

Mandatory transport biofuels

Costs and benefits of mandatory biofuel blends in transport fuels

**Report to Ministry of Economic
Development**

22 November 2004

Preface

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Authorship

This report has been prepared at NZIER by John Stephenson, Preston Davies, and Rebecca Schrage and reviewed by Peter Clough.

8 Halswell St, Thorndon
P O Box 3479, Wellington
Tel: +64 4 472 1880
Fax: +64 4 472 1211
econ@nzier.org.nz
www.nzier.org.nz

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Executive Summary

At the request of the Ministry of Economic Development we have prepared this report to assess the relative costs and benefits to the New Zealand economy of a requirement for transport fuels to contain a mandatory percentage of biofuels. Measures aimed at increasing the use of biofuels in the New Zealand economy are part of a series of initiatives being evaluated by the government in an effort to increase the amount of renewable energy used in New Zealand.

The National Energy Efficiency and Conservation Strategy includes a goal of ensuring 30 petajoules of consumer energy used in New Zealand is derived from renewable sources by the year 2012. In the case of renewable fuel use in the transport sector, the government has laid out a target of 2 petajoules (PJ) of energy use from renewable sources by the year 2012. Our report focuses on evaluating the kinds of biofuel use requirements which might best deliver this target for the transport sector.

Three broad scenarios for mandatory biofuel use are considered.

- A mandatory percentage of biodiesel to be blended with automotive diesel.
- A mandatory percentage of biofuels, either ethanol or biodiesel to be blended with petrol or automotive diesel.
- A mandatory percentage of total transport fuel sales to consist of biodiesel or ethanol.

In order to analyse these scenarios we have assessed the economic impacts of various blend levels and of phased requirements for fuel use out to 2012.¹ Key issues we have considered in our evaluation are:

- Costs to consumers.
- Distortions to productive resource allocation in the economy.
- Supply constraints on blend levels and biofuel alternatives.
- Benefits from reductions in CO₂ emissions.
- Reductions in vehicle emissions and associated health effects from pollutant reduction.
- Impacts of biofuel blend requirements on competition in the transport fuels market

Our report does not consider the full quantum of costs and benefits to society of biofuel use. This is partly because considering all costs and

¹ Our analytical framework includes a partial equilibrium analysis. Ideally we would have used a computable general equilibrium model for our analysis, however, time and other resource constraints meant that this was not feasible.

benefits of biofuel use would require a more substantial research process than has been possible within the scope of this research. As such, this report should not be taken as the final word on biofuel use but rather as a contribution to a larger set of policy research programmes and initiatives of which the cost effectiveness of biofuel targets is a small part.

In our analysis we find that biodiesel is the least cost biofuel for meeting the government's renewable transport fuel target. A mandatory biodiesel blend of 3% of diesel would deliver 2.15 PJ of renewable fuel use in the transport sector by 2012. We estimate the net present value to consumers of such a requirement would be positive with the cost to consumers amounting to \$378,000, against a benefit from CO₂ emission reductions of \$10,127,000.

The cost to the economy overall would in fact be higher than this due to resource allocation distortions valued at \$106 million in present value terms (approximately 0.02% of GDP). However, without further analysis it is not possible to say whether any of this cost is a net cost to the New Zealand economy. It is quite possible that additional benefits from biofuel use, such as environmental benefits from mitigated atmospheric pollution, would offset this cost. Our research would be enhanced by further study in New Zealand into the full quantum of benefits (environmental, social, cultural, and economic) from biofuel use.

The results of a requirement to blend ethanol with petrol, in the absence of resource allocation costs, would also be positive. However, the costs would be greater than for biodiesel. For example, assuming no loss in fuel efficiency a 3% ethanol/petrol blend requirement would reduce consumer welfare by \$3.4 million in present value terms compared with a benefit from CO₂ emission reductions of \$9.7 million. Resource allocation distortions are also larger at around \$192 million (between 0.01% and 0.04% of GDP between 2006 and 2012).

If we factor volumetric fuel efficiency losses into the price of ethanol, the benefits from CO₂ reductions decrease and the cost to consumers increases. A 3% ethanol/petrol blend would result in a \$5.8 million reduction in consumer welfare and \$9.5 million in benefits from reduced CO₂ emissions. Similarly resource allocation distortions increase to \$314 million.

In addition to the costs that ethanol/petrol blends impart on the economy over and above those in the case of biodiesel blends, ethanol/petrol blends do not have the same pollutant reduction qualities of biodiesel. This is partly because the conventional alternative to ethanol (i.e. petrol), produces less harmful emissions than diesel fuels which would be displaced by biodiesel. As a result, the cost of reducing vehicle emissions through biofuel blends is higher per tonne of emission reduced in the case of ethanol blends compared with biodiesel blends. In the case of emissions of particulate matter (the emissions which produce the vast majority of costs to human health) the

cost of each tonne reduced from ethanol blends is typically hundreds of times greater than cost per tonne of emissions reduced from biodiesel blends.

Ethanol/petrol blends would also deliver less renewable fuel use compared with biodiesel. A 3% ethanol/petrol blend requirement would see 2.05 PJ of renewable fuel use by 2012, compared with 2.15 PJ of renewable fuel use in the case of a 3% biodiesel/diesel blend requirement. As such, biodiesel/diesel blends appear a more desirable biofuel choice than ethanol/petrol blends if the government was to institute a requirement for biofuel blends in transport fuels.

Though ethanol blends are more costly than biodiesel blends, ethanol production is increasing rapidly worldwide. Thus, New Zealand would be able to import ethanol to meet just about any level of ethanol/petrol blend desired by the government and a small amount of ethanol could be sourced domestically.

Conversely, global biodiesel production is small and additional domestic production facilities would need to be constructed to supply biodiesel/diesel blends at any percentage blend level. As a result blends over 3% are not likely to be feasible out to 2012 because of uncertainty over supply of biodiesel. Indeed, in our view a phasing of required blend levels would be prudent. In addition to this, regulations implementing the blend target would need to have a caveat that while a 3% blend was required, supply side shocks or other production delays could be considered in lowering the required blend percentage.

Installing a mandatory requirement for a given percentage of transport fuel sales to include biofuels would help mitigate supply side issues in the case of biodiesel. It would allow firms to vary their use of biofuel blends based on variable supply constraints. Firms would have the flexibility to use biodiesel or ethanol if supply constraints warranted it or if the cost of either fuel fell considerably. It would also allow fuel suppliers to target biofuel provision in a least cost manner – targeting consumers who are least responsive to price changes and possibly targeting wholesale or bulk consumption.

However, a biofuel sales requirement is likely to see biofuel sales restricted almost exclusively to ethanol over the medium term due to issues around security of supply of biodiesel. If sufficient biodiesel production were to come on line in New Zealand to allow widespread use of biodiesel, then we would still expect a significant portion of biofuel sales to consist of ethanol. Therefore, given the cost of ethanol blends against biodiesel blends, a biofuel sales target would not be a least cost option for reaching the government's target of 2PJ of renewable fuel use in the transport sector by 2012.

The effect of an imposition of a biofuels requirement on transport fuel suppliers would not adversely impact on competition in the transport fuels industry. Sufficient threats to entry would exist that would prevent biofuel suppliers from seeking uncompetitive prices for their products. However, biofuel suppliers, particularly domestic producers would need to be monitored by regulatory authorities in the same manner in which petroleum fuel suppliers are currently monitored to mitigate collusive anti-competitive behaviour.

Summary of mandatory blend options

Thousands of New Zealand dollars (2004), PJ used in 2012, millions of litres of biofuels required

Option	Consumer welfare loss	Benefit from CO ₂ reduction	PJ of renewable fuels used in 2012	Resource Cost	Biofuel required in 2012	Notes
BD3	\$378	\$10,127	2.16	\$139,806	59.9	Biodiesel production may not be sufficient
BD5	\$1,000	\$16,854	3.59	\$232,519	99.9	Biodiesel production is not likely to be sufficient
BD5 phased from 2006	\$301	\$7,492	3.59	\$106,017	99.9	Biodiesel production may not be sufficient
BD5 phased from 2008	\$235	\$5,369	3.59	\$77,369	99.86	
E3	\$5,765	\$9,519	2.03	\$314,940	85.5	
E5	\$10,195	\$15,866	3.4	\$525,822	142.5	The Motor Industry Association has said its members will not accept anything above E3
E5 phased from 2006	\$3,991	\$6,970	3.4	\$221,208	142.5	
3% sales target	\$5,765	\$9,519	2.03	\$314,940	85.5	We expect a sales target to be a de facto E3 target in the medium term. Any biodiesel use would lower these figures
5% sales target	\$10,195	\$15,866	3.4	\$525,822	142.5	We expect a sales target to be a de facto E5 target in the medium term. Any biodiesel use would lower these figures.

Notes: (1) Options for 10% blends are not shown here as they are not considered feasible within the time horizon covered by this report.

Source: NZIER

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1. Introduction

The Ministry of Economic Development (MED) has requested a report detailing the costs and benefits of mandatory biofuel blends for transport fuels.

MED has asked that three alternatives for mandatory biofuel blends be considered:

- A mandatory percentage of diesel to comprise biodiesel.
- A mandatory percentage of transport fuels to comprise biofuels (biodiesel or some other biofuel).
- A mandatory percentage of transport fuel sales to comprise biofuels.

This report focuses on the use of ethanol and biodiesel blended with petrol and diesel respectively. While these fuels can, under some circumstances, be used on their own and there are other bio-fuels which may be investigated, we have chosen to look entirely at these two fuel blends because on the face of it they represent the most feasible bio-fuel options to meet a renewable fuels target for transport biofuels in New Zealand.

Additional potential elements related to biofuel use, other than mandatory blends, such as fuel quality standards, tax exemptions, and grants or subsidies are not considered in this report.

1.1 Policy context

The policy context surrounding bio-fuels for transport is articulated in a range of policy initiatives including:

- the Sustainable Development Programme of Action which identifies principles for sustainable development policy and decision-making. Sustainable energy is one of the key action areas with desired outcomes including energy use in New Zealand becoming progressively more efficient and less wasteful, and renewable sources of energy are developed and maximised;
- the New Zealand Transport Strategy which sets out the government's overall vision for the transport sector. One of the objectives of this strategy is ensuring environmental sustainability through reducing local and global environmental effects and shifting from non-renewable to renewable resources;
- climate change, air quality and waste policies which support greater supply of renewable transport energy;
- the National Energy Efficiency and Conservation Strategy which promotes energy efficiency, energy conservation and renewable energy with the objective of moving New Zealand towards a sustainable

energy future. It contains an overall target of an additional 30 petajoules (PJ) of consumer energy from renewable sources by 2012 and includes an indicative target of at least 2 PJ per year for transport.

These policy initiatives provide the framework within which biofuel use is being considered by the government. Our consideration of the cost effectiveness of various biofuel targets is but a contribution to this wider body of work. Moreover, ours is but one contribution to work being conducted by officials looking at the costs and benefits of biofuel use in the transport sector (amongst other things).

1.2 Approach

Our over-arching approach to assessing the relative costs and benefits of transport bio-fuel targets is a cost effectiveness framework. Assessing the costs and benefits of renewable energy sources can be confounded by the fact that the full benefits of renewable energies are not likely to be accrued until some time in the future and that the precise nature of these benefits is difficult to forecast. This means that the costs of renewable fuel use in today's terms is often perceived or assessed to be in excess of the benefits. This is where policy intervention is necessary to make a judgement on the desirability of renewable fuel use. As a consequence the focus of this report is on how a renewable fuels target might be achieved, the relative costs, benefits, and implementation issues of different approaches rather than whether renewable transport fuels are valuable in and of themselves.

Within our cost-effectiveness framework, our analytical approach is both quantitative and qualitative. In the case of quantitative analysis we utilise a partial equilibrium framework to assess the relative costs and benefits of various mandatory bio-fuel blends. In this part of the report we assess the costs to consumers and to the economy, in dollar terms, of instituting mandatory biofuel blend requirements. We then compare these costs against the quantifiable benefits of reductions in greenhouse gas emissions and derive a net present value of the benefits (positive or negative) for various fuel types and blend percentage scenarios.

Time constraints on the production of this report mean that we have not been able to fully explore all of the economic issues around biofuel use. In particular we have not fully assessed the impact on industry of implementing biofuel blend requirements. To do so would require greater time and resources necessary to use a general equilibrium model of the New Zealand economy. That said, through the paper we provide a qualitative assessment of the effects of mandatory biofuel blends on industry and other areas of the economy.

The scope of our brief and time available also mean that we have not considered the full quantum of social, environmental, and cultural costs and benefits associated with biofuel use. In our view these are important and

best investigated within a more comprehensive and resource intensive research process than the one which underpins this study.

In our analysis we have relied heavily on existing literature regarding the unit costs and technical feasibility of bio-fuels. We are especially indebted to the work of Duncan and Copeland (2004) and have drawn on their estimates of the non feed stock costs of ethanol and biodiesel use and their estimates of reductions in vehicle emissions from biofuel use.

Our report begins by outlining the nature of biodiesel and ethanol as biofuels. We sketch briefly the relative merits of each type of biofuel and provide an assessment of the likely impact of these biofuels on transport fuel prices, taking into account the probable unit costs of producing each type of fuel. We also discuss issues around the supply of each biofuel.

Section 4 of the report discusses our partial equilibrium framework for analysing the impacts of ethanol and biodiesel blends. Section 5 provides the results of our analysis in terms of costs of biofuel blends to consumers and to allocative efficiency in the economy compared against the benefits of reductions in CO₂ emissions from combustion of transport fuels.

In section 6 we provide a method for assessing the cost effectiveness of biofuel blends in reducing non-CO₂ vehicle emissions. In that context we also provide an analysis of the relative allocative distortions arising in the economy from mandatory biofuel blends.

Following from our largely quantitative analysis we discuss potential for biofuel blends to be mandated on a per-sales basis, rather than a percentage of fuel basis. We then discuss additional costs and benefits of mandatory biofuel blends which are not included in the partial equilibrium framework.

Section 9 provides our assessment of potential competition issues arising in the transport fuels supply industry.

2. Biodiesel

2.1 Background

The word biodiesel is a generic term which refers to diesel fuel substitutes derived primarily from non-fossil fuel feedstocks. Biodiesel is typically formed through two distinct production processes. One is the transesterification of feedstock oils or fats through reaction with methanol and a potassium hydroxide catalyst. The other is production of synthetic diesel fuel made from biomass through gasification. In the following we discuss biodiesel produced by transesterification of oils or fats.

