Bioenergy Opportunities from Forests in New Zealand

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Abstract An analysis on New Zealand's bioenergy resources found that plantation forest derived and other wood residues are the largest bioenergy resource now and into the future (2040).

New Zealand's forest and wood processing industries are based almost entirely on intensively managed plantations (~1.75 million hectares) of introduced species (*Pinus radiata* (89 %)), Douglas Fir (6 %) and a mixture of other species including eucalypts (1.5 %). The location, productivity and age class distribution of the resources is described in a national dataset, allowing prediction of future harvest volumes.

From the data available it is possible to determine supply trends at a national and regional level. There is a clear increase in wood supply between 2010 and 2030. Given the mix of logs that will occur, a large increase in the volume of chip grade logs is expected (up to 3.0 million tonnes per annum). Further, there is not expected to be a commensurate increase in uptake of these logs by the pulp and paper or reconstituted panel industries.

The highest priority for New Zealand in terms of fossil fuel substitution is liquid fuels for transport, and specifically a drop-in diesel. We have other options for electricity and heat production. Given that 97.7 % of our existing plantation resource is softwood this presents challenges for some biomass to liquid fuel conversion routes, such as enzymatic hydrolysis.

The volumes of residues and pulp logs potentially available could theoretically produce sufficient volumes of liquid fuels to meet 5–6 % of total liquid fuel demand or 15–16 % of diesel demand.

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Studies of the potential for forestry derived bioenergy found that there would be significant environmental benefits from establishing a larger forest resource on low productivity hill country grazing lands, and that this resource could provide a very substantial part of New Zealand's future liquid fuel demand.

1 Introduction

The combination of energy challenges, population density and land resources in New Zealand suggests that one of the most important future renewable energy opportunities for New Zealand is the large-scale production of transportation fuels from woody biomass.

New Zealand is a small (26.7 million hectare, population 4.4 million) island nation, with a developed market economy in the South Pacific. The economy is largely based on production and export of primary produce (dairy, meat, forestry, fishing, wool, fruit and vegetables). Primary produce makes up three quarters of our exports and forestry is the third largest earner, behind dairy and meat (Statistics New Zealand 2010). Per capita energy consumption is high (similar to France and South Korea) especially in transport fuels (ranked 11th globally).

Energy supply and environmental issues facing New Zealand are similar to the rest of the world including;

- Tight oil supply and rising prices
- Concerns over our greenhouse gas emissions and climate change

New Zealand has a large (~70 %) part of its electricity supply produced from renewable resources (hydro, geothermal, wind) with a government strategy to increase this to 90 % over the next 20 years (MED 2011a).

Heat energy is largely (56 %) supplied from gas and coal resources, with 28 % from biomass (mostly in the wood processing industry) and ~10 % from geothermal (MED 2010). Coal resources are large and coal is a relatively cheap fuel for industrial heat. Gas supply has been relatively cheap but prices are rising as the giant Maui field declines (de Vos and Heubeck 2009). New gas discoveries are being sought.

New Zealand has a number of small oilfields. Production is mostly exported as the one domestic oil refinery is not suited to the type of crude they produce. The currently producing wells are expected to peak in the near future and domestic oil production will decline rapidly unless new discoveries are made (de Vos and Heubeck 2009). The government is encouraging new exploration (MED 2011a).

Beyond domestic resources of energy, New Zealand is dependent on imported oil (~85 % of liquid fuels is derived from imports) (MED 2010), and we are a small market in a remote part of the South Pacific at the end of a long supply chain, which implies potential vulnerability in a supply constrained world.

Of New Zealand's greenhouse gas (GHG) emissions around half come from agriculture (ruminant animals and fertiliser). Of our energy related GHG emissions 54 % are from liquid fuels, 29 % from natural gas and 12 % from coal, (MED 2011b).

There is clearly scope to reduce energy related GHG emissions from greater use of renewable energy, including biofuels, especially in transport.

This energy and GHG emissions structure leads to a focus on finding alternatives to oil and gas for liquid fuel and heat supply.

New Zealand's low population density also means that there are significant opportunities for bioenergy to play a significant role in meeting renewable transport fuel challenges.

Residual and waste biomass resources would only be able to meet a small percentage of transport fuel demand (Scion 2008a). However, use of effluents and municipal wastes for energy has significant environmental upsides in terms of reduced GHG emissions and reduced waste discharge (Scion 2008b), and so should be a short term development priority.

New Zealand's largest potential source of biomass for energy is New Zealand's sustainably managed plantation forestry estate (New Zealand's remaining native forests are protected from logging). In addition, New Zealand has a significant quantity of low to moderate productivity land that could be afforested to provide significant biomass resource without significantly impacting New Zealand's most valuable export industries which utilize high-value grazing and cropping land. It is estimated that utilizing 1.0 million hectares or 12 % of the low productivity land could produce a biomass resource capable of supplying 30 % of New Zealand's transport fuel by 2040, using reasonably conservative conversion factors (BANZ 2010).

