Bioenergy Options for New Zealand - Summary

Summary by Peter Hall (corresponding author for the Bioenergy Options Project)

Introduction

The Bioenergy Options for New Zealand project began in March 2007. This project was initiated to consider the potential contribution of bioenergy to New Zealand's energy future. It began by exploring the bioenergy potential of existing biomass resources, being the residues or wastes from a range of industries. The project concluded in October 2009 with a report that demonstrates how New Zealand can become self-sufficient in transport fuels produced from biomass grown in sustainably managed forests.

The opportunity to substitute fossil fuels with domestically-produced biofuels would bring profound long-term economic and environmental benefits to the country through better utilising our natural capital.

This summary presents the key findings from each of the five reports in the Bioenergy Options study.

The 5 reports are as follows:

1. ***Situation Analysis*** - Biomass resources and conversion technologies
2. ***Pathways Analysis*** - Energy demand, pathways evaluation, Economics of purpose grown energy forests, Life cycle analysis of biomass resource to consumer energy
3. ***Research and Development Strategy***
4. ***Analysis of large-scale bioenergy from forestry - productivity, land use and environmental & economic impacts***
5. ***Transition Analysis - the role of woody biomass from existing plantation forests, species options & drivers for change in energy supply.***

Summary

1. Situation Analysis

This study looked at New Zealand's residual and waste biomass resources and their energy potential via a range of conversion technologies.

New Zealand's current consumer energy demand (2007) = 576 PJ

Heat	190 PJ (33%)
Electricity	141 PJ (24%)
Road Transport Fuels	212 PJ (6.3 billion litres, Petrol 3.4, diesel 2.9)
All Liquid Fuels	245 PJ (8.1 billion litres (inc. Jet 1.4, Fuel oil 0.4) (42%)

Current residual biomass resources

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

Residues are not enough.

As energy demand (especially for oil and gas) rises in the future, biomass 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.

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

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

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

2. Pathways Analysis

The Pathways Analysis looked at energy demand by region versus the available residual resources, the potential of a variety of biomass to user energy pathways and the GHG footprint (via Life Cycle Analysis) of a range of options with relevance to New Zealand's resources.

Life Cycle Analysis – Woody residues to consumer energy

Potential scale - current 26 PJ p.a. of primary energy, rising to 46 PJ p.a. by 2030.

Summary

	Combustion Heat	**Combustion CHP**	**Ethanol**	**Gasification Heat**	**Gasification CHP**	**Gasification Biodiesel**
Efficiency	60	42	42	51	36	35
MJ in per GJ out	133	205	283	177	250	254
EROEI*	7.5	4.9	3.5	5.6	4.0	3.9
GWP ** kg CO2 equiv / GJ	7.9	11.9	21.4	9.9	14.0	14.3
Economics Cost / GJ	$15.6	$27.6	$59.4	$31.2	$42.0	$34.5
Technology status	Mature	Mature	Developing	Developing	Developing	Developing

* EROEI – energy return on energy invested ** GWP – Global warming potential

Life Cycle analysis - Purpose-grown forest to consumer energy

Potential scale of resource – up to 3.372 million ha of forest producing up to 600 PJ pa of primary energy.

Summary

	Combustion Heat	**Combustion CHP**	**Ethanol**	**Gasification Heat**	**CHP**	**Gasification Biodiesel**
Efficiency	60	42	42	51	36	35
MJ in per GJ out	91	144	222	129	182	185
EROEI	10.9	6.9	4.5	7.7	5.5	5.4
GWP kg CO2 equiv. / GJ	4.9	7.5	17.1	6.5	9.1	9.3
Economics Cost / GJ	$34.5	$54.8	$86.6	$53.2	$72.6	$65.4
Technology status	Mature	Mature	Developing	Developing	Developing	Developing

Other LCAs

	Straw CHP	Canola Biodiesel	Kiwifruit AD CHP	Effluents AD CHP
EROEI	17.6 : 1	2.2 : 1	11.3 :1	7.2 :1
GHG Reduction	90%	62%	90%	200%
Scale	0.6 PJ pa elec 1.8 PJ pa heat	39 PJ pa off 1.0 M ha	0.06 PJ pa	5-6 PJ pa