The bulk of world supply of biodiesel is produced using vegetable oils, primarily in Europe where rapeseed oil is the principal input. However, biodiesel can also be produced from waste fats and tallow. Tallow as a feedstock has not been very widely used, but it has been singled out as the most likely feedstock for biodiesel production in Australasia due to the large quantities of tallow available from meat processing. A recent study on the feasibility of biodiesel production in New Zealand suggested that sufficient tallow production existed to support biodiesel production in New Zealand for a 6% biodiesel/diesel blend (hereafter biodiesel/diesel blends are referred to as BD[blend%]) (Judd, 2002). In this report our discussion of the costs and benefits of biodiesel/diesel blends focuses on biodiesel produced from tallow in New Zealand.

Biodiesel is used in Europe and the United States at levels of BD5, BD20, and in some cases neat or 100% biodiesel as a transport fuel. For the most part, biodiesel is best used in low level blends. The higher the level of biodiesel used in a blend, the greater the likelihood of problems occurring in unmodified vehicles. This is particularly the case for biodiesel produced from tallow, which on its own begins to crystallise (cloud point) at under 20°C (Judd 2002). Problems around cloud point can be mitigated through additives however, though this is an issue that would need to be dealt with by fuel quality authorities rather than in the present context.

At lower blends, biodiesel has useful properties, including increasing the lubricity of the fuel. Fuel lubricity is important because in many diesel engines some moving parts are lubricated by the diesel itself. Thus the introduction of biodiesel can lead to reduced engine wear and some studies even suggest increased fuel efficiency compared with low-sulphur content diesel.

The most commonly cited negative effect of biodiesel on vehicle performance is reduced power (Prakesh, 1998). This is due to the fact that biodiesel contains slightly less energy than regular diesel on a volumetric basis. Many of the studies which cite loss of power as an adverse effect of biodiesel use also note that the problems can be attributed partly to fuel quality issues.

In the following, we look at BD blends of between 1% and 10%. We assume that a biodiesel production industry will be set up in New Zealand. World production of biodiesel is such that fuel would not likely be able to be imported. However, it is possible that vegetable oils might be imported as an input to domestic biodiesel production. This possibility is considered later.

2.2 Unit costs of biodiesel blends

Drivers of the unit costs of biodiesel blends include:

- Feedstock costs.
 - The price of tallow.
 - The price of alternative feedstocks, e.g. vegetable oils.
 - The price of other inputs (methanol and potassium hydroxide).
- Non feedstock costs
 - Capital expenditure on plant
 - Operating expenditure for plant
 - Transportation, storage, and distribution costs
 - Blending costs.

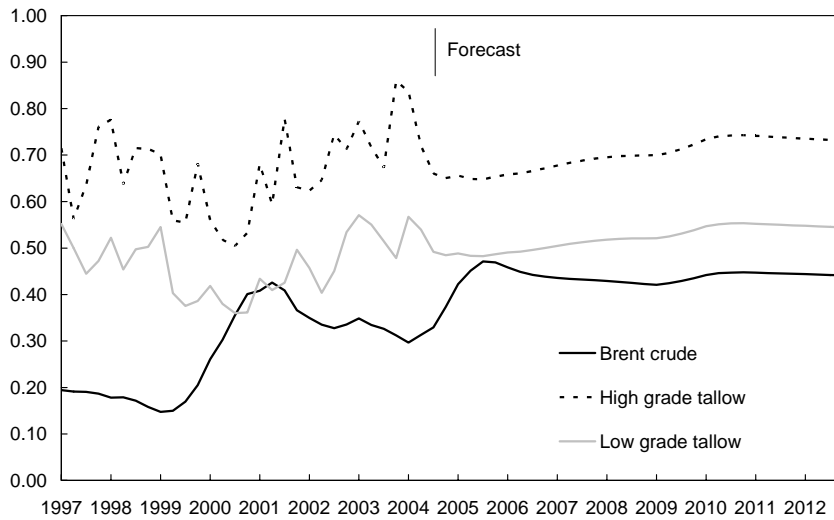
Our assumption that the bulk of supply would have to come from domestic biodiesel production has the effect of raising the price of biodiesel from the raw input to including the capital costs associated with producing in the New Zealand market (though capital costs would on average over the long run also be reflected in biodiesel prices on the world market). Despite this, the primary driver of biodiesel costs is the feedstock input, which in this study is tallow (given that is the feedstock for which New Zealand has the largest available stock).

To conduct our analysis of biodiesel prices we have forecast the price of tallow out to 2012. For our forecasts we have used a reference price that is the mid range between high grade tallow and low grade tallow. This is not problematic in as much as the two prices move together, but it does affect the level of the cost of tallow inputted to our model. If biodiesel was to be manufactured in New Zealand from low grade tallow, we would expect a reduction in the difference between the diesel pump price and the BD5 pump price – though BD5 would not be cheaper than entirely petroleum based diesel.

Figure 1 shows the path of our forecasts for tallow prices compared with our forecasts for crude oil prices. The forecast for tallow is based on historical movements in the price of tallow on European commodity spot markets, and on an observed structural upward shift of meat and meat bi-product prices in the past four or five years. Our forecast for Brent crude prices are those produced in NZIER's *Quarterly Predictions*.

Figure 1 Tallow and crude oil prices

New Zealand dollars per litre



Source: NZIER

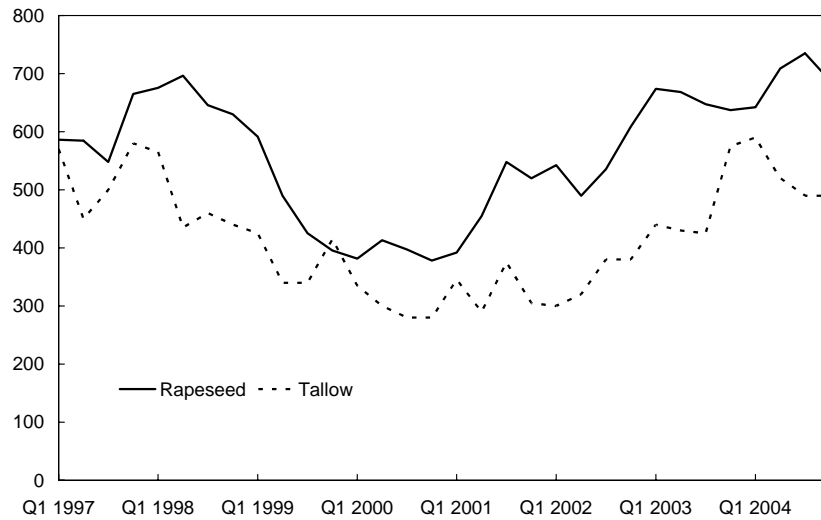
If the price of alternatives to tallow, such as rapeseed or canola oil, were to fall below that of tallow, we would expect a switch from tallow feedstocks to vegetable oil stocks. However, tallow prices have almost always tracked below vegetable oil prices in international markets (see Figure 2). As such we have not considered vegetable oil feedstocks and their effect on biodiesel prices.

The non-tallow costs used in our analysis are those reported in Duncan and Copeland (2004). We have divided the costs into those assumed to vary proportionally with the tallow feedstock price and those considered to be constant in cents per litre. The transport costs and costs of additional feedstock chemicals are assumed to be 22.32% of the price of the principal tallow feedstock. Those costs deemed to remain constant are the non-tradable blending costs, capital costs, and operating expenditure costs, assumed to be equal to 4.5, 4.9, and 0.003 cents per litre respectively.

Part of the additional non-tallow cost of biodiesel is offset by the production of saleable by-products such as glycerol. Duncan and Copeland (2004) estimate sales of by-products reduce the cost of biodiesel by 17 cents per litre. In our analysis we have assumed that the price of by-products moves in line with the price of tallow, and as such is a constant proportion of the cost of tallow equal to 26.4% of the price of tallow. Hence the proportion of non-tallow costs included in the biodiesel price is a net price reduction on the price of tallow of 4.08% - before the addition of the constant cent per litre costs outlined above.

Figure 2 Tallow and rapeseed oil prices

US\$ per metric tonne



Source: Datastream

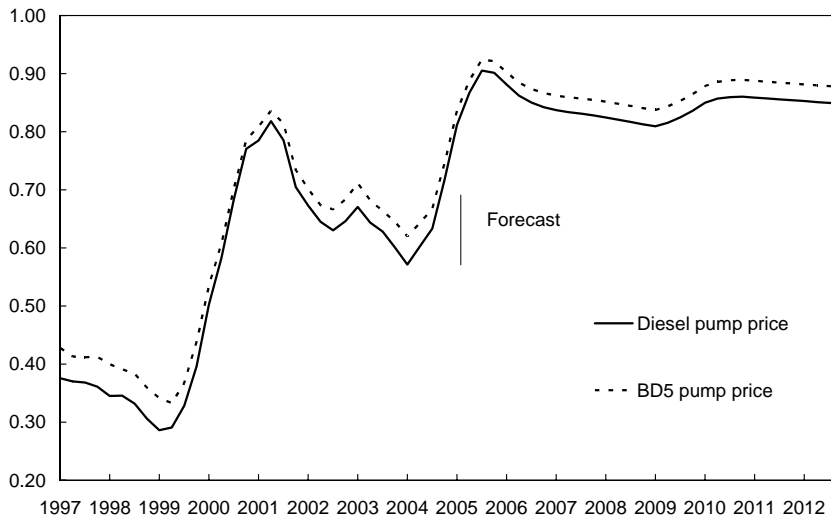
2.3 Biodiesel blend pump prices

Figure 3 shows our forecasts for the pump price of biodiesel. The price of BD5 is seen to track the price of diesel very closely. This is because 95% of the price is derived from diesel. But note that through 2004 and into 2005 the increase in oil prices makes the price of BD5 nearly indistinguishable from the price of diesel.

Later we provide two series for pump prices in the case of ethanol blends, one series per litre of fuel and one series adjusted for fuel consumption efficiency of ethanol blends. This is not done for biodiesel because the fuel efficiency of biodiesel is around 99% that of regular diesel and consequently the impact on price from lost fuel efficiency is negligible in a BD5 blend.

Figure 3 Diesel and 5% biodiesel blend pump prices

New Zealand dollars per litre



Source: NZIER

Table 1 provides the path of likely pump prices of various biodiesel blends relative to diesel pump prices. To make the price of diesel directly comparable to biodiesel blends, we have added an equivalent retail premium to each of the raw fuel input costs based on the average difference between the retail diesel and crude oil prices in the past four years. In reality this premium will vary through time and as a result the realised price of diesel may differ from the precise value at the pump currently. Furthermore, our reference prices for both diesel and biodiesel/diesel blends are the average annual price which dampens the effects of price shocks on the reference price in any given year. For the sake of comparison we have included the notional price of biodiesel blends were they to have been introduced from this year on.

Table 1 Diesel vs. biodiesel blend pump prices

NZ cents per litre

Year	Diesel price	BD3 price and price difference		BD5 price and price difference		BD10 price and price difference	
2004	71.78	73.50	1.72	74.64	2.86	77.50	5.8
2005	90.15	91.34	1.19	92.13	1.98	94.10	3.95
2006	84.21	85.67	1.45	86.63	2.42	89.05	4.84
2007	82.81	84.41	1.59	85.47	2.66	88.13	5.31
2008	81.27	82.94	1.67	84.06	2.79	86.85	5.58
2009	83.62	85.34	1.71	86.48	2.86	89.34	5.72
2010	86.03	87.77	1.74	88.93	2.90	91.83	5.80
2011	85.42	87.15	1.73	88.30	2.88	91.18	5.76
2012	84.81	86.53	1.72	87.68	2.87	90.54	5.73

Source: NZIER

2.4 Effects of biodiesel on vehicle emissions

Biodiesel blends can have significant positive effects on vehicle emissions. The precise nature of the effects depends on the level of the blend, fuel quality, and the type of vehicle using the blend. Typically, biodiesel use results in reductions of tailpipe emissions of unburned hydrocarbons, carbon monoxide, particulate matter, and CO₂. Relative to low sulphur diesel, emission reductions from a 10% biodiesel/diesel blend are expected to be:

- 2.4% reduction in carbon monoxide
- 2.0% reduction in non-methane volatile organic compounds (NMVOC)
- 2.3% reduction in particulate matter.
- 0.05% reduction in CO₂ emissions.

The principle emissions of interest in this study are those of CO₂ and of particulate matter. The former is the most prolific greenhouse gas and the gas on which carbon taxes will be charged post 2007. Particulate matter is of interest because it is these emissions which are most closely related to ill health effects from vehicle emissions. Preliminary New Zealand research conducted by NIWA for the Ministry of Transport has estimated that 399 people above the age of 30 die prematurely every year due to particulate matter emissions from vehicles (NIWA, 2002).

From a survey of New Zealand and Australian research, Duncan and Copeland (2004) suggest that the potential benefits of reductions in emissions of particulate may be equivalent to 5.4 cents per litre of diesel

displaced by biodiesel. These estimates are problematic because the extent of adverse health effects depends on the concentration of people as well as the stock of particulate matter in a given area. Indeed Duncan and Copeland point out that a significant proportion of biodiesel would need to be consumed in Auckland for there to be significant positive health impacts from particulate matter reductions.

Duncan and Copeland suggest that concentration of a BD20 blend in the Auckland market could deliver the most health benefits from reductions in emissions of particulate matter. In our view, this is not an option. Mandating biodiesel blends in specific regions of New Zealand would require either requiring Auckland transport fuel suppliers to use BD20 blends, or vehicles in Auckland to provide proof they are using BD20 blends. The former would doubtless be circumvented by large diesel consumers purchasing fuel elsewhere in the country and the latter would require an inordinate enforcement cost.

Problems around accurately estimating emission reductions and positive health impacts of emission reductions mean we have not independently estimated the precise monetary value of such reductions. However, in section 6 we draw on existing studies in a discussion around the health benefits of reduced vehicle emissions.

In our analysis tailpipe CO₂ emissions are assumed to reduce by 0.1% for every 10% of biodiesel in a diesel/biodiesel blend. In addition to this, for each 1% of biodiesel in a biodiesel blend, 0.924% of emissions are assumed to be due to biodiesel and therefore from a renewable source which does not increase the stock of CO₂ in the ecosystem. The net effect being that, based on CO₂ emissions alone, a 10% blend of biodiesel in diesel would result in an approximate 10% reduction in the amount of greenhouse gas emissions produced as a result of automotive diesel consumption.