We present a summary of a recent analysis of New Zealand's potential future energy challenges and the potential of bioenergy to meet some of these challenges. As suggested above, this analysis points strongly towards a strategy of large-scale production of transportation fuels from woody biomass and wastes.

Forestry for biofuels is seen as a low risk option as the wood can be used for fuel, lumber, reconstituted wood products, carbon sequestration or a mix of these. There are environmental benefits from afforestation of hill country and there is potential to have food production (cattle grazing) of the same land for at least part of the rotation.

In Sect. 2 we briefly outline New Zealand's current and future energy supply and demand options. Section 3 discusses New Zealand's residual biomass. Sections 4 and 5 covers New Zealand's largest biomass resource, wood from plantation forests, and the potential for greater future afforestation, including environmental benefits. Section 6 gives a brief summary of wood to liquid fuel conversion technologies trialled in New Zealand. Sections 7 and 8 present the challenges we face and a summary.

2 Energy Demand / Supply

Electricity demand in New Zealand (NZ) is ~149 PJ per annum or 41,392 GWh (MED 2010), and on average around 60 % of this demand is met by hydroelectric generation. Whilst demand is increasing, NZ also has significant renewable

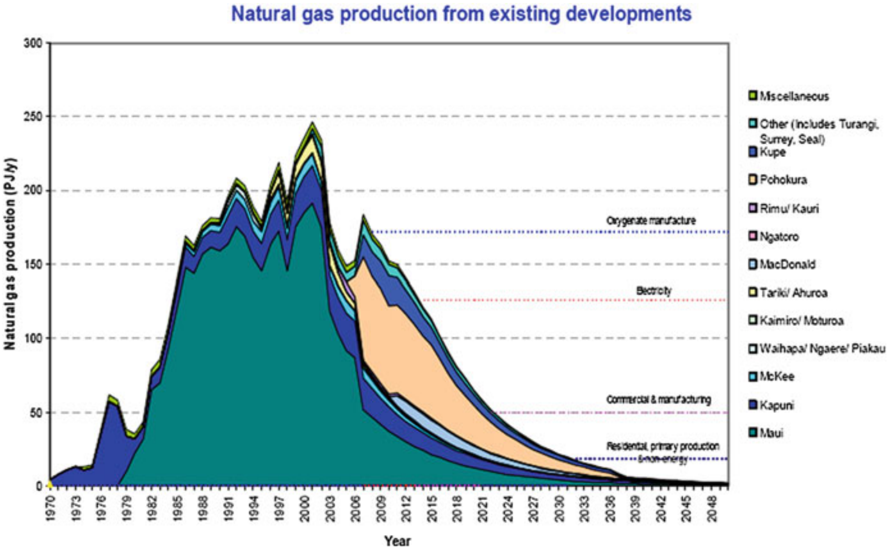

Fig. 1 New Zealand's proven gas resources (de Vos and Heubeck 2009)

resources that can be harnessed to generate more electricity including; further hydro development as well as extensive geothermal, wind and marine (wave and tide) resources which are yet to be fully exploited (NIWA 2009). Recent major developments have been from geothermal and wind, with investigation of marine projects underway. Burning biomass to generate electricity is a low priority at a national level, and will probably only occur where there are co-generation opportunities or site specific drivers such as remote communities or off-grid demands.

Heat demand is circa 195 PJ per annum. Most of this is met from coal and gas, with 55 PJ coming from wood and wood processing, including pulp mill black liquor (MED 2010) Black liquor is the lignin stripped from the wood during pulping; this is distilled and then burned in a recovery boiler to extract chemicals and to provide process heat. Firewood for domestic heating is a small contributor, at around 2–3 PJ per annum. New Zealand has extensive coal resources and this is not expected to a constraint in the medium term. Gas is used extensively for heat and for electricity generation. Gas supply is an issue in the near term and may be a driver of bioenergy development unless current exploration for new resources is successful. New Zealand's gas reserves are shown in Fig. 1. A key energy resource for New Zealand has been the massive Maui gas field which has provided the bulk of the gas supply for 30 years; this field is now in decline.

New Zealand has a small amount of domestic oil production, and most of it is exported, as the single oil refinery in New Zealand is tuned to run on imported crudes that are heavier than those we produce domestically. Consumption of liquid fuels is ~215 PJ per annum. We import over 90 % of our oil needs and around two thirds of our transport fuels are refined in New Zealand with the rest imported as refined product.

In an analysis of liquid biofuel use in NZ the Parliamentary Commissioner for the Environment (PCE 2010) concluded that in New Zealand we should;

- Focus on biofuels that benefit the environment
- Invest in biofuels that can be produced in large quantities, and in New Zealand's case this means wood and other ligno-cellulosics (straw residues and possibly miscanthus) as the resource
- Focus on drop-in biodiesel because;
  - Diesel for heavy machinery and freight drives our primary production industries and is thus more important to the economy than petrol for private transport
  - Drop in substitutes will be possible and desirable as blending and infrastructural incompatibility issues are avoided

We support these findings and would add jet fuel as product to focus on as it is critical to the air transport industry.