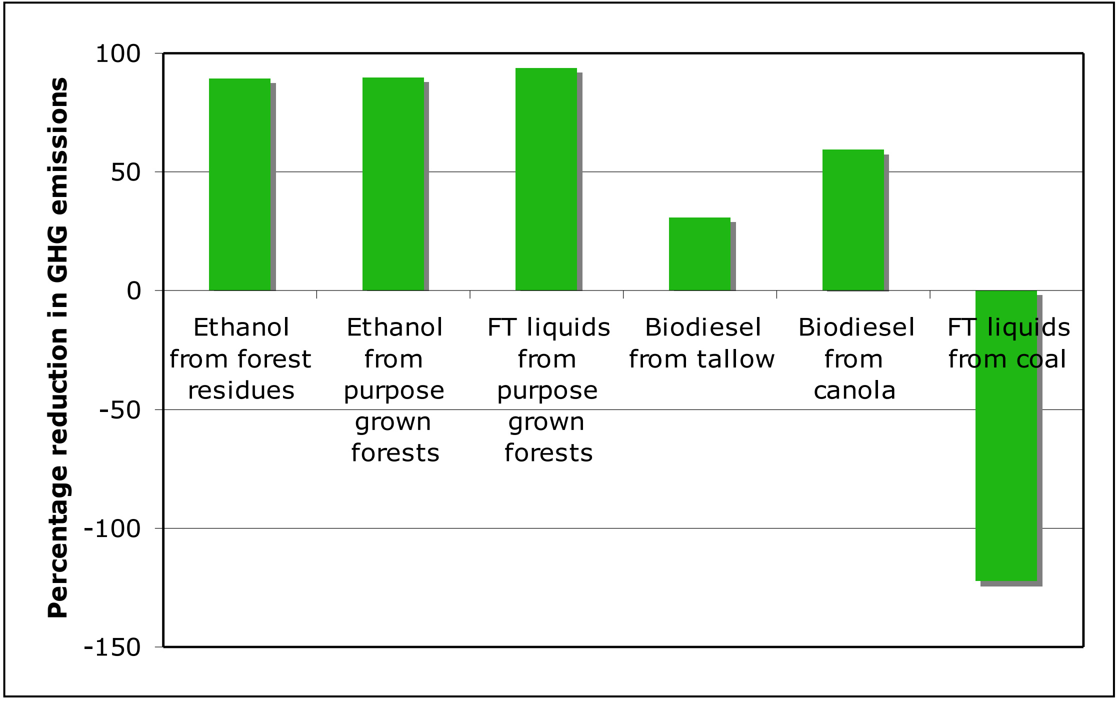
Key points
The use of residuals often gives an excellent energy return on energy invested.

For the effluents, there is a substantial environmental driver for their use. The GHG reductions are very substantial, as not only do you displace a fossil fuel, but you eliminate the CH4 emissions form the biodegradation of the material, which would otherwise go uncaptured. The solid waste volume can be reduced by 80%, with major impacts on waste disposal.

Utilisation of municipal waste, industrial effluent and agricultural waste for energy has the potential benefits of:

- Reducing greenhouse gases by displacing fossil fuels
- Reducing greenhouse gases released during decomposition.
- Reducing effluent and landfill waste disposal volumes and toxicity
- Reducing nutrient loading of waterways
- Off-setting waste management costs

Liquid fuel options - Percentage reduction in GHG emissions when used to replace petrol or diesel.

