower, 1990)

The study needs to be updated, based on modern efficient hydro turbines (the 1990 study assumed 70% efficiency) and utilising any flow data that has been recorded over the past 20+ years (and taking into account changes in town water demand). A 150kW hydro plant may be quite economic – however its lack of scale does mean that development and consenting costs (assuming resource consent is required) do have a bigger impact on the viability.

Outside of Nelson City, the proposed Waimea Community Dam with the added hydro option is likely to be beneficial in providing a small reduction in net demand at the Stoke GXP, which will marginally improve wholesale electricity prices in the region.

It is unlikely that the other rivers and streams in Nelson City represent viable opportunities for hydro from a technical and economic perspective. Some niche micro-hydro opportunities may exist for some land owners to generate power for their houses but the energy potential from such opportunities is likely to several orders of magnitude lower than solar energy potential in Nelson City.

4.4.6 Viability/Barriers to Development

The key barriers to development of hydro in Nelson City are:

- Lack of significant water resources not otherwise being used for town water supply;
- Competing / conflicting demands for water resources between recreational uses (e.g. fishing, rafting), water supply for potable water and irrigation – makes consenting hydro projects challenging and expensive;
- Potential for silt and gravel build up behind dam structures during flood events, reducing storage capacity.

4.5 Bioenergy

This section covers bioenergy opportunities that are already technically and commercially proven and can be adopted within the 10 year focus period. These include:

- Combustion of woody biomass for heat and/or electricity supply using boilers and steam turbine technology; and
- Digestion of putrescent wastes to produce biogas for use in boilers for heat or reciprocating engines for combined heat and power (CHP).

CHP, also commonly known as cogeneration, is the generation of both heat and electricity in a single plant.

This section also discusses emerging technologies that might be developed sufficiently to be adopted in a longer 25-30 year time frame. There are many competing bio-energy conversion processes under development and it is uncertain which of these will develop into technically and commercially viability options. Only technologies that are already at an early stage of commercial operation are considered to have potential for Nelson City during this focus period.

Applicable technologies for each utilisation option are discussed in the relevant subsection. Further details can be found by reference to research undertaken by Scion, the Forestry Crown Research Institute (Scion, 2007).

Liquid biofuels options are discussed in section 4.6: Transport Fuels.

4.5.1 Summary of Potential

Bioenergy opportunities in Nelson City are summarised in the table below and discussed in more detail in subsequent subsections.

Biomass categories	Clean woody biomass	Contaminated woody biomass and combustible waste	Putrescent waste
Current sources	• Waste stem wood from forestry skid sites • Pulp logs • Urban tree removal • Sawmill chip, sawdust and shavings	• Forest residue recovery • Bark • Recovery from urban waste • Woody agricultural residues	• Municipal waste water plant sludge • Urban food wastes • Food processing wastes
Future sources	• Purpose grown forest and woody crops	• Increase forest residue recovery	• Animal wastes • General MSW
Current use options	• Heat and electricity using boilers and steam turbines • Pellet manufacture	• Heat and electricity using specialised boilers and steam turbines	• Landfilling producing LFG • Anaerobic digestion producing biogas
Growth potential in Nelson	• Wide-spread growth in use for heat	• Niche - limited • Heat and electricity for industrial developments.	• Niche – limited • Bell Island WWTP option
Drivers	• Potential cost savings • Sustainability • Lower exposure to international oil prices and NZ currency value	• Potential cost saving • Sustainability • Avoided waste disposal costs	• Sustainability • Improved waste water treatment • Avoided solid waste disposal costs • By-products - fertilisers
Barriers	• Cost competitiveness • Planning rules • Established and reliable wood fuel supply chain	• Cost competitiveness • Better disposal alternative uses such as composting and mulching • Effect on removal of nutrients from land	
Emerging technology options	• Gasification for CHP • Liquid fuels using pyrolysis/gasification or hydrolysis/fermentation	• Liquid fuels using niche thermal and chemical processes	

4.5.2 Biomass Resource in Nelson

The assessment covers the biomass resource in and around Nelson City. In the right circumstances, it may be practical and economic to transport raw biomass up to 150 km from its source, so biomass from the Tasman and Marlborough Districts may be used to supplement local supply.

The available biomass resource can be classified in three broad categories:

4.5.2.1 Clean Woody Biomass

Clean woody biomass is generally sourced from solid tree stem and branch wood. Consequently it should be free from significant soil contamination, heavy metals and other man-made chemicals. This makes it suitable for use as a boiler fuel either green (approximately 50% moisture content), seasoned (approximately 30% moisture content) or dry. It is suitable for chipping and burning in standard commercially available packaged boilers and is the preferred feedstock for wood pellet manufacture and biofuels.

In Nelson the main sources of this type of biomass are:

- Urban tree removal and clean woody biomass recovered from the urban waste stream. Urban wood can be used provided that it is not a wood composite, treated or painted. This is a limited resource in Nelson and a minor percentage of the overall supply;
- Sawmill residue streams: sawmill chip, sawdust and shavings that can be green or dried. There are several significant sawmills in or near Nelson and together they produce approximately 150,000 t/y chip, 50,000 t/y sawdust and smaller quantities of shavings. The sawdust and shavings are generally burnt at the sawmill site to produce the heat for kiln drying. Sawmill chip could be available for bioenergy applications, but most of it is currently purchased by Nelson Pine (in the Tasman District) as feed stock for their MDF mill. Nelson Pine also import chip and pulp logs from the Marlborough District;
- Stem wood recovered from forestry skid sites. With log harvests of approximately 2.3m t/y in the top of the South Island, there is potential to recover approximately 100,000 t/y stem wood from skid sites, subject to the economics. Some of this material is already recovered for Nelson Pine's fuel supply and for domestic firewood. Further recovery depends on the economics, and the relative cost of alternatives such as pulp grade logs;
- Whole trees removed from rural land and pulp logs from existing exotic forests. This is by far the largest bioenergy resource near Nelson. Harvested pulp logs in the upper South Island are currently used to supply Nelson Pine or are exported. Overall the pulp log supply in the Top of the South Island is approximately in balance, with a surplus forecast to develop in the next few years and continue until at least 2030. This is illustrated by the following information sourced from National Exotic Forest Description (Ministry of Primary Industries, 2012), and Nelson Marlborough Forest Industry and Wood Availability Report (Ministry of Agriculture and Fisheries, 2006).

  The location of the exotic forest estate in the region, and its ownership is shown in the resource map in Appendix A. Forest areas and pulp log availability forecasts for the top of the South Island are as follows:

	Nelson City	Tasman District	Marlborough
Forest area[1]	9,000 Ha	86,000 Ha	74,000 Ha
Total annual log harvest	160,000t/y	1,500,000t/y	650,000t/y
Forecast pulp log harvest			
Now	included	250,000 t/y	140,000 t/y
2020	included	380,000 t/y	240,000 t/y
2030	included	520,000 t/y	260,000 t/y

Notes
1. 90% of exotic forest are Pinus Radiata, 9% are Douglas Fir and the balance mostly Eucalypts

The age class of un-pruned forest plantations in the top of the South Island are as follows:

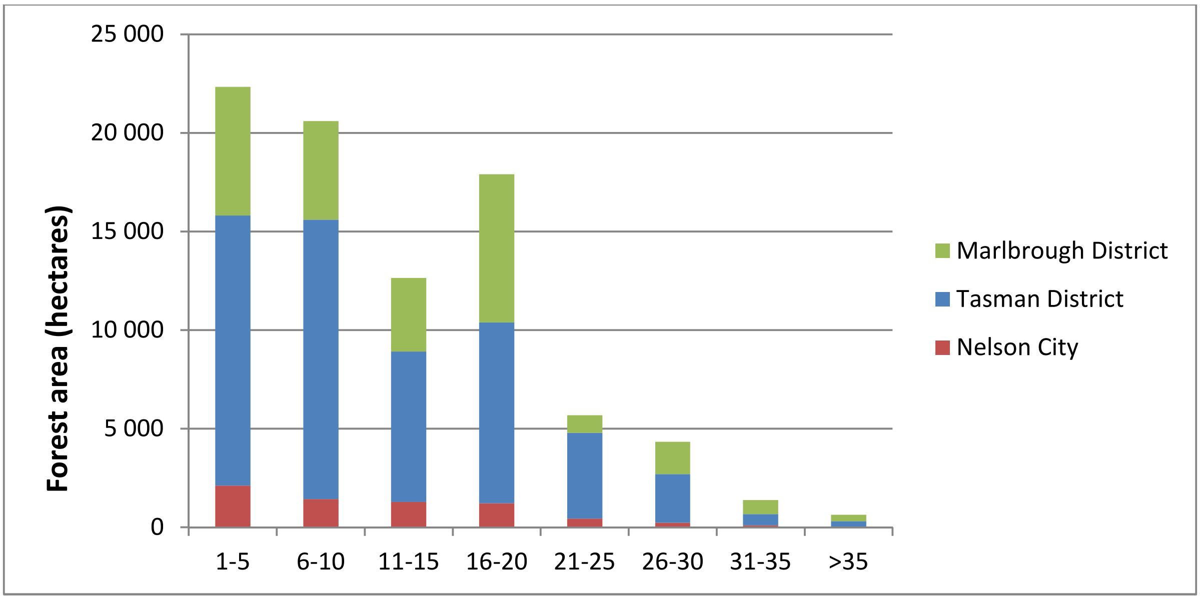


Figure S - Age Class of Forest Plantations in the Top of South Island

Nelson Pine is the sole processor of pulp wood in the Nelson-Tasman region. They require approximately 850,000 t/y and use a mix of wood chip and pulp logs. As there is currently a shortage of pulp wood or chip in the Nelson area the shortfall is imported from Marlborough. In the future this shortfall should ease and by 2020 there should be a local surplus for bioenergy applications; and

- Potentially, in the future, purpose grown trees or woody plants such as Willow/Salix and Miscanthus grass. These plants are grown commercially overseas, but their suitability for the NZ environment and their commercial viability here is uncertain. Even if proven in NZ, they are unlikely to be a supply option for Nelson within the 30 year timeframe due to the lack of suitable production land near Nelson, and the time needed to prove their viability in NZ and to develop an efficient supply chain.

Figure T - Pulp log seasoning/ chipping operation and forest skid site residues.

Wood pellets are normally manufactured from sawdust. These are best suited to domestic heating applications where their higher energy density and convenience is preferred. The main supplier in NZ, the Nature's Flame business in Taupo, produces up to 60,000 t/y but small quantities are also produced locally by AZ Wood.

4.5.2.2 Contaminated Woody Biomass

This type of biomass is typically contaminated with soil, green matter or sourced from other residues (such as straw) that are corrosive or abrasive when burnt. However it should be free of heavy metals, plastic and other man-made chemicals. This material is best suited to larger industrial or horticultural heat applications because they require more specialised custom designed boilers. In Nelson the main sources of this type of biomass are:

- Forest residues contaminated with soil. For the Nelson Tasman area up to 100,000 t/y of these low grade residues may be recoverable;
- Bark residues from sawmills. With modern harvesting techniques most bark is removed from the log in the forest and this is now a minor waste stream; and
- Woody horticultural wastes and vine prunings from the surrounding Tasman region. The volume of this material has not been quantified, but could be a significant biomass resource. It is said to be currently dumped or burnt in situ.

These types of woody fuel can be burnt in conventional boilers, with appropriate technology, and the economics can be positive because the project may attract gate fee revenue from avoided landfill charges.

On a larger scale, there is also an opportunity to use MSW or biosolids as a fuel for electricity generation or cogeneration as part of a regional solution. NZ currently does not use MSW or biosolids as a fuel, even though these are used overseas in Europe and America. In NZ there are major barriers to this option as follows:

- Burning MSW and biosolids is currently not permitted under the National Environmental Standards (NES);
- Public perception is negative and there is legitimate concerns over the potential for harmful air emissions; and
- Landfill disposal is still relatively cheap.

This fuel resource option is therefore very unlikely to be an option for the top of the South Island.

4.5.2.3 Putrescent Waste Material

Some types of wet biomass can be suitable for anaerobic digestion to produce biogas. This material is normally too wet to burn, but can be converted to biogas, and a residual sludge stream. Feed stock with a carbon/nitrogen ratio of 20:1 to 30:1 is desirable. Gas yields from suitable material are in the order of 8 GJ/ tonne dry matter.

In Nelson the main sources of this type of biomass are:

- Municipal Waste Water sludge. The Bell Island Waste Water Treatment Plant produces approximately 1,500 t (dry matter)/y of this material;
- Food processing wastes such as from meat processing sludge (Alliance), apple pomice (ENZA Foods) and grape marc, or in the future from aquaculture. A report by Waste Solutions (Waste Solutions , 2007) suggested there was potential to collect up to 8,000t (wet basis)/y of this type of biomass in the Nelson-Tasman region;
- Animal manure, potentially in the future if a large scale piggery was established (for example); and
- Municipal Solid Waste decomposing anaerobically in the landfill to produce LFG or as feed stock from putrescent waste diversion.

Biogas can be used for generating electricity, with the option for heat recovery, or for heat only applications as per the Nelson Hospital project.

4.5.3 Economics of Biomass

4.5.3.1 Cost of Biomass

As previously discussed, the major bioenergy resources near Nelson are pulp logs, sawmill chip and residues, and forest residues. Some of the residues are low cost, but as the use of bioenergy in Nelson increases, the cost of pulp logs is likely to set the cost of the fuel. This is effect is illustrated below.

