Report to:

Bioenergy Association of New Zealand

PRELIMINARY ANALYSIS OF THE ECONOMIC IMPACT OF THE NEW ZEALAND BIOENERGY STRATEGY

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Preliminary EIA of the NZ Bioenergy Strategy

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1 Executive Summary

The Bioenergy Association of New Zealand (BANZ) commissioned BERL to complete a preliminary economic impact assessment of the New Zealand Bioenergy Strategy (herein referred to as the 'Strategy'). Included in this assessment are an indication of the macroeconomic impacts of the Strategy, identification of the other wider economic benefits from the Strategy's implementation, and a discussion of the associated environmental gains from further developing the potential of the bioenergy sector.

The current state of literature on the wider economic benefits of bioenergy strategies presents difficulty in drawing definitive conclusions on New Zealand's potential as a generator and user of bioenergy. This report is an initial attempt to address this information gap and to assist policy-makers in making decisions about the role bioenergy should play in achieving higher economic growth and generating employment for New Zealand in the future.

1.1 Model findings

This study used the BERL general equilibrium model to assess the macroeconomic impact of the Strategy. Its summary findings are:

- the bioenergy sector in 2010 produced almost 47.6PJs of output, comprising: 25PJs of biomass and biogas for heating; 0.9PJ of biofuel for transport; and 21.7PJs black liquor produced and used directly in the paper and pulp industry.

- the Strategy holds the production of black liquor constant at an annual 21.7PJs up to 2040. Thus, this study assesses the macroeconomic impact of the Strategy excluding black liquor production; covering expansion in the bioenergy sector arising from increased energy from biomass for heating and transport uses.

- excluding black liquor, the 25.9PJs of production in 2010 from the bioenergy sector for heating and transport equated to output at a gross value of $249m. A 'business-as-usual' projection of the New Zealand economy, sees the bioenergy sector (excluding black liquor) grow by approximately 2.2 per cent per annum to 2040, taking production to 50.2PJs at a real gross value in terms of constant 2010$s of $483m.

- the Strategy sees the bioenergy sector (excluding black liquor) expand to 140.6PJs by 2040, or an expansion of 180 per cent on the 2010 level, substituting for energy from existing (or traditional) sources. This expansion is driven by an increasing domestic and international demand for heat from wood fuel and biogas technologies, and for transport fuels in the form of biogas, biodiesel or bioethanol.

- the implementation of the Strategy adds 1.2 per cent to the business-as-usual projection in terms of annual GDP in 2040; that is, real GDP measured in 2010$s would be $6.1 billion more with the Strategy, than without it[1].
    - the additional GDP includes a 0.9 per cent addition to real household consumption spending; 1.5 per cent on export volumes; and employment for an extra 27,000[2] full-time equivalent positions.
    - the trade balance improves by more than $1.9 billion.
- amongst the modelling assumptions incorporated, these findings are critically reliant on there being sufficient capital resources attracted to the sector to enable the expansion in bioenergy output.
- these gains are further improved where the expansion of bioenergy output, in line with the Strategy, is accompanied by the development and export of co-products.
    - it is undoubtedly difficult at this stage to quantify the potential of these co-products.
    - for indicative purposes though, a model scenario that assumes additional exports from bioenergy co-products equivalent to (an, arguably, conservative) 10 per cent of the value of the Strategy level of bioenergy output
        - lifts the gain in real GDP in 2040 from $6.1 billion to $6.3 billion
        - lifts the improvement in the 2040 trade balance from $1.9 billion to $2.0 billion.
- higher oil prices unambiguously lead to an inferior business-as-usual projection for the New Zealand economy. However, compared to this projection, the modelled gains from the implementation of the Strategy are larger. In the situation of 50 per cent higher real world oil prices, real GDP in 2040 would be $6.5 billion higher with the Strategy, than without it.

[1] As a gauge to the scale of this impact, the direct contribution to GDP of the combined dairy, meat and other food processing sectors in 2010 totalled $6.4 billion.

[2] Again, as an indication of the scale of this impact, the meat processing sector in 2010 directly employed approximately 25,500 full-time equivalent positions.

1.2 Liquid fuels

The significant component of the Strategy is the conversion of wood fibre into liquid fuels through the construction of six processing plants. It should be emphasised there is not a question of 'either' existing bioenergy industry, 'or' liquid fuels. The latter is additive to existing industries in whatever scale is economic at the time. For example, existing industry such as biodiesel production from canola is essential to the success of new liquid fuel supply.

Because of the size of this component and its importance to the Strategy, and the uncertainty of the source material on synthetic fuel production, BERL undertook its own validation of the data. This assessment is presented in this report, but the reader should not draw the inference that liquid fuel production is being promoted more than any other bioenergy sector. The reality is that data for existing industries is well established and known to industry participants. On the other hand, liquid fuel from forests is wholly at the research stage.

The investigation shows that synthetic liquid fuel production from the perspective of the individual operator is at best marginal in terms of financially viability, *given our current knowledge and the assumptions made.* The financial return, although positive, is unlikely to be sufficient for the risk faced by an investor. We note, however, that this assessment could well alter in future years as research into potential technologies proceeds.

1.3 Impact on the external deficit

However, our modelling suggests there are potentially significant wider economic benefits in terms of critical macroeconomic indicators.

Arguably, the macroeconomic impact of the Strategy of greatest significance is that on the trade balance. The past three years has seen the global economy become weary, and wary, of debt. This is likely to be at the forefront of the economic climate for the coming decade. Consequently, economies like New Zealand that have severe structural external deficits will need to reduce their exposure and vulnerability to international debt finance. Our modelling suggests the Strategy can play a significant role in efforts to reduce this deficit through a combination of lower import requirements and increased export opportunities.

Further, this argument is magnified if the potential for the development and export of co-products is successfully pursued and harnessed. Similarly, higher world oil prices would reinforce this argument, as would higher carbon price.

1.4 Other wider benefits

Other wider economic benefits not captured in our modelling could include potentially better rates of utilisation of transport and social infrastructure in regional communities, thereby improving the viability of the provision of such infrastructure. In turn, the viability of the communities themselves may also be enhanced.

In addition, the Strategy enables more productive (and so more efficient) land use options to be developed. This is especially the case where land not appropriate for pasture or other agriculture is currently under-utilised or, indeed, lying idle.

The Strategy also introduces the potential for a more diversified forestry industry. Providing feedstock to the bioenergy industry is one option for this industry and, potentially, reduces its exposure to volatile exchange rate and international log price influences. The increasing role of iwi and other Māori organisations in the forestry industry could well be pivotal in this regard.

Improvements in biodiversity, erosion control and water quality, and reductions in greenhouse gas emissions and wastes can also be argued to arise from the Strategy. However, detailed quantification of these impacts was beyond the scope of this study.

1.5 Concluding comments

The precise quantum of the modelled benefits is likely to remain the subject of conjecture given the uncertainty surrounding key assumptions. We would argue, however, that the modelling suggests that the Strategy, at the least, provides a modest positive macroeconomic impact. Additional benefits, both wider economic and other, imply that this positive impact could quickly magnify to a significant benefit to 'NZ Inc'.

The issue then is how to resolve the disparity between investments that are unlikely to be attractive from the perspective of an individual operator and the desire to unlock the opportunity to reap these benefits on behalf of NZ Inc.

In providing a framework for the future development of the bioenergy sector, the Strategy provides the initial foundation to tackle this challenge. For example, if investments are to make it beyond first base, uncertainty as to the supply of feedstock will need to be addressed.

Without the Strategy, there is little likelihood that this uncertainty would be addressed.

With the Strategy, conversations can be pursued with relevant industry stakeholders.

The pursuit of these conversations will undoubtedly further improve our knowledge of the likely impact of any significant expansion of the bioenergy sector. Moreover, with further interrogation and so measurement of the many dimensions of national benefit, the case for an expansion in the bioenergy sector would likely become more robust.

At this stage of our knowledge though, we believe this study provides evidence of a prima facie case that the expansion of the bioenergy sector envisaged by the Strategy has the potential to yield significant positive benefits to NZ Inc.

2 Introduction

In May 2011 Business and Economic Research Limited (BERL) was commissioned by Bioenergy Association of New Zealand (BANZ) to undertake “a preliminary economic analysis of the baseline scenario set out in the Strategy”[3]. The RFP highlighted two main considerations to be addressed by this study.

- The economic rationale of the vision targets – essentially a ‘macro-economic’ analysis.
- A macro analysis of the economic drivers for primary players, the optimal timing, and the externalities that are derived.

Notably, a micro-economic analysis from the financial perspective of specific parties or sectors is being separately undertaken and is not part of this study. However, the RFP did request identification for each biofuel the economics of producing useful energy from biomass relative to the mineral/carbon potential.

The assignment is to critically examine the Strategy based on its underlying assumptions. It is not the intention of this report to assume anything different from the foundation with which we were provided.

The Bioenergy Strategy contemplates a three-phase approach:

- foundation building (2010 to 1015);
- development (2015 to 2020); and
- expansion (2020 to 2040 and beyond).

In its analysis, BANZ regards the second phase as development of new technology, that is implemented in the third; so groups these together. For the purposes of analysing the economic output of the sector, it is more convenient to regard the strategy as having essentially two time horizons:

- 2010 to 2020 that sees acceleration of business growth in existing bioenergy industries and strengthening the market for conventional current technologies. The ‘Development’ phase from 2015 until 2020 contains emerging technologies.

[3] From Request for Proposal (RFP).

- 2020 to 2040 that sees implementation of the new bioenergy industries in addition to existing industries and considerable growth in the bioenergy sector.

This distinction into two main periods is important. In the first period, existing bioenergy industries are essential to building markets and confidence. These resources include:

- Wood fibre in log, chip or pellet form for boilers and fires;
- Short rotation crops such as miscanthus, pine, salix, etc for solid or liquid fuel;
- Cooking oils, tallow etc for liquid fuels; and
- Municipal and industrial waste for biogas.

Taken together these industries supply some 8.5 percent of New Zealand's consumer energy. It is an important contribution; nearly as large as the share of consumer energy currently taken by natural gas.

In the second and third phases of the strategy, the existing industries expand by a total of 60%. In addition, the Strategy proposes that, by 2040, 30% of the county's transport fuels could be derived from biomass. The result, in total, is that bioenergy could supply more than 25% of New Zealand's projected energy needs.

Historically biomass has been, and remains, the largest renewable source of energy at the global level (by a factor of five over hydro, according to the International Energy Agency (IEA)). It is likely that this will remain the case for the time horizon envisaged in the NZ strategy.

From all projects and industries foreshadowed by the strategy, there will be macroeconomic benefits and other wider economic benefits beyond those that accrue directly to the investor. Such economic benefits include:

- economic growth in sectors of the economy which provide goods or services to industries related to the strategy
- employment across these and associated sectors
- exports and improvement of the trade balance
- improved utilisation of, and so reduced per-unit costs, of infrastructure

- production of what is known as co-products[4], particularly from forest biomass, which would be difficult or expensive to produce otherwise; and

- improved potential returns to currently underutilised land and consequent business changes.

The second class of wider benefits are, in cases, more difficult to quantify. They are uncertain because they depend on decisions presently difficult to forecast, such as where investments are located and how they might be operated. Methods to express in dollar terms these benefits are in their infancy; indeed some are 'intangible' and cannot be quantified. Methods such as 'triple bottom line[5]' are used by leading agencies to assist decision-makers to assess their attractiveness in some cases. Such benefits include:

- greenhouse gas reduction.

- reduced exposure to imported fuel price volatility

- reduction of erosion and nutrient leaching

- improvement in biodiversity

- waste reduction

- risk effects such as the value of real options which are available.

To quantify each of these wider benefits of the Strategy is beyond the scope of this report. This report aims to give the reader some feel for the magnitude of these wider benefits by quoting related research, but without the implication that these results can be directly translated to the Strategy.

BERL's approach to addressing the first class of economic benefits is to use its computable general equilibrium (CGE) model of the national New Zealand economy. It is a multi-industry model separately identifying 60 industries making up the New Zealand economy, as well as the inter-relationships between the industries. This is ideally suited to examining the two questions in the RFP because it identifies all the main sectors in which bioenergy is involved. Note that the existing bio-energy activities, such as wood supply to boilers, are

[4] We note that bioenergy is also a co-product of other economic activity. That is, the feedstock of the energy production is residue from forest harvesting and wood processing.

[5] The triple bottom line approach is also known as "people, plant, and profit" approach. It captures social, economic and environmental components of measuring a project, strategy or organisation's performance and success. The triple bottom line approach is used in studies related to full public cost accounting and corporate social responsibility.

already part of normal business in the economy. BERL has taken the view that this forms part of the 'base case' or 'business-as-usual' situation to which the Strategy would be added. In other words, the Strategy is to produce activities and outcomes that are additional to business-as-usual.

A model of this type captures most of the first group of benefits listed above. Economic activity, employment, exports, the trade balance and increased use of infrastructure are all calculated within the modelling structures (that is, they are 'endogenous'). Other quantified benefits such as co-products must be added to the value of product streams as 'exogenous' parameters[6]. This report will identify these benefits, but it is not possible to break them down into individual product streams. The reason for this is that, although each component of the Strategy is quantified separately at the beginning, they must be grouped into the industry sectors required by the model.

BERL has quantified components of the Strategy using the energy amounts measured in PJ supplied by BANZ.

In addition, sensitivity analyses of the modelling results to changes in two main assumptions. These are the price of imported oil and the market for co-products derived from wood fibre.

This report first provides the context for the analysis in section 3, while the modelling results are presented in section 4. An explanation and discussion of other economic benefits and other wider benefits is presented in sections 5 and 6, using material published by Scion and others.

The very substantial initiative in the Strategy during the Expansion Phase is the conversion of wood fibre into liquid fuels by building six processing plants. This is by far the largest proposal in the strategy as transport fuel is a major issue for New Zealand to face; which also means that it is the most significant opportunity for Bioenergy. It should be emphasised there is not a question of 'either' existing bioenergy industry 'or' liquid fuels. The latter is additive to existing industries in whatever scale is economic at the time. For example existing industry, such as biodiesel production from canola, is essential to the success of new liquid fuel supply.

Because of the size of this sector, its importance to the Strategy, and the uncertainly of the source material on synthetic fuel production, BERL undertook its own validation of the data. This assessment is presented in this report, but the reader should not draw the inference that liquid fuel production is being promoted more than any other bioenergy sector. The

[6] That is, imposed externally on the model by the modeller.

reality is that data for existing industries is well established and known to industry participants. On the other hand, liquid fuel from forests is wholly at the research stage. This assessment of synthetic liquid fuels is provided in sub-section 7.3, following an outline of biomass resources and product options sub-sections 7.1 and 7.2.

3 Context

There are difficulties associated with drawing definitive conclusions on New Zealand's potential as a generator and user of bioenergy, and on the role the bioenergy sector plays in promoting growth and creating economic opportunities. This results from the dearth of evidence of the wider economic benefits of a large-scale bioenergy production and widespread use of biomass and biofuel for heating and transport. We recognise that there is a need to establish and quantify its socio-economic and environmental contribution.

This section presents the context upon which BERL will assess the economic impact of the Bioenergy Strategy in terms of gross domestic product (GDP), employment and other key macroeconomic indicators. First, we will briefly present the trend in the New Zealand's energy sector, and bioenergy industry. Second, we will give an overview of the NZ Bioenergy Strategy, and then set out the framework from which we will be measuring the economic impact of the Bioenergy Strategy.

3.1 Trends in the New Zealand energy sector

New Zealand's primary energy supply is largely sourced from non-renewable sources such as oil, coal, and gas, while the rest is supplied by renewable resources such as geothermal, hydro, wind, waste heat, biogas and biomass. Of the total primary energy supply, non-renewable sources supplies over 60 percent, with oil and gas as leading contributors.

Over the past decade, the composition of primary energy source in the country has been changing. The share of renewables to total primary energy has increased to about 35 percent in recent years, from less than 30 percent in early 2000s. This positive trend is also seen in the production of woody biomass and biogas. Woody biomass and biogas production had grown 2.2 percent per annum since 1990s.

In terms of total consumer demand, New Zealand is a significant user of conventional energy. But, recent trends signal increased use of biogas, solar and wood. The use of these alternatives to conventional energy increased to 10 percent of total consumer energy demand, from a seven percent to nine percent level in the 1990s. This emerging shift to alternative energy types is attributed to availability of alternative energy types to consumers. Although this energy mix is more likely to be used for heating, transport fuel options now includes biodiesel and electricity.

New Zealand remains reliant on conventional energy types. But, future energy transitions are likely to be characterised by a mix of fuel types as emphasis on renewable energy and carbon savings is increasing. For this reason, bioenergy becomes an important prospect for New Zealand.

3.2 The bioenergy industry

Bioenergy is an inclusive term for all forms of biomass and biofuels. It represents one of the most significant opportunities available to meet energy needs and to reduce domestic carbon emissions. At its current state, the bioenergy industry contributes about 8.5 percent of the total energy use in New Zealand. It is at a crucial stage of its development and requires a closer look at the options available, by both the public and private sectors.

