Final Report

Enabling Biofuels: Biofuel Economics

Prepared for

Ministry of Transport

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Background

In August 2005, the Government agreed in principle to the introduction of a mandatory biofuels sales target for renewable transport biofuels. This report analyses the appropriateness of quantity targets and how they might be achieved.

Previous reports on supply,[1] distribution[2] and vehicle risks[3] have identified that there are likely to be physical or cost constraints related to fuel distribution that will limit the volumes of ethanol that can be sold in New Zealand. The issues include requirements for double containment of ethanol petrol blends (tanks have a second skin), constraints related to petrol volatility which increases with ethanol blends, and ethanol's affinity to water (water is absorbed by ethanol and fuels mixed with ethanol) which means it has to be transported separately and blended as close to final sale as possible. In contrast, biodiesel has few distribution problems.

Estimated maximum quantities of biofuel sales are summarised in Table E1. The effective PJs are a measure of the energy value of the fossil fuel displaced, taking account of the different energy content of litres of biofuel and conventional fuels and the enhanced combustion efficiency resulting from a higher oxygen content.

Table E1 Maximum Biofuel Quantities

Product	2008	2010	2012
		Million litres	
Ethanol	17	27	40
Bio-diesel	36	70	122
Biofuel	53	97	162
		Effective PJ[1]	
Ethanol	0.5	0.8	1.1
Bio-diesel	1.3	2.5	4.3
Biofuel	1.7	3.2	5.4

Net Costs and Benefits

The net costs and benefits of biofuels supply are estimated from the costs of production and the benefits that include:

- security of supply benefits, particularly reductions in New Zealand's obligation to store oil as part of its member ship of the International Energy Agency (IEA); and
- environmental benefits, particularly reduced CO_2 emissions.

The analysis of private costs of production is used to compare costs of biofuels with the costs of petroleum-based alternatives.

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[1] Hale & Twomey, Landcare and Covec (2006) Enabling Biofuels. Biofuels Supply Options. Report to the Ministry of Transport

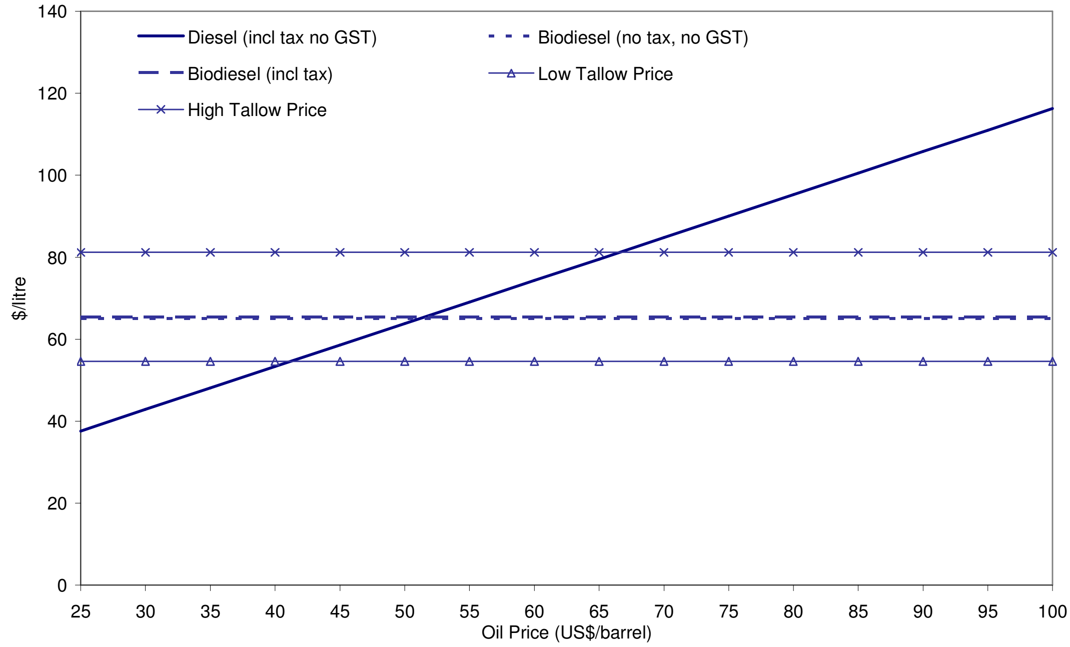
[2] Hale & Twomey (2006) Enabling Biofuels. Biofuels Distribution Options. Report to the Ministry of Transport

[3] Hale & Twomey (2006) Risks to vehicles and other engines. Report to the Ministry of Transport

Biodiesel

Figure ES1 shows the comparison of the costs of production of biodiesel from tallow and conventional diesel including an average, low and high price of the tallow feedstock. It suggests that at an average tallow cost, biodiesel is lower cost to produce than conventional diesel at oil prices of $52/barrel or above.[4]

Figure ES1 Comparison of Diesel and Biodiesel Supply Costs



For policy purposes the analysis takes a social perspective, ie it assesses the costs and benefits to society as a whole. Taking account of the security of supply and environmental benefits (including a CO_2 price of $15/t), and using a 10% discount rate, the oil price above which biodiesel has net benefits for New Zealand, is US$45/barrel. At a 5% discount rate the value falls to US$43/bbl.

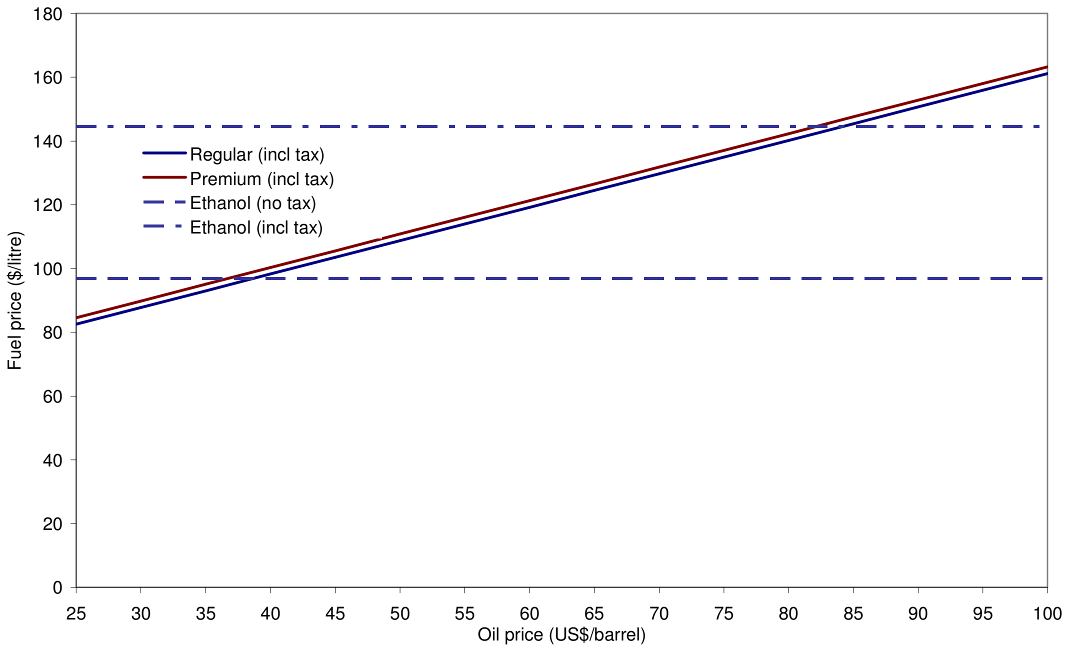
Ethanol

Figure ES2 shows a similar analysis for ethanol in comparison with supplies of regular petrol. Ethanol is competitive with petrol only if petrol is taxed and ethanol is not. If ethanol was also taxed (or if neither fuel was taxed), then ethanol is a lower cost fuel only at oil prices above US$84/bbl, compared with US$39/bbl if ethanol is not taxed.

Analysis of the net social costs of supply of ethanol in comparison with regular petrol suggests that the oil price, above which ethanol has net benefits for New Zealand, is US$80/barrel or US$78/bbl at a 5% discount rate.

[4] A private discount rate of 15% is used plus an exchange rate of US$0.6:NZ$1

Figure ES2 Comparison of Costs of Supply of Ethanol and Petrol



Targets

The analysis of costs and benefits of biofuel supply suggest that:

- Replacement of diesel with biodiesel from a tallow feedstock would have positive net benefits for New Zealand under reasonable assumptions regarding future oil and feedstock prices;
- Supplies of biodiesel from other feedstocks or directly imported would not be expected to produce net benefits for New Zealand;
- Limits to the total potential supplies of biodiesel are set by the distribution system;
- Replacement of petrol with ethanol is not expected to produce net national benefits;
- Currently there are limits to the potential supply of ethanol as a petrol mix, particularly because of the limited number of service stations with double containment to reduce pluming of fuels.

The quantities of tallow-based biodiesel available are approximately 130,000 tonnes per annum or close to 150 million litres. This is approximately 5.2 PJ. The limits to supply noted in Table ES1 are likely to be important in setting targets for policy.

Policy

There is considerable uncertainty in the economic analysis, associated with the costs of feedstocks and oil prices, and also because of the rapid development of the technologies. Any policy to support and encourage the supply of biofuel should provide incentives for both biodiesel and ethanol supplies.

Policy options include incentive payments (subsidies) or tax breaks (no excise duty on biofuels). These approaches have a number of difficulties because of the price uncertainty, passing price risk on to government and consumers.

Instruments based simply on the internalisation of estimated external costs would not be expected to provide sufficient incentive for investment in biofuels supply, because of the significant uncertainties in current market prices, particularly for oil.

Mandatory sales obligations would provide certainty to the market, while passing cost risk on to industry and, in turn, consumers. The cost uncertainty could be limited through the introduction of a buy-out mechanism as include in the UK's Renewables Obligation (RO).

Adding a trading element to the mandatory sales target would provide more flexibility and reduce costs. Trading could be introduced to allow sales between firms within a time period and could be extended to include trading over time, either via multi-year compliance periods or formalised banking and/or borrowing.

Reverse auctions allow the government to estimate how much subsidy it would be willing to provide to obtain supplies. It provides considerable price and volume certainty but still requires government expenditure to obtain biofuels. It also has less up-front certainty for industry; it needs to undertake considerable pre-planning to ensure that it bids at the right price. It also requires industry to commit some time in advance as to the amount it would supply over time; there is considerable cost risk associated with this approach that may limit bids or mean bids are high in price.

A mandatory sales target with trading would be the least cost instrument to meet a specified target for biofuels supply. If introduced, to avoid inter-biofuel distortions, excise duties on ethanol should be raised to equal that on petrol.

1. Introduction

1.1. Objectives

In August 2005, the Government agreed in principle to the introduction of a mandatory biofuels sales target for renewable transport biofuels.