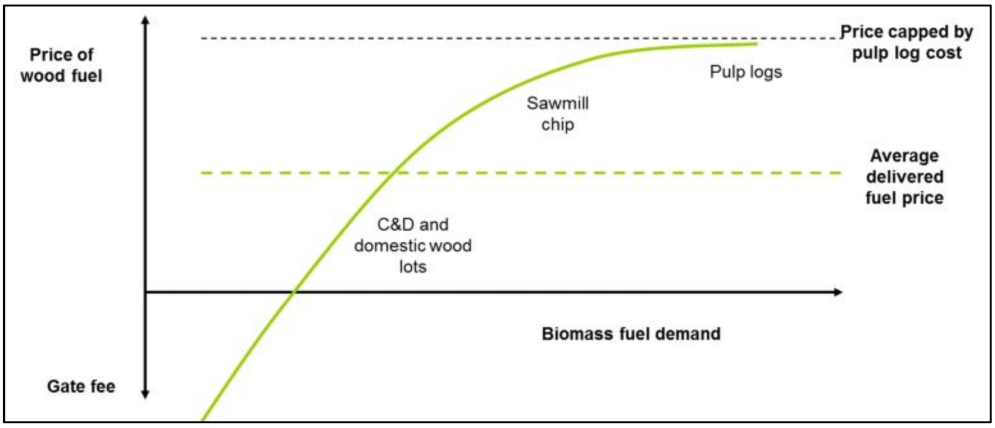


Figure U - Wood Fuel Price Curve

The cost of pulp logs delivered to Nelson has been relatively stable for many years and is currently around $50/t ($5/GJ). The cost to season, store and chip pulp wood and deliver it as a seasoned chip fuel to a customer would add approximately $6/GJ, meaning that the delivered cost of seasoned chip in Nelson should be approximately $11/GJ. In the future, the real cost of this fuel may rise as demand for wood energy increases.

4.5.3.2 Combustion Efficiency

The combustion efficiency of burning woody biomass increases as the fuel moisture content reduces. It is therefore important to minimise the moisture content of the wood through seasoning or drying the material.

The effect of the moisture content (with all other parameters constant) is illustrated below:

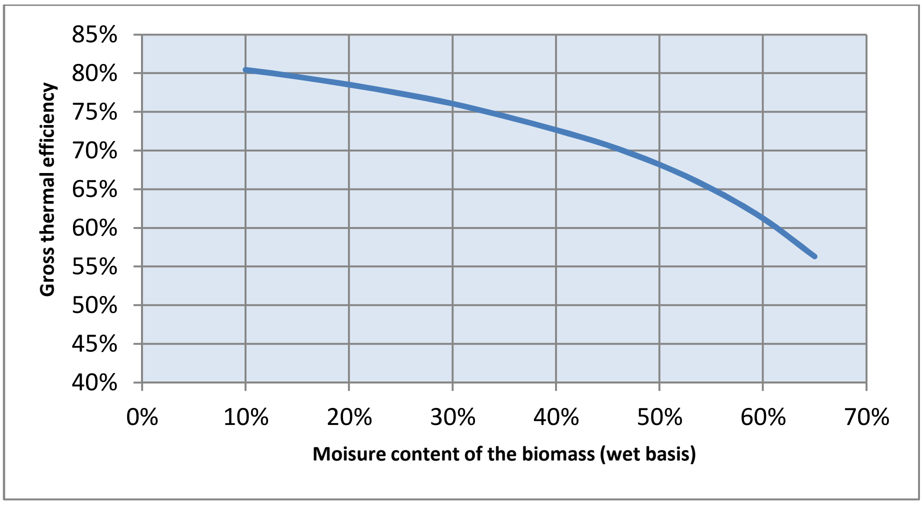


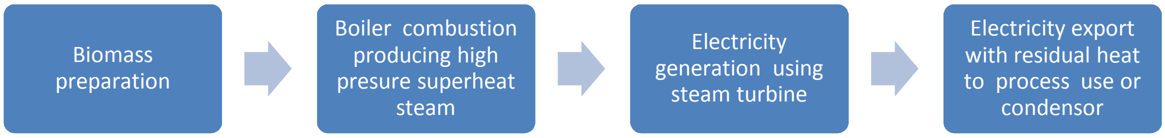
Figure V - Effect of Moisture Content on Gross Thermal Efficiency of Biomass

4.5.4 Bioenergy Applications

4.5.4.1 Electricity Generation Using Woody Biomass, Including Cogeneration

The convention technology used to generate electricity from woody biomass is fully mature, relatively simple and reliable. With optimal design, it can be nearly as efficient as next generation technologies such as bio-gasification combined with combined cycle plant.

The basis process flow is shown below:



Boiler technology can be standard packaged domestic and smaller commercial industrial units suitable for good quality wood fuel, or bespoke designs for larger applications or for more difficult fuels.

To illustrate the application: a 140 MW_{th} steam boiler would use 400,000 t/y green biomass to produce 2.6 PJ steam and this steam would be supplied to a 40 MW_e condensing steam turbine to produce 320 GWh/y electricity, enough to supply the entire Nelson City (ignoring peaks). This type of electricity generation may approach commercial viability if the cost of the biomass fuel was around $50/t and the value of the electricity was around $140/MWh.

This option is therefore technically feasible for a location in the Nelson City region. However, within the period to 2030, it is not likely to be economically competitive with other forms of renewable generation (mostly in other regions) such as wind, geothermal or hydro-power.

A variation on this option would be cogeneration, where the steam turbine exhausts steam at a higher pressure to match a process heat demand. In the above example, if the steam was discharged at 10 bar g, the power output would drop to around 14 MW_e and 126 MW_{th} steam would be available for process heating. There are no industries in Nelson that could suit this option, even at a much smaller scale.

4.5.4.2 Heating Opportunities Using Woody Biomass

Heating using wood chip or pellet fuel is the most promising short term bioenergy option for increasing sustainability in Nelson City. There is potential to convert many of the remaining heat demands in the city that are still using fossil fuels.

Hot flue gas from the combustor can be used directly (for space heating or drying) or indirectly to heat a fluid (water or oil) so that the heat can be transported to the end user.

This is a fully mature technology in widespread use in NZ, including Nelson. The most common technology applicable to Nelson is packaged space heaters and boilers (made both in NZ and imported).

Figure W - Domestic and commercial pellet heaters

For larger applications, wood chip is a more cost effective fuel and a hot water or steam boiler is normally used. These units typically require more sophisticated fuel handling, combustion and flue gas filtering systems.

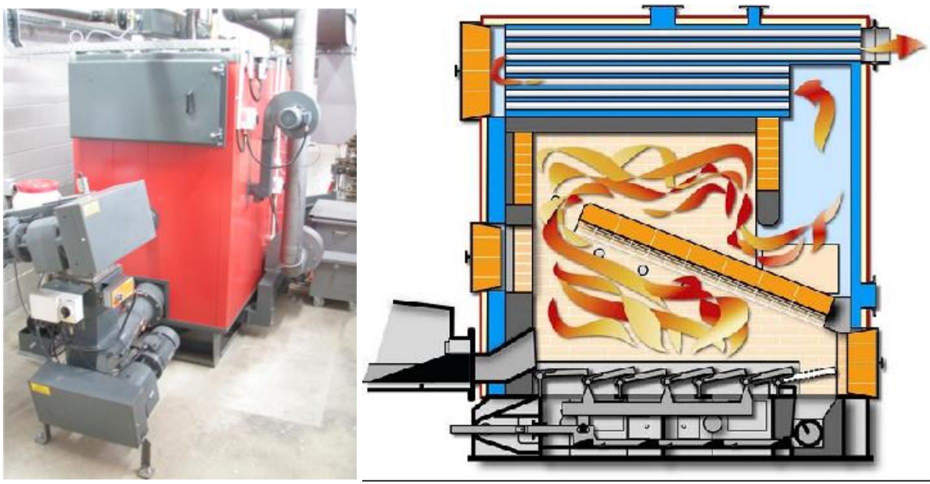


Figure X - Packaged wood chip boiler and combustion system

As illustrated in section 3, the cost of heat from wood fuel is similar to heat using a coal fuel or from heat pumps, and much cheaper than using liquid fossil fuels. This is before other drivers are considered such as emissions to air, sustainability, and security of supply of liquid fossil fuels.

Wood pellets will also be a competitive fuel option where it is a substitute for liquid fossil fuels or electric resistance heating.

Examples where wood to heat options may be commercially viable in Nelson include:

- Private homes and commercial buildings;
- Community facilities such as hospitals, rest homes, schools, swimming pools and public buildings; and
- Industries that currently use fossil fuels.

All of these applications are subject to Nelson City's Air Quality Plan which is intended to improve the city air quality to meet the National Environmental Standard for air quality. The plan generally permits the installation of domestic scale (up to 40kW) approved "ultra-low emission" pellet heaters. It also facilitates the installation of industrial-size (40kW to 200kW) wood pellet burning units in situations where they are replacing existing coal or solid wood boilers.

Nelson does not have the scale, urban density or climate for a district heating scheme, as are common in Europe. However, it may be possible to establish industrial or commercial hubs where one heat plant can service a cluster of users. This approach may provide economies of scale and lower the capital establishment costs for new business.

Specific examples of the larger opportunities to increase biomass to heat uptake in Nelson are as follows:

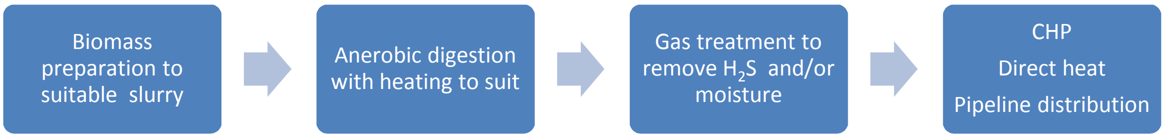
Heat user	Owner	Current fuel	Fuel usage
Juice concentrator	ENZA Foods	LFO	1.6m l/y; 0.07 PJ/y
Fish processor	Sealords	LFO	1,400 t/y; 0.06 PJ/y
Brewery	McCashins	Coal	400 t/y; 0.01 PJ/y
Nelson Hospital and laundry	Crown	Coal	1,500 t/y; 0.04 PJ/y
Sawmill	Waimea	Part coal	5,000 t/y; 0.1 PJ/y
NMIT	Crown	Diesel	90,000l/y; 0.003PJ/y

NCC is already heating many of its buildings with electricity (direct resistance and heat pumps), but there is potential to consider wood energy for base load heating in its high occupancy buildings and for heating the Nayland pool. There is also potential to convert schools and rest homes in the city. To be consistent with the Air Quality Plan these conversions would need to replace fossil fuel and reduce particulate emissions to air.

4.5.4.3 Biogas Opportunities, Including LFG

Anaerobic digestion uses microbes to produce a biogas by digesting biomass slurry. The biogas produced is typically around 60% methane. With suitable treatment and stable gas properties, this gas can be used as a boiler or engine fuel.

The basis process flow is shown below:



This technology is most commonly used in NZ at municipal waste water treatment plants (MWWTP) for electricity generation, where sludge digestion is part of the water treatment process. There are currently biogas CHP installations at the Mangere, Bromley and Hamilton MWWTPs. There is also potential to use this technology at the Bell Island WWTP, if it is to be upgraded to include anaerobic digestion. A recent feasibility study (Waste Solutions , 2007) suggested this could generate up to 350 kW electricity or up to 1,100 kW if additional putrescent wastes were added to the MWWTP sludge. This option may be viable as an add-on project if NCC decided to convert the Bell Island to anaerobic digestion based on other waste water treatment drivers.

In NZ, outside the MWWTP application, there is limited potential for this technology. Potential applications include:

- Diversion of putrescent food wastes from landfill for digestion. A scheme of this type considered for Christchurch would have required 20,000 t/y waste and produced enough gas for 600 kW of generation. This material can be mixed with sewerage sludge and processed at an existing MWWTP.
- Digestion of concentrated animal wastes, particularly from pig farming. Large scale pig farming requires sophisticated waste water treatment and digestion is a suitable add-on to this process. It is possible that this type of option could be commercially viable because of the avoided gate fees.

LFG from the York Valley Landfill is already used for heat at Nelson Hospital, displacing coal fuel. LFG is drawn out of the landfill, treated and compressed and piped to the Hospital. It may be possible to increase LFG recovery at the Landfill (albeit with some risk to gas quality and reliability) for use at the Hospital or by other nearby heat users.

Figure Y - Nelson Hospital Landfill Gas Plant

4.5.4.4 Pellet or Briquette Manufacture

There is potential for biomass and pulp wood to be processed into fuel pellets or briquettes. These could be used for domestic and commercial heating in Nelson or exported to Japan and other Asian countries that are increasing the use of these fuels. This is a credible scenario for Nelson within the next 20 years.

This type of operation is best suited to regions where large volumes of sawdust are generated. The sawdust is pulverised, dried and pelletised, usually with a binder. For Nelson City, the current use of sawdust for process heat at sawmills could be substituted with other woody biomass to enable this option.

For commercial viability, this type development would need a secure export market prepared to pay up to equivalent liquid fuel prices. Technology is being developed to manufacture torrified wood pellets and these have a higher energy density. This should improve the economics for pellet export.

4.5.5 Emerging Technologies

4.5.5.1 Technology Status

Beyond the 10 year focus of this study, there are other emerging bioenergy technologies that could develop into commercial proven options for Nelson. The most promising of these and their current development stage are summarised below:

Research and development to demonstration stage	Early commercial stage
Biomass integrated gasification and combined cycle (BIGCC) power generation	Gasification for CHP with reciprocating engines
Pyrolysis for bio–crude oil for refining for transport fuels	Gasification for direct fired kilns
Wood to ethanol using hydrolysis and fermentation	Combustion with ORC for power generation
Wood to ethanol using gasification and fermentation	
Hydrothermal treatment of MSW	

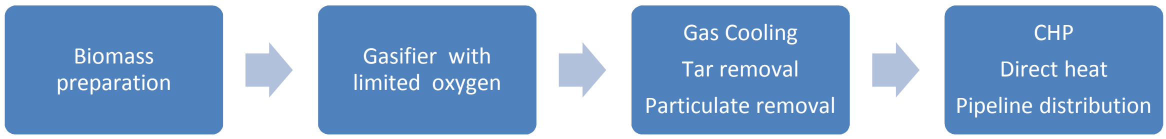
For Nelson, wood gasification (discussed below) and wood to biofuels technologies (discussed in section 4.6.4) could advance during the next 20 years to the fully commercial stage.

4.5.5.2 Gasification

This base technology is very mature and relatively simple, but the downstream gas treatment is much more challenging and, for most bioenergy applications, it is not fully mature.

When heating biomass in an oxygen deficient environment, combustion is prevented and volatile gases such as Carbon Monoxide, Hydrogen, and methane are generated. This syn-gas can be used in a similar way to biogas.

The basis process flow is shown below:



Heat is used to dry the feedstock or support gasification. Steam can be injected into the gasifier to increase gas calorific value so that it is suitable for reciprocating engines.

