



New Zealand's EnergyScape™



2000

2005

2030

2050

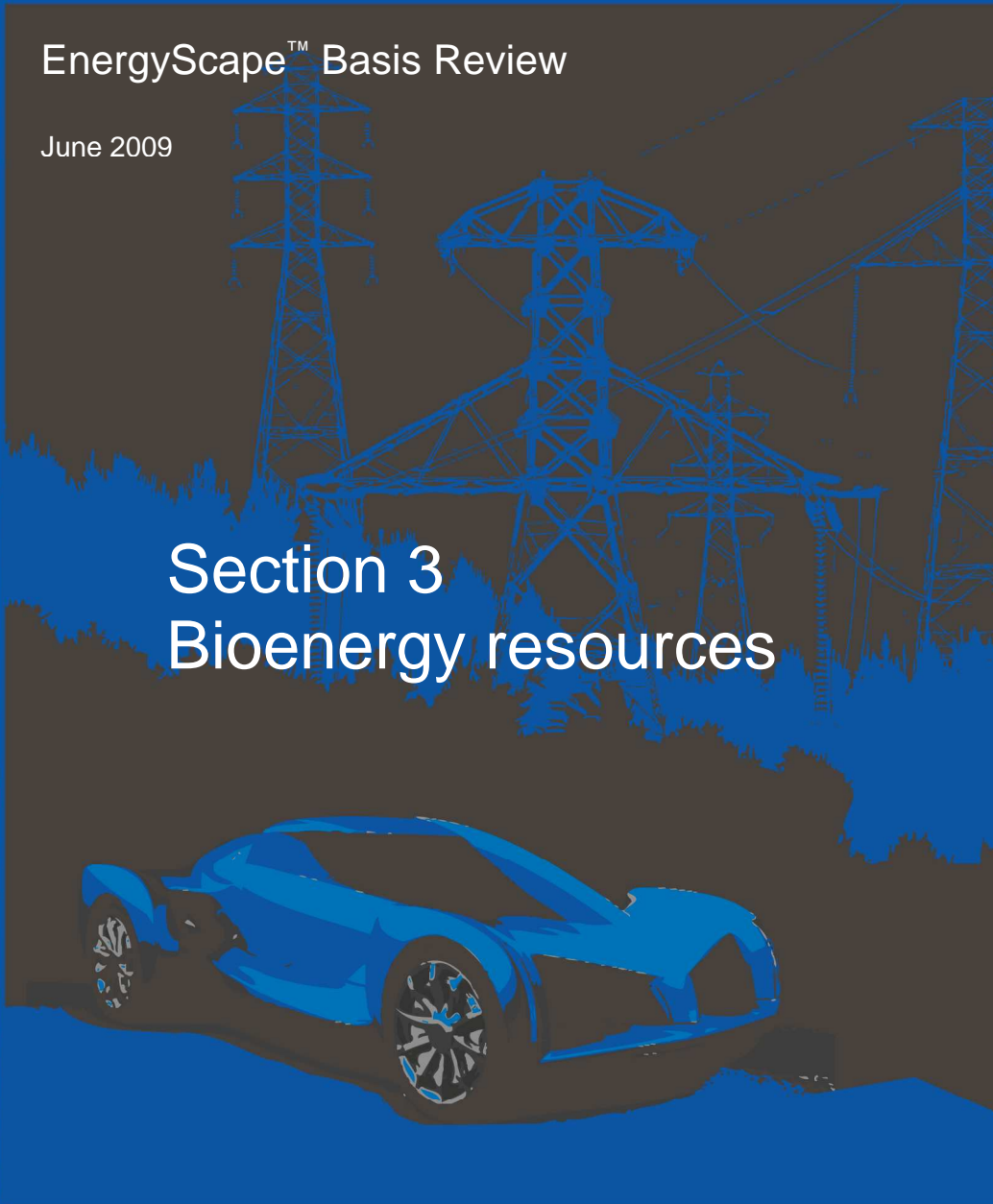


EnergyScape™ Basis Review

June 2009



Section 3 Bioenergy resources



INDUSTRIALRESEARCH LIMITED



SCION



NIWA
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EnergyScape™ Basis Review

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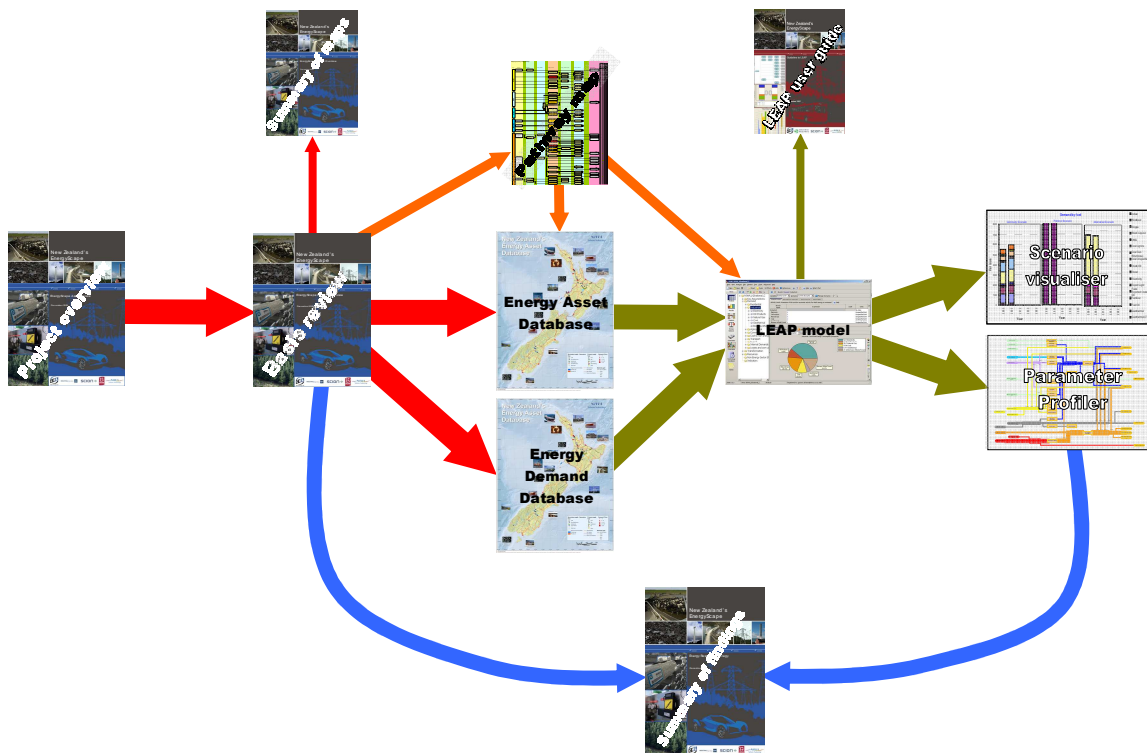
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SUMMARY

The EnergyScape project is a collaborative research initiative that seeks to develop tools that can support energy policy development by considering the impact of integrated solutions for the long-term time horizon, at a regional level on a broad range of social parameters. To achieve this aim, the project has developed a series of linked tools (the EnergyScape framework) which can unify economic data, energy data, system assumptions and facilitate improved understanding of the complexities and dependencies of: resource depletion, energy substitution, transmission costs, conversion efficiencies, locality effects, scale, demand controls, environmental impact (on land, water and the atmosphere) and risk.

The linkages between some of the key deliverables of the project are illustrated below:



The “EnergyScape Project Overview” report provides the foundation for the research effort, by outlining the scope, purpose and methodology that would be utilised by the research project. The “EnergyScape Basis Review” documents the status of energy infrastructure and flows for all energy pathways in New Zealand. Data pertaining to the pathways described in the “Basis Review” were captured in an “Energy Asset Database” and an “Energy Demand Database”. These databases provide input to Long Range Energy Alternatives Planning (LEAP) models and subsequent analysis tools.



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This “EnergyScape Basis Review” is intended to provide a broad introduction¹ to New Zealand’s energy infrastructure. The seven (7) sections of the report cover the full spectrum of the energy system from resources, through generation, distribution, conversion and end-use:

Section 1 – Energy end-use

Section 2 – Renewable resources

Section 3 – Bioenergy resources

Section 4 – Earth resources

Section 5 – Distribution infrastructure

Section 6 – Secondary conversion

Section 7 – Hydrogen options

All energy sectors (e.g. industrial end-use, wind power, coal to liquids) are given separate chapters in the relevant section. Each chapter has been written so that if the reader only has interest for one particular area, an appreciation for how that area contributes to New Zealand’s energy portfolio, now and in future can be gained by reading that section in isolation. In addition to describing the current status of public domain knowledge pertaining to energy resources, each chapter also deals with the efficiencies, risks and research applicable to this energy sector. These chapters provide the philosophy for populating the New Zealand energy asset and end-use databases.

Section 3 summaries the work undertaken by Scion in the “bioenergy options” programme, which is interlinked with EnergyScape. Significant conclusions drawn from this section include:

- If all of the residual biomass presently available could be harnessed, it would only contribute to about 6-7% of New Zealand’s primary energy demand. If biomass is ever to make a more significant contribution, purpose-grown biomass is required.
- Although New Zealand has internationally competitive (and highly efficient) agricultural productivity, conventional bio-fuels are only likely to contribute a relatively minor portion of New Zealand’s future mobility demand, because of limited feedstock capacity.
- The only biomass resources with the potential to compete with synthetic fuels (e.g. derived from gas or coal) are: forest residues from either purpose grown whole forests, or large scale short rotation forests (SRF). Using this biomass to support New Zealand’s transport future would provide a low carbon, moderate (but reasonably certain) cost, and low risk solution.
- Further development of the wood pellet market may provide opportunities both in the domestic heat market and value added export market.
- Anaerobic digestion of farm manures, industrial effluents, municipal solid wastes and sewage sludges to produce biogas is a proven technology with opportunities in niche situations. While the overall contribution of anaerobic digestion to New Zealand’s energy demand will remain relatively small, this technology provides multiple secondary benefits such as mitigation of odour and GHG emissions and options for nutrient recycling / fertilizer displacement.

¹ Capable of being read by the interested public i.e. those with some familiarity with energy system concepts.



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Bioenergy on an industrial scale is an emerging market with considerable technical and economic complexity. A full review of bioenergy resources was undertaken as a separate project by Scion. The review in this document is substantially derived from the report produced under the Scion project: *Bioenergy Options for New Zealand: Situation and Pathways Analysis* (Hall and Gifford, 2008) which is available from the Scion (www.scionresearch.co.nz) and EnergyScape (www.energyscape.co.nz) websites.