3 Residual Biomass Resources

In 2007, major studies of New Zealand's current and potential energy resources were commissioned by the government – Bioenergy Options for New Zealand and New Zealand's EnergyScape.

A summary of the biomass/ bioenergy resources derived from these studies is presented in Table 1. These figures represent those residues and wastes that are not currently being used.

Table 1 New Zealand's potential bioenergy resources, PJ per annum (Scion 2008)

Residual waste type/ source	2005 PJ p.a.	2030 PJ p.a.
Forest residues	14.6	34.4
Wood process residues	7.0	9.1
Municipal wood waste	3.5	2.2
Horticultural wood residues	0.3	0.3
Straw	7.3	7.3
Stover	3.0	3.0
Fruit and vegetable culls	1.2	1.2
Municipal biosolids	0.6	0.7
Municipal solid waste, landfill gas	1.9	2.3
Farm dairy	1.2	1.2
Farm piggery	0.1	0.1
Farm poultry	0.0	0.0
Dairy industry	0.4	0.4
Meat industry (effluent only)	0.5	0.5
Waste oil	0.2	0.2
Tallow	3.6	3.6
Total	**45.9**	**66.5**
Available biomass as % of consumer energy	8.5	9.2
Available biomass as % of primary energy	6.6	7.3

Residues Are Not Enough for A Bioenergy Future

As energy demand (especially for oil) rises in the future, biomass wastes and residuals are insufficient to meet more than a small amount of the energy demand.

Woody biomass is the largest biomass resource, and forest and wood processing residues are the largest contributors.

These insights led to a concept strategy being developed that outlined the potential of wood from new purpose-grown energy forests. It became apparent that energy from forests could be a huge contributor to low carbon energy in a New Zealand context.

This concept envisioned 3.2 million hectares of forests, providing 100 % of New Zealand's liquid fuels and some heat fuel. NZ has 9.6 million hectares of hill country grazing, of which 0.8–1.0 million hectares is highly vulnerable to erosion.

Whilst there are a wide range of biomass resources available to use, and many of these such as municipal wastes and industrial effluents, have significant environmental benefits if consumed for energy, clearly the largest opportunity comes from woody biomass, which is over half the current bioenergy resource and with a rising volume and percentage contribution out to 2030.

There is some current use of forest harvest residues for bioenergy, but it is a small proportion (estimated at 12–14 %) of the total resource.

If the existing residual wood resources and future volumes from existing forests are to be used then a market needs to be developed. Currently wood energy (including black liquor from pulp and paper mills) provides ~55 PJ per annum of primary energy, mostly as heat in the wood processing industry. Historically increased use of wood as fuel outside of the wood processing industry has been constrained by several key issues including;

- Cheap fossil energy from coal and gas
- Variable quality of biomass fuels provided for heat production (moisture and ash content)
- Uncertainty of supply (as forest and wood processing residue production is dependent on the health of domestic and international lumber and log markets)
- Cost of infrastructure change

4 New Zealand's Forests

New Zealand's forest and wood processing industries are based almost entirely (over 99.9 %) on intensively managed plantation forests of introduced species. The plantation forest estate is approximately 1.75 million hectares, with 89.3 % of the area in *Pinus radiata*, 6.3 % Douglas Fir, 2.1 % other softwoods, 1.5 % *Eucalyptus* species and 0.7 % other hardwoods. Thus, 97.7 % of the wood resource (by area) is

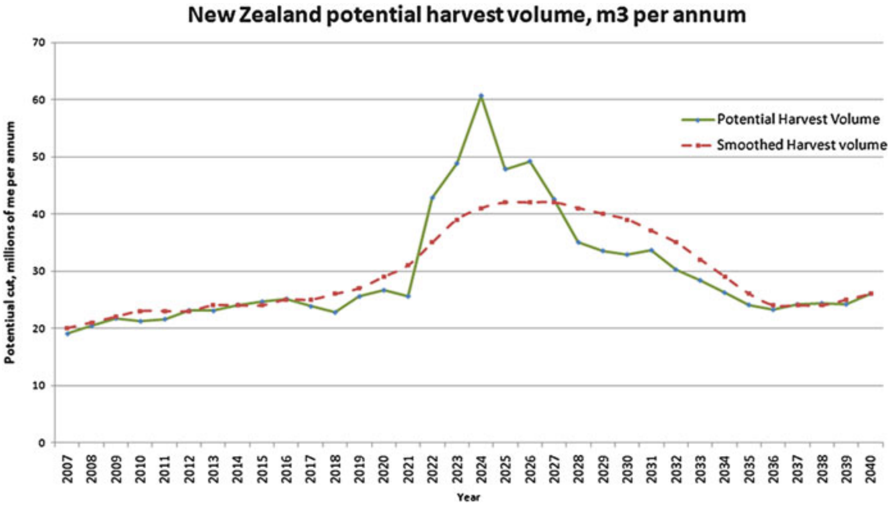

Fig. 2 New Zealand's potential forest harvest volume (MAF 2010)

softwoods. This resource is well described in terms of its area, location, yield and age class distribution, in the National Exotic Forest Description (NEFD) a national dataset maintained by the Ministry of Forests (MAF 2010) and associated maps and data sets (Ministry for the Environment 2007). This data can be used to predict the volume of material that is potentially available for harvest; at national (Fig. 2), regional and territorial authority levels. The most common species, *Pinus radiata*, is typically grown on a ~28 year rotation (25–32).