The existence of carbon taxes and carbon credits for renewable fuels yields a useful reference point for our analysis of the benefits of bio-fuel blends. The government has capped carbon taxes at \$25 per tonne of CO₂. We assume that emissions are valued at \$15 per tonne in the market. Hence we value the reduction in CO₂ from biodiesel use at \$15 per tonne of CO₂ reduced compared to a baseline forecast (see section 4.1).

2.5 Biodiesel supply issues

Biodiesel production is limited worldwide and, as mentioned above, this leads us to assume that biodiesel production to meet mandatory transport fuel blend targets will need to be met almost exclusively from domestic production. Currently New Zealand has only one domestic biodiesel producer, but production is in very small quantities. Thus any mandatory

fuel target would have to be contingent on the entry of additional biodiesel producers into the New Zealand market.

One international biodiesel producer, Argent, have said that they could enter the New Zealand market and be at full production of 55 million litres within four years of the decision to invest. This suggests firstly that a mandatory biodiesel blend could not feasibly be introduced before 2008. It also suggests that the extent of a mandatory blend percentage is restricted to quantities less than 55 million litres per annum.

Later in this report we investigate the impact of introducing a mandatory biodiesel blend target before 2006. This is indicative only as it remains to be seen as to whether sufficient biodiesel will be produced in New Zealand prior to 2008. The timing of a mandatory biodiesel target will therefore have to take into account this supply side constraint.

In our view, the implementation of a biodiesel blend requirement for diesel and decision around the precise blend percentage will require further consideration of these supply side issues in discussion with potential producers of biodiesel. In our view it would be prudent to have an implementation mechanism which is linked to the level of biodiesel production in the economy. That is, blend requirements might well be a fixed percentage of domestic production up to and including a desired target level. For instance, a blend target of 3% may be chosen, with regulations specifying that use of such a blend would be contingent on domestic biodiesel supply being sufficient to supply that level. For every 10 million litres deficit in supply, the required blend would fall by 0.5%.

We understand that a number of Australian companies have looked into biodiesel production and some plants are already producing. We would suggest discussion with Australian firms with interests in biodiesel production to assess the future feasibility of importing biodiesel from Australia if necessary.

The imposition of a mandatory biodiesel/diesel blend would also require the creation of a New Zealand biodiesel standard. Biodiesel is not presently approved for use in blending with diesel and any such approval would certainly require a standard against which the properties of biodiesel could be considered. Moreover the quality and properties of fuels known as biodiesel are so variable that a standard is necessary to ensure consumers and vehicle manufacturers would be willing to accept biodiesel as a viable transport fuel source.

3. Ethanol

3.1 Background

We have chosen ethanol/petrol blends as the only alternative biofuel that could be used in mandatory transport fuel blends. Ethanol has a substantial pedigree as a biofuel, having been used in the United States, Europe, and Brazil for many years. Moreover, the global supply is growing rapidly.

That said, vehicle manufacturers in New Zealand and the Motor Industry Association have indicated an unwillingness to support ethanol blends over 3% (Duncan and Copeland, 2004). However, internationally, car manufacturers have expressed a willingness to accept blends up to 10%. This is the case in the United States and in Australia.¹ In general, vehicle manufacturers accept that “nearly all recent model conventional gasoline vehicles are fully compatible with 10% ethanol blends” (IEA 2004). This suggests that while there appears to be a reluctance to accept E5 or E10 in New Zealand, acceptance is far from out of the question.

Ethanol can also be blended with diesel to produce a fuel known as diesohol. We have not directly considered diesohol because of the inordinate cost difference between ethanol based biofuels and tallow based biodiesel. It is unlikely that ethanol prices will ever be small enough, relative to tallow/biodiesel prices for diesohol to be economically viable over biodiesel.

Ethanol in petrol blends is known to have a number of both positive and negative effects on vehicle performance – though the precise effects vary by make of vehicle and through the life of the vehicle.

Ethanol, or more precisely anhydrous ethanol which is used in transport fuel blends, is more volatile than petrol and as a consequence in most countries where ethanol is blended with petrol the blend is limited to either 5% or 10% blends. The additional volatility of ethanol over petrol can have a negative impact on vehicle performance.

Ethanol can also damage engine components, particularly seals and rubber fuel lines. Also, ethanol is more corrosive than fossil fuels and as the ethanol level in fuel increases engine wear can increase as a result.

However, ethanol has a high oxygen content relative to petrol and as a result burns more cleanly than petrol, potentially leading to a reduction in engine deposits. This higher oxygen content also leads to more efficient energy use,

¹ See <http://www.deh.gov.au/atmosphere/ethanol/petrol/issues.html#vehicleop>

with more kilometres able to be travelled per petajoule of ethanol than per petajoule of petrol.²

3.2 Unit costs of ethanol blends

The cost of ethanol blend fuels is primarily related to feedstock costs. However, instituting a mandatory bio-fuels target will impart additional costs, impacting on the price of transport fuels, associated with the cost of importing, transporting, storing, blending and distributing ethanol petrol blends.

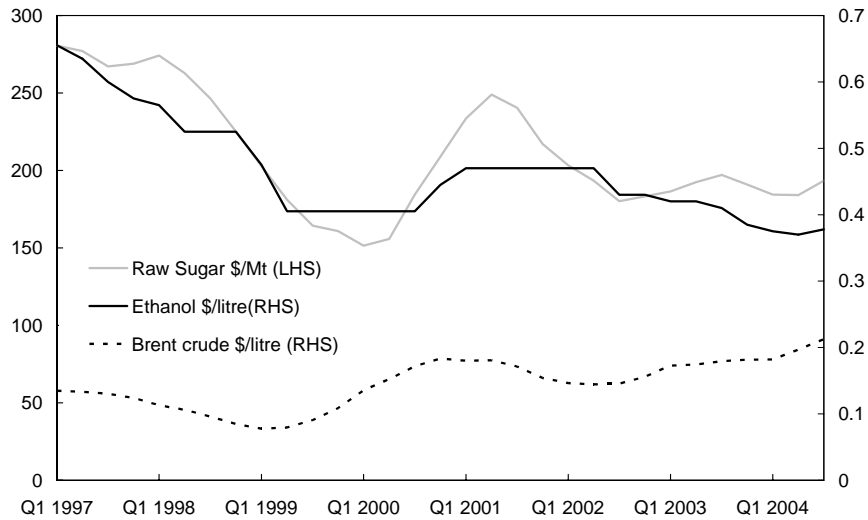
The non-feed-stock costs associated with ethanol petrol blends have been estimated by Duncan and Copeland (2004) to be 1.1 New Zealand cents per litre of ethanol. In the following analysis we have assumed that this cost remains constant through time. The cost is added to the production of ethanol blended petrol before the imposition of an observed retail premium (the average difference between crude prices and pump prices).

Ethanol is typically more costly per litre than petroleum based fuels. However, the price of ethanol has declined over time. In their recent confidential report to the Energy Efficiency and Conservation Authority Duncan and Copeland (2004) have assumed an increase in the price of oil leads to a proportional increase in the price of ethanol. This assumption is based on an observed positive relationship between the net price of ethanol in the United States and US wholesale gasoline prices. This comparison is potentially misleading because of a variety of distortions in the US market, not least of which is the subsidy to US sugar producers which is the major component in US ethanol production.

² Kilometres travelled per petajoule is only way to view fuel efficiency. Later in this section of the report we discuss the efficiency of ethanol in terms of volume of fuel required per kilometre. This measure of efficiency is more appropriate when our discussion is price in terms of litres rather than petajoules.

Figure 4 Ethanol, sugar, and crude oil prices

Rolling annual average US dollar spot market price



Source: Datastream

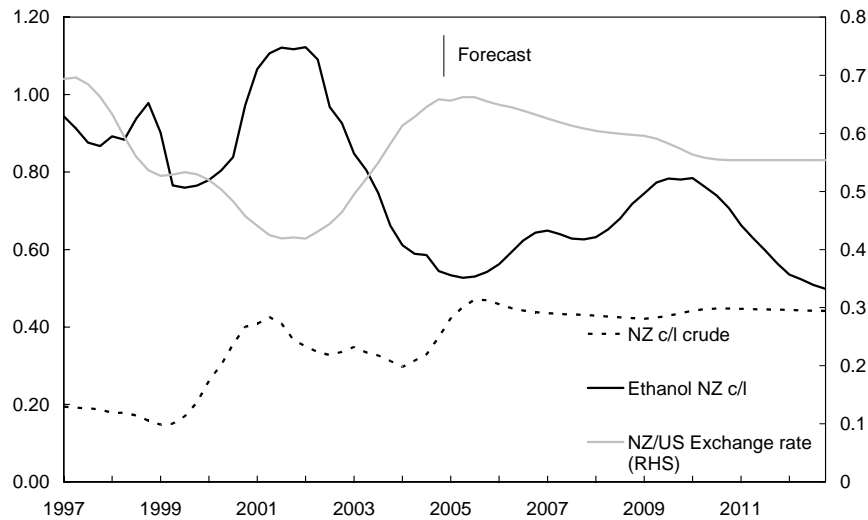
Indeed our analysis of the price of ethanol suggests that in the past ten years the price of ethanol has been negatively correlated with the price of oil, suggesting that as oil gets more expensive ethanol is becoming a more economically viable substitute for oil.

Figure 4 shows that ethanol prices are in fact more closely correlated with the price of sugar than the price of crude oil. This relationship is not surprising in so far as the bulk of world ethanol supply is from sugar production.

The fact that ethanol prices do not track crude oil prices is important because it means that the relative cost of ethanol is likely to be inversely related to the price of oil and as the price of oil rises ethanol use becomes increasingly less costly. The downward track of ethanol prices over time suggests that the use of ethanol may be increasingly less costly in the future, particularly as crude oil prices are rising on the back of strong world demand growth and uncertainties surrounding world supply.

Figure 5 shows the path of our forecast for ethanol prices versus crude oil prices.

Figure 5 Ethanol and crude price forecast



Source: Datastream, NZIER

In addition to the cost of ethanol per litre and costs of distribution, storage, and blending, ethanol is also more costly than petrol as a transport fuel because it is less fuel efficient. The precise loss in fuel efficiency from ethanol/petrol blends depends upon the type of vehicle, the feedstock used to produce the ethanol, and the age of the vehicle. In general, ethanol has lower energy content than petrol (per litre of fuel) and so more ethanol is required per kilometre of travel than petrol. The impact of fuel efficiency has been modelled as a price effect in our study, with ethanol raising the price of fuel by the percentage increase in fuel consumption estimated in Duncan and Copeland (2004) of 2.6% for every 10% of ethanol in an ethanol/petrol blend.³

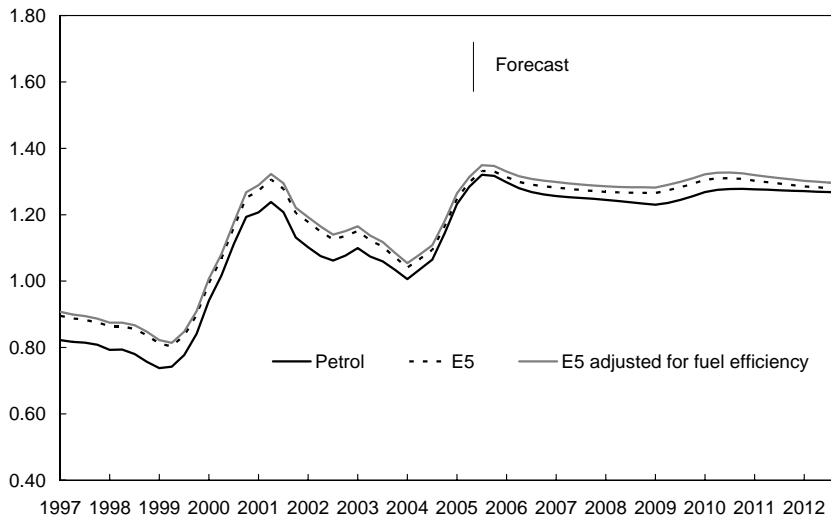
3.3 Ethanol blend pump prices

In Figure 6 two paths are provided for the price of an ethanol blend at the pump. One is the price of the ethanol blend assuming that the ethanol input provides for equivalent fuel efficiency of petrol. The second is adjusted for a 1.3% efficiency difference whereby the E5 blend leads to a 1.3% increase in fuel consumption which we have modelled as a price impact or additional tax.

³ When one takes account of “well to wheel” costs and energy use in fuel production, ethanol produced as a bi-product of manufacturing processes is typically more efficient than petrol. However, our interest here is in the cost to consumers from mandatory biofuel blends. Hence, the only measure of efficiency we are considering is that which impacts directly on consumers.

Figure 6 Petrol and 5% ethanol blend pump prices

New Zealand dollars per litre



Source: NZIER

Table 2 provides the path of likely pump prices of various ethanol/petrol blends relative to petrol pump prices. The pump prices have been standardised using a retail premium as per the case for our biodiesel forecasts and our reference prices for both petrol and ethanol/petrol blends are the average annual price as was the case for biodiesel. For petrol prices, where the price varies depending on whether the fuel is premium or regular, we have used the premium fuel price as an upper bound for our forecasts. Thus the prices forecast for ethanol/petrol blends are those for ethanol blended with premium petrol.

While ethanol currently benefits from an exemption from petrol excise duty, this exemption is due to expire in two years. Given our brief not to consider subsidies or other incentives, we have modelled the price of ethanol without the exemption from excise tax.⁴

In the table and hereafter ethanol petrol blends are referred to by the acronym E[percentage blend of ethanol].

⁴ Strictly speaking there has never been an excise on ethanol and so in policy terms it is not an exemption. But, to the extent that ethanol is a perfect substitute for petrol (at low level blends), any exclusion of ethanol from petrol taxes is in effect an exemption, which is akin to a subsidy.