Grow

Extract

Transport

Convert

Distribute

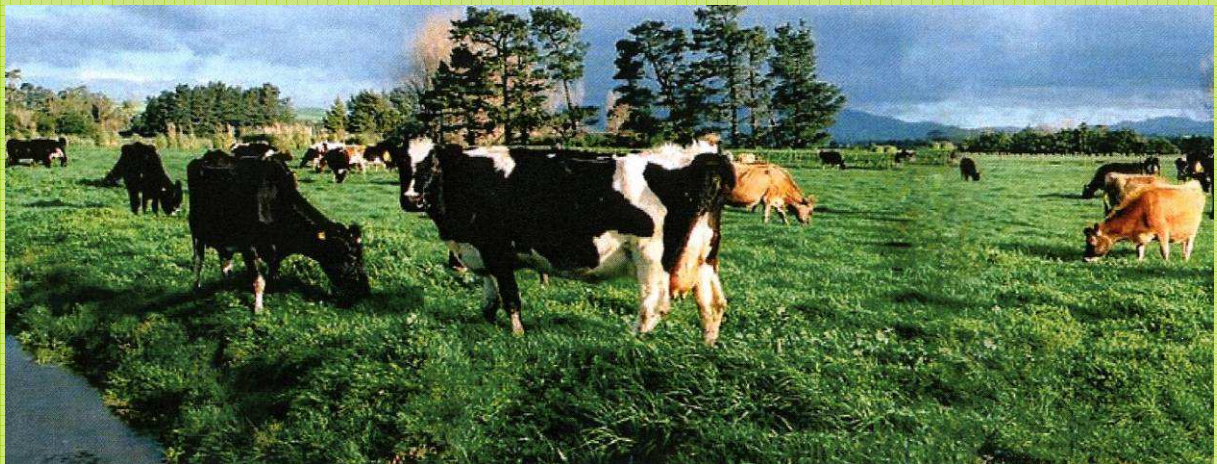
End use

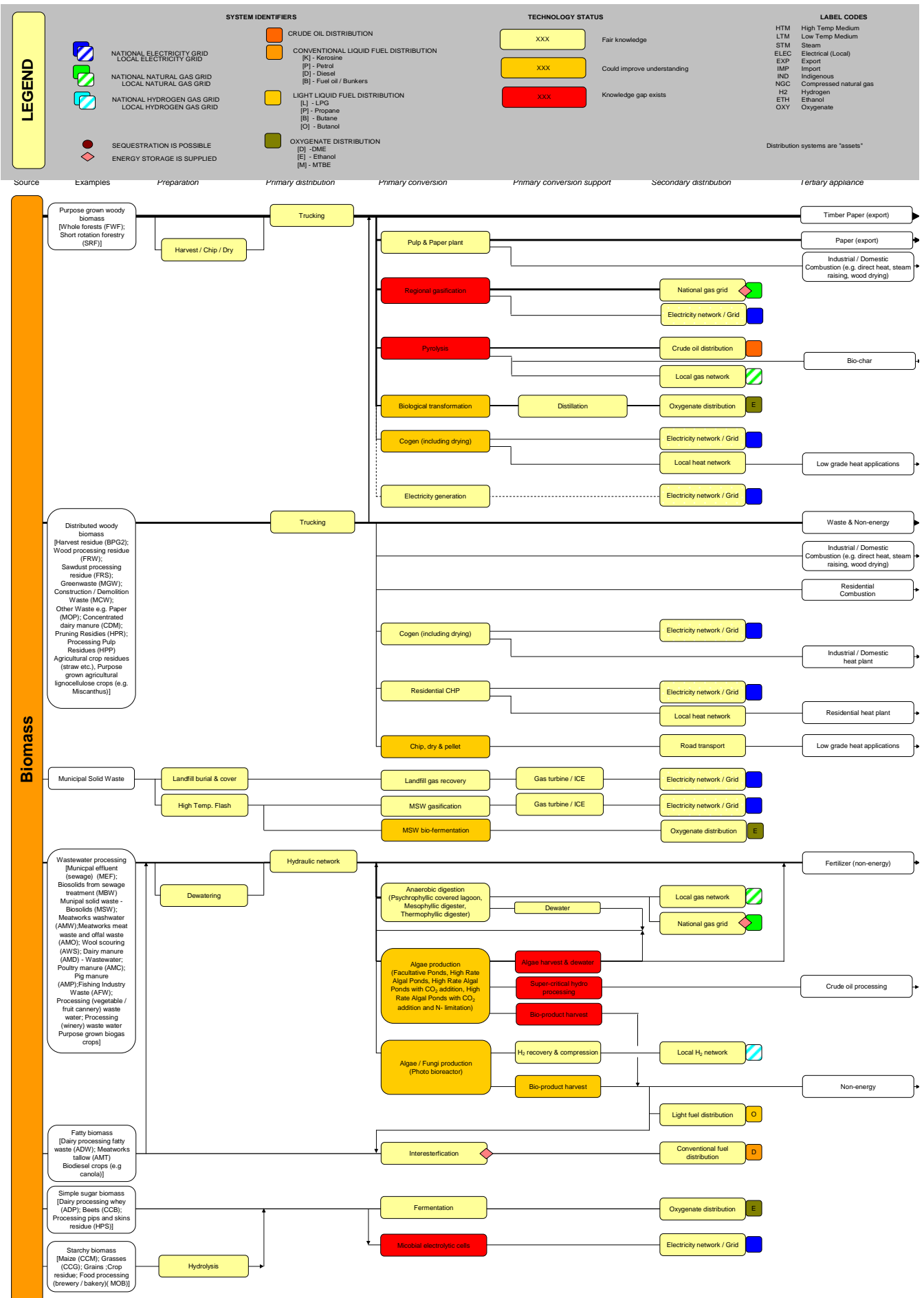


Reuse

Section 3

Bioenergy resources





3. BIOENERGY RESOURCES

3.1 BIOENERGY RESOURCES

3.1.1 General introduction

On a per capita basis, New Zealand is a primary production powerhouse. In addition to being a world leading dairy producer, New Zealand is a major exporter of seed products, forestry products, meat (beef, lamb etc), processed food, fish and aquaculture. This position has grown out of New Zealand's capacity to grow biomass cost-effectively. High biomass productivity can be used to derive export incomes when commodity prices are high, and may supplement domestic energy production when commodity prices are low.

Bioenergy comes from any fuel that is derived from biomass - recently living plants and animals. The words 'recently living' distinguish bioenergy from other energy resources such as natural gas, coal and oil (also termed fossil fuels). Because the carbon in biofuels was recently extracted from the atmosphere by growing plants, the combustion of biofuels does not result in a net increase of carbon dioxide in the Earth's atmosphere. Bioenergy is thus seen as a renewable and GHG neutral energy resource. However, the growth, production and combustion of biomass may require the use of fossil fuels and may generate pollution. Interest in bioenergy and biofuels has increased recently due to their potential to:

- Reduce environmental impacts i.e. air pollution, soil erosion, surface water run-off and GHG emissions²
- Substitute for energy imports i.e. energy security benefits
- Improve New Zealand export balance
- Aid economic development in rural areas

Since current bioenergy resources are often distributed and can be readily combusted for heat in small-scale applications, these technologies dominate the current bioenergy scene. However, when reviewing the potential to generate liquid fuels (biofuels), the scale and distribution of the resources must be commensurate. If resources are too distributed, then high gathering and collection costs can limit commercial viability.

When biomass export prices are low, it can be attractive to convert biomass into biofuels. For instance, the development of ethanol production from sugar cane was motivated by an excess supply of Brazilian sugar cane when world sugar prices were low. Similarly, the use of rapeseed to produce biodiesel in Europe was motivated by excess production when world prices were low.

By far the greatest source of biomass in New Zealand is forestry harvest. In 2005, forest harvest was approximately 19.3 million m³ (~173 PJ). A significant proportion of this is excess to domestic consumption or processing capacity, and it was exported as logs – approximately 5.3 million m³

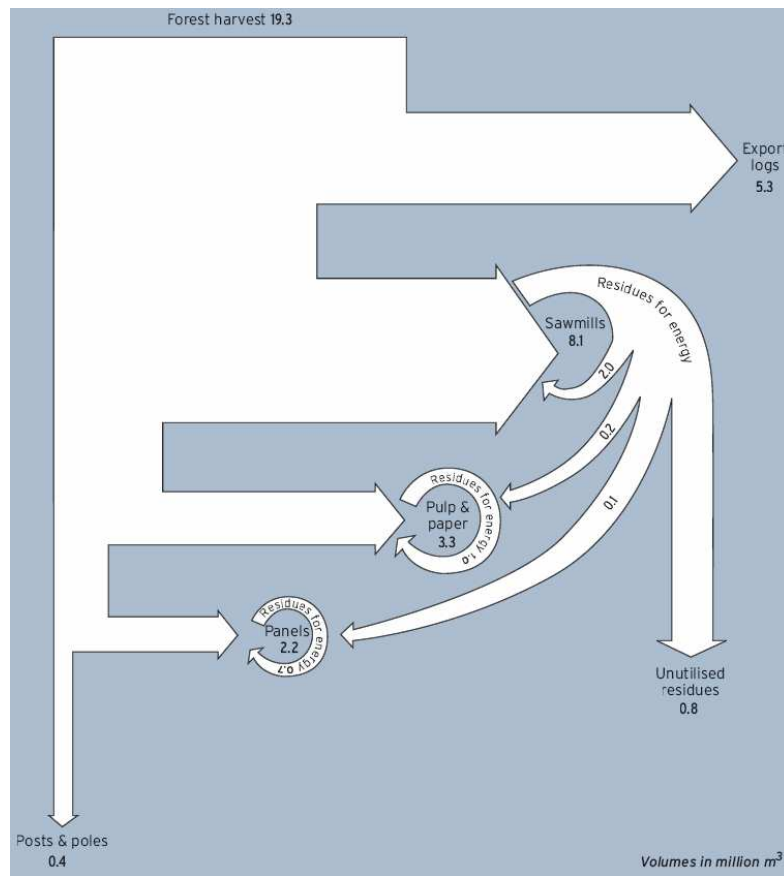
² Refer to discussion in Chapter 2 of "Bioenergy Options for New Zealand – Analysis of large-scale bioenergy from forestry" (Hall and Jack, 2009)

(~48 PJ). If export prices were low or energy equivalent production was cost-effective, then ‘second generation’ technology transportation fuels could utilise this material.

The remaining forestry and associated wood processing residues (~27.1 PJ) provide the largest resource that is currently available for bioenergy generation. This biomass is currently only partially utilised for highly-distributed heat generation. Figure 3.1.1 illustrates the current use of forest harvest for product yield and energy use.

New Zealand also produces various feedstock (e.g. tallow) that can be used in ‘first generation’ technology to produce relatively minor quantities of transport fuels.

Figure 3.1.1 – Current wood processing volumes and residue flows



Source: Hall and Gifford, 2008

3.1.1.1 Pathways

The diversity of bioenergy resources and energy conversion systems is considerably greater than other energy resources considered in this review. Consequently, pathways are developed that are categorised by generic types of conversion processes. A full view of the pathway is presented in the Pathway Overview Map at the start of this document.

Seven basic feedstock categories have been identified on the basis of ease of conversion and scale:

1. Purpose grown woody biomass resources
2. Distributed woody biomass residue resources
3. Municipal solid waste
4. Waste water processing
5. Fatty biomass resources
6. Simple carbohydrates
7. Starchy biomass

There are a number of conversion technologies which produce different forms of usable energy from biomass such as: direct combustion for heat, fermentation for ethanol production, gasification / pyrolysis for the production of liquid or gaseous fuels, and, anaerobic digestion to produce methane (biogas). Not all feedstock will be suited to all conversion systems.

The energy products available from biomass range from industrial heat to liquid biofuels. The main conversion processes considered in this report generate the following energy products:

- Heat via combustion (direct or indirect).
- Combined heat and power – cogeneration of heat and electricity via combustion.
- Gasification
- Synthetic fuels and chemicals from Fischer-Tropsch (or similar) processing
- Bio-crude from pyrolysis.
- Ethanol from the biochemical conversion of sugars, starch, and lignocellulosic compounds.
- Biodiesel from the chemical and mechanical processing of animal and plant fats and oils.
- Biogas from anaerobic digestion.

Combustion is a well-developed technology that is commonly used in New Zealand. Equally, anaerobic digestion is a mature technology with a wide range of biofuel end-use options which have been practiced, globally, for many years, especially in Europe, Asia and the Americas. These technologies provide value not only for generating energy, but also for disposing of waste in environmentally-neutral ways. The value of combustion heat and biogas is largely determined by the type and value of fuels substituted, and is greatly enhanced if natural gas or liquid fossil fuels can be replaced. Combustion heat and biogas are harnessed most effectively when the location and scale of biomass resources matches the local demand.

Gasification and pyrolysis are existing technologies that are not yet fully commercial. These technologies have the potential to yield liquid transportation fuels. Liquid transport fuels are comparatively high-value and have a broad demand base, hence, there is significant interest from capital investors in these technologies.

Chemical / mechanical processing is used in New Zealand to produce biodiesel in relatively small quantities from waste cooking oil. Interest is developing in the use of tallow and growing canola to produce biodiesel at larger scales. Future applications for enzyme technology, gasification and pyrolysis in New Zealand are still being researched.

It is important to recognise that transport biofuel (i.e. transportation energy) technologies are generally considered to fall into either first or second generation categories:

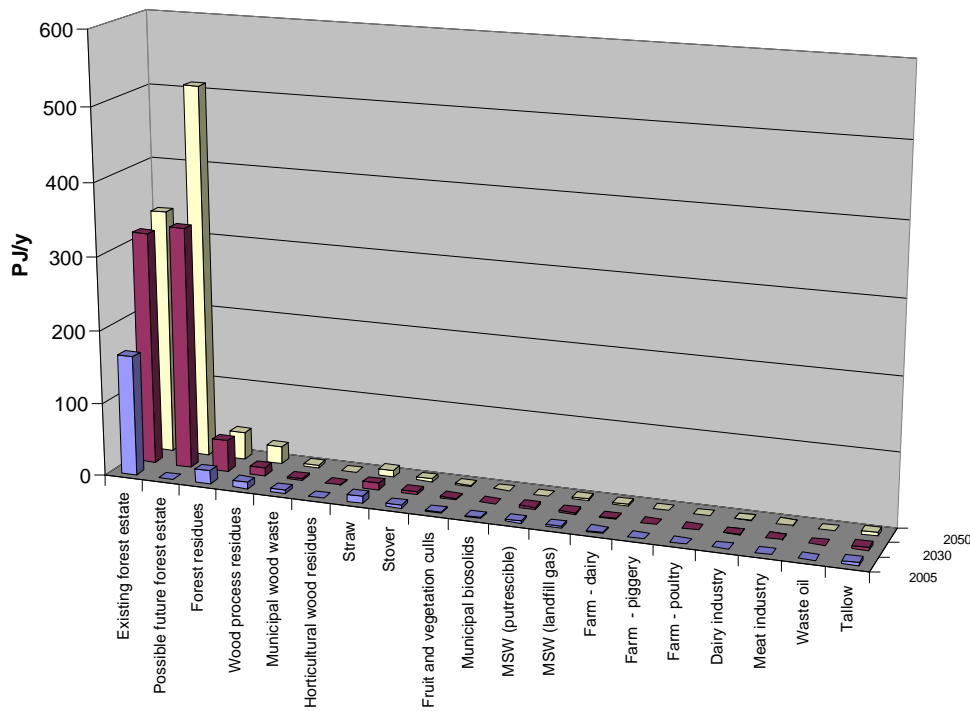
1. First-generation biofuels refer to proven conventional technologies that transform sugar, starch, vegetable oil, or animal fats into biofuel. The basic feedstocks for the production of first generation biofuels are often seeds or grains, such as: wheat, which yields starch that is fermented into bioethanol or pressed to yield vegetable oil that can be processed into biodiesel.
2. Second-generation biofuel technologies use more complex and less well understood biomass conversion technology to transform a variety of wastes and non-food crops, including woody biomass, into biofuel. Some feedstock examples include: stalks of wheat, corn, wood waste and special bioenergy crops (e.g. Miscanthus). Many second-generation biofuels are under development - such as biohydrogen, biomethanol, biodimethylether (DME), biomethane, Fischer-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel.

Bioenergy schemes can be developed at both an industrial scale and a distributed-scale level. The value of distributed-scale (e.g. community and urban scale) bioenergy is often under-estimated. This scale of production matches well with residential heat demand and could well aid to alleviate energy poverty, whilst providing enhanced environmental quality.

3.1.1.2 Scale

The primary sources of biomass in New Zealand derive from forestry, agriculture, processing and municipal sources. Figure 3.1.2 and Table 3.1.3 summarise the potential biomass resources identified in New Zealand:

Figure 3.1.2 – Possible biomass resource for energy production (PJ/year)



Source: Hall and Gifford, 2008

The resource assessment indicates that if all residual biomass could be harnessed, it would only contribute about 6 – 7% to New Zealand’s primary energy demand. If biomass is ever to make a significant contribution, purpose-grown biomass is required.

By far the greatest source of biomass in New Zealand is forestry harvest. New Zealand’s current forest estate produces more than 5.3 million m³/year of logs for export (i.e. in excess to domestic consumption). If export prices were to drop, then domestic consumption as biofuel would be attractive for self-sufficiency and forestry sector viability. This situation is similar to the excess sugar and rapeseed productions that stimulated biofuel production in Brazil and Europe. The difference with the New Zealand situation is that biofuel production based on woody residues is reliant on “second generation” biofuel technologies.