For the year to March 2010 the forest harvest volume was 20.5 million cubic metres and to March 2011 the figure will be around 25.5 million cubic metres.

New Zealand's forest industry faces some significant challenges in the next 30 years as represented by Fig. 2. The first challenge is 2020–2025, when the volume of wood potentially available to harvest trebles in a space of 3–4 years.

The second challenge is that post 2025; the potential cut goes into steep decline, and is back to current (2011) levels by around 2035.

These changes reflect the age class distribution of the established forests and are largely driven by a planting boom in the mid 1990s. It is unlikely that the forest will (or even could) be harvested at the peak of the potential rate. Whilst some smoothing of the harvest volume (dotted line = approximation) will occur and may ease the supply glut/infrastructure bottleneck situation, we still face a harvest volume that could double and halve over a 15 year period.

However, there will still be a substantial increase in forest harvest (a total cut of up to 40 million cubic metres per annum is realistic), with a consequent increase in harvest residues (as indicated in Table 1) and there will also be an increase in the volume of low grade/low value logs (pulp/ chip grade). This increased volume of low grade logs could be in the order of 4.0 million tonnes per annum (~20 % of the harvest), with some doubt over the ability of the existing pulp, paper and reconstituted panel industries to consume this material. The existing New Zealand pulp mills are ageing, at capacity, and there are no plans to expand these or build new ones. This is a reflection of the dropping demand worldwide for all paper products except tissue.

The conclusion from this is that there is a potential resource of 3–4 million cubic metres per annum of softwood biomass available for non-traditional uses. This material has an energy equivalence of up to 27.7 PJ (3.6 % of New Zealand's primary energy demand of 776 PJ).

5 Potential for Future Afforestation

An analysis of the potential for further afforestation for production of biomass for energy was undertaken as part of the Bioenergy Options for New Zealand project (Scion 2009, various authors).

This study looked at the energy supply volume, cost, land use change and associated environmental and macro-economic impacts of four large-scale afforestation scenarios, for liquid biofuels production. These afforestation scenarios ranged from 0.8 to 4.9 million hectares.

These figures need to be seen in the context of other national level data; NZ has 9.6 million hectares of hill country grazing land, of which 0.8–1.0 million hectares has been identified as being at high risk of erosion, and 2.5 million hectares of which is earning less than $100 per ha per annum in its current use (typically sheep and beef grazing).

The scenario seen as realistic but still with significant impact is scenario 2 (Table 2, shaded), with ~1.8 million hectares of new afforestation (Map – Fig. 3).

In Table 2;

- LPe = litres of petrol equivalent
- TEB = total extractable biomass = total recoverable stem volume + bark + (branch biomass × 0.8) + (0.8 of the estimated 15 % of the above ground biomass in currently unmerchantable stem breakage)

The large-scale afforestation scenarios were based on the assumption that the crop would be radiata pine. This does not mean that all the afforestation would or should be this species. It is however the species that has the most information available at a national level on its productivity, across a wide range of sites, thus allowing more detailed and accurate predictions than is possible for other species.

The forest management regime (high stocking, minimum tending) assumed in the new afforestation scenarios gives market options for the logs produced other than 100 % to energy, for example, 56 % sawlog and 44 % chip grade logs. It also gives high volumes of carbon sequestered/ stored (Fig. 4).

There are substantial variations in afforestation areas between regions, for a wide range of reasons. New afforestation areas are limited in Waikato, Bay of Plenty (Central North Island) and the West Coast of the South Island. A large percentage of Waikato land area is high value cropping or dairying suitable. The Bay of Plenty already has a high proportion of land under forest and the West Coast has significant areas in the conservation estate and their small plantation forests have performed poorly for climatic, soil drainage and fertility reasons.

Table 2 Summary of potential biomass and liquid fuel production (assumes sustained yield harvest on 25-year rotation with earliest harvest in 2037)