This report provides data and analysis that can assist in decisions about the appropriateness of quantitative targets and how they might be achieved. It takes cost, availability and other information from the separate reports provided by Hale & Twomey and others on supply,[5] distribution[6] and vehicle risks.[7] This information is combined with estimates of the benefits of biofuels to provide an assessment of the net benefits to New Zealand of different levels of biofuel use. In addition, practical issues relating to trade and consumer response are addressed.

Policy instruments that might be used to encourage the use of biofuels are assessed also, taking account of expected effectiveness and costs.

1.2. Background and Implications of Work to Date

Biofuels targets can be achieved through blending biodiesel with diesel, ethanol with petrol or some combination of the two.[8]

The previous reports have identified that there are likely to be physical or cost constraints related to fuel distribution that will limit the volumes of biofuels that can be sold in New Zealand. The issues include:

- requirements for double containment of ethanol petrol blends, ie that tanks need to have a second skin. Currently approximately 20% of New Zealand service stations, servicing close to 30% of demand, have double containment in place (2005 estimate). Tanks are converted on replacement, and by 2012 over 50% of supply should be via double containment tanks. The cost of accelerating tank replacement to enable early and wide us of ethanol, would be $215-275 million. For a 50 million litre plant, this would result in an additional cost in the order of 70 to 90 cents per litre.[9] These costs are not included in the analysis in this report—the current extent and natural rate of expansion of use of double containment is treated as a constraint to ethanol use.

[5] Hale & Twomey, Landcare and Covec (2006) Enabling Biofuels. Biofuels Supply Options. Report to the Ministry of Transport

[6] Hale & Twomey (2006) Enabling Biofuels. Biofuels Distribution Options. Report to the Ministry of Transport

[7] Hale & Twomey (2006) Risks to vehicles and other engines. Report to the Ministry of Transport

[8] There is also the potential to blend ethanol with diesel as diesohol. This has a number of technical difficulties and has not been assessed in the technical reports.

[9] At a 15% discount rate and 15 year lifetime.

- constraints related to petrol volatility which increases with ethanol blends. Volatility requirements (measured as RVP and E70)[10] are included in current fuel specifications. Meeting these requirements would require special petrol blendstock with low volatility. This is likely to be costly to run in parallel with normal petrol grades, which would be necessary because of the double containment restriction.[11]

- Ethanol's affinity to water (water is absorbed by ethanol and fuels mixed with ethanol) means it has to be transported separately and blended as close to final sale as possible. This has requirements for additional distribution and terminal facilities.

In contrast, biodiesel has few distribution problems. There are potential problems relating to the cold properties, ie its ability to pour at low temperature, which means roll-out might concentrate initially on the north of the North Island. However, recent developments suggest that this might be overcome. For example, biodiesel is currently being produced and sold in Scotland,[12] at much lower temperatures than found in New Zealand, and a recent study of B20 (20% biodiesel) in Kansas reported no problems throughout winter. [13]

Taking account of the limitations because of distribution, estimated maximum quantities of biofuel sales are summarised in Table 1. The effective PJs are a measure of the energy value of the fossil fuel displaced, taking account of the different energy content of litres of biofuel and conventional fuels and the enhanced combustion efficiency resulting from a higher oxygen content.

Table 1 Maximum Biofuel Quantities

Product	2008	2010	2012
		Million litres	
Ethanol	17	27	40
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Biofuel	53	97	162
		Effective PJ[1]	
Ethanol	0.5	0.8	1.1
Bio-diesel	1.3	2.5	4.3
Biofuel	1.7	3.2	5.4

[1] Assumes 27.84MJ/l for ethanol and 35.3MJ/l for biodiesel, taking account of energy content and impacts on combustion efficiency

Source: Adapted from: Hale & Twomey , Landcare and Covec (2006) Enabling Biofuels. Biofuels Distribution Options. Report to the Ministry of Transport

[10] RVP = Reid Vapour Pressure; a measure of the pressure exerted by the vapour delivered from a liquid at a given temperature and pressure.

E70 = a measure of how much petrol has evaporated at 70°C. The petroleum specifications set lower and upper limits to ensure good starting and engine performance when warm.

[11] The RVP requirement has been relaxed in the analysis. Without the relaxation, port terminal costs for ethanol blend are likely to increase by 100-200% which will make ethanol blending costs prohibitive (20-30 c/l blending and port terminal cost even in high throughput cases).

[12] www.argentenergy.com/

[13] Hale & Twomey (2006) Risks to vehicles and other engines. Report to the Ministry of Transport

The initial economic analysis demonstrates that ethanol is a higher cost fuel than petrol but that the costs of biodiesel are closer to the costs of petroleum-based diesel. The cost issues are explored in greater detail below.

In this report, we take as given the practical constraints but we analyse the cost issues further, assessing the costs and benefits from private and public policy perspectives.

2. Costs and Benefits of Meeting Targets

2.1. Approach to analysis

This section compares the costs and benefits of biodiesel and ethanol supply and consumption in New Zealand. There are two approaches to analysis. Firstly, the private costs and benefits are assessed to identify whether biofuels are likely to be supplied without government intervention. Secondly, we examine costs and benefits from a societal perspective, as a means for understanding whether the optimal level of supply is greater (or less) than what the market is likely to supply, and thus if there is a rationale for government intervention. This includes a different treatment of tax in the analysis and the identification of market failures and the requirement to price externalities, ie costs that fall on society that currently are not priced by the market, such as environmental impacts.

2.2. Private versus Social Perspective

2.2.1. Market Failure and Externalities

The justification of government intervention in biofuels supply is based on the existence of market failures that result from externalities in supply costs. Specifically, some of the costs and benefits of fuel supply are not priced in the market; these are the impacts on the environment and security of supply. A number of other impacts of fuel use and transport activity are common between the two fuel types; these include impacts on roads and congestion effects.

The environmental effects include emissions of greenhouse gases and a number of local pollutants. The security of supply benefits accrue largely because the supply of biofuels reduces the government's need to tender for oil storage to meet IEA requirements for oil storage. These benefits accrue to the government and not to industry. There are benefits of security that accrue to market participants, eg where biofuels reduce the likelihood of interruption of supply associated with a number of international events, but it is not clear that this is a market failure, because market participants are able to contract in a way that expresses their willingness to pay for security.

There is the potential also for disruption in supplies of biofuels or their feedstocks, which may reduce the security of supply benefits of biofuels. These issues are explored in more detail in Section 2.4.1.

2.2.2. Discount Rates

From a private perspective, the costs of biofuel production include the capital and operating costs of production plus the costs of feedstocks. Capital costs are discounted over the expected economic life of plants at a private cost of capital. The private cost of capital is an opportunity cost of allocating resources to biofuel production versus some other investment, taking account of market risk.

When analysis is undertaken for public policy purposes, the perspective is different. Resources diverted into biofuel production have impacts both on investment and consumption (eg where there is an impact on purchase prices). Thus the analysis uses a combination of an opportunity cost of consumption and an opportunity cost of capital investment. Opportunity costs of consumption can be thought of as being proxied by rates of return that would persuade individuals to save rather than consume. Social opportunity costs of capital are lower than private rates because the risk is spread widely across society; this can be approximated by a risk-free rate of interest. When these factors are combined, the resulting discount rate is lower than the private cost of capital.

New Zealand has traditionally used a discount rate for public policy purposes of 10%, although arguably the appropriate rate would be closer to 5%, nearer to the current real risk-free rate. Some other countries use very low rates, eg the UK has recently adopted 3.5% as its discount rate for public policy purposes, with much lower rates for projects with long term effects.

For analysis here we use the following rates:

- a private rate of 15%;
- a social rate of 10%; and
- an alternative social rate of 5%.

In practice, capital costs are a low proportion of total costs for all but the smallest of plants such that the costs of biofuels are reasonably insensitive to discount rate assumptions.

2.3. Costs

The analysis below starts with an assessment of costs from a private perspective. A social perspective is introduced when the costs and benefits are combined in Section 2.5.

Biofuel costs are compared with conventional petroleum based on fully built up cost into the port distribution terminals. All costs associated with the biofuel feedstock (and associated transport and storage), processing costs, costs in transporting biofuel to the port terminals and specific costs at the terminals to enable them to blend the biofuels into conventional fuel are included. For the case assuming blending biodiesel at the refinery, refinery storage and blending costs are included along with subsequent transport costs to port terminals. Petroleum fuels are costed into port terminals using a conventional import parity price build up, which is the way these fuels are priced in the New Zealand market. Other terminal distribution costs (normal storage and loading fees), transport to commercial or retail sites, and retailing costs are excluded as these will be similar for both standard and biofuels blended fuels from that point on.

2.3.1. Biodiesel Supply Costs

Estimates of capital costs for biodiesel plants from a number of studies, including two New Zealand studies undertaken for EECA and more recent Australian studies, are summarised in Table 2.

The data suggest clear economies of scale in production. Analysis of these results produced the statistically significant (R^2=0.96) relationship shown in Figure 1, and defined by the formula:

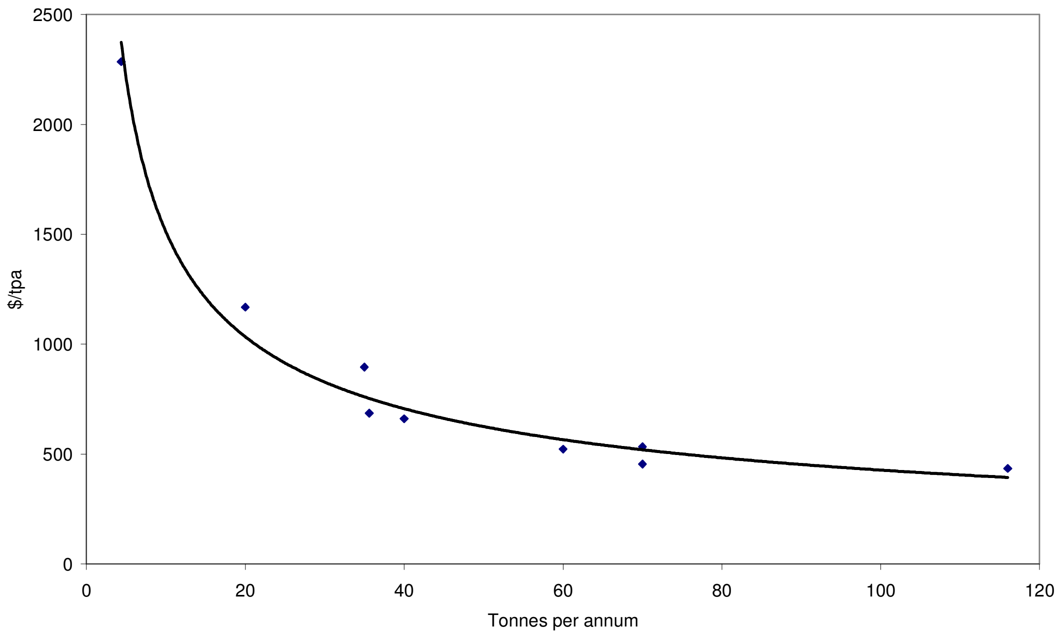
$$\$/tpa = 5349.4 \times capacity\ (tpa)^{-0.5486}$$

Table 2 Capital Costs - Biodiesel Plants

Plant Capacity ('000 tpa)	million litres pa	Capital Cost $million	Year of data	2006$million	$/tpa
116 [1]	133	45.7	2001	50.5	435
70 [1]	80	33.8	2001	37.3	534
4.4 [1]	5	9.1	2001	10.1	2285
20[2]	23	21.0	2002	22.5	1125
40[2]	46	23.8	2002	25.5	637
60[2]	69	28.2	2002	30.2	503
70[2]	80	29.7	2002	31.8	455
35[3]	40	22.1[5]	2001	24.4	686
35[4]	40	29.3	2002	31.4	896

Source: [1] Judd B (2002) Biodiesel from Tallow. Prepared for Energy Efficiency and Conservation Authority; [2] Duncan J (2003) Costs of biofuels production. Prepared for EECA; [3] Amadeus Petroleum NL (2001) Annual Report; [4] CSIRO, ABARE and BTRE (2003) Appropriateness of 350 Million Litre Biofuels Target. Report to the Australian Government Department of Industry Tourism and Resources.[5] The original costs (A$12 million) are assumed to exclude non-plant capital costs, eg roads, storage etc. We assume this increase costs by 50%.