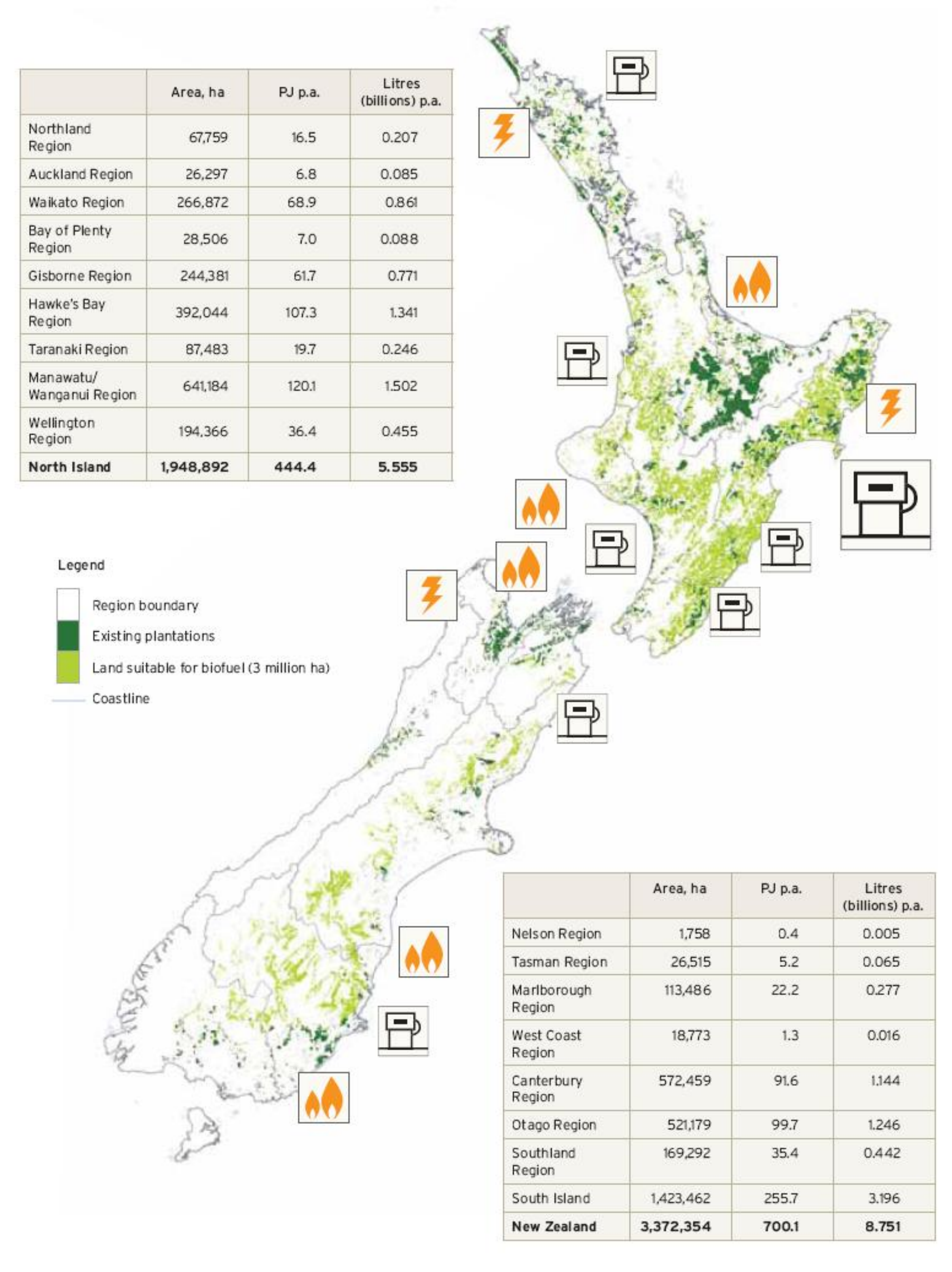


The use of wood residues and purpose grown forest derived wood gives greater reductions in GHG emissions than biofuels from tallow and oil seed crops. It is vastly superior to liquid fuels derived from coal.

The use of biomass from forests is more efficient in its land use than seed or nut crops as the entire biomass volume can be sued, as opposed to just a specific part of the plant.

Potential forested area (3.372 million ha) by region, potential energy (PJ per annum) and equivalent in biofuels, potential for heat and transport fuel processing

- New Zealand's energy potential from afforestation of hill country, assumes sustained yield harvest off a 25 year rotation



	Area, ha	PJ p.a.	Litres (billions) p.a.
Northland Region	67,759	16.5	0.207
Auckland Region	26,297	6.8	0.085
Waikato Region	266,872	68.9	0.861
Bay of Plenty Region	28,506	7.0	0.088
Gisborne Region	244,381	61.7	0.771
Hawke's Bay Region	392,044	107.3	1.341
Taranaki Region	87,483	19.7	0.246
Manawatu/ Wanganui Region	641,184	120.1	1.502
Wellington Region	194,366	36.4	0.455
North Island	**1,948,892**	**444.4**	**5.555**

	Area, ha	PJ p.a.	Litres (billions) p.a.
Nelson Region	1,758	0.4	0.005
Tasman Region	26,515	5.2	0.065
Marlborough Region	113,486	22.2	0.277
West Coast Region	18,773	1.3	0.016
Canterbury Region	572,459	91.6	1.144
Otago Region	521,179	99.7	1.246
Southland Region	169,292	35.4	0.442
South Island	1,423,462	255.7	3.196
New Zealand	**3,372,354**	**700.1**	**8.751**

3.0 Bioenergy Research and Development Strategy

A summary of the research and development priorities that would enable development of bioenergy in New Zealand were identified

Bioenergy from plantation forestry

- Develop new high-yield, low-input forest species and management systems for multiple forest and wood products including energy.
- Develop efficient harvesting and logistics systems.
- Adapt transport fuel conversion processes for New Zealand feedstocks.
- Develop an implementation plan for New Zealand.

From scale of supply, greenhouse gas mitigation, energy balance and technological maturity perspectives, this theme was identified as the most promising approach for bioenergy to make a significant contribution to New Zealand.

Biomass waste utilisation

- Demonstrate technologies on site (for example anaerobic digestion of effluents for combined heat and power).

Biomass residuals for distributed generation

- Develop integrated industrial solutions.
- Demonstrate technologies at different scales.

Next-generation feedstocks and conversion technologies (for example ligno-cellulosic material to liquid biofuels)

- Review and assess technologies and feedstocks.
- Develop new feedstocks and conversion technologies.

First-generation biofuels

- Science-based assessment of environmental impacts.

Why forests?

Establishment of a large-scale woody biomass resource producing multiple products including energy could mitigate a number of risks that are associated with other options, by:

- Being based on an existing industry;
- Not impacting key exports from arable and high-value pastoral land;
- Acting as significant long term energy store;
- Providing carbon sequestration during the establishment phase and additional carbon stocks from new forest area;
- Providing environmental services, such as, sustainable land management: stabilizing erosion prone land, low input (e.g. fertilizer, pesticides) land use, improving water quality;
- Potential to producing sustainable co-products such as traditional timber products and high-value biomaterials and chemicals;
- Providing the forest industry with a significant alternative market for low value products;
- Stimulating regional development;
- Providing year round biomass supply (not seasonal).

Realising this strategy for New Zealand will require multi-disciplinary research, strong industry and pan-government involvement. It will also require close collaboration with international researchers and industries.

4. Large scale bioenergy from forestry

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.

The land use scenarios developed for the study are outlined in Table 1.