The difficulties with gasification are:

- Low gas heating value and variable consistency. The gasification process produces a relatively low grade raw gas that is of marginal quality as engine fuel. If air is used for the gasification process the gas calorific value (CV) will be around 4 to 6 MJ/m^3 and if oxygen is used the CV can be increased to 10 to 15 MJ/m^3;
- Gas treatment. The raw gas contains particulates and condensable contaminants, as well as potentially heavy metals if these are found in the biomass feedstock. For use in engines, the raw gas needs to be cooled and these contaminants need to be removed. This technology is not yet technically or commercially mature.

While there are a lot of enthusiastic technology developers in this space, commercially proven technology is rare. The best example overseas is in Austria where an early industrial scale plant has now been in operation for over five years; however this is a subsidised operation.

Figure Z - Güssing 2MWe gasification and CHP plant

Once commercially proven, this technology could start to displace combustion/heat-only applications with CHP plants provided that the overall energy efficiency is superior to the current approach of using combustion for heat and importing grid electricity.

In the future this technology may also be the precursor for producing liquid fuels used with the Fischer-Tropsch process.

4.5.6 Viability/Barriers to Development

The key barriers to the further uptake of bioenergy in Nelson City include:

- For heating, it is not necessarily as cost competitive as coal and it is not as convenient as grid electricity used with a heat pump;
- There is a higher value utilisation option (MDF manufacture) for much of the currently available clean woody biomass in the region;
- The wood fuel supply sector in the region currently has limited scale and competitiveness; and
- There are Air Quality Plan rules that limit the increased use of wood fuels for heating in the urban area where it may adversely impacts on air quality.

4.6 Transport Fuels

4.6.1 Conservation and Efficiency

While out of the scope of this assessment, it is important to note that the most immediate way to reduce the use of fossil fuels for transport is through conservation and efficiency gains.

Conservation can be achieved by avoiding unnecessary vehicle use, increasing the use of public transport, car-pooling and by walking or cycling instead of driving. These changes can be assisted by encouragement, pricing incentives, planning policy and urban design.

Efficiency gains can be achieved through the use of smaller and more efficient vehicles (including electric hybrids), improved road design and driving skills. These changes can be assisted by encouragement, national regulation, car emission standards, pricing incentives such as through vehicle registration fees and other public policy measures.

If liquid fuel use in Nelson was reduced by 15% through these measures, 0.3 PJ/y of fuel savings and 21,000 tCO_2e/y emission reductions would be achieved.

4.6.2 Comparison of the Renewable Options

If Nelson City is to significantly reduce its reliance on liquid fossil fuels during the next 25 years, it is most likely to be as a result of one or more of the following options:

- Electric vehicles using grid electricity assuming that the additional electricity will be generated from a similar mix of renewable and fossil fuels as is presently used;
- Internal combustion engine (ICE) driven vehicles using biofuels produced with woody biomass; and
- Electric vehicles using grid electricity generated from North Island natural gas in a CCGT power plant, or a wood fuelled power plant if it became economic.

It is important to note that biofuels are not carbon zero, and in fact some consume significant quantities of fossil fuel in their production. For example woody residue fuels are reported (AEA Group, 2009) to result in indirect emission of approximately 5kg CO_2e/GJ. Indirect emissions from corn ethanol produced in the USA are estimated to equal or exceed the replaced fossil fuels.

The overall fuel running cost and GHG emissions (tank to wheel) of the above options are illustrated by the simple comparison below:

	Petrol +ICE	Grid + BEV_1	CCGT +BEV	Bioethanol $+ICE_2$
Cost comparison per GJ				
Fuel cost to tank or battery charge	$54/GJ	$67/GJ	$67/GJ	$54/GJ
Fuel to wheels efficiency	17%	80%	17%	17%
Delivered energy at wheels	$317/GJ	$84/GJ	$394/GJ	$317/GJ
Emissions comparison per GJ				
For fuel or electricity only	70kgCO_2e/GJ	45kgCO_2e/GJ	125kgCO_2e/GJ	15kgCO_2e/GJ
For delivered energy at wheels	410kgCO_2e/GJ	56kgCO_2e/GJ	735kgCO_2e/GJ	90kgCO_2e/GJ

Notes:
1. Charging using off peak electricity could reduce this by around 50%;
2. Wood to ethanol conversion efficiency of 50%, wood feedstock emission of 5kgCO_2e/GJ plus 5kgCO_2e/GJ processing emission assumed.

This simple comparison shows that:

- The Grid + BEV option is by far the cheapest fuel option and results in by far the lowest GHG emission; and

- The Bioethanol + ICE option (once the technology meets assumed performance levels) may be competitive with the current Petrol + ICE option and would also significantly reduce GHG emissions.

4.6.3 Electric Vehicles

The use of NZ grid electricity and Battery Electric Vehicles (BEV) is a promising and emerging renewable energy opportunity for Nelson.

Hybrid vehicles such as the Toyota Prius are well established in the NZ market and vehicle manufacturers are now ramping up production of BEVs. Electric motor bikes are already in widespread use in China to combat city air pollution. World-wide production of battery electric cars is now around 100,000/y and forecast to grow to around three million vehicles per year by 2015. While these vehicles are relatively expensive now, their cost should come down as mass production increases. For example, Nissan is reported to have reduced the cost of its Nissan Leaf in the US market for 2013 by 18% (Cleantech News, 2013).

The overall fuel running cost and GHG emissions (tank to wheel) for a BEV are far superior (compared to a conventional car driven by an internal combustion engine) as previously illustrated.

The present challenges for electric vehicles versus conventional petrol / diesel vehicles include (EECA, 2013):

- **Higher cost** – BEVs cost significantly more to buy than the equivalent conventional vehicle. For example a brand new 5-door Nissan Leaf BEV costs about $70,000 whereas a new Nissan Micra ST (ICE) costs about $23,000. The savings in running costs for BEVs is insufficient at present to make the BEV an economic choice; however as fuel prices increase and BEV pricing decreases this will change.
- **Shorter Range** – BEVs do not travel as far on a full charge as conventional vehicles can on a full tank, with BEVs ranging from 100-150 km. Recharging times range from six to eight hours on a standard 230V 15amp connection (although some vehicles have fast charge capability which enable them to be charged to 80% full in 30 minutes when connected to a fast charge station – typically direct current). While this may be a concern to some people, about 90% of vehicles in NZ drive less than 40km per day, well within the current range of BEVs.
- **Charging During Peak Hours** – this is a common challenge faced by the electricity industry around the world – the potential for large numbers of BEVs being connected to the grid after work causing network overloading and causing power price spikes. This can be managed with smart charging equipment that can control charging levels depending on pricing and control signals from the electricity retailer and distributer.
- **Noise and Safety** – BEVs make very little noise, giving little warning to pedestrians and other road users when approaching.

Figure AA - Nissan Leaf and Mitsubishi iMiEV Electric Vehicles

Some of the above issues may well be addressed with the emergence of plug in hybrids. Toyota is currently trialling plug-in electric Prius vehicles, which are anticipated to become commercially available in New Zealand in 2015. These will have smaller battery capacities than full electric vehicles, resulting in a shorter range on battery power (18km) but more importantly will have a lower up front cost.

With its relatively compact size, Nelson City is well suited to the use of BEVs and hybrid BEVs for local commuter travel. If 10% of local journeys were in BEVs, 0.2 PJ/y of petrol and diesel would be saved and 14,000t CO_2e/y emission avoided.

4.6.4 Biofuels

4.6.4.1 Ethanol production from woody biomass

While there are many competing technologies under development for using wood to produce ethanol, this section considers the most well-known option using hydrolysis and fermentation. This technology is expected to be suitable for NZ's Pinus Radiata wood resource.

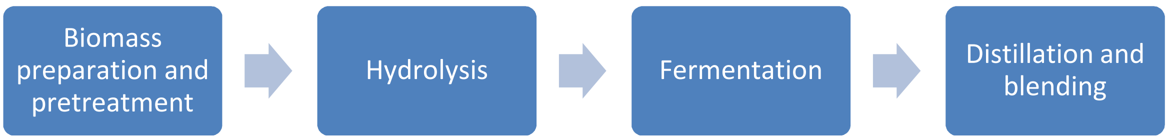
The fermentation technology to produce ethanol from sugars is well proven. Sugar from sugar cane or sugar beet are converted by microbial fermentation to a "beer" and then distilled to produce the grade of ethanol required. Large scale production of ethanol from sugars and corn starch, particularly in Brazil and USA, is now widespread.

To use this process in other regions, research and development is now focusing on producing sugars from woody biomass in a cost effective way. In simple terms there are two new conversion steps needed to do this:

- Firstly, pre-treatment to break up the rigid structure of the biomass by physical and chemical means so as to make the lignocellulose available for conversion; and
- Secondly, the conversion of the free cellulose to sugar using either chemical or enzymatic hydrolysis. This breaks down the larger cellulose molecules into smaller sugar chains.

This produces C_5 and C_6 sugar molecules that are harder to ferment than natural sugars, so there is also a need to develop more efficient microbes for the fermentation process.

The overall process flow for the wood to ethanol process is shown below:



Using this process, wood can be converted to ethanol and lignin. Lignin can be used as a fuel or chemical feedstock.

Several recent private feasibility studies (not in the public domain) for using this technology in NZ are understood to conclude that ethanol could be produced for less than $1/litre (ex-refinery), theoretically making it already close to economic viability. However these studies are based on assumptions about the performance of the technology that have not yet been realised. Note that, by volume, ethanol has only 66% of the energy content of petrol.

When the technology performance targets are reached, a commercial scale bioethanol plant could be built, for example (Scion, 2007), to use 700k t/y green wood, with an energy conversion efficiency of around 35%, producing in the order of 85m litres/y ethanol, enough to satisfy Nelson City's entire transport fuel demand. The plant would cost approximately $300m (25% less if built as part of an existing pulp and paper plant conversion) and, at current pulp log costs, produce ethanol at a cost (ex-refinery) in the order of $1/litre (GCV of 23 MJ/l and $43/GJ). This would equate to a pump price of order $2/litre petrol equivalent excluding the existing sales tax of 61c/litre.

Once the technology is technically and commercially proven, NZ should have sufficient low value land to grow suitable forests or woody biomass crops to support large scale bio-refineries.

Although technically not mature, this wood to ethanol technology is important because eventually it may form the basis for a large scale liquid biofuel industry in NZ. However, it is very unlikely this would be established in Nelson because other regions have larger surplus biomass resources, additional land for purpose grown woody biomass, shorter supply chains and better infrastructure.

4.6.4.2 Bio Crude Oil

There is also much research and development underway into producing bio crude from woody biomass and municipal solid waste (MSW).

Examples of promising technologies under development for this application include:

- Fast pyrolysis to produce bio crude by rapidly heating the biomass to around 400°C in the absence of oxygen. The production of a raw bio-crude at laboratory scale by pyrolysis is not overly difficult, but the fluid contains water, is acidic and relatively unstable. To produce a viable “on-specification” transport fuel, the raw bio-crude would need to be stabilised and refined. The basic process has the advantage of being relatively simple and cheaper than alternatives.
- Wood gasification followed by conversion of the syn-gas to a bio-fuel using the Fischer–Tropsch synthesis process. This process is more complex but both of the process steps are at early commercial development stage; and
- Wet thermal oxidation where biomass is pressurised and heated in a wet environment, breaking down the organic matter to produce a bio-crude and residue cake. This process is at an early stage of development but appears to have promise and may be suited to the use of MSW as a feed stock.

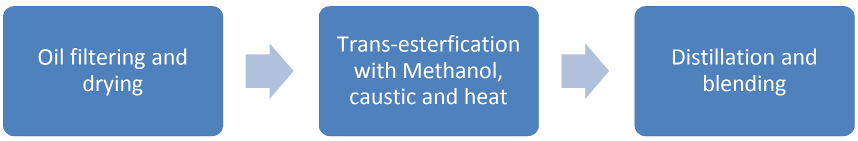
If any of these technologies develop into a viable option in NZ, they will be better suited to large scale development, and are therefore also likely to be established elsewhere.

Another technology option that is being developed globally and locally by Aquaflow Technology is bio-oil produced from algae. While as a standalone energy process this currently does not appear to be commercially viable, it may have niche applications for improving the water quality in polluted lakes, with bio-oil as a by-product.

4.6.4.3 Biodiesel

The technology for producing biodiesel from fats and oils is fully mature and in widespread use overseas and in NZ.

The process flow is shown below:



A small NZ biodiesel industry was established around 2005 using tallow and used cooking oil feed stocks. These are not good feed stocks because they produce an inferior product (compared to vegetable oils) and there is a limited supply of cheap low grade tallow.

More recently Solid Energy developed a canola oil supply chain in Canterbury which has opened up the possibility of a larger scale domestic feed stock supply. However, at present this operation does not appear to be commercially viable. Another option is the import of vegetable oil feed stocks from Asia, which may become commercially viable but is unlikely to be accepted in NZ because of concerns about food supply and environmental impacts in Asia. All of these feed stocks and processing options also result in significant indirect emissions.

In Nelson there may in the future be niche opportunities for biodiesel production from waste cooking oil/fats, tallow, or imported "sustainably produced" imported vegetable oils. These are unlikely to have a material effect on Nelson City's overall sustainability.

4.6.5 Biofuel Development Opportunities for Nelson

The only current opportunity is for niche biodiesel production using waste oil and low grade tallow. Other production options may develop and be commercially viable for Nelson within the 30 year outlook.

Opportunities to develop biofuels technology in Nelson may emerge in the coming years. Research and development of biofuel technologies is increasing, with very significant public and private sector funding available overseas. Even in Australia, there are significant financial grants available to biofuel technology developers. NZ is therefore not likely to be at the forefront of the major technology developments, but may have a role in niche applications. While public funding options in NZ are currently limited, they may improve over time as the potential and importance of the sector is recognised by Government.

As an example, Scion and the Rotorua City Council have partnered to undertake a pilot plant development of a wet thermal oxidation process for sewerage sludge, branded as the "Waste to Gold" process. Funding of $4.7m is understood to have been secured from the Waste Minimisation Fund for this programme. This type of technology development approach could be used in Nelson, if niche bioenergy technology developers can secure the funding support for its development. Currently local company, Aquaflow Technology, is understood to be active in this sector.