The future growth of the industry is likely to be influenced by four predominant factors:

- fuel supply security- Biomass diversifies the total portfolio of fuels used and imported by a country. This can reduce the risks of supply disruptions both in terms of quantity and in price. Biofuels for transport can replace imported oil while solid biomass such as wood pellets for residential heating can reduce dependency for oil imports and diversify fuel portfolio.

- cost effective emission reduction of greenhouse gasses. The demand for biomass is especially growing due to commitments to reduce green house gas emissions and opportunities with the carbon credits and the emissions trading scheme (ETS).

- socio-economic development. Research has indicated the potential strong positive links between developing bioenergy use and local development. Reliable biomass markets can provide a sustainable source of income for local communities engaged in agro-forestry and dairy activities. Furthermore, the development of international market for bioenergy in the future may provide substantial benefits in improving trade balance.

- sustainable management and the rational use of natural resources. Large-scale production and use of biomass for energy will require the use of land and adequate infrastructure. The export market can be the trigger for obtaining benefits, when biomass production can be combined with better agricultural management, and with restoration of degraded and marginal lands. This potential contribution can come from value-added from co-products, investment opportunities and other wider economics benefits of expanding the bioenergy sector.

Given the high expectations for bioenergy on a global and national scale, the pressure on available biomass resources is rapidly increasing. Thus, any market activity aimed at bioenergy production rests significantly on a reliable and sustainable supply of biomass. High prices for fossil fuels have also driven the competitiveness of biomass use. In addition, the development of CO_2 markets, as well as ongoing, learning and technological improvement and subsequent cost reductions for biomass and bioenergy systems, have also strengthened the economic drivers for increasing biomass use, production and eventually, trade.

Another driver that is likely to influence the need to have a reliable biomass resource and develop the bioenergy potential is the development of markets for bioenergy products. This is true for both available residues as well as possibilities for dedicated biomass production such as agro-forestry. The possibilities to export biomass derived commodities and co-products for the world's energy market create an important incentive and reliable supply of biomass

The same is true for biomass users and importers that rely on a stable and reliable supply of biomass to enable investments in infrastructure and conversion capacity.

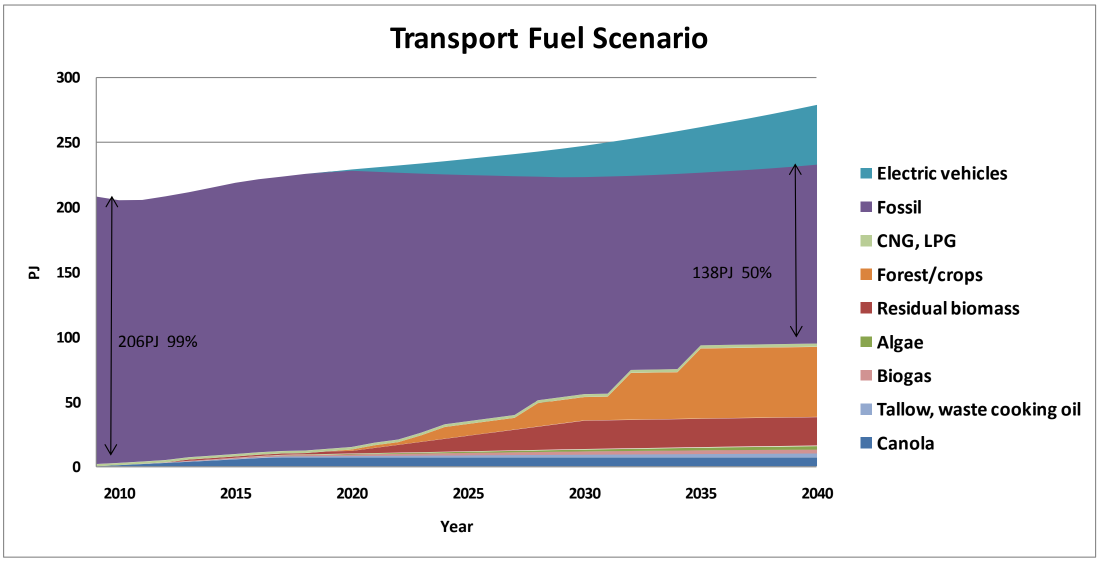
At the moment, the desired stability and sustainability of bioenergy production is far from achieved. Uncertainty as to the availability of biomass resource is a constraint, and reliable domestic and international markets have to be developed for the bioenergy industry to realise its potential. Further, viable bioenergy pathways are expected to continue to be developed in response to rising energy costs. The Strategy sets out potential targets for the sector and pathways for future growth in the industry.

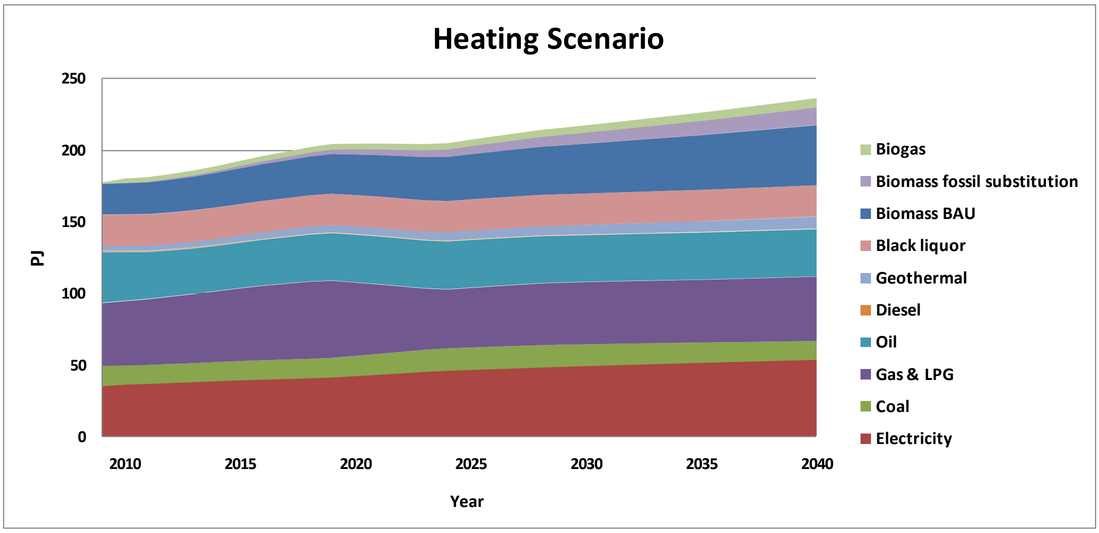
3.3 The NZ Bioenergy Strategy

The New Zealand Bioenergy Strategy covers the development of a nationally significant bioenergy business sector. By realising greater value from the country's existing forest resources and new energy crops, the bioenergy sector is expected to create economic opportunities, environmental gains and social benefits. The Strategy envisions a domestic and international demand driven growth for the bioenergy sector.

Under the Strategy, bioenergy use increases to 25 percent of total consumer energy by 2040. Of this increase in bioenergy consumption, is a 60 percent increase in the use of biomass for heating. Biomass for heating will almost double its current level, from 25PJs to 48.5PJs by 2040. Adopting the Strategy will allow biomass to substitute about 22 PJs of conventional energy types for heating requirements by 2040. The Strategy further conveys the potential of the bioenergy sector to supply 30 percent of the country's future transport fuels needs from biomass. At this scale, the biomass required to produce liquid fuels will require new planting trees and crops in addition to existing stocks of forest residues. These scenarios for transport fuel and heating are depicted in Figure 3.1.

Figure 3.1 Energy output scenarios from NZ Bioenergy Strategy





The Strategy identifies the production of liquid fuels from woody biomass as a major economic opportunity. It proposes a stream of activities to produce liquid fuels from canola, biogas, tallow, residual biomass and forest feedstock. The single largest proposal is in the conversion of residual biomass and forest feedstock to liquid fuels. That is, for the bioenergy industry to supply 30 percent of transport fuels by 2040. Under the transport scenario of the Strategy, products derived from petroleum decline from 206 PJs in 2010 to 138 PJs in 2040. This would require substantial investment and forest harvesting, and thus a need for an economic investigation of the potential value added from t value-added from this new industry.

3.4 The need for wider economic benefit analysis

With oil prices projected to rise significantly, bioenergy production is expected to grow dramatically and become profitable as fuel substitution take place. However, the implications of this growth are less clear. Optimists foresee a world leading to a stabilization of world fuel prices, and that there are growth and development opportunities with an enhanced bioenergy sector. Others are less sanguine. They point to the rise in food prices, insufficient investment, and land use. While recognizing the potential of bioenergy production to provide new markets for farmers and generate employment, they are concerned that bioenergy plantations will take land from its current productive uses.

The environmental implications of bioenergy production are also the subject of debate. Bioenergy has often been pointed to as a means for reducing GHG emissions. This is because plant biomass captures carbon from the air. Conversion of this biomass to bioenergy and subsequent combustion returns the carbon to the air, thus creating a cycle. However, this cycle is not completely closed, as bioenergy require energy for their growth, processing, and transportation, thus implying positive net emissions. Scion (2009) calculates that the energy balance of different bioenergy pathways. The evidence indicates that bioenergy, particularly those derived from the more efficient crops, are a substantial net energy contributor.

Other concerns regarding environmental impacts, including GHG emissions, are related to land use. GHG reduction from bioenergy use compared with that of fossil fuel depends upon land use and the source of land used for bioenergy production. In particular, clearing new land for bioenergy production can generate large emissions of GHGs (particularly CO2) due to burning and decomposition of organic matter. While increasing bioenergy production has generated considerable discussion on the potential implications for growth and development, such debates are supported by relatively few quantitative economic analyses.

In this context, the current analysis is useful as it provides information that will enable us to gain better understanding of the wider economic impact of optimising the use of biomass resources and enhancing bioenergy production. A wider economic benefit analysis reflects many of the key aspects of the debate outlined above. Highly relevant issues can be grouped into economic, social and environmental dimensions. The economic dimension includes macroeconomic impact on national growth, employment and trade balance, land use, infrastructure and other investments; the social dimension covers institutional arrangements in production (plantation versus crop growers), land area expansion, reduction of resources available for food production; and environmental dimensions, which includes carbon saving, biodiversity, and waste reduction.

In order to capture the economy-wide impact of a much larger bioenergy industry as set out in the Strategy, we utilise an economic modelling framework that captures the macroeconomic gains from an enhanced bioenergy. The macroeconomic impact of the Strategy is measured in terms of GDP, employment, exports, consumption and trade balance. The result of this analysis is presented in section 4. We then discuss the other economic factors arising from the Strategy in section 5, and a selection of the social and environmental dimensions in section 6.

4 Macro-economic impacts

The main objective of this analysis is to provide a quantitative insight into the wider-economic benefits of the Strategy. Specifically, the analysis covers quantification of the macroeconomic impact of increasing bioenergy output for heating and transport. Gross Domestic Product (GDP), employment, trade balance and consumption effects are modelled using a computable general equilibrium model.

The macro level analysis focuses on how increasing bioenergy output for heating and transport can impact directly and indirectly on the economy. The impact on standard macroeconomic indicators such as the level of economic output (GDP), consumption, employment, export volumes, and the trade balance can be measured.

The following sections briefly describe the modelling tool used (a computable general equilibrium (CGE) model), the phases of the Bioenergy Strategy to be modelled, and the modelling results.

4.1 CGE model and what it does

Economists use economic models to simplify and understand the behaviour and interrelationships between the various industries and participants in the economy. The CGE is a standard economic model widely used in estimating the impact of a change in one industry on other industries and the whole economy.

The CGE model allows us to perform simulations to investigate the effect of particular events (or ‘shocks') on macro-economic variables (e.g. GDP and consumption) and industries. For example, we could estimate the changes in macro-economic variables resulting from a:

- change in population growth, which affects household spending growth;
- technological breakthrough that results in increased productivity in particular industries;
- world events (e.g. political turmoil) that reduces the demand for our exports;
- change in policy (e.g. increased government spending on hospitals), and;
- changes in the price of commodities (e.g. milk solids or oil).

The model itself is made up of data and equations, which depict the workings/flows of economic transactions in an economy. The relationships captured within the model derive from input-output tables[7], coupled with national account data (GDP) on household and government consumption, investment, exports and imports.

Behavioural equations are imposed to reflect consumers' and firms' responses to demand, supply and price changes. The model mimics changes in the demand, supply and price of goods, services, commodities and labour and capital resources such that all markets remain in equilibrium. In this context, equilibrium is the situation where the supply of an item is equal to its demand. The CGE model calculates the new equilibrium between the demand and supply of factors of production, and goods and services when there is a change or shock in one industry in the model. That is, producers, consumers, workers and investors must adjust their supply or demand until they are satisfied with the current market prices and quantities.

In order to assess the interrelationships between changes in one industry on the rest of the economy, these models follow various neoclassical assumptions to ensure the impact can be measured. These assumptions are:

- **Market-clearing prices** – In line with the condition for equilibrium, prices adjust to their 'market-clearing' level; that is to the level where demand in a particular market equals supply in that market.
- **Zero (pure) economic profit** – Zero economic profit means the return to capital invested in a industry are equivalent to the returns to capital available in alternative investment opportunities.
- **Cost-minimising firms** – Firms are assumed to shift between alternative production processes in order to minimise the unit costs of production of goods and services. The alternative choices are between relatively labour-intensive or capital-intensive processes, as well as between imported or domestically-sourced material inputs.
- **Utility-maximising consumers** – Consumers are assumed to shift their demand for goods or services in response to price and income changes in order to maximise their individual well-being.

For the purposes of this study, the CGE model measured the economic impact of the bioenergy industry expanding its production levels consistent with those of the different phases of the Strategy.

[7] Input-output tables indicate how much each industry requires of the production of each other industry in order to produce each dollar of its own output. It shows how the output of one industry is an input to each other industry.

4.2 Baseline business-as-usual (BAU) or base case

Table 4.1 presents the base case indicators. These indicators describe the key macroeconomic indicators up to 2040 given current conditions and policy initiatives. In other words, the base case should be viewed as a continuation of 'business-as-usual', or BAU. The BAU indicators are comparators, against which the outcome of modelling of the Strategy can be compared.

Note that in the BAU, production by the bioenergy sector, mainly biomass and biogas for heating, continues to grow at rate of about two percent per annum. This takes production by the bioenergy industry to about 50.2PJs in 2040, or approximately double the level of output in 2010.

Table 4.1. Business-as-usual (BAU) macroeconomic indicators

	2010	2020	2024	2028	2032	2035	2040
GDP (2010 $m)	187,302	230,497	259,491	299,372	355,794	414,169	509,223
%pa from 2010		*2.1*	*2.4*	*2.6*	*3.0*	*3.2*	*3.4*
GDP per capita (2010 $)	42,941	48,316	54,393	62,753	74,580	86,816	106,741
%pa from 2010		*1.2*	*1.7*	*2.1*	*2.5*	*2.9*	*3.1*
Consumption	109,491	136,775	154,366	178,323	211,518	245,348	304,559
Exports	52,425	64,870	73,165	84,697	101,294	118,599	145,667
%pa from 2010		*2.2*	*2.4*	*2.7*	*3.0*	*3.3*	*3.5*
Factor cost GDP	164,243	200,992	225,970	260,322	309,031	359,570	441,158
%pa from 2010		*2.0*	*2.3*	*2.6*	*2.9*	*3.2*	*3.3*
Trade balance ($m)	2,735	3,535	3,135	2,735	2,535	2,535	2,535
Employment (000s)	1,811	2,000	2,073	2,149	2,227	2,288	2,393
%pa from 2010		*1.0*	*1.0*	*1.0*	*0.9*	*0.9*	*0.9*
Real wage rates	100.0	106.4	112.6	122.1	136.3	151.3	171.5
Trade balance (%GDP)	1.46	1.18	0.85	0.59	0.42	0.34	0.25
Govt balance (%GDP)	-2.59	-2.66	-2.55	-2.46	-2.37	-2.32	-2.31

all values, unless otherwise stated, expressed in 2010$m

4.3 Timing of 'shocks' modelled

To determine the appropriate 'shocks' to impose on the model, data was gathered from different levels of bioenergy production envisioned in the Strategy. Production targets for biomass, biogas and liquid fuel (canola; residual biomass; algae; tallow, wastes and cooking oil; and forest/crops) were obtained from BANZ. These production values are converted into NZ dollar terms using projected value per GJ base estimates reported in the Scion

Bioenergy Pathways report in 2008.[8] These production values were imposed on the model in each of the relevant years, according to the phases of the Strategy.

4.3.1 Foundation and building phase (2010-2015)

This phase of the strategy focuses on preparing the bioenergy industry for growth based on existing resources, markets and processes. Activities under this scenario include promotion of mature bioenergy technologies, positioning of biofuels in the market, and generation of wider public and private investor support for the bioenergy industry. Increases in bioenergy production for heating are modest.

By 2015, bioenergy for heating composed of biomass production is expected to increase by 14 percent from its 2010 level to 25 PJs, and biogas up 15 percent to 3.4 PJs.

4.3.2 Development phase (2015-2020)

Once the bioenergy industry has gained solid position in the energy market, and investment commences, the development phase begins. Among the investment envisioned in this phase is the building of wood processing mills and technical advances that will allow more efficient harvesting of forest residues. This is in response to increasing wood fuel demand and export of wood chips and pellet. In turn, increasing economies of scale due to the expansion of productions of wood fuels for domestic use and export will encourage more forest-owners to invest in energy crops as a co-product.