New afforestation / land use change scenarios

	Descriptive area, Millions of hectares	Actual area, hectares
Scenario 1	0.8	765,181
Scenario 2	1.8	1,855,669
Scenario 3	3.3	3,386,648
Scenario 4	4.9	4,927,040

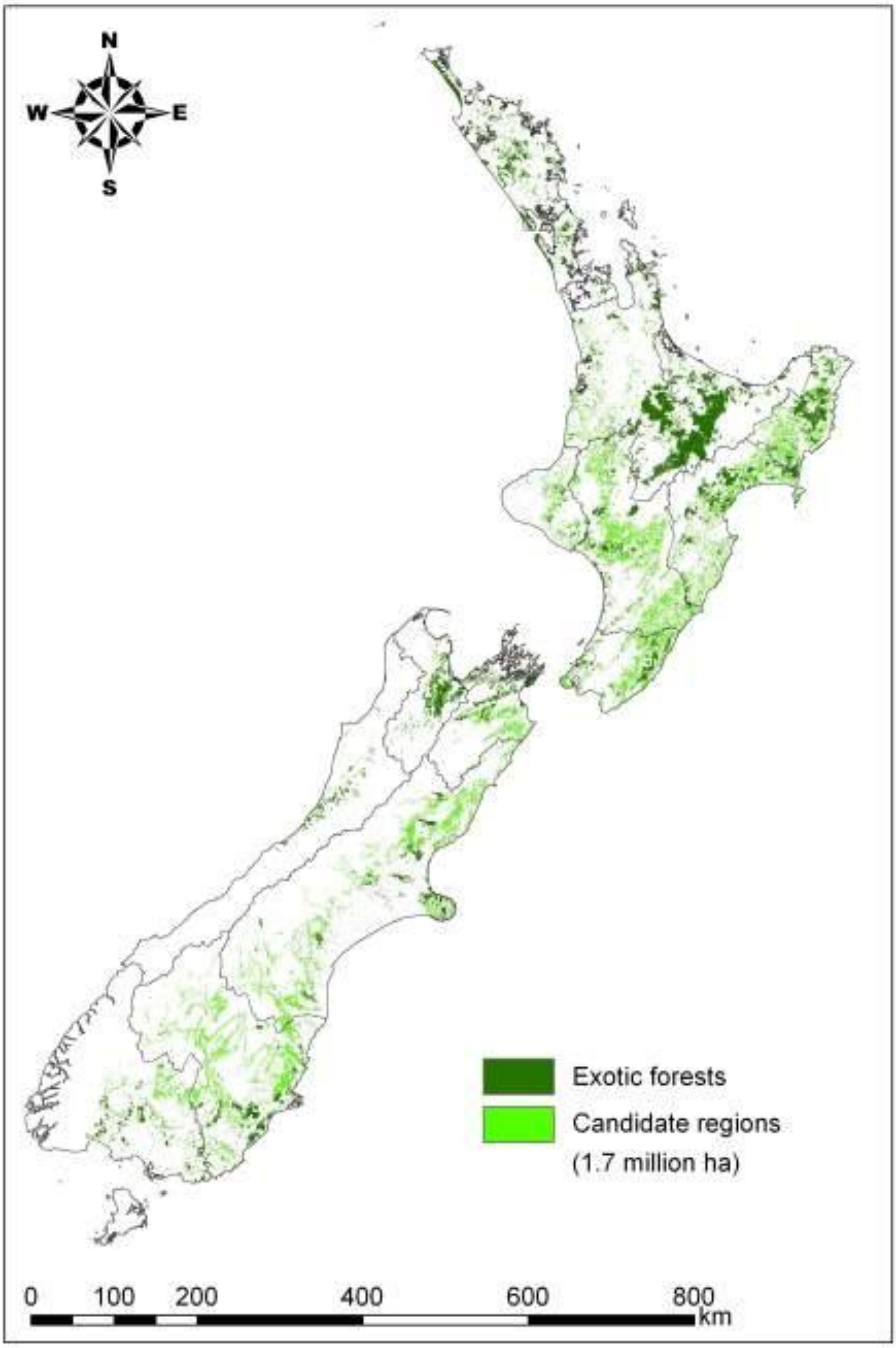
Summary of potential biomass and liquid fuel production (assumes sustained yield harvest on 25-year rotation)

	Scenario 1 / 0.8		**Scenario 2 / 1.8**		**Scenario 3 / 3.3**		**Scenario 4 / 4.9**	
Region	**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**

- LPe = litres of petrol equivalent
- TEB = total extractable biomass = total recoverable stem volume + bark + branches x 0.8 +upper stem x 0.8 of the estimated 15% of the above ground biomass in 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 radiata. It is however the species that has the most information available at a national level on its productivity, thus allowing more detailed and accurate predictions than is possible for other species.

Example afforestation scenario map - showing existing forest estate and potential additional 1.7 million ha of plantation forest.



The forest management regime assumed in the scenarios gives market options for the logs produced other than 100% to energy, for example:

- 56% sawlog and 44% chip

It also gives high volumes of carbon sequestered /stored

Woody biomass offers a variety of energy end-use options

- Solid fuel for heat and/or cogeneration of heat and power
- Liquid fuel production
- Feedstock for gas production

For a given estate area, some of the land could be retained as carbon forests, some logged, and there are a range of options for marketing the material produced.

