Bioenergy from forestry

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Introduction

New Zealand, along with the rest of the world, faces the significant challenges of lowering its greenhouse gas footprint and replacing fossil fuels with suitable energy alternatives. Bioenergy is a carbon-neutral renewable energy source that has an important role in meeting these challenges.

There are a myriad of ways of converting biomass to consumer energy (heat, electricity and liquid fuels). The critical question is what should be the source of the biomass (which is essentially stored solar energy in the form of carbon and oxygen). A partial answer is to use biomass residues, as these offer cheap resources and excellent environmental benefits. However, as fossil resources eventually dwindle, residual biomass cannot supply sufficient material to meet future energy demand.

Given the rising population in New Zealand and the world, demand for staple foods (grains vegetable etc) is not going to diminish. For this reason, it will be necessary to chose land for growing biomass that minimises the food/ energy competition issue. In New Zealand this is clearly our low productivity land currently used for extensive grazing. This land can be productive in forestry and is harvestable with current technology.

Could we fuel a significant part of our economy with forest derived fuels? Yes, we could. But should we? We need to at least consider this option thoroughly, along with other options.

The idea of using forests for fuel is not a new one and has been suggested before (NZ Energy Research and Development Committee, 1979). Its viability will depend on supplies of fossil fuels, the costs of these fuels, developments in climate change, competing technologies and competing alternative renewables.

However, forests can provide many environmental, economic and social values. Even those forests grown to produce maximum biomass for energy can contribute to traditional log supply (sawlogs, chip, export etc) or it could remain on site as a long term carbon store (whilst providing erosion protection and water quality benefits), or some mix of all of these options.

Given the risk mitigation potential and non-dollar values, energy from forests must have a place in our energy future.

In this article we explore New Zealand's bioenergy potential from forestry, based on the results of the Bioenergy Options for New Zealand project (Hall and Gifford 2008, Hall and Jack 2008)

New Zealand's Bioenergy Options - Summary

New Zealand's consumer energy demand totals around 576 petajoules (PJ) per annum, made up of 190 PJ of heat, 141 PJ of electricity and 245 PJ of liquid fuels. Due to conversion and transmission losses the total primary energy demand is much higher, at around 743 PJ per annum (MED, 2006). Currently biomass wastes and residuals provide around 45 PJ of primary energy, typically in provision of heat. The vast majority of heat energy is used within the wood processing industry (pulp mills, sawmills, lumber driers etc) with an estimated 8PJ used in domestic heating.

Over the past fifteen years there have been a number of studies that have looked at both forestry and wood processing wastes, in order to determine the volume of waste material that could be used for carbon neutral energy supply. A recent study (Hall and Gifford, 2008) looked at New Zealand's biomass supply more broadly. It was found that New Zealand has a variety of biomass resources suitable for energy production which arise from forestry, agriculture, industrial processing and municipal sources. The contribution that these resources could make to New Zealand's energy demand is outlined in Table 1. These figures do not include wood processing, forestry or other residues that are already being used, only the proportion which is currently estimated to be unused.

Forest residue is the single largest biomass resource, with agricultural straws and stovers second. Over time the wood processing residues sector (3rd currently) is expected to exceed agricultural residues, on the assumption that increased processing will follow the increased availability of harvested wood. Agricultural residues are assumed to stay relatively static, although there may be some change in the type of crop being grown. Tallow could potentially make a significant contribution to the production of liquid biofuel, but there is competition for the resource, with the bulk of it already being sold, much of it exported. Gas from municipal waste could also make a contribution of several PJs. Effluents and biosolids come from a variety of sources

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Table 1 - Total possible residual biomass resource for energy production (PJ/year)

Type/source	2005	2030	2050
Forest residues	18.3	43.0	36.9
Wood process residues	8.8	11.4	23.0
Municipal wood waste	4.4	2.7	3.6
Horticultural wood residues	0. 4	0.4	0.4
Straw	9.1	9.1	9.1
Stover	3.8	3.8	3.9
Fruit and vegetable culls	1.5	1.5	1.6
Municipal biosolids	0.9	1.1	1.2
Municipal solid waste, putrescible	2.8	2.9	2.9
Farm dairy effluent	1.5	1.5	1.6
Farm piggery effluent	0.1	0.1	0.1
Farm poultry litter	0.04	0.04	0.1
Dairy industry effluent	0.5	0.5	0.6
Meat industry effluent	0.6	0.6	0.7
Waste oil	0.2	0.2	0.2
Tallow	4.5	4.5	4.5
Total energy from residuals, PJ p.a.	57.3	83.1	90.0
NZ primary energy	743.0	890.0	1090.0
NZ consumer energy	576.0	720.0	880.0
All biomass, as % of consumer energy	9.9	11.5	10.2
All biomass, as % of primary energy	7.7	9.3	8.2

and are widely dispersed around New Zealand. Collectively they are estimated to be capable of producing 4.5 PJ of energy. Woody residues from all sources are currently over half of the total biomass resource in terms of energy content. By 2050 this could be as high as 65%.