Total bioenergy production is expected to increase by a further 15 percent from Scenario 1. Biomass production for heating reaches 28 PJs. Transport fuels from bioenergy will significantly increase to 7.6 PJs, of which over 70 percent is from canola, 13 percent from residual biomass while the rest are from biogas and tallow/waste cooking oil.

4.3.3 Expansion phase (2020 to 2040 and beyond)

In this phase, the bioenergy industry is expected to experience significant increases in the production of energy crops as well as of related co-products. Among the milestones achieved at this phase is the inflow of investments into bio-refineries for the production of transport fuels and other biomaterials. While bioenergy technologies are expected to mature

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[8] The value per GJ of output by bioenergy pathway is presented in Table 9.1 in the Appendices section. The values are adjusted based on petrol price and producer-price indices to reflect price changes from 2008 and 2010, and to project value per GJ up to 2040. The projected price is then cross-referenced with MED projections reported in the 2010 Energy Outlook. 2010 biodiesel price is estimate d at 103 c/l or $26.4/GJ. Value per GJ of other energy products such as coal, petrol, oil & gas, and electricity used in the CGE modelling is presented in Table 9.1 in the Appendices section.

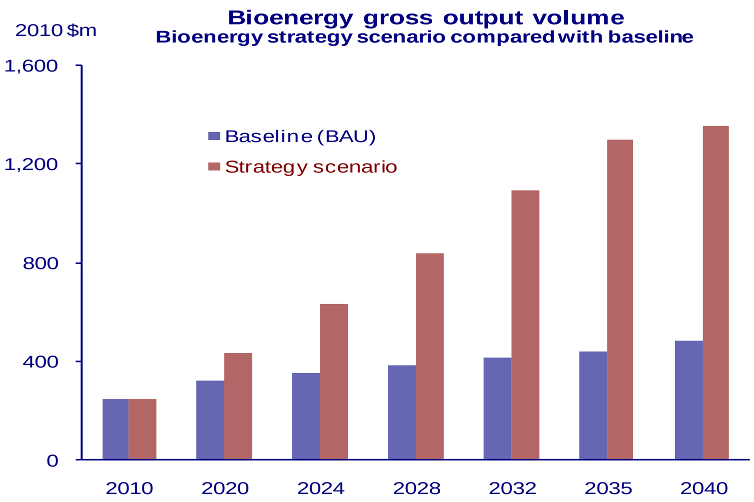
at this phase, on-going research and development on biomaterials and other co-products is likely to support the expansion of the bioenergy industry.

4.4 Results

4.4.1 Base case compared with the Strategy

In 2010, the industry's output is estimated at 25.9PJs, with an estimated value of $249 million[9]. This is about five percent of the 2010 gross value of the forestry and log industry (about $4.5 billion).

Figure 4.1 Comparison of gross output volume



Assuming business-as-usual conditions (i.e. growth, technology, energy policies, domestic demand for and supply of energy) to continue up to 2040, bioenergy industry output is projected to increase to 50.2PJs, with a real value of over $483 million[10].

Under the Strategy, bioenergy production more than quadruples the 2010 level in 2040, from 25PJs to 141 PJs (about $248 million to $1.3 billion in real 2010$). This level of output is about 25 percent of the total consumer energy. The Strategy also sets out that real gross output of the bioenergy sector grows faster (5.8 percent per annum) compared to the baseline case (2.2 percent per annum).

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[9] The total bioenergy sector produced 47.6PJs in 2010. Of this total, 21.7 PJs was black liquor. Black liquor is a waste product generated when wood chips are boiled to produce pulp. The black liquor used contains, apart from process chemicals, organic compounds (lignin) that are burned to produce energy, while the black liquor is recovered. Most of this energy is used directly in the pulp production process. The Strategy leaves the production of black liquor at 21.7PJs annually to 2040. Consequently, to modelling of the macroeconomic impacts we focus on the bioenergy sector excluding black liquor, as this is the component of the sector that is projected to expand in the Strategy scenario.

[10] All values, unless otherwise stated, are expressed in terms of <u>real</u>, or constant-price, 2010$ values.

The overall findings suggest that the development and expansion of the bioenergy industry can potentially generate GDP, employment and export gains for New Zealand. Economic benefits from trade and household consumption spending are also generated. The positive impact on the national economy accrues once the expansion phase of the Strategy has commenced.

4.4.2 Impact on the wider economy

Table 4.2 presents key macroeconomic indicators with the establishment of the bioenergy industry, assuming enhanced production levels for heating and transport. The estimated impact on the macro-economy suggests that the Bioenergy Strategy positively contributes to the national economy. The GDP and employment gains suggest the potential of the bioenergy sector to create wider economic gains from development of co-product.

Table 4.2 Macroeconomic indicators with Strategy – difference from BAU

	2020	2024	2028	2032	2035	2040
GDP (2010 $m)	418	1,082	2,025	3,521	5,026	6,090
GDP per capita (2010 $)	88	227	424	738	1,053	1,277
Consumption	196	497	905	1,536	2,158	2,610
Exports	94	276	589	1,129	1,703	2,186
Factor cost GDP	334	886	1,675	2,936	4,213	5,122
Trade balance ($m)	63	198	446	892	1,380	1,942
Employment (000s)	3	7	12	20	25	27
Trade balance (%GDP)	0.02	0.05	0.09	0.14	0.18	0.19
Govt balance (%GDP)	0.03	0.08	0.12	0.18	0.21	0.21

all values, unless otherwise stated, expressed in 2010$m

In summary:

- the bioenergy sector (excluding black liquor) in 2010 produced almost 25.9PJs of output at a gross value of $249m.
- the model results indicate that the development and expansion of the bioenergy sector would increase national GDP up to $6.1 billion by 2040. This contribution to GDP is about 1.2 percent above the 2040 baseline business-as-usual GDP.

- a 'business-as-usual' projection of the New Zealand economy, sees the bioenergy sector grow by approximately 2.2 per cent per annum to 2040, taking production to 50.2PJs, at a real gross value in terms of constant 2010$s of $483m.

- the Strategy sees the bioenergy sector (excluding black liquor) expand to 140.6PJs by 2040, or an expansion of 180 per cent on the 2010 level, substituting for energy from existing (or traditional) sources.

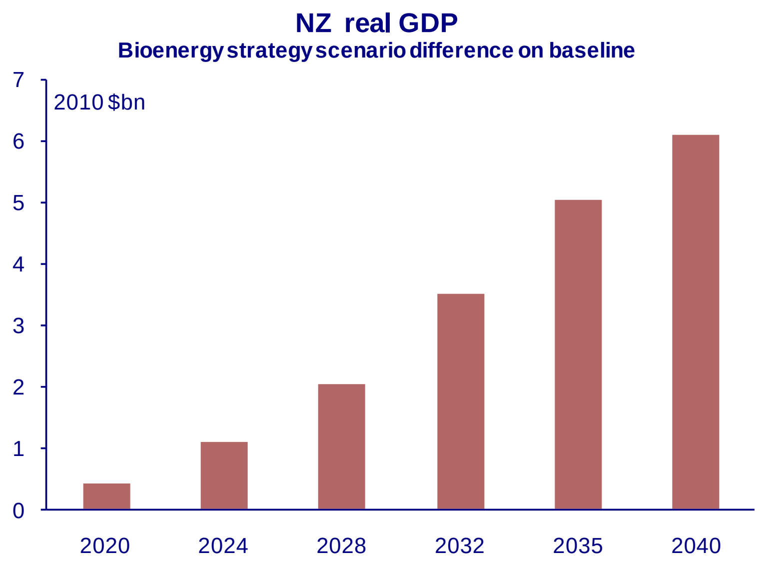
- the implementation of the Strategy adds 1.2 per cent to the business-as-usual projection in terms of annual GDP in 2040; that is, real GDP measured in 2010$s would be $6.1 billion more with the Strategy, than without it.

  * the additional GDP includes a 0.9 per cent addition to real household consumption spending; 1.5 per cent on export volumes; and employment for an extra 27,000 full-time equivalent positions

  * the trade balance improves by more than $1.9 billion.

As for all model-based experiments, these findings are contingent on the assumptions within which the 'shock' is implemented. Of these assumptions, arguably the most critical is the assumption that there are sufficient capital resources attracted to the sector to enable the expansion in bioenergy output. Consequently, Table 4.2 lists the Strategy's contribution to the national economy in terms of GDP and other main macroeconomic indicators.

Figure 4.2 NZ real GDP with Strategy – difference from BAU



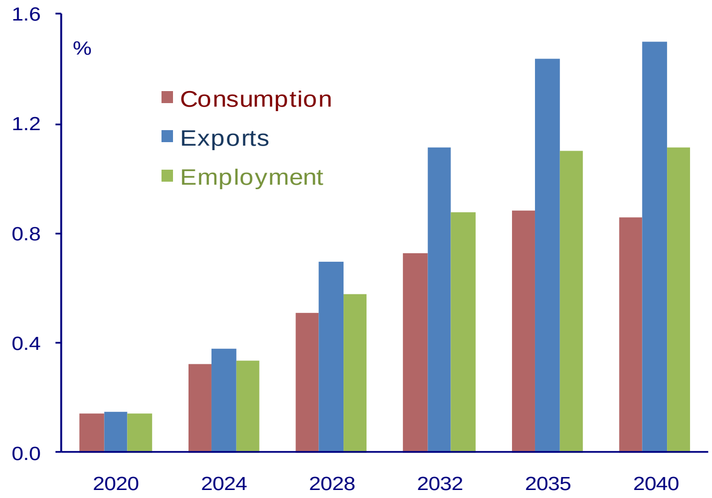
At the end of the development phase of the Strategy (2020), the bioenergy sector is expected to have established a sound foundation in New Zealand's energy market, and investments in wood processing mills and technical advances that will allow more efficient harvesting of forest residues. These activities would enable the bioenergy sector to meet its output targets and contribute to national GDP. By 2020, the Strategy's value-added to the national economy is about $418 million. This contribution to GDP is equivalent to about three percent of the total GDP of New Zealand's manufacturing sector in 2010.

GDP gains from the Strategy jumps up to over a billion dollars in 2024 and up to $6 billion in 2040, once investments to build bio-refineries and other related infrastructure are made.

Of this gain in GDP, the value added from the bioenergy and forestry sectors is estimated to be $313 million and $188 million in 2040, respectively. Figure 4.2 shows the increase in GDP contribution from the Strategy due to economies of scale gained by building bio-refineries as per sequence identified in Section 7.3.3.

In line with the GDP gains, there are also additional employment opportunities created by the increasing bioenergy output. By 2020, the bioenergy sector is expected to provide employment to about 3,000 FTEs. This contribution to national employment is about two percent of total FTEs in the primary sector in New Zealand.

Figure 4.3 Selected indicators with Strategy – difference from BAU



Increasing output in the bioenergy sector is projected to contribute as much as 27,000 FTEs (about 1.1 percent of the national employment) on the 2040 baseline. At this stage, the bioenergy sector supplies about 25 percent of the projected total consumer energy in New Zealand.

The addition to consumption spending is relatively small until 2028, but starts to kick-in by 2032 to 2040. The increase in consumption spending grows to total an extra $2.6 billion in 2040, which is the equivalent of a 0.9 percent addition on the baseline level of consumer spending.

The Strategy's impact on exports is proportionately greater than the impact on consumption and employment. Growth in export volumes during the early periods of the expansion phase of the Strategy is almost flat but begins to pick up by 2032 from the baseline level. By 2040, the Strategy contributes an additional $2.1 billion to New Zealand's export volumes, equivalent to an extra 1.5 percent on the BAU.

Additional exports under the Strategy contributes further to New Zealand's over-all trade performance, with the trade balance (exports net of imports) improving by $2 billion (in current $ terms), or about 0.20 percent of the national GDP in 2040.

4.4.3 Short-term implications of the strategy

In the year 2020, the results show that the contribution of the Bioenergy Strategy to the wider economy is approximately $400 million per year. In that year, the main bioenergy components are into the heating market and canola for liquid fuels. The large-scale production of liquid fuels from forests has not commenced. If the production of liquid fuels from forests were to be excluded from the analysis, the value of this contribution would rise consistent with the growth in oil prices and of the output of this component of the bioenergy sector.

This result is therefore useful because it demonstrates the contribution of bioenergy that would be sustained if the large scale production of liquid fuels from forests were to be abandoned. BERL has not explicitly modelled this scenario, but the result indicates that a limited Strategy does have economic value.

4.5 Sensitivity analysis

There are two assumptions incorporated in the above analysis of the impact of the Strategy that are tested below.

Firstly, the above analysis assumes no additional products are developed alongside the expansion of the bioenergy sector. The development of co-products is, arguably, central to the potential contribution to the New Zealand economy arising from a significantly larger bio-energy sector.

Secondly, higher world oil prices could also change the nature of the impact of the Strategy on GDP and other macroeconomic indicators.

In summary, testing the influence of these two factors on the model results of the impact of the Strategy yields the following.

- gains are further improved where the expansion of bioenergy output, in line with the Strategy, is accompanied by the development and export of co-products.
  - it is undoubtedly difficult at this stage to quantify the potential of these co-products.
  - for indicative purposes though, a model scenario that assumes additional exports from bioenergy co-products equivalent to (an, arguably, conservative) 10 per cent of the value of the Strategy level of bioenergy output
    - lifts the gain in real GDP in 2040 from $6.1 billion to $6.3 billion
    - lifts the improvement in the 2040 trade balance from $1.9 billion to $2.0 billion.
- higher oil prices unambiguously lead to an inferior business-as-usual projection for the New Zealand economy. However, compared to the inferior business-as-usual projection, the modelled gains from the implementation of the Strategy are larger. In the situation of 50 per cent higher real world oil prices, real GDP in 2040 would be $6.5 billion higher with the Strategy, than without it.

4.5.1 Introduction of co-products

Large-scale bioenergy production is expected to make co-products, which contribute to the economic value of the Strategy. Co-products are also seen as pivotal in creating a sustainable and viable 'bioeconomy' in New Zealand. However, the precise quantum of the gains are difficult to estimate given the current state of technology, as well as the uncertainty as to which products would be developed. The range of potential co-products is discussed in sub-section 5.1 below.

To gauge some indication of potential gains to main macroeconomic indicators from the development of co-products, we model the impact of an additional export revenue equal to 10 percent of the Strategy value of bioenergy production. In volume terms, this amounts to an extra annual $135m (measured in 2010$s) in direct export revenue by 2040. While this is arguably a conservative approach, it provides an indication of the sensitivity of the model results to assumed revenue from co-products.

Table 4.3 summarises the impact of the introducing the contribution of co-products to the economic value of bioenergy production.

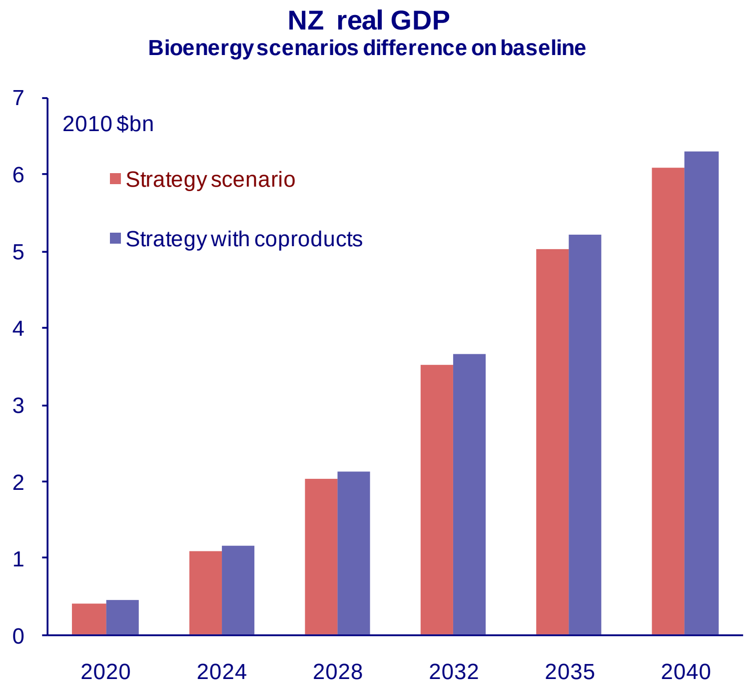
Table 4.3 Selected indicators with Strategy plus co-products – difference from BAU

	2020	2024	2028	2032	2035	2040
GDP (2010 $m)	463	1,154	2,129	3,669	5,211	6,295
GDP per capita (2010 $)	97	242	446	769	1,092	1,320
Consumption	219	532	954	1,604	2,242	2,703
Exports	118	313	644	1,206	1,799	2,291
Trade balance ($m)	78	224	486	953	1,459	2,037
Employment (000s)	3	7	13	20	26	28
Trade balance (%GDP)	0.02	0.06	0.10	0.15	0.19	0.20
Govt balance (%GDP)	0.04	0.08	0.13	0.19	0.22	0.22

all values, unless otherwise stated, expressed in 2010$m

Table 4.3 lists results for main macroeconomic indicators from extra revenue from co-products accompanying the increase in bioenergy production, relative to the business-as-usual case.