Region	Scenario 1 / 0.8		Scenario 2 / 1.8		Scenario 3 / 3.3		Scenario 4 / 4.9	
	TEB p.a. m^3 millions	LPe, p.a. millions	TEB p.a. m^3 millions	LPe, p.a. millions	TEB p.a. m^3 millions	LPe, p.a. millions	TEB p.a. m^3 millions	LPe, p.a. millions
Northland	0.29	25.2	1.08	94.2	3.07	267.1	8.38	728.8
Auckland	0.01	0.9	0.51	44.3	1.15	100.6	2.47	214.8
Waikato	0.23	20.4	4.39	382.0	11.35	987.4	16.88	1,468.3
Bay of Plenty	0.02	2.3	0.44	39.4	1.24	107.8	2.29	199.2
Gisborne	0.26	22.9	6.26	544.8	10.93	950.7	13.26	1153.6
Hawke's Bay	0.51	44.9	8.47	736.8	16.86	1,466.3	20.12	1,750.1
New Plymouth	0.52	45.4	2.60	226.5	3.83	333.6	4.84	421.5
Manawatu-Wanganui	1.35	117.7	16.08	1,389.2	25.93	2,252.2	29.80	2,591.4
Wellington	0.36	31.4	5.73	499.0	7.97	693.2	9.76	849.4
Tasman	0.10	8.8	0.81	710.4	1.24	108.3	1.70	148.4
Nelson	0.00	0.1	0.11	9.3	0.13	11.7	0.14	12.9
Marlborough	0.88	77.2	3.24	288.1	4.16	362.0	5.58	485.7
West Coast	0.14	12.5	0.34	30.1	0.94	81.9	1.29	112.5
Canterbury	9.90	861.2	12.14	1055.7	18.86	1,640.2	27.16	2,361.7
Otago	6.47	563.4	8.27	714.3	13.12	1,141.5	17.54	1,525.4
Southland	1.49	129.9	3.00	261.0	5.79	503.7	7.39	642.9
Total*	**22.59**	**1964.2**	**73.55**	**7,039.1**	**126.63**	**11,011.2**	**168.67**	**14,666.1**

In Table 2;

- LPe = litres of petrol equivalent
- TEB = total extractable biomass = total recoverable stem volume + bark + (branch biomass x 0.8) + (0.8 of the estimated 15% of the above ground biomass in currently unmerchantable stem breakage)

However, other regions (East Coast, Hawkes Bay, Manawatu-Wanganui – East and lower North Island) have large areas that could go into forests as these regions have large areas of hill country grazing on land that is prone to erosion.

Table 3 summarises the environmental impacts of the afforestation scenarios on some key variables (erosion, water yield, N leaching and Carbon) (Scion 2009a).

For Scenario 2 the net gain in carbon stock, in 2050 versus 2005, was 651.1 million tonnes of CO_2 equivalent (Fig. 4). Potential displaced emissions were 3.4 million tonnes of CO_2 equivalent per annum by 2035.

All the afforestation scenarios provide increased carbon stocks. The two mid-range scenarios (2 and 3) increase carbon stocks by 650 million tonnes and 1,188 million tonnes respectively. At the lower scale of planting scenario 1 increases CO_2 equivalent stocks by 207 million tonnes and at the higher end scenario 4 increases CO_2 equivalent stocks by 2039 million tonnes. The two mid-range scenarios might also provide reductions in agricultural GHG emissions of around 3.3 and 7.3 million tonnes of CO_2 equivalent per annum, and transport GHG emissions reductions of 12.1 and 21.9 million tonnes of CO_2 equivalent per annum.

New Zealand's net GHG emissions in 1990 were 41.299 million tonnes of CO_2 equivalent and in 2006 were 54.951 million tonnes (MED 2008), an increase of 13.655