Figure 1 Capital Costs ($/tpa) of Biodiesel Plants



Source: Covec analysis

In comparison with these estimates, projected capital costs for plants that might be built in New Zealand by one developer[14] were slightly higher, but for a more capital-intensive technology than is typical. In practice, capital costs are a small proportion of total costs and, given this, the costs appear to be reasonable estimates.

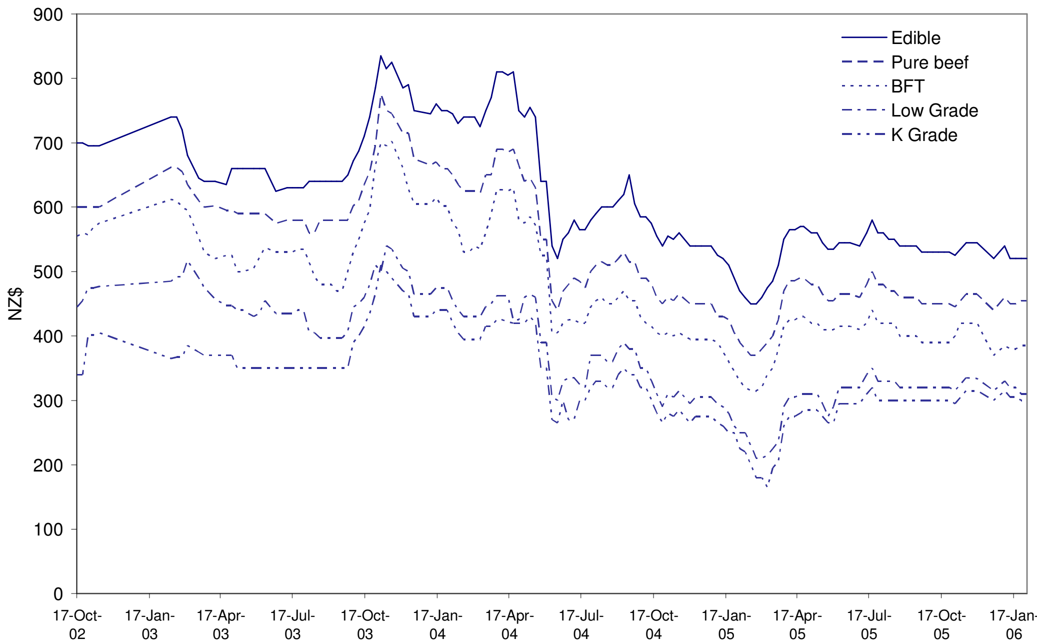
Feedstock requirements for production are assumed to be as listed in Table 3. The relevant tallow prices are export values; the tallow assumed to be available for biodiesel production is that which is currently exported. The initial work on supply costs[15] uses a recent average value of approximately $520/t, however tallow prices vary with grade (Figure 2) such that the costs will vary depending on the quantity diverted from export, in the range of $400-700/tonne. New Zealand tallow exports are very largely of inedible tallows and thus at the lower end of the price range.

Table 3 Feedstock Requirements and Yields

Feedstock	Kg/kg biodiesel	Price (US$/t)	Price (NZ$/t) (@0.65)
Tallow	1.0		$400-700
Methanol	0.114	$300	$462
Glycerol	0.1	$900	$1,385

Source: Hale & Twomey, Landcare and Covec (2006) Enabling Biofuels. Biofuels Supply Options. Report to the Ministry of Transport

Figure 2 Tallow Export Prices



Source: EECA

[14] Argent Energy

[15] Hale & Twomey, Landcare and Covec (2006) Enabling Biofuels. Biofuels Supply Options. Report to the Ministry of Transport

There are a number of other potential feedstocks for production of biodiesel. These include palm oil, rapeseed and jatropha. Palm oil is the main option that is traded internationally, and with potential for import in the short term. Costs for production from palm oil are estimated; the results are shown in Table 4.

Table 4 Costs of Biodiesel Production

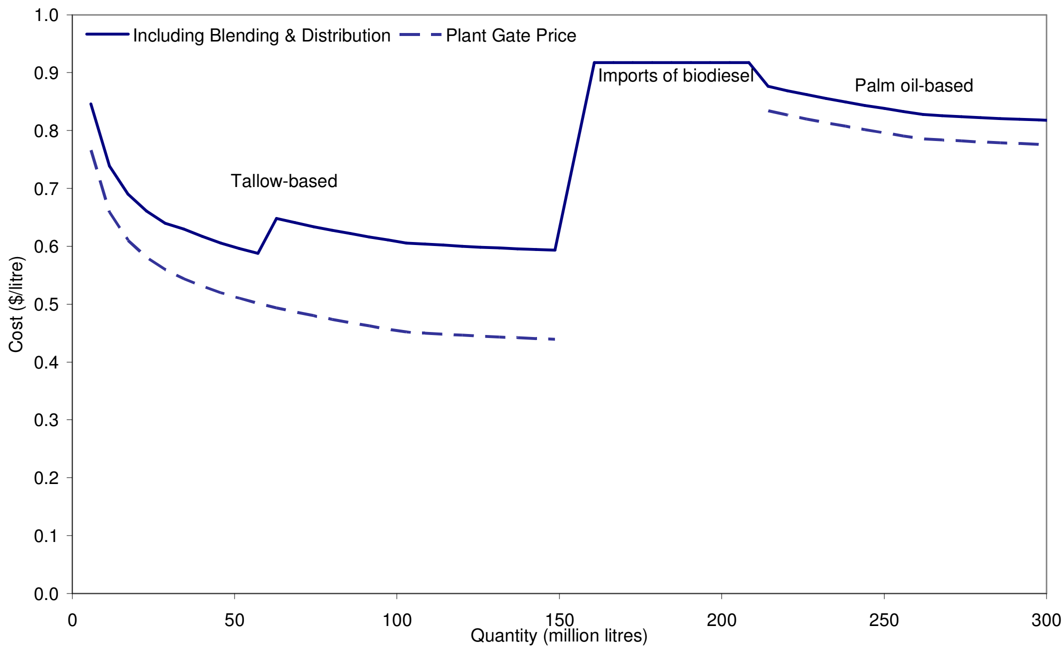
Plant Size		Capital costs	Feed-stock	Methanol	Other	Total	Glycerol credit	Net	Distri-bution & Blending	Net
Ktpa	Million litres	Tallow-based $/litre								
5	6	0.33	0.40[1]	0.05	0.11	0.89	0.12	0.77	0.08	0.85
20	23	0.15	0.40	0.05	0.10	0.70	0.12	0.58	0.08	0.66
40	46	0.11	0.40	0.05	0.09	0.64	0.12	0.52	0.09	0.61
60	69	0.08	0.40	0.05	0.08	0.61	0.12	0.49	0.15	0.64
120	137	0.06	0.40	0.05	0.06	0.56	0.12	0.44	0.15	0.60
		Palm Oil $/litre								
50	60	0.09	0.73	0.05	0.08	0.95	0.12	0.83	0.04	0.88
60	71	0.08	0.73	0.05	0.08	0.94	0.12	0.82	0.04	0.86
120	143	0.06	0.73	0.05	0.06	0.89	0.12	0.78	0.04	0.82

[1] @ $520/tonne f.o.b. (or $460/tonne sold in NZ)

Source: Hale & Twomey, Landcare and Covec (2006) Enabling Biofuels. Biofuels Supply Options. Report to the Ministry of Transport

The average costs of production of biodiesel of different aggregate volumes are shown in Figure 3.

Figure 3: Costs of Biodiesel Production



The cost of biodiesel production from tallow shows increasing economies of scale up to a level of 150M litres; the figure assumes that, up to 150 million litres, tallow is produced from successively larger plants, operating at capacity. If, in contrast, 150 million litres was produced from three 50 million litre plants, the costs for producing 150 million litres would be the same as estimated for 50 million litres in Figure 3. From 150M to 200M litres importing biodiesel is the least cost option, while above 200M litres, production in New Zealand from Palm Oil is economic; the assumption is that, if importing palm oil a minimum sized plant would be used and that the smallest plant built using imported product would be 50 ktpa. Hence production above 150 million and below approximately 210 million litres is assumed to be imported biodiesel (if available).[16]

Figure 4 compares the costs of biodiesel supply with the supply costs for petroleum-based diesel at different oil prices. The diesel supply costs are estimated using oil prices, refining margins and freight in New Zealand. The costs ignore any wholesale or retail margins, which would also apply to biodiesel supply. The estimates include tax (at 0.355cents/litre) in the supply costs for diesel, and with and without tax options for biodiesel—it makes very little difference.