Table 3.1.3 – Possible biomass resource for energy production (PJ/year)

Type / source	2005	2030	2050
Existing forest estate	164	318	335
Possible future forest estate*	0	330	510
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 vegetation culls	1.5	1.5	1.6
Municipal biosolids	0.8	0.9	0.9
Municipal solid waste (putrescible)	2.8	2.9	2.9
Municipal solid waste (landfill gas)	2.4	2.5	2.5
Farm - dairy	1.5	1.5	1.6
Farm - piggery	0.1	0.1	0.1
Farm - poultry	0.04	0.0	0.1
Dairy industry	0.5	0.5	0.6
Meat industry	0.6	0.6	0.7
Waste oil	0.2	0.2	0.2
Tallow	4.5	4.5	4.5

* Based on scenario 2 from Hall and Jack, 2009

Transport fuel production is only likely to be economic at: a decentralised small scale, minimising logistic cost and maximising secondary benefits; or at industrial scale of >10,000 billion-barrels per day (bbl/d) (~18 PJ/year). Therefore, the most likely bioenergy feedstock with sufficient resource for industrial large scale production of transport biofuels would be purpose grown woody biomass.

In 2005, New Zealand's total heat demand was determined to be around 190 PJ/year. As heat demand is often localized, with vast numbers of wood-burner heaters as small as 0.002 MW (~0.00006 PJ) each being commercially viable, there is good opportunity to match demand with various bioenergy resources.

3.1.2 Myth busting

Over the last few years much media attention has been focused on a perceived “food vs. fuel conflict”. This theory is based on the idea that land that is used for the production of biomass for energy production could have alternatively been used for the production of food, notwithstanding production economics, production efficiencies and adverse environmental effects like soil erosion. It is true that to produce large volumes of biofuel, large areas must be devoted to biomass production, but this argument has significant flaws. Competition for arable land is not unique to bioenergy production e.g. dairy production and residential housing use land that could have produced staple foods. Indeed, the inclusion of bioenergy production into an existing farming operation can increase areal food production e.g. Canola production in Canterbury.

Because the production of ethanol from corn in the United States has been widely documented as having a low net energy benefit (i.e. substantial amounts of fossil energy are used to produce corn ethanol), and low GHG emissions savings; it is commonly assumed that all biofuels have low net energy benefit. This is not the case - most biofuels (e.g. tallow biodiesel, bio-methane from manures, canola biodiesel) have been shown to have good net energy benefits (Goodall 2009). However, it is difficult to be generic about the sustainability of biofuel production pathways - each biofuel pathway needs to be considered in its local setting. For example, rapeseed production in Europe often uses excess nitrogen from livestock farming, but if rapeseed was produced in central Canada, then nitrogen fertiliser would be required which heavily diminishes the environmental benefit. Biomass fuels produced in New Zealand have the potential to realise a high net energy benefit and achieve impressive reductions in life cycle GHG emissions.

The potential contribution of bioenergy towards meeting national and international energy demand has been subject to much speculation / propaganda in recent years. Proponents of bioenergy technology often overstate the potential of the sector, whilst protagonists often deliberately underestimate the size and value of the potential bioenergy contribution. Identifying a ‘rational’ position amongst these often controversial claims is complicated by the stark national and regional capacities and influences on biomass production that exist. In general, regions with a high proportion of productive agricultural or forestry land per capita are potentially able to achieve high levels of bioenergy in the energy mix. A prime example for this is Brazil, where a very productive sugar cane industry and a rather moderate population density, have allowed the country to substitute over 40% of the annual petrol consumption with bioethanol (IEA 2006). Other countries with proportionately large potential for bioenergy include the Scandinavian states, east European states, Argentina and New Zealand. New Zealand is blessed with a mild and temperate climate and a high proportion of productive agricultural and forestry land per capita. In combination with a great potential for renewable electricity generation New Zealand has therefore, in theory, the opportunity to derive all its current energy requirements from renewable resources. This option is definitely not available to the world as a whole with current population and consumption levels.

Bioenergy schemes have many favourable features. It is therefore the belief of many economists that the only issue holding back the development of the bioenergy sector is cost competitiveness with conventional fossil fuels; and once the cost of fossil fuels reaches parity with bioenergy alternatives the sector will develop rapidly. This view is however too simplistic. Many benefits

provided by bioenergy schemes are non monetary or indirect, e.g. good environmental performance, national energy security, improved balance of trade etc., and therefore provide no direct incentives for potential bioenergy producers and users to develop the industry. Furthermore many bioenergy systems require comparatively large capital investments and labour inputs, while long term operational costs are generally low. Lack of capital and skilled labour can therefore seriously constrain the development of the sector even if underlying economics are favourable. Further, increases in the cost of fossil fuels are rarely uniform, as the wild swings of the crude oil price during 2008 demonstrate. This makes financing of relatively capital intensive alternative bioenergy schemes difficult and risky. The development of bioenergy resources purely based on market economics will therefore most likely be slow and sketchy. This transition process could be greatly accelerated and broadened if regulatory bodies recognize the many secondary benefits of bioenergy and actively support pilot developments in the bioenergy sector – without consistent support / planning; the development of the bioenergy sector may take decades.



3.1.3 Introduction to resources

In this chapter we review the current and future availability of seven basic feedstock categories. The categories have been defined by the ease of conversion to biofuels and potential scale of the resource. It should be noted that there may be a difference between the total amount of a resource which is potentially available and the proportion that is technically and economically available. This may vary from resource to resource, based on its scale, location and accessibility.

3.1.3.1 Purpose-grown woody biomass resources

New Zealand forests contain a large resource of woody biomass that can potentially be used for energy production. This resource includes:

- Existing forest estate
- Purpose-grown forest estate
- Short rotation forest (SRF)

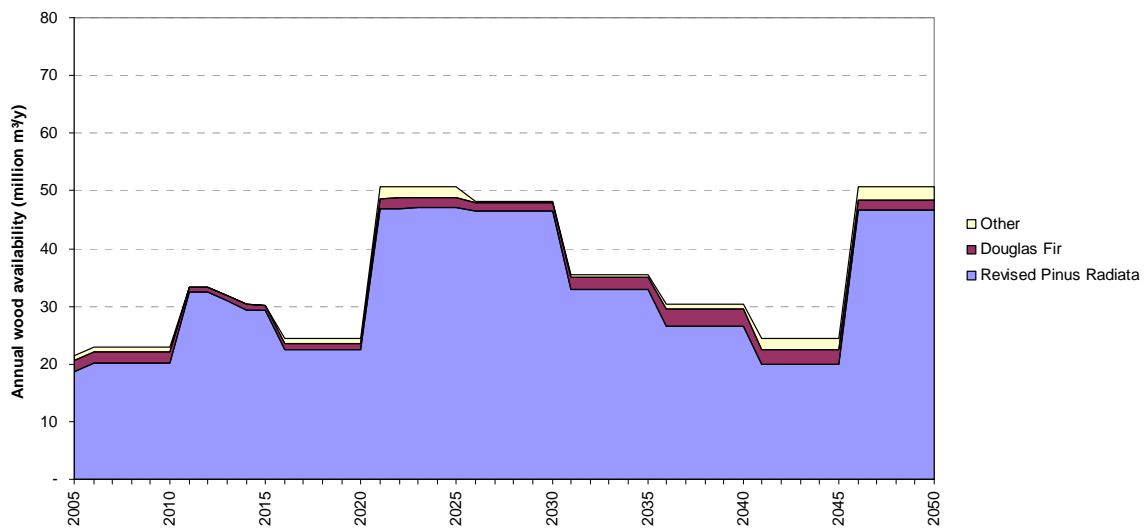
3.1.3.2 Existing forest estate

The current forest estate includes ~1.7 million hectares of pine plantation forests, with 0.112 million hectares of Douglas Fir and 35,000 hectares of other softwoods and ~50,000 hectares of Eucalyptus species and other hardwoods. At the aggregated national level, the dominance of Radiata Pine is evident. Harvesting increases to a peak as stands, which were established in the mid-1990s planting boom, mature around 2025 and beyond.

The annual wood supply was determined from the MAF National Exotic Forest Description (2006) (see Figure 3.1.4). The areas used were averages over five-year age classes within Territorial Authority boundaries. Harvesting was assumed to take place at age: 30 years for Radiata Pine; 40 for Douglas Fir, Cypress and other softwoods and; 25 for all hardwood species. All areas were assumed to be replanted back to the same species after harvesting, with no net deforestation or afforestation.

Land-use changes and afforestation will strongly affect future forest harvest. Forecasts beyond 2036 are influenced by restocking and afforestation decisions. Sufficient land (at least 0.8 million ha in low-intensity use, and as much as 4.9 million ha) is potentially available to support a significant planting programme, which would result in higher rates of harvesting than used for the above volume assessments. The deforestation of mixed-age-class associated with dairy farm conversions that is currently occurring will not be reflected in current harvest projections. Actual forest areas that will be lost are hard to predict precisely, but as much as 50,000 ha could be cleared during the period 2005 to 2010.

Figure 3.1.4 – Forecast annual wood supply from current forest estate



Source: Modified from Hall and Gifford, 2008

The Central North Island region dominates current and future wood supply. At present, it provides over 30% of the national cut and this dominance will continue, peaking in 2026 to 2030, when it is possible that in excess of 70% of the national cut will be from this region alone. In the next 5-10 years, Northland will see a significant rise in harvest, and, in the next 10 to 15 years, East Coast will have a major increase in cut.

3.1.3.3 Purpose-grown forest estate

New Zealand has a significant area (~9.2 million ha) of marginal land or low-to-moderate-productivity hill country grazing (Hall and Jack, 2009). This land has potential for future afforestation, to store carbon and provide biomass which can be substituted for fossil fuels, since low-productivity grazing land on rolling to steep terrain has minimal competition regards food production and cropping, and the environmental benefits of afforestation are high.

Four afforestation scenarios are considered in Hall and Jack, 2009 (for full details, see Chapter 1). These are for 0.8, 1.8, 3.3 and 4.9 million ha of purpose-grown forest for bioenergy purposes, respectively. The scale of the energy provision associated with each scenario can be compared to the current national energy demand - 740 PJ of primary energy, 560 PJ of consumer energy and 245 PJ of transport energy.

How much consumer energy is derived from each scenario is dependent upon how much of the forest harvest is sold as logs – up to 56%, and what the woody material is converted into:

- Heat with 85% conversion efficiency
- Liquid fuels with 35% conversion efficiency
- Electricity with 30% conversion efficiency

Table 3.1.5 illustrates the amount of primary bioenergy and liquid fuels that could be obtained from both full utilisation of forest for bioenergy; and multiple use of forest, under the four afforestation scenarios.

Table 3.1.5 – Stored primary energy by afforestation scenario

Scenario (million ha)	Harvest post 2035 (million tonnes/yr)	Full harvest to bioenergy		Multiple product forest	
		Primary energy in harvest (PJ/yr)	Bioenergy as liquid fuels** (PJ/y)	Primary bioenergy* harvest (PJ/yr)	Bioenergy as liquid fuels** (PJ/y)
0.8	19,588	144	50.4	63	22
1.8	69,030	510	179	224	78
3.3	125,983	932	326	410	143
4.9	178,950	1,324	463	582	204

* 44% of harvest to energy, 56% exported as sawlogs.

** 35% conversion efficiency.

Source: Based on Tables 4 & 6 of Hall and Jack, 2009.

Assuming New Zealand’s gross energy demand grows at only low to moderate rates, then our total heat and transport fuels demand could be met by sourcing biomass from around 3.3 million hectares of production forests, using hauler extraction methods and full harvest to bioenergy. A forest resource capable of supplying New Zealand’s energy demands would take around 25 years to establish. This can be achieved by planting forests of various species at a planting rate of around 100,000 ha / year.

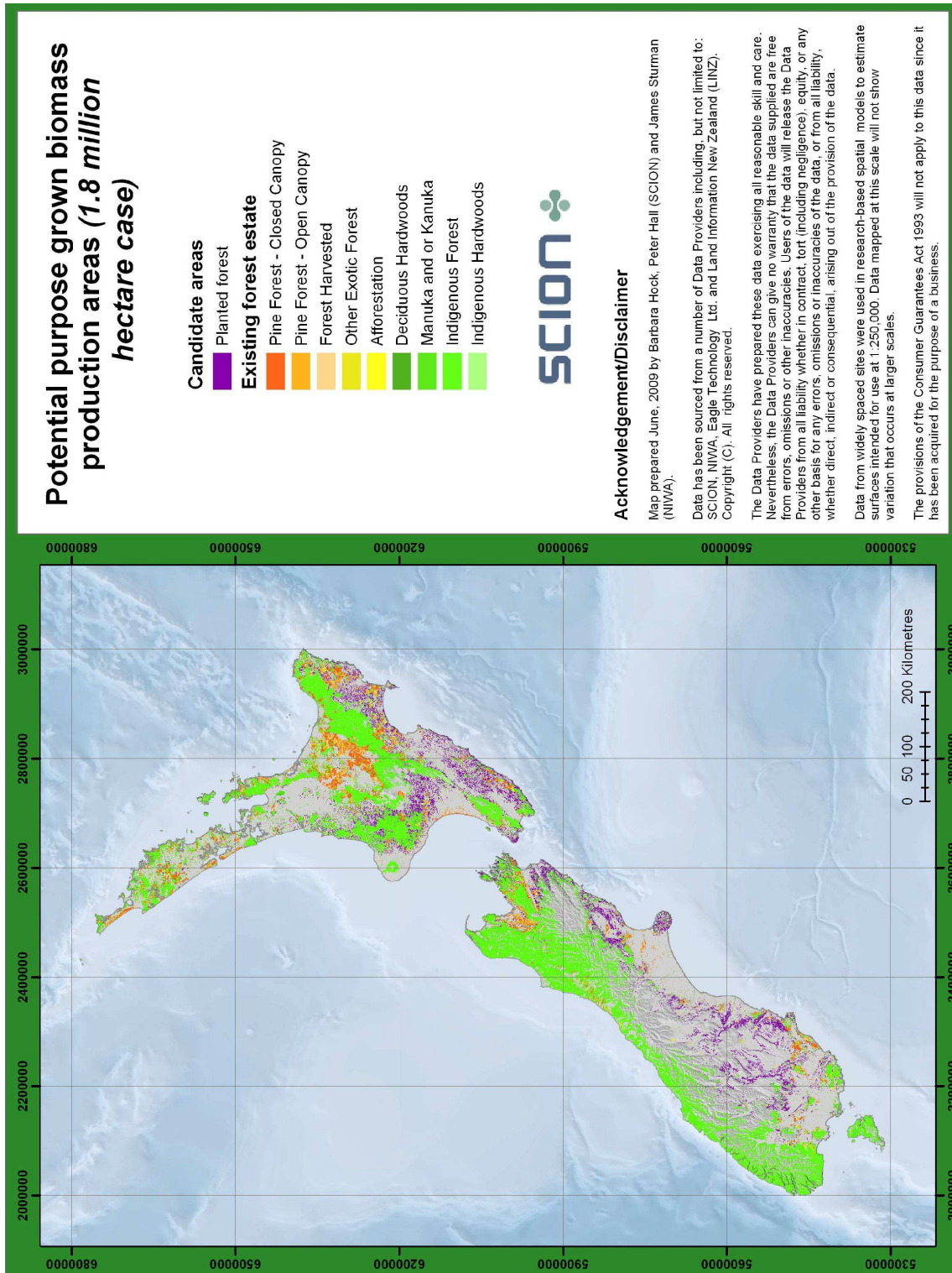
An energy forest estate of approximately 3.3 million ha could provide most of New Zealand’s heat and liquid fuel demand.