Table 2 Petrol vs. ethanol blend pump prices

NZ cents per litre, assuming no fuel efficiency loss from using an ethanol/petrol blend

Year	Petrol price	E3 price and price difference		E5 price and price difference		E10 price and price difference	
2004	114.39	115.68	1.29	116.55	2.16	118.71	4.32
2005	131.69	132.45	0.76	132.96	1.27	134.23	2.55
2006	126.10	127.57	1.48	128.56	2.47	131.03	4.93
2007	124.78	126.20	1.43	127.16	2.38	129.53	4.75
2008	123.32	125.29	1.96	126.6	3.27	129.87	6.55
2009	125.54	127.77	2.23	129.27	3.73	132.99	7.45
2010	127.80	129.58	1.77	130.76	2.96	133.71	5.91
2011	127.23	128.25	1.01	128.93	1.70	130.62	3.39
2012	126.66	127.34	0.68	127.79	1.13	128.92	2.26

Source: NZIER

3.4 Effects of ethanol on vehicle emissions

Tailpipe emissions from ethanol powered vehicles are less than for petrol powered vehicles, largely because ethanol is cleaner burning than petrol. Precise reductions in emissions from ethanol blended fuels depend on the feed-stock used to create the ethanol. For example, ethanol from sugar cane produces the least emissions compared with ethanol produced from other biomass such as wood pulp. However, a typical E10 is estimated to significantly reduce tailpipe emissions relative to emissions from unleaded petrol. Typical reductions are as follows:

- 26.9% reduction in carbon monoxide.⁵
- 14.4% reduction in non-methane volatile organic compounds (NMVOC)
- 0.1% reduction in particulate matter.
- 1.0% reduction in CO₂ emissions.

Ethanol has been linked with increases in emissions of nitrogen oxides (around 5%), but these are considered to be minimal costs given the reduction in other emissions. Notably, ethanol does not confer the same benefits in terms of reduced emissions of particulate matter compared with that of biodiesel largely because emissions of particulate matter from petrol

⁵ This figure is an upper bound on CO reduction. The Energy Efficiency and Conservation Authority has suggested that reductions of this magnitude may only apply for older vehicles which do have fuel injection systems.

are significantly less than those from diesel fuel. Consequently the estimated health benefits from ethanol use are insignificant.

CO₂ emissions are assumed to reduce by 1.0% for every 10% of ethanol in an ethanol/petrol blend. In addition to this, for each 1% of ethanol used in an ethanol/petrol blend, 0.667% of emissions are assumed to be due to ethanol and therefore from a renewable source which does not increase the stock of CO₂ in the ecosystem. The net effect being that, based on CO₂ emissions alone, a 10% blend of ethanol in petrol would result in an approximate 8% reduction in the amount of greenhouse gas emissions produced as a result of unleaded petrol consumption (disregarding for the moment any impact from increased fuel consumption as a result of ethanol/petrol blends).

The benefits of reductions in CO₂ emissions have been modelled using an assumed \$15 per tonne value of CO₂ as outlined above for biodiesel.

3.5 Ethanol supply issues

New Zealand's dairy industry produces ethanol as a by-product of dairying and research suggests that around 11 million litres of ethanol (0.3 PJ) per annum may be available for blending with petrol (Duncan, 2003). This is a small amount, and the most likely scenario is that a bio-fuel blend of ethanol in New Zealand would require the importation of ethanol.

We do not see any major problems in accessing sufficient supply of ethanol through importing. While only about 10% of world production of ethanol goes onto the world market, this proportion is expected to increase in the future, with the IEA expecting that worldwide fuel grade ethanol should reach about 80 billion litres by 2012 from around 22 billion in 2002 (IEA, 2004). Moreover, production is becoming increasingly efficient with the introduction of new fuel production technologies and as a result the cost ethanol is likely to fall in the future increasing its viability as a mineral fuel alternative.

That said, if the amount of ethanol traded on world markets continues to be only around 10% of world production, this would result in only \$8 billion litres available for purchase on the world market. As such, net importing countries of ethanol (of which New Zealand would be one if an ethanol/petrol blend requirement was instituted) could well face higher prices, particularly if the trend towards ethanol/petrol blends continues the world over. This would have the effect of raising world prices for ethanol above our forecasts.

An additional element that needs also to be considered is that ethanol production is subsidised in Europe and the United States. If these subsidies are removed in the future then the price of ethanol will rise. In addition to

this, export quotas and subsidies exist for sugar producers which lower the cost of sugar on world markets. International trade liberalisation through the WTO could well lead to increases in sugar prices and subsequent increases in the price of ethanol. Thus there are non-trivial risks to our forecasts of ethanol prices.

4. Partial equilibrium analysis

In the following we use a partial equilibrium framework to estimate the impact of mandatory biofuel blends out to 2012. We assume the introduction of a mandatory bio-fuels target behaves like a tax.

There are two elements of a bio-fuels target which do not behave precisely like a tax normally would in the context of partial equilibrium analysis. A classical partial equilibrium approach to assessing the effects of taxation would require assessing the productive and consumptive costs of the tax alongside the benefits to consumers and producers from government expenditure which draws on revenue from the tax. When we model the mandatory biofuels targets as taxes, there is no corresponding revenue to the government.⁶

The second element is that our reference good is consumption of transport fuels, petrol and diesel. Introduction of biofuels would, all other things held constant, result in an increase in consumption of transport fuels where the energy content of biofuels is less than the energy content of traditional transport fuels. In order to account for this effect we adopted an approach which views existing consumption of transport fuels not as consumption of petrol or diesel itself but of an input to transport as a good. As such, our base case of, for instance, 2,000,000 litres of petrol consumed, represents 2,000,000 of our transport good. When a blend is imposed we assume that all of the efficiency reduction is passed on as a price increase.⁷

The measurement of the impact of taxation in partial equilibrium frameworks has received considerable attention in the research literature. This research has looked at the impact in areas such as choice among consumption goods; willingness to work; willingness to save; the production pattern in society; and the use of inputs by particular industries (Diewert and Lawrence, 1994). Therefore, a well established framework exists in terms of measuring the total excess burden of a proposed tax. Figure 7 below is useful as a stylised representation of the impact of a tax in terms of

⁶ That is, with the exception that negative changes in consumption of transport fuels will result in a small change in excise tax revenue to the government from transport fuel consumption.

⁷ As noted in section 3, the efficiency loss is only volumetric and does not refer to efficiency in terms of energy per kilometre travelled. However, it is essential that we account for this volumetric loss in price terms because a simple dollar per litre price increase would not account for the fact that the price of the reference good (transport) has changed in excess of the change in per litre fuel price.

efficiency.⁸ The market demand curve is traditionally downward sloping and we have assumed that competitive conditions exist in the market, such that the supply curve can be taken to be horizontal.⁹

The current (pre-tax) situation is represented by the point C, where the price is P_0 and the quantity is Q_0 .¹⁰ At price P_0 (and indeed at any price level on the demand curve) some people pay less for the product than what they would be willing to. All we reveal when we buy a product is that it is worth at least the price being charged. Thus, the demand curve shows us that there are some who would be willing to pay a price close to D, and by paying only P_0 , they receive a “surplus” equal to $(D - P_0)$. It is the loss of this **consumer surplus** that explains the excess burden (or deadweight loss) of a tax.

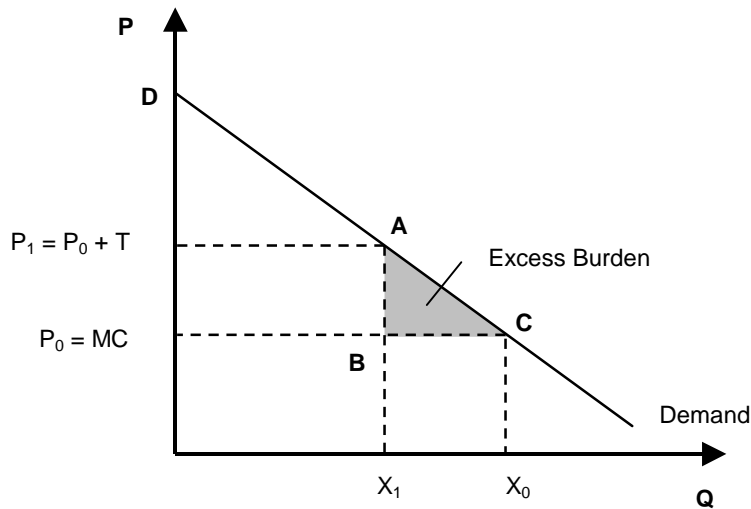
Now consider the situation after a tax is imposed that raises the price from P_0 to $P_1 = P_0 + T$, where T is the tax per unit. First, the government collects revenue, equal to T times the number of units purchased (X_1). This is equal to the area of the rectangle $P_1AB P_0$. Second, since consumers must now pay a price of P_1 , the consumer surplus generated in the market is reduced from the area of triangle $DC P_0$, to the area of the smaller triangle DAP_1 . The excess burden is equal to the original (pre-tax) consumer surplus minus the after-tax surplus minus the total taxes collected by the Government.

⁸ This representation has actually been used in a New Zealand petrol market context to estimate deadweight welfare losses associated with higher than competitive prices arising from market power of petrol suppliers. See Pickford and Wheeler (2001).

⁹ Most of the material in this section draws on Case and Fair (1996). Similar exposition is provided in most introductory and intermediate microeconomic texts.

¹⁰ Note that the demand curve we have used is assumed to be the Hicksian (or compensated) demand curve, where income is “adjusted” at each change in tax rate to leave the consumer at least as well off as previously. Therefore, we are only estimating the substitution effect of the tax imposition, and thus the distortion. If there were no substitution effect, there would be no distortion. Stiglitz (2000) claims that the compensated and uncompensated demand curves approximate each other when demand is not sensitive to small changes in income, which we believe to be the case here.

Figure 7 The Excess Burden of a Tax



Source: NZIER

In other words, the original value of consumer surplus (triangle $DC P_0$) has been broken up into three parts: the area of triangle DAP_1 that is still consumer surplus; the area of rectangle $P_1AB P_0$ that is tax revenue collected by the Government; and the area of triangle ACB that is lost. Thus, the area ACB is an approximate measure of the **excess burden** of the tax. The **total burden** of the tax is the sum of revenue collected and the excess burden: the area of $P_1AC P_0$.

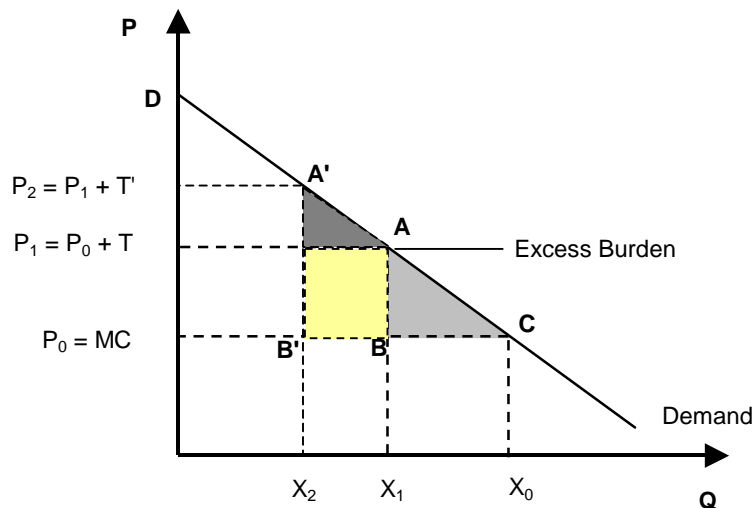
In the case of mandatory biofuel blends the government does not collect revenue, so alternative interpretation needs to be applied for the area of rectangle $P_1AB P_0$. In this context the area of rectangle $P_1AB P_0$ is the resource cost of providing the transport fuel blend. It is the value of productive resources that is being diverted to biofuel production and blending over and above that which would be required for the production of transport fuels in the absence of government intervention in the market.

In our partial equilibrium model the change in consumer behaviour in response to the tax determines the size of the excess burden. Here, consumer behaviour is reflected in the elasticity of demand. For instance, in the figure above, if the demand curve was steeper (demand was less elastic- meaning it is relatively unresponsive to changes in price) the triangle ACB would be smaller. This means the excess burden would also be smaller and less distortion would result from the imposition of the tax. If demand were perfectly inelastic (a vertical line), there would be no distortion and therefore no excess burden. The tax would simply transfer part of the surplus being earned by consumers to the producers of bio-fuel blends.

While the triangle ACB, in Figure 7, measures the excess burden of a move from P_0 to P_1 , what we are interested in here is a series of such movements over a period of time, as the proposed “tax” may not be “one-off” in nature. Figure 8 below shows the effect on the excess burden of subsequent increases in the tax. When the price increases from P_1 to P_2 the deadweight loss is now the triangle $A'B'C$, which includes the original triangle ACB plus the trapezium $A'ABB'$. What this means is that the size of the excess burden increases at a greater rate than the increase in the tax. In geometric terms, the additional excess burden as a result of successive price increases (resulting from an increase in tax) is the sum of rectangles and triangles, rather than just the triangles. In this report’s estimates it is the sum of these successive price increases that is measured.

There are likely to be many aspects to the make-up of the market demand curve for transport fuels, and a generalised approach would not adequately capture these. The characteristics of the demand for petrol by households are likely to differ from those of firms. Indeed, there is likely to be considerable variation within both these groups as well as between them. In order to better capture the differing effects, it is useful to disaggregate the overall demand schedule into smaller, sub-groups which are analysed separately.

Figure 8 Excess burden from successive “tax” increases



Source: NZIER

Our estimates crucially depend on the elasticity measure used in calculating the response of consumers to an increase in price. There are three major reasons why demand for petrol/diesel would be inelastic. The first is that it is a derived demand: few (if any) consumers purchase fuel for its own sake. Fuel is used as an input into production of other goods and services, the demand for which determines the demand for fuel. As a necessary input into

production, this makes the responsiveness of demand to price less than would otherwise be the case.

The second reason is that there are few available substitutes for petrol/diesel. This lack of substitution opportunities essentially means that even large increases in price will not discourage consumption of petrol/diesel, as few viable alternatives are available, at least in the short run.¹¹ In addition, a large proportion of the diesel that would be subject to the tax is likely to be for commercial use, and demand therefore would be less elastic (i.e. less discretionary) than domestic use.

Finally, the proportion of total income spent on petrol is relatively low. This means that the price of petrol could rise considerably without greatly affecting the quantity demanded. Contrast this with for instance, a car or a refrigerator, which accounts for a larger share of total income, and hence if these prices rise, consumers are more likely to be put off purchasing such items. While there are a large number of items for which the proportion of total income spent on them is less than petrol, there are also a number where more is.

There is no singularly accepted empirical estimate of the price elasticity of demand for fuel (petrol and diesel), though it is generally acknowledged that demand is inelastic.¹² In a New Zealand context, Assendelft and Gale (1989) use a price elasticity of demand for petrol of 0.18 and 0.10 for the corresponding diesel elasticity.¹³ These estimates are based on work done previously by Hughes et al, at the then Ministry of Energy.