The base case analysis is undertaken using an assumed $520/tonne for tallow; high and low tallow prices of $700/tonne and $400/tonne are also shown.[17]

Figure 4 Comparison of Diesel and Biodiesel Supply Costs

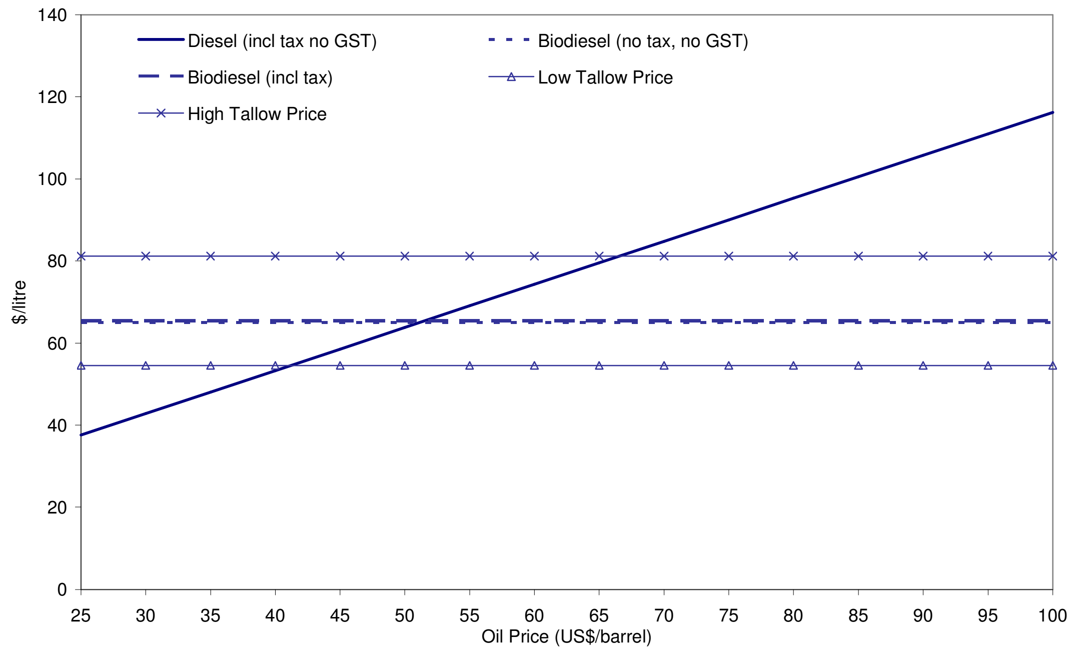


Table 5 shows the oil price at which the costs of biodiesel supply is equal to the costs of diesel supply at different $US:$NZ exchange rates. These cut-off points are sensitive to the tallow price and the exchange rate. There is some suggestion that tallow prices will be driven down in the absence of demand for biofuels production because of the shift away globally from tallow use in food production, however this is currently uncertain.

[16] 0.875kg/litre of biodiesel

[17] These are all f.o.b. prices at a NZ port. It is assumed that the costs of tallow supplied ex plant in New Zealand will be less some freight element, estimated at $60/tonne.

Table 5 Oil Prices (US$/barrel) for Economic Biodiesel Supply

Exchange rate (US$:NZ$1)	Tallow Price (NZ$/tonne) Base ($520/t)	$400/t	$700/t
		Oil price (US$/barrel)	
0.5	40	31	52
0.55	46	36	59
0.6	52	41	67
0.65	57	46	74
0.7	63	51	81

Also it is noteworthy that the majority of New Zealand sales of tallow are inedible, such that very little would be priced at $700/tonne. Given these considerations, the base case average price ($520/tonne) is a better picture of actual costs. There is also the potential for upward pressure on tallow prices from demand for biodiesel production in other countries; this issue is explored in more detail in Section 3.3.3. The analysis has assumed that biodiesel production from New Zealand tallow uses product that is currently exported, and that the tallow currently supplying existing domestic markets will have an equal or higher value (otherwise it would be exported also). If the value of tallow in biodiesel production is close to the value in these other markets, and some surplus processing capacity in New Zealand, there is likely to be upward pressure on tallow prices in these other domestic markets also.

The emerging picture is one in which biodiesel production is economic under a set of reasonable assumptions regarding future prices and exchange rates but is uneconomic under other reasonable assumptions. The analysis suggests considerable market uncertainty for potential market entrants.

Prices

The cost of production of biodiesel is not necessarily the same as the market price. Market prices would be expected to equal production costs in highly competitive markets where there is competition amongst biodiesel producers. This is very unlikely to be the case in New Zealand. In the absence of competition, prices can rise to the costs of the marginal producer. The definition of the marginal producer depends on the policy stance on biofuels.

If biodiesel is simply competing in the market against conventional diesel then the maximum price that biodiesel can sell at is the price of the alternative diesel, assuming no quality differential. It means, if production costs were lower than for conventional diesel, the price of biodiesel would rise to the conventional diesel price. If there is a potential export market for biodiesel, this also influences price; local producers would price at least as high as the value of biodiesel in the alternative market, less transport costs.

The equation is different if the government makes biofuel use compulsory. Here the price that biodiesel can rise to is set by the price of the alternative marginal[18] fuel that would be used to meet the target. This might be imported biodiesel, biodiesel manufactured from palm oil or another biofuel, eg ethanol.

For policy purposes, the concern is with the costs of production as these are the costs to the nation. The difference between production costs and market prices is a producer surplus (profit) rather than a cost. This surplus would be retained in New Zealand by New Zealand-owned firms, but might be expatriated by foreign-owned firms. If expatriated it would be a cost to New Zealand.

2.3.2. Ethanol Supply Costs

There are a number of different production methods and feedstocks for ethanol production. In this study, we have focussed on the following feedstocks and production processes:

- Corn/Maize: Starch conversion to sugars, fermentation and distillation
- Sugar beet: Fermentation and distillation
- Wood: Acid Hydrolysis, fermentation and distillation[19]

Each of the different feedstocks and processes has had their manufacturing costs investigated independently.

Capital Costs

A recent Australian review paper suggests that the fixed capital costs of ethanol production from grain are around 75-80% higher than those for biodiesel.[20] We have used capital costs for ethanol production from maize that follow the same decreasing average cost curve, but with a vertical shift in the curve. At the high-production (relatively efficient) end of the cost curve, this gives variable capital costs comparable to those found in the literature.[21,22,23,24]

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[18] The marginal fuel is the most expensive fuel that would be used where a target was met at least cost. Fuels would be used in turn in order of price from lowest to highest. Our concern is with the most expensive fuel that would be used to meet the target, as that is the one that would be displaced by a lower cost fuel.

[19] Manufacture from wood is untested commercially at this stage although at least one plant is expected to come into production in 2006. Fulton, L., Howes, T. and Hardy, J. (2004) Biofuels for Transport, An International Perspective. Study by the IEA

[20] CSIRO, ABARE and BTRE (2003) Appropriateness of 350 Million Litre Biofuels Target. Report to the Australian Government Department of Industry Tourism and Resources.

[21] Fulton, L., Howes, T. and Hardy, J. (2004?) Biofuels for Transport, An International Perspective. Study by the IEA.

[22] AEA Technology (2002) International Resource Costs of Biodiesel and Bioethanol. Report to the UK Department for Transport.

[23] Shapouri, H. and Gallagher, P. (2005) USDA's 2002 Ethanol Cost-of-Production Survey.

[24] CSIRO, ABARE and BTRE (2003) Appropriateness of 350 Million Litre Biofuels Target. Report to the Australian Government Department of Industry Tourism and Resources.

We have adjusted the capital cost curve for wood and sugar beet in the same manner, so that at the high-production end of the curve, the variable costs are also comparable to those found in the literature.

Operating Costs

Operating costs are defined here as all costs that are not capital or feedstock costs. The literature contains large variations in the estimation of operating costs. Where there is a range of costs reported in different sources, a mid point has been used. Table 6 shows the operating costs by feedstock/production process.

Feedstock Costs, Availability and Co-product Values

The feedstock cost consists of two parts: the conversion yield (how much ethanol is produced from one tonne of feedstock), and the price of that feedstock. Once again, there are large variations in the literature in the estimation of conversion yield. In these cases, a midpoint has been used. Table 7 summarises the feedstock costs used in the analysis.

Table 6: Operating Costs

	Wood[1, 2]	Maize[1,2,3,4]	Sugar Beet[2]
Operating Cost ($/l)	$ 0.25	$ 0.11	$ 0.17

Source: [1] Fulton, L., Howes, T. and Hardy, J. (2004) Biofuels for Transport, An International Perspective. Study by the IEA. [2] AEA Technology (2002) International Resource Costs of Biodiesel and Bioethanol. Report to the UK Department for Transport. [3] Shapouri, H. and Gallagher, P. (2005) USDA's 2002 Ethanol Cost-of-Production Survey. [4] CSIRO, ABARE and BTRE (2003) Appropriateness of 350 Million Litre Biofuels Target. Report to the Australian Government Department of Industry Tourism and Resources.

Table 7: Feedstock Costs

	Wood	Maize	Sugar Beet
Feedstock ($/t)[1]	$ 44.00	$ 280.00	$ 68.70
Transport costs ($/t)	$ 25.00	$ 25.00	$ 25.00
Conversion yield (l/t)	300[2]	408[2]	98[3]
Feedstock Cost ($/l)	$ 0.23	$ 0.75	$ 0.96

Source: [1] Section 6.3 [2] Fulton, L., Howes, T. and Hardy, J. (2004) Biofuels for Transport, An International Perspective. Study by the IEA. [3] AEA Technology (2002) International Resource Costs of Biodiesel and Bioethanol. Report to the UK Department for Transport.

Co-products of ethanol production differ by feedstock and production process. Where a range of co-product values have been found in the literature, we have assumed a midpoint value.

Distribution and Blending Costs

There are two components to distribution costs: The costs of delivering the feedstock to the ethanol production plant; and the costs of distributing the ethanol to the blending facility. We have assumed a constant cost of $25/t over all feedstocks for the first component, and $0.02/l over all feedstocks for the second. A blending/holding cost of $0.07/l is assumed.

Table 8: Co-product Values

	Co-product[1]	Value of Co-products ($/l)
Wood	Electricity	$0.03[2]
	Ash	
	Acetic Acid	
Corn/Maize25	Corn Oil	$0.19[2, 3]
	Corn Feed	
	Corn Meal	
Sugar Beet	Pulp	N/A
	Animal Feed	

Source: [1]http://www.dft.gov.uk/stellent/groups/dft_roads/documents/page/dft_roads_024054-04.hcsp, 16/03/2006. [2] Fulton, L., Howes, T. and Hardy, J. (2004) Biofuels for Transport, An International Perspective. Study by the IEA. [3] AEA Technology (2002) International Resource Costs of Biodiesel and Bioethanol. Report to the UK Department for Transport.