A possible initial regime could be: 30,000 hectares of short rotation coppice on the ‘low-slope’ land, 20,000 hectares of medium rotation crop on steeper land and 70,000 hectares of Radiata on the steep hill country land. It would be possible to phase planting to give a balance of short-term crops for energy production, but with a longer-term transition to longer-rotation forests on the steep marginal land.

Other wood resources (utilisation of residues) would be maximised over the initial 10 years. The use of the biomass would be directed to heat applications in the short-term, and more material would be diverted to transport biofuels as second-generation biofuel technologies mature. The biomass resource would predominantly be used for heat and liquid fuels – though, increasingly, material would be used for combined heat and power (CHP). For CHP to be viable, a local heat demand is necessary, whereas, the electricity generated can be transmitted via the national grid to non-local end-users.

The scope of 1.8 million hectare afforestation scenario (scenario 2) is compared to the existing forest estate in Figure 3.1.6 overleaf.

Figure 3.1.6 – Potential purpose grown biomass production



3.1.3.4 Short rotation forestry

Fast growing tree species, such as eucalypts, acacia and willow, have potential as purpose-grown bioenergy crops for New Zealand. These short rotation forestry (SRF) crops can offer more favourable energy balance than agricultural crops, and may provide other high-value by-products. Some can be converted into transport fuels, such as ethanol or biodiesel. Short rotation forestry crops could also provide a means of supplementing the wood residue resource available from forests.

Eucalyptus Nitens is considered the main species suitable for short-fibre pulp production and bioenergy in New Zealand. However, its growth is limited to colder sites (Southland), as, in warmer climates (Central North Island), it is susceptible to insect and fungal attack which cause unacceptable growth losses. Acceptable biomass values have been generated with *Acacia species* by using very high initial stockings. The Acacia resource was established to provide logs for chip exports. A New Zealand willow project is currently under way to assess the bioenergy potential of this crop using agricultural equipment for harvesting.

The use of co-products is required to make SRF competitive as a land use. Co-products having direct financial benefit include: charcoal, pharmaceutical products, salinity mitigation, sawn timber, waste application, carbon credits, animal fodder, wood by-products (e.g. xylose). Other benefits of SRF include: increased biodiversity; nutrient and sediment capture from agricultural crops; creation of landscape diversity; waste-water refining; phyto-remediation, riparian strips; snow fences; erosion control; and social / community benefits.

Currently, there is no SRF resource in New Zealand being commercially used for bioenergy production, with a small area (<20 ha) established as trials. Some expansion of the willow SRF resource is planned for the Lake Taupo area, with the development of a 20 ha nursery to provide planting stock for a planned 1,200 - 1,500 ha planting programme in 2009. It is unlikely that there will be any commercial SRF harvesting operations in New Zealand in the next 3 - 5 years, as there is currently no resource to harvest.

It is estimated that 2.6 million hectares of SRF would be needed to meet New Zealand's current demand for liquid fuels (petrol and diesel). Estimates of lignocellulosic productivity per hectare, and potential for conversion to ethanol (assuming 300 litres per dry tonne), suggest that around 70,000 ha of plantation land would have been required to provide biomass and generate sufficient ethanol for the now repealed biofuels obligation target³ of 3.4 % via a petrol-ethanol blend.

The major constraints to SRF are land use competition (slope must be <15° to enable mechanised harvesting) and the costs of growing and harvesting. The issue of tree health must also be carefully managed to avoid resource collapse if the genetic base is not kept robust. Plantings of mixed clones are required to avoid total crop failure from a new insect or disease outbreak. Water demand from SRF is only akin to forest plantation water use - there would be no irrigation systems unless the SRF was used for wastewater disposal / treatment.

³ <http://www.beehive.govt.nz/release/biofuel+law+change>

3.1.3.5 Distributed woody biomass resources

Distributed woody biomass sources considered for bioenergy production in New Zealand include:

- Forest residues
- Wood processing residues
- Municipal wood waste
- Horticultural wood residues
- Agricultural crop residues

3.1.3.5.1. Forest residues

Residues from routine harvesting operations offer a significant resource that is already available, with no need to plant new areas or use any additional land. The use of these harvesting residues potentially creates a new value stream for forest growers. Residual materials result from logging at two locations in the field:

1. In the forest (cutover) large trees frequently break when they hit the ground, typically at around two-thirds to three-quarters of the tree height. Often, these broken sections and branches are small and of low-value, so they are not extracted to the landings, but left on the cutover to rot away.
2. On central landings (skid sites) tree-length material is cut into logs. Off-cuts from the base, tip and midsections of trees become waste material that averages 4 – 6 % of the extracted volume. Because these landings are centralised processing sites, they make it relatively easy to recover significant volumes of wood residues.

Systems to harvest logging residues currently yield about 250,000 tonnes of residue per annum, which is largely used as fuel in heat plants servicing wood processing facilities. This is approximately 27 % of the landing residue resource, or 7 % of the total forest residue resource. The bulk of this material is being used at large wood processing sites in the Central North Island and some in Nelson and Hawke’s Bay. The economics are driven by the fact that these sites have wood-burning heat and power plants on-site to utilise processing residues and have a demand for additional fuel.

Table 3.1.7 - Logging residues (m³) at landings

	2005 - 2010	2016 - 2020	2026 - 2030	2036 - 2040	2046 - 2050
COR* hauler ¹	1,449,000	1,656,000	3,380,000	2,142,000	1,637,000
COR ground based ²	1,226,000	1,429,000	2,648,000	1,802,141	2,204,000
Landing residues	924,000	1,224,000	2,410,000	1,519,131	2,540,000
Total	3,599,000	4,309,000	8,438,000	5,463,454	6,381,000
Landing + COR ground based	2,150,000	2,653,000	5,058,000	3,321,000	4,744,000

* COR = Cutover residues

1 = Hauler = steep terrain logged by cable hauler systems

2 = Ground based = flat to rolling terrain logged by wheeled or tracked machines

Volumes of residues potentially available from forest harvesting are significant, and will increase over time to 2030 (see Table 3.1.7), with the maximum quantity of residues expected to be over 5 million tonnes in 2026 - 2030. Five million tonnes equates to 200,000 truck loads, or sufficient feedstock for two large pulp mills.

The availability of forest residues over the next 30 years will be largely determined by the current extent and age of plantations together with the rotation length. The volume of biomass available for energy uses can be estimated by calculating residues as a proportion of total recoverable volume from the forests.

3.1.3.5.2. Wood process residues

By far the biggest wood residue category is wood chips arising from sawmills where 26 % of the log input volume ends up as chip. These wood chips are a high-value, raw material for the pulp and paper industry and reconstituted wood panel industries. These chip supplies are currently not available for energy production, although this would change if timber or panel or pulp production were reduced for any reason.

The wood processing industry is also one of the largest users of bioenergy (46 PJ per year) in New Zealand. The high use of bioenergy within the industry is driven by the fact that manufacturers have a large demand for heat and, if the residues produced on site are not used, this material would have to be disposed of, incurring a cost. There are alternative uses for these residues:

- Sawdust can be used as a raw material for medium density fibreboard (MDF), particle board or wood pellets. The value of sawdust is increasing as more uses for this material are identified.
- Bark is used extensively for landscaping and as a solid fuel for boilers. Shavings can be used as a raw material for wood pellets, animal bedding or as boiler fuel.

New Zealand sawmills produce 3.5 million tonnes of wood residue arising from debarking and primary breakdown operations, with an additional 0.6 million tonnes coming from other wood processing sectors. Over 3 million tonnes of this is used in other wood processing operations or for bioenergy, leaving an estimate of approximately 1 million tonnes of residues available for expanding current uses or developing new opportunities.

Of this 1 million tonnes it is estimated that the wood pellet market uses 0.2 million tonnes and landscaping and other users use 0.1 million tonnes. Based on these assumptions it has been calculated that less than 0.8 million tonnes of mixed residues are available at a national level. This material is believed to be mostly from smaller sawmills, particularly in the Southern North Island (scattered and sometimes remote processing) and Central North Island (large volumes of processing, where supply of residues exceeds demand). An overview of these quantities is shown in Figure 3.1.1.

3.1.3.5.3. Municipal wood waste

Over 500,000 tonnes of wood-waste are land-filled each year in New Zealand. These woody residues are generally classified as green waste from gardens and timber waste arising from construction and demolition activities. Municipal wood waste represents a potential resource for bioenergy options as incentives are put in place to reduce volumes being land-filled.

Both green and timber waste availability is greatest around large population centres, particularly the Auckland Region. The main current users of biomass fuel (i.e. the forest industry) are located some distance from these centres. Most green wastes arise from domestic properties, while the

timber fraction of construction and demolition waste comes from commercial activities. Actual volumes are difficult to determine due to a general lack of information about the size and nature of New Zealand waste streams. An estimate of municipal wood waste quantities is given in Table 3.1.8.

The use of municipal wood waste resources may be compromised or greatly complicated due to contaminants such as other household rubbish, and in particular timber treatment agents in demolition waste. Some of the contaminants can produce toxic emissions and ash residues when combusted. Alternative uses for green waste include commercial compost, mulch or various bioenergy options. Alternative uses for timber waste include recycling and reusing, particleboard manufacturing, fuel for combustion, or production of other bioenergy-related fuels.

Table 3.1.8 - All wood waste to landfill, based on the effects of the NZ waste strategy (2002) (tonnes/year)⁴

	2005	2010	2015	2020	2025	2030
Northland	16,700	7,000	46,00	81,00	8,700	9,300
Auckland	165,400	74,500	84,300	95,500	108,100	122,500
Waikato	40,600	17,400	18,800	20,200	21,900	23,600
Bay of Plenty	23,900	11,100	12,000	12,900	14,000	15,100
Gisborne	5,600	2,500	2,800	3,000	3,400	3,700
Hawke's Bay	17,800	7,400	7,600	7,900	8,300	8,600
Taranaki	9,800	3,900	4,000	4,100	4,200	4,300
Manawatu	26,500	10,700	10,900	11,000	11,200	11,400
Wellington	85,100	36,200	38,700	41,400	44,300	47,400
Tasman	6,200	7,000	2,800	3,100	3,300	3,600
Nelson	5,800	2,400	2,500	2,600	2,700	2,900
Marlborough	5,900	2,500	2,800	3,000	3,300	3,600
West Coast	4,100	1,700	1,700	1,800	1,900	2,000
Canterbury	58,900	25,700	28,200	31,000	34,000	37,300
Otago	27,700	11,900	12,900	13,900	15,100	16,300
Southland	17,600	7,000	7,100	7,200	7,200	7,300
New Zealand	520,000	229,000	245,00	267,00	292,000	319,000

3.1.3.5.4. Horticultural wood residues

The horticultural sector produces woody residues through the removal of over-mature trees and orchard prunings. Wood is removed at pruning time, either in winter or summer. The resource is currently of limited scale - 46,000 tonnes per year, with 48% from Hawke's Bay, 18% from Tasman, 14% from Otago and the remaining 20% is shared between Northland, Bay of Plenty and Gisborne. The future of this bioenergy supply is highly dependent on the developments in this sector which include: conversion of land use, mulching of prunings into soil, dwarfing of trees.

⁴ Evanson, T. and P. Hall, 2007: "Resource Assessment of Municipal Wood Waste - green waste and untreated wood waste". Report prepared for the Bioenergy Options Programme, 2007.

3.1.3.5.5. Agricultural crop residues

Many agricultural crops produce stalks (straws) that are currently cultivated into the ground at the end of cropping. Not all crop residues are available for use as bioenergy feedstock. The available fraction should be decided on the basis of what is surplus to the needs of sustainable soil management. Typically, it can be assumed that 50% of the crop residues are available for use as bioenergy feedstock. Many crop residues (straw) can be used as boiler fuel for stationary heat or CHP, as widely practiced in Denmark, or in future be used for transport biofuel manufacture as second generation technologies mature.

The two regions that currently grow sufficient volumes to support large-scale production of crop residue based biofuels are Canterbury and the Waikato. AgriEnergy (based in Temuka, South Canterbury) advocate small-scale plants located close to crop growers. Residues are produced as a by-product of other farming activity, therefore only the additional handling costs are assigned to the residues, as the growing costs have already been paid. This handling is well mechanised. The straw costs are estimates based on past production of baling and handling straw. An overview of sources and cost is shown in Table 3.1.9.