A significant driver of the use of biomass resources for the production of energy will be the relative cost of coal, gas and petroleum. Rising costs will increase demand for bio-energy. Some of this cost may be driven by the value of carbon, although there is considerable uncertainty around the timing and impact of carbon trading. Predicting oil prices has proved to be a difficult and largely futile exercise in the short term. In 2008 oil prices have gone from US$98/bbl to US$147/bbl and back to US40/bbl. However, in the long term (5 to 10 years) it is likely that oil and gas prices will rise. Gas prices are likely to rise independent of international trends, as they are driven by domestic supply and this is likely to become restricted post 2015 (de Vos et. al. in prep.)

A significant finding (Table 1) was that even if all the biomass resource was utilised, they still only make a relatively small contribution to the national energy demand (7 to 9% of primary energy).

In this study we also looked at the conversion options available to use the biomass, including: combustion (to heat and combined heat and power (CHP); pyrolysis; gasification; biochemical/enzymes and chemical and mechanical processing (for oil crops and fats).

The best use of the biomass often depends on its initial form (liquid, solid, effluent) and there are many ways to convert biomass from its raw form to a useable form of energy.

Some of the more mature and promising options were analysed further in a second report (Hall and Jack, 2008). This analysis considered the overarching energy environment at a national and international level. Some of these factors were: New Zealand, via the NZES (MED, 2007) has expressed a desire to reduce its carbon emissions and be carbon neutral by 2040; oil supplies are finite and expected to peak in the near to medium term future; domestic gas supply is likely to be constrained in the next 5 to 10 years (de Vos et al, in prep.); energy demand is rising year on year; we are currently 71% dependant on fossil fuels for energy (coal, oil and gas), we currently import 80% of our transport fuel needs in an environment where supply and price are volatile.

Given the above factors, it is in our interests to be more efficient and conservative about our fuel use and to develop greater domestic supply from cleaner alternatives. New Zealand has a wide range of renewable resources that can be utilised to make electricity (de Vos et al in prep) and the imminent supply challenges lie in liquid fuels (international supply) and gas supply (domestic).

The use of waste or residual biomass is an obvious route to meeting these challenges, but the ability of residual biomass resources to meet our energy demand must be kept in perspective. A variety of residual biomass resources could be used to create liquid transport fuels, in volumes from a few million to several hundred million litres (Figure 1). It can be seen how these same contributions stack up versus current demand for around 8.1 billion litres of various liquid fuels (petrol, diesel, jet fuel and heavy fuel oil) (Figure 2).

There are a number of good reasons to utilise the residual materials as energy. They are very low carbon fuels,

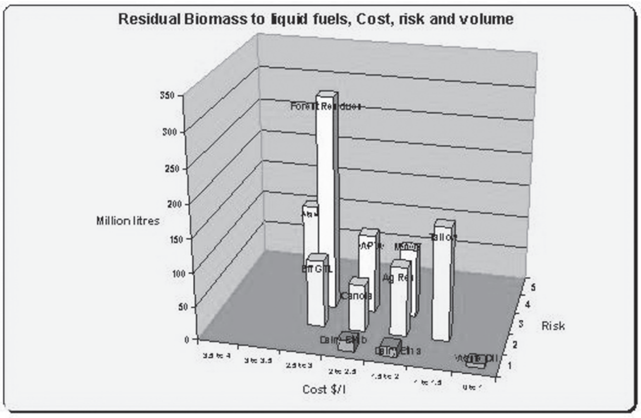

Figure 1 - Residual biomass to liquid fuels

Key: WPW = Wood processing waste, MWW = Municipal wood waste, Eff GTL = effluents gas to liquids, Ag Res = agricultural residues, Dairy eth a and b = ethanol from Dairy factories, a is that which is currently made, b is that which is estimated to additional. Price is in $per litre at the pump including taxes. Risk is a subjective assessment based on the state of the technology and potential competition for the resource. That is; making biodiesel from waste cooking oil is easy and known, the resource is limited but accessible, for algae to liquid fuels, the resource does not exist (but could be grown on effluents) and the technology is still being developed, at considerable cost.

