Opportunities for biofuels in New Zealand

Ian Suckling, Scion, Rotorua, New Zealand

With contributions from: **Dr Paul Bennett, Dr Rupert Craggs, Dr Ferran de Miguel Mercader, Prof. Mohammed Farid, Peter Hall, Prof. Shusheng Pang, Dr Mathew Stott and Dr Kirk Torr.**

Introduction

New Zealand is a geographically-isolated country with a land area of 269,190 km^2 (between that of Italy and the United Kingdom), but with a comparatively small population (4.47 M). It has a temperate climate, with an export-focussed economy highly dependent on agriculture, particularly dairy products, meat, wood and wood products, fruit and seafood.

Consumer energy demand in New Zealand in 2014 was 573 PJ, dominated by oil (44%) and electricity (25%) (Fig. 1) [1]. Of particular note:

- Almost all of New Zealand's fossil oil is imported, mainly (80%) to meet the country's transport fuel needs. There are however also significant exports of unrefined crude oil (30% of total oil consumption) as these sweet crudes are not processed at New Zealand's only oil refinery. Per-capita use of transport fuels is relatively high due to the country's low population density and the nature of the economy.
- A total of 80% of New Zealand's electricity was generated from renewable resources in 2014, mainly using hydro (57%), geothermal (16%) and wind (5%). New Zealand is on track to meet the country's target of 90% renewable electricity by 2025.
- Bioenergy, mainly as woody biomass, is used primarily in the wood processing sector as a source of process heat, but a portion is also burnt to heat private homes.

The largest opportunity for increased use of bioenergy in New Zealand is therefore as a replacement for imported fossil transport fuels, particularly diesel and aviation fuels where there are no current replacements for liquid fuels. There are also significant shorter-term opportunities to increase the use of bioenergy for commercial and industrial heat.

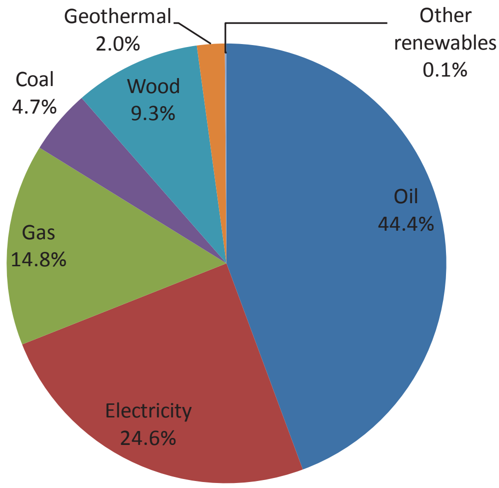

Figure 1. Consumer energy use in New Zealand in 2014 [1].

Bioenergy Feedstock Options

Wood from plantation forests is the largest biomass resource in New Zealand and also the one with the most potential to expand to allow large-scale biofuels production [2]. While existing residual biomass resources offer an attractive and potentially low-cost feedstock for biofuel production, they could only ever provide 6% of the country's total transport fuel demand, meaning purpose-grown feedstocks would be required for high levels of biofuels implementation [3].

New Zealand could sustainably supply all its transport fuel demand by 2030 from forests grown on lower productivity land [5]. There is 9.2 million ha of hill country that is either marginal land, or low to moderate productivity hill country grazing, and converting just 30% of this land to forests would be sufficient to meet the country's total transport fuel demand while still retaining the higher-value flat land for food production. Such large-scale forestry for bioenergy will also have significant economic and environmental benefits.

New Zealand already has a well-established plantation forest estate and wood processing industry, providing a strong base to grow a future biofuel and biochemicals industry [4]. The forest estate, totalling approximately 1.73 million hectares, is composed largely of radiata pine (*Pinus radiata*, ~90%, grown on a rotation of 25-30 years) and Douglas-fir (6%, 40-45 year rotation).