4.7 Marine Energy

4.7.1 Technology Review

Marine or ocean energy is an emerging area of renewable generation and refers to a range of technologies and techniques for extracting energy from the ocean. These include:

- **Tidal barrages** –involves creating a dam like structure across a bay or river that allows sea water to flow in during high tide and then releasing the water back during low tides through conventional low head hydro turbines;
- **Wave power** –harnessing the energy potential in the rise and fall (heave), pitch and rotational motions (surge) of ocean waves via a floating, sea-bed mounted or shore based wave energy converter;
- **Ocean current**[25] – capturing the energy from the flow of ocean currents in channels, typically utilising submerged floating or fixed turbines (similar to wind turbines);
- **Ocean thermal energy conversion** – uses the temperature differential between cooler deep water and warm shallow water to drive a heat engine and create electricity.

Tidal barrages are a fairly well established and proven marine energy technology. However they require tidal ranges of around 5-12m to be economic, whereas New Zealand's tidal range is around 2-3m (Meridian Energy, 2006).

Ocean thermal energy conversion is very early in its technical development and most likely to be suitable in waters that have a large (>20^{o}C) temperature difference between the surface and 1 km depths i.e. the Tropics.

The primary marine energy technologies that have potential for future development in New Zealand are wave power and to a lesser extent ocean current. These are described below.

4.7.1.1 Wave Power

Wave power refers to a number of techniques for converting wave energy into electricity (and in some cases potable water). Considerable R&D investment has been occurring in the UK, Europe and US in the last decade to develop economically viable wave energy converters that will ultimately be able to compete with other renewable energy technologies. The wave energy industry is at a similar stage of development as the wind energy industry was in the late 1970s – there are a large number of different techniques and approaches that are currently being developed to turn wave energy into electricity i.e. there is a lack of technology convergence.

Some of the key wave energy converter (WEC) approaches are summarised below along with some of the leading examples that are under development:

Technology Approach	Description / Examples (EMEC, 2012)	Pros / Cons
Shore Based Oscillating Water Column (OWC)	Involves channelling waves into a chamber where the rise and fall of the waves drives air through two-directional air turbines (e.g. Wells turbine) to create electricity. E.g. Voith Hydro Wavegen Limpet (Islay, Mutriku), Pico Island OWC (Azores, Portugal)	• Proven technology + • Does not require subsea cabling + • Expensive due to civil infrastructure - • Lower wave energy potential at shore - • Environmental impact (visual, noise) -
Floating OWC	Similar approach to shore based OWCs, but based on a floating or near shore structure. E.g. Oceanlinx Greenwave (Pt. Kembla, NSW), OceanEnergy OE Buoy	• Proven power offtake + • Near shore so higher wave energy and lower environmental impact (than on shore)+ • Relatively large and expensive structure – • Subsea cabling costs -

[25] Sometimes referred to as marine current, tidal current or tidal flow.

Technology Approach	Description / Examples (EMEC, 2012)	Pros / Cons
Floating Point Absorbers	Typically a floating buoy-like structure which absorbs energy from all directions through its movements at or near the water surface. It converts the motion of a buoyant floating section relative to a heavier semi-submerged section. Power off take may vary, but most commonly based on hydraulic rams / motors E.g. WET-NZ (Wellington NZ), OPT Powerbuoy, Columbia Power Technologies Manta, Wavebob, Fred Olsen Bolt	• Typically located offshore in 50-100m depths (highest wave energy, lowest impact)+ • Some devices can absorb wave energy from all three wave motions (heave, surge, pitch)+ • Lower expected cost / MWh + • Power offtake more challenging and more subsea cabling -
Platform Mounted Point Absorbers	Typically involves mounting point absorbers connected to a breakwater or sea platform (e.g. oil rig, offshore wind turbine) with the rotating arms driving hydraulic pistons / motors. E.g. COPPE Pecem wave plant (Brazil), Wave Star C5 (Hanstholm, Denmark)	• Relatively low cost when connected to existing infrastructure + • Energy offtake limited to wave heave only – • Breakwaters and sea platforms tend to be in lower wave energy environments -
Attenuators	A long (100m+) floating absorber which operates parallel to the wave direction and extracts energy from the relative motion of multiple segments via hydraulics. E.g. Pelamis P2 (EMEC, UK)	• Typically located offshore in 50-100m depths (highest wave energy, lowest impact)+ • Power offtake more challenging and more subsea cabling -
Pendulums	Seabed mounted WEC that extracts energy from wave surges – typically with a broad paddle like structure mounted on a pivoted joint that oscillates as a pendulum in response to wave movement. Power offtake is typically (but not always) based on pumping pressurised sea water to an onshore hydro turbine E.g. AW-Energy WaveRoller (Portugal), Aquamarine Oyster 800 (EMEC UK), Carnegie Wave Energy CETO 5	• Where on shore hydro is used, reduced cost and complexity of transmission connection + • Wave devices are submerged / not visible + • Mounted near shore and energy capture based only on surge (lower wave energy) -
Overtopping	Either a shore mounted or floating structure that captures water into a storage reservoir as waves overtop the device. The water is then returned to the sea through a conventional low head hydro turbine. E.g. Wave Dragon, WavePlane	• Proven power conversion technology + • Large floating structure is expensive and difficult to moor (both examples broke their moorings in storms) -

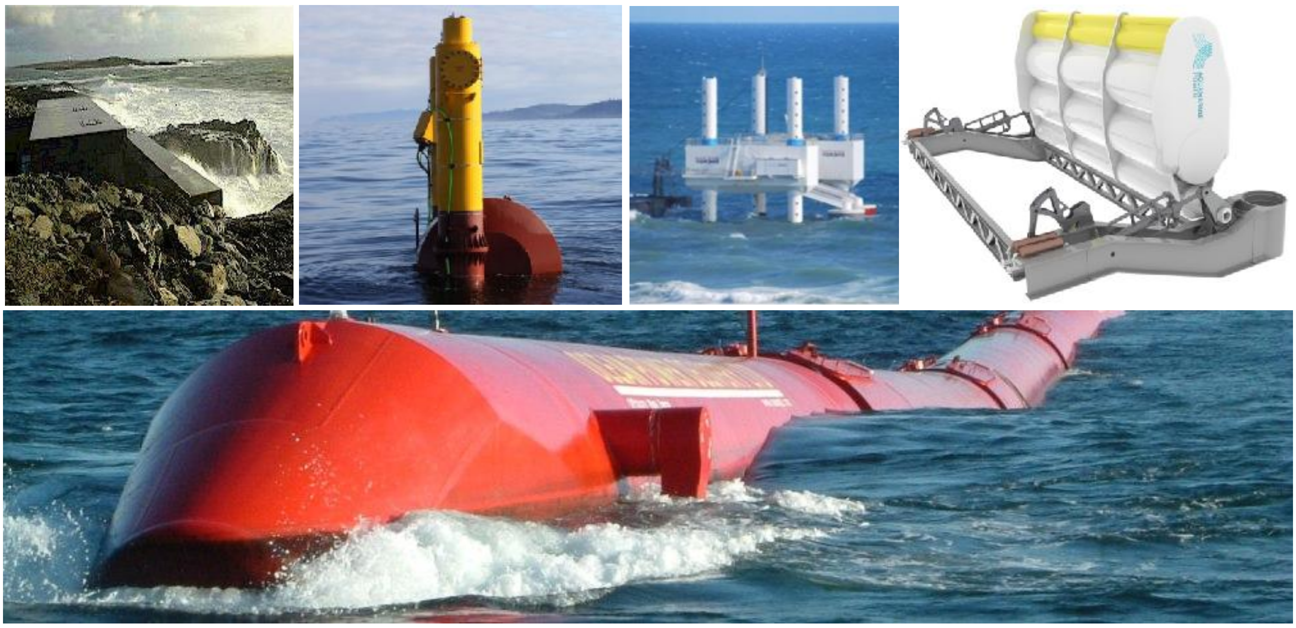


Figure BB - Examples of Wave Energy Converters[26]

4.7.1.2 Ocean Current

As with wave energy converters, ocean current technology development has seen considerable investment occur over the past decade, particularly in the UK. While there are a few unique approaches to harnessing ocean currents being considered, many of the leading technology developers have converged on a horizontal axis turbine design, like an underwater wind turbine (such as the Marine Current Turbines Seagen shown in Figure CC below).

[26] Limpet OWC at Islay, WET-NZ 1:2 scale WEC at Oregon, USA, WaveStar C5 Demonstration Plant at Hanstholm, Oyster 800 and Pelamis P2

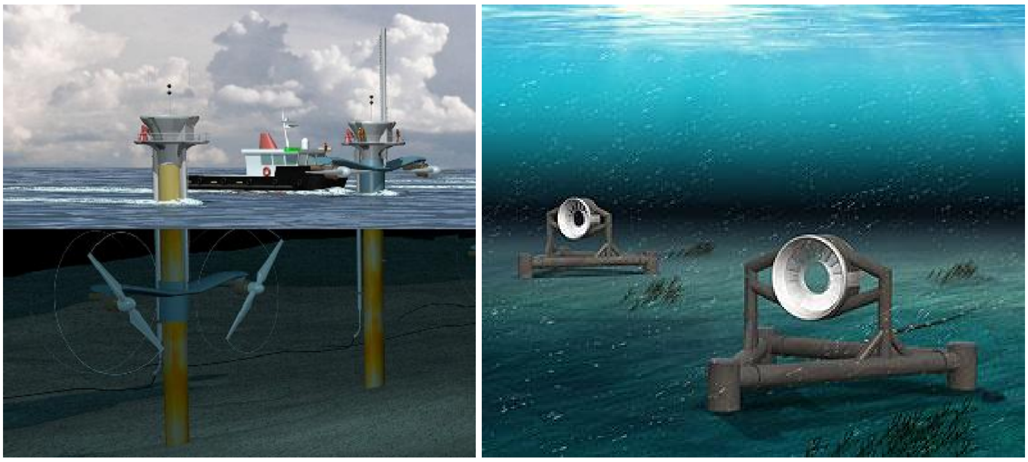


Figure CC - Artist Impression of Array of Seagen Ocean Current Turbines (Marine Current Turbines, 2013) and OpenHydro

There are a range of methods to fix ocean current turbines to the seabed including:

- **Seabed mounted / gravity base** – physically attached to the sea bed or fixed by virtue of its weight;
- **Pile mounted** – similar to the mounting of large wind turbines where the device is attached to a pole penetrating the sea bed. Horizontal axis turbines can yaw about this structure. In some cases such as the MCT design above, the turbines can be raised above the water level to allow for maintenance;
- **Floating** – the device is buoyant and floats in-stream via flexible or rigid moorings attached to the seabed. For maintenance purposes the moorings can be loosened to allow the device to be floated to the surface (EMEC, 2011).

Piling is expensive and time consuming, so companies like MCT are moving towards gravity bases for future designs.

4.7.2 Economics of Marine Energy

To be commercially viable in New Zealand, the LCOE for future wave farms and ocean current farms will need to competitive with the LCOEs of alternative forms of electricity generation in the markets.

4.7.2.1 Wave Power

The LCOE for a given wave energy technology will be affected by:

- The strength and consistency of the wave energy resource (typically measured in kW/m of wave front) and the efficiency of the WEC's operating principles to convert the three primary wave motions into energy;
- The amount and type of materials incorporated in the device construction (including mooring or mounting systems) and the efficiency of the power take off mechanism;
- The size of the WEC and the array of WECS i.e. economies of scale;
- The distance to shore based transmission infrastructure, and approach to transmitting energy to shore (i.e. subsea cabling or pressurised water pipes);
- Ease of maintenance;
- Macroeconomic factors such as depreciation, interest rates and renewable energy support mechanisms and incentives.

4.7.2.2 Ocean Current

The key drivers of LCOE for ocean current devices are the same as wave energy devices. Ocean current turbines follow the same generation principles as wind turbines, and therefore their power output is also proportional to velocity cubed. However, since the density of water is about 800 times that of air, the size of the ocean current turbine rotors are significantly smaller (i.e. between 10 and 20m diameter) than wind turbine rotors to produce the same power output.

4.7.2.3 Carbon Trust Study

Information on LCOE for wave energy converters and tidal current devices in general is fairly sparse given the early state of industry development. These technologies are not yet available off the shelf, so cost and performance information is tightly held. The leading analysis to date was undertaken by the UK Carbon Trust in 2011 (Carbon Trust, 2011) with information obtained from the leading wave and ocean current device developers and experienced marine engineering companies.

As shown in Figure DD, the Carbon Trust assessment of the LCOE of the first ocean current farms is expected to be between 25 p/kWh and 40 p/kWh (NZ \$450/MWh to \$720/MWh) and the first wave farms between 38 p/kWh and 48 p/kWh (NZ \$660/MWh to \$870/MWh). This was based on available information at the time on a handful of full scale ocean current and WEC device costs, and assumed a discount rate of 15% and an operating life of 20 years. The range of the dark band was dependent on the strength of the ocean current or wave energy resource that the array was operating in and the lighter bands indicated optimistic and pessimistic cost and technical assumptions.

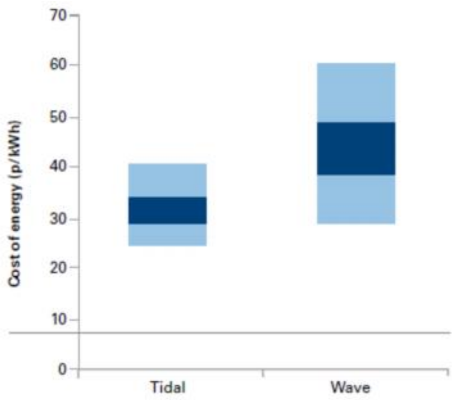


Figure DD - Baseline costs for benchmark first farms of wave and tidal devices (Carbon Trust, 2011)

Carbon Trust looked at the impact on the LCOE of wave energy and ocean current devices from “learning by doing” as the cumulative installed capacity increases; economies of scale effects as the size of arrays increases; and innovation. It found that on its own “learning by doing” would not have a sufficient cost reduction impact to result in a LCOE below 20 p/kWh (NZ \$360/MWh), unless several GW of devices were installed, which at these high costs would not be economically feasible.