Table 3.1.9 – Summary of residue production⁵

	Wheat	Barley	Maize	Field/seed peas	Herbage seeds
Grain yield (t/ha/y)	8.5	7.5	12.5	3.0	
Grain DW yield (t/ha/y)*	7.4	6.5	10.8	2.4	
Crop production	277,483	263,071	221,085	23,254	
Harvest index**	0.5	0.5	0.5	0.3	
Residue DW production (t/y)	277,483	263,071	221,085	54,260	200,000
Surplus DW residue (t/y)	138,742	131,536	110,542	27,130	100,000
Surplus residues (PJ)***	2.2	2.1	1.8	0.4	1.6
Straw handling costs (\$/tonne)	22	22	20	25	

* Dry weights are based on moisture content in wheat and barley = 13 %; maize = 14 %; field peas = 20 %

** 50 % of straw for typical scenario, but varies with soil and crop regime.

*** Assumes 16.5 GJ/tonne dry weight

To supplement agricultural crop residues and to balance the seasonality of production it is possible to cultivate grasses and special crops (e.g. Miscanthus) for second generation transport fuel processes and boiler fuel. Research into cropped non-woody biomass for use in stationary heat and second generation transport biofuels is still immature. Large financial investments are currently being made in North America and Europe, with encouraging early indications of net energy yields, economics and environmental impact.

⁵ For details see Hall and Gifford, 2008: “Bioenergy Options for New Zealand: Situation analysis: Biomass Resources and Conversion Technologies”. Rotorua: SCION.

3.1.3.6 Municipal solid waste (MSW)

A large quantity of putrescible or digestible material is contained in domestic household refuse that goes to landfill. These solids can be used for anaerobic (biogas) digestion, and recent studies in the United States suggest that gasification of municipal solid waste and enzymatic processing of autoclave treated waste could contribute significantly to national ethanol production. Equivalent studies have not been undertaken in New Zealand.

Much of the putrescible waste that currently goes into landfill is subject to anaerobic digestion under rather uncontrolled conditions within the landfill producing landfill gas. Landfill gas often creates odour problems, safety hazards and contributes to GHG emissions due to its high methane content. Waste management systems are now designed to capture this powerful greenhouse gas. Many landfills increasingly capture landfill gas and flare it. Only a few use the captured gas as an energy source. Technology for utilising landfill gas for heat and power generation as well as transport fuel is mature and readily available. Currently, the landfill gas resource is approximately 3 PJ/year, and this is expected to increase considerably as more landfill operations deploy landfill gas collection systems and the population increases.

The quantities of this material that are potentially available for biogas production are presented in Table 3.1.10.

Table 3.1.10 - Quantities of municipal solid waste (putrescibles) and indicative energy content

	Digestible MSW dumped (tonnes/year)	Residual landfill dumped (tonnes/year)	Digestible MSW gas potential (PJ/year)	Residual landfill gas potential (PJ/year)
	2005	2005	2005	2005
Northland	13,000	91,000	0.09	0.08
Auckland	132,000	914,000	0.92	0.79
Central North Island	52,000	364,000	0.36	0.31
Gisborne	4,100	29,000	0.03	0.02
Hawke's Bay	14,000	97,000	0.10	0.08
Southern North Island	95,000	661,000	0.66	0.58
Nelson / Marlborough	14,000	99,000	0.10	0.09
West Coast	3,000	23,000	0.02	0.02
Canterbury	46,000	322,000	0.32	0.28
Otago / Southland	35,000	246,000	0.25	0.21
Total New Zealand	408,000	2,846,000	2.85	2.46

3.1.3.7 Wastewater processing

Potential bioenergy feedstocks in the form of manure are produced by farm animals throughout New Zealand. Urban centres generate similar waste that is processed at sewage treatment plants. Significant volumes of processing wastes also arise from dairy factories and meat works. Collectively, these urban and municipal waste streams represent a large, under-utilised bioenergy resource.

Anaerobic digestion harnessing biogas is the dominant treatment process for these materials. This process generates a nutrient rich digestate (spent liquor) by-product that in many cases can be used as an agricultural fertilizer or as a medium to grow algae biomass, in particular in the case of municipal waste waters.

This section includes the following sources:

- Municipal biosolids
- Industrial effluents
- Farm manures
- Algal biomass

3.1.3.7.1. Municipal biosolids

Many reticulated sewage treatment plants in New Zealand produce sewage biosolids (60 % primary sludge, 40 % secondary sludge) that can be used to produce biogas at various scales of operation. Sewage biosolids digestion is an industry standard in Europe and many other parts of the world, but has not yet been widely deployed in New Zealand. New Zealand cities like Manukau, Christchurch and Hamilton have sewage biosolids digesters with biogas conversion to electricity. The main purpose of anaerobic digestion of sewage sludge is to save on sludge disposal costs and improve sludge dewatering. The biogas energy can be used for electricity generation and typically contributes significant cost-savings to the treatment plant operation. The volume of available municipal biosolids is directly proportional to the size of urban population centres, with the largest concentrations, therefore, being available from the Auckland, Wellington and Christchurch metropolitan areas.

Excellent examples of using municipal wastes as a bioenergy resource are available in North America, throughout Europe (particularly Sweden) and in parts of Asia. The city of Christchurch uses municipal effluent to produce biogas for electricity generation, as do other urban centres. Estimates of the quantities of materials and indicative energy availability are summarised in Table 3.1.11.

Table 3.1.11 - Quantities of municipal biosolids available for energy production

	Dry mass (t/year)	Dry mass (t/year)	Gas (PJ/year)	Gas (PJ/year)
	2005	2020	2005	2020
Northland	1,095	1,204	0.014	0.02
Auckland	29,565	40,150	0.364	0.51
CNI	9,125	5,402	0.11	0.07
Gisborne	730	730	0.009	0.01
Hawke's Bay	2,920	2,774	0.034	0.04
SNI	14,235	15,074	0.176	0.19
Nelson / Marlborough	2,190	2,445	0.025	0.03
West Coast	365	182	0.002	0.00
Canterbury	9,490	10,730	0.118	0.14
Otago / Southland	3,650	3,758	0.046	0.05
Total New Zealand	73,000	82,000	0.90	1.08

The total potential energy contribution is in the order of 1 PJ/year of gas. Although some expansion of this resource is expected out to 2020, the overall increase in potential energy is small.

3.1.3.7.2. Industrial effluents

Dairy factories, meat and other processing industries in New Zealand generate vast volumes of effluent. These effluents are currently treated in a number of ways, but mechanical aeration and land irrigation are dominant treatment and disposal methods. Alternatively a proportion of these industrial effluents could be utilised energetically via anaerobic digestion. A prime example for such technology is the anaerobic wastewater treatment system at Fonterra Tirau, which has reliably provided a substantial proportion of the dairy factory energy demand as biogas for over 2 decades.

The seasonality of the biogas from primary production wastes, fits well with the seasonality of rural power demand (dairy farm irrigation) and is best utilised in the sector. The quantities of dairy processing waste follow those of dairying activities, with significant potential in the Central North Island, Taranaki, and the South of the South Island. Meat processing potential follows a similar pattern.

The quantities of industrial effluents available for energy production are summarised in Table 3.1.12. Around 1.2 PJ of energy could potentially be extracted from these wastes as biogas (methane).

Table 3.1.12 - Quantities of wastes and estimates of energy from industrial effluents

	Dairy processing methane (t/year)	Meat processing methane (t/year)	Dairy processing gas (PJ/year)	Meat processing gas (PJ/year)
	2005	2005	2005	2005
Northland	818	896	0.04	0.044
Auckland	-	503	0	0.022
Central North Island	4,939	3980	0.25	0.201
Gisborne	11	165	0	0.01
Hawke's Bay	-	1339	0	0.063
Southern North Island	2,334	4330	0.12	0.023
Nelson / Marlborough	185	387	0.01	0.021
West Coast	322	248	0.02	0.011
Canterbury	1,363	2585	0.07	0.126
Otago / Southland	1,184	2890	0.06	0.145
Total New Zealand	11,150	17,320	0.57	0.67

Wool processing wastes are insignificant in comparison to the other processing industries (less than 0.5 % of total industrial processing waste resource). Any solid waste, from tanneries and wool scouring operations, is currently deposited to landfill.

3.1.3.7.3. Farm manures

New Zealand agriculture produces a large amount of manure. Most of this is produced by grazing animals and is not collected. However, most pig and poultry production is based on housed systems where all manure is collected. In addition, dairy cattle spend a significant amount of time in milking sheds and the effluent collected from milking sheds is a significant potential resource. Some New Zealand dairy farmers are moving cows into stand-off pads or herd-homes during the winter months for soil management reasons. Cows could spend up to 20 hours a day over three months in these systems, resulting in a greater amount of manure being collected, which may increase the bioenergy potential of this resource substantially.

Wet wastes of this kind are suitable for anaerobic digestion. Utilising these agricultural manures for energy production via anaerobic digestion avoids further negative environmental effects such as odour and fugitive GHG emissions, as long as the process is designed and operated appropriately.

New Zealand livestock produce over 15 million tonnes of faecal dry matter / year, which is mostly deposited onto grazed pastures and cannot be easily collected. Most poultry and pig manure is collected in manure management systems. This represents a total resource of about 85,000 tonnes of dry matter / year.

In addition, a small fraction of dilute dairy effluent (44 million m³) is collected in effluent ponds on farms. Using these wastes energetically via anaerobic digestion improves the usefulness of these wastes for irrigation and improves the fertilizer value which has been estimated to be worth about \$21 million annually.

The distribution of farm manure that is potentially available for energy is summarised in Table 3.1.13. The total energy contribution from digestion of farm manures is estimated to be in the order of 1.5 PJ.

Table 3.1.13 - Distribution of farm manures by region

	Dairy dry mass (000t/year)	Piggery dry mass (000t/year)	Poultry dry mass (000t/year)	Dairy gas (PJ/year)	Piggery gas (PJ/year)	Poultry gas (PJ/year)
	2005	2005	2005	2005	2005	2005
Northland	270	1	1.0	0.08	-	0.006
Auckland	96	-	18.8	0.02	0.01	0.1128
Central North Island	1,608	5	15.0	0.54	0.03	0.09
Gisborne	-	-	0.2	0	-	0.0012
Hawke's Bay	65	1	0.7	0.03	-	0.0042
Southern North Island	885	4	16.5	0.27	0.03	0.099
Nelson / Marlborough	78	-	0	0.03	-	0
West Coast	112	-	0	0.04	-	0
Canterbury	477	19	1.4	0.27	0.05	0.0084
Otago / Southland	400	2	2.0	0.24	0.000	0.012
Total New Zealand	3,990	30	55	1.52	0.1	0.04

Many manure digestion systems can be supplemented with purpose grown crops such as grasses, grains and legumes to improve biogas productivity and provide economies of scale for individual digestion systems. Bioenergy cropping for anaerobic digestion feedstock is a well established practice in Europe, particularly Germany. The advantage of a biogas cropping system is the ability to grow a larger variety of species and cultivars, ideally suited to local climatic conditions, with high areal net energy yields, which can be up to 5 times higher than for grain based bioethanol production on a given plot of land.



3.1.3.7.4. Algal biomass

At present there is no commercial production of algal biomass in New Zealand. However, existing waste streams that offer potential are shown in Table 3.1.14.

There are several constraints to algae biomass resource production from wastewater ponds that will limit the realisation of the potential of this resource. These include: suitability and availability of low-cost land, suitable climate for algae growth, harvest costs and harvesting efficiency.

Harvesting of microalgal biomass is regarded as the single most limiting factor in expanding application of microalgae for production of feedstocks. Options for harvesting algae from pond effluent include filtration and micro-straining, centrifugation, settling, (augmented by bioflocculation or chemical flocculation) and flotation.

Microalgal biomass must be dried before conversion into liquid products such as biodiesel or bio-oil, but this is energy intensive. The total energy requirement may be several times that of the biofuel produced from the algae, unless waste heat or energy efficient drying methods (e.g. solar drying) are used.

Table 3.1.14 - Algal biomass resource potential

Municipal wastewater:	The potential daily algal biomass yield from each existing Waste Stabilisation Pond (WSP) in New Zealand was calculated from wastewater flow data to give a total of 41 tonnes per day (dry weight). By converting all existing WSP in New Zealand to High-Rate Algal Pond (HRAP), the potential daily algal biomass yield could increase to 164 tonnes dry weight/day. If all municipal wastewater was treated in HRAP with CO ₂ addition, the potential daily algal biomass yield could be further increased to 475 tonnes dry weight/day.
Dairy farm wastewater:	The daily algae production potential from dairy farm wastewater in New Zealand using HRAP with CO ₂ addition would be 1093 tonnes dry weight/day. This is more than double that which could be produced from all municipal wastewater, however, with the production spread over many farms, cost-effective small-scale harvesting and processing technology will be required to realise this potential.
Pig farm wastewater:	There are approximately 250 commercial pig farms in New Zealand, each with an average of 1000 pigs. As all of the daily manure production is treated, the daily algae production potential from piggery wastewater in New Zealand using HRAP with CO ₂ addition would be 83 tonnes dry weight/day. The high and concentrated wastewater flows of commercial piggeries compared to those of the largest dairy farms makes piggeries attractive potential sites for algae biomass production.
Poultry waste:	Poultry farming is gaining popularity in New Zealand with approximately 350 laying hen and broiler chicken farms with a total of 24 million chickens. The daily algae production potential from chicken farm manure in New Zealand using HRAP with CO ₂ addition would be 136 tonnes dry weight/day. However, as most poultry farms have solid manure collection systems, often with 100% export of the manure, the potential for algae production may be harder to realise than for other agricultural manures.

3.1.3.8 Fatty biomass resources

Fatty / oily biomass resources can be used to produce biodiesel using first generation technologies. Three primary feedstocks considered are:

- Waste vegetable oils,
- Tallow
- Oil seed

The use of waste cooking oils is well established with a number of operations selling biodiesel made from waste cooking oil. These operations range from 0.25 to 1 million litres per annum. This source of fuel is limited, as the resource of oil is estimated at between 5 - 6 million litres per annum. However, it can be produced at a cost competitive with diesel pump prices and is already making a contribution to New Zealand's liquid fuel supply.

The tallow resource from meat processing is currently considered to be around 170,000 tonnes per annum, varying with stock slaughter rates. Tallow is a commodity used for pharmaceuticals and soap production and, therefore, prices follow international demand. In 2007, when tallow prices were around \$600 per ton, tallow-derived biodiesel could have been cost competitive with conventional diesel. In March 2008, the international demand for tallow had increased the price to above \$1,200 per ton, so biodiesel production from this source is no longer cost competitive and plans for a biodiesel power plant were abandoned in August 2008⁶.