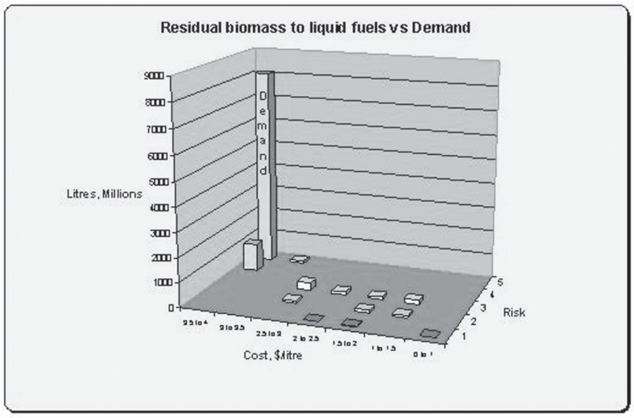

Figure 2 - Residual biomass to liquid fuel compared to liquid fuel demand

and the utilisation of waste has additional environmental benefits; e.g. reduced effluent loads, reduced volumes of material going to landfill (up to 80%) and reduced methane emissions.

The question then becomes, if we need to make large volumes of low carbon energy from biomass in order to meet demand in an environmentally-benign way, where will this material come from? There are a variety of options for purpose-growing biomass: oil seed rape for biodiesel (mature), algae to biodiesel (experimental), and wood to heat via combustion (mature), wood to gas via gasification and then to heat, CHP, electricity or liquid fuels (developing) and wood to liquid fuels via a variety of routes, including enzymes to ethanol (developing). These options need to be considered in broad terms, including cost and their ability to meet demand as well as their environmental impacts, For example:

- biodiesel from oil crops compete for arable land and require intensive fertilisation, however it is currently the most cost competitive option.
- liquid fuels from algae can only make a small contribution (2 to 3% of current demand) if based on effluents, and still faces significant cost hurdles (which rise if algae are produced from artificially fertilised ponds).
- large-scale bioenergy from any source will lead to land use change and competition.

Due to the land resource available in New Zealand (2.375 million ha of arable land and 9.288 million ha of land unsuitable for arable use) and our reliance on agriculture for food supply and export earnings, an option worth considering is to focus our biomass growing efforts on low productivity land (unsuitable for arable and intensive grazing uses) where we can grow biomass (and thereby store solar energy) on a large scale. It is theoretically possible to grow enough biomass via forestry on 3.3 million ha of low productivity and marginal lands to supply all of our current liquid and heat fuel demand. It is not possible to meet these demands from arable crops such as oil seed rape, due to the limited area of arable land that New Zealand has, and the competing demand for this land (food supply).

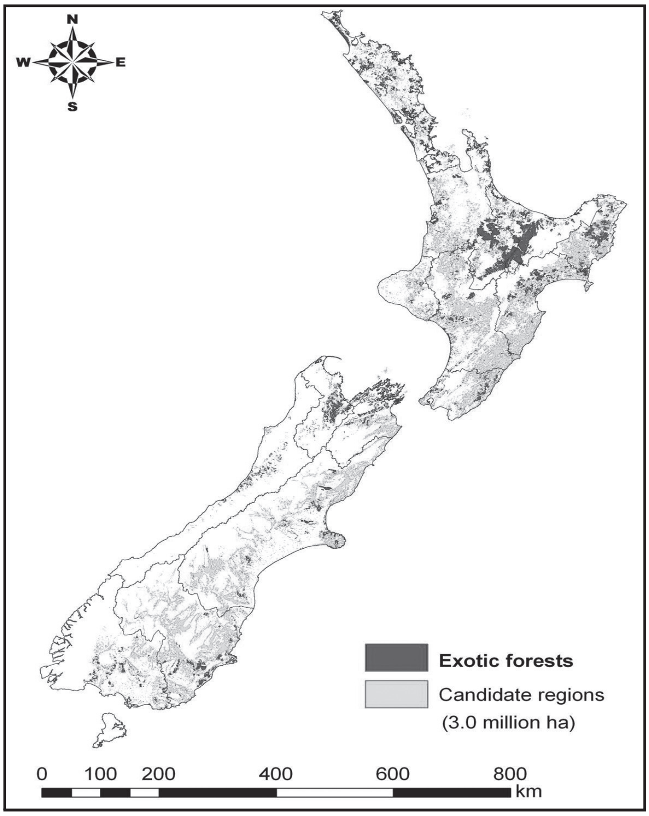

Figure 3 - map showing existing forest estate, and what an additional 3.3 million ha could look like, utilising low productivity hill country.

Table 2 - Summary - Forest residues to energy, potential scale: current 26 PJ p.a. of primary energy, rising to 46 PJ p.a. by 2030, Energy balance, greenhouse gas (GHG) emissions, other environmental benefits, economics, technology status.

	Combustion Heat	Combustion CHP	Enzymes Ethanol	Gasification Heat	Gasification CHP	Gasification Biodiesel
EROEI	7.5:1	4.9:1	3.5:1	5.6:1	4.0:1	3.9:1
GHG reductions*	92%	94%	75%	90%	83%	83%
Cost ($/GJ)	$15.60	$27.60	$59.40	$31.20	$42.00	$34.50
Technology	status	Mature	Mature	Developing	Developing	Developing

* Compared to heat from coal, electricity from the grid and fossil transport fuels. CHP = combined heat and power.