Figure 4.4 Strategy plus co-products impact on GDP – difference from BAU



In 2020, GDP increases by $463 million (about 10% higher than the impact of the Strategy scenario on GDP of $418 million). The impact of the Strategy with co-products rises to $6.2

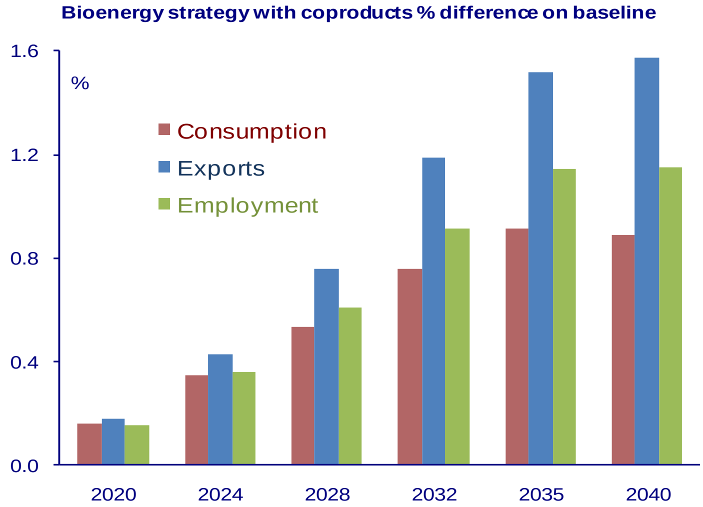
billion in 2040, making the estimated additional GDP from the inclusion of co-products at $205 million in 2040. This addition is illustrated in Figure 4.4.

Figure 4.5 shows the additional employment, consumption and exports accruing from the Strategy alongside the development of some co-products. Employment, consumption and export impacts are positive, though marginal. Compared to the other two economic indicators, increases in export volumes are the most encouraging.

Total export receipts increase by 1.6 percent (about $2.3 billion) from the baseline in 2040. In the same period, employment generated totals 28,000 FTEs, up 1,000 FTEs compared to the scenario without the co-products contribution.

With additional employment generated, household spending is stimulated. Growth in consumption spending is modest, but slightly higher in this scenario. Additional consumption spending is close to half of the total real GDP gain ($6.3 billion) in 2040. Unlike the impact on export volumes, consumption and employment effects then to ease up in 2040. This trend flows on from the narrowing of scale effects reflected in the estimated GDP gains over the same period.

Figure 4.5 Selected indicators with Strategy plus co-products – difference from BAU



Overall, enhanced bioenergy production (i.e. an expansion of the bioenergy sector accompanied by the development of a range of co-products) has a positive impact on the wider economy. The Strategy's impact is anchored on laying the foundations and requisites that would allow the bioenergy sector to achieve its potential to contribute to economic growth.

4.5.2 *Sensitivity to oil price*

Imposing a higher (by 50%) world oil price on the modelling exercise unambiguously leads to an inferior outcome for the BAU New Zealand economy. However, implementing the Strategy onto this inferior BAU outcome leads to relative gains to the Strategy as listed in Table 4.4.

Table 4.4 Selected indicators with Strategy and higher oil price – difference from BAU

	2020	2024	2028	2032	2035	2040
GDP (2010 $m)	218	1,405	2,464	4,138	5,840	6,480
GDP per capita (2010 $)	46	294	516	867	1,224	1,358
Consumption	99	634	1,087	1,788	2,486	2,753
Exports	17	376	739	1,354	2,011	2,310
Trade balance ($m)	-2	269	559	1,071	1,634	1,994
Employment (000s)	1	9	15	23	29	28
Trade balance (%GDP)	0.00	0.07	0.11	0.17	0.21	0.20
Govt balance (%GDP)	0.02	0.10	0.15	0.21	0.25	0.22

all values, unless otherwise stated, expressed in 2010$m

It is noticeable that with the situation of higher oil prices in the baseline, the gains to the Strategy in terms of GDP and other macroeconomic indicators are larger than those discussed in sub-section 4.4 above. In particular, the $6.1 billion gain to the Strategy in 2040 GDP lifts to a nearly $6.5 billion gain in the case of world oil prices being 50% higher. Similarly, additional employment as a result of the Strategy is also greater in the case of higher oil prices. Note that while the gain to export volumes is also greater, the direct impact of higher oil prices on the trade balance negates some of this additional gain.

The stability of the model results to significant changes in the world oil price confirm that the estimates of the wider macroeconomic benefits to the Strategy are sound. However, the picture for the microeconomic benefits and costs for individual projects remains needs to be assessed on a case-by-case basis.

Further, it should be noted that these findings assume that, consistent with a standard general equilibrium approach to the analysis, the price of bioenergy output is set in line with costs of production. This is in line with the expectation that the long-term development of an international market for biofuels would see the world price for biofuels output align to its costs of production, rather than to the world price of oil.

5 Other economic benefits

A major investment in bioenergy using wood biomass as the feedstock will have significant effects beyond the limits of the project, which need to be included in the analysis. The effects of an investment are often not limited to direct benefits to users and indirect benefits that may be captured by an analysis that incorporates only first level effects.

The main wider economic changes, which specific bio-energy investment projects cause in their directly affected geographic or industrial area of the economy, are in economic behaviours. The four main categories affected are:

- Location behaviour, and thus land use, urban form and urban density
- Business behaviour which changes the profile of industries in a given location
- Residential and labour participation behaviour
- Demand for and usage of transport modes and other infrastructure services.

Changed business behaviour will be particularly important in enabling new businesses based on new materials. These businesses could potentially yield substantial additional value to the direct impacts of the Strategy itself. These industries would be based on materials arising as co-products from the processing of large quantities of wood, and we shall examine this aspect in detail. Conservative assumptions as to the quantum of benefits from such co-products were incorporated in the modelling scenarios, as described in section subsection 4.5.1 above.

This section discusses the potential range of developments in the co-products area, as well as effects on infrastructure and land use and on greenhouse gas emissions.

5.1 Co-products

One of the most significant new wider benefits of the Strategy is that it creates a platform to manufacture co-products from wood. Wood is a complex biological substance. It contains chemical products that have been used for centuries. Isolating these products so they can be sold may be expensive if viewed as a ‘stand-alone’ commercial process.

But, when the substrate of wood is broken down during the process of fuels production, materials are liberated as a by-product at low marginal cost. This is particularly true when the bio-conversion processing route is followed, in contrast to the thermo-chemical route. In the latter, the substrate of the wood is destroyed during the process of gasification and chemicals obtained are in the nature of by-products from this gasification or subsequent gas syntheses.

During the bio-conversion route by contrast, the wood is converted to pulp, and materials within the wood maintain their integrity. They may be separated out prior to the pulp undergoing processing to liquid fuels. The International Energy Agency (IEA) has provided a useful summary as part of their bio-refinery Task 42[11] project.

Some insight into what is possible may be gained by examining a stand-alone plant which is operating as a pilot to produce valuable wood-based products. Lignol Energy Corporation[12] of Canada is operating a 1 tonne per day pilot plant. It produces ethanol, HP-L lignin, furfural, and other chemicals. A 'demonstration bio-refinery' rated at 100 to 300 tonnes per day is being constructed. They state the potential market for HP-L lignin resin is bigger than US$6.3 billion. A commercial plant of up to 2000 tonnes per day wood feedstock is being planned.

For the purposes of estimating the wider economic benefit of co products reference may be made to the existing Borregaard sulfite mill[13] in Sarpsborg, Norway, which has operated for many years. It produces a mixture of speciality cellulose 56percent, lignin and vanillin 30 percent, and bio-ethanol 25 percent. Of the incoming biomass, 90 percent is used for marketable products rather than the lignin being used for fuel.

A typical yield, for 1000 kg of wood, is:

- 400 kg speciality cellulose, also known as 'dissolving pulp', for construction materials, cosmetics, food, paint/varnish and as a cotton substitute in textiles
- 400 kg lignin for concrete additives, animal feed, dyestuff, oil well additives
- 50 kg ethanol for car care, paint/varnish, pharmaceuticals
- 20 kg yeast for food and protein feed for animals
- 3 kg vanillin food , protein feed and pharmaceuticals

Possible values of these products are

[11] IEA Bioenergy Task 42 Bio-refinery, see http://www.iea-bioenergy.task42-bio-refineries.com/publications/?eID=dam_frontend_push&docID=58

[12] http://www.lignol.ca/

[13] http://www.borregaard.com/

- speciality cellulose (i.e. dissolving pulp) $1,500/tonne [Price at the end of 2009 was US$1,320/tonne, but spot prices have reached US$2,400/tonne and lows of US$550/tonne in 2008]
- Lignin (lignosulponates) $1,400/tonne [US$200 – 2,300/tonne depending on grade and purity]
- Ethanol $1,134/tonne [US$2.70/US gallon landed from Brazil]
- Yeast $1,000/tonne
- Vanillin $16,000/tonne [US$5.9/lb]

Using these prices, 1 OD[14] tonne of wood would yield chemical products worth $1,285. By comparison, export pulp from 1 OD tonne is worth $462. We are not suggesting here that it is preferable to make co-product material rather than pulp. Markets do not exist for substantial quantities of the materials listed above. Rather, there is the indication that, where co-products can be separated during the production of bioenergy at low marginal cost, they have the capacity to add value. Such value can be legitimately added to the revenue of bio-energy and will increase as markets for materials develop. In time, these products could be worth at least 10 percent of the total product stream.

A route presently exists to extract co products from wood, not necessarily related to bioenergy; to process wood before sending it to the pulping process. Known as 'Value prior to Pulping' (VPP), the process extracts hemicelluloses, which makes ethanol, acetic acid etc. Pulp is then produced in the normal way. Essentially an existing or new pulp mill in New Zealand would be designed to implement VPP, which provides co-products and enhances the value of the mill. This option is likely to be attractive in New Zealand.

It is beyond the scope of the BERLs report to fully investigate and put a value on possible co-products for the bioenergy strategy. Our objective here is to point out that it is essential to include co-products in any examination of a biofuel industry, and actively seek the means to maximise the production of valuable products. For indicative purposes, we have provided a (arguably, conservative) measure of the potential wider economic benefits of the development of co-products through our modelling results presented in sub-section 4.5.1 above.

[14] Oven-dried.

5.2 Infrastructure

Forestry is a regional activity involving large land areas and rural communities. In cases where there is population decline in these communities, the trend could be arrested or reversed through the establishment of forestry or related processing activities. Communities involved in forest maintenance and harvesting may see their population enhanced. There are direct benefits to the housing market arising from greater demand for dwellings. Also greater usage of community services such as medical and sports facilities brings the benefit of a more secure outlook for such services. The diversity of both the usage pattern and the client base is improved.

For forestry workers who prefer living in larger communities, greater travel distances become the norm. This is now evident in New Zealand where employees are known to live in Taihape, but travel to work in forests remote from the township. These communities benefit from the greater spending of such employees compared to the previous residents who are frequently on lower incomes.

There is also a positive effect on road utilisation. Roads around potential forests, by their nature, are typically under-utilised. The transport requirements of both workers and forest materials will raise the utilisation of roads. Increased utilisation reduces the per-unit costs, improving the longer-term viability and so economic performance of the roading network. There would also be greater utilisation of other networks including electricity and telecommunications.

5.3 Land use

Land use change associated with bioenergy production is currently less than one percent of global agricultural land (IEA Bioenergy, 2011).[15] In New Zealand, bioenergy production is supported largely by the forestry sector. Woody biomass and biogas largely use forest residues and use little pastoral or horticultural land. However, land use is a concern when planting more energy crops and more forests are necessary for the Strategy.

Enhanced bioenergy production can lead to both direct and indirect land use change. Direct land use change involves changes in land use on the site used for bioenergy feedstock production; such change includes changes in crop rotation patterns, conversion of pasture land, and changes in forest management or the conversion of natural ecosystems. Indirect land use change refers to the changes in land use that take place elsewhere as a consequence of the bioenergy production.

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[15] Göran Berndes (2011). *Bioenergy, land use change and climate change mitigation*. IEA Bioenergy.

Implementation of the Bioenergy Strategy requires general investment in roads, transport and other social infrastructures, as opposed to the dedicated investments normally associated with resource extraction. The improvements to social infrastructure as a result of bioenergy investments can often result in a change in value of the land with consequent positive business changes. A recent research by Ascari and Opus International in peri-urban Auckland shows that increases in accessibility to areas generate increases in land values in these areas. This can give a sound, observable measure of the market-perceived benefits from investments to improve accessibility.[16]

To some extent the increase in accessibility is a direct benefit from investment on forestry and bioenergy. However, it is not yet recognised as an approach to measuring the actual benefits, and so it is included as a wider economic benefit.

Regional land use patterns will tend to change. Scion notes that[17] over 60 percent (9,288,000 ha) of New Zealand's available productive land is hill country which is unsuitable for cropping and 23 percent (3,600,000 ha) is unsuitable for pasture. The use of steeper lands to grow biomass via forests is a potentially large-scale solution to carbon neutral energy supply, including liquid fuels.

Furthermore, biofuels from arable crops have low yields in terms of litres per ha (land-use efficiency). For example, canola could yield 1360l/ha/pa of biodiesel, whereas forests could potentially produce the equivalent of 2400 l/ha/pa of liquid biofuels (diesel equivalent).

Scion notes[18] their land use projections are that Otago and South Canterbury have large areas of land identified for afforestation. Manawatu/Whanganui and Gisborne and southern Hawke's Bay also have large areas of land potentially suitable for afforestation. However, if the land selection is based on clustering of forest to meet energy demand, the usage patterns would be different. Scion's selection was based on obtaining low productivity land that did not compete with high value food production.

Another indirect benefit arises from the change in the pattern of the earning capacity of the land. A diversified income stream for the land-owner is provided which improves business resilience and lowers its systemic risk.

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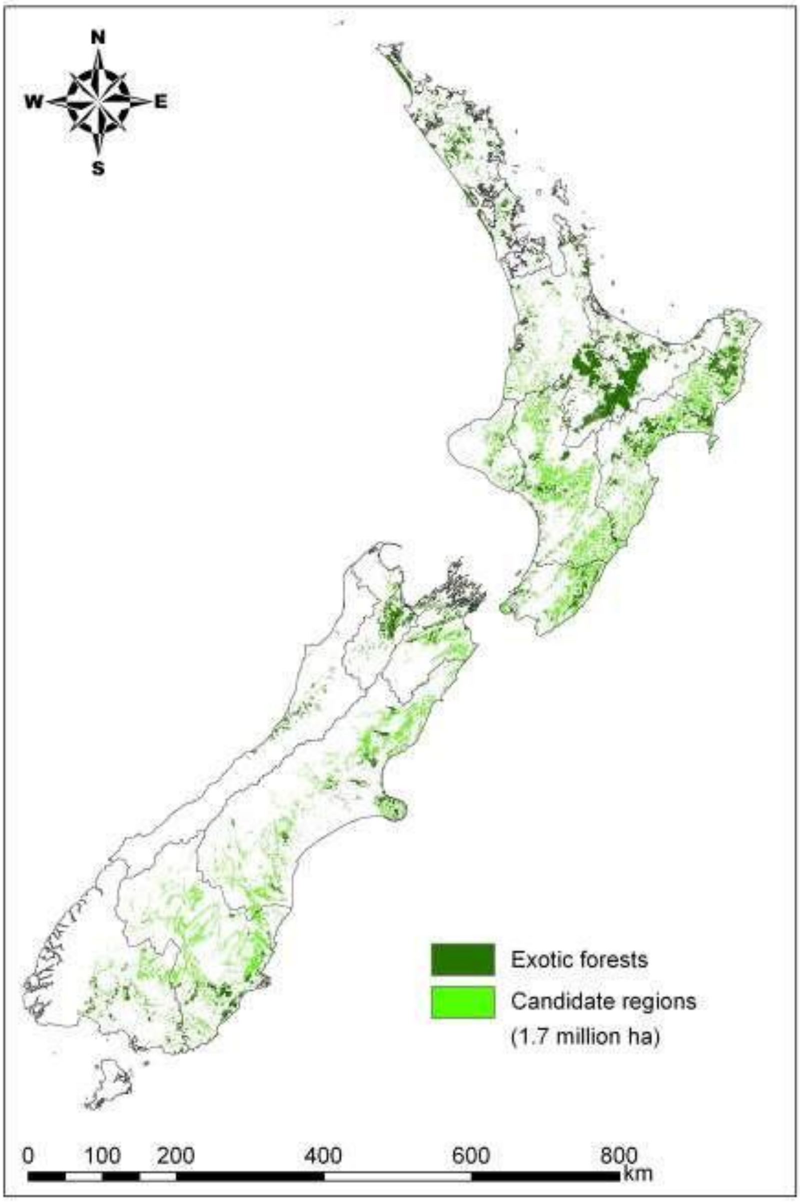
[16] BERL and Ascari are now progressing this research further in a project funded by NZTA. The work is close to developing an analytical process which will show, at a high level the land use, land value, productivity, economic activity and wider benefits of proposed transport investments that can bring about transformational change.