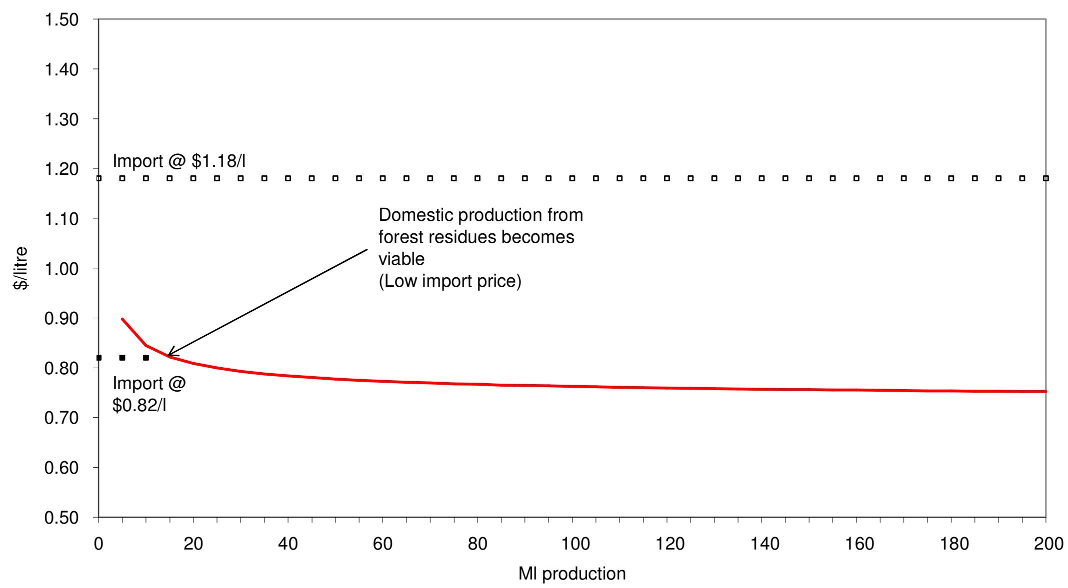
Total Costs

The costs discussed above have been aggregated by feedstock to find the most economical combination of feedstocks to produce ethanol from in New Zealand. A production cost for ethanol produced from whey has also been included.

Ethanol production from wood residues is the most competitive option for all levels of production. The cost of ethanol production from wood residues is estimated to be between NZ$1.03/l (for production at a 5M litre plant) and NZ$0.77/l (20M litre plant). Importing ethanol (from Brazil) is another option; a world price of ethanol is assumed at between $0.51 and $0.88/l, and a shipping cost of $0.23/l added. A blending cost of $0.07/l is assumed, giving a total cost of importing ethanol of between $0.81 and $1.18/l.

The aggregate New Zealand ethanol supply curve is shown in Figure 5.

Figure 5: Aggregate ethanol supply



[25] Wet-milling of corn has been assumed, as the co-products of wet-milling corn have a greater value.

The commercial viability of ethanol production from forest residues is not certain; to our knowledge there are no plants operating currently. However, there are demonstration plants in operation using the same process and ready for commercial roll-out according to their manufacturers,[26] and forest residue plants are planned for commissioning in the near future.[27]

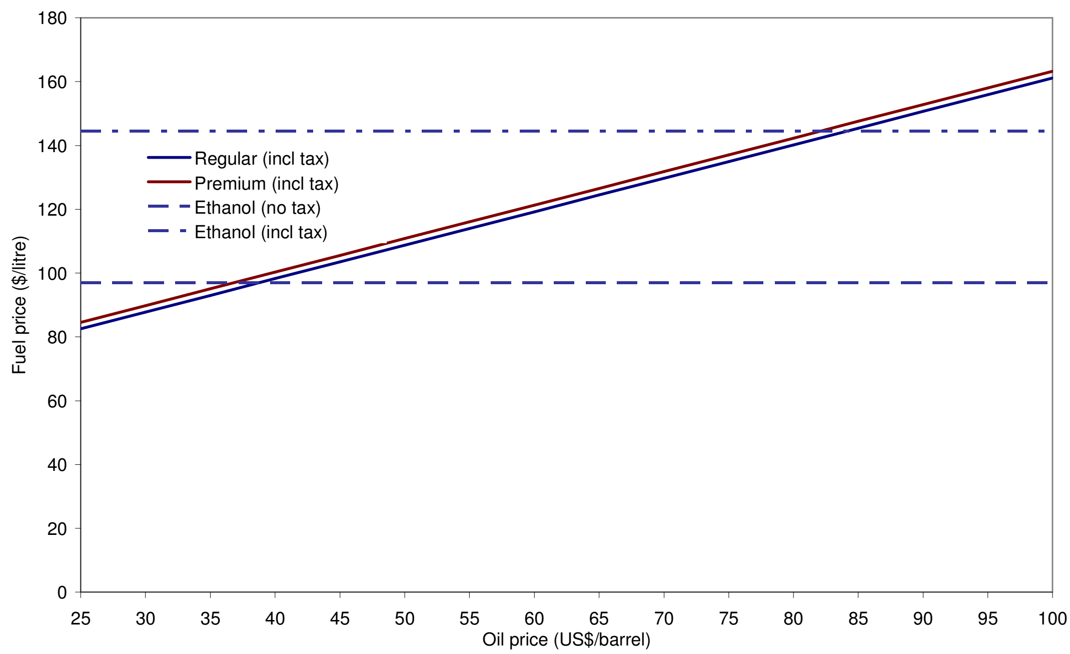
The most economic source of ethanol is very dependent on the import price. At high-end import prices, domestic ethanol production is the most economic source.

At low-end import prices, importing ethanol is the most economic method of supply until a quantity level of 45m litres. From this point on, forest residues would be used to produce ethanol.

Figure 6 shows a comparison of the costs of supply of ethanol and petrol at different oil prices (and an exchange rate of 0.6). It compares petrol with tax with ethanol with and without tax. The ethanol price has been converted into a petrol equivalent, ie the price per litre is the price required to purchase an amount that would displace a litre of petrol; thus it is higher than the estimated price per litre of ethanol.

The diagram shows that ethanol is competitive with petrol only if petrol is taxed and ethanol is not. If ethanol was also taxed (or if neither fuel was taxed), then ethanol is a lower cost fuel only at oil prices above US$84/bbl, compared with US$39/bbl if ethanol is not taxed.

Figure 6 Comparison of Costs of Supply of Ethanol and Petrol



[26] Iogen Corporation (2005) Cellulose Ethanol http://www.iogen.ca/cellulose_ethanol/what_is_ethanol/cellulose_ethanol.pdf

[27] Fulton, L., Howes, T. and Hardy, J. (2004) Biofuels for Transport, An International Perspective. Study by the IEA

Prices

The analysis above focuses on the costs of supply. As discussed under biodiesel above, this is not necessarily the same as the market price of ethanol, which will be influenced also by world prices of ethanol.

- If ethanol competes simply under market prices, its maximum price will be set by the price of alternatives. If there is competition with other ethanol producers, this might set the price, but it can rise no higher than the price of petrol.
- If biofuel use is compulsory, eg in the form of a sales obligation, the price of ethanol can rise to the price of the marginal fuel that would meet the government's requirement. This might be imported ethanol or some other biofuel.
- If ethanol could be exported from New Zealand, the world price, less transport costs would set a minimum sales price in New Zealand.

As noted above for biodiesel, for policy purposes, the concern is with the costs of ethanol production rather than price. The producer surplus (difference between costs and price) is not a cost to the nation, unless this surplus is expatriated profit by foreign-owned firms.

2.3.3. Vehicle impacts

The recent report to the Ministry of Transport that accompanies this study,[28] investigated the possible harm that biofuels could cause to vehicles and other engines if they were introduced into New Zealand.

Biodiesel

The main potential problems associated with the use of biodiesel were found to be:

- Degradation of fuel system components
- Corrosion of fuel system components
- Fuel system blockages
- Microbial growth in old fuel
- Low temperature properties affecting engine operability

The first three of these were found to diminish in severity as the concentration of biodiesel decreased, and also as the age of the engine decreased. Microbial growth was found to be slightly more of an issue in biodiesel than in mineral diesel. This could impact on engine performance of engines that are used infrequently (eg backup generators). Mineral diesel may need to remain available for these applications.

B20 blends have been used extensively and successfully in the US for many years, and B5 blends are permitted in Europe without any labelling. All major diesel engine makers endorse B5 blends.

[28] Hale & Twomey (2006) Risks to vehicles and other engines. Report to the Ministry of Transport

Ethanol

The main potential problems associated with the use of biodiesel were found to be:

- Degradation of fuel system components
- Corrosion of fuel system components
- Phase separation
- Fuel system blockages
- Volatility changes affecting engine operability
- Enleanment affecting engine operability
- Paint damage from spillages

Most of these problems are caused by the higher level of corrosiveness of ethanol compared to petrol. Increased corrosiveness can lead to or accelerate component failure, particularly those made from rubber or soft metals.

Ethanol also has a solvent effect, which could loosen gums that have built up in petrol engines over a period of time. These gums could clog filters resulting in reduced engine performance. This solvent effect could also harm car paintwork if spilt while refuelling. However, the aromatics used in petrol have a similar effect, and ethanol's water-solubility makes it easier to wash than petrol.

Water dissolves in ethanol to a much greater extent than in petrol. The higher water content in fuel could impact engine performance, or in extreme cases cause the engine to not run.

E10 blends have been used in the US for over 25 years, and have recently been introduced to Australia. Around 65% of New Zealand's fleet is manufacturer-endorsed to use an E10 blend. This is despite manufacturers' strong incentives to be conservative in their endorsements.

E5 blends can be sold in Europe without labelling. This is assumed to imply that European regulators consider E5 to be safe for their existing fleet. New Zealand has a large number of imported Japanese vehicles that will not have been considered by European regulators, but as older European vehicles were not designed to use ethanol, and have been deemed safe; there is no reason to expect any problems with an E5 blend in Japanese imported cars in New Zealand.

For analysis, we have not included additional costs related to vehicle risks from the use of biofuel blends. This is consistent with an assumption that biofuels are used in low concentration blends, or higher concentration blends are targeted at vehicles that can use such blends.

2.4. Benefits

The benefits considered in analysis are security of supply and environmental improvements.

Security of supply benefits are the reduced risks of shortages of fuel supply. The environmental benefits are associated with reductions in emissions of CO_2 and a number of local pollutants.

2.4.1. Security of Supply

The benefits of biofuels supply include improvements in security of supply of transport fuels and a reduction in New Zealand's IEA obligation for oil storage.

Reduced Supply Disruption

New Zealand is at risk to disruptions to its oil supply as a result of both internal and external events.[29] It mitigates this risk through domestic production, oil storage and emergency procedures to limit oil demand in the event of a disruption.[30, 31]

As a result of biofuels supply, an oil supply disruption will have a lesser impact. Supply of biofuels reduces use of petroleum-based fuel and ensures that any disruption affects fewer consumers, all customers to a lesser extent or, if limited oil is efficiently rationed, ensures the effects are limited to those customers that value oil the least.[32]

It should be noted that supply disruptions also can affect biofuels, or their feedstocks. However, the security of oil supply benefits would only be reduced if supply disruptions were simultaneous, ie if supplies of biofuels or their feedstocks were disrupted at the same time as those of biofuels. This is possible, especially because biofuels are substitutes for oil products; if there is a disruption in supply of oil, biofuels destined for New Zealand might (depending on contractual arrangements), be diverted elsewhere.

A cost benefit analysis of oil security and the benefits of storage concluded that the optimal level of storage for New Zealand to reduce the risks of supply disruption was less than the level of storage required of New Zealand by the IEA. [33] However, this analysis could not take account of all of the costs of supply disruptions, including general equilibrium effects in the economy. The government is currently ensuring that oil storage in New Zealand is raised to the level required by the IEA. What this means is that the *measurable* benefits of biofuels supply on security of oil supply are less than or equal to[34] the benefits measured as a reduction in the costs of oil storage to meet the IEA requirement. We thus use the benefits measured as reductions in oil storage requirement as a measure of oil security benefit.