Assendelft and Gale posit that in the time between the work of Hughes et al and their work, some 9 years, the effects of structural change and the large reductions in the real price of petrol may mean that demand for both petrol and diesel is more inelastic than even these estimates. They cite an overseas study that estimates an average international price elasticity of demand for petrol of 0.11. More recent government energy forecasts in New Zealand have used long run price elasticities of demand of 0.19 for petrol and 0.13 for diesel, with corresponding income elasticities of 0.62 and 1.26.¹⁴

Goodwin (1992) and Oum et al (1992) present evidence of the low demand elasticity for automobile transport, as well as the consumption effects of price changes in petrol. Both these studies confirm that demand elasticities for transport (automobile) and demand for petrol to fuel that transport are

¹¹ In the longer run, people are not as constrained, as new technologies and methods of substitution become available.

¹² Demand is considered inelastic when the elasticity of demand for a good or service is less than 1 (in absolute value).

¹³ These elasticities are presented as absolute values. Strictly speaking, they are negative numbers, but for presentational purposes, the negative sign is omitted.

¹⁴ Ministry of Commerce (2000) "Energy Outlook to 2020", Energy Modelling and Statistics Unit

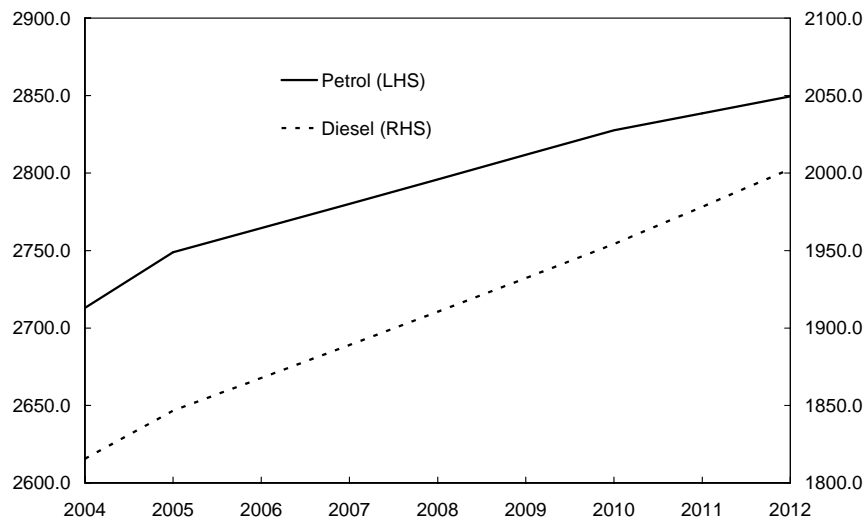
low. Goodwin (1992) however, surveys empirical estimates of petrol price elasticities (generally thought to lie in the range 0.1-0.4) and finds that these traditional estimates may understate the true elasticity. He estimates the unweighted mean value of 120 elasticities of petrol consumption with respect to price is 0.48. This is still regarded as evidence of an inelastic demand, despite the apparent rise in elasticity relative to conventional wisdom.

For the sake of comparability with MED’s forecasts of mineral fuel consumption we have utilised the estimates of short run price elasticities published in their *Energy Outlook* publication (MED, 2003). These elasticities are -0.05, for petrol consumption and -0.08 for diesel consumption.

4.1 Baseline forecasts

Figure 9 Transport fuel consumption forecasts

Millions of litres of diesel (RHS) and petrol (LHS)



Source: NZIER

In order to assess consumptive and productive impacts using our partial equilibrium framework we have forecast consumption for each year out to 2012 and assessed impacts in terms of their deviation from baseline forecast in each year.

In producing our forecasts we have used MED’s forecasts of transport fuel consumption, adjusting them as we deemed necessary given the time since the last *Energy Outlook* was published in October 2003.

Our forecasts have been split between diesel consumption and petrol consumption. Figure 9 shows our forecast for the path of petrol and diesel transport fuel consumption out to 2012 in millions of litres of fuel consumed.

On top of these forecasts we have assumed a constant conversion of fuel to CO₂, using conversion factors from MED (2004). Different factors apply for regular and premium petrol and diesel as follows:

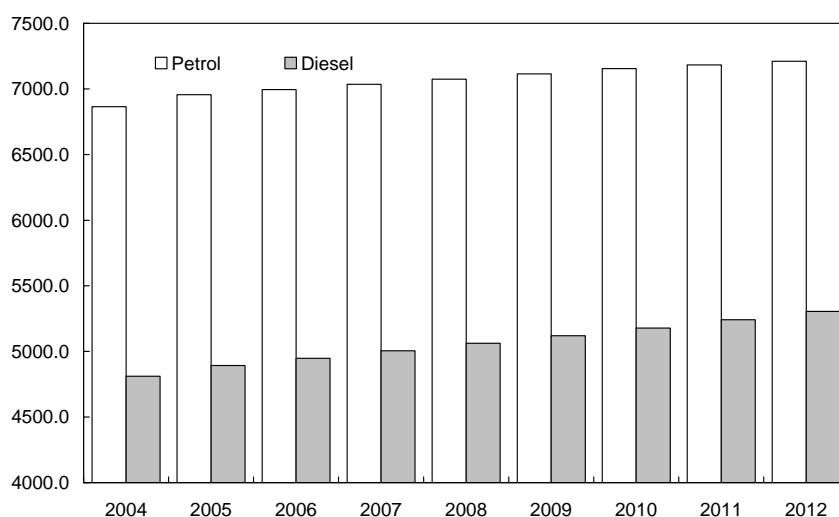
- Regular petrol emits 66.2 kt of CO₂ per PJ of fuel consumed.
- Premium petrol emits 67.0 kt of CO₂ per PJ of fuel consumed.
- Diesel emits 69.5 kt of CO₂ per PJ of fuel consumed.

Because we have not discriminated between regular and premium petrol in our analysis we have taken an average of the conversion factors for regular and premium petrol weighted by the proportion of fuel used of each type in New Zealand in the year to June 2004. This yielded a conversion factor of 66.38 kt of CO₂ per PJ.

Our baseline forecast of Co2 emissions is presented in Figure 10.

Figure 10 BAU forecast of transport CO₂ emissions by source

Kilo tonnes of CO₂



Source: NZIER

4.2 Assumptions

Like all modelling work, these estimates required some assumptions to be made. In the interests of tractability, we assumed that the full amount of the tax is passed on to consumers in the form of higher prices.¹⁵

We also assume the elasticity of demand for petrol/diesel is uniform across all consumer types. In reality, demand responsiveness is likely to differ across sectors and different types of consumers. Despite this, we believe the

¹⁵ That is, we have assumed a horizontal supply/marginal cost curve in terms of Figure 7.

approach to be valid for a broad level assessment of what are the economy-wide implications of the “tax”.

Finally, we have forecast the deadweight loss based on total transport diesel and petrol consumption. This ignores the fact that some consumers of transport fuels and a large number of diesel consumers are in fact businesses who will, typically pass the costs of fuel price increases on to final consumers/households. As such, the most appropriate analysis to conduct would have been to separately assess the impact of transport fuel price increases on consumers and on producer output prices. However, this would have required a time consuming analysis of the elasticities of consumers for the full range of consumer goods. Furthermore, it would have required a parallel assessment of price pass through by industry and by product. This sort of analysis is possible in the context of a general equilibrium model, but not feasible for the sort of partial equilibrium analysis conducted above.

Our “second-best” approach to evaluating the dead-weight loss from mandatory biofuel blends would be expected to underestimate the full extent of the deadweight loss. This is because consumers’ demand for goods other than transport fuels is typically less inelastic than for transport fuels. As such, increases in fuel prices passed on to consumers through prices of other goods would result in greater deadweight losses than have been estimated here.

Indeed, the literature suggests that our estimates of the deadweight loss are, due to methodological issues, on the conservative side. Creedy (2004, 2003) provides evidence that the excess burden or deadweight loss from taxation increases by a magnitude over and above that which we have estimated. Indeed Creedy suggests that a doubling of “tax” rates results in a (approximate) quadrupling of the excess burden or deadweight loss imposed by the tax.

5. Results of partial equilibrium analysis

In this section we present our estimates of the costs and benefits of introducing biofuel blend requirements under a variety of scenarios. The estimates are based on a series of scenarios varying by the type of biofuel in the blend, the percentage of biofuel in the blend, and the timing of the imposition of biofuel targets.

Our analysis compares changes in fuel consumption, price, and CO₂ emissions with those of our forecasts (“Business as usual” (BAU)) for consumption, prices, and emissions in each year out to 2012. Taking price and consumption changes compared with BAU we calculate the deadweight loss to consumers for each year out to 2012. The costs for each year are then discounted through time (using a 10% annual compounding discount rate) and summed to give the present value costs of each blend scenario.

To calculate the benefits of reduced CO₂ emissions compared with business as usual we calculate the implied level of CO₂ at the new consumption level (taking into account reduced emissions levels given the percentage of biofuels used) and deduct this from the BAU CO₂ emissions in each year. As per the deadweight loss to consumers, the benefit from reductions in CO₂ in each year is discounted through time and then summed to give the overall present value of the benefits of introducing mandatory biofuels. The costs of each scenario are then deducted from the benefits to yield the overall net present valued benefit (positive or negative) of each scenario.

We also provide estimates of the resource costs of each scenario. The present values of resource costs for each scenario are presented in present value terms discounted by the same (10%) rate as for the net present value calculation above.

5.1 Biodiesel blends

For the case of biodiesel blends, we have assessed the effects of 3% (BD3), 5% (BD5), and 10% (BD10) mandatory blends with diesel introduced in 2006. We have also assessed the impact of phasing in blends of 1% between 2006-2008, rising to 3% between 2009-2011, and reaching 5% in 2012. We have not assessed the impact of blends including efficiency losses as the relative fuel efficiency of bio-diesel relative to diesel means the resulting variation is negligible. We have also examined the impact of phasing from 2008 at 1% per annum to 2009, rising to 3% in 2010, and then to 5% in 2012.

Table 3 shows that the net present value benefits from biodiesel blends are all positive and are increasing in the percentage of biodiesel that is blended with diesel. We also see that a 3% blend is sufficient to achieve the government's target of 2 PJ of transport energy being derived from renewable sources by 2012. That is, blends of 5% or 10% would be unnecessary to meet government renewable fuel use targets for the transport sector, though welfare by this measure would increase if such blending requirements were able to be introduced. But, this does not take into account the resource costs of biodiesel blend requirements.

Table 3 Present value impacts of biodiesel blends

Thousands of New Zealand dollars (2004), PJ used in 2012

Blend	Dead weight loss	Benefit from CO ₂ reduction	Net Cost/benefit	PJ of renewable fuels used	Resource Cost
BD3	\$378	\$10,127	\$9,748	2.16	\$139,806
BD5	\$1,000	\$16,854	\$15,854	3.59	\$232,519
BD10	\$3,842	\$33,589	\$29,748	7.16	\$462,583
BD5 phased from 2006	\$301	\$7,492	\$7,191	3.59	\$106,017
BD5 phased from 2008	\$235	\$5,369	\$5,134	3.59	\$77,369

Source: NZIER

5.1.1 Resource costs

Table 4 provides a summary of the present value of biodiesel blend resource costs by year and as a percentage of GDP. These resource costs are in all instances larger than the present value benefits of biodiesel blends estimated above and are typically double.

These resource costs represent an efficiency loss to the New Zealand economy and a transfer of productive resources and income from the rest of the economy to transport fuel providers and biodiesel producers in particular. It is difficult to be precise about the actual cost to New Zealand in income terms from this resource cost. However, we can say that it will reduce productivity gains associated with transport use.

Over the last twenty years, efficiency gains in the transport sector have led to overall increases in productive efficiency in the New Zealand economy and changes to resource allocation. Dairy processing, for instance, is now more centralised than it was twenty years ago as a result of transport becoming more efficient and dairy processors being able to take advantage of economies of scale from central processing as the cost of transport has fallen. This sort of productivity gain will be eroded by the introduction of biodiesel blend requirements. However, whether the marginal change in fuel prices will be sufficient to significantly alter investment decisions is not clear.

Without the benefit of a general equilibrium analysis we cannot be sure what the aggregate negative impact of this resource cost will be, nor who in the economy will bear most of it. Nonetheless, the fact remains that the resource costs are non-trivial and in excess of the benefits outlined above.

Table 4 Resource costs from biodiesel blends

Present value (PV) thousands of New Zealand dollars, and % of GDP(1)

Year	BD3		BD5		BD10	
	(\$)	% of GDP	(\$)	% of GDP	(\$)	% of GDP
2006	22,348	0.02	37,178	0.03	74,013	0.06
2007	22,547	0.02	37,502	0.03	74,617	0.06
2008	21,777	0.02	36,216	0.03	72,032	0.06
2009	20,503	0.02	34,096	0.03	67,817	0.06
2010	19,124	0.02	31,805	0.03	63,265	0.06
2011	17,496	0.02	29,097	0.03	57,879	0.06
2012	16,008	0.02	26,623	0.03	52,957	0.06

Notes: (1) Present value of March year nominal GDP as forecast by NZIER

Source: NZIER

5.1.2 Supply side constraints

As outlined in section 2.5, supply of biodiesel is largely constrained to production of around 55 million litres per annum from around 2008. In the above scenarios most of the consumption will outstrip supply. Table 5 outlines the quantity of biodiesel required to serve demand under each scenario, by year.

Table 5 Required supply of biodiesel by blend

Millions of litres

Year	BD3	BD5	BD10	BD 5 phased from 2006	BD5 phased from 2008
2006	55.9	93.2	186.0	18.7	-
2007	56.6	94.2	188.0	18.9	-
2008	57.2	95.3	190.0	19.1	19.1
2009	57.9	96.3	192.2	57.9	19.3
2010	58.5	97.4	194.4	58.5	58.5
2011	59.3	98.6	196.8	59.2	59.2
2012	59.9	99.9	199.2	99.9	99.9

Source: NZIER

This shows that unless we assume slightly more than 55 million litres of biodiesel becomes available, per annum, after 2008, then the only feasible option for a mandatory biodiesel blend is 1%.

BD1 requirements introduced in 2006 would deliver net present valued benefits of \$3.3 million, excluding a present value resource cost of \$46 million, and delivering 0.72 PJ of renewable fuel use in the year 2012. A BD1 requirement introduced in 2008 would yield a net present benefit of \$2.2 million, excluding resource cost of \$32 million, while delivering 0.72 PJ of renewable energy use in 2012.