[17] Hall, Peter and Jack, Michael, 'Bioenergy options, large scale bioenergy from forestry, Scion, April 2009, p 1.

[18] Ibid, p 4

Some notion of the location of the areas in which bioenergy forests could be grown is shown in Figure 5.1.

Figure 5.1 Area covered by the Scion Scenario 2[19]



5.4 Greenhouse gas (GHG) reductions

Large-scale bioenergy production results in substantial reductions in greenhouse gases, both by reducing fossil fuel use in transport and by removing land from agricultural

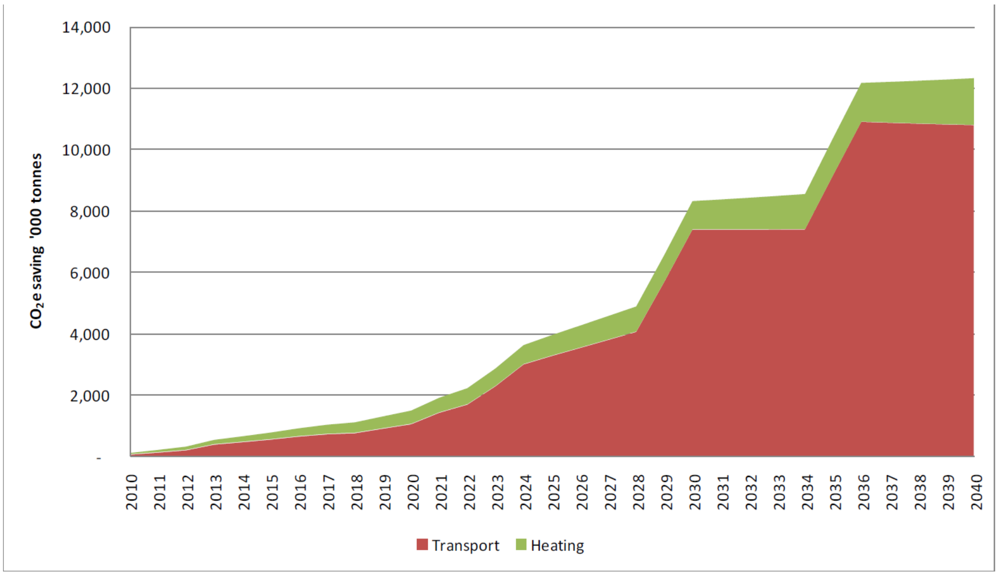
[19] Peter Hall and Michael Jack, 'Analysis of large-scale bioenergy from forestry, Bioenergy options project', April 2009, p 34. The area covers 1.8 million ha showing existing plantation and scenario candidate areas.

production. The combined impacts of these two factors result in emissions reduction of between 5 and 15 million tonnes of CO_2-e per year from 2035 onwards. These figures correspond to approximately 13 percent of New Zealand's total GHG emissions in 2006. Of the reduction in GHGs from these changes, 10 percent came from reduced agricultural emissions. The fact that lower intensity land use is being displaced means that GHG reductions are not as high as would be the case if forestry areas were greater.

Once plantation forests are fully established they will store substantial amounts of carbon, as long as they remain sustainably harvested. This stored carbon is equivalent to up to 500 million tonnes net CO_2-e removed from the atmosphere and stored. These estimates assume an even rate of establishment and harvest on a 25-year rotation and the subsequent age-class distribution for the afforested area.

Owners of forests can opt into the New Zealand Emissions Trading Scheme (ETS) and earn New Zealand Units (NZU) for carbon sequestered in the process of forest growth. Owners of forests also have to pay penalties or surrender NZUs if they deforest or harvest their forests. Since it is planned that the bio-energy forest be sustainably harvested, there will be a net gain to forest owners through the ETS.

Figure 5.2 BANZ estimate of carbon dioxide savings resulting from the Strategy



New Zealand emitters can presently meet their ETS obligations through the off-shore Clean Development Mechanism. The creation of a substantial New Zealand forest industry will enable these emitters to source NZUs using onshore credits. Figure 5.2 shows carbon savings from the Strategy. BANZ estimates that CO_2-e savings[20] is about 11 million tonnes per year or 35 percent of the total transport fuel required. At a $50 price per tonne of emissions, this level of carbon savings is valued at $55 million per year.

[20] . Although bioenergy is often said to be carbon neutral, carbon savings are affected by agricultural practice, production and processing methods, and transportation of the feedstock.

6 Other wider benefits

This section presents other potential benefits from adoption of the Strategy. These benefits are often referred to as 'intangibles' because many of them are difficult to quantify in a manner acceptable to policy analysts. The current project is limited to describing these benefits, and future work on the social and environmental impact of the Bioenergy Strategy can attempt to determine monetary equivalents of these social and environmental gains.

Among the opportunities presented by developing a bioenergy anchor is its contribution to sustainability, biodiversity and other related environmental gains. In recent studies, Scion has identified that the key environmental impacts, particularly for forests for bioenergy[21]:

- more sustainable land use from improved water quality and reduced erosion and sedimentation
- improvements in biodiversity
- some reductions in water availability
- greenhouse gas (GHG) reductions and increased carbon stocks

Also to be considered are likely implications for iwi and Māori organisations and enterprises, as well as risk effects such as the value of real options that are available. We explore these factors below.

6.1 Implications for Māori

Māori organisations own or manage an increasing area of the NZ forest sector from which feedstock for biofuels could be sourced; specifically some of the largest suitable lands for new potential biofuel production. In addition, iwi could be a potential source of development capital for bioenergy development.

The participation and involvement of, and collaboration with, Māori organisations will undoubtedly be a critical component in determining the ability of the Strategy to generate wider economic benefits.

The main involvement is presently through the following entities:

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[21] Hall, Peter and Jack, Michael, 'Bioenergy options, large scale bioenergy from forestry, Scion, April 2009, p 9

1) Tuwharetoa's Lake Taupo Forest Trust (LTFT) has been participating in the stumpage from the Crown Forest Licences (CFLs) on their lands for many years. They have consequently established in 2004 an investment entity Taupo Moana Group Ltd, and have attracted funds from a number of the large Maori entities. They are now looking at the whole carbon 'industry' and market, whether that is best sourced from radiata, or from indigenous forest regeneration.

2) The Central North Island partnership (CNI) now owns the land under Kaingaroa forest, and will, within less than 25 years be operating the forest and other land uses on it. The CNI formation was conceived and driven by Tumu Te Heuheu, the Tuwharetoa paramount chief, practical ecologist; and former head of Nga Whenua Rahui which is the Maori equivalent of the QE2 Trust. In 2009 the CNI announced its three strategies for development within 25 years:

   a) to become strong in the world market for quality wood products
   b) to become the owner of the main intellectual property on geothermal resources
   c) carbon farming on all the marginal, and/or inaccessible land within their area.

3) The Far North tribes are discussing allocation of the large state forests among themselves, including Aupouri and others, which will have capacity in forest management. There is considerable marginal land suitable for bioenergy such as in north Hokianga. This would be ideal for indigenous regeneration (and recreation use) and/or radiata/fast-growing species like eucalypts.

6.2 Sustainable land use

Converting some land from their currently low-productivity use as pastoral grazing to forestry could lead to a number of additional environmental benefits, including reduced erosion and reduced nutrient leaching into waterways. Analysis showed that the total erosion could be reduced by over 5 percent, with erosion reductions particularly significant in the eastern, central and lower North Island regions. These are regions where a combination of highly erodable soils, grazing for land use and heavy rainfall events are currently a cause for concern.

The eastern and southern North Island regions show reductions in erosion of 15 percent to 24 percent. Given the scale of erosion in these regions, the actual amounts of erosion mitigated are estimated to be millions of tonnes per annum. Specifically, the Manawatu-Whanganui and Gisborne regions had 340,000 ha and 117,000 ha of afforestation with reductions in erosion of 3.1 and 8.9 million tonnes per annum respectively. The use of these and other data (water yield, nutrient run-off impacts etc.) can be used to prioritise regional establishment areas.

The economic value of reduced erosion could be considerable. Kirschbaum and others (2011) of Landcare research have monetized avoided soil erosion at $1/tonne.[22] This would mean that up to $12 million per year could be added to the benefits.

Analysis also showed that in the long term, nitrogen leaching from afforestation of grazed pastures could be reduced by approximately 3 percent at a national level. Regions that would have significant benefits in terms of reduced nitrogen leaching from afforestation were in the east and south of the North Island. Leaching rates can remain high for several years if the soil already contains a large amount of surplus nitrogen, but in the long term, afforestation will reduce nitrogen leaching.

6.3 Biodiversity

Broadly speaking, the Strategy is likely to result in an improvement in biodiversity. However, afforestation of land that has historically never been forested (e.g. native grasslands in Central Otago) is not desirable from a biodiversity perspective.

Plantations established on marginal pastoral land and exotic scrub pasture would improve the species richness of insects, plants and native birds. They will also benefit native species by improving connectivity between currently fragmented native forest remnants (this is especially so for Canterbury). Where afforestation reduces erosion and sedimentation, improved water quality will lead to greater aquatic biodiversity and improved native fish habitat. In general, the higher the afforestation area, the greater will be the benefits in terms of connectivity, forest area, and gains from improvement in water quality. On the negative side, there could be a risk of spreading wilding pines or other weeds in some regions.

However, careful species selection, management of boundaries and monitoring of at-risk areas would avoid the development of wilding issues, as they develop slowly over many years and early intervention will control any spread. Some areas currently in scrub might revert to native forest if left undisturbed; in which case planting exotic forest would not produce a long-term biodiversity benefit. However, this process is likely to be very slow.

Overall, bioenergy forests present a major opportunity to return forest cover to areas of formerly forested land. If managed appropriately they have the potential to significantly increase both terrestrial biodiversity and aquatic water quality and biodiversity at a landscape level. Research on biodiversity aspects of new bioenergy forests is required to

[22] Kirschbaum M, Trotter C, Wakelin S, Baisden T, Curtin D, Dymond J, Ghani A, Jones H, Deurer M, Arnold G, Beets P, Davis M, Hedley C, Peltzer D, Ross C, Schipper L, Sutherland A, Wang H, Beare M, Clothier B, Mason N, Ward M 2009. Carbon Stocks and Changes in New Zealand's Soils and Forests, and Implications of Post-2012 Accounting Options for Land-Based Emissions Offsets and Mitigation Opportunities - Including Appendices. Landcare Research Contract Report: LC0708/174.

guide planning and afforestation scenarios. Early consideration of biodiversity issues will ensure maximum future biodiversity benefits from new forests.

Methods to quantify in economic terms the benefit of improved biodiversity is are being developed. One leading New Zealand authority is Prof Murray Patterson of Massey University[23] whose research focuses on improved understanding of the mechanisms at work.

6.4 Water availability

Afforestation is likely to have important impacts on water availability. Planting forests results in greater water interception and subsequently less water being available for other purposes. In particular, Canterbury and Otago already have high levels of water allocation (mainly for irrigation) and large areas targeted for afforestation in all scenarios. Therefore there could be water availability issues in these regions. In developing a large-scale afforestation plan, water availability would be a key consideration, and would affect the decision on how much forest to establish within some regions.

In New Zealand 750,000 ha of land is irrigated. However, water allocation is carried out through allocation rather than a market in which a price is discovered. As a result, the economic cost of less water being available for irrigation or other purposes would take some research to identify.

6.5 Waste reduction

Significant sources of bioenergy arise from using agricultural, industrial or municipal waste. Agricultural waste includes piggery and dairy effluent, and plant waste from harvesting crops. Municipal waste includes green waste in tips and biogas which may be emitted.

In many cases the full cost of disposing of this waste is not reflected to the party undertaking disposal. To the extent that waste disposal is not being paid for at a rate reflecting the externalities, there will be an economic benefit in waste reduction. There is a wider economic benefit in that the cost is not borne by the community as a whole; rather, the waste is reduced and converted to a profitable use.

The cost of disposal of waste in public landfills is considerable and varies throughout New Zealand. General waste for commercial customers is priced at around $100 per tonne, there is high incentive for companies who produce wood waste to avoid this expense.

[23] Dominati,E., Patterson, M.G., MacKay,A .2010. A Framework for Classifying and Quantifying the Natural Capital and Ecosystem Services of Soils. *Ecological Economics*. Volume 69, Issue 9, 15 July 2010, Pages 1858-1868

6.6 Risk effects

The way bioenergy investments are scoped and the bounds of the effects that are evaluated are central to maximising the productivity of investments. The assessment of network effects and the exploration of real options can go some way to addressing these issues.

Network effects are a core issue in project definition. The effects of an enhancement to one part of the network can depend on consequences in other parts of the network and enhancements that may be implemented. This can mean that individual enhancements appear uneconomic; but are attractive when viewed collectively.

Bioenergy projects will form part of the network of supply investments for liquid fuels. This network comprises projects to supply complementary fuels of petrol and diesel/jet fuel. They sit alongside the process in which crude oil is imported and refined at Whangarei. Clearly, this is not a 'sequential' network; but it is an integrated system of supply where one investment cannot be viewed in isolation to the others.

There is another important attribute of investments in bioenergy. Because they are staged in time they create what is known as real options which are capable of valuation. Decisions and investments can be made sequentially, creating real options, which have value. Real options is the term coined to distinguish them from 'financial options' – the option (but not obligation) to buy or sell a financial instrument in the future.

There are five types of real options:

1. Waiting-to-invest option: holding the necessary resources available to make the investment, but waiting until the time to do so is propitious.
2. Growth option: building an asset that can have its capacity expanded at a later date.
3. Flexibility option: the ability to alter the course of the investment after it is built.
4. Exit option: the ability to get out of an investment.
5. Learning option: making an investment enables the holder to learn about an uncertain quantity, technology, or opportunity.

Trigeorgis (1996)[24], for instance, discusses:

- Natural resource investments including options to defer or abandon a resource such as a forest

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[24] Trigeorgis, L (1996), Real options, MIT Press

- Land development including its value based on its best immediate use but also its option value if development is delayed

- Large-scale energy projects and regulation in which government subsidies to large-scale energy projects can be valued as put options

- Research and development in which numerous option values are embedded in R&D projects.

Bioenergy investment in New Zealand can lower the effect of price volatility of imported oil. The project risk (or 'beta' ß) may be effectively lower as a result. The required rate of return to compensate for risk will be reduced and the cost of capital will be lowered.

In New Zealand, we find that in regions where there is capacity and capability to produce nearly all of the forms of wood product there is a reasonably strong, robust market for most forest and wood products. Uses for Radiata particularly include solid wood as lumber either as clearwood, appearance grade, or construction grade; further manufacturing as finger-jointed lengths, mouldings or veneers; manufacture of pulp, paper, or panel products from pulp logs, waste from other processes or chipped wood. Alternatively, there is the export market for generally lower grade logs, smaller diameter logs and for chip.

This range of possible products provides resilience to changes in relative international product prices, and to New Zealand's wide fluctuations in the average and specific currency exchange rates. In regions and forest and wood complexes with this range of product there is ability for the various end use shares to 'move up and down the trunk' as relative prices change. The creation of another substantial use as in bio-energy is expected to further increase the resilience of the industry to fluctuations in market conditions.

However, this reasoning should not be taken too far. Stroombergen and McKissack[25] have used an econometric model of the demand for petrol to simulate the effects of price uncertainty on demand by comparing fuel consumption between a volatile price path and a steady price path. They concluded that there was a real gain in welfare from having access to the actual price that was volatile but often lower than the smoothed price.

The question then arises of how long it takes to make up a welfare loss caused by a lack of access to oil when it is cheaper than biofuels. Stroombergen and McKissack concluded that any loss would be quickly offset once the price of oil was high enough for biofuels to compete. This conclusion assumes, in line with standard general equilibrium economic

[25] Stroombergen A, and McKissack D, 'General equilibrium analysis of bioenergy supply from New Zealand's forests estate and the impacts of volatile fuel prices', Bioenergy options Transition report, October 2009, p 132.

analysis, that the long-term development of an international market for biofuels would see its price align to costs of production, rather than to the world price of oil.

7 Biomass resources, products and liquid fuels

The bioenergy sector is currently small in scale, but represents a significant opportunity for achieving long-run energy security, economic growth and carbon emission reduction targets. This section briefly outlines the composition of the sector and the challenges it faces.

7.1 Biomass resources and products

Energy from biomass is as old as human habitation, and wood was the first fuel for heating and cooking. During the industrial revolution in the nineteenth century the predominant energy form became coal; and then there was a transition to oil in the twentieth century. The next predominant energy form will be natural gas and biomass. However, future energy transitions are likely to be characterised by a mix of fuel types. There will be increasing emphasis on renewable energy, and on lowering emissions of “greenhouse gasses”. For these reasons, bio-energy is an important prospect for New Zealand.

The Strategy lists current and potential bioenergy resources as follows:

- conventional forestry harvests, including residues (with significant volumes currently exported as logs); predominantly Pinus radiata, but with a wide range of other species available
- short rotation forestry crops including Radiata pine, Salix, Acacias and Eucalypts
- agricultural crops including oil-bearing plants such as Canola, and grasses such as Miscanthus
- agricultural residues such as straws, poultry litter, dairy and piggery effluent
- municipal, agricultural and industrial process residues and wastes which may be burnt or digested to produce methane
- algae (a by-product of waste treatment) as a basis for biodiesel production.