New Zealand Bioenergy Strategy

The New Zealand Bioenergy Strategy, developed jointly by the New Zealand forestry and bioenergy sectors, envisions bioenergy supplying more than 25% of the country's consumer energy needs by 2040, including 30% of the country's transport fuels (Table 1) [6]. Plantation forests are seen to be the main feedstock for this expansion, building on the strong existing forestry sector, although biofuels from agricultural sourced materials, algae and municipal and industrial process residues will also be important.

A preliminary macro-economic analysis of the scenario proposed in the NZ Bioenergy Strategy has provided support for a *prima facie* case that expansion of the bioenergy sector has the potential to yield significant positive economic, environmental and social benefits for the country [7]. These benefits are significantly greater if co-products are also produced.

Table 1. Impact of implementation of the NZ Bioenergy Strategy [6,7].

Year	**Biofuels**	**Biofuels plus co-products**[a]
Bioenergy sector production (PJ)	162.3	
GHG savings (CO_2-e, m tonnes)	10.8	
Difference from Business-as-usual		
GDP (2010 $b)	6.09[b]	6.30
Trade balance (2010 $m)	1,942	2,037
Employment (000s)	27[c]	28

[a] Assumes an additional export revenue equal to 10% of bioenergy production.
[b] New Zealand's GDP in the year to December 2014 was $240 billion.
[c] Approximately 1.1% of national employment.

Support for Biofuel Production

New Zealand currently provides only limited Government incentives to encourage biofuel implementation, with neither a mandate nor any target for biofuel use in place. This may change in the future, depending on the political climate and greenhouse gas (GHG) reduction targets. Currently, fuel ethanol (including imported bioethanol) is exempt from excise duty, providing some incentive for its use in transport fuels. On top of this, the New Zealand Emissions Trading Scheme zero-rates the biofuel component of any transport fuel. In practice the latter has had little impact, due to the low prices for carbon (NZ Units) and the fact that only half of the emissions from transport fuels incur a carbon price. The New Zealand Energy Strategy, which sets the strategic direction for the energy sector, recognises biomass as a resource having considerable potential, and indicates that the Government will encourage biomass-to-energy developments [8].

Greenhouse Gas Emissions

New Zealand's GHG emissions are dominated by emissions from the agricultural (48%) and energy (39%) sectors (Fig. 2) [9]. The high proportion of emissions from the agricultural sector, mostly as methane and nitrous oxide, reflects the country's high level of agricultural production. In spite of improvements in emissions intensity, New Zealand's total greenhouse gas emissions (81 Mt CO_2-e in 2013) have increased by 21.3% over 1990 levels, while energy sector emissions have grown by 32%. This has been largely driven by strong economic and population growth.

Liquid fuel combustion emissions, driven by the transport sector, have increased by 50% over 1990 levels and are now responsible for over 55% of the total energy sector emissions [10]. Liquid transport biofuels therefore represent one of the few options to significantly reduce the country's emissions, as New Zealand already has a high proportion of renewable electricity, a growing population and almost half the country's emissions come from agriculture where ways to significantly reduce emissions without reducing production are not yet available.