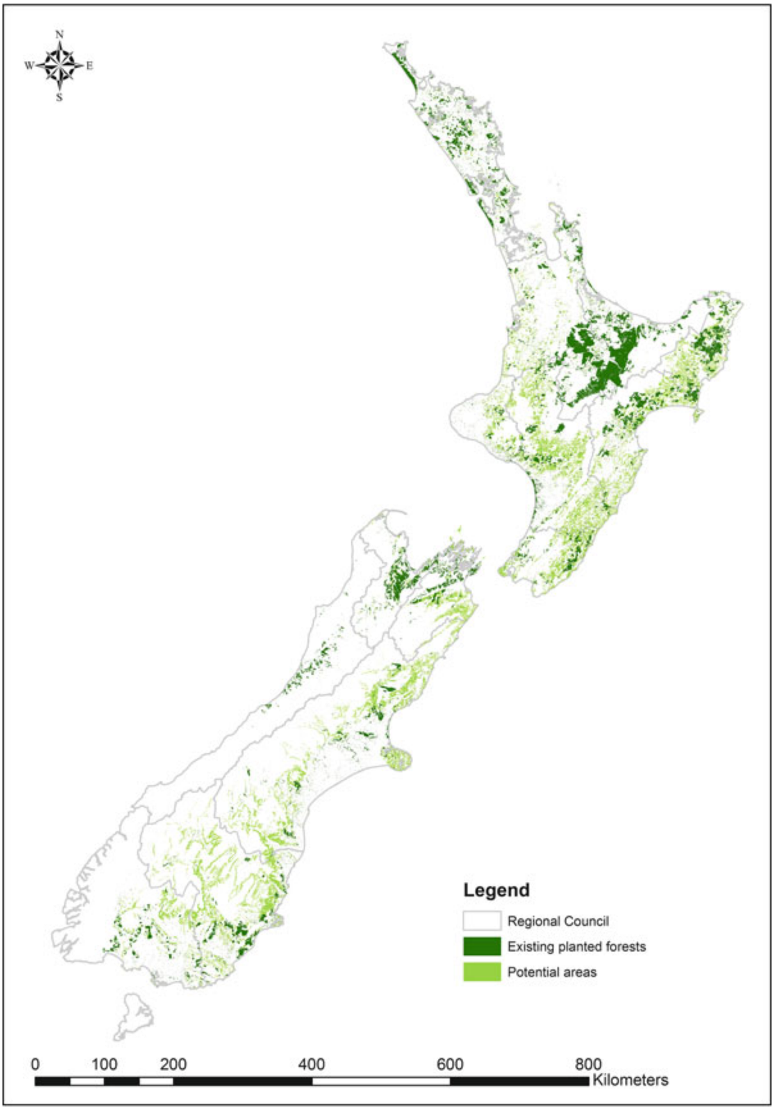

Fig. 3 Example afforestation scenario map - showing existing forest estate and potential additional ~1.7–1.8 million hectares of plantation forest

million tonnes of CO_2 equivalent. The increase in carbon stocks from the afforestation scenarios is substantial in comparison to these figures. For example, the increase in carbon stocks for Scenario 2 of 651 million tonnes of CO_2 equivalent is equal to; about 11 years of net emissions, or 47 years of the 1990–2006 difference in net emissions.

There are also beneficial impacts on indigenous biodiversity. The land being targeted for afforestation is typically in exotic grasses, with low biodiversity and the

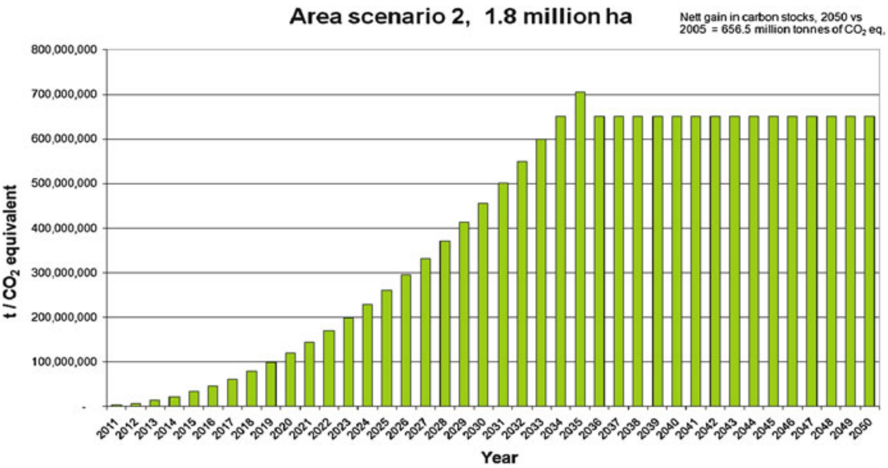

Fig. 4 CO_2 equivalent of carbon stock increase for forest area scenario 2, 1.8 million hectares

Table 3 Environmental impacts (national level) of afforestation scenarios

Scenario No. & millions of ha of new forest	GHG impacts, Reduced emissions, millions of tonnes, CO_2e	Stored carbon, millions of tonnes, CO_2e	% reduction in erosion	% reduction in N leaching	% reduction in water yield
1. 0.8	5.02	207.8	1.1	0.3	0.9
2. 1.8	15.49	651.1	8.0	3.4	2.6
3. 3.2	29.21	1188.5	16.6	8.4	5.1
4. 4.9	37.29	2039.7	20.2	12	7.2

flora and fauna is typically introduced species. The establishment of forests, even those with introduced tree species as the crop, has been shown to lead to greater biodiversity, with many of the species in the sub-canopy being native scrubs with associated indigenous birds and insects (Pawson 2009).

Further, for a given estate area, some of the land could be retained as permanent carbon forests, some logged, and there are a range of options for marketing the material produced. These market options reduce the financial risk involved in growing the crop.

5.1 Softwood Conversion

The nature of our forest resource is that it is largely, and will be for the foreseeable future, dominated by softwoods (principally *Pinus radiata*). Softwoods have higher lignin contents and are more recalcitrant than hardwoods when subject to a biochemical conversion process (enzymatic hydrolysis to ethanol). Thus we need (and have) a research program focussed on developing processes and treatments that overcome this recalcitrance.

Table 4 Comparison of possible *Pinus radiata* regimes and crops (Radiata Pine Calculator Version 3.0 Pro)

Regime type	Initial and final stockings	Total merchantable. Volume, m^3/ha (at age 25)	Piece size, m^3	% sawlog	% pulp
Conventional[a] sawlog focussed	833 / 364	771	2.11	90	10
Compromise	700 / 518	876	1.69	86	14
Biomass, volume focussed	833 / 667	910	1.36	56	44

[a] Thin to 400 sp/ha at mean crop height of 14 m, approximately age 7

5.2 Yields

There are many items that contribute to the cost of a log product, or a product derived from wood. A major influence is the cost of capital, other influences are crop and conversion yields. Identification and development of conversion processes that give the maximum energy yield from a given amount of wood is critical to the success of a biofuel development.