The report concluded that an innovation-led scenario will be required to deliver step change reductions in device structure, operations and maintenance costs, and improvements to energy yield. These are likely to make significant contributions to reducing the overall cost of energy from wave and ocean current devices.

This can be seen in Figure EE below which shows that under the innovation scenario, the LCOE for wave energy devices could drop to around 15 p/kWh (NZ \$270/MWh) by 2025 and ocean current devices by 2020 – equivalent to the cost of offshore wind. The long run cost for both wave and tidal current devices could drop below 10 p/kWh (NZ \$150/MWh) by the time 14 GW of wave power and 6 GW of tidal devices have been deployed respectively – around 2040.

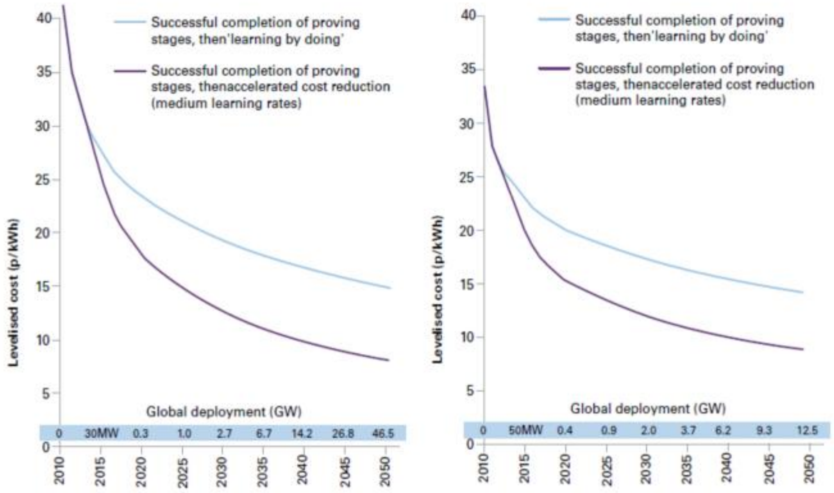


Figure EE - Possible cost reduction pathways for wave (left) and tidal energy (right) under "business as usual" and innovation scenarios (Carbon Trust, 2011)

The key takeout from the above analysis is that without significant incentive mechanisms to support their development and construction (or unanticipated technology breakthroughs), it is unlikely that either form of marine energy technology will be cost competitive against alternative renewables in mainland New Zealand in the next 25 - 30 years. At the point in time when they do reach grid parity, this will primarily be in regions where the ocean current resource is high (i.e. mean speeds >2m/s) or wave energy potential is high (mean wave energy flux of 20 kW/m or greater).

4.7.3 Ocean Current Resource

New Zealand's primary ocean current resources are the Cook Strait, Foveaux Strait, Cape Reinga, and confined harbour inlets and channels (e.g. Kaipara Harbour, Manukau Harbour, French Pass and Tory Channel). The most significant of these tidal currents are in the Cook Strait around Terawhiti Head, Wellington with mean spring tide flows of up to 3 m/s. (MetOcean Solutions Ltd, 2008).

A map showing the power density of tidal resources is included in Appendix A (NIWA et al., 2009).

As Tasman Bay has an unrestricted entrance, the flow of water in and out of the bay due to tides would be too low to generate useful energy from a tidal current turbine.

4.7.4 Wave Resource

New Zealand's primary wave resources are on its west coast, particularly in the south west of the South Island with mean energy flux in excess of 50 kW/m – however this resource is remote from population centres and transmission infrastructure. There are significant areas of greater than 20 kW/m wave energy resource near the upper South Island (Westport), and the west coast of the North Island from New Plymouth to Northland. The east coast has lower resources with an annual average wave power of 13.7 kW/m near Wairarapa and 10.8 kW/m near Gisborne, East Cape (MetOcean Solutions Ltd, 2008).

A map showing the mean wave energy flux magnitude around New Zealand is included in Appendix A (NIWA et al., 2009). A close up of the Tasman Bay region shows that wave energy resources of 10-15 kW/m within the outer bay and toward Motueka, with resources of around 5-10 kW/m within Nelson City Council's territory. This is due to the protection provided by Farewell Spit from the predominantly westerly wave fronts.

The inner portion of Tasman Bay is also extremely shallow at around 36m with the outer portion reaching 90m (Te Ara, 1966). Depending on how quickly the bay drops to these depths, this may favour near shore sub-surface wave energy devices rather than floating point absorbers which are typically designed for 50m+ depths.

The total gross annual wave energy resource in Nelson City is estimated to be between 1750 GWh and 3500 GWh (12.6 PJ) per annum[27]. The technically feasible energy potential would be an order of magnitude lower due to constraints from device spacing, conflicting water uses, distance to transmission and the Horoirangi Marine Reserve. For example a notional 5 km long array of wave energy devices (e.g. 50 x 33m wide 800kW Oyster WEC devices[28]) in Nelson City's territorial domain of Tasman Bay could have a technical energy potential of around 100 GWh per annum.

As will be the case with wind energy in Nelson City, there will be a long list of higher wave energy sites around the country (particularly on the West Coast) that will be more economic first and ahead in the national merit order than a site in Nelson. It is therefore highly unlikely that wave energy will be economically viable in Nelson within the next 25-30 years.

4.7.5 Viability/Barriers to Development

Nelson City has no ocean current resources in its territorial waters so this technology will not play a future role in its energy mix.

While Nelson City does have wave resources there are a number of factors that will prevent wave energy being a contributor to Nelson's energy mix in the next 25 years. These are:

- Comparatively low wave energy resources in Tasman Bay, particularly in the Nelson City territory;
- Wave energy technology is still in its infancy and not expected to be economic in mainland NZ in the next 25 years without significant government support and incentives.

[27] Based on 5 – 10 kW/m x ~40km x 8760 hours.

[28] Note this is an illustrative example only. The current Aquamarine Oyster devices are being designed for the much higher wave energy environments of Scotland. Whether future Oyster devices will be optimised and suitable for lower wave energy environments such as Nelson is not known.

4.8 Summary of Renewable Energy Sources

The table below summarises the renewable energy resources (and associated technologies for conversion into electricity) in Nelson City, the primary barriers to their development in the region. It provides the total technical resource potential and levelised cost of energy based on currently technologies, and an assessment of commercial potential in the next 25 years based on the anticipated future levelised cost for technologies within that time frame.

Renewable Technology	Primary Barriers to Development	Resource Quality in NCC	Technical Resource Potential in NCC (future commercial)	Current LCOE in NCC (future LCOE[29])
Wind Farms	Lack of wind resource in district, limited available elevated land, visual impact and noise concerns	Poor - <6 m/s	150 GWh (highly unlikely)	$150-180/MWh ($125-150/MWh)
Wind turbines – small scale	Lack of wind resource in district, cost of small scale wind turbines, visual and noise impacts	Poor - <5 m/s	As above (possibly <0.1GWh)	~50 c/kWh (30-50 c/kWh)
Hydroelectricity	Lack of high mean flow / significant height differential rivers in district, silt, topography	Low	<1 GWh (possible)	$95-135/MWh (same)
Solar Hot Water	Cost and affordability, many roof orientations in NCC not optimal, affecting LCOE	Good - 4kWh/m^2/d	40 – 50 GWh (6 - 12 GWh)	19-34c/kWh (same)
Solar PV – Rooftop (Residential scale)	Cost and affordability, low FITs for exported power, many roof orientations in NCC not optimal	As above	SWH + 28 – 31 GWh (6 – 26 GWh)	22–27c/kWh (15–21c/kWh)
Solar PV – Rooftop (Commercial scale)	LCOE relative to lower commercial tariffs.	As above	65 – 75 GWh (1.6 – 7 GWh)	18-19c/kWh (12-15c/kWh)
Passive Solar Design	Limited ability to improve existing housing stock. Trade-offs between PSD and aesthetic design.	As above	4 – 12 GWh (4 – 12 GWh)	Not applicable
Solar PV Farms	Land requirements. Economics in NZ due to ~30% lower solar resource compared to Queensland / California.	As above	6 - 13 GWh (unlikely)	$310-350/MWh ($180-200/MWh)
Solar Thermal	Require direct insolation, low cloud and large land area. Significantly higher cost that solar PV farms.	As above	Nil	Not applicable
Putrescent Waste Biogas – Electricity at MWWTP	Cost competitiveness.	Niche - ~9kt pa	2-5 GWh (2-5 GWh)	$100-140/MWh (same)
Clean Woody Biomass – Electricity Co-Generation	Cost competitiveness, established and reliable wood fuel supply chain. Alternative local uses	Good – 460kt pa (limited surplus)	<320 GWh (unlikely)	$140/MWh (at $50/t)
Ocean Current	Lack of resource in region, technology not commercial and 15-25 years from being economic in NZ	Very poor - <0.1m/s	Nil	Not applicable
Wave power	Relatively low resource in region, technology not commercial and 15-25 years from being economic in NZ	Poor 5-10kW/m	50 - 100 GWh (highly unlikely)	$660-870/MWh ($150-200/MWh)
Total			**665–760 GWh (~2.7PJ) (20 -63 GWh – 0.23PJ)**	

[29] In $2013

The following table shows renewable energy resources in Nelson City that could potentially be substituted for existing fossil fuels used for heating and transport.

Renewable Resource for Fuel Substitution	Primary Barriers to Development	Resource Quantity in NCC	Technical Resource Potential in NCC (future commercial)	Current cost in NCC (future cost[30])
Clean Woody Biomass – Heating	Cost competitiveness, established and reliable wood fuel supply chain. Alternative local uses	Good – 460kt pa (limited surplus)	0.3-0.6PJ (0.15-0.3PJ)	$16-34/GJ [31] (same)
Clean Woody Biomass – Pellets for Heating	As above	As above	Included above (0.1PJ + exports)	$20-30/GJ (same)
Residue Woody Biomass - Heating	Cost competitiveness, better alternative uses, effect on removal of nutrients from land	Niche – ~100kt pa	Incl. above	$10-16/GJ [26] (same)
Biofuels - Wood	Ethanol from wood at early commercial stage	Good but limited surplus	Limited surplus	Pre-commercial ($2-3/litre[32])
Biofuels – Biodiesel	Utilising waste cooking oil/fats, tallow etc – inferior to vegetable oil. Limited supply and indirect emissions	Poor	Minimal	Not applicable
Fuel substitution – Electric Vehicles	Upfront vehicle cost relative to conventional and limited range. Charging infrastructure	Not applicable	0.8 PJ_{net} [33] (0.16PJ_{net})	Pre-commercial[34]
Total			**1.1-1.4PJ (0.15-0.6PJ)**	

[30] In $2013
[31] Excluding non-fuel operating and capital plant cost
[32] Petrol equivalent cost at pump
[33] Net PJ figure as conversion from liquid fuels to electric vehicles would result in an increase in electricity usage of around 20% of the fossil fuel energy saved
[34] Running costs of BEVs currently about 25% of ICEs, but vehicle cost 2-3x higher so is not economic, but will improve as fuel costs increase and BEV prices reduce

5 Influences on the Uptake of Renewable Energy

5.1 Economics

The cost competitiveness of renewable energy options are the key influence on their increased uptake. Wind, Hydro, Geothermal and Solar PV power generation, and biomass and SHW for heat supply instead of fossil fuels are in general all at, or approaching, a competitive supply cost.

The cost comparisons in this report are indicative only and there are many secondary economic factors that currently, or may in the future, effect the economics, for example:

5.1.1 Specific Project Factors

There are numerous factors typically effect specific project economics. For example its scale, location, proximity to connecting regional infrastructure, ease of site development, levels of new site infrastructure needed, asset utilisation levels and the required environmental mitigation measures.

Timing with respect to the ruling economic conditions can also have a significant effect. For example the economics of capital intensive projects such as wind farms can be significantly affected by the NZ currency exchange rate and global demand for turbines at the time of commitment.

5.1.2 Cost of GHG Emissions

The NZ Emissions Trading Scheme (ETS) was intended to encourage GHG emission reduction making renewable energy options more cost competitive. The price of NZ Emission Units (NZU) has a cap of \$25/tCO_2e and a one for two obligation on emitters, effectively halving the capped price. With the Global Financial Crisis, the cost of NZUs is currently very low and the NZ Government has not signed up to the next Commitment Period under the Kyoto Protocol, meaning the short term price outlook for ETS units is very low. This is having the effect of reducing public support for renewable energy and slowing its uptake.

However in the long term the NZU price is expected to recover. A report prepared by Covec for the Parliamentary Commissioner for the Environment (PCE) in 2010 forecast NZU prices based on action needed to say within a range of global atmospheric CO_2 concentration limits. The report (Covec, 2010) suggests a NZU price of \$50/NZU by 2020 and \$100/NZU by 2030 medium assuming global action to limit CO_2 levels below 550ppm. The Covec forecasts are shown below:

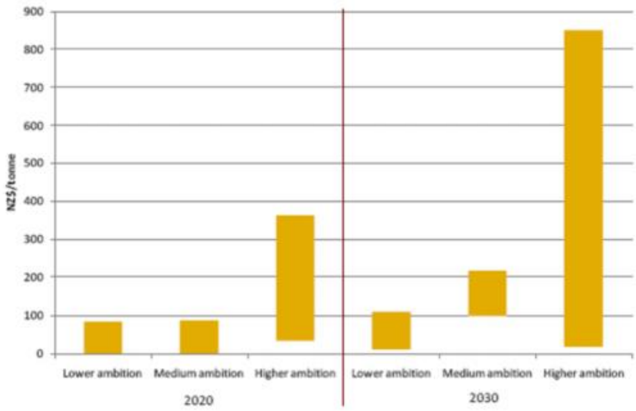


Figure FF - Forecast NZU Costs (Covec, 2010)

The MED reference electricity price path assumes an NZU price of \$25/NZU. This equates to a price increase on electricity from a CCGT power plant of around \$10/MWh, or \$2.40/GJ for coal fuel.

At this stage the current uncertainty with the Kyoto protocol and any replacement treaty remains a major uncertainty risk to the value of renewable energy opportunities.