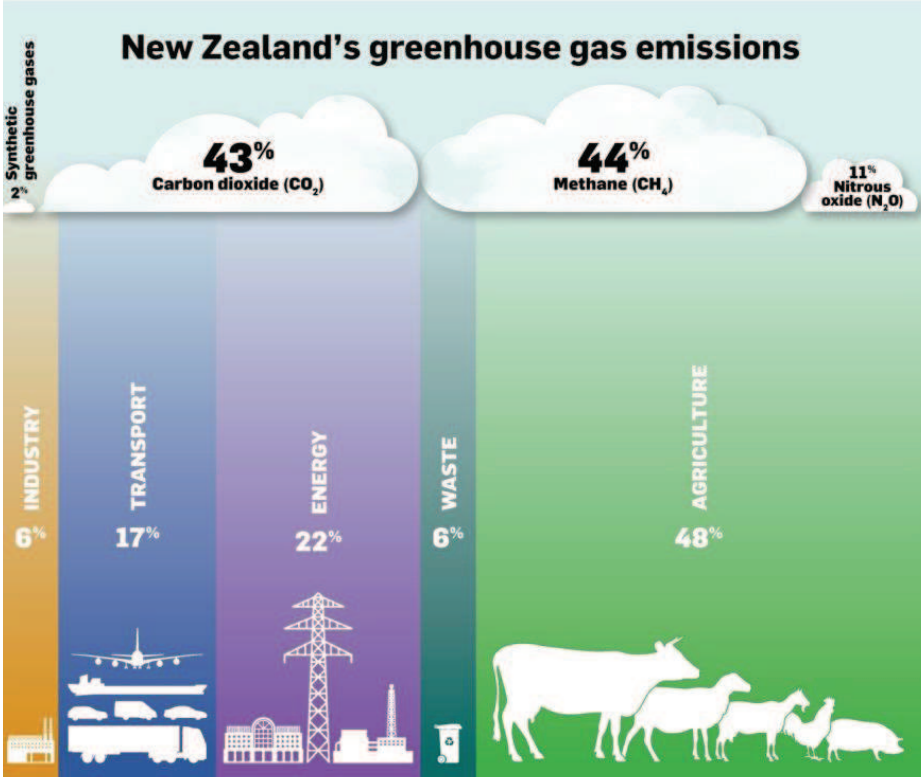

Figure 2. New Zealand's greenhouse gas emissions for 2013 [11].
©Ministry for Environment. Used with permission.

Conventional Biofuel Production

The production of conventional biofuels is already well established in New Zealand. However, biofuel use remains low compared to many other countries **(<0.1% of total transportation energy)**, reflecting the low level of Government incentives. An estimated 4.2 million litres of conventional biofuels were produced in New Zealand in 2014, mainly as ethanol from whey and biodiesel from tallow and used cooking oils (Figure 3) [1]. Total biofuel consumption was 5.7 M litres in 2014, including imports of a further 1.5 million litres of bioethanol.

Figure 3. Biofuel production in New Zealand. Adapted from ref. [1].

Biodiesel production levels still remain well below those reached when the biodiesel grants scheme was in place, but have increased over 2013 levels. The largest current domestic producer is Green Fuels, which produces biodiesel from recycled vegetable oil [12]. Biodiesel production is set to rise further next year, with fuel distributor Z Energy constructing a 20 million litre per year plant to produce biodiesel (B100) from tallow (a by-product of the meat industry) for sale to commercial customers. It has been estimated that New Zealand produces sufficient tallow to produce up to around 5% of the country's diesel fuel needs [13].

Bioethanol is currently produced by Anchor Ethanol Ltd at three dairy factories by fermentation of whey, a cheese by-product [14]. Interestingly, a local brewery has developed a process to strip ethanol from the yeast slurry, a by-product of the beer brewing process, and then distill it to produce bioethanol. This bioethanol, available in quite limited amounts, is blended with fossil petroleum to create a transport fuel marketed as "DB Export Brewtroleum" [15].

Research and Development Activity

A number of New Zealand universities and research institutes are actively involved in biofuels research as summarised below.

The **University of Auckland'**s biofuels research has focussed mainly on the conversion of waste products into biofuels, including [16]:

- Upgrading of low-grade tallow and used vegetable oil to esterify the free fatty acid impurities with glycerol, making them easier to convert into biodiesel
- Development of a fast reactor for biodiesel production, capable of reducing the reaction time to a few seconds
- Production of oil and chemicals by pyrolysis of waste plastic, including using microwave pyrolysis.

The **University of Canterbury's** research has focussed on the development of thermochemical technologies to convert woody biomass to liquid biofuels [17]. This has included work on steam gasification of biomass, including development of a 100 kWth dual fluidised bed gasifier, two lab-scale reactors for removal of tars and gas contaminants from biomass gasification producer gas and construction of a micro-channel Fischer-Tropsch (FT) reactor for synthesis of liquid fuels from wood-derived producer gas. More recent research has focussed on producing high grade liquid fuels by biomass pretreatment followed by fast pyrolysis.

GNS Science is the leading earth sciences provider in New Zealand. GNS specialises in the enrichment and isolation of novel microorganisms from New Zealand's geothermal areas. Since 2007, they have focused on bioprospecting for novel cellulolytic and thermotolerant bacteria and enzymes that could be used to increase the rate of cellulose degradation, and improve biofuel production [18].