Currently many New Zealand plantation forest management regimes target the growth of large diameter, high quality sawlogs, which gives greater market value in the current paradigm, but in doing so these regimes sacrifice total volume production. Some compromise on the traditional approach needs to be considered in order to fully enable a biofuels future. Achieving this will not be easy given the time frames of forest rotations and the risk involved in taking a new approach to forest growing. However, modelling suggests that yield gains are possible with minor changes to the approach to forest management (Table 4).

The biomass focussed regime gives a volume increase of 18 % over the conventional regime, but only ~4 % over the compromise regime. The compromise regime would give ~14 % more volume than the conventional regime. Modelling runs for the figures in Table 4 assumed a productive Central North Island site with re-establishment on harvested forest cutover.

5.3 Land Use Change

New Zealand has seen significant land use change over the last 800 years due to two waves of immigration and settlement. Prior to human occupation most of the land mass was covered in forest (with the exception of high altitude grasslands, scrublands and mountain ranges). Much of this forest has been removed and converted to grazing land (Fig. 5).

The remaining indigenous (native) forest cover (Fig. 5) is now largely protected and is managed by the Department of Conservation as national parks and reserves. It will not be available for timber or energy use. The expansion of the plantation

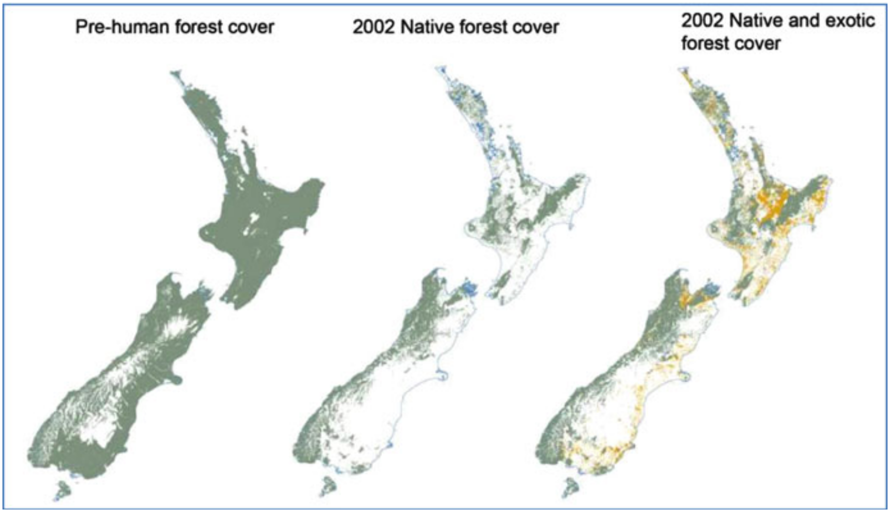

Fig. 5 Historical and current forest cover

forest estate would get much of the previously forested land which was cleared for grazing back into a ground cover much more like its natural state. Further, stock grazing (typically beef cattle) within plantations forests is possible and has been used throughout New Zealand on a variety of plantation forest sites. Thus hill country forests can produce food as well as logs, for at least part of the rotation.

5.4 Economic Welfare

One of the most important questions around bioenergy would be: what are the macro economic effects of large scale forestry for energy on economic welfare measures, such as standard of living?

In most of the scenarios considered biofuels lead to a decrease in productive efficiency and this implies a reduction in economic welfare. However, the production and use of biofuels reduces CO_2 emissions, so if there is an international price on carbon, New Zealand's liability to purchase offshore emission units is ameliorated. This generates a gain in Real Gross National Disposable Income. In addition, the increase in allocative efficiency reflected in increases in the terms of trade for high oil prices also leads to increases in economic welfare.

Further, economically it is better to use only the lower value logs for energy and higher grade logs for sawn lumber as opposed to all of them for energy. Forests should be regarded as having multiple values, including environmental and recreational, and many potential end-uses for the wood, including Carbon. These values offer risk mitigation for the afforestation for energy strategy.

Volatility of oil prices also has an impact on the viability of a biofuels industry, and its potential for producing economic gains. Specifically, it was shown (Stroombergen and McKissack 2009) that when oil prices exceed the costs of biofuels the contribution of biofuels to economic welfare could potentially quickly outweigh the losses to economic welfare that would occur if regulation force the blending of biofuels and fossil fuels when oil prices are low enough to undercut the cost of biofuels.

The costs of not developing a biofuels option may be high if a sudden increase in oil price occurs, as in 2008 and 2011. New Zealand's exchange rate versus the US dollar is also an important factor in fuel price at the pump, for much of the last 2 years (2009–2011) the New Zealand dollar has been at 0.7–0.8 well above the long run average of 0.65, insulating consumers from some of the impact of the recent increases in oil price.

The Bioenergy Association of New Zealand recently published a Bioenergy Strategy for New Zealand (BANZ 2010), that aims for biofuels from forests providing 30 % of New Zealand's liquid fuel demand in 2040, equivalent to 3.243 billion litres. An analysis of this strategy by BERL (2011) estimates that this strategy would increase GDP by 1.2 %, or $6.1 billion dollars.