5.1.3 Financial Incentives

Because of NZ's already high percentage of renewable power generation and political aversion to subsidies compared to overseas, there are only limited financial incentives available to support renewable energy uptake in NZ. Support options include:

- EECA crown loan scheme operated by EECA: a small fund available only to public sector institutions. It could be used by NCC for its own renewable energy initiatives or purchase of EVs. Effective interest rates are around 2-4% per annum;
- EECA renewable energy programmes. These include grants for feasibility studies and capital grants of up to 40% but capped at $100,000 per project;
- Waste levy and associated waste minimisation grant scheme is administered by MfE: these are allocated to encourage waste minimisation, recycling and beneficial reuse. The grant pool is currently around $10m per annum, and grants have been made to support biosolids treatment R&D;
- Primary Growth Programme fund administered by MPI: this is a substantial grant fund and offers dollar for dollar support to approved projects. Funding is currently around $70m per annum. It is possible that this fund could support the development of a new wood energy supply chain, or the introduction of new methods for biomass forest recovery;
- NZTE, support for technology development on an ad-hoc basis where they believe there is potential for significant economic benefit;
- MBIE, Technology Development Grants – up to 50% co-funding to support R&D with the administration of this understood to soon be moving to the Callaghan Institute;
- Biodiesel industry Grants Scheme mechanism administered by EECA: supporting existing producers. The scheme was intended to distribute $36m over three years to existing producers at a rate of $0.42/litre biodiesel produced. It has now been discontinued; and
- Marine Energy Deployment Fund administered by EECA. Originally budgeted for $8m over four years from 2007, this scheme has now ended with less than half the funds allocated due to a number of projects being cancelled.

NZ does not have a support scheme within the ETS framework to incentivise marginally economic renewable energy projects where they would reduce the NZ Government's Kyoto obligations. A scheme of this type (Projects to Reduce Emissions) was trialled in NZ around 2004-6, and NZUs were allocated under this scheme for the Nelson LFG Utilisation Project.

Nor does NZ have Feed-in Tariffs (FITs) or renewable energy obligations as are common overseas. These are unlikely to be introduced here within the 10 year focus. However tax incentives such as accelerated depreciation could be politically acceptable.

Elsewhere in NZ, another avenue for support is from community owned Energy Trusts. The Network Tasman Trust is understood not to make grants of this type but this might be possible with a change of policy.

5.1.4 Solid Waste Disposal Costs

Historically bio-wastes and biomass have been landfilled, however the cost of this has risen significantly and there is strong regulatory pressure to divert organic matter to other more beneficial uses. Landfill charges in Nelson are currently $93/t (exclusive of GST) including the $10/t Waste Levy. The Waste Levy can be increased by regulation.

In addition under the ETS, from 2013, an emission charge will apply as a gate fee to organic matter that is landfilled. This will add to the gate fee ($12/t general waste to the York Valley landfill at $25/NZU) and will also incentivise landfill operators to maximise the recovery of LFG.

5.2 Policy and Regulation

At a national level there are a number of policies and regulations in place to encourage the uptake of renewable energy. These include the:

- NZ Energy Strategy 2011-2021 and National Policy Statement for Renewable Electricity Generation 2011 with the goal to increase renewable electricity generation to 90% by 2025;
- National Energy Efficiency and Conservation Strategy (NEECS) which seeks to reduce energy intensity and increase the use of renewable energy, particularly from woody biomass;
- National Environmental Standard (NES) for air quality which is mandatory and seeks to improve the air quality, particularly in urban areas to meet the National standards. It also prohibits incineration of certain wastes;
- Distributed Generation Regulations – Part 6 of the Electricity Industry Participation Code, 2010 covering connection of distributed generation;
- The New Zealand Waste Strategy sets out the Government's long-term priorities for waste management and minimisation and established the Waste Levy; and
- Nelson Air Quality Plan which places controls on certain activities in Nelson. While it limits growth in the number of conventional domestic wood burners within the urban area, it does allow for growth in the number of approved "ultra-low emission" pellet burners. For industrial scale uses, the plan provides regulatory incentives for replacement of existing coal burning appliances with wood fuel.

While aspirational national renewable energy goals are in place there is a lack of supporting policy and programmes. Government support is waning and NCC has recently discontinued its Solar Saver Programme.

There are also political and policy barriers, including:

- The Resource Management Act which has been blamed for preventing the consenting of some renewable energy projects. The Government is in the process of changing the RMA to reduce this barrier;
- Water ownership and rights with respect to Maori;
- Protection of rivers under Water Conservation Orders (WCOs) which are the major RMA tool for river protection; and
- Access to public land for development of hydro and wind projects, including land control by DOC.

5.3 National Policy Statement on Renewable Electricity Generation

The National Policy Statement on Renewable Energy Generation 2011 (NPS REG) applies to renewable electricity generation activities at any scale, and covers the construction, operation, maintenance and upgrading of new and existing structures associated with renewable electricity generation. This includes small and community-scale renewable generation activities, systems to convey electricity to the distribution network and/or the national grid, and electricity storage technologies associated with renewable electricity storage. It also covers all renewable generation types – hydro, wind, geothermal, solar, biomass, and marine – along with associated investigation activities, such as wind masts and geothermal test bores (Ministry for the Environment, 2011).

The NPS REG confirms that:

- Renewable electricity generation, regardless of scale, makes a crucial contribution to the well-being of New Zealand, its people and the environment, and any reductions in existing REG will compromise achievement of the Government's renewable electricity target of 90% of electricity from renewable sources by 2025; and
- The development, operation, maintenance and upgrading of new and existing REG activities throughout New Zealand, and the associated benefits of REG, are matters of national significance.

The key expectations for local authorities to meet the objectives of the NPS REG include:

- Local authorities are required to adopt a positive and proactive policy response to REG activities in policy statements and plans that applies at national, regional and local levels;
- In developing policy and plan provisions, and assessing resource consent applications, heritage orders and notices of requirement, decision-makers are required to recognise and provide for the cumulative national, regional and local benefits of REG activities;
- In developing policy and plan provisions, and assessing resource consent applications, heritage orders and notices of requirement, decision-makers are required to have particular regard to the practical implications of achieving New Zealand's renewable electricity target and the constraints associated with developing, operating, maintaining and upgrading new, existing and consented REG activities;
- The NPS REG has immediate effect in considering and determining resource consent applications, heritage orders and notices of requirement; and
- Local authorities are encouraged to engage early with electricity generators to understand the issues associated with developing, operating, maintaining and upgrading new and existing REG activities, and in developing regional and district policies to give effect to the NPS REG.

5.4 Social and Environmental Factors

Public acceptance of the need to reduce the use of fossil fuels is gradually growing and this is reflected in the regulatory framework detailed in section 5.2 above. However, except for the not insignificant number of early adopters, this does not necessarily translate into a willingness to pay a premium for renewable energy.

Arguably, Nelson has more than the national average numbers of early adopters as well as active community groups promoting sustainable living, such as the Nelson Environmental Centre.

There are a range of sector groups that promote and advocate for renewable energy such as the NZ Wind Energy Association, AWATEA, SEANZ and the Bioenergy Association of NZ. These associations advocate for their sector, disseminate information on the benefits of renewable energy, promote quality standards and provide support to their members.

Security of supply is a concern for the region. Local renewable energy options for Nelson have the potential to lessen the local impacts of volatile international fossil fuel prices and interruptions to their delivery to the region.

Local renewable energy developments also provide local economic benefits to the community; bring investment, reforestation, skills and jobs to the community.

Renewable energy also has the potential to improve Nelson's air quality which does not yet fully comply with the NES, despite recent improvement. Solar PV, solar hot water heating and low emission wood fuelled heating systems all have the potential to further improve the air quality.

6 Road Map for Renewable Energy in Nelson

6.1 Key Renewable Energy Opportunities in Nelson

The key commercial renewable energy opportunities that could be commercially developed in Nelson City over the next 25 years are:

- Residential rooftop solar photovoltaics;
- Residential solar water heating;
- Commercial-scale rooftop photovoltaics and possibly small-scale <100kW commercial solar PV arrays;
- Niche micro hydro and biogas at NCC Maitai Dam and Bell Island WWTP facilities;
- Embedded energy efficiency through encouraging passive solar design in new housing and retrofitting insulation and double glazing in existing housing stock during refurbishment;
- Small-scale wind turbines and run of river micro-hydro in niche rural off-grid scenarios;
- Direct conversion from fossil fuel heating to low-emission wood fuel heating systems;
- Niche biodiesel and wood pellet manufacture; and
- Limited substitution of transport fuels with electricity via electric and hybrid electric vehicles (via early adopters).

Based on currently available information on the available Nelson City renewable resources and projected technology economics relative to alternative energy sources, the following renewable energy technologies are not expected to be commercially developed in Nelson City in the next 25 years:

- Large scale woody biomass electricity generation / biofuel facilities;
- Utility scale wind turbines / wind farms;
- Wave energy converters / wave farms;
- Solar PV farms (>500 kW); and
- Next generation liquid biofuels based on future surplus low grade woody biomass.

However, while the above list is not anticipated to be economic within the timeframe, this may not prevent early developers seeking to consent these facilities well ahead of the anticipated commercial timeframe – as has been the case with some large scale marine energy developments seeking resource consent around the country.

6.2 Meeting the Requirements of NPS REG

The following table summarises the key renewable electricity generation resources in Nelson City and their applicability to the city with respect to the NPS REG. While the NPS REG requires that councils provide for small and community-scale renewable electricity generation, it should be noted that, with the exception of solar photovoltaics (which are most likely to be small-scale and owned by residents or businesses), it is not possible to predict what proportion of other renewable resources in the City are likely to be developed and owned by the community.

NPS REG Policy		Technical Potential	Commercial Potential	Applicability to Nelson City Council
E1 –	Solar	130 – 155 GWh	8 -33 GWh	Roof top solar PV and small scale PV arrays applicable Solar thermal and utility scale PV farms not anticipated to be viable within next 25 years
	Biomass	5 – 320 GWh	2 – 5 GWh	Small scale waste biogas applicable
	Tidal	None	N/A	Not applicable
	Wave	50 – 100 GWh	<1 GWh	Not anticipated to be viable within the next 25 years
	Ocean Current	None	N/A	Not applicable
E2 –	Hydro	<1 GWh	<1 GWh	Small and micro-scale hydro applicable
E3 –	Wind	10 - 150 GWh	<1 GWh	Small scale wind turbines in niche remote rural off-grid situations applicable Large scale wind farms not anticipated to be viable within next 25 years
E4 –	Geothermal	None	N/A	Not applicable
F –	Small and Community scale	Incl. above (especially solar)	Incl. above (especially solar)	Included above

If all of the above commercially viable renewable electricity generation potential (~40 GWh) were developed within the next 25 years, Nelson City would only meet 10% of its electricity demand from local renewable resources and contribute about 0.1% to the national energy target. However it would not be practical to expect Nelson City to generate 90% of its electricity supply from uneconomic renewable resources within its district when there are more economic renewable resources that can be developed in neighbouring regions and transmitted to Nelson at a lower overall cost.

6.3 Scenario for Setting Regional Goals

The future uptake of renewable energy in Nelson City will be largely dictated by its local cost competitiveness, i.e. the relative cost of the fossil fuel alternatives (including the GHG emission cost) and the associated capital and operating costs, and to a lesser extent by national policy, regulation and public perception. NCC and its residents have little influence on these factors. Consequently specific renewable energy goals for Nelson City cannot be logically derived from the national goals. An alternative approach is therefore needed to established achievable and economically rational goals for Nelson City based on actions that can be "owned" by the local community.

The assessment has identified immediate opportunities for "action" by increasing the uptake of solar PV and hot water, wood heating. There may also be viable niche opportunities in hydro, wind, early adoption of electric / hybrid vehicles and biogas energy developments. In the longer term other emerging technologies in biomass power, mass market electric vehicles and biofuels may also reach their commercial "tipping point".

Based on this assessment, achievable Regional Goals (on a per-head of population basis) over the next 25 year period might be to:

- Reduce consumption of electricity and transport fuels by 15% through conservation and efficiency measures;
- Convert 10% of the remaining vehicle miles from liquid fossil fuel to hybrid or full electric vehicles;
- Install 20MW (25-30 GWh pa) of embedded renewables; and
- Convert 50% of the remaining commercial and industrial heat demand currently using fossil fuels to wood fuel.

If these targets were achieved, ignoring the effects of population growth and the expected increase in the percentage of grid renewables from outside the region, Nelson City's energy balance would change as follows:

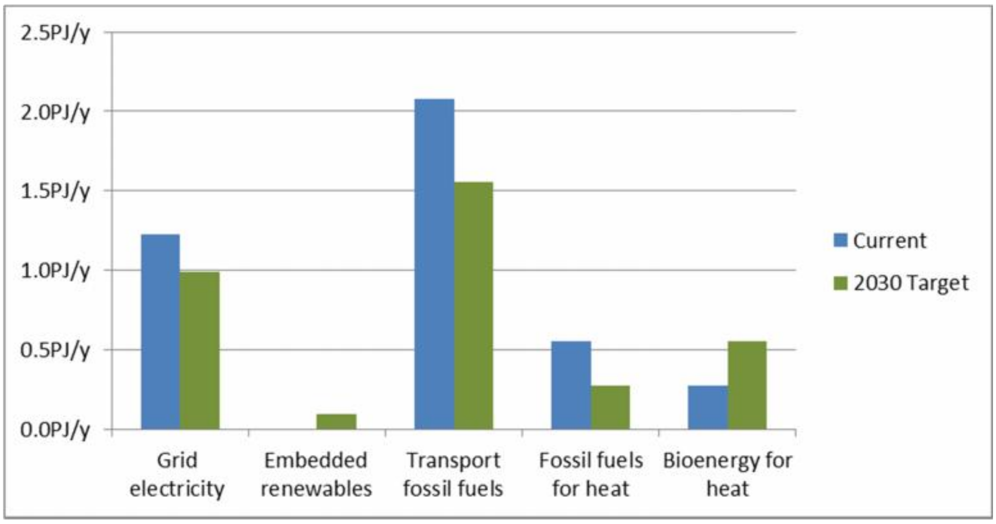


Figure GG - Impact on Nelson City Energy Use from Possible 2030 Targets

Overall the sustainability indicators for Nelson would be improved as follows:

KPI	Units	Current	By 2033[1]	Change
Overall energy use	PJ/y	4.1	3.5	16% reduction
Overall GHG emissions	kt CO_2e/y	233	167	28% reduction
Renewable energy share		29%	40%	11% increase

1. With illustrative targets achieved.

The above scenario is intended to promote discussion on possible targets that could be adopted by NCC and its residents. The targets used for the scenario comparison are not recommendations, rather chosen to illustrate what might be possible with a concerted action plan.