One option to produce algal biomass for use as a biofuel feedstock, potentially already economically viable today, is to grow and harvest algae produced as part of the operation of wastewater treatment pond systems. Over the last 20 years the **National Institute of Water and Atmospheric Research** (NIWA) has maintained a research program involving laboratory, pilot-scale and full-scale studies to address the major issues limiting the widespread application of wastewater algae production and biofuel conversion [19]. **NIWA** is currently operating a demonstration enhanced pond system containing two full-scale 1 ha high rate algal ponds (HRAP), and including the largest wastewater treatment HRAPs augmented with CO_2 addition in the world (Figure 4). This system will enable actual measurement of the hydrodynamics of hectare-scale ponds, demonstrate the performance improvements with CO_2 addition and provide large quantities of algal biomass for further algal biofuels research, currently being conducted in collaboration with The University of Auckland.

Figure 4. NIWA's demonstration-scale high rate algal pond system at Cambridge.

Scion is a Government-owned research institute, focussed on improving the international competitiveness of the New Zealand forest industry and building a stronger biobased economy. This includes a range of bioenergy and biorefinery research and development activities across the whole value chain from resource establishment through to product development. Areas of focus include [20]:

- Biochemical routes for converting softwoods to biofuels and chemicals, focussing particularly on pretreatment, saccharification and fermentation of the resultant sugars to biochemicals and bioplastics
- Thermochemical technologies for converting wood to liquid fuels and chemicals
- Wood-based biorefinery co-products – extractives, lignin and hemicelluloses
- Woody biomass feedstock supply and growing plantation forests for energy production
- Defining the best options for biofuel deployment in New Zealand
- Opportunities to integrate bioenergy production into existing wood processing sites, including synergies between geothermal energy and wood processing. In this case Scion is collaborating with the University of Waikato and GNS Science.

Commercial Developments

LanzaTech, founded in 2005 in New Zealand, has developed a gaseous feedstock-based fermentation process to take carbon-rich waste gases (containing carbon monoxide, carbon dioxide and/or hydrogen) from sources like steel mill chimneys and convert them into biofuels like ethanol or green chemicals like 2,3-butanediol [21]. They have successfully scaled up their gas feedstock fermentation process from the laboratory through a pilot plant at the Glenbrook Steel Mill south of Auckland, on to two pre-commercial scale demonstration plants (100,000 gal/yr ethanol) in China, and are now looking to build their first commercial-scale ethanol plant in China. The company has recently relocated to Chicago in the United States.

Alternative Energy Solutions has a demonstration pyrolysis plant which turns waste wood into bio-oil and biochar [22]. This company proposes building small bio-oil plants near to where waste wood is produced, cutting transport costs and providing distributed power for rural and provincial communities. **CarbonScape** [23] has developed a technology that uses microwave heating of waste biomass such as sawdust to produce activated carbon products suitable for adsorbent applications or steel-making, together with a bio-oil targeted towards end uses such as heating and higher value pharmaceutical and cosmetic products. Christchurch company **Solvent Rescue Ltd** [24] has developed processes for producing crude oils via hydrothermal liquefaction of a range of biomass sources including fresh water algae, wood, wool-scouring waste and treated wood waste after first removing the wood treatment chemicals (copper, chrome and arsenic) [25].

Newsprint manufacturer **Norske Skog** and fuel distributor **Z Energy** have recently completed their Stump to Pump study to determine the technical and commercial feasibility of establishing a business in New Zealand to convert forest waste into a sustainable liquid transport fuel biofuels [26]. The partners concluded that sufficient forestry residues exist to support such an industry and that a technically feasible path exists to convert forestry residues to liquid fuels. However, they have put this project on hold until economic conditions for it are more favourable.