Environmental Impacts (1.8 million ha scenario)

Scenario, millions of ha, new forest	GHG impacts, Reduced emissions, millions of tonnes, CO2 e	Stored carbon, millions of tonnes, CO2e	% reduction in erosion	% reduction in N leaching	% reduction in water yield
0.8	5.02	207.8	1.1	0.3	0.9
1.8	15.49	651.1	8.0	3.4	2.6
3.2	29.21	1188.5	16.6	8.4	5.1
4.9	37.29	2039.7	20.2	12	7.2

Economic welfare

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

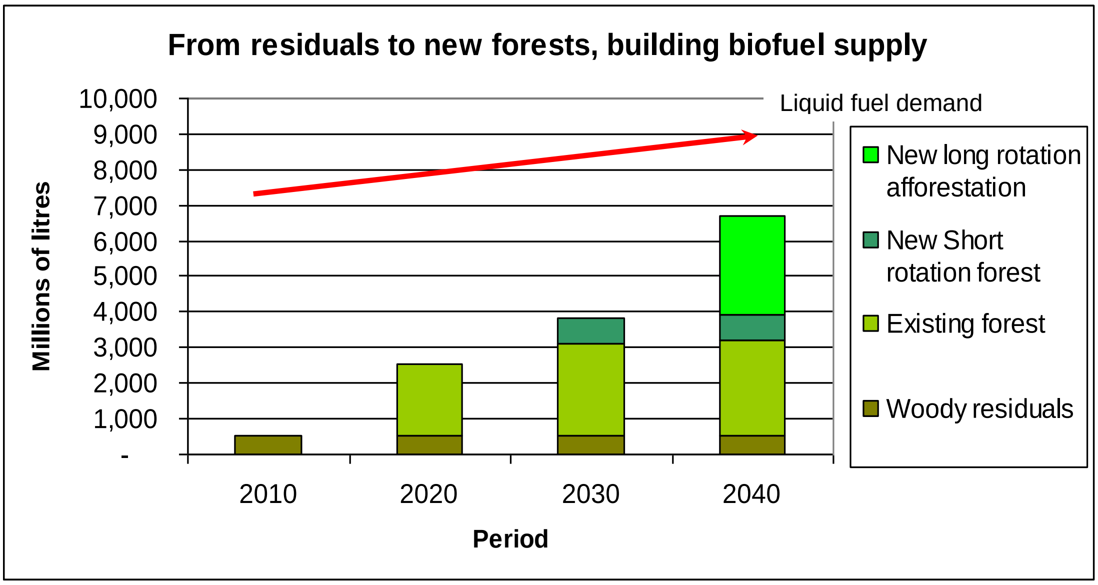
In most of the scenarios considered biofuels lead to a decrease in productive efficiency and this implies a reduction in economic welfare. However, the production and use of biofuels reduces CO_2 emissions, so if there is a price on carbon, New Zealand's liability to purchase offshore emission units 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.

Key Finding;

Economically it is better to use only lower value logs for energy and S grade logs for sawn lumber as opposed to all of them for energy

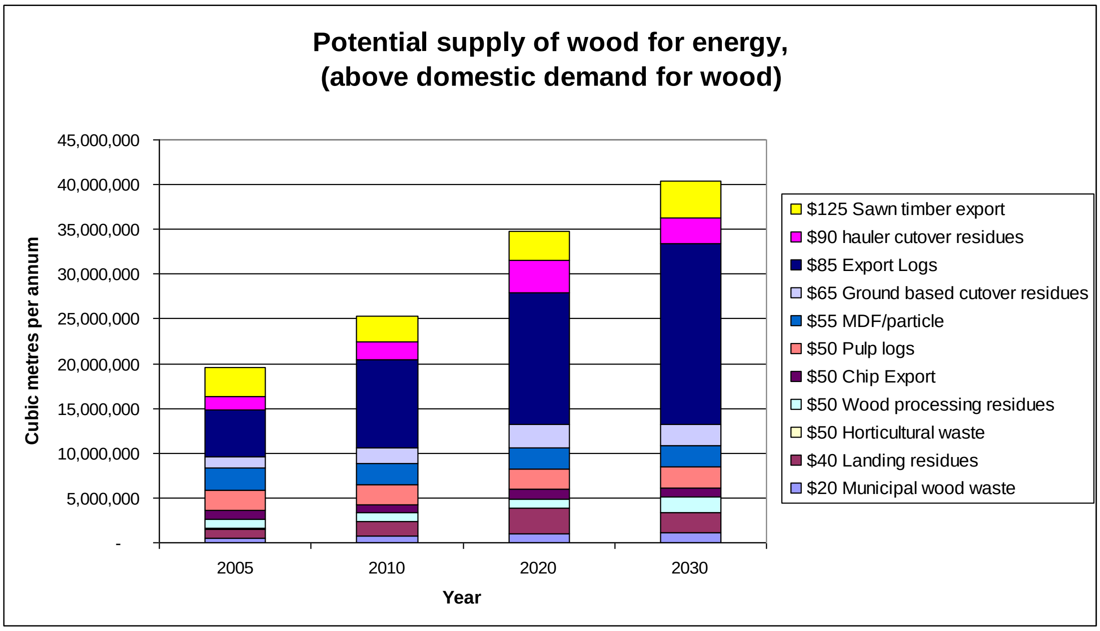
5. Transition Analysis

This report focuses on the potential of the existing forest estate to enable a transition from residues to a large-scale bioenergy supply from new forests; That is - what can we get from existing estate and what are the drivers in terms of energy supply? It also addresses new forest species options and economic impacts of oil price shocks.