The crop most likely to be used for producing oil for biodiesel in New Zealand is canola (oil seed rape). Biodiesel New Zealand has announced plans to establish a crop resource sufficient to provide 70 million litres of biodiesel per year. This project will be centred in South Canterbury, and will require in the order of 45,000 ha of arable land. Arable farmers are welcoming the option to grow canola as part of their rotation, since this Brassica crop provides soil health benefits and offers novel weed and pest control mechanisms for arable farms that in the past have exclusively produced small grains. Canola oil can alternatively be used for human and animal consumption or as base material for lubricants and hydraulic oil. As a by-product of oil extraction canola cake (de-oiled canola seeds) is produced which is gaining popularity as a protein-rich feed supplement among livestock farmers. The total volumes of canola based biodiesel production in New Zealand is restricted by the fact that the crop should only be grown once every three to four years on the same plot of land due to disease, pest and weed risks, and a continuing trend to convert arable farms to dairying. Therefore canola based biodiesel will remain a niche opportunity that nevertheless could provide several hundred million litres of transport fuel for New Zealand annually.

In comparison to tallow based biodiesel, biodiesel derived from canola has far superior properties, in particular reliable cold weather performance. Based on these properties, biodiesel derived from tallow would have restricted markets in winter (to warmer climates e.g. Auckland), or minimum blend with mineral diesel fuel (e.g. must have more than 80% mineral diesel).

⁶ The Scotsman, 2 August 2008

3.1.3.9 Simple carbohydrate biomass

Simple carbohydrate biomass resources can be used to produce biogas using anaerobic digestion or fermented to yield ethanol. Some of the feed stocks considered are:

- Horticultural residues (non-woody)
- Simple sugar biomass
- Starchy biomass

3.1.3.9.1. Horticultural residues (non-woody)

Significant volumes of fruit and vegetable residues arise from food harvesting, packaging and processing operations. Although these horticultural residues are frequently used as stock food or composted, they can also be used for energy production. Horticulture residues could be used to produce biogas through anaerobic digestion, or converted to ethanol.

Approximately 126,000 tonnes (dry weight) of fruit and vegetable residues could be used for energy. Horticultural wastes tend to have high moisture content. However, the wastes are centralised at the packhouse / factory so it is feasible to minimise additional transport costs by locating the energy production plant close to (or within) the packhouse. The potential energy contribution is in the order of 1.5 PJ/year⁷.

3.1.3.9.2. Simple sugar biomass

Whey, a by-product of the dairy industry, is a unique feedstock for the manufacture of bioethanol in New Zealand, utilising first generation conversion technologies. The lactose contained in whey is fermented to ethanol by yeast cultures, and the ethanol subsequently recovered from the fermentation beer by distillation. The residual biomass contained in the spent liquor post distillation is a potential feedstock for anaerobic digestion, which can provide biogas as the energy source for distillation. Such measures can greatly improve the net energy balance of whey ethanol production, and have been practiced in New Zealand for over two decades at Fonterra Tirau.

Anchor Ethanol, a subsidiary of Fonterra, produces 16 million litres of ethanol (0.34 PJ/a) per year at Tirau, Edgecumbe and Reporoa. Most of this ethanol is used within the food, cosmetics and pharmaceuticals industry, but limited volumes of this ethanol have been blended into petrol and retailed as E10 by Gull Petroleum since 2007. There is very limited scope for expansion of the whey ethanol sector. While sufficient whey to roughly double the existing ethanol production in New Zealand is currently produced, this raw material may not be available for the production of bioethanol, since whey is also used for the production of other, higher value food products (e.g. whey protein and extracts).

Cultivation of simple sugar biomass crops may increase the volumes of first generation bioethanol that can be produced in New Zealand. In a 2003 survey, around 61% of world ethanol production was produced from sugar crops, such as sugar beet, sugar cane or molasses [Taylor (2007)]. While

⁷ Key reference: Saggar, S., D. Giltrap, V. Forgie and R. Renquist, 2007, Bioenergy Options Report: Review of Agricultural Resources. Report prepared for the Bioenergy Options programme, 2007. (Refer CD).

these crops are not currently grown in New Zealand, sugar beets can be produced in Tasmania, where growing conditions similar to New Zealand exist. Potential yields and economic key indicators for sugar beet cropping in New Zealand are given in Table 3.1.15 and Table 3.1.16. In general it can be concluded that with no sugar industry currently established in New Zealand and a multitude of alternative bioenergy options available for development, it appears unlikely that New Zealand will see the development of a first generation bioethanol industry based on sugar crops in the near future.

3.1.3.9.3. Starchy biomass

Manufacture of bioethanol from starch crops (e.g. maize, wheat) is a well established technology around the world. The United States is the second largest producer of ethanol in the world, using maize as the major feedstock. However, maize based ethanol production in the United States is subsidised, and without this subsidy would be uneconomic in New Zealand. Other grains that have been used for ethanol production include wheat, in Australia, Canada, France and Sweden, and barley in Spain (IEA 2004). Approximately 20,600 ha of maize grain (predominantly in the Waikato / Central North Island) and 39,400 ha of wheat and 49,900 ha of barley (predominantly in Canterbury) are currently grown in New Zealand, while around 2.0 million ha of land would be suitable for cropping.

An important aspect of growing crops is whether or not this can be achieved continuously over many years with minimal soil deterioration. One New Zealand study, over six years, indicated that harvesting crops for biogas production could be practised without detectable damage to the soil, provided the digester effluent (digestate) was applied as a substitute fertiliser [Ross et al. (1989)]. Anaerobic digestion of biomass, like ethanol fermentation, extracts only the organic content of the material while the nutrient content of the biomass is largely retained in the spent liquor (digestate). Spent liquor can be returned to the cropping land to replenish soil nutrient supply creating a closed loop nutrient supply for the energy cropping system, or potentially be used as a medium to grow algae.

Water availability could limit the ability to grow crops in some areas. National water allocation increased by approximately 50% between 1999 and 2006. Irrigation accounts for 77% of water allocations by volume. In the future, climate change could lead to increased irrigation demand in some (mostly eastern) regions.

Land is only likely to switch to growing bioenergy crops if the gross margin from bioenergy farming is greater than the gross margin of any other suitable land-use, and the labour and management inputs are not vastly different. Table 3.1.15 shows typical gross margins for potential land uses that might switch to bioenergy farming.

It is unlikely that New Zealand will see a marked expansion of the bioenergy cropping sector unless government regulation encourages a more rapid uptake. However some niche opportunities exist, as demonstrated by the establishment of a canola based biodiesel industry in Canterbury, and further opportunities will arise where special circumstances (e.g. nutrient caps, bio-security issues, farmer's lifestyle considerations) challenge the viability of conventional farming practices.

Table 3.1.15 - Gross marginal returns from different farm types

	Gross marginal return (\$/ha)	References
Sheep and beef farming	508	MAF Policy (2006b)
Maize grain 2003/04	1029	Lincoln University (2006)
Maize silage and winter feed	701	Lincoln University (2006)
Wheat	966	Lincoln University (2006)
Wheat silage	538	Lincoln University (2006)
Barley	709	Lincoln University (2006)
Sugar beet*	777	Thomson and Campbell (2005)
Rape seed (canola)**	456	Nix (2004)
Miscanthus**	118	Nix (2004)

* Based on Tasmania data for high risk commercial “worst case” scenario

** Based on UK values

** Sterile hybrid miscanthus is likely to be trialled in New Zealand in 2009

Estimated costs of recovering agricultural energy crops are summarised in Table 3.1.16.

Table 3.1.16 - Yields and farm working (FW) expenses for potential bioenergy crops

Production system	Typical yields (t/ha)	Farm working expenses (\$/ha)	References
Maize grain with winter fallow	12.5 (dry)	2400	Lincoln University (2006)
Maize silage sold to stack with winter grazing	18 (DM)	3500	Lincoln University (2006)
Wheat	8.5 (dry)	1500	Lincoln University (2006)
Wheat silage	15 (DM)	2300	Lincoln University (2006)
Barley	7.5 (dry)	1100	Lincoln University (2006)
Sugar beet*	60 (FM)	4400	Thomson and Campbell (2005)
Rape seed (canola), winter**	3.2 (dry)	820	Nix (2004)
Miscanthus**	12.5 (oven dry)	680	Nix (2004)

* Based on data from Tasmania

** Based on UK data

3.1.4 Introduction to conversion technology

The conversion of biomass resources to different usable forms of energy relies on a range of different technologies, some of which are still to be proven commercially. The technologies covered are:

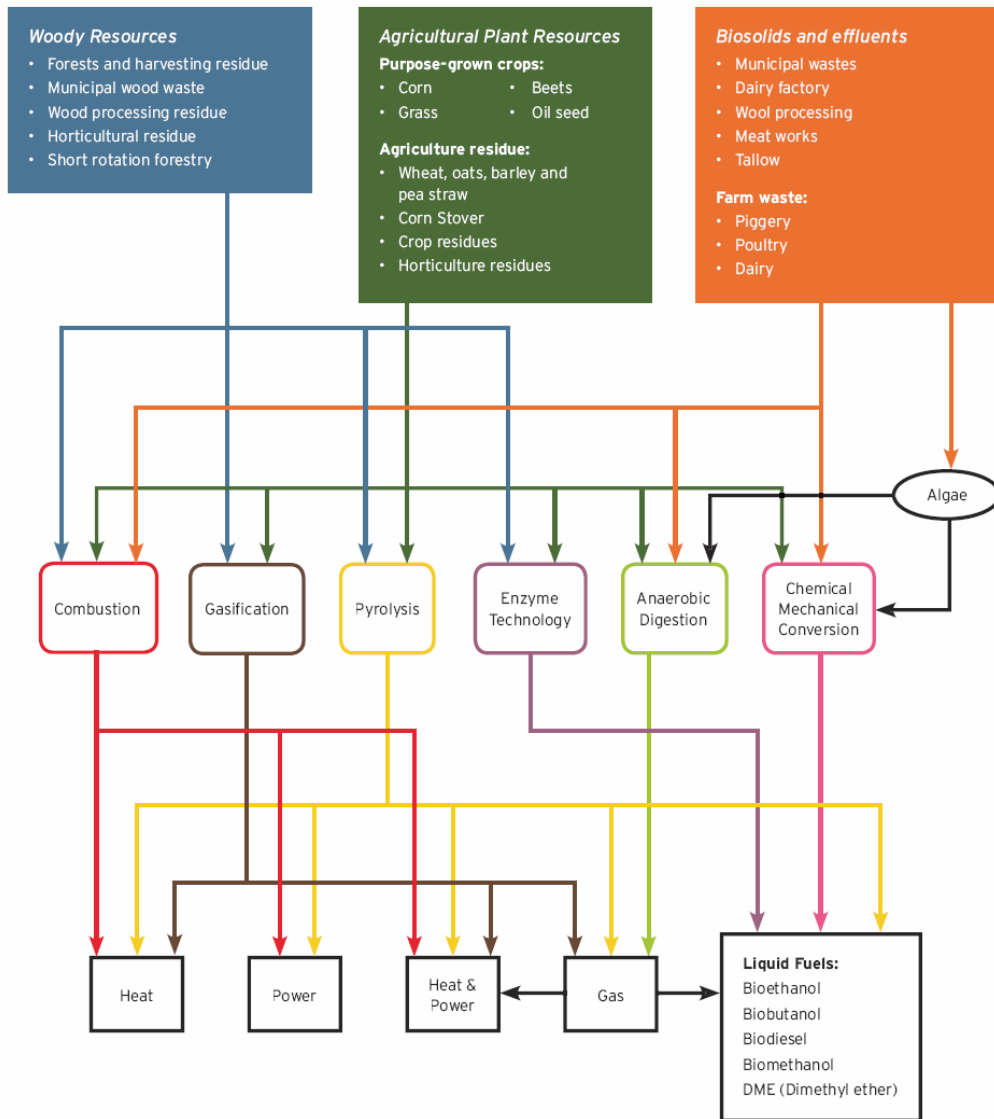
- Combustion - burning biomass to generate heat.
- Gasification - using partial combustion to produce gas from biomass.
- Pyrolysis - using heat in the absence of oxygen to break organic matter down to its chemical components.
- Anaerobic Digestion – microbiologically degrading organic material in the absence of oxygen.
- Chemical and Mechanical processing – converting canola, waste oil, and tallow to biodiesel by pressing and / or trans-esterification.
- Biochemical and enzyme technology - biological catalysts that can be used at critical stages of the bioconversion process to replace more energy-intensive methods.
- Algae processing – advanced harvesting, super-critical extraction and a combination of the above technologies can all be used convert algae biomass into usable fuels.

Methods for producing biofuels are often classified as “first generation” (well-proven technologies based on easily converted feedstocks) or “second generation” (methods using new technologies and/or feedstocks):

- “First generation” biofuel technologies refer to current technologies used for converting biological feedstocks to transport fuels. These technologies can only convert readily processable feedstocks such as sugarcane sugars, milk sugars, starch and tallow. First generation technologies include ethanol production from whey, grains or sugar cane and biodiesel production from vegetable or animal oils.
- “Second generation” biofuel technologies require further development and are used to convert more difficult feedstocks such as woody biomass (lignocellulosic) to transport fuels. Second generation technologies include ethanol production, from cellulose or gasification followed by a “gas to liquid” process, and, biodiesel production from algae.

The relationships between resources, conversion technologies and energy end-use options are shown in Figure 3.1.17.

Figure 3.1.17 - Possible resource, conversion and end-user energy options



3.1.4.1 Combustion

Combustion of biomass is a mature technology and widely used both in New Zealand and overseas. In New Zealand the largest user of biomass combustion is the wood processing industry. Wood residues contribute 19 PJ of energy to saw milling and panel manufacture and a further 25 PJ (including black liquor) to the pulp and paper industry.