Table 3 - Summary - Forests to energy, potential scale: up to 3.372 million ha of forest producing up to 600 PJ p.a. of primary energy. Energy balance, GHG emissions, other environmental benefits, economics, technology status.

	Combustion Heat	Combustion CHP	Enzymes Ethanol	Gasification Heat	Gasification CHP	Gasification Biodiesel
EROEI	10.9:1	6.9:1	4.5:1	7.7:1	5.5:1	5.4:1
EROEI	10.9:1	6.9:1	4.5:1	7.7:1	5.5:1	5.4:1
Cost ($/GJ)	$34.50	$54.80	$86.60	$53.20	$72.60	$65.40
Technology status	Mature	Mature	Developing	Developing	Developing	Developing

* Compared to heat from coal, electricity from the grid and fossil transport fuels

Comparative costs for liquid fuels:

Petrol at $1.50 per litre	= $46.58 per GJ
Diesel at $1.30 per litre	= $36.31 per GJ

In order to compare some of the options for going from a residual or purpose grown biomass resource to consumer energy, a series of life cycle assessments were carried out (Sandilands, Love and Hall, 2008). The results of some of these analyses are presented in Tables 2 and 3.

A critical figure in the viability of a biomass to energy supply chain is energy return on energy invested (EROEI). A ratio of greater than 1:1 indicates a positive return, and the higher this ratio is, the better.

In Tables 2 and 3 it can be seen that all of the biomass conversion options for forestry biomass offer significant GHG reductions, even when the fossil fuel consumption in the supply chain is included. The cheapest conversion option for biomass is combustion to heat, as this is a mature technology with high conversion efficiency. However, currently there needs to be a demand that cannot be met from a cheaper alternative (coal or gas) before biomass is taken up in this use, or another driver (common in wood processing) of a supply of biomass on-site that would otherwise have to be disposed of.

In Figure 4 it can be seen that the use of biomass derived biofuels has a significant positive impact on GHG emissions, whereas the use of coal to liquids has a large negative impact. It should be noted that biomass can be co-fired with coal in a liquid fuels production system, and the percentages of the blends will dictate the level of GHG emissions. There is significant interest in the coal to liquids option for transport fuel supply in New Zealand, based on the Southland lignite resource.

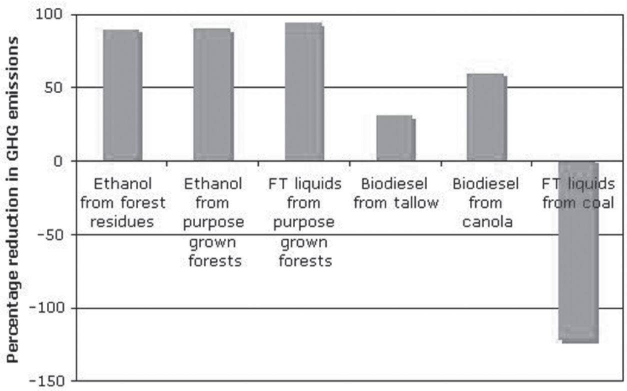

Figure 4 - Percent reduction in GHG emissions for some biomass to liquid fuels routes compared to fossil petrol and diesel.

The biodiesel (FT liquids) produced from woody biomass can be used directly in the existing fuel supply infrastructure, the technologies to do this are being further developed to reduce costs and improve efficiency and yield.

Woody biomass is seen as a significant source of energy and particularly liquid fuels, not just in New Zealand but also internationally (Metzger and Huttermann 2008).

Conclusions

Energy is a fundamental driver of our economy and our lifestyles. Cheap abundant energy allows economic growth and competitive exports. New Zealand has for decades enjoyed relatively cheap energy from domestic supplies of electricity, coal and gas and from imported oil. However, we face rising energy costs and diminishing supplies of fossil fuels (gas/domestic and oil/imported).

A further consideration is greenhouse gas emissions and climate change and how to address these issues.

An option for New Zealand is the use of large-scale plantation forestry to capture, store and supply energy in a variety of forms, but principally for heat and liquid fuels.

Why do we need to reconsider this option? We are heavily dependant on imported oil and it will run out eventually.

Renewable alternatives will be required to provide affordable low-carbon transport fuels.

The liquid fuels produced from biomass can, in some cases, be fitted directly into the existing fuel delivery and fleet infrastructure. Use of residual biomass resources to produce this type of fuel is a good start point, but will not provide a long-term solution. Forestry is considered to be the most viable option for large-scale purpose-grown biomass for energy.

New Zealand has significant areas of land that are suitable for forestry, and in some cases better suited to forestry than its current use as extensive grazing. We already have the ability to grow and harvest such forests and to be internationally competitive.

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