However, it may be reasonable to assume growth in output sufficient to meet a 3% blend after 2008. But, unless there is a significant increase in capacity over and above the possible 55 million litres suggested by Argent, then a 5% mandatory blend is not feasible.

Indeed, New Zealand's present tallow production notionally allows for a total of around 104,000 litres of biodiesel annually. This precludes the use of a 10% blend. But if additional sources of production come on line, there is potential supply capable of serving a 5% minimum blend.

One would expect that the announcement of a target would lead to the introduction of biodiesel plant into the New Zealand market. Unfortunately we have not had time to canvass any likely candidates to check the validity of such an assumption. Thus for fuel security reasons a 3% blend seems most reasonable.

5.2 Ethanol blends

Table 6 Present value impacts of ethanol blends

Thousands of New Zealand dollars (2004), PJ used in 2012

Blend	Dead weight loss	Benefit from CO ₂ reduction	Net Benefit	PJ of renewable fuels used	Resource cost
No fuel efficiency loss					
E3	\$3,407	\$9,697	\$6,289	2.03	\$192,077
E5	\$5,895	\$16,155	\$10,260	3.4	\$319,840
E10	\$12,870	\$32,279	\$19,408	6.8	\$638,242
E5 phased	\$2,290	\$7,101	\$4,810	3.4	\$130,803
Fuel efficiency loss					
E3	\$5,765	\$9,519	\$3,754	2.05	\$314,940
E5	\$10,195	\$15,866	\$5,670	3.4	\$525,822
E10	\$23,390	\$31,734	\$8,344	6.9	\$1,056,166
E5 phased	\$3,991	\$6,970	\$2,979	3.4	\$221,208

Source: NZIER

For ethanol we have assessed the effects of 3% (E3), 5% (E5), and 10% (E10) mandatory blends with petrol introduced in 2006. We have also assessed the impact of phasing in blends of 1% between 2006-2008, rising to 3% between 2009-2011, and reaching 5% in 2012. Each of these scenarios is assessed under the assumption of a loss of fuel efficiency and under the assumption of no loss of fuel efficiency.

Our partial equilibrium analysis shows that ethanol blends would impart a cost to the welfare of consumers ranging from \$3 million to \$23 million in present value terms depending on which blend scenario is used. While the benefits are larger than the costs – ranging from \$6.9 million to \$32.3 million – they are smaller than is the case for biodiesel/diesel blend requirements and the costs are larger. This makes ethanol a more costly biofuel option compared with biodiesel in terms of meeting the government’s renewable transport fuels target.

Differences between the net benefits of ethanol/petrol blends and the net benefits of biodiesel/diesel blends are due to variations in:

- Price

- Emissions reductions
- Tax structure underpinning the prices of petrol and diesel.

Ethanol/petrol blends are cheaper on average than biodiesel/diesel blends over our forecast horizon (see Table 7). Other things being equal this would lead to smaller costs for the lower priced biofuel blend. However, deadweight losses are larger in the case of ethanol blends compared with biodiesel blends because petrol attracts significantly higher taxes than diesel. As a result, deadweight losses and resource costs are larger compared with the case of biodiesel blends.¹⁶

At the same time as the costs from ethanol requirements are larger than for biodiesel requirements – all other things being equal – the benefits of ethanol/petrol blends are smaller than biodiesel/diesel blends because emission reductions are smaller per litre of ethanol/petrol blend compared with biodiesel/diesel blends.

Table 7 BD3 vs. E3 changes in transport fuel prices

% increase on BAU transport fuel price (1)

Year	BD3	E3 with no efficiency loss	E3 with efficiency loss
2006	1.72	1.17	1.96
2007	1.92	1.14	1.93
2008	2.06	1.59	2.39
2009	2.05	1.78	2.58
2010	2.02	1.39	2.18
2011	2.02	0.80	1.59
2012	2.03	0.54	1.32

Notes: (1) BD3 price change as % of BAU diesel price and E3 price change as % of BAU petrol price.

Source: NZIER

¹⁶ See section four for a discussion of the cumulative impacts of existing taxes on deadweight losses/excess burdens from new taxes.

5.2.1 Resource costs

Table 8 Resource costs from ethanol blends

Present value thousands of New Zealand dollars, and % of GDP(1)

Year	E3		E5		E10	
	(\$)	% of GDP	(\$)	% of GDP	(\$)	% of GDP
2006	33,755	0.03	56,214	0.04	112,209	0.09
2007	29,765	0.02	49,570	0.04	98,952	0.08
2008	37,460	0.03	62,367	0.05	124,403	0.11
2009	38,979	0.04	64,888	0.06	129,389	0.12
2010	28,271	0.03	47,075	0.05	93,933	0.09
2011	14,811	0.02	24,671	0.03	49,277	0.05
2012	9,034	0.01	15,051	0.02	30,076	0.03

Notes: (1) Present value of March year nominal GDP as forecast by NZIER

(2) Assuming no fuel efficiency loss

Source: NZIER

In the above, the resource costs of an ethanol blend in present value terms ranges from \$130 million to \$1.06 billion. This figure represents the total value of productive resources that would need to be devoted to ethanol/petrol blends over and above that which would be devoted to transport fuel production to meet the consumptive needs of petrol consumers at the pre-blend price. To put this figure into perspective, the value of the productive loss in 2006 from an E10 blend, in present value terms is, is \$112 million, which is around 0.09% of our forecast of GDP in present value terms in the year to March 2006. This number may appear small, however is a significant distortion to the allocation of resources in the economy and represents a windfall to producers and merchants of ethanol blends.

Thus, although the net present value of the decision to institute a mandatory ethanol blend does not appear huge relative to GDP and to the present bill for petrol consumption in New Zealand, the productive distortions to the New Zealand economy suggest that a mandatory ethanol blend is highly problematic.

5.2.2 Supply side constraints

Table 9 Required supply of ethanol by blend

Millions of litres

Year	E3	E5	E10
Assuming no fuel efficiency loss			
2006	82.8	138.1	275.9
2007	83.4	138.9	277.5
2008	83.8	139.6	278.9
2009	84.3	140.4	280.3
2010	84.8	141.2	282.1
2011	85.1	141.8	283.5
2012	85.5	142.4	284.7
Assuming a fuel efficiency loss			
2006	82.9	138.2	276.2
2007	83.4	139.0	277.8
2008	83.8	139.7	279.2
2009	84.3	140.5	280.7
2010	84.8	141.3	282.5
2011	85.2	141.9	283.8
2012	85.5	142.5	285.1

Source: NZIER

As mentioned earlier in section 3.5, the majority of ethanol required to meet a mandatory ethanol/petrol blend will need to come from imported ethanol. Table 9 outlines the level of imported ethanol required by percentage of blend. Notably the volumes of ethanol required are large with only about 15% of requirements under an E3 requirement likely to be able to be met from domestic production. Given the cost of ethanol over and above the value of crude oil and refined petrol, the introduction of a mandatory ethanol blend would result in a non-trivial expansion in New Zealand's balance of payments deficit. For example, assuming a loss of fuel efficiency, an E3 blend would mean an increase in expenditure on transport fuel imports of NZ\$500 million in 2006, over and above what it would otherwise be in the absence of a blend.

6. Benefits of reduced non-CO₂ emissions compared with resource costs

Hitherto our analysis has provided only cursory treatment of benefits from reductions in non-CO₂ vehicle emissions and the costs to the economy of biofuel blends which we have loosely labelled “resource costs”. In this section we provide additional cost benefit analysis which uses these costs and benefits to assess the relative cost effectiveness of various biofuel blend scenarios.

As discussed above, the precise implications of resource costs and hence the net costs of each option cannot be determined in the static model we have employed. However, we can borrow from general equilibrium concepts to assess the relative size of the resource cost in each alternative. In a general equilibrium context relative costs of production and prices of output determine the allocation of resources within the economy. Here we work backwards. We begin with the resource cost, which is known, and then assume that the marginal benefit, or price, of emission reductions is sufficient to induce an efficient allocation of resources which includes production and sale of biofuel blends.

Although the allocation of resources implied by each biofuel blend option would not be chosen by the market, this does not necessarily mean that such an allocation would be inefficient. Here we assume that the market is unable to adequately price the social benefits of a reduction in vehicle emissions and hence in the absence of government intervention resource allocation in the economy is socially sub-optimal with respect to transport fuels.

To evaluate the marginal benefit of various emission reductions (the price at which biofuel production and sale is an efficient allocation of resources) we have worked backwards from the resource costs to calculate an implied price or marginal social benefit of each tonne of non-CO₂ emissions reduced. We begin by calculating the net benefit of biofuel blends (i.e. the cost to consumers less the implied benefit from CO₂ reduction). We then subtract this benefit from the resource costs, to yield a representation of the net cost to the economy of each blend requirement option. We then divide this through by the tonnes of emissions reduced to achieve an implied price per tonne of emission reduced.

In our analysis we have considered emissions of carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), and particulate matter (PM). These emissions have varying effects on health and the environment and so we have chosen to weight each emission by their relative impact on

human health¹⁷. The weights we have used are informed by two Australian studies cited in Duncan and Copeland (2004). These studies provide estimates of health costs per tonne of vehicle emissions. We use these estimates to weight each tonne of reduced emissions by the relative size of health costs per tonne of emission for each type of pollutant. The weights and costs from the Australian studies are shown in Table 10.¹⁸ This approach gives the most weight to particulate emissions. As such, tonnes of PM reduced are priced against a greater share of the resource costs than CO and NMVOC. This is intended to reflect the fact that if PM emissions are more costly than CO or NMVOC emissions, then the price (or marginal benefit) per tonne of PM reduced should reflect this.¹⁹

Table 10 Health costs from atmospheric pollution and weights applied to emission reductions

Pollutant	Estimated health cost per tonne (1)	Weight
CO	\$3.3	0.000008
NMVOC	\$944	0.0025
PM	\$379,611	0.9975

Notes: (1) NZ\$, converted from AUS\$ at 0.9:1 (AUS\$:NZ\$)

Source: Duncan and Copeland (2004)

In calculating the implied price per tonne of emissions reduced we are assuming that the marginal social cost of each mandatory blend option will be just sufficient for the resource allocation to be optimal. That is, for the marginal benefit to be equal to the marginal cost. If we sum the value of the benefits of all emissions reduced then add the net present benefit and subtract the resource cost we will invariably arrive at the conclusion that the net cost/benefit of each option is zero. Thus we cannot look to the net benefit of the subsidy to determine if the various policy alternatives are desirable. However, we can look at the implied prices to determine which is the more cost effective means of achieving equivalent reductions in emission. Table 11 provides the results of our analysis.

¹⁷ Unfortunately we do not have data with which to weight the emissions by environmental impact. However, the benefit from reductions in CO₂ emissions provides an adequate proxy of overall environmental benefits.

¹⁸ Health costs from vehicle emissions vary by concentration of population. The Australian studies cited in Duncan and Copeland (2004) refer to four bands of population concentration when providing estimates of vehicle emission costs. In calculating our weights we have used only band 1 or large city estimates.

¹⁹ The costs used to inform our weights are for atmospheric pollution in general and not emissions exclusively from automotive engines.

Table 11 Non-CO2 emission reductions and implied price per tonne of emission reduced

Costs, benefits, and emission reductions are the present valued sum of all values over the horizon of our analysis. Implied price is average annual price.

Option	Resource cost (\$millions)	Net benefit (\$millions)	present Reduction in CO2 emissions (t)	Reduction in CO2 emissions (t)	Reduction in NMVOC emissions (t)	in NMVOC emissions (t)	Reduction in PM emissions (t)	CO emissions (\$)	Implied price of CO emissions (\$)	Reduction in NMVOC emissions (\$)	Implied price of NMVOC emissions (\$)	Reduction in PM emissions (\$)	Implied price of PM emissions (\$)
BD3	\$139,806	\$9,748	12,843	2,353	116			\$0.90	\$0.90	\$137	\$137		\$1,116,897
BD5	\$232,519	\$15,854	21,384	3,918	193			\$0.90	\$0.90	\$137	\$137		\$1,117,322
BD10	\$462,583	\$29,748	42,657	7,816	386			\$0.90	\$0.90	\$137	\$137		\$1,118,385
BD5 phased from 2006	\$106,017	\$7,191	10,526	1,929	96			\$0.80	\$0.80	\$127	\$127		\$1,032,378
BD5 phased from 2008	\$77,369	\$5,134	8,116	1,488	74			\$0.80	\$0.80	\$121	\$121		\$976,749
E3	\$314,940	\$3,754	265,403	26,190	1.55			\$0.01	\$0.01	\$30	\$30		\$200,280,388
E5	\$525,822	\$5,670	443,542	43,775	2.60			\$0.01	\$0.01	\$30	\$30		\$199,397,771
E10	\$1,056,166	\$8,344	893,101	88,172	5.30			\$0.01	\$0.01	\$30	\$30		\$197,242,718
E5 phased from 2006	\$221,208	\$2,979	216,077	21,323	1.26			\$0.01	\$0.01	\$25	\$25		\$172,416,986

Source: NZIER

Table 11 shows that for ethanol blends the implied price being paid for CO and NMVOC emission reductions is significantly less than for biodiesel blends.¹ However, these emissions are considerably less costly in terms of their effects on human health than particulate emissions.

In the case of particulate emissions, biodiesel blends offer the least cost approach to reducing health costs associated with atmospheric pollution. Given the estimated health costs of particulate emissions relative to other emissions this suggests that, other things being equal, biodiesel blend requirements offer the least cost alternative for reducing health costs associated with vehicle emissions.

That is not to say that any of the biofuel blend options provides a cost effective means of reducing health costs from vehicle emissions. Comparing the health cost estimates in Table 10 against the implied prices in Table 11 suggests that none of the biofuel blend requirements provides a cost-effective means of mitigating health costs from vehicle emissions. The price of reducing particulate matter emissions is at best more than twice the cost of these emissions. Moreover, the estimates presented in Table 10 apply only to large Australian cities and so are at best only applicable to Auckland.

As mentioned above, our analysis is not designed to yield an accurate analysis of the desirability of the policy alternatives in question. However, comparing implied prices with estimated health cost benefits is useful for putting our estimates into perspective.