6.4 Role for Nelson City Council

NCC already appears to have a progressive policy for encouraging sustainability and renewable energy. However more can be done in the city, for example:

6.4.1 General

- Setting clear and achievable goals for renewable energy uptake;
- Waiving or reducing building or resource consenting fees for small-scale renewable energy installations where the activity is not a permitted use under the Nelson Resource Management Plan (e.g. micro scale wind turbines)[35];
- Leading by example, by ensuring that renewable energy opportunities within NCC's operations are fully investigated and undertaken if commercially viable;
- Facilitating buyer clusters (e.g. schools, business groups) to achieve economies of scale for standard PV solutions or physical clusters of wood to heat users;
- Encouraging better and more efficient residential and commercial building design;
- Influencing Nelson Electricity and Network Tasman to minimise the barriers for connection of embedded generation and to proactively encourage these opportunities, including potentially providing financial support;

[35] NCC already waives building consent fees for SHW and rooftop PV does not normally require a building or resource consent

- Continuing to promote sustainability and public education: collaborating with interested parties such as EECA, NEC, Tasman District and industry associations; and
- Encouraging private sector investment in renewable energy supply and technology development within the city.

6.4.2 Solar PV and Hot Water

- Investigation opportunities to install Solar PV on council facilities and remote stations where the technology is approaching the grid supply costs; and
- Encourage private sector low interest financing of residential solar PV and solar hot water system e.g. Kiwibank Sustainable Energy Loans.

6.4.3 Wind

- Support the establishment of 10m wind masts at elevated sites to build up long term wind data and make provisions relating to erection of 10 to 80m masts for wind monitoring;
- Ensure that any noise restrictions for large and small scale wind turbines in the Plan are consistent with the new NZS 6808:2010 standard for assessing noise; and
- Determine whether any ridgelines and hilltops in the district should have restrictions on wind turbines to manage visual effects on local community and mark on District Plan.

6.4.4 Hydro

- Update the pre-feasibility study for Maitai hydro dam;
- Support the development of the Waimea Community Dam in the Tasman District; and
- Encourage / support the responsible development of hydro in the top of the South and West coast that improve security of supply and reduce regional wholesale electricity prices.

6.4.5 Bioenergy

- Actively promote wood to heat uptake as a priority sustainability measure (subject to meeting air quality goals within the urban area);
- Revise the Air Quality Plan to accommodate new generation domestic wood burning appliances, if and when these become commercially available, and where these are shown to meeting acceptable emissions performance standards in “real life situations”: i.e. similar or superior to ultra-low emission pellet burners;
- Consider treating the use of seasoned wood chip as similar to wood pellets, if air emissions are demonstrated as equivalent or better;
- Encouraging the development of a reliable wood fuel (seasoned wood chip and pellets) supply chain in the Nelson Tasman region; and
- Update the pre-feasibility study for the biogas power generation options associated with the Bell Island WWTP.

6.4.6 Transport

- Planning for and promoting the future use of electric vehicles (including plug-in hybrids and electric motorbikes) and establishing facilities for their road use, parking and recharging; and
- Consider demonstration electric (or hybrid-electric) vehicles as part of NCC operations (assuming these could be funded / sponsored by third parties such as EV manufacturers or energy companies whilst the cost is still relatively expensive).

7 Glossary of Terms

General

AC	Alternating Current
BIGCC	Biomass integrated gasification and combined cycle power generation
Capacity Factor	The amount of electricity generated by a facility over the course of a year divided by the total amount it could potentially generate if it ran continuously at full capacity
CHP	Combined heat and power - also commonly known as cogeneration, is the generation of both heat and electricity in a single plant
DC / HVDC	Direct current / high voltage direct current transmission. Used for the bulk transmission of electricity from point to point. In New Zealand, the HVDC transmission network links the South Island (at Benmore power station) to the North Island (at Haywards substation), and typically flows from south to north.
GCV	Gross Calorific Value - the amount of heat produced by the complete combustion of a material or fuel measured in units of energy per amount of material
GHG emissions	Greenhouse Gas emissions– referring to emissions of greenhouse gases produced from human activity including carbon dioxide, methane, nitrous oxide and some synthetic industrial gases
GXP	Grid exit point – the interconnection point between local electricity lines companies (e.g. Nelson Electricity, Network Tasman) and the national grid (Transpower)
ICE	Internal combustion engine
LCOE	Levelised Cost of Energy ($/kWh) - the price at which electricity must be generated from a specific source to break even over the lifetime of the project
LFG	Landfill gas – a complex mix of gases (including methane) produced by the action of micro-organisms on organic material in a landfill
LPG	Liquefied petroleum gas – typically propane or butane derived from refining petroleum or natural gas
MfE	Ministry for the Environment
MBIE	Ministry of Business, Innovation and Employment – incorporates former agencies of Ministry of Economic Development (MED), Ministry of Science and Innovation, Department of Building and Housing, and Department of Labour
MSW	Municipal Solid Waste – commonly referred to as trash or garbage (everyday items discarded by the public)
Nelson City	The territorial area under control of Nelson City Council
Nelson / Tasman Region	The region including Nelson City and Tasman District
ORC	Organic Rankine Cycle – uses an organic fluid with a lower boiling point than water-steam to

	recover heat from lower temperature sources such as biomass combustion, industrial waste heat and low temperature geothermal
PV	Photovoltaic – photovoltaic solar panels convert light energy (photons) from the sun to electricity utilising the photovoltaic effect (creation of voltage or electric current in a material upon exposure to light)
SHW	Solar hot water system
Thermal Generation	In the context of this report, refers to conventional power generation sources that rely on fossil fuels such as coal, oil or natural gas.
Transpower	State owned enterprise that owns and operates the National Grid

Power Units

kW	Kilowatt - unit of power equivalent to 1,000 Watts
MW	Megawatt - unit of power equivalent to 1,000,000 Watts
MVA	Mega Volt Ampere – unit of apparent power equivalent to 1,000,000 volt amperes (the unit used for the apparent power in an alternating current electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current). In alternating current systems when voltage and current are in phase (i.e. unity power factor), the apparent power (MVA) will be equal to the real or active power (MW)

Energy Units

kWh	Kilowatt hour – unit of energy equal to the energy converted or consumed at the rate of 1,000 Watts in one hour
MWh	Megawatt hour - unit of energy equal to the energy converted or consumed at the rate of 1,000,000 Watts in one hour
GWh	Gigawatt hour - unit of energy equal to the energy converted or consumed at the rate of 1×10^9 Watts in one hour
TWh	Terawatt hour - unit of energy equal to the energy converted or consumed at the rate of 1×10^{12} Watts in one hour
GJ	Gigajoules – measure of energy equal to 1×10^9 Joules, and also equal to 277.8 MWh
PJ	Petajoules – measure of energy equal to 1×10^{15} Joules

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Appendix A Resource Maps

SOLAR

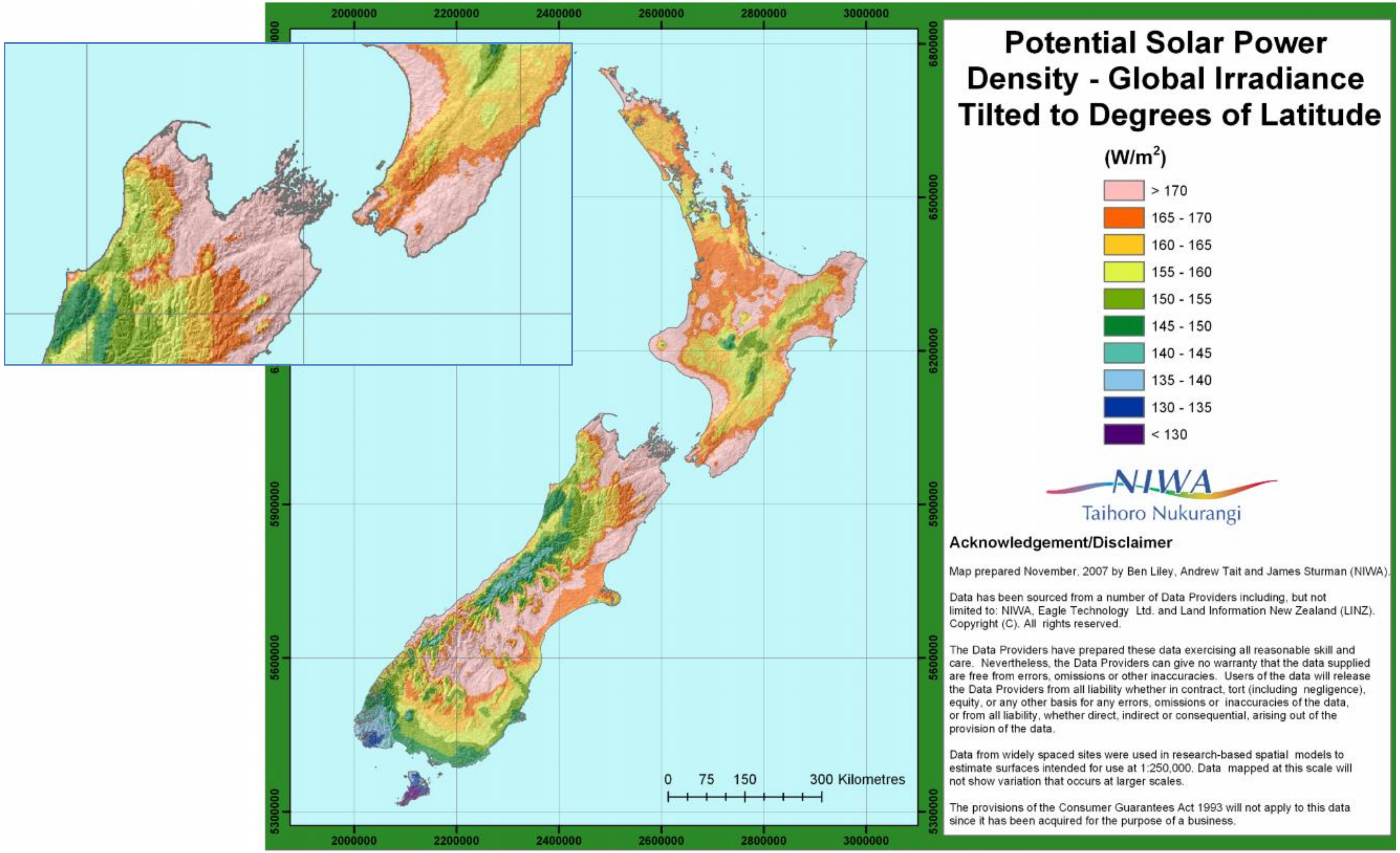


Figure HH – Potential Solar Power Density (NIWA et al., 2009)

BIOMASS

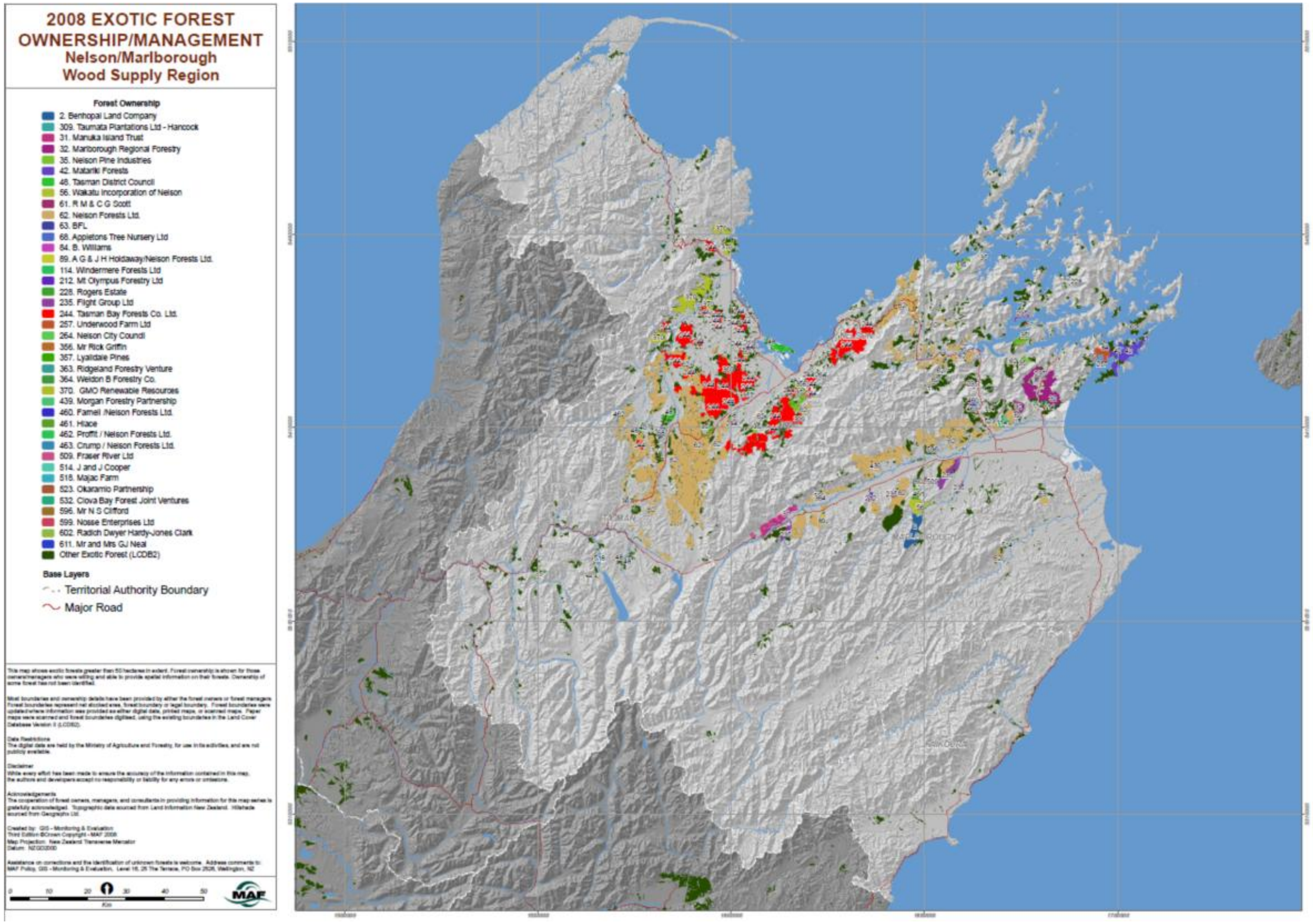
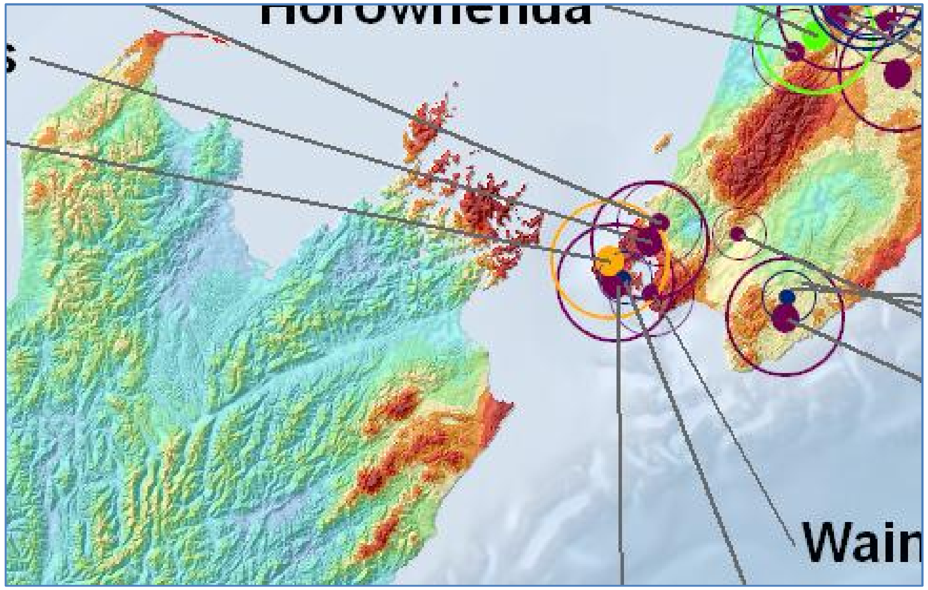