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[29] Hale & Twomey (2004) International Energy Agency Inventory Targets and New Zealand Oil Market Supply Security. A Report to the Ministry of Economic Development

[30] Covec and Hale & Twomey (2005) Oil Security. Prepared for the Ministry of Economic Development.

[31] Covec and Hale & Twomey (2005) Oil Demand Restraint Options for New Zealand. Prepared for the Ministry of Economic Development.

[32] The most obvious simple rationing system is pricing. These issues are explored in more detail in: Covec and Hale & Twomey (2005) Oil Security. Prepared for the Ministry of Economic Development

[33] Covec and Hale & Twomey (2005) Oil Security. Prepared for the Ministry of Economic Development.

[34] The government has estimated that the quantity of the costs missing from the analysis were sufficient to justify storage at the levels required by the IEA

If less oil is stored because of the reduced IEA obligation, the security of supply benefits are somewhat reduced from biofuels. The net benefits can be described as:

- If there is no supply disruption, there are benefits from a reduced requirement for oil storage;
- If a supply disruption occurs, and because oil storage does not mitigate all risks, there are additional benefits from having biofuel supplies, although these are offset somewhat by the reduced storage of oil.

Below we explore the benefits associated with the IEA storage reduction, before returning to the net benefits.

IEA Obligation

As an IEA member, New Zealand benefits from the IEA's emergency management procedures that would be instigated for an external event. For its part, the IEA requires New Zealand, and other members, to hold 90 days oil in storage. This obligation is reduced if New Zealand either produces biofuels domestically or imports them.

The government has recently invited tenders for the provision of oil storage to meet the national oil storage obligation to the IEA, and to reduce the risks to the nation of a disruption. The development and use of biofuels reduces the requirement for storage under the IEA's rules, and would improve New Zealand's security to the extent that supply risks for biofuel feedstocks were lower than risks of oil supply disruption.

The formula that is used to define the oil supply requirement is:[35]

Total Net Import Requirement =
*Net Crude Imports (Imports less Exports less stock build) * 0.96* [36]
*+ Net Product Imports (Imports less Exports less bunkers less stock build) * 1.065* [37]

Daily Net Import = Total Import Requirement/365
*IEA Inventory Target = Daily Net Import *90*

Thus every litre of oil that is displaced by the use of biofuels reduces the requirement for storage by 1/365*90 = 0.25 litres.[38] The cost of additional storage includes the costs of capital for the stock (oil or product) and the depreciation of the tank (the oil or product does not depreciate).[39] The most recent published costs of the stock obligation suggest costs, using this approach, of NZ$111/tonne or about 9.1 c/l.[40] Therefore the saving from producing a litre of biofuel is 0.25 of this, ie about 2.3 c/l. This saving will vary with the

[35] Covec and Hale & Twomey (2005) Oil Security. Prepared for the Ministry of Economic Development.
[36] The factor is included to represent typical yields
[37] The factor is included to represent typical yields
[38] This applies both to imported biofuels and that manufactured in New Zealand.
[39] And we assume that oil does not appreciate in value either
[40] Hale & Twomey (2005) Analysis of Feedback on tendering Process for Additional Stock to meet New Zealand's IEA Obligation. A Report to the Ministry of Economic Development

cost of crude oil and with decisions made on the holding of stock to meet oil security and IEA obligations.

Net Security Benefits

As noted above, if there is a supply interruption there will be biofuel available but less oil will be stored because of the reduced obligation. For every 1 litre of biofuel available, 0.25litres less oil (or product) will be stored. The net impacts are complicated by the fact that biofuel is not a complete substitute for conventional fuel; it needs to be mixed. If there was a complete supply disruption, few vehicles would be able to run on 100% biofuel. The net impact depends on the maximum potential mix.

If there is a low limit to how much biofuel can be mixed with other fuels, the fact that more biofuel is available in a supply crisis may make little difference—the maximum mix sets the limit on fuel availability, or in simple terms we are limited by the fuel available with which to mix the biofuel. If there is a potential for significant mixes of fuel then the total quantity of fuel available is the binding limit and we are better off is more biofuel is available.

Figure 7 illustrates using hypothetical data. If we assume that 5% of current fuel use is biofuel but then add 1 more litre of supply, the quantity of conventional fuels used falls by 1 litre[41] (we assume that the percentage of biofuel use goes up to just above 5%) and the quantity of oil stored falls by 0.25litres. If there is a supply failure, the fuel available is the smaller of the sum of conventional fuel in storage and biofuel supplies, or conventional fuel in storage plus the maximum biofuel mix. Figure 7 illustrates that, at low maximum potential biofuel mixes, the biofuel mix sets the limit on how much is used and an extra litre of biofuel supply has a disbenefit because it reduces the amount of conventional fuel stored. Above a maximum mix of approximately 16.7% the total fuel available becomes the binding constraint and having additional biofuels supplies is a benefit equal to 1 litre of biofuel less 0.25 litres of conventional fuel (0.75 litres).

Figure 7 is estimated on the basis of a complete supply failure. If there is a limited supply failure, then the maximum percentage mix becomes less important, ie we would not have sufficient biofuel to increase the mix to 10% if we wanted to; total fuel availability is the constraint and there are benefits from additional biofuels supplies. That said, the supply failure, if it occurred would have only a small impact.

If we examine the benefits of additional fuel available in a supply crisis (or the costs of reduced availability), the oil security cost benefit analysis[42] suggests that, at the margin, there is little to no benefit of additional storage and thus of additional fuel available. This is largely because the events for which there is a quantifiable probability of occurrence can be managed with the amount of fuel that will be stored to meet IEA requirements.

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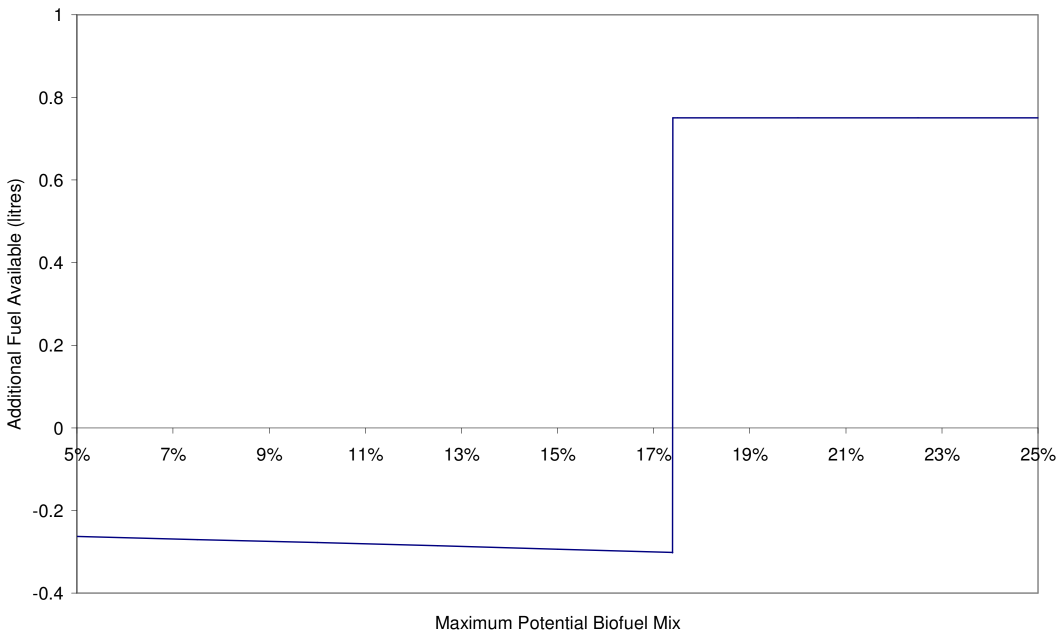
[41] or slightly less, taking account of differences in energy content

[42] Covec and Hale & Twomey (2005) Oil Security. Prepared for the Ministry of Economic Development.

Figure 7 Additional fuel Available from 1 litre of Additional Supply of Biofuel



The analysis here suggests that the cost reductions associated with the reduced IEA requirement are the only benefits that need to be quantified. The fact that biofuel supplies may be disrupted does not affect this measure of benefits.

2.4.2. Environmental Benefits

The environmental benefits of biofuels result from the reductions in emissions. We are unaware of New Zealand-specific studies so make use of international studies. The full effects are not clear; this reflects the absence of data and the fact that the full life cycle differences vary, depending on feedstocks and the methods and fuels used in production of biofuels. In use, biofuels have a significant impact on greenhouse gas emissions; specifically, CO_2 emissions from biofuels are treated as zero for the purposes of estimating national inventories under the UNFCCC[43] because the CO_2 emissions result from recently absorbed CO_2—"carbon in" equals "carbon out" over a short time frame, such that both can be ignored. However, the same principle does not apply to CO_2 emitted during the process of biofuel manufacture.

The recent Australian Task Force report[44] summarises recent estimates of emissions, building on the 350 million litres study[45] that, in turn, is based substantially on a study by CSIRO.[46] We use the results of the CSIRO comparison of fuels, but note the recent

[43] United Nations Framework Convention on Climate Change

[44] Australian Government Biofuels Taskforce (2005) Report of the Biofuels Taskforce to the Prime Minister. Available at: www.dpmc.gov.au/biofuels/final_report.cfm

[45] CSIRO, ABARE and BTRE (2003) Appropriateness of 350 Million Litre Biofuels Target. Report to the Australian Government Department of Industry Tourism and Resources.

[46] Beer T, Grant T, Morgan G, Lapszewicz J, Anyon P, Edwards J, Nelson P, Watson H and & Williams D Comparison of Transport Fuels Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles. Available at: www.greenhouse.gov.au/transport/comparison/index.html

estimates by the Task Force that suggest the impacts on particulate matter may be different from that estimated by CSIRO and the 350ML report. Specifically, the Taskforce notes a possible 40% reduction in tailpipe emissions from the use of ethanol (as E10).

PM_{10} emissions occur both in upstream processing (and transportation of fuels) plus as tailpipe emissions. It may be that tailpipe emissions are most important because of the greater proximity to people affected. In addition, the US EPA notes a 49% reduction associated with animal derived biodiesel and 33% for vegetable based product.[47] These are considerably greater than the estimates in the CSIRO study.

The effects on PM are thus highly uncertain, and we use sensitivity analysis below to examine the impacts.

The estimates of emission are shown in Table 9 on the basis of the CSIRO study. The table shows emissions from low sulphur diesel and unleaded petrol alongside the biofuel alternatives—tallow-based biodiesel and ethanol. For the biofuels Table 9 includes the emissions per MJ as a percentage of the emissions from conventional fuels.