7. Additional cost-benefit considerations

7.1 Distribution

The size of the deadweight loss/excess burden is not the only consideration important in assessing the impact of a tax. The second issue relates to the distribution, or incidence of the tax: who pays? The issue of who pays is important from both an efficiency and an equity perspective. As alluded to above, a desirable property of an efficient tax is that it is paid by those who derive the most benefit (or most use) from the item/product to be taxed. From an equity perspective, this effectively avoids one section of the population bearing an unnecessarily or unfairly high proportion of the tax.

There are two key dimensions in which we are interested. First, we are interested in the distribution of the tax in terms of producers and consumers. That is, what proportion of the tax is borne by suppliers and what proportion

¹ As mentioned in a previous footnote to section 3.4, the reduction in CO emissions from ethanol blends is apt to be overstated because the reduction figures used in this study are for older vehicles which do not have fuel injection systems.

is borne by demanders of the good to be taxed? We are also particularly interested in the within-group distribution: who, among the group that bears the majority of the burden, are more heavily affected?

In work done on the possible distributional effects of a carbon tax on petrol consumption, it was found that the costs of a petrol tax would fall almost completely on consumers. The degree to which these costs are able to be passed on to consumers is determined by the relative inelasticity of demand for petrol versus the relative elasticity of supply of such. Due to the relatively inelastic demand for petrol, consumers bear most of the cost (price rise) of the tax (Kerr, 2001).²

7.2 Direct effects

When looking at the direct effects of the tax in terms of consumer purchases, Kerr (2001) considered any petrol tax would be regressive in nature.³ That is, households with higher income levels spend more on petrol but less as a percentage of income, than lower income households. The regressivity of the tax was still evident after attempting to correct for household size differences. An important point though, is that excluding the lowest income group suggests a much less regressive relationship over most of the income range. This is because the lowest income group is thought to be strongly represented by the self-employed- who tend to under report income (Kerr, 2001).

There are a number of issues associated with the use of household income as an indicator of welfare.⁴ Kerr cites Poterba (1990) as suggesting expenditure is a more relevant measure of welfare because it represents “permanent income.” People who spend a lot relative to their income generally do so because they have high savings or expect higher incomes in the future (Kerr, 2001). When expenditure on petrol is modelled as a share of expenditure in each decile, the regressivity witnessed when using expenditure on petrol as a share of income is no longer present. In such modelling, it is the middle-income earners who bear the greatest cost relative to their total current and permanent income.

A similar result is obtained in work on the distributional effects of a petrol tax in the UK. It was found that the effect of a petrol tax increase on the cost of living of the poorest households is smaller than the effect on richer households, with the greatest effect being on middle-income households (Smith, 2000).

² In figure 1, we assumed a horizontal (perfectly elastic) supply curve, meaning that consumers would bear the entire price rise as a result of the tax.

³ This analysis is based on data from the Household Economic Survey produced by Statistics New Zealand.

⁴ See Kerr (2001, p.31) for a more thorough treatment.

7.3 “Indirect” effects on consumers

These analyses consider only the direct incidence of a petrol tax- the costs to consumers of purchasing the petrol directly. Consideration should also be given to the indirect effect through increases in prices of goods that require petrol as an input. Analysis by Casler and Rafiqi (cited in Kerr, 2001) suggests that these indirect effects reduce the regressivity of fuel taxes. That is not to say that the regressivity is removed completely, but that the purchasing behaviour of relatively richer households means that they bear a greater proportion of the indirect costs of the tax that is passed through in goods markets.

While the wider economy-wide effect on industries would require general equilibrium modelling, we can draw some broad conclusions from looking at possible price effects. The Producer Price Index, compiled by Statistics New Zealand, surveys price movements in inputs and outputs across a range of factors and industries. Diesel and petrol are major inputs into a range of industrial and manufacturing processes.

A broad survey of the weights given to commodities in the index indicates that the major sector that would feel the impact of increases in prices is Transport and Storage, where diesel has a 4.8% weighting and petrol 1.7%. This means that, all else equal, a 10% increase in the price of both petrol and diesel would see an increase in costs in this sector of around 0.65%. At a more disaggregated level, diesel and petrol have weightings of 10.30% and 4.6% respectively in the Road Transport sector. This indicates a 10% increase in price would lead to an increase in the costs of road transport of about 1.49%. Road Transport accounted for 1.1% of New Zealand GDP in 2003.

Table 12 Sectoral Inputs and industry size

Industry sector	Weighting in PPI (% of cost)		Cost effects of 10% increase in price of fuel (%)	Industry share of GDP (%)
	Petrol	Diesel		
Road transport	4.6	10.3	1.49	1.1
Rail and other transport	3.0		0.3	0.5
Water transport	9.2*		0.92	2.4
Air transport	14.2		1.42	
Personal and community services	3.4		0.34	1.5
Public administration and Defence	2.6		0.26	3.0
Retail trade	2.0		0.20	5.4
Wood and Paper product manufacturing	2.4		0.24	2.0
Agriculture	2.7	2.5	0.52	5.4

Notes: * Likely to include marine-based fuels

Source: Statistics NZ, NZIER

Other sectors where petrol and diesel are important inputs are summarised in Table 12 below. This shows that the Retail Trade sector is a large part of the New Zealand economy, and has a reasonably high proportion of input costs explained by transport fuel.⁵ Another sector with a relatively high fuel input, and large share of GDP, is agriculture. While this is only indicative, it gives some idea of sectors that might feel some price pressure from mandatory biofuel blends and concomitant increases in fuel prices.

The relative importance of diesel in the road transport industry also suggests that mandatory biofuel use targeted at diesel (i.e. mandatory biodiesel

⁵ Statistics NZ advise that not all sectoral information is broken down to the petrol and diesel level, and that the more generic “fuel” definition includes petrol, diesel, and some other gases. Those cells where we have combined the petrol and diesel contribution are actually in the “fuels” category.

blends) would see measures aimed at renewable fuel use being disproportionately foisted upon a single sector of the economy and not necessarily that part of the economy which produces the most fuel emissions nor that which consumes the most fossil fuels. On the face of it, this is problematic, however it is our view that the price impacts of such measures would, on balance, be felt by consumers (i.e. households) rather than firms in the road transport industry.

In summary, while we have not undertaken detailed empirical analysis, we believe the distributional effects of price increases are likely to be more heavily felt by households than producers. This is due to the relative inelasticity of demand for petrol by consumers, and the relatively elastic supply of the petroleum industry.⁶In line with other studies, the impact of the “tax” would likely be slightly regressive.

8. Targeting fuel sales

MED has asked that we consider the impact of requiring a mandatory percentage of total transport fuel sales to be bio-fuels, rather than a mandatory percentage of each litre of fuel to contain a biofuel component. The precise implications of this approach are unclear and would depend on firm behaviour. However our analysis suggests it may see a blend requirement becoming a de facto ethanol blend requirement, with the results in terms of net costs and benefits being the same as those outlined above for ethanol.

In deciding whether to sell biodiesel or ethanol to fulfil a mandatory blend requirement firms would most likely base their decisions on:

- Choices of other firms
- Security of supply of ethanol and biodiesel

If a firm chooses to supply biodiesel blends while another chooses to supply ethanol blends, then the firm which chooses biodiesel is likely to lose diesel customers to the firm offering ethanol blends because the diesel price will be cheaper from the ethanol supplier. Similarly, the firm which chooses to offer ethanol blends is likely to lose petrol consumers to the firm which offers diesel at the higher biodiesel blend price but petrol at the lower non-ethanol blend price.

Whether a firm chooses to supply more of one fuel or the other will most likely depend on the section of the market served by the firm. A supplier who is heavily dependent on diesel sales may choose to offer mainly ethanol blends, while a firm which serves a mainly petrol consuming market will most likely choose to offer mainly biodiesel blends.

⁶ See LECG (2003) for a discussion of the structure and competitiveness of the petroleum industry.

In our view, it is also likely that fuel prices will rise across the board, with conventional fuel prices rising to cross subsidise the sale of biofuel blends. Assuming that cross-subsidisation does not occur to the point where prices are kept artificially high, cross-subsidisation would have no material effect on our cost benefit analysis above. Thus a fuel sales target would have costs and benefits somewhere between the bounds of our above analysis. If one-third of a 3% requirement were met with biodiesel and two-thirds were met with ethanol, the net result in terms of costs and benefits would simply be one third of the BD3 benefits (and resource costs) described above plus two-thirds of the E3 benefits described above.

Security of supply will feature quite strongly in biofuel choices by firms and may preclude sales of biodiesel over the medium term. That is, other things being equal firms would choose the fuel with the lowest supply side risk because insecurity of supply places risks on investment in infrastructure such as storage and distribution facilities⁷. Given the relative security of supply of ethanol over biodiesel, at least at present, we would expect fuel suppliers to initially choose to offer ethanol blends over biodiesel blends. This would have the effect of making a biofuel sales target a defacto ethanol blend sales target. This may be problematic in so far as the net benefits of biodiesel are greater than ethanol.

However, there is merit in a sales target because it would give transport fuel providers additional flexibility for implementing biofuel requirements in a least cost manner. We would expect the end result in terms of benefits to be the same as that for mandatory fuel blend percentages, but the costs might be slightly smaller. Costs that might be minimised include losses in consumer welfare and economy-wide costs in terms of allocation of resources.

A sales target would provide transport fuel producers and merchants with flexibility to target biofuel supply at those consumers who have the most inelastic demand with respect to fuel use. Dead-weight losses would be minimised as a result. A biofuel sales target may therefore result in transport fuel suppliers offering a range of biofuel blended products, from low biofuel blends or straight conventional fuels targeted at one consumer group to fuels with high percentages of biofuels targeted at other consumer groups.

It is not possible to say with any certainty whether transport fuel suppliers would offer a range of biofuel blends and what the range of products may be. Indeed it may be the case that the costs of differentiating between one group and consumers and another may outweigh the benefits of targeting certain consumers. However, the thrust here is that transport fuel suppliers are best placed to determine if the benefits of offering a range of different

⁷ To the extent that separate infrastructure and distribution facilities are required for supplies of ethanol and biodiesel blends.

blend percentages outweigh the costs. With a mandatory blend percentage, rather than sales percentage, suppliers' would not have the flexibility to explore such an option.

Similarly, resource costs in terms of infrastructure required to produce, blend, and store, and distribute biofuels might be minimised if firms have the flexibility to determine where they supply biofuels and in what percentage blends. That is, it may be feasible for firms to offer biodiesel at higher blends in built up areas, for example. Or fuel suppliers may be able to target bulk/wholesale purchasers and hence not have to put distribution or storage facilities in place at all points of sale. This could yield economies of scale and reduced overall resource costs – which would be reflected also in the pump prices of biofuel blends and thus reduce consumer losses. As above, we cannot pre-judge what the outcome would be in this regard. Transport fuel suppliers are best placed to know if their existing clientele and cost structures allow for such cost minimisation strategies. But, as above, if biofuel use was required on a percentage blend basis, this flexibility would not be available.

As mentioned above, any minimisation of costs to consumers from mandatory biofuel use would, however, be small compared with the quantum of potential costs outlined in section 5. Therefore, our best estimate of the costs and benefits of a mandatory biofuels sales target of 5% of fuel sales phased in from 2006 would result in costs and benefits not materially different from the E5 analysis above. That is: a present value total cost to consumers of \$4 million between 2006 and 2012; resource allocation costs of \$221 million; and benefits from CO₂ reductions of \$7 million. This cost would of course be lower if a significant biodiesel industry had been established in New Zealand.

The targeting of transport fuel sales requires the same supply side considerations as in the case of biodiesel blends. If a mandatory sales target were implemented in the absence of a biodiesel supply industry in New Zealand, then fuel suppliers would have no choice but to offer ethanol blends. The end result in terms of net costs would be exactly the same as for ethanol blends. That is, a requirement for 5% of transport fuel sales to consist of bio-fuels would mean a \$50 million net present cost to the economy and a resource cost of \$238 million in the year 2012 – in present value terms.

A biofuels target based on percentage of fuel sales would also confer an additional benefit related to implementation of a biofuel use target. It would allow firms to blend to their own specifications based on quality variations in biodiesel through the year. It would also allow firms to adjust their blends for times when supply was short – avoiding perverse results where firms are in breach of legal obligations due to seasonal variation in output or a brief biofuel supply side shock.

There may, however, be additional compliance issues associated with requiring a percentage of fuel sales to include biofuels. Under such a requirement, compliance would most likely need to be checked through audits of transport fuel firms sales and purchase records or regular reporting by transport fuel suppliers. Given the difference in fossil fuel and biofuel prices, firms would have an incentive to provide inaccurate reports of how much biofuels they had used. We would not expect widespread falsification of documents, however the fact remains that checking the validity of fuel supplier reports could be a time consuming and costly process for New Zealand regulatory authorities.

Alternatively if firms were required to use a fixed percentage of biofuels in all fuel sold, then this could be verified more accurately through spot or regular audits of fuel composition at retail and wholesale outlets. However, this too would be costly as tests for checking blend percentages are difficult and expensive to conduct.

9. Effects on the transport fuels industry

The timeframe available does not permit a “full blown” assessment of the competitive impacts of a mandatory biofuels target in the transport fuels industry. There are two basic issues concerning competition. The first is whether the structure of the industry would have implications for competitive behaviour? That is:

- Could a monopoly situation of a single provider of blending services result from a mandatory biofuels policy?
- What is the prospect of collusion between the incumbents?

The second issue is the extent to which the benefits of competition accrue to those outside of the country? In other words do the existing conditions permit or encourage suppliers to make overseas sales, where prices may be higher?

All of these aspects are concerned with the (negative) effect on consumer welfare, either from anti-competitive behaviour, or from harm in the form of higher prices and/or reduced supply as a result of overseas opportunities removing the focus from the domestic market. These issues will be looked at separately below, with a particular focus on the first issue. This discussion draws heavily on a study by Pickford and Wheeler (2001) which covers issues such as industry structure, market structure, and barriers to entry, oligopolistic pricing, collusion, new entry and non-price competition in the oil industry.