References

1. Ministry of Business, Innovation and Employment,. *Energy in New Zealand 2015*. 2015; Available from: http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-in-new-zealand/Energy-in-New-Zealand-2015.pdf.
2. P. Hall, *Bioenergy options for New Zealand: Key findings from five studies.* Wiley Interdisciplinary Reviews: Energy and Environment, 2013. 2: p. 587-601.
3. P. Hall, J. Gifford, S. Saggar, D. Giltrap, V. Forgie, R. Renquist, S. Huebeck, et al. *Bioenergy options for New Zealand. A situation analysis of biomass resources and conversion technologies*. 2007. Available on request from http://www.scionresearch.com/general/publications/reports/environmental-issues.
4. New Zealand Forest Owners Association and Ministry of Primary Industries. *New Zealand plantation forest industry. Facts and figures*. 2013; Available from: http://www.nzfoa.org.nz/images/stories/pdfs/foa_facts_figures_2013.pdf.
5. P. Hall and M. Jack, *Bioenergy options for New Zealand - Analysis of large-scale bioenergy from forestry*. 2009, Scion. Available on request from http://www.scionresearch.com/general/publications/reports/environmental-issues.
6. Bioenergy Association of New Zealand, Forest Owners Association, New Zealand Farm Forestry Association, New Zealand Institute of Forestry, NZBio, Forest Industry Contractors Association, and Future Forests Research, *New Zealand Bioenergy Strategy*. 2010, Bioenergy Association of New Zealand. Available from: http://www.bioenergy.org.nz/resource/nz-bioenergy-strategy
7. G. Nana, J. Boshier, and A. Generosa. *Preliminary analysis of the economic impact of the New Zealand Bioenergy Strategy Report for Bioenergy Association of New Zealand* 2011; Available from: http://www.bioenergy.org.nz/resource/occasional-paper-16-preliminary-analysis-economic-impact-nz-bioenergy-strategy
8. Ministry of Economic Development. *Developing our energy potential. New Zealand energy strategy 2011-2021 and New Zealand energy efficiency and conservation strategy 2011-2016*. 2011; Available from: http://www.med.govt.nz/sectors-industries/energy/pdf-docs-library/energy-strategies/nz-energy-strategy-lr.pdf.
9. Ministry for the Environment. *New Zealand's greenhouse gas inventory 1990-2013 Snapshot April 2015*. 2015; Available from: http://www.mfe.govt.nz/publications/climate-change/new-zealands-greenhouse-gas-inventory-1990%E2%80%932013-snapshot.
10. Ministry of Business, Innovation and Employment. *Energy greenhouse gas emissions*. 2015; Available from: http://www.med.govt.nz/sectors-industries/energy/energy-modelling/publications/energy-greenhouse-gas-emissions/energy-greenhouse-gas-emissions-2014.pdf.
11. Ministry for the Environment. *New Zealand's Climate Change Target*. 2015; Available from: http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/climate-change-consultation-document.pdf.
12. http://www.greenfuels.co.nz/
13. http://www.transport.govt.nz/ourwork/climatechange/biofuels/
14. https://www.fonterra.com/nz/en/About/Our+Companies/Anchor+Ethanol+Ltd
15. http://gull.nz/fuel/db-export-brewtroleum/
16. For additional information please contact Prof. Mohammed Farid (m.farid@auckland.ac.nz)
17. For additional information please contact Prof. Shusheng Pang (shusheng.pang@canterbury.ac.nz)
18. For more information please contact Dr Matthew Stott (extremophiles@gns.cri.nz)
19. For more information please contact Dr. Rupert Craggs (rupert.craggs@niwa.co.nz)
20. For additional information please contact Dr Paul Bennett (paul.bennett@scionresearch.com) or Dr Ian Suckling (ian.suckling@scionresearch.com)
21. http://www.lanzatech.com/
22. For additional information please contact Gavin Hedley at gavin@aesbioenergy.co.nz
23. http://carbonscape.com/
24. http://www.solventrescue.co.nz/
25. https://www.mfe.govt.nz/sites/default/files/media/Bathurst%20Chris%2004290.pdf
26. Norske Skog Tasman/Z Energy stump to pump project. Final report. 2014; Available from: http://www.mpi.govt.nz/document-vault/4975