In presenting these data, we note that this is not a comprehensive estimate of impacts. The Australian Taskforce report notes that "studies that have tested the vehicle combustion of biofuels generally restrict tailpipe emission measurement to the pollutants carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx). Reliable data, in particular, for GHG emissions, particulate matter (PM) and air toxics is generally unavailable". [48]

Table 9 Life Cycle Emissions from Fuels (plus biofuel emissions as percentage of petroleum-based fuel emissions)

Emission	Low Sulphur Diesel (50ppm)	Tallow-based biodiesel	Unleaded Petrol	Ethanol (wood waste)
CO_2	0.074kg/MJ	0.04kg/MJ (54%)	0.071kg/MJ	0.008kg/MJ (11%)
PM_{10}	32mg/MJ	30mg/MJ (94%)	38mg/MJ	51mg/MJ (134%)
NOx	0.9mg/MJ	1.3mg/MJ (144%)	0.2mg/MJ	0.8mg/MJ (400%)
HC	0.13g/MJ	0.14g/MJ (108%)	0.17g/MJ	0.59g/MJ (347%)

Source: CO_2 emissions from low sulphur diesel and unleaded petrol: Table 10 adjusted to include consumption of 6.7% of fuel in production. All other emission rates from: Beer T, Grant T, Morgan G, Lapszewicz J, Anyon P, Edwards J, Nelson P, Watson H and & Williams D Comparison of Transport Fuels Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles. Available at: www.greenhouse.gov.au/transport/comparison/index.html.
Percentage differences = Covec estimates (biofuel emissions as percentage of petroleum-based fuel)

[47] US EPA (2002) cited in Duncan J (2002). Blending ethanol into petrol an overview. Energy Efficiency and Conservation Authority.

[48] Australian Government Biofuels Taskforce (2005) Report of the Biofuels Taskforce to the Prime Minister. Available at: www.dpmc.gov.au/biofuels/final_report.cfm

The 350 ML report estimates that the impacts of ethanol use included a significant increase in mean aldehyde exhaust emissions including formaldehyde and acetaldehyde, and a seemingly uniform reduction in the aromatics: benzene, toluene and xylene.

However, despite noting these, we are unable in this analysis to include these effects in the overall cost benefit assessment, because of the absence of associated damage cost estimates. Levels of aromatics in New Zealand fuels are already very low so the benefits from ethanol mixes are not significant.

SO_2 is included as an environmental benefit in some studies, but the evidence on whether there is a net reduction is unclear. We discuss SO_2 below, although the effects in cost terms are so minimal that they can effectively be ignored.

Below we also examine the damage cost estimates for CO_2, PM and NOx.

CO_2

There are two main ways of estimating the costs of greenhouse gas emissions in monetary terms. One is to estimate the future expected price of emitting carbon, either in the form of an expected tax level in New Zealand or the expected price of international permits; the other is to estimate damage costs.

Policy Costs

The New Zealand government had announced the introduction of a carbon tax from April 2007.[49] It would have been set at a level of $15/tonne of CO_2 equivalent and retained at that level until 2012 (unless the price diverged significantly and on a sustained basis from the international price). Subsequently it decided not to continue with this broad tax, but has retained the option to introduce a tax on a narrower group of industries, including electricity generators.[50] Previously this might have provided a suitable benchmark estimate of the cost to New Zealand of CO_2 emissions.

Under the Kyoto Protocol, if New Zealand expects to fail to meet its target, it can purchase emission rights from other countries that allow it to increase its emissions.[51] Similarly, if New Zealand expects to emit less than the target it can sell surplus emission allowances. Because of this market in emission allowances, every emission has a cost to the nation—either because of the requirement to purchase one more allowance or because of the lost opportunity to sell an allowance. The expected international price of emission allowances is thus an estimate of the cost to New Zealand of emitting greenhouse gases.

[49] Implementing the Carbon Tax. A government consultation paper. May 2005. Policy Advice Division, Inland Revenue Department.

[50] Cabinet Minute CBC Min (05) 20/10: Climate Change: Review of Policy and Next Steps. (www.climatechange.govt.nz/resources/cabinet/cbc-min-05-20-10.html)

[51] government to government or entity (firm) to entity or some combination

The most significant existing market for emission allowances is the EU emissions trading scheme. In that market, which is providing one early indication of future international prices of allowances, CO_2 allowances are trading at a price of more than €25/t CO_2 [52] (NZ$43/t CO_2) and prices are expected to rise to higher levels during 2006. However, there is also a substantial market in the Kyoto mechanisms outside of the EU and specifically credits from the clean development mechanism (CDM) and joint implementation (JI).[53] These have been selling at prices significantly below the EU trading price and below NZ$15/tonne,[54] and current estimates suggest that aggregate potential supply is considerably greater than expected demand.[55]

Damage Costs
It would be rational for countries to set targets on the basis of some understanding of the costs of control and of damage costs. For this reason, an assessment of damage costs may be a useful way to estimate future expected prices of carbon emissions. This assumes that the global community, via the UN Framework Convention on Climate Change, would examine the costs and benefits of emission reductions and establish targets (or other means of influencing domestic policy) in such a way that the international price effect of emitting greenhouse gases approached the damage cost estimates.

Estimates have been made of the damage costs of greenhouse gases (Appendix A) with the most comprehensive assessment suggesting a cost of less than NZ$23/t CO_2.

The proposed New Zealand tax rate ($15/t CO_2) appears to be a reasonable estimate both of possible policy costs and of damage costs. And, the government, when outlining the details of the carbon tax, set a maximum price of $25/tonne of CO_2, which is also the estimated maximum likely damage cost. We have used this as our maximum in this work.

For analysis we use two price scenarios, a low price of NZ$15/t CO_2 and a high price of $25/t. The results are shown in Table 10. It uses emission factors and energy values of regular petrol and diesel. A displacement factor is applied; this is the litres of petroleum-based fuel that would be equivalent to a litre of biofuel on a useful energy basis, ie taking into account the difference in energy value and oxygen enhancement. The savings presented are per litre of biofuel and include kg CO_2 per litre and the resulting monetary benefit in cents per litre at two carbon prices.

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52 http://www.europeanclimateexchange.com
53 The CDM is currently the largest volume market (Point Carbon (2006) Carbon 2006. Towards a truly global market)
54 The average price for 2005 was approximately €6.50/tonne (NZ$11.50/tonne). Source: Point Carbon (2006) Carbon 2006. Towards a truly global market
55 Point Carbon (2006) Carbon 2006. Towards a truly global market. Available at: www.pointcarbon.com

Table 10 CO_2 Savings from Life Cycle Emissions

	kt CO_2/PJ[1]	MJ/l[2]	Kg CO_2/l	Displacement litre:litre	Reduction[4]	Saving kg/l	c/l @ $15/t	c/l @ $25/t
Regular Petrol	66.20	34.86	2.31	0.8	89%	1.64	2.5	4.1
Diesel	69.50	37.86[3]	2.63	0.912	46%	1.11	1.7	2.8

[1] Source: Ministry for the Environment (2005) New Zealand's Greenhouse Gas Inventory 1990-2003 (Table A2.1); [2] Source: MED (2006) Energy Data File January 2006; [3] 50ppm Sulphur Diesel; [4] Table 9 (ie 100%-11% and 100%-54%)

Particulates

The costs of particulate emissions are estimated in Annex B. The range of cost estimates is $2,383-$15,622/tonne. These values are considerably lower than other estimates used in analysis in New Zealand because they reflect an estimate of marginal costs, ie the costs of changes in emissions. We use a value towards the lower end of this range reflecting an assessment that these might still over-estimate costs. The resulting estimates of benefits of PM_{10} reductions, in costs per litre, are presented in Table 11 using the same approach as discussed above for CO_2.

Table 11 PM_{10} Savings

	g PM/km	l/100 k	g PM/l	Displacement	Reduction	Saving g/l	$/t PM10	c/litre
Regular Petrol	0.05	9	0.56	0.8	40%	0.18	5000	0.09
Diesel	0.02	10	0.20	0.912	40%	0.07	5000	0.04

The benefits are inconsequential.

2.4.3. SO_2

Sulphur oxides including SO_2 and, to a lesser extent, SO_3 are formed when sulphur-containing fuel is combusted in oxygen. Biofuels do not contain sulphur.

Emission rates for petrol and diesel are estimated from the sulphur content of the fuel. We assume the following current concentrations:

- **Petrol**—fuel specification is 150ppm (0.015%) but in practice it is much less than this and closer to 75ppm (0.0075%);
- **Diesel**—50ppm (0.005%).

SO_2 can have direct health effects on breathing, respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease[56], however it is not clear that this effect is measurable. In addition SO_2 has secondary effects as it combines with other molecules to form sulphate aerosols (a small particulate) and sulphuric acid (acid rain).

[56] http://www.enviropedia.org.uk/Acid_Rain/Sulphur_Dioxide.php

The Ministry for the Environment[57] notes that there have been no exceedances of guidelines or the proposed national standard for SO_2 concentrations. It suggests that concentration levels are not of concern and implies that there are thresholds for effects, ie there are no levels below which there is no appreciable damage. However, much of the epidemiological literature, and the approach adopted in other countries, has not supported the existence of thresholds.[58]

There has been no primary research into the costs of SO_2 emissions in New Zealand. Analysis of the direct health impacts, both here and internationally, have noted the difficulties in separating out the effects of SO_2 from those of other pollutants, particularly noting the close relationship between emissions of SO_2 and particulates. The European ExternE study initially concluded that the evidence for SO_2 damaging health was too weak for this effect to be included in the analysis of costs; specifically there was no evidence of causality because of the strong relationship between SO_2 emissions and that of other pollutants. More recent outputs suggested that there was evidence of a direct effect.[59] However, the latest studies are ignoring these effects because of the lack of clear evidence of causality[60]. We have not included them in this analysis.

There is no evidence of acidification effects in New Zealand and we ignore these effects.

There has been little work to analyse the component parts of particulate concentrations in New Zealand and of the contribution from SO_2. The limited work that has been undertaken[61] notes the presence of sulphates; citing this work, Fisher and King[62] suggest that the fraction of particulates due to sulphates might be 10-30% of the total, depending on the atmospheric conditions.

The European work under ExternE and the more recent work for CAFE quantifies the sulphate aerosol effects and some of the acidification impacts. More recently, questions are being asked about the extent of the sulphate impact. As AEA Technology notes[63]:

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[57] Ministry for the Environment (2004) Proposed National Environmental Standards for Air Quality. Resource Management Act Section 32 Analysis of the costs and benefits.

[58] AEA Technology Environment (2005). Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment.

[59] European Commission (1998) ExternE Externalities of Energy Methodology 1998 Update

[60] Paul Watkiss, AEA Technology, personal communication

[61] Fisher GW, Thompson A and Kuschel GI (1998) An Overview of the Elemental Analysis of Ambient Particulates in New Zealand. NIWA Report AK98029 (www.smf.govt.nz/results/5006_ak98029.pdf)

[62] Fisher GW and King D (2002) Cleaning Our Air: Implications for Air Quality from Reductions in the Sulphur Content of Diesel Fuel. NIWA Report AK02007.