Of all these resource, woody biomass, including the biomass derived from fuel crops, has by far the highest potential for wealth creation from the full range of applications (including bioenergy). The bioenergy produced is often a by-product of the production of primary bio-products. The use of wastes and effluents, while small in energy potential, offers significant opportunities for reducing waste volume and green house gas emissions as well as improving quality of waste water discharge.

In 2009, biomass supplied 7.7 percent of primary energy in New Zealand. The supply of the heating market with bioenergy is progressing and prompted by the market and by industry demand. A major issue to users of woody biomass for heating is the need for adequate volumes of quality wood fuel at consistent and known prices. Some promising applications of wood energy have stalled because the fuel supply has not been up to the job. It appears that while the technology is sound it is the application of the technology which is holding back greater use. Wood pellets and torrefaction which produce high quality fuels will probably expand, encouraged by industry demand.

The Strategy identifies the production of liquid fuels from woody biomass as a major economic opportunity and will thus be dealt with in the next chapter. To evaluate the economics of the bioenergy types which are on a smaller scale, BERL has used the 'Bioenergy pathways' report written by Scion.[26]

7.1.1 Straw heat and power

Canterbury is the principle region where arable crop residues are available in sufficient quantities to consider using straw as a fuel for heat plant. The total resource of surplus straw in Canterbury is 210,000 tonnes per annum. This resource is equivalent to 0.6 PJ of electricity and 1.8 PJ of heat.

The heat plant modelled in the analysis could produce 3060MJ of electricity and 8700MJ of heat at a cost of $164. The greenhouse gas reductions of straw to heat and electricity via CHP are significant (>90percent) when compared to electricity from the grid and heat from coal. [27]

Energy return on energy invested is highly in favour of straw CHP with an EROEI of 17.6 to 1, whereas the same energy from grid electricity and coal for heat is 0.8 to 1.[28]

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[26] Hall, Peter and Jack, Michael, 'Bioenergy options for New Zealand; Pathways Analysis' August 2008; Scion Energy Group.

[27] It is unlikely that straw would be used to generate electricity. The use of biomass to generate electricity is not seen to be economic during the term of the strategy to 2040.

[28] An initial finding on the economics of this bioenergy pathway suggests that CHP is not economic in New Zealand.

Table 7.1 Key findings on straw and heat power[29]

Potential scale of resource	Significant regional resource, 0.6 PJ electricity and 1.8 PJ of heat from 210 000 tonnes of straw /year in Canterbury
Energy balance	EROEI ratio of 17.6:1
GHG emissions	Greater than 90% reduction in comparison with coal for heat and grid electricity
Other environmental benefits	Avoids burning crop stubble
Technology status	Mature
Economics	Currently not economically viable

7.1.2 Canola to biodiesel

At current prices, growing canola as a feedstock to create biodiesel is received grant of 42.5 c/litre. The GHG emissions from producing and using canola biodiesel are favourable compared to producing and using fossil diesel, with GHG emission reduced by 62 percent. [30]

The energy balance (energy out: energy in) of the canola to biodiesel production chain is 2.22:1. This means the system is viable in the long term, fuelling itself, and producing an excess. This energy balance is better than that of fossil diesel. The price of canola seed will be driven by the potential revenues from alternative arable crops (wheat oats).

The economic viability depends critically on the price of canola seed. For example, a modest 20 percent increase in the price of canola seed results in production of canola biodiesel ($42/GJ) no longer being economically viable compared to fossil diesel. Also, the use of residual meal from processing the oil seed for stock food, and its associated value, is critical to the cost competitiveness of biodiesel from canola. The price of glycerol has a small but significant effect on the cost competitiveness of producing biodiesel from canola.

Table 7.2 Key findings on canola to biodiesel[31]

Potential scale of resource	39 PJ of liquid fuels (1.1 billion litres, assumes maximum crop area of 1 million ha)
Energy balance	EROEI ratio of 2.2:1
GHG emissions	Greater than 62% reduction with fossil diesel
Technology status	mature
Economics	Currently economically viable

[29] Forgie V. and Andrew R. Landcare Research May 2008. Lifecycle assessment of using straw to produce industrial energy in New Zealand. Report prepared for the Bioenergy Options for New Zealand – Pathways Analysis project.

[30] Andrew R and Forgie V. Landcare Research 2008. Life cycle analysis of canola biodiesel in New Zealand. Report prepared for the Bioenergy Options for New Zealand - Pathways Analysis project.

[31] Andrew R and Forgie V. Landcare Research 2008. Life cycle analysis of canola biodiesel in New Zealand. Report prepared for the Bioenergy Options for New Zealand - Pathways Analysis project.

7.1.3 *Tallow to bio-diesel*

Animal fats, just like plant oil, can be used to produce biodiesel. Biodiesel from tallow has advantages. It has higher cetane[32] number than the plant oil biodiesel. This means cleaner and more efficient burning in diesel engines. However, it tends to crystallise at much higher temperature than biodiesel from plant oil. A study on exhaust emission from tallow methyl ester biodiesel blends show decreasing levels of all measured exhaust emissions including carbon dioxide, oxides of nitrogen and matriculate matter.[33] Further studies will have to be completed on the power and fuel consumption from this biodiesel blend before a defined conclusion is reached.

A study by CRL[34] provides a life cycle assessment of one of the more attractive biofuel options for New Zealand, namely biodiesel derived from domestically produced tallow. This life cycle assessment involved a primary energy and greenhouse gas emissions inventory of the production of tallow-derived biodiesel in New Zealand, from the farmer's paddock to the exit gate of the biodiesel plant.

The results of this analysis found tallow-derived biodiesel to have a primary energy input/output of 0.50. This compares to an energy input/output of 1.19 for fossil diesel (at a similar point in the supply chain). Combining these, the use of tallow-derived bio-diesel provides a 58 percent decrease in primary energy. A similar analysis for greenhouse gas emissions found the domestic production and use of biodiesel from domestically-sourced tallow to have around 51 percent of the global warming potential of fossil diesel, that is, a 49percent decrease over the use of fossil diesel.

7.1.4 *Anaerobic digestion of effluent to biogas*[35]

The total methane production potential from processing waste, municipal waste and manure in New Zealand of 5-6 PJ biogas/annum is capable of producing up to 630,000 MWh/annum of additional renewable electricity from waste. The direct fluorescent antibodies (DFA) sludge digestion technology is directly transferable to the dairy processing sector. With both meat and dairy sectors combined this technology could supply 1 PJ of methane biofuel

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[32] Cetane number (CN) is a measurement of the combustion quality of diesel fuel during compression ignition.

[33] Boeille, N. (2006). *Assessment of bus exhaust emissions from tallow methyl ester biodiesel blends.* Auckland Uniservices Limited-Auckland University. Available at: https://www.eeca.govt.nz/sites.

[34] Barber, Andrew, Campbell, Andrew and Hennessy, Wayne, ‘Primary energy and net greenhouse emissions from biodiesel made from New Zealand Tallow’, CRL Energy Report 06-11547b. See http://www.eeca.govt.nz/sites/all/files/crl-energy-report-06.pdf

[35] Thiele J 2008. High level Life cycle analysis Report for Anaerobic Digestion of DAF sludge from a meat processing plant. Report prepared For Bioenergy Options programme. (Refer to CD).

which is sufficient to replace 2 percent of the current national power production from natural gas.

Anaerobic digestion presents significant environmental benefits from avoided emissions from decomposing effluent and reduced waste. Technical knowledge and the technology is sufficiently mature to proceed to implementation in the New Zealand primary processing sector. Uptake could be accelerated by an attempt to identify early implementation sites and by the creation of demonstration facilities.

The anaerobic digestion of effluents is already economically viable in New Zealand in selected favourable situations. Often the value of the solid residue for use as a fertiliser is significantly greater than the energy value Extending operation to 12 months would make this system more economically attractive. The economic feasibility of a digester facility design can be improved with effluent irrigation to land instead of “ammonia stripping and discharge to water course” (subject to land availability).

Table 7.3 Key findings on anaerobic digestion of effluent to biogas[36]

Potential scale of resource	Nationally 5-6 PJ/annum consumer energy from processing industry waste material and municipal bio-solids/animal manure to biogas.
Energy balance	EROEI ratio of 7.2:1
GHG emissions	>200% reduction in comparison usual land disposal and grid electricity
Other environmental benefits	80% reduction in waste
Technology status	Mature
Economics	Economic at favourable sites

7.2 Profitability summary of bioenergy options

In their Bioenergy Options Pathways Report[37], the Scion Energy Group provides a summary of the economics of bioenergy. This report was published in August 2008 using assumptions accepted at the time. Perhaps the most important was the world price of crude oil, which underwent a significant decrease after reaching a record peak of US$145 in July 2008. On December 23, 2008, WTI crude oil spot price fell to US$30.28 a barrel, the lowest since the financial crisis of 2007–2010 began, and traded at between US$35 a barrel and US$82 a barrel in 2009.

The world oil price used by Scion resulted in negative profitability of fuels sources from purpose-grown forest (PGF). Table 7.4 summarises Scion’s key findings of costs and value

[36] Thiele J 2008. Potential Assessment from Anaerobic Digestion (AD) of Municipal Biosolids and Effluent and Dairy Factory, Meat Processing and Wool Processing Waste. Report prepared for Bioenergy Options for New Zealand–Situation analysis.

[37] Hall, Peter and Jack, Michael, ‘Bioenergy Options for New Zealand; Pathways Analysis’ August 2008; Scion Energy Group.

per GJ output by bioenergy pathway. Because significant technical progress has been made on converting PGF to liquid fuels over the past few years, BERL decided to re-estimate the economics of this route, which is presented in the following sub-section 7.3.

Table 7.4 Cost and value per GJ output of bioenergy pathways

Description	Cost	Value per GJ output	Profit (loss per GJ output)
Wood to heat	$6.76	$6.78	$0.33
Wood to CHP	$11.74	$12.58	$ 1.39
Wood to EtoH	$20.56	$31.66	$13.80
Wood-Gas-Heat	$25.14	$6.73	-$18.05
Wood-Gas-CHP	$30.06	$16.79	-$12.55
Wood to gas to FT	$24.15	$21.05	$5.71
Wood to Pyrolysis to LF	$13.09	$14.11	$1.79
PGF to heat	$32.40	$6.78	-$24.86
PGF to CHP	$42.67	$12.58	-$28.63
PGF to EtOH	$56.53	$31.66	-$23.79
PGF to Biodiesel	$56.53	$31.66	-$23.79
PGF-gas-heat	$50.35	$6.73	-$43.62
PGF-gas-CHP	$61.24	$16.80	-$44.45
PGF to gas to FT	$52.67	$26.06	-$23.91
PGF to pyrolysis to LF	$40.02	$14.11	-$25.66
Straw to Heat	$5.77	$6.79	$1.17
Straw to CHP	$9.75	$12.56	$3.02
WVO to biodiesel	$18.99	$24.95	$23.76
Tallow to biodiesel	$24.92	$24.97	$3.56
Rapeseed to biofuels	$47.15	$25.00	-$16.93
Coal to Heat	$6.88	$6.79	-
Coal to FT	$23.62	$26.06	$5.68

Source: SCION, 2008

7.3 Assessment of liquid fuels

The Strategy proposes a stream of activities to convert biomass to liquid fuels. The contributions in PJ/y are summarised in the following table at the start of each decade.

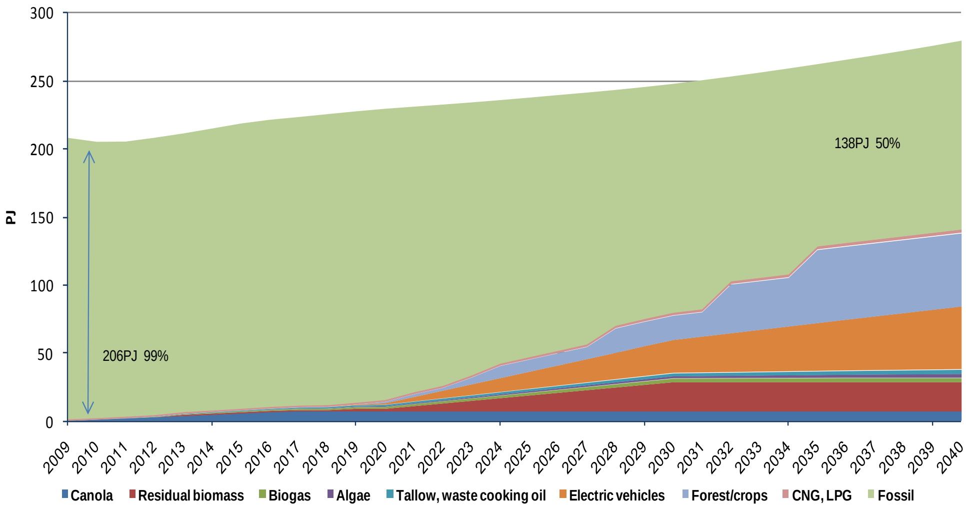
Table 7.5 Contribution to liquid fuel by energy type

Bioenergy type	2020	2030	2040
Canola	7.0	7.0	7.0
Residual biomass	2.0	22.0	22.0
Biogas	1.3	2.7	3.1
Algae	0.5	1.5	2.8
Tallow, cooking oil	1.1	2.2	3.2
Forest and crops	1.0	18.0	54.0

Production of liquid fuels from canola, biogas and tallow is well researched and the costs established. The size of these industries is each relatively small.

The single largest proposal in is the conversion of residual biomass and forest feedstock to liquid fuels. The strategy proposes that, by 2040, products derived from petroleum decline from 206 PJ/y to 138 PJ/y, and is illustrated in Figure 7.1 below.

Figure 7.1 Transport fuel scenario



It is apparent these routes would involve substantial investment and forest harvesting, and the operating data and economic return is not well defined. For these reasons BERL has carried out an independent assessment of liquid fuels production so that the data to which we had access could be validated.

It is clear that a significant component of future transport fuels will remain petroleum products because that is what much of the vehicle fleet will still be using in 2040. However the patterns of demand and supply are not easy to predict. New Zealand's Energy Outlook 2010[38] states:

"Around half of the energy used by New Zealand consumers is in the form of refined oil products (mostly petrol and diesel). Most of this is used for transport and in mobile off-road uses such as in the construction industry and on farms. Stationary uses such as in boilers and diesel generators make up a relatively small amount of diesel demand. New Zealand has a well developed oil production industry but for technical and economic reasons most of our crude oil is exported. Therefore nearly all of the oil used in New Zealand is imported."

From forecasts of petroleum product consumption by Ministry of Economic Development, it may be inferred that the requirement for transport fuels from the bioenergy resource will require a mix of petrol and diesel/jet-fuel. There will be a continuing demand for petrol into which ethanol can be blended up to 15%. In respect of distillates, it is likely that a mixture comprising diesel and kerosene will be required. The question then becomes how much of each fuel type. In the absence of firm predictions, the following strategy assumes that in 2040 a balance of product will be required.

The BERL project for BANZ is not trying to "forecast" the shape of the liquid fuels industry or predict specific projects; rather we seek a reasonably credible economic evaluation of the biomass strategy. We need broad, but realistic, values of product streams and the size of these streams. This will give an estimate of the total economic value of this new industry. To derive cost and yield data, particular conversion technologies were investigated, and these will be used as representative of a wider range of technology. The economic performance of some processing routes is enhanced by co-products which are available, depending on their operating configuration.

Liquid fuels are now being made from a wide variety of biomass sources. These include agricultural crops including oil-bearing plants such as canola and grasses such as *miscanthus*; agricultural residues such as straw and dairy effluent; and algae. The purpose of this paper is to focus on liquid fuels from woody biomass, which is a very substantial resource capable of wealth creation.

A wood processing facility which can produce biofuels and a range of other marketable products is now commonly termed a 'bio-refinery'.

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[38] Ministry of Economic Development, New Zealand's Energy Outlook 2010, p 4.
Download from http://www.med.govt.nz/upload/76133/Energy%20Outlook%202010.pdf

7.3.1 *Forest requirements and costs*

The number and size of the number of processing plants to achieve the outputs proposed in the Strategy are large. These 'bio-refineries', and the forest to supply them, will have a substantial economic effect on the regional and national economies. It is this impact which BERL has been asked to assess.

It is likely that a considerable amount of feedstock for liquid fuels production will be from residue which remains in the forest after logs have been extracted for export. In the event that purpose-grown forest is required, assumptions published by Scion[39] provide a guide to the forest requirement. Purpose-grown forest for bioenergy will be denser than forest for export logs, and all residue will be removed at harvesting and included in the yield. In this situation Scion uses a biomass yield of approximately 795 cu m per hectare[40].

The energy content of green wood is approximately 6.5 GJ per tonne, and the conversion efficiency to liquid fuels is between 0.43 and 0.55, depending on the conversion route employed. On this basis the forest requirement to produce transport fuels in 2040 is approximately 15 M m3 from 19,000 ha.