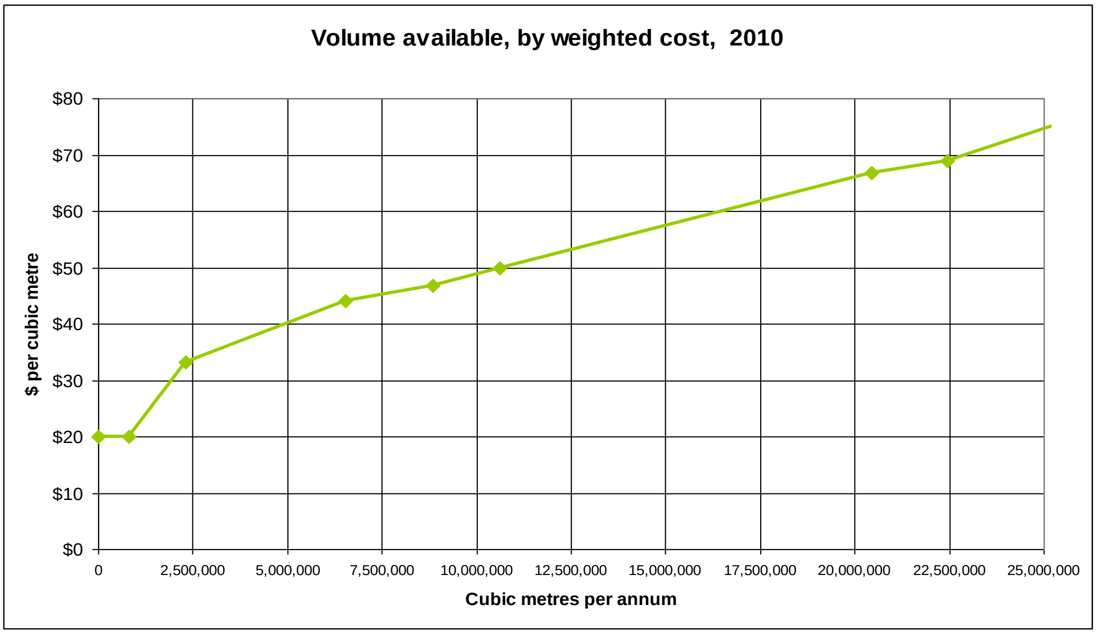


Using some of the existing forest harvest (chip logs) for energy plantations provides a stepping stone in supply to build from the small contribution from residuals to the potentially nationally significant supply from a large new forest estate.

Different sources of supply have different costs, the graph below outlines supply volume by cost from the existing wood residuals and forest harvest over time.



Volume of biomass available by weighted average cost, 2010



Price of oil (US$ per barrel) required to make biofuels from wood competitive, by exchange rate, tax regime and feedstock price

		Foreign exchange rates NZ$ to US$		
Feedstock price	**Tax applied**	**0.55**	**0.65**	**0.75**
$50 per m^3	**GST**	117	138	159
$50 per m^3	**Excise + GST**	156	185	212
$85 per m^3	**GST only**	144	171	196
$85 per m^3	**Excise + GST**	185	216	249

New Zealand’s long run historical average exchange rate versus the US dollar is in the 0.6 to 0.65 range.

A revised afforestation scenario was developed, to alleviate some environmental issues identified with larger afforestation scenarios in the previous study (water yield in drought prone regions and biodiversity impacts in inland Otago).

Energy production from lower grade logs (L grade and pulp), log volumes and energy equivalent, per annum

Region	**Energy grade logs, m^3 per annum**	**Energy, PJ per annum**	**Energy, lpe * per annum**
Northland	220,533	1.57	22,053,286
Auckland	124,598	0.88	12,459,758
Waikato	1,103,793	7.84	110,379,270
Bay of Plenty	109,266	0.78	10,926,596
Gisborne	1,613,302	11.45	161,330,193
Hawke's Bay	1,386,893	9.85	138,689,344
Taranaki Region	825,368	5.86	82,536,838
Manawatu-Wanganui	4,602,840	32.68	460,283,993
Wellington	1,951,051	13.85	195,105,149
Tasman	300,616	2.13	30,061,554
Nelson	38,413	0.27	3,841,327
Marlborough	1,060,051	7.53	106,005,114
West Coast	91,587	0.65	9,158,713
Canterbury	2,682,106	19.04	268,210,648
Otago	2,311,575	16.41	231,157,515
Southland	1,088,345	7.73	108,834,481
Total	**19,510,337.8**	**138.52**	**1,951,033,778**

* lpe = litres of petrol equivalent

New Zealand’s liquid fuel demand is currently around 8.1 billion litres

Maximum productivity of potential tree species for bioenergy production

	Species	Stem volume MAI m^3/ha/yr	Basic wood density (kg/m^3)	Stemwood oven-dry tonnes/ha/yr
1	*Pinus radiata*	60.1 - 63.8	420	25.2 - 26.8
2	*Eucalyptus fastigata*	46.0	500	23.0
3	*Eucalyptus. nitens*	42.5	520	22.1
4	*Eucalyptus regnans*	45.7	460	21.0
5	*Eucalyptus saligna*	33.8	610	20.6
6	*Sequoia sempervirens*	57.9	340	19.7
7	*Eucalyptus maidenii*	31.4	561	17.6
8	*Acacia dealbata*	33.5	510	17.1
9	*Eucalyptus botryoides*	23.7	620	14.7
10	*Acacia melanoxylon*	22.0	590	13.0
11	*Eucalyptus globoidea*	19.8	630	12.5
12	*Eucalyptus delegatensis*	24.5	470	11.5
13	*Cupressus macrocarpa*	27.3	400	10.9
14	*Cupressus lusitanica*	27.4	380	10.4
15	*Pseudotsuga menziesii*	23.9	400	10.1
16	*Eucalyptus E. pilularis*	15.9	580	9.2
17	*Pinus ponderosa*	20.8	400	8.3
18	*Pinus nigra*	18.8	430	8.1
19	*Larix decidua*	17.8	450	8.0
20	*E. muelleriana*	13.6	550	7.5