Additional Wood Processing Potential

New Zealand exports significant volumes of saw logs in unprocessed form. In the year to June 2011 this figure peaked at ~12.2 million tonnes p.a. or 50 % of the total annual harvest.

If New Zealand's solid wood processing industry expanded to process even half this log export volume then there would be a supply of sawmill residues of ~3 million cubic metres (~20 PJ) per annum available for use as bioenergy feedstock.

Summary

Taking all these findings together we get to the point where we could look to forests to provide the feedstock for liquid fuels (biodiesel/jet fuel) production as a major focus of bioenergy development.

6 Processes Suitable for Converting Woody Biomass to Liquid Fuels Investigated in New Zealand

6.1 Acid Hydrolysis (AH)

Acid hydrolysis of wood to produce ethanol is an established technology and New Zealand had a significant research programme including a pilot plant in the late 1970s. However, after the 1970s oil shock, research and development on this topic ended in New Zealand, although development has continued elsewhere (Bluefire Ethanol).

6.2 Enzymatic Hydrolysis (EH)

Production of ethanol from wood and other ligno-cellulosic biomass via enzymatic hydrolysis is a topic of global R&D. Scion in New Zealand is working on EH of softwoods, principally *Pinus radiata*, which poses significant challenges due to the recalcitrance and higher lignin contents inherent in softwoods. Innovative pre-treatments are used to improve cellulose availability. The lignin left over after EH could be used for biochemical/ biopolymer production or for production of heat and electricity for the process.

6.3 Gasification and FT (GFT)

Production of advanced biofuels (biodiesel) via gasification of woody biomass and Fischer Tropsch catalysis has potential in a New Zealand context, especially if the economic scale of the plant can be reduced. R&D on this topic is underway in NZ (University of Canterbury). Feasibility studies of biomass GFT plants or co-firing of biomass with lignite or coal have been undertaken, but no developments are currently planned. NZ has a very large lignite resource (6.3 billion tonnes recoverable) in Southland and Otago and using this resource for liquid fuel production via GFT has been considered. Co-firing of biomass and lignite would help with the poor GHG profile of a pure lignite fired GFT plant.

6.4 Pyrolysis and Hydro-treating / Refining

Several groups have, or are, looking at pyrolysis of woody biomass to produce bio-crudes, liquid boiler fuel or advanced liquid fuels (typically jet fuel or diesel replacements).

6.5 Competing Conversion Technologies

Globally there is significant R&D on creating liquid biofuels from woody and ligno-cellulosic biomass. There is no clear technology winner and there is a need for unbiased analysis of the fundamentals (thermodynamics and efficiencies) of a range of technologies to determine which will have the greatest potential in a New Zealand context (feedstock, costs, fuel type, economic scale) – which may assume a wood to liquid fuel (biodiesel) paradigm.

7 Challenges

New Zealand thus has a number of challenges and opportunities that could be brought together to provide an energy solution based on forests.

Energy Challenges;

- High per capita liquid fuel consumption
- Limited domestic oil resources
- Rising oil/ liquid fuel prices
- Volatile oil prices
- Potential constraints on oil supply

Environmental Challenges

- High GHG emissions
- Erosion on steep grazing lands
- Water quality from grazing land run-off

Forest Challenges

- Expanding resource with significant increase in residues and low grade logs (2011–2030)
- Inconsistent wood supply volumes (declining harvest post 2030)

Technology development or identification

- Determining which wood to liquid fuel conversion technology is the most cost effective for New Zealand.

Making it happen

- Establishment of a large forest resource / biofuels supply will not happen without significant long-term buy-in and commitment from industry, landowners and government.

Opportunities

- To meet some of the national liquid fuel demand / increasing fuel cost issues, with low carbon liquid biofuels made from existing and potential domestic forest resources, with environmental and economic benefits.

8 Summary

New Zealand has a large and well established forest industry, based on exotic softwood plantations. This resource will provide an expanding harvest over the next 15–20 years.

Use of woody biomass as a heat fuel is well established in the wood processing industry and is slowly expanding, but there is still a significant but geographically distributed wood residue resource that is unutilised.

There is significant potential to utilise marginal lands to expand the forest resource and stabilise the harvest volume at a level of 40 million cubic metres per annum. This material could provide a base for a domestic biofuels industry.

Changes to the wood processing industry (expansion) could increase the wood processing residue volume, creating a substantial bioenergy feedstock.

A key future energy need is likely to be liquid fuel and the priority is diesel for primary industries.

Technology development in New Zealand needs to focus on identifying which conversion route will best take the very large potential of the woody biomass resource through to the priority demand of an advanced biodiesel.

Forestry for bioenergy represents a low risk option, in that the crop, whilst slow to establish and mature can be used for many other products; lumber, reconstituted wood products, solid fuels and Carbon storage.

Establishment of forests on hill country grazing land currently providing low economic returns could improve returns to land owners as well as providing improved environmental outcomes (reduced erosion etc.).

Multiple-use management of forests is common and there are many instances of stock grazing within plantation forests and thus the food versus fuels issue which occurs when farm land is converted to energy crops is mitigated by further developing a food and fuels paradigm in a forestry context.

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