This corresponds to the 'Preferred scenario' of forest development suggested by Scion[41] which proposes a 30% cut from the existing estate which would yield a biomass volume of 12.9 M m3 in 2030 and 17.3 M m3 in 2050, respectively. In addition there would be 1.1 million ha of new forest of which 44% would be allocated to energy production. This would make available a biomass volume of 17.4 M m3 in 2050. The total biomass possible for energy production in 2050 would therefore be 34.7 M m3.

From the Scion report on Large scale Bioenergy[42], we obtain the approximate costs for the production of biomass from energy forests using an improved supply chain and yields as $72.4 per tonne of feedstock. This scenario reflects that the low productivity land is used.

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[39] Hall, Peter and Jack, Michael, 'Bioenergy options, Large scale energy from forestry' April 2009, p3

[40] 1 cubic metre (m3) of wood = ~ 1 tonne of wood (green, 59% moisture content)

= 6.5 gigajoules (GJ) per tonne, green

= 140 litres of ethanol = 94 litres of petrol equivalent

= 95 litres of biodiesel = 100 litres of petrol equivalent

[41] Peter Hall and Michael Jack, 'Analysis of large-scale bioenergy from forestry, Bioenergy options project', April 2009, p 20.

[42] Hall, Peter and Jack, Michael, 'Bioenergy options, large scale bioenergy from forestry, Scion, April 2009, p 8

Harvesting and transport make up 61% to 70% of delivered cost and growing costs are 25% to 32%. Growing has a greater proportion of the cost when productivity is lower.

7.3.2 Biofuel production technologies

Diesel and jet fuel pose particular problems when synthetic fuel is envisaged. Manufacture from coal, lignite or wood into paraffinic liquids involves chemical synthesis at high temperature. By contrast, petrol can be made from methanol by a catalytic reaction. Methanol is a world commodity manufactured from natural gas and can also be made from biomass at higher cost. Ethanol, easily available from fermentation, can be blended up to 15% into petrol. Most fuel ethanol in the world is made from grain or sugar canes which are rich in sugars, and the US is planning implementation of an expanded program of ethanol blending into gasoline.

The technology of synthetic liquid fuel from biomass is being commercialised in Canada, US, and Europe. Mabee and Saddler (2006) explain that there are two main routes to extract valuable products from forests[43]:

1. The Bio-conversion platform. This involves pre-treatment of the wood chips which are composed of cellulose and hemicellulose (around 72%), lignin (27%), and 2% extractives which can be converted to turpentine and tall oil. The wood is first broken down to pulp, and hydrolysis is then employed to convert the cellulose structure into carbohydrates. This is typically carried out by enzymes, although acid hydrolysis can be used. The sugar liquor may then be used as a feedstock for production of alcohols and chemical products. While ethanol is widely understood, butanol can also be produced.

   Lignin has been used mainly as a fuel for combustion, but processes are being developed to convert up to 10% of it to high-value use. Stewart[44] has the view that lignin is promising as a component in thermoplastics of which polyethylene and polypropylene comprises 60%.

2. The Thermo-chemical platform. This involves gasification of the wood and then synthesis to liquid fuels. There are several technologies available, many (but not all) being variants of the well-established Fischer-Tropsch (FT) synthesis. The reaction produces a predominance of paraffins, so is very suitable for producing diesel and jet fuel, as at SASOL in Johannesburg, South Africa. An array of chemical products with high value

[43] Mabee W E and Saddler J N, 'The potential of bioconversion to produce fuels and chemicals, Pulp and Paper Canada, 107:6 (2006) p 34.

[44] Stewart D, 'Lignin as a base material for materials applications: chemistry, application and economics, Industrial crops and products 27 (2008) Elsevier, p 202-207.

can also be derived. A disadvantage of FT synthesis that it is capital intensive and releases a large amount of energy which may be used for process heat or electricity generation.

Most processing routes fall within these two platforms. For example, producing bio-oil by pyrolysis is a well-established thermo-chemical process in which biomass is volatised by high temperatures and then condensed to a liquid. The oils are acidic and tend to be unstable, so need to be hydro-reformed before they are used as transport fuels.

At the other end of the technological spectrum is the 'Super Critical Water' process of Ignite Energy, Australia.[45] Water at 374 degrees C and 218 atmospheres is used to depolymerise wood chips into a liquid with similar characteristics to crude oil, which is then conventionally reformed. Recent advances mean that the product is closer to a distillate than crude oil, so upgrading to diesel and jet-fuel is relatively simple. When this process is commercialised it will be particularly valuable in New Zealand.

There is a very substantial amount of work going on in the world relating to ligno-cellulosic biofuels. Some of the new technologies to make transport fuels from woody biomass are entering the commercialisation stage, and a useful summary of a selection is provided by the IEA.[46] The IEA lists three companies making liquid fuel from wood:

1. Syntec biofuels, Canada, which makes ethanol, methanol, n-butanol and n-propanol using gasification and catalytic synthesis

2. Choren Industries, Germany, which makes transport fuels by Fischer-Tropsch synthesis.

3. Lignol Energy Corporation, Canada, which produces ethanol from C6 sugars. A number of potentially valuable co-products are also made.

7.3.3 Biofuel production facilities in New Zealand

Both of the major processing platforms involve what are becoming known as 'bio-refineries'. To implement the Strategy, a number of bio-refineries are required in New Zealand, close to the source of wood. The question now becomes how many, what type and where they might be located?

New Zealand has experience with wood processing facilities on a world scale. Carter Holt Harvey's Kinleith mill at Tokoroa uses 2.1 million tonnes per year of wood to make 270,000

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45 http://biofuelsdigest.com/bdigest/2010/12/27/another-wonder-down-under-ignite-energy-develops-low-cost-biomass-conversion-using-supercritical-water/

46 http://www.iea-bioenergy.task42-biorefineries.com/publications/?eID=dam_frontend_push&docID=58

tonnes of pulp and 330,000 tonnes of paperboard annually.[47] The Tasman mill near Kawerau processes 1.4 million tonnes per year of wood to produce 295,000 tonnes of pulp for the manufacture of paper.

If the biofuel conversion facilities are each built to be somewhat larger than Kinleith, this implies that 6 biofuel 'refineries' will be needed to achieve the biofuels targets in 2040. The processing capacity of each of the six bio-refineries would be 2.5 million tonnes per year of wet wood. Essentially this implements the bioenergy strategy in which six new refineries are built, each contributing 9 PJs of energy, in the following sequence:

- one by 2024
- another one by 2028
- a further two by 2032
- a further two more by 2035

Implemented on this scale, bioenergy from forests would be a very major new industry in New Zealand. The cost of each bio-refinery would be very substantial (approximately NZ $1.0 billion), as would the labour, energy, water and transport requirements. Each would be similar in size to the Kinleith Mill near Tokoroa[48]

Outputs of the bio-refineries

The Bioenergy Strategy emphasises the production of liquid fuels from wood. A significant component of future fuels will remain petroleum-like products because that is what much of the transport fleet will still be using in 2040. Because diesel and jet fuel will remain in high demand, it is likely that either a super-critical water facility or Fischer Tropsch synthesis will be required to produce distillate. There will also be a continuing demand for petrol into which ethanol can be blended up to 15%.

The approach of the BERL work is to assume that in 2040 three of the refineries will produce distillate, and three will maximise the production of ethanol. The economic performance of both of these refining routes is enhanced by co-products which are available depending on

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[47] http://www.chhgraduates.co.nz/our-company.php

[48] Dr Ganesh Nana, Mat Arcus, Jason Leung-Wai, Kel Sanderson, Mark Goodchild in BERL #4231. In this study, BERL examined the economic Impact of the Kinleith Mill in September 2003 for Carter Holt Harvey Ltd. This project involved two studies. The first focussed on assessing the direct, indirect and induced employment, income and GDP impacts of the operations of the Kinleith pulp and paper mill. The impacts on the South Waikato district as well as on the national economy were assessed. A second study investigated issues surrounding the electricity price and availability and its importance to the New Zealand forestry industry.

their operating configuration. The analysis for BANZ required broad, but realistic, values of product streams and the size of these streams. This will give an estimate of the total economic value of this new industry.

Bio-refineries are generally in the pre-commercial stage. However a working guide to their economic performance can be derived in the following analysis.

7.3.4 Fischer-Tropsch processing yield and value

Choren GmbH in Germany[49] provides the following information for the yield of Fischer-Tropsch (FT) liquids, called BTL liquids, from their 'Carbo-V process' bio-refinery[50]:

"Annual capacity of the Beta plant is 18 million litres of BTL generated from 65,000 tons of wood, leading to CO2 savings of up to 89%. It is run by a work force of 70 persons. The Sigma plant will employ some 200 personnel, producing 270 million litres of BTL from 1 million wood."

The published yield is 270 litres or 0.216 tonnes of FT liquid per OD tonne of wood (Using the conversion 1000 litres is 0.8 tonnes).

The BERL calculations will use a 'mid figure' yield suggested by Scion of 235 litres or 0.202 tonne per OD tonne of wood; data originally obtained from Choren. Therefore the yield from each refinery is 284 million litres per year of FT liquid fuel.

A reliable estimate of cost and yield for FT liquids is provided by Davy Process Technology. For a 487,000 ODT pa plant Davy's estimate on a US Gulf Coast basis is US$580 million. Other evaluations of biomass to FT projects using oxygen based gasification come up with similar capital costs. For an estimate of the cost of a larger plant, a scale price on this capacity to the power of 0.7 is assumed. For construction in New Zealand a location factor of about 1.2 – 1.3 is assumed, which results in an estimate of NZ$870 - $950 million.

The present value of the products (landed ex Singapore) is NZ$1.20 per litre or NZ$160/barrel, NZ$1200 per tonne. Using NZ$1.20/L x 235 L/OD t of wood, we obtain the present weighted average value of Fischer-Tropsch liquid per OD tonne of feedstock is NZ$282, at a yield of 235 litres.

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49 Contact: CHOREN Industries GmbH, Frauensteiner Strasse 59, 09599 Freiberg/Germany. Tel: +49 (0)3731 26 62-0, fax: +49 (0)3731 26 62-25, e--mail: info@choren.com; web: www.choren.com

50 Ref http://www.iea-bioenergy.task42-biorefineries.com/publications/?eID=dam_frontend_push&docID=58

7.3.5 Ethanol processing yield and value

Again, each bio-refinery processes 3570 OD t/d. This is equivalent to 1.21 M m3 OD wood; that is 2.95 M m3/year of wet wood from a forest.

One OD tonne of soft wood contains:

- 1-2% extractives, which can be converted to tall oil and turpentine
- 25-30% lignin
- 25-30% hemicelluloses
- 42% cellulose

Considerable research has gone into converting this 72% of sugars to ethanol, for which several processes now exist. In this process, lignin is available as a co-product, and this enhances the economic return. This is further explained later in this report which develops the economic benefit of a fully integrated bio-conversion processing facility. Work is also well progressed into converting sugars to bio diesel. When this is commercialised it will be particularly valuable, given the importance of distillate to the transport fleet.

The US National Renewable Energy Laboratory (NREL) recently published a revised cost of ethanol production[51], which gives a capital cost of USD422.5M for a 2,205 ton/day plant. This translates to a capital cost per plant of 422.5/0.8 x 3570/(2205 x 0.907) = NZD 943M per plant of the scale above.

Enzymatic hydrolysis followed by fermentation is one of the most studied options and has an estimated operating cost of US$1.4 to 2.50 US$ per gallon; equivalent to NZ$0.66 per litre, using NZD=0.8USD. The value of ethanol is obtained from the commodity price in the US of US$2.70/US gallon; equivalent to NZ$0.89/litre or NZ$1,134/t.

Although lignin is under study as a product to which value can be added, there is currently no market for it. We will assume that over the next decade this market will develop and, based on a range of prices for lignosulfonates, the value will be in the region of $1.40/kg. This would be additional to ethanol. If we assume that half the lignin can be sold as a co-

[51] Humbird, D, Davis R, Tao L, Kinchin D, D. Hsu D, and A. Aden A, 'Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol; Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover; NREL/TP-5100-47764, May 2011. See http://www.google.co.nz/url?sa=t&source=web&cd=1&ved=0CB4QFjAA&url=http%3A%2F%2Fwww.nrel.gov%2Fdocs%2Ffy11osti%2F47764.pdf&rct=j&q=nrel%20mesp%20ethanol%20&ei=zJv1TaGlKY--sQOLsvTZCw&usg=AFQjCNEhknYymn2o5Qs91Xf_poGkwBxkCQ&cad=rja

product during the production of biochemical ethanol (and that component of process heat is obtained elsewhere) then this makes a significant difference to the total value.

It is significant that this augmented value is roughly equal to the value of bleached kraft pulp. There is therefore not an economic loss in making ethanol compared to pulp so long as lignin is sold as a co-product. As a result, ethanol will probably be an important component of the liquid fuels strategy.

The present weighted average value of ethanol (plus lignin as a co-product per OD tonne of feedstock) is NZ$492, at a yield of 333 litres.

7.3.6 Summary

In summary, the product yields for the different processing routes and their values are presented in the following table.

Table 7.6 Summary of NZ bio-refinery yield and value

	Yield, l/OD tonne feedstock	Product, NZD/l	Value NZD/OD tonne wood	Comment
Fischer-Tropsch	235	1.2	282	
Biochemical ethanol	333	0.89	296	
Biochemical ethanol plus lignin co-product			492	
from ethanol	333	0.89	296	
from lignin (as kg)	140	1.4	196	50% lignin recovered*
Bleached kraft pulp	440	1.05	462	
Dissolving pulp	320	1.4	448	

*Lignosulfonate price

7.3.7 Oil price forecast

In 2040, oil prices are likely to be at a much higher real price than now. BERL will use the Ministry of Economic Development oil price forecasts to establish this price. The New Zealand Energy Outlook 2010[52] states:

"The Reference Scenario's oil price projection is based, in the short term, on the New York Mercantile Exchange (NYMEX) oil futures market and, in the longer term, on the prices modelled in the International Energy Agency's World Energy Outlook 2009 Reference Scenario. In this scenario, real oil prices rise steadily to US$115 per barrel (bbl) by 2030 (in real terms).

[52] Ministry of Economic Development, New Zealand's Energy Outlook 2010, p 9.
Download from http://www.med.govt.nz/upload/76133/Energy%20Outlook%202010.pdf

In the high oil price sensitivity case, international crude oil prices are higher than the Reference Scenario and reach US$172/bbl by 2030 in real terms. This equates to pump prices of around $3.50 and $3 per litre for petrol and diesel respectively[53]. In the low price sensitivity case, crude oil prices are assumed to remain at US$70/bbl in real terms."

It must be noted that in June 2011, the West Texas (WT) price for crude oil is US$97 and for Brent Crude is US$119. The oil price is presently at the forecast for 2030 in real terms. For reasons of prudence we will therefore assume oil prices increase by some 20% from 2011 in real terms from present prices by 2030, and 30% by 2040. This is slightly above the medium price of the MED Energy Outlook; prices are in real 2011 US dollars.

It should be noted that some predictions have New Zealand's exchange rate falling back relative the US$, which would push fuel prices considerably higher. This would be particularly so if the NZ$ declines to be much closer to its long-run average.

Table 7.7 Oil price forecast

	MED Low	MED medium	MED High	BERL US$/B	BERL NZ$/l
Year 2011	$70	$70	$70	$100	$0.786
Year 2020				$110	$0.865
Year 2030	$70	$115	$172	$120	$0.943
Year 2040				$130	$1.022

7.3.8 Total economic value of bio-refinery operation

Capital requirement

The capital cost for F-T is from Davy quoted above, and for ethanol is from NREL also quoted above. It can be seen that for each plant (of throughput 1.303 M OD t/y) the cost is in the region of NZ$1 billion per plant, irrespective of the type.

Table 7.8 Capital requirement of bio-refinery operation

	Cost $NZ/plant	No of plants	Cost $NZ
F-T fuels	$910 M	3	$2.730 B
Ethanol	$943 M	3	$2.829 B
TOTAL $			$5.559 B

Net annual benefit

The net annual benefit has been calculated for two sample years, 2011 and 2040.

[53] MED notes that "*the higher oil prices bring forward the point where second generation biofuels become economic and by 2030 they provide more than 200 million litres of fuel. This is only a small proportion of our total fuel demand, reflecting the business risks of an emerging technology competing with the future oil price."*

Table 7.9 Net annual benefit from bio-refinery operation

	Cost $B/y 2011 oil price	Cost $B/y 2040 oil price	Income $ B/y 2011 oil price	Income $ B/y 2040 oil price
Sales revenue			3.026	3.704
Forestry feedstock	1.283	1.452		
Production cost fuel	1.305	1.697		
Total cost	2.583	3.149		
Net benefit			$443 M/y	$555 M/y

The significance of this result is that the return in the year 2040 is approximately $500 million on an investment of $6 billion. On a simple payback basis, the return from the bio-refineries is less than 10% per year. If undertaken on a stand-alone basis this return is likely to appear insufficient to the individual operator in light of the risks inherent in such an investment.