Potential species for afforestation were identified by determining maximum biomass productivity from bets sites and ranking them. Some species are only suitable to a limited range of sites.

It is readily apparent that the hardwoods (Eucalypts and to a lesser extent Acacias) with their higher wood density and reasonable growth offer greater productivity than many softwoods. However, the high volume production from Redwood places it in the 10 most productive species, along with radiata pine, the eucalypts and some acacias. *Pinus radiata* topped the ranking. (Note, that this is the maximum growth recorded from an extensive database – these are not typical figures).

Other species identified as worthy of further investigation:

Abies grandis – Grand Fir (cool, high altitude sites)
Picea sitchensis – Sitka Spruce (wet cool sites)
Tsuga heterophylla - Western hemlock (shady sites)
Sequoiadendron giganteum - Giant sequoia (high altitude sites)
Taxodium distichum - Swamp cypress (wet sites)
Pinus attenuata X *radiata* hybrid (snow prone sites)

Finding species suitable for cooler high altitude sites would extend the land base potentially available.

Economic Impacts

An earlier study showed that it is cheaper to use existing forest resources than to establish a new dedicated 100% energy forest for this purpose. Even if carbon was set at $100/tonne of CO_2, and oil was priced 50% higher than is currently the case, there would be no net economic benefit. This is due to the high value of the wood product exports that would be displaced in this case.

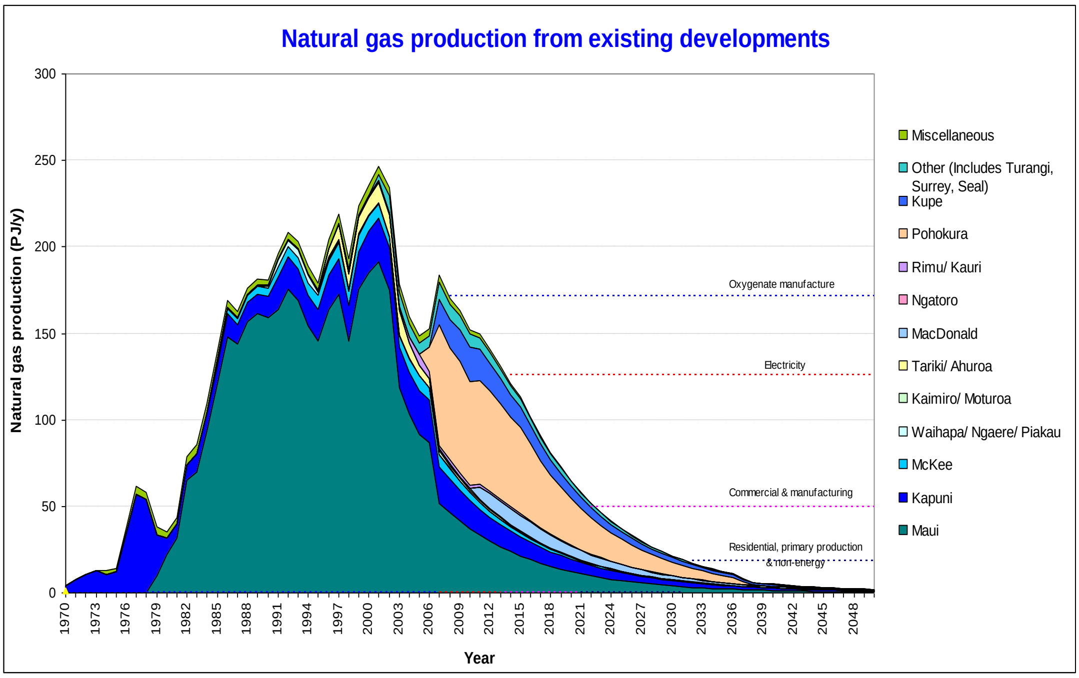
It would be simplistic to disparage biofuels in view of these high hurdle prices, because delaying action until biofuels were justified could be a very expensive strategy in the long term. While choice of biofuels in times of low oil prices would be a sub-optimal decision, and may be very unprofitable during the establishment phase, this is soon overwhelmed by the advantages gained during high oil prices – as is likely to be the case in the future.

In addition, as the forest industry is currently facing both increasing harvest volumes without the necessary domestic processing facilities and the threat of pulpmill closures, having other options for the harvest may mitigate some of the risks. If either of these situations eventuates then biofuel production from the harvest does provide a net benefit to the economy under the above assumptions for CO_2 and oil price.

Using existing forest rather than new forest means that there is no loss of agricultural land to forest planting. But a new forest would enable a range of valuable products (timber, wood panels, paper) in addition to biofuels and this could easily outweigh the loss in agricultural production.