Combustion can be used in a variety of ways to create heat, or to make steam for a combined heat and power, or power-only system. The efficiency of combustion systems is influenced by the size of the installation, with larger systems being more efficient. Combustion for heat is the most efficient of these systems, and can be over 90 % in large-scale applications. Combined heat and power (CHP) systems are 60 – 70 % efficient and power generation-only systems around 30 % efficient.

Combustion systems can cope with green (high moisture content) biomass fuels, with moisture contents of up to 55 % acceptable in most. However, system efficiency improves with lowering

moisture content. Industrial combustion systems can cope with particle sizes of up to 150 mm, or can be designed to run on fine material such as saw / sander dust.

In many biomass systems, co-firing with coal or gas is possible and is used to meet rapid changes in heat or steam demand. In some cases, coal fired systems can have 10 to 15 % of the input fuel substituted with biomass.

Almost any biomass can be combusted, including de-watered biosolids, although ash contents in some of these fuels are very high (25 – 30%), whereas clean wood has an ash content of less than 1%.

Combustion of biomass is considered to be carbon-neutral, as the carbon was absorbed from the atmosphere during the production of the biomass [MED (2007)]. The sulphur emissions from woody biomass are very low compared to coal. Biomass ash, particularly that from plant material has lower heavy-metal levels than coal ash and can be returned to the soil to replace nutrients such as potassium, magnesium and phosphorous.

Straw and stover may be directly combusted, although this has significant technology-related issues relating to the chemical composition of the material. High chloride and sodium and other inorganics can contaminate boiler surfaces. Therefore special technologies are required.

Pelletising wood residues is a recent development and the pellets are being used to replace coal in small boiler systems (schools) and in domestic fireplaces and boilers. Due to their flowable nature, the materials in-feed can be automated.

Due to its technological maturity, existing widespread use, flexibility-of-scale and fuel-type, combustion will typically be the primary means of converting biomass to energy in the short-term. It is also a very efficient means of converting biomass to user energy, particularly heat.

3.1.4.2 Gasification

Biomass gasification is incomplete combustion in a restricted air supply. This produces a gas containing CO, CO₂, hydrogen and methane. This gas can be used in internal combustion engines, gas turbines or converted into other products, including liquid fuels, such as ethanol and biodiesel, or a wide range of chemicals. Gasification is an effective way to convert biomass into a gas stream that can be used for a wide range of applications. There are still some technical challenges in getting the gas to a specification suitable for use in turbines and internal combustion engines.

Gasifiers are complex and have higher demands in terms of feedstock specifications than combustion systems. The feedstocks typically need to be dry (< 20 % moisture content wet weight) and have small particles size (<10 mm). The feedstock influences the gas produced and the design of the system must be matched to the intended use.

There is significant development underway worldwide looking at gasification at both small- and large-scale. The large-scale gasifiers are aimed at Biomass Gasification combined cycle heat and power systems and production of liquid biofuels. Gasification is seen as having significant potential to utilise biomass to produce heat power and gas for chemical and biofuel production. Gasification of biomass has been researched extensively for the past 15 years, and there are indications that

some of the technologies are approaching commercialisation, albeit in countries where biofuel production is subsidised. If oil prices remain high, gasification of biomass and then conversion to liquid fuels will become more prominent and closer to economic viability. Gasification, coupled with heat plant or combined cycle heat and power generation, may be viable in some New Zealand industries depending on the cost of carbon emissions.

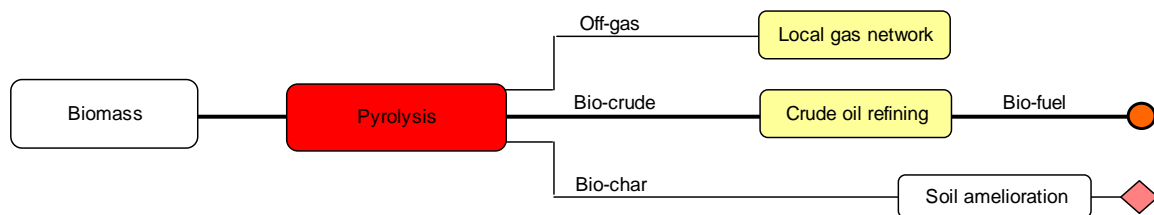
There are no commercial gasifying systems operating in New Zealand, but there are two experimental facilities (Page Macrae and University of Canterbury), and Alternative Energy Solutions have imported a 30 kW gasifier coupled to an internal-combustion engine / electric-generator for demonstration and sale.

Installation and operating costs (derived from overseas data) are \$1,000 – \$1,600 per kW of gas output and 4.5 – 6.6 cents per kWh of gas respectively. Life cycle analysis of a Battelle Ferco gasifier to electricity system found that net energy was highly positive and carbon closure was 95 %. Biomass gasification compares favourably with coal combustion as it has lower sulphur oxide, nitrogen oxide and fine particulate emissions and cleaner ash.

3.1.4.3 Pyrolysis

The pyrolysis process involves the chemical decomposition of organic material by heating in the absence of oxygen. This process produces a mixture of ‘raw’ bio-crude, char and gases - the mix and proportions being dependant on the temperature and vapour residence times. Bio-crude production is enhanced with moderate temperatures and short residence times. Biochar production requires lower temperatures and longer residence times. Any organic matter can be pyrolysed, but it needs to be dried and size reduced prior to processing.

Figure 3.1.18 - Schematic of the pyrolysis process



Feedstocks should be less than 10% (w/w) moisture content and particle size is generally very small (<2 mm) although ablative systems can use large piece size. The moisture content of the feedstock ends up in the bio-crude, consequently having a direct impact on the energy content of the produced bio-crude. Low-ash content fuels are better, but fluidised bed reactors can cope with higher ash levels than other systems.

Pyrolysis is currently receiving greater research investment than in the past. Much of this is in the area of creating chemical products from the biomass as much as the energy. The interest in the creation of biochar as a carbon storage / sequestration mechanism is a relatively recent development and is also receiving greater research investment. Many of the possible technology options are still developmental, and there is little solid information on production and cost.

Currently there are no commercial pyrolysis systems in New Zealand and few worldwide. There is a laboratory-scale system at AgResearch in Christchurch, and Alternative Energy Solutions is investigating the importation of a small-scale system from Advanced BioRefinery (Canada).

The oil produced typically has a fuel energy content of 17 MJ/kg, which is denser than raw biomass, and this reduces storage and transport costs. Bio-oil is not suitable for use in internal combustion engines, but is being trialled for use in gas- and coal-fired power stations. Further refining or gasification of bio-oil can produce fuel for gas turbines or biodiesel, but these options are still under development.

3.1.4.4 Anaerobic digestion

Anaerobic digestion is an established technology that is used widely around the world and is well established in New Zealand, with a variety of waste streams being treated. In Germany, there are over 4,000 farm-scale biogas plants, mainly used for electricity generation (CHP).

Anaerobic digestion can take a wide range of biomass resources and effluents and produce biogas that has an energy content of around 22 MJ/m³. Biogas is very flexible, since it can be purified to natural (methane) gas quality and exported into the national natural gas network; used for transport fuel; used for heating and CHP etc.

The economic viability of the biogas pathway can vary widely. Since feedstock is generally very cheap (i.e. mostly waste products) the revenue is determined by the cost of alternative disposal method. The anaerobic digestion of these waste streams removes much of the organic matter and leaves nutrient-rich water, which can be re-used within the plant or used as a fertiliser. Recent developments in algal research suggest that this nutrient-rich water could be used for growing algae, which can, in turn, be used for anaerobic digestion or, possibly, production of biodiesel.

The anaerobic digestion of waste streams has considerable environmental value i.e. GHG abatement, nutrient runoff reduction, reduced sludge and effluent discharge.

3.1.4.5 Enzymes

The use of enzymes in a New Zealand context is likely to be (and currently is) focussed on using second-generation technologies for the conversion of biomass to liquid biofuels. The reason for this is that we have a large and uncommitted woody biomass resource available. The potential to expand the supply of woody biomass is also likely to be larger than the alternatives, due to the ability to economically recover forests grown on marginal lands. Overseas research and development in this area is expected to see commercial-scale plant in operation within 5 years.

Feasibility studies of utilising enzymes on woody biomass to make second-generation biofuels are under way in New Zealand. Indications are that achieving the feedstock supply (needed by the larger-scale plant in order to achieve optimum economic size) will be a challenge. Costs are estimated to be in the order of \$1.34 per litre of gasoline equivalent at the plant (before distribution, tax and margin are added), or \$2.00 per litre pump price.

Challenges to be addressed are: reducing the delivered cost of woody biomass feedstock, the cost of enzymes and creating co-products to add value.

3.1.4.6 Chemical and mechanical

The creation of liquid fuels from oils, fats and oil crops is a well understood technology (transesterification), and processing yields are near to theoretical limits. The three main sources of raw material in New Zealand are, or are likely to be: waste cooking oil, tallow from meat processing and oil crops (canola).

3.1.4.7 Algae processing

Micro algae are widely believed to be the precursor of much of the world's fossil oil and gas reserves. Today, algal biomass is seen as a potential resource for bioenergy production. Algae are far more productive than conventional agricultural crops and can be grown cost-effectively in open pond systems as a by-product of wastewater treatment. The unique composition of algae makes them a suitable candidate for production of an aviation fuel supplement, which is attracting much international interest.

Oxidation ponds, which are the most common form of waste stabilisation pond (WSP) in New Zealand, provide an opportunity for algal biomass production. Conventional WSP, are however, not optimised for the production of algal biomass, and algae production can be significantly increased by upgrading to High Rate Algal Ponds (HRAP). This process will also enhance the wastewater treatment performance, both in terms of absolute pollutant removal and treatment consistency.

Conversion products for realising the bioenergy potential of algae biomass include biodiesel, biogas, bio-ethanol, and bio-oil. Of these conversion options, bio-oil production, using super-critical water reactors, shows considerable promise, but requires further research. Super-critical water technology is a possible approach for cost-effective conversion of algae to energy products.

Biogas production from anaerobic digestion of algal biomass is a mature and effective technology that is readily available for commercial application. Algal biomass is an unfavourable feedstock for conventional biomass conversion technologies (i.e. combustion, gasification and pyrolysis), because drying is an unavoidable and expensive step. Converting wet microalgae biomass (5 – 30% solids) to crude oil, using super-critical water conversion may be a more achievable goal.

Algae production solely for energy production is currently unviable, but the value of co-benefits such as wastewater treatment or co-products, like bioplastics and fertiliser, (wastewater nutrient recovery or cyanobacteria nitrogen-fixation) could greatly improve economics.

3.1.4.8 Other

International trends for biomass processing are towards multiple products from the biomass resource, not just energy, with the term bio-refinery being used. This is not that different from the concept of an oil refinery that also, typically, produces many different products, not all of them energy. Conversion technologies are merging into integrated systems (gasification and pyrolysis giving energy and other products). Even combustion technologies are being viewed as having other products (ash for fertiliser) and high carbon monoxide (CO) gas streams, which have the potential to be processed to create liquid fuels e.g. ethanol by Lanzatech.

3.1.5 Asset characterisation

The “biomass driven” scenario modelled by EnergyScape is based around the afforestation of 1.8 million hectares i.e. Scenario 2 from the “Analysis of large-scale bioenergy from forestry” report (Hall and Jack, 2009) with 44% of the harvest being used for liquid fuels production, and 30% of the harvest being gasified regionally (and introduced into the gas network), with the remainder being exported as logs.

For many of the resources it is possible to put a value on the cost of delivering the raw material to some point of use. For others, the dispersed nature of the resources and associated variability of transport costs often makes it difficult to be precise about these costs. A range of likely delivered costs for raw material (in a fuel form) are shown in Table 3.1.19.

Table 3.1.19 - Delivered cost of raw material (in a fuel form)

Resource type	Cost range \$/GJ
Forest trees	8.70 to 15.50
Forest residues landing	3.20 to 3.70
Forest cutover (easy)	4.10 to 4.70
Forest cutover (steep)	6.00 to 7.00
Municipal wood waste	2.00 to 2.60
Wood process waste	0.25 to 2.30
Horticultural wood residues	3.70 to 4.70
Straw	2.6 to 5.20
Stover	2.6 to 5.21
Fruit and vegetable culls*	1.45
Biosolids*	18
MSW*	18
Landfill gas*	20
Dairy / piggery / poultry manure*	18
Dairy factory effluent*	18
Meat works effluent*	18
Waste oil	29.50
Tallow	21.50

*The fuel form for these resources is biogas from a digester. No transport cost is applied, as it is assumed it will be utilised close to the digester.

The costs presented here are based on calculations of actual cost, which may be different from the market price being charged, due to different perceptions of the return that investors look for in order to cover risk.

The 60 million litre per year rapeseed derived biodiesel development by Solid Energy is expected to be forthcoming under all scenarios.

3.1.5.1 Wood processing residue transportation

The viability of transporting wood processing residues is dependant on the volume and type of residues produced, distance from residue user, energy density of the residue, and truck configuration. A small sawmill in an isolated location far from a residue user will produce small amounts of residue which may not be viable to use on-site or for transport to another user. Transport costs from site to site will vary with the type of product:

- Sawdust \$0.18 to \$0.25 per tonne-km
- Off-cuts \$0.18 to \$0.27 per tonne-km
- Dry shavings \$0.54 to \$0.81 per tonne-km (shavings are very low density)

3.1.5.2 Construction waste recovery

Fuel quality may be improved by segregation prior to processing and screening, and blending afterwards. For example, screening of fines <20 mm (estimated cost 5 - 7 \$/tonne) and blending of higher-moisture-content green waste with drier wood-waste, perhaps on a 1:2 basis, will improve fuel quality (though reduce the weight/m³ of fuel produced). With blending, fuel can be produced to user's specifications. Fuel cost and quality must thus be balanced.

3.1.5.3 Establishment costs of purpose grown forests

The cost of reforestation growth and harvest, will be modelled as:

Scenario (million ha)	Yield (m ³ /y)	Full harvest to bioenergy		Multiple product forest	
		Growing*	Road	Harvest	Transport**
0.8	640	28.06	5.87	38	15
1.8	940	19.10	3.99	38	15
3.3	940	19.10	3.99	38	15
4.9	908	19.78	4.14	38	15

* This includes land rental, land preparation, planting, weed control and forest maintenance.