8 Conclusion

This report presents the potential benefits from development and expansion of the bioenergy sector in New Zealand. The findings from the modelling exercise suggest that an expanding bioenergy industry in line with the Strategy is likely to contribute positive wider economic benefits to New Zealand. Greater gains are generated once new energy products are developed and bio-materials are co-generated. Further, the analysis suggests the value of even broader collaborations across the public and the private sectors to achieve the outcomes envisioned in the Strategy.

The expansion of the bioenergy sector has social, economic and environmental implications. However, complex interactions of a variety of factors ultimately determine whether bioenergy options are socially, economically, and environmentally sustainable. A diverse portfolio of bioenergy options based on the availability of biomass sources, land use, the structure of forestry and agriculture sectors, investment in infrastructure, feasibility of conversion technologies, environmental sensitivities, and the decisions of forest owners (including, in particular, iwi and Māori organisations) makes a comprehensive assessment challenging. Nevertheless, bioenergy developments should understand the broader societal contexts that will influence and be affected by the implementation of the Strategy, as well as the wider economic benefits.

The analysis presented in this report has scope and methodological limitations. It is, however, an initial step in providing information for the private and public sectors to further understand the role of the bioenergy sector as driver of economic growth. To improve economic analyses, a better understanding of forestry resources and timelines for infrastructure development is needed. Further studies on wider economic impact, environmental gains and other intangible benefits are needed. These new models need to consider the range of issues that are likely to influence the growth of the bioenergy sector. Future assessment of the economic contribution of the bioenergy sector can include analysis of how different policy options may affect biomass production; refining capacity; industry structure; competitive uses of land; price valuation of energy crops; carbon, and trade and international markets. An informed understanding of these issues will influence how components of a new bioenergy industry will develop in New Zealand.

Critical decisions, though, are likely to rest with stakeholders in the forestry industry. The expansion of bioenergy production will depend whether the forestry industry is able to (or willing to) transform biomass to meet energy demand. For the potential gains from the Strategy to be realised, decisions by public and private sector investors on the development of the bioenergy sector and those in the forestry sector will need to be aligned.

9 Appendices

9.1 Costs and value per GJ of output for bioenergy industry output

The following table shows 2008 costs and value per GJ of output used in estimating the baseline NZ$ value of bioenergy output. The costs and value per GJ of output are adjusted using petrol, producer price indices to reflect price changes from 2008 to 2010.

Table 9.1 Cost, value and Co2 emissions per GJ of output by bioenergy pathway

Description	Cost	Value per GJ output	CO_2 equivalent emissions kg/GJ output
Wood to heat	$6.76	$6.78	4
Wood to CHP	$11.74	$12.58	5.9
Wood to EtoH	$20.56	$31.66	8.5
Wood-Gas-Heat	$25.14	$6.73	4.7
Wood-Gas-CHP	$30.06	$16.79	5.7
Wood to gas to FT	$24.15	$21.05	5.2
Wood to Pyrolysis to LF	$13.09	$14.11	4.8
Straw to Heat	$5.77	$6.79	4.5
Straw to CHP	$9.75	$12.56	6.5
WVO to biodiesel	$18.99	$24.95	7.4
Tallow to biodiesel	$24.92	$24.97	42.8
Rapeseed to biofuels	$47.15	$25.00	32.7

Source: Scion, 2008

9.2 Fuel Substitution

The following table presents fuel substitution envisioned in the Strategy.

Table 9.2 Fuel being substituted by bioenergy (in PJs)

	Electricity	Coal	Gas & LPG	Oil	Diesel	Total
2010	0	0.1758	0.0762	0.2797	0.0083	0.5399
2011	0	0.3504	0.1519	0.5418	0.0152	1.0594
2012	0	0.5335	0.2319	0.8018	0.0220	1.5892
2013	0	0.7230	0.3156	1.0638	0.0289	2.1313
2014	0	0.9217	0.4037	1.3365	0.0364	2.6983
2015	0	1.1304	0.4966	1.6257	0.0446	3.2972
2016	0	1.3449	0.5928	1.9331	0.0535	3.9243
2017	0	1.5587	0.6891	2.2495	0.0627	4.5601
2018	0	1.7800	0.7894	2.5859	0.0727	5.2281
2019	0	2.0328	0.8750	2.9296	0.0830	5.9205
2020	0	2.3376	0.9154	3.2661	0.0927	6.6119
2021	0	2.6700	0.9454	3.6072	0.1026	7.3251
2022	0	3.0211	0.9634	3.9406	0.1120	8.0372
2023	0	3.3927	0.9724	4.2770	0.1214	8.7635
2024	0	3.7553	0.9973	4.6280	0.1315	9.5120
2025	0	4.0779	1.0765	4.9724	0.1410	10.2678
2026	0	4.4016	1.1573	5.3140	0.1502	11.0232
2027	0	4.7285	1.2399	5.6549	0.1593	11.7826
2028	0	5.0624	1.3243	5.9966	0.1683	12.5516
2029	0	5.3640	1.3999	6.3404	0.1772	13.2815
2030	0	5.6642	1.4751	6.7059	0.1872	14.0323
2031	0	5.9619	1.5483	7.0939	0.1980	14.8021
2032	0	6.2600	1.6213	7.5005	0.2096	15.5913
2033	0	6.5569	1.6934	7.9148	0.2213	16.3864
2034	0	6.8556	1.7658	8.3410	0.2335	17.1958
2035	0	7.1555	1.8381	8.7758	0.2459	18.0153
2036	0	7.4613	1.9170	9.2199	0.2588	18.8570
2037	0	7.7751	1.9992	9.6802	0.2724	19.7269
2038	0	8.0899	2.0816	10.1411	0.2859	20.5986
2039	0	8.4072	2.1648	10.6069	0.2997	21.4785
2040	0	8.7277	2.2490	11.0801	0.3136	22.3704

Source: BANZ, 2011

9.3 Other measures of macro benefits

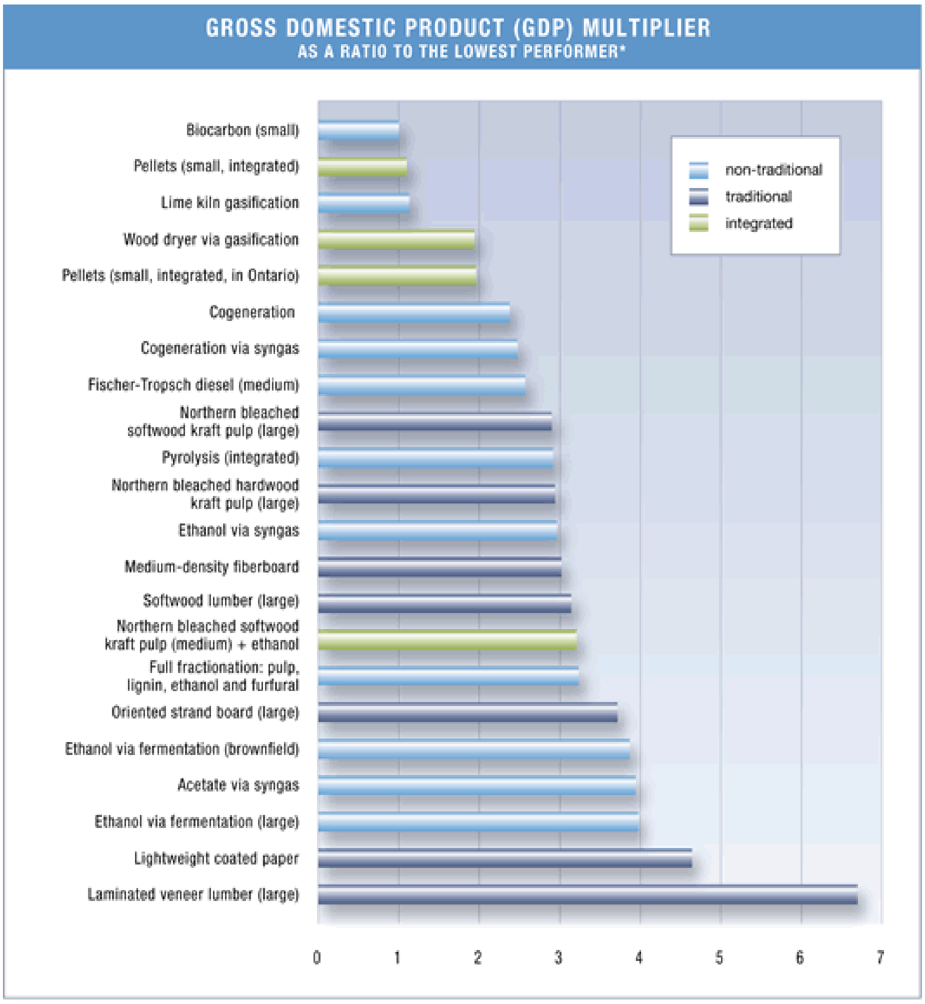
Some studies use ‘multiplier analysis’ to assess the impact of larger bioenergy sectors. In particular, GDP and employment multipliers are commonly used terms to describe the extent to which increased bioenergy production can lead to greater economy-wide impacts. It should be noted that these multipliers are, in essence, a simplified form of macroeconomic analysis, incorporating much stricter assumptions in their calculations. A general equilibrium modelling approach provides more robust findings.

Nevertheless, relative multipliers for different forms of bioenergy processes do provide a useful indication of the relative impacts across potential range of options. These are presented below.

9.3.1 Economic growth

Implementing the Strategy will produce wood-derived products such as pellets which will be used as heating fuel, and biofuels which will substitute for imported petroleum products. Provided the production cost is less than the equivalent petroleum product cost there will be direct economic benefit.

Figure 9.1 Estimates of GDP multipliers of bio-carbon facility[54]



* A multiplier of 2 means that this process generates twice the GDP of a small biocarbon facility.

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[54] Natural Resources Canada, 'Social impacts of technologies', http://canadaforests.nrcan.gc.ca/rpt/multipliers 2011, p 2

In addition, for an industry policy of this type there are substantial economic multipliers. Implementation of the Biomass Strategy will involve constructing and operating very substantial components of infrastructure. Networks of roads, shipping and energy will be utilised. In addition the use of municipal waste for the production of bioenergy will have economic and social impacts but they will be significantly less than comes from the use of woody biomass resources as many are replacement for existing activities such as landfills.

Natural Resources Canada has the view that for the conversion of woody biomass to energy multipliers of the order of 3 may be expected over the lowest performer, a small bio-carbon facility. The data is presented in Figure 9.1 this sentence needs to be finished or deleted. The experience by BERL in New Zealand is that most Economic Impact Assessments (EIAs) for multiple-industry activities or facilities result in overall multipliers of about 2. Some industries with strong, diverse supply chains have multipliers of 3 or 4; but in general a mixed-output processing/manufacturing complex would not be expected to have multipliers as high as those reported for Canada.

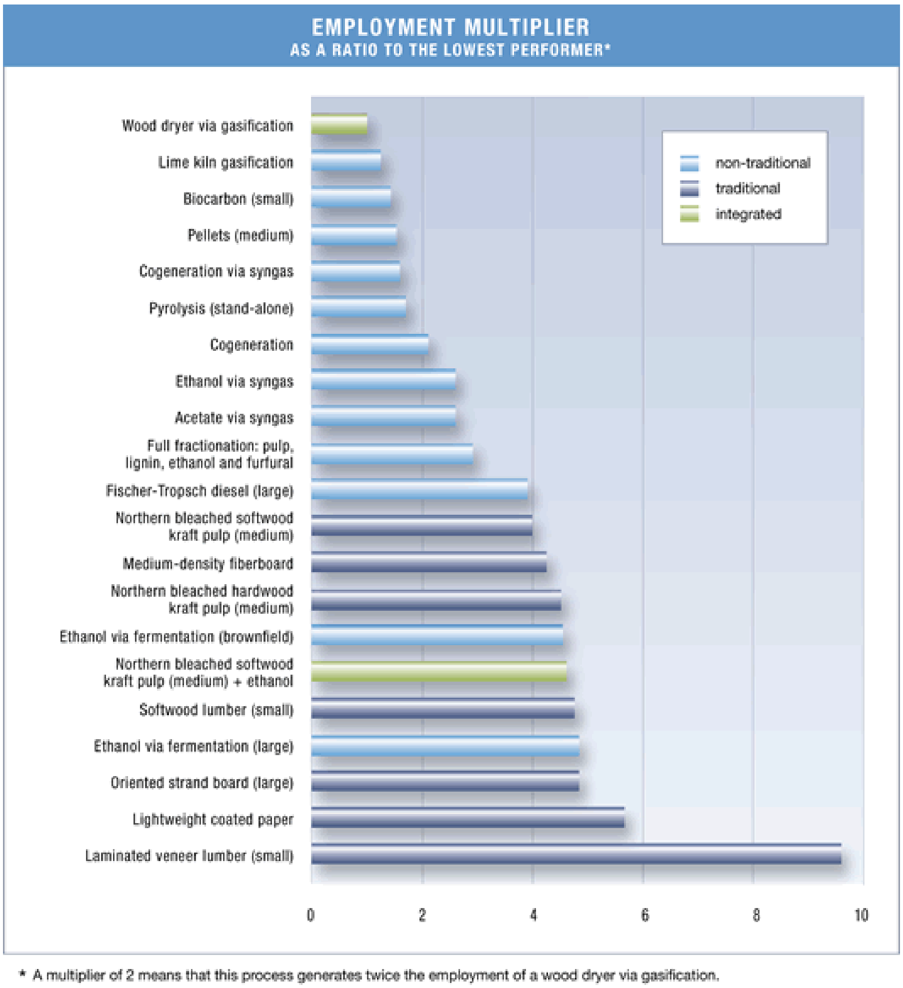
9.3.2 Employment

Producing energy from biomass is much more labour intensive than conventional fuels. This is particularly true for large scale liquid fuels from forests, which is in stark contrast to importing crude oil into Whangarei, refining it, and then shipping product around New Zealand ports. The input of labour is relatively small compared to the value which is generated.

The forest feedstock involves ground preparation including deployment of roads throughout the area. Seedlings are then planted and maintained as they grow. Trees are then harvested and trucked to the processing plants. Forest residue is collected and transported to the processing plant.

Natural Resources Canada presents data which shows that the employment multiplier is of the order of three times that of the lowest performer, a wood drier via gasification. This is shown in Figure 2. While this synergy may exist for biofuel produced on a limited scale, it is not clear that it should be the case for the production of liquid fuel on a large scale.

Figure 9.2 Estimates of employment multipliers of bio-carbon facility[55]



Natural Resources Canada has evaluated labour and GDP multipliers[56] and has put forward a view that employment is enhanced when bioenergy production is combined with traditional forest products:

"Labour and GDP multipliers made it clear, for instance, that in most of the cases examined under BioPathways, the production of traditional forest products creates more jobs and generates more national income than emerging bio-industries alone. A pulp mill, for example, produces more direct jobs than a new wood dryer via gasification (a ratio of 4:1).

The Bio-pathways Project concluded that an operation that combines bioenergy production with traditional forest products has the greatest potential to generate both greater returns on

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[55] Natural Resources Canada, 'Social impacts of technologies', http://canadaforests.nrcan.gc.ca/rpt/multipliers 2011, p 2

[56] http://canadaforests.nrcan.gc.ca/rpt/multipliers

investments and jobs. Integrating an ethanol plant into a pulp mill, for example, generates more jobs than a stand-alone pulp mill."

Marshall has provided an aggregate figure for employment in Canada. [57] The BC forest industry, based on employment and timber figures for 1997-1999, creates approximately 790 processing jobs per million cubic metres of timber. This does not include jobs in logging, silviculture, and government, which are all assumed to be unaffected by raw log exports. Natural Resources Canada presents data which shows that the employment multiplier is of the order of three times that of the lowest performer, a wood drier via gasification.

Employment generated by the forest sector in New Zealand is more significant than the number employed implies. The employment pattern strengthens the regions' communities because the:

- employment generated is spread among settlements around the region;
- forestry and wood processing industries are 'core drivers' and their growth expands demand for services to the businesses and the people and families involved;
- employment generated is nearly all year-round, fulltime rather than seasonal or part-time as with pastoral-based industries and tourism; and
- sector employs a greater proportion of younger aged people than for the regions' workforce overall, so the employees raise their families in the regions' settlements.

The forest sector's industry employment pattern contrasts with those seen in rural areas based on the pastoral industry. Recent dairy conversions and other changes have seen higher on-farm employment and employment in construction activity but reduced employment in towns, because employment based on processing and its support industries have become centralised in three or four main processing plants in the South and North Islands.

On the other hand the forestry and wood processing sector has a location and employment pattern that provides sound employment to people around the regions. A key difference is that the silvicultural work and the harvesting work in the forests are done by gangs run by SME business owner/operators. These gangs and their owner/operators live in the distributed regional settlements, providing wealth in the communities.

[57] Marshall, Dale, 'Down the value chain, the politics and economics of raw log exports', Canadian centre for policy alternatives, BC Office • 1400–207 w. Hastings st. • Vancouver • BC • v6b 1H7 telephone: 604-801-5121 • fax: 604-801-5122 • email: info@bcpolicyalternatives.org • www.policyalternatives.ca Nov 20 2002, p3

The young families retain the social services in the settlements, and the owner/operators generally contribute to settlement governance functions as on the school Board of Trustees and other functions. Retaining viability in regional settlement communities retains options for development of other industries over time.