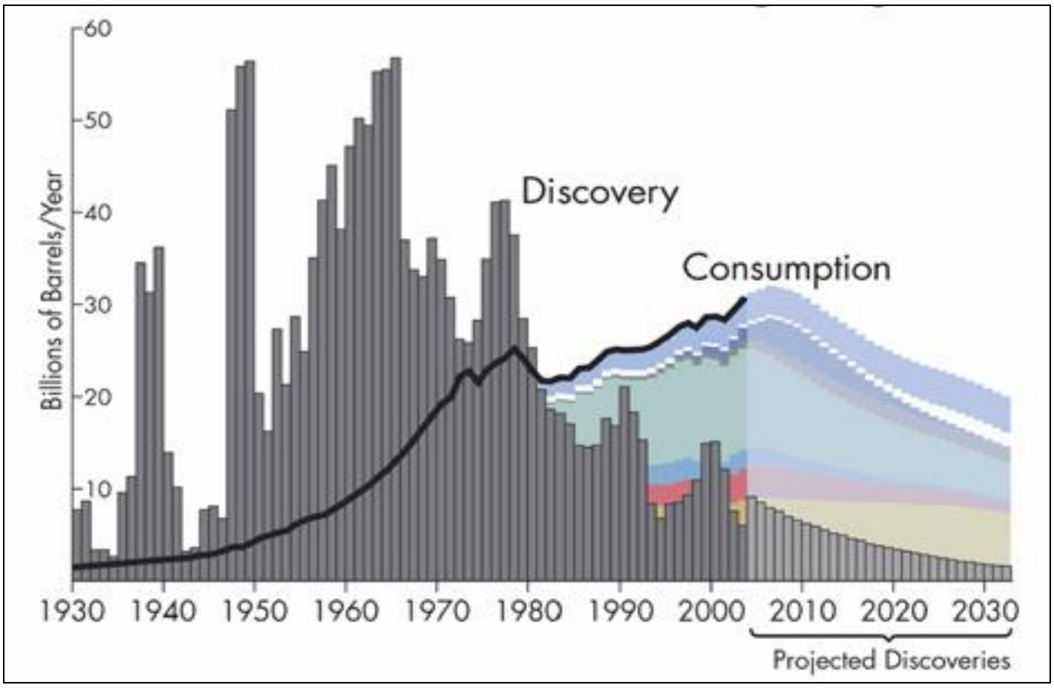
Drivers in energy supply

New Zealand faces declining gas supply in the medium term, unless new discoveries are made in the near future (see graph below).



New Zealand and the world face the prospect of declining oil supply and increasing oil prices. New oil fields being developed (Brazil, Athabasca) are more expensive to extract from than the current key supply fields in the Middle-east.

World oil production and world oil discoveries for the period 1930 to 2030



Source: Past discoveries based on ExxonMobil (2002), 3 year moving average and compiled by Colin Campbell. ASPO Switzerland http://www.peakoil.ch/new/e/wirdwenigergefunden.php .

Conclusions

Over the next 25 years New Zealand is likely to face a substantial increase in gas and oil prices.

Oil prices are also likely to increase more rapidly than food prices, which will negatively impact New Zealand's terms of trade.

The new development required to mitigate the risks associated with these price increases is likely to lock New Zealand into one particular pathway longer term.

One option is to redevelop the fossil fuel resource, requiring greater oil and gas exploration and the pursuit of coal-to-liquids to meet growing energy demands.

The alternative option is the biomass scenario that, in the transition period while a large-scale forestry resource is established, utilises the existing forestry resource with the aim of producing low-carbon biofuels and synthetic natural gas.

Significant risks are associated with each pathway. The biomass scenario is dominated by techno-economic risks, due to high costs associated with immaturity of technology, but it does not have the long term environmental and price risks associated with the fossil fuel redevelopment scenario.

The bioenergy option puts New Zealand on a path that could meet our energy supply needs while providing other significant benefits. These benefits include: reducing our greenhouse gas emissions; mitigating risks in the forest industry (which is key to offsetting carbon emissions from other industries); using our land more sustainably; and promoting regional development. In the long term this is obviously the preferable path.

The true challenge in the looming transition from oil is to deploy environmentally acceptable energy technologies rapidly enough to replace current options. This study shows that sufficient biomass resources exist from the current forest harvest for bioenergy to play a key role in this transition. The advantages of avoiding a disrupted climate and other fossil-fuel problems outweigh the costs of doing so.

Biomass supply from existing and new plantation forests can provide a continuum of increasing biomass supply that builds over time, 2010 to 2050. This is a realistic means of transitioning from a fossil-based energy supply to a truly renewable and domestic (stable) energy supply.

If fossil energy has declined and become substantially more expensive, it becomes even harder to build the next generation of energy infrastructure. This implies a need to plan now and act soon to develop the alternatives.

"The world's energy system is at a crossroads. Current global trends in supply and consumption are patently unsustainable – environmentally, economically, socially. But can - and must - be altered; there is still time to change the path we are on."
International Energy Agency, World Energy Outlook, 2008.

"Oil will not run out tomorrow, but we need to prepare for the day it does"
Fatih Birol 2009, Chief economist, International Energy Agency.

Bioenergy Options Reports are available from:

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