9.1 Industry structure

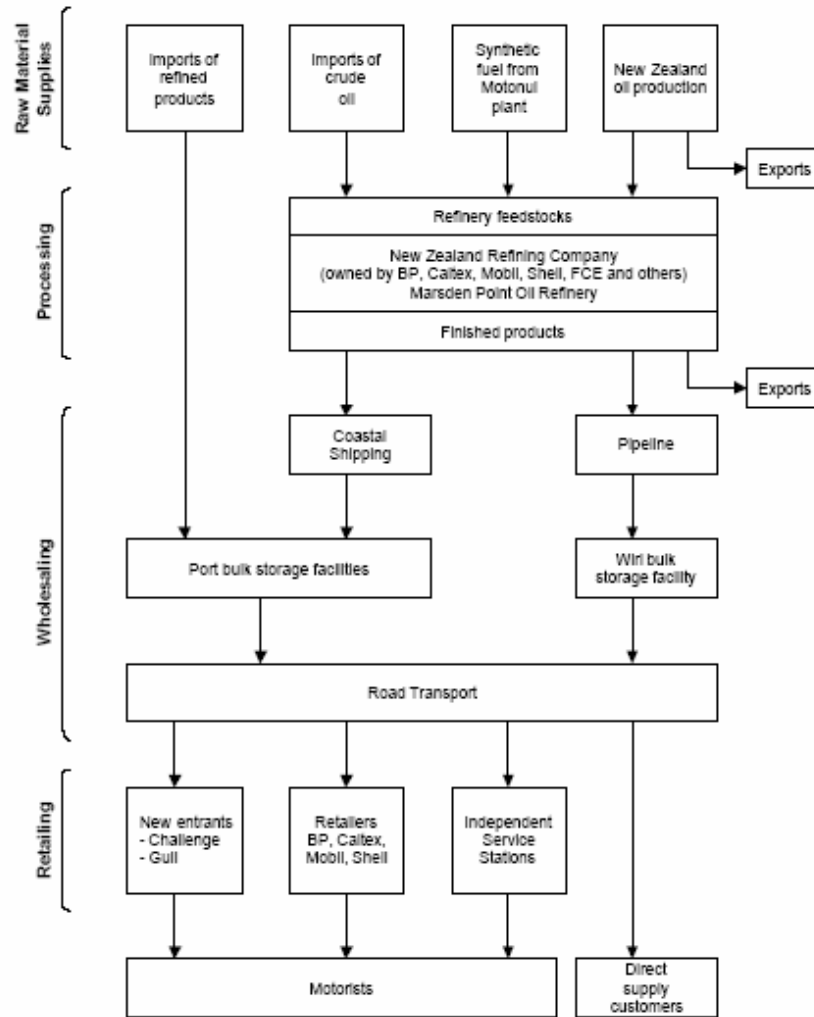
Figure 11 below is a stylised depiction of the vertical structure of the oil industry used by Pickford and Wheeler (2001) to assess the effects of deregulation of the petrol industry in 1988.⁸ There is a relatively high level of vertical integration in the industry. The four major oil companies are significant shareholders and customers in the refinery company. Finished product is distributed in roughly equal proportions either through the Wiri pipeline or coastal tankers and road. Despite the involvement of BP, Caltex, Mobil and Shell, the product only becomes differentiated by company at the point where the retail delivery trucks are loaded and company-specific additives are added.

The four major companies, while being the major wholesalers and retailers of refined products, also own most of the bulk storage facilities, as well as owning or contracting with most of the retail outlets. Pickford and Wheeler (2001) note that not all four majors are represented at all of the ports, and “hosting” arrangements involving leasing capacity from the others are used when one of the wholesalers exceeds its own capacity or has no capacity. There are obvious efficiencies here, given the scale economies inherent in storage, however, such mutual co-operation benefits each of the incumbents, but might hinder an entrant if it were to be denied access on similar terms. Duncan and Copeland (2004) claim that: “ *[the] most likely location for ethanol to be blended into petrol will be at the principal storage depots of the oil companies*” and

“ *[the] New Zealand oil products storage and distribution network has little or no surplus storage capacity and locations where blending occurs will require additional storage facilities and equipment for blending ethanol into the petrol base stock*” (p.14).

⁸ The actual diagram is produced by the Ministry of Economic Development, and has subsequently been updated, but without any significant changes.

Figure 11 Structure of the New Zealand Oil Industry (excluding exploration)



Source: Pickford and Wheeler, 2001

9.2 Market structure

Miller (1989) identified inherent conditions that were thought likely to cause oligopolistic interdependence between the wholesalers: the few sellers; a consumer view of a homogeneous and non-complex product; transactions between sellers and buyers being frequent, stable, and numerous (aiding price monitoring by rivals); an inelastic demand (making collusion potentially more profitable); and a history of cooperation between the companies (because of regulation and joint activities).

A key characteristic of petrol is its technical homogeneity. Stripped of its brand, buyers would not be able to distinguish the offering of one supplier from that of another. Better informed buyers are also aware that all domestically produced petrol comes from the one refinery, albeit that it is

mixed to varying degrees with imported petrol. Hence, not surprisingly, buyers seem to treat each brand as being a very close substitute with all other brands, and hence typically will buy from the lowest-priced option. This suggests that the cross-price elasticities of demand between brands will be very high, meaning that a small rise in one company's price will result in a large fall in sales as consumers switch to other brands, and vice versa. All this is consistent with the observation that prices of brands are very uniform, if not identical—down to one-tenth of a cent per litre—across a particular locality. This is often seen as evidence of collusive behaviour.

There are some particular features of the oil industry which further raise suspicions about possible collusion. These are the horizontal arrangements between the companies themselves, and the vertical arrangements between the companies and many of their dealers. As discussed above, the former include the Marsden Point refinery, the Wiri pipeline, the Wiri terminal, and the coastal tankers, all of which are directly owned or controlled by the four majors, together with the “hosting” and “borrow and loan” arrangements between them. ACIL (1997, pp. 29-31) argued that such arrangements are efficiency enhancing, partly because they yield economies of scale, particularly with respect to the refinery, and partly because they allow all four companies to compete over nationwide networks. They are also a feature of the oil industry overseas. On the other hand, it could also be that such joint activities provide opportunities for company representatives to meet and to develop understandings which could soften the competition between their companies.

Vertical arrangements, in terms of the supply arrangements between the oil companies as wholesalers and their retail dealers, may be more difficult to justify on efficiency grounds. According to ACIL, these typically include such restrictive provisions as the following:

- lengthy terms and termination clauses (five years and 6-12 months respectively);
- the supplier having first right of refusal to purchase the site on termination;
- exclusive dealing (solus) arrangements; and
- equipment to be owned and installed by the supplier. However, this length of lease may, for the supplier, both facilitate planning (through establishing a stable demand base) and allow sufficient time to amortise the costs incurred in installing tanks, pumps and signage, while giving the retailer security of supply over its principal product (Scott, 1997, pp. 20-21).

The Commerce Commission has successfully prosecuted one or more of the oil companies under the Commerce Act in two separate collusion cases,

though both were what might be termed non-standard pricing issues. It is difficult to prove overt collusion, unless one of the parties involved spills the beans. The “leader-follower” pattern of parallel price changes could be seen as a form of tacit collusion, but it is difficult to see how else price changes needed to reflect changes in raw material costs could be introduced, in a market characterized by a homogeneous product and oligopolistic interdependence between firms.

However, it is possible that this practice could give rise to an upward bias to prices if one company were to become the recognized price leader, and were able to gain the compliance of the others through signaling intended price changes in advance of their implementation (Pickford and Wheeler, 2001). The increase in pump prices as a result of biofuel blending requirements would be scrutinized by the Commerce Commission, motoring organizations, the press and the public at large, and this scrutiny would tend to limit the opportunities for (overt) collusion by the oil companies.

9.3 Entry

The petrol market in New Zealand has been characterised as one in which there has been relatively little entry following deregulation. Depending on which side is expressing their views it may be because the profits are too low as a result of existing competition and “high” margins might indicate “high” distribution and servicing costs rather than “high” profits, or it could be due to entry barriers.

Considering ease of entry is of interest for two reasons. First, it allows an assessment of the “pressure” on incumbents to act competitively, and second, it provides context for considering whether a single, dominant player is likely to enter the market for production and supply of biofuels. It is important to keep in mind that it is not actual entry that is a major constraining force on anti-competitive behaviour (though the entry of Gull and Challenge in 1998/99 coincided with a period of price-cutting). What matters is the threat of, or the potential for, other parties to enter.

Pickford and Wheeler (200, p.33) suggest entry barriers may arise in a number of ways:

- entry may require a substantial investment in sunk costs (including initial business planning and organisation, promotion, and specialised equipment and facilities) which can not be recouped upon exit, together with direct exit costs
- because of environmental clean-up costs. By adding to the “down-side” risk, these may deter entry in the first place;
- an entrant may face a higher cost of capital because it lacks the track record of the incumbent, and hence entails a higher risk;

- the incumbent may enjoy a “first mover” advantage of lower costs from being first on the “learning curve”, or of superior product differentiation from being able to establish its brand before others appeared;
- size may allow economies of scale in brand promotion and maintenance;
- the incumbent may credibly be able to threaten potential entrants with strategic forms of behaviour, which would make entry less profitable (especially where sunk costs are a significant component of entry); and
- entry may involve a scale of operations which would be hard to sustain by the share of the market likely to be gained (there are substantial scale economies in bulk shipping and, to a lesser extent, with terminal storage and retail outlet operation).

The critical considerations for an entrant are the post-entry price, and its unit cost given its likely market share, both of which have to be assessed in the context of the changed structure of the market. A study by ACIL (1997) looking into entry barriers in the downstream oil industry, found as follows: “No permanent or long run cost advantages to incumbents were identified and therefore the conclusion can be drawn that there are no barriers to entry.” (ACIL, p.108)

However, it conceded that a new entrant could “initially experience a small cost disadvantage” because of the “time to achieve the intended scale of operations.” Scott (1997, cited in Pickford and Wheeler (2001)) reached a similar conclusion: “At most, the ‘problem’ seems to be that, in order for a potential entrant to avoid significant cost penalties and risks, new entry must occur at a scale which is large relative to the overall size of the market.” However, he recognised the potential pitfalls associated with entry:

“A rational new entrant would have to make complex commercial calculations in order to choose the scale of entry, the distribution of wholesale and retail outlets, internal transport and take measures to offset a range of risks. At the wholesale end there exist potential disruptions to supply and strong economies of scale and therefore ‘lumpiness’ in the physical size of various facilities. At the retail end there are the possibilities of disrupted internal transport and variations in demand which might overwhelm normal storage facilities. The relationship between the optimal economic scale of transport and storage facilities and the price elasticities of demand for the product need careful balancing also. This industry has strong economies of scale in several places in the chain and a new entrant would have to set up their system in such a way as to take advantage of them in order to be competitive.” (p. 27)

These arguments apply to entry into the downstream oil industry. This is due to an acknowledgement that it would be impractical for a new entrant to build its own refinery, given that the market is too small to allow the

Marsden Point refinery to exploit all of the economies inherent in refining technology. It is suggested that the minimum efficient scale for a new refinery is about twice the current size of the Marsden Point refinery (ACIL, 1997, p.103). The principles of the arguments apply to the situation of a potential new entrant considering blending opportunities in terms of ethanol, or biodiesel. While it appears that there are no barriers to entry, the sunk costs (which have largely already been experienced by the incumbents), degree of vertical integration and shared facilities arrangements enjoyed by the incumbents may act as significant disincentives to invest.

While a new entrant could be encouraged to incur capacity costs to enter in order to export the bulk of its biofuel output, there is considerable doubt as to whether New Zealand enjoys a comparative advantage in biofuel blending.

9.4 Oil company views on competition

As part of an assessment of the efficacy of implementing a regional petrol tax, the Auckland City Council commissioned a study by the Law and Economics Consulting Group (LECG). As part of that work, the views of oil companies on the competitive environment were sought. They indicate that the competitive environment has changed significantly since the mid 90's:

- Competition between oil companies is now far stronger than ever before, with huge pressure on profit margins. This is partly due to the entry of new, independent, low-cost operators into the market in recent years. Prices are more volatile as a result; with one oil company estimating that petrol prices may now be changing as often as 50-60 times per quarter, whereas around 1996, petrol prices often remained stable for two or more quarters at a time.
- Oil companies are very aware of each other's price movements in all regions and are also very aware of external price signals. It is estimated that they can react to price signals from other companies within 45 minutes. This makes it almost impossible for any company to follow a particular policy without the others noticing it and acting accordingly.
- There is now significant competition between fuel retailers in one region with those in other regions, and consumers are generally more aware and better informed of fuel prices and the differential between regions.
- Oil companies are extremely sensitive about perceptions of price collusion and at least one company indicated that their awareness of this issue has resulted in them accepting prohibitive corporate guidelines about consultation or even attending industry forums where competitors may be present.
- The presence of low cost, independent operators in urban areas, specifically in Auckland, provides a point of reference for fuel prices that did not exist in the past.

These comments provide a backdrop against which we can place the observations around pricing and the presence of collusion. The addition of Gull and Challenge no doubt intensified the competitive nature of the market, and saw increases in non-price competition as well.

9.5 Summary

We have briefly traversed the industry and market structure for oil in New Zealand. This was thought a useful reference point for considering competition issues in the fuels industry associated with a mandatory biofuels target. We saw that while there was no apparent evidence or history of overt collusion, it is in fact very difficult to prove a case of this nature, unless one of the parties involved confesses. Thus, while there may always be suspicions of collusive behaviour, some aspects of the industry mean that this suspicion is unavoidable and will continue.

On balance, the prospect of the four majors engaging in collusive behaviour that sees prices above competitive levels following mandatory transport biofuels implementation seems possible, but remote. Indeed, Duncan and Copeland (2004) posit that with the degree of shared facilities and interdependence within the New Zealand market, some kind of co-ordination of industry responses is likely. They go on to say that "... there may well be a need for an authorisation from the Commerce Commission, as per the Commerce Act, to enable liaison between the companies" (p.47).

There is some debate as to whether barriers to entry are more apparent than real. While entry costs may be considered high by some, they are not necessarily entry barriers. Entry is never costless, and new entrants incur costs in setting up that incumbents also incurred at the time they entered (Pickford and Wheeler, 2001).

The degree of set-up costs, economies of scale in storage, the relative dearth of entry since deregulation and the established arrangements of the incumbents also mean that the prospect of a new player entering the market for biofuel blending and establishing dominance seems remote. Similarly, there is little reason to believe that New Zealand has a comparative advantage in the production of biofuels such that a player would take advantage of any support offered in terms of introducing biofuels in New Zealand to exploit export opportunities (to the detriment of New Zealand consumers).

In sum, our cursory assessment indicates that possible impacts of the introduction of mandatory biofuels targets on the competitive environment of the fuels industry are likely to be minimal, and certainly not outside those already considered by the Commerce Commission, the industry, the public and other interested parties.

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