Figure II – 2008 Exotic Forest Ownership / Management in Nelson / Marlborough Region (Ministry of Agriculture and Forestry, 2008)

WIND



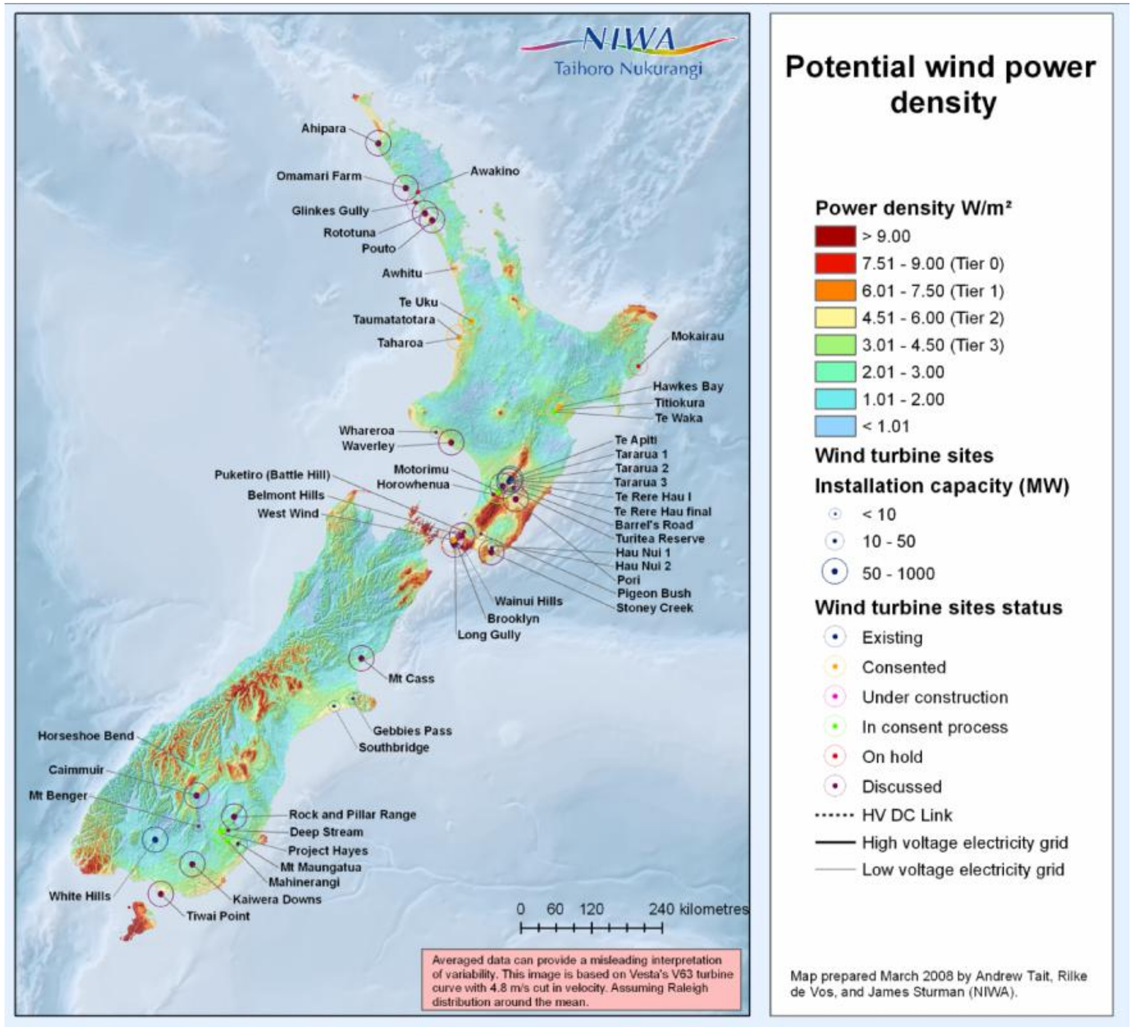


Figure JJ – Potential Wind Power Density (NIWA et al., 2009)

WAVE ENERGY

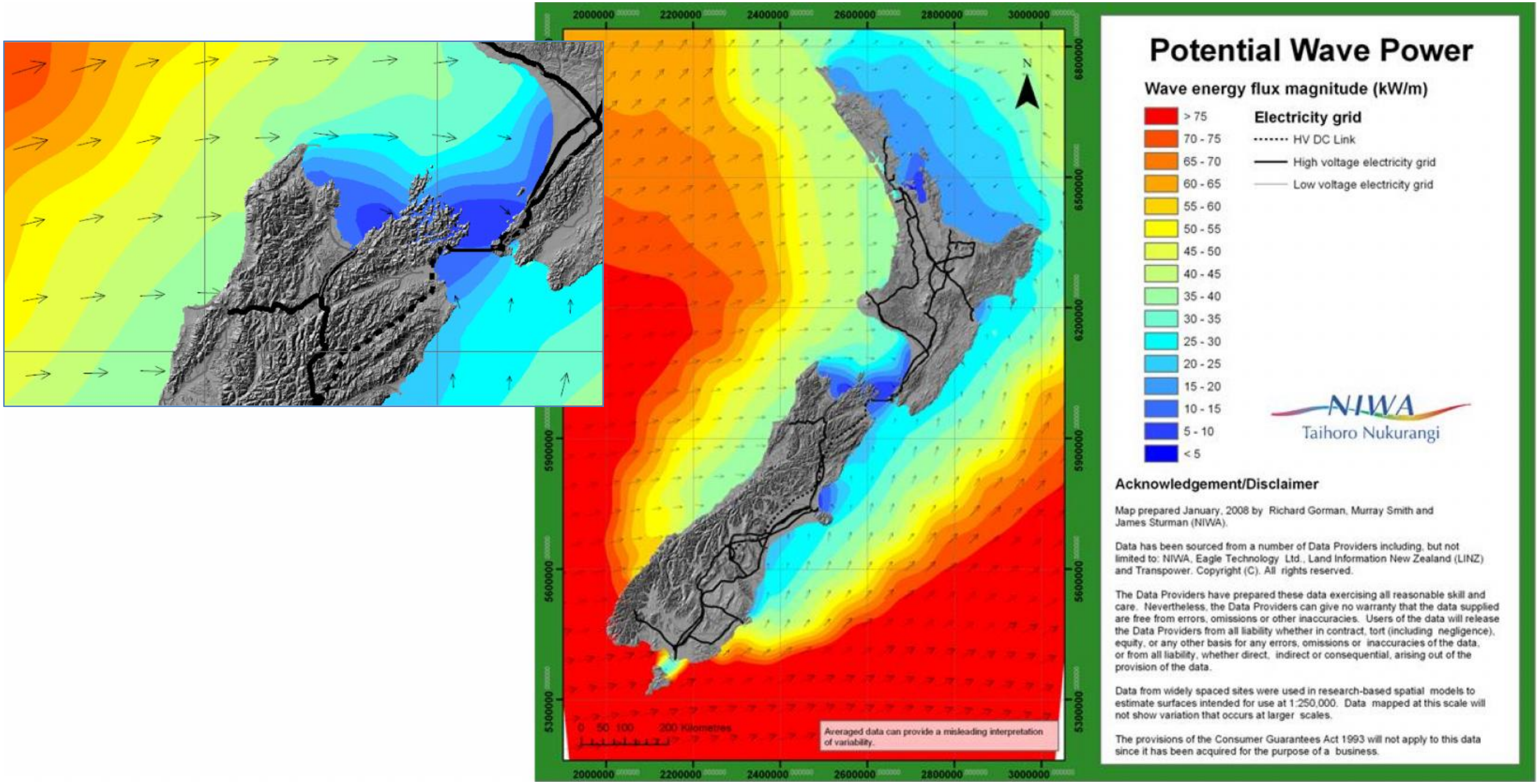


Figure KK – Potential Wave Energy – Peak Flux Magnitude (kW/m) (NIWA et al., 2009)

OCEAN CURRENT

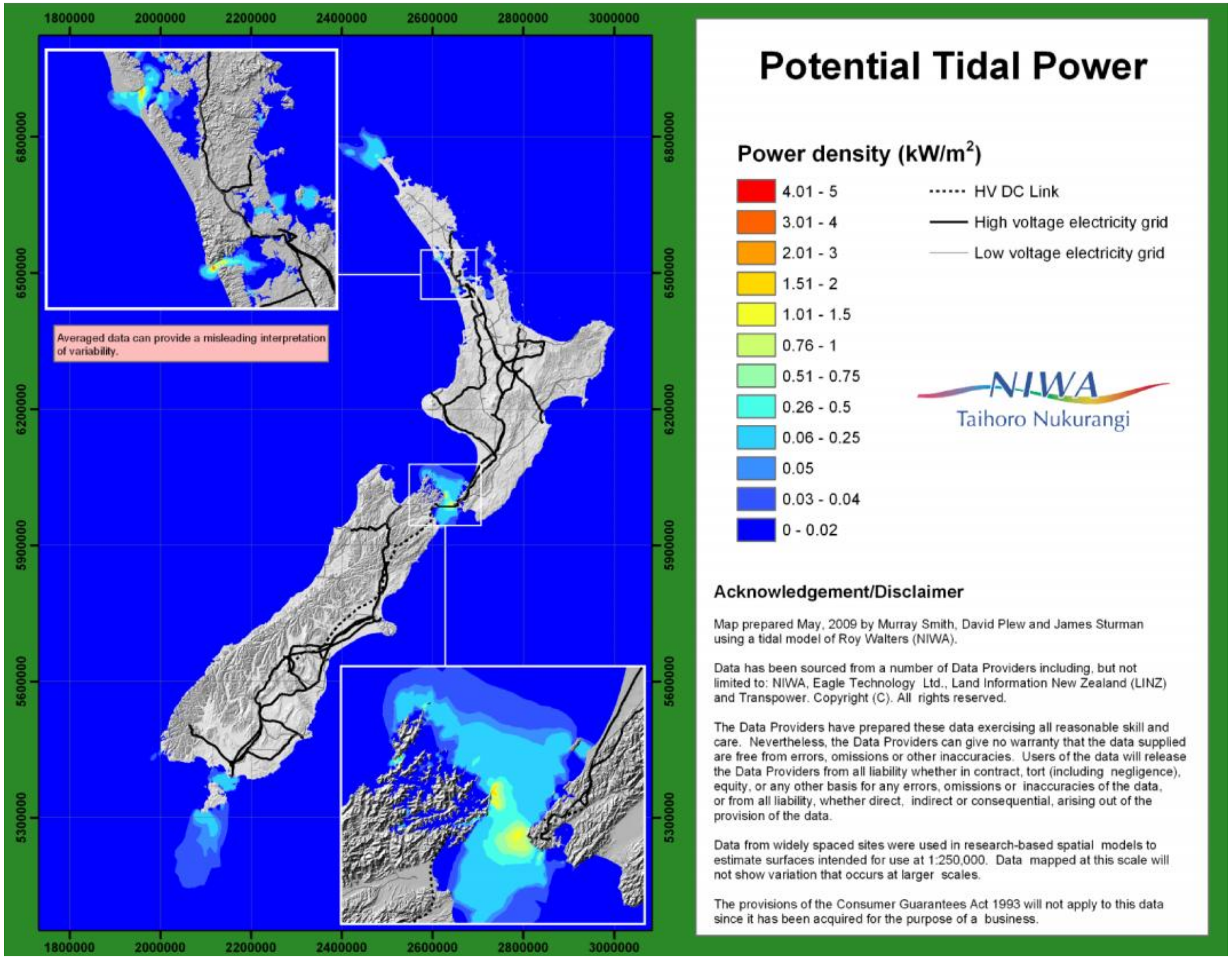


Figure LL – Potential Tidal Power Density (NIWA et al., 2009)