** Average transport distance assumed to be 75 km. Includes cost of uplift.

Source: Table 7 from Hall and Jack, 2009

A large part of the costs could be offset by carbon credits and substitution of fossil fuels with renewable energy. Planting large forests would protect against a potentially large greenhouse gas emission liability from the Kyoto agreement.

3.1.6 Research status

Bioenergy has significant potential, but numerous areas have not had sufficient research investment.

Table 3.1.20 – Research status

(Green highlight indicates ‘Fair knowledge’, Amber indicates ‘Could improve’, Red indicates ‘Knowledge gap exists’)

	International	New Zealand	Comment
Land-use change	Evolving	Mature / Advancing MAF, MfE	Improved documentation on land-use change and land-use change costs would be valuable. LUCAS database development will aid in this regard.
Woody resource assessment	Mature	Evolving MAF	Improved definition of resource opportunities, in particular ownership, feedstock characterisation and extraction on steep slopes, is required.
Woody biomass supply and conversion	Evolving	Evolving BANZ, BRANZ, CRL Energy	Improved understanding of materials handling and freight costs, line fees and firing equipment. Overall aim is an increased utilisation of biomass.
Common costing and Life-Cycle Analysis databases	Advancing	Immature SCION, NIWA, CAENZ	Access to common understanding of asset characteristics and costs aids, improves planning and allows accurate comparison of options.
Municipal resource assessment	Evolving	Immature SCION, NIWA	Can putrescible waste be used for electricity and transport fuel generation?
Improving uptake of anaerobic digestion technology	Mature	Advancing AgResearch, NIWA, Process Systems	Can improve the economic viability and environmental footprint of primary production sector. Several years behind Europe and US.
Woody biomass to transport fuel pathway analysis	Evolving	Immature SCION, MAF	Further assessment and small-scale trials (pilot plants) are required to evaluate which pathway (Enzymes - butanol, Enzymes – ethanol, Gasification or Pyrolysis) is most appropriate for NZ.
Advancing thinking on preferred woody biomass pathways	Evolving	See above	Further assessment and small-scale trials to improve understanding of: scalability, gas clean up, syn-gas processing, biochar, biomass to synthetic natural gas, Fischer-Tropsch, Haber-Bosch Process, Bio-crude production, refining and densification.
Oily biomass to transport fuel pathway analysis	Evolving	Immature SCION, MAF	Further assessment and small scale trials are required to evaluate which pathway (Jathropha, Algae, and Tallow etc.) is most appropriate for NZ.
Advancing thinking on preferred oily biomass pathways	Evolving	See above	Further assessment and small-scale trials are required to evaluate: Co-benefit value, material handling, harvesting and conversion.
Carbon Capture and Storage (CCS)	Immature	Immature MAF, AgResearch, Massey Uni	Evaluate and assess opportunities from biochar, SRF and algal sequestration.

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	International	New Zealand	Comment
Social and non-economic impacts	Evolving	Evolving MAF, MfE, Motu	Further assessment of land use impacts and feedback systems would be valuable. The role of self-reliance on proportion of distributed generation, nutrient management, soil conservation and biodiversity, would be valuable.
Policy planning	Advancing	Immature Various	Research input to planning is currently very limited by world standards.
Urban biomass opportunities	Evolving	Immature	Advance understanding of how urban biomass opportunities could alleviate energy poverty.
Biomass combustion technology	Advancing	Advancing	Improved efficiency and reduced air quality impacts can be achieved.

3.1.7 Summary

New Zealand has an internationally competitive (and highly efficient) primary production sector, so it is not surprising that there are many opportunities of significant bioenergy generation in this country. Advancing bioenergy production has many advantages that support a sustainable, progressive New Zealand. These include:

- Generation of revenue from medium- and low-productivity land whilst reducing environmental degradation.
- Increasing energy self-sufficiency and reducing impact of market forces.
- Reducing national GHG profile.

From this study, some observations regarding the potential for bioenergy in New Zealand include:

- If all of the presently-available residual biomass could be harnessed, it would only contribute to about 6-7% of New Zealand's primary energy demand. If biomass is ever to make a more significant contribution, purpose-grown biomass is required.
- The limited feedstock capacity of "first generation" biofuels suggests that these fuels are only likely to contribute a relatively minor portion of New Zealand's future mobility demand.
- The biomass resources with the largest potential to displace substantial amount of fossil fuels (e.g. gas, oil or coal) are: forest residues from either purpose-grown whole forests, or large-scale short-rotation forests (SRF). It is noted that growing forests on steep terrain and marginal grazing lands, at sufficient scale, could make a real contribution to reducing oil imports without adversely affecting export production.
- Further development of the wood pellet market may provide opportunities both in the domestic heat market and value-added export market.
- Anaerobic digestion of farm manures, industrial effluents, municipal solid wastes and sewage sludges to produce biogas is a proven technology with opportunities in niche situations. While the overall contribution of anaerobic digestion to New Zealand's energy demand will remain relatively small, this technology provides multiple secondary benefits such as mitigation of odour and GHG emissions and options for nutrient recycling / fertilizer displacement.
- Market forces determine the utilisation of residual biomass material, thus, the highest-value / lowest-cost is likely to be the winner.

Biomass could play a significant role in New Zealand's pathway towards becoming the 'first truly carbon neutral' nation. This will only be achieved with quality planning and the support of research to advance technologies, logistics and efficiencies. The planting of marginal land with forests and provision of supporting bioenergy businesses could future-proof New Zealand's economic prosperity in the face of uncertain commodity markets. If international fuel prices increase prohibitively, then a large proportion of our energy could be domestically supplied. Alternatively, the resource can be converted to value-added products for export.

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Glossary

GLOSSARY OF COMMON TERMS

~	Approximately
Afforestation	To convert land into a forest by planting trees or their seeds.
ADCP	Acoustic Doppler Current Profiler – a measuring device that can be used for determining marine current flow speeds.
Assets	A physical item (or group of items) of infrastructure the either extract, convert or distribute energy e.g. wind farm, coal mine, electricity network.
AU	Ammonia Urea
Bar.g	Barometric gauge pressure – the pressure of a gas registered by a measurement gauge device, relative to the ambient pressure.
Bounded map	Land areas where activity is consider to be of low likelihood due to existing planning logistics e.g. Road in a National Park.
Bbl	“Esso” blue barrel – 42 US gallons, the international volumetric unit of oil.
Bpd	Barrels per day
BRANZ	Building Research Association of New Zealand - an independent consulting and information company providing resources for the building industry.
BTL	Biomass to liquids
CAPEX	Capital expenditure
CSS	Carbon Storage and Sequestration – The process of capturing greenhouse gas emissions can storing them for several hundreds of years
CCS	Carbon Capture and Storage (or Sequestration)
CCT	Carbon Capture and Trade
CGH ₂	Compressed Gaseous Hydrogen
CHP	Combined Heat and Power. Electricity (power) production alone generates a lot of waste heat and is therefore doesn't recover maximum value from fuel. Heat generation achieves a fuel to energy output ratio, but doesn't produce high value electricity. A CHP operation combines the advantages of both.
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
CO ₂ EQV	A common measure for greenhouse gas warming potential. This unit aggregates the emissions from CO ₂ , CH ₄ , SF ₆ , N ₂ O _x , HCF and PCF to Carbon Dioxide Equivalent.
CPI	Consumer Price Index
CTL	Coal to liquids
DME	Di-methyl Ether
DoC	Department of Conservation
DSM	Demand Side Management
E ³	A database used to assess Energy use, Economics and Emissions for processes
EDF	Energy Data File – Annual summary of New Zealand's energy demand. Maintained by MED.
EECA	Energy Efficiency and Conservation Authority
EERA	Energy Efficiency Resource Assessment
EEUD	Energy End-Use Database – Maintained by EECA
EEZ	Exclusive Economic Zone
EPRI	Electric Power Research Institute
EROEI	Energy Return on Energy Invested
EROFEI	Energy Return on Fossil Energy Invested
EtOH	Ethanol

F-T	Fischer-Tropsch process. A technology developed in Germany (1920s) which uses catalytic reactions to synthesise complex hydrocarbons from synthesis gas (carbon monoxide and hydrogen).
FC	Fuel Cell
FCV	Fuel Cell Vehicle
Firm capacity	A baseline (minimum) generation capacity that can be maintained on an inter-annual basis (e.g. dry year capacity of hydro power station).
FPSO	Floating Production, Storage and Offloading – a ship-based facility that accompanies off-shore oil and gas drilling platform operations.
FRST	Foundation for Research, Science and Technology
FTE	Full-Time Equivalent – the equivalent number of people employed in full-time positions within an industrial sector.
GBS	Gravity-Base Structure – a heavy-duty, off-shore, oil storage facility that is used to assist in off-shore oil drilling operations.
GDP	Gross Domestic Product
GHG	Greenhouse Gas – Emissions that add to radiative warming of earth eg. CO ₂ , CH ₄ , SF ₆ , PFC, HFC.
GIS	Geographical Information System
GJ	Giga-Joule = 1,000,000,000 Joules = 10 ⁹ Joules of energy
GTL	Gas to liquids
GWP	GHG warming potential
HRAP	High Rate Algal Pond – a type of waste-water treatment pond
HEEP	Heat Energy Efficiency Programme
HERA	Heavy Engineering Research Association
ICDP	International Continental Drilling Programme – towards the study of the Earth's crust, natural mineral resources and interactions with surface ecological systems.
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
IGCC	Integrated Gasification Combined Cycle
In-gate	All off-road transportation i.e. agriculture, forestry, mining, recreational and off-road vehicles.
IPCC	International Panel on Climate Change
Kt	kilo-tonne – equivalent to a million kilograms or a Giga-gram.
L/100 km	Litres per 100 km – a measure of fuel consumption used for road transport vehicles
lde	Litre of Diesel equivalent – a unit of measure for comparing the energy content of alternative fuels with that of a litre of conventional Diesel fuel.
LEAP	Energy pathway visualisation software – Long-range Energy Alternatives Planning.
LEAP framework	The database, output files and visualisation tools that are associated with running LEAP.
lge	Litre of gasoline equivalent – a unit of measure for comparing the energy content of alternative fuels with that of a litre of conventional gasoline (“petrol”) fuel.
LNG	Liquefied Natural Gas (mainly methane @ -160°C)
LPG	Liquefied Petroleum Gas (mainly propane and butane)
mcf	thousands of cubic foot per day
MED	Ministry of Economic Development
MEDF	Marine Energy Deployment Fund – administered by the EECA
MeOH	Methanol
MEPS	Minimum Energy Performance Standard
MJ	Mega-Joule = 1,000,000 Joules = 10 ⁶ Joules of energy

mbbls	Thousand barrels – non-SI unit of volumetric measurement of oil
mmbbls	Million barrels – non-SI unit of volumetric measurement of oil (1mmbbl of crude oil contains approximately 6 PJ of energy)
MOT	Ministry of Transport
mmscf	millions of standard cubic feet
MT	Magneto-Tellurics – a technique used for mapping sub-surface rock features, relating to their natural, electrical conductivity.
Mt-km/kt _{equivalent}	Mega-tonne-kilometre travelled per kilo-tonne(equivalent) of various industrial stock moved.
MTG	Methanol-to-Gasoline plant
MW	Mega-Watt = million Watts – measurement of power output
NA and AN	Nitric Acid and Ammonium nitrate
NGL	Natural Gas Liquids
NZ	New Zealand / Aotearoa
NZBCSD	New Zealand Business Council for Sustainable development
NZES	New Zealand Energy Strategy
NZEECS	New Zealand Energy Efficiency and Conservation Strategy
O and G	Oil and Gas
OPEX	Operational Expenditure
OWC	Oscillating Water Column – a form of wave energy conversion technology for marine applications.
Peak Oil	Defined as the maximum production (bpd) of a field, a province, or the world
Phase	The stage of development of an asset – eg. Research, Construction, Operating.
PHEV	Plug-in Hybrid Electric Vehicle
PJ	Peta-Joule = 10 ¹⁵ Joules = thousand, million, million Joules – measurement of energy.
PKT	Passenger Kilometres Travelled – used in the quantification of personal transportation
Risk score	An indication of the likelihood that a phase of asset development will fail (0 – Minimal to no risk; 5 – Extreme to almost total risk). When risk probabilities are applied to applied to Policy, research and financing costs an implementation risk (\$000s) is calculated. When risk probabilities are applied to applied to operating capacity, an operational risk (MW) is calculated.
RMA	Resources Management Act
RON	Research Octane Number – a measure of the quality of a fuel, commonly seen at transport fuel filling stations to indicate the relative octane rating of petrol.
PWD	Public Works Directive
PV	Photo-Voltaic – relating to the conversion of solar energy, carried by photons, directly into electrical energy (via photo-voltaic cells that are built into panels or arrays).
RVP	Reid Vapour Pressure (The propensity of “light ends” to evaporate from crude oil).
SHW	Solar Hot Water
SI	le Systeme International d’unites – the international system for defining common units of measurement.
SMR	Steam Methane Reformation
SRF	Short Rotation Forest
StatsNZ	Statistics New Zealand
SUV	Sports-Utility Vehicle
Sweet gas	Well gas with low sulphur content (<4ppm H ₂ S), as distinct from sour or “dirty”

TJ	Tera-Joule = 10^{12} Joules of energy
TE	Thermo-Electric – relating to the conversion of thermal radiation directly into electricity (via thermo-electric cells that are built into panels and arrays).
t-km	Tonne-kilometres - used in the quantification of goods transportation
Tm ³	Tera-cubic metres – used as an SI alternative to “trillions of cubic feet” for measurement of natural gas reserves
tph	Tonnes per hour
TW	Tera-Watt = million-million Watts – measurement of large power output
US	United States of America
USDoE	United States Department of Energy
VFM	Vehicle Fleet Model – developed by the Ministry of Transport
VKT	Vehicle Kilometres Travelled – Generally associated with passenger transportation.
WGIP	Wind Generation Investigation Project – set up by the Electricity Commission
WEC	Wave Energy Converters
WSP	Waste Stabilisation Pond – for waste-water treatment