[63] AEA Technology Environment (2005) Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. p 14

Evidence is coalescing that, with fine particles from combustion sources, toxicity resides especially in the primary particles, as opposed to the secondary particles (sulphates, nitrates)…. In general, toxicologists are more sceptical than epidemiologists about the adverse effects of secondary particles. This reflects differences in toxicological evidence.

- *There is substantial epidemiological evidence of associations between health and sulphates. In these studies sulphates may of course be a marker for other aspects of the mixture, rather than a direct causal agent. They do suggest however that if sulphates are reduced, as part of the reduction of a mixture, then there will be real benefits to health.*
- *There are many fewer epidemiological studies showing relationships between nitrates and health. This may be due at least in part to difficulties in measuring nitrates.*

However, this has not, to date, led to changes to the quantification of sulphate impacts, ie they are measured as though they were fine particles.

In this report we measure the impacts of SO_2 via its effect as a small particulate. The detailed analysis is provided in Annex B. The work has considerable uncertainties and Annex B raises fundamental questions about approaches currently used to value the damage costs of emissions, including those used in the recent cost benefit analysis of the national air quality standards. [64] The estimated costs for SO_2 range from $794-5,113/t.

Table 12 Savings of SO_2 from Petrol and Diesel

	ppm	Kg/litre	g SO2/litre	$/t SO2	c/litre
Diesel	50	0.843	0.084	2954	0.025
Petrol	75	0.747	0.112	2954	0.033

As for PM, they are inconsequential.

2.4.4. NOx

Nitrogen oxides is a collective term used to refer to two species of oxides of nitrogen: nitric oxide (NO) and nitrogen dioxide (NO_2). They are formed during fuel combustion. At high concentrations, NO_2 can be highly toxic causing direct health effects. Nitrogen dioxide reacts in the atmosphere to form nitric acid and nitrate aerosols.

Impacts in terms of quantified benefits for NOx savings are even smaller than for PM_{10} and are ignored in analysis.

2.5. Net Costs and Benefits

In this section the costs and benefits estimates are brought together to estimate net benefits to New Zealand of biofuels supply. The approach is as follows:

- costs of supply are estimated using a social rate of discount for capital costs;

[64] Ministry for the Environment (2004) Proposed National Environmental Standards for Air Quality. Resource Management Act Section 32 Analysis of the costs and benefits.

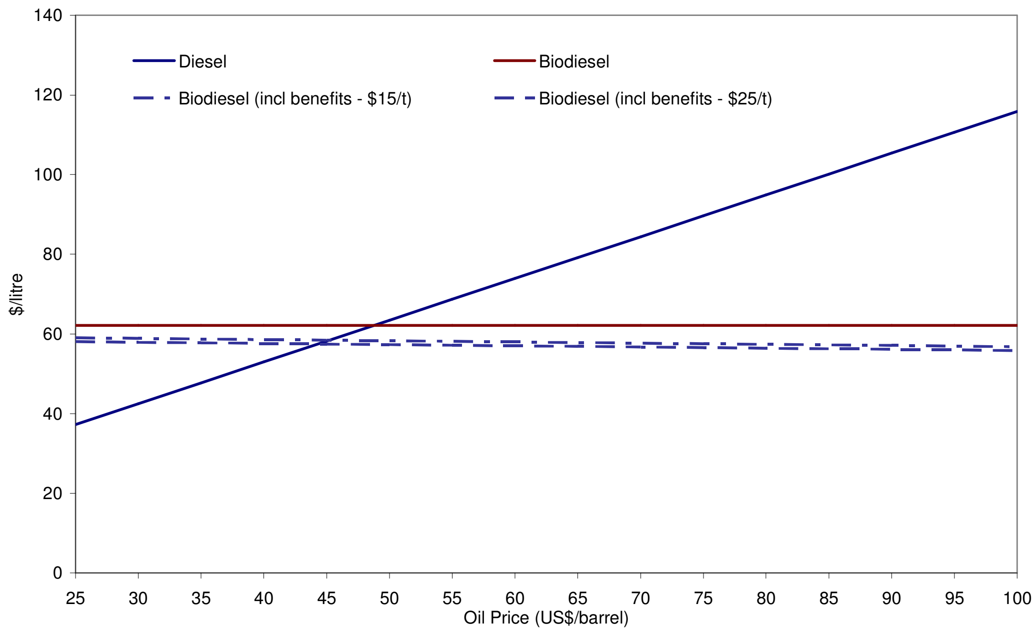
- all taxes are removed from the assessment;
- benefits from security of supply and emissions reduction are added.

As noted above, the analysis has not included costs related to vehicle risks from the use of biofuel blends, based on the assumption that biofuels are used in low concentration blends with no risks to vehicle operation, or higher concentration blends are used but targeted at vehicles that can use such blends.

2.5.1. Biodiesel

The results for biodiesel are shown in Figure 8 at a 10% discount rate. It suggests that the oil price, above which biodiesel has net benefits for New Zealand, is US$45/barrel at a CO_2 price of $15/t or US$44/barrel at a CO_2 price of $25/t. At a 5% discount rate these values fall to US$43/bbl and US$42/bbl respectively.

Figure 8 Net Costs and Benefits - Biodiesel



The values used in calculations are shown in Table 13 at a 10% discount rate and an exchange rate of 0.6.

Table 13 Social Costs of Supply (c/litre)

Oil price (US$/barrel)	Diesel (c/l)	Biodiesel (c/l equiv)[1]	Security	Environment (@ $15/t)	Total (@ $15/t)	Total (@$25/t)
40	53.0	62.16	2.0	1.7	58.4	57.3
50	63.5	62.16	2.3	1.7	58.1	57.0
60	73.9	62.16	2.6	1.7	57.8	56.7
70	84.4	62.16	2.9	1.7	57.5	56.4

[1] This is a measure of the price of supplying sufficient biodiesel to displace a litre of conventional diesel

The biodiesel supply prices above are adjusted to take account of the reduced energy value. Thus they are priced in cents per litre of conventional diesel equivalent. The actual costs of supply is less than this amount by a factor of 0.912.

These estimates are sensitive to a number of additional input assumptions, including most importantly, the price of tallow. At 62c/l, the cost of tallow is 70% of the biodiesel production cost. The impacts of varying tallow price are shown in Table 14, including the base case assumption of $516/t.

Table 14 Impacts of Tallow Price on Biodiesel Production Costs

	Biodiesel price	Oil @ US$40/bbl		Oil @ US$60/bbl	
Tallow Price	(c/l equiv)	Total (@ $15/t)	Total (@$25/t)	Total (@ $15/t)	Total (@$25/t)
400	51.03	47.3	46.2	46.7	45.6
500	60.63	56.9	55.8	56.3	55.2
516	62.16	58.4	57.3	57.8	56.7
600	70.22	66.5	65.4	65.9	64.8
700	79.82	76.1	75.0	75.5	74.4

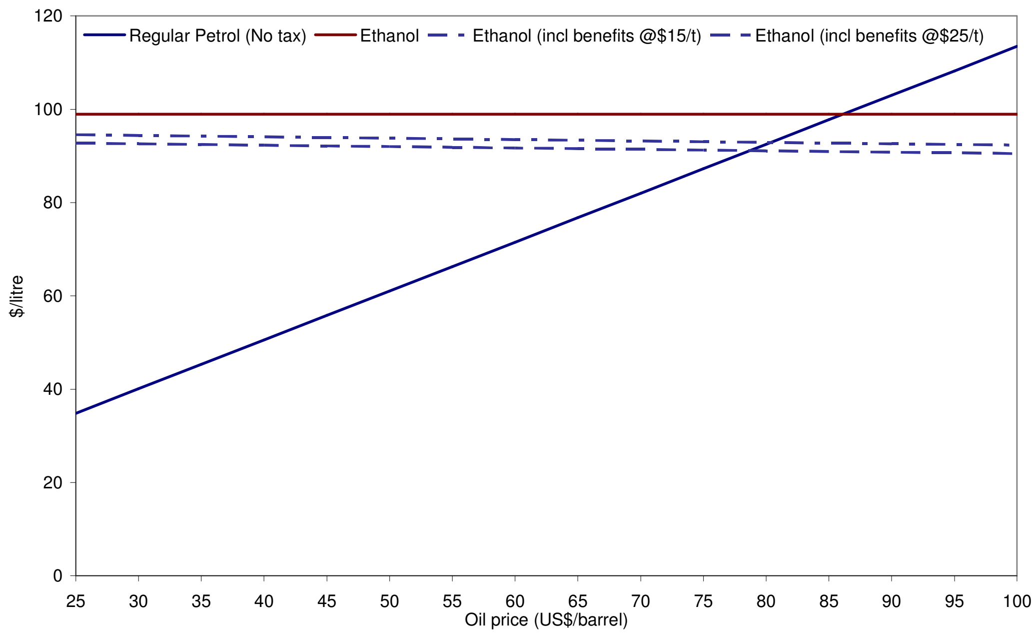
The $400-700 range is based on the spread of prices in the market in recent years, although as noted above, weighted average prices are significantly lower. It is possible that prices may rise to high levels if there is an increase in global demand for tallow because of biodiesel demand.

For biodiesel supply using palm oil, the cut-off level at which the social costs of supply of biodiesel equals the supply cost of conventional diesel is much higher: an oil price of US$100/bbl using a value of CO_2 reduction of $15/t.

2.5.2. Ethanol

The net social costs of supply of ethanol in comparison with regular petrol are shown in Figure 9. It suggests that the oil price, above which ethanol has net benefits for New Zealand, is US$80/barrel at a CO_2 price of $15/t or US$79/barrel at a CO_2 price of $25/t. At a 5% discount rate these values fall to US$78/bbl and US$77/bbl respectively.

Figure 9 Net Costs and Benefits - Ethanol



The values used in calculations are shown in Table 13 at a 10% discount rate and an exchange rate of 0.6.

Table 15 Social Costs of Supply (c/litre)

Oil price (US$/barrel)	Regular Petrol (c/l)	Ethanol (c/l equiv)[1]	Security	Environment (@ $15/t)	Total (@ $15/t)	Total (@$25/t)
40	50.6	96.9	2.0	2.8	92.1	90.2
50	61.0	96.9	2.3	2.8	91.8	89.9
60	71.5	96.9	2.6	2.8	91.5	89.7
70	82.0	96.9	2.9	2.8	91.2	89.4

[1] This is a measure of the price of supplying sufficient ethanol to displace a litre of regular petrol

Feedstock costs are a significant proportion of total costs: 30% at cost of 96.9c/l. The impacts of varying the feedstock costs for production from wood are given in Table 16. These are based on the possibility of feedstocks rising with the price of gas as a fuel substitute in heat plant for timber processing. Currently industrial gas prices are close to $7/GJ,[65] but are expected to rise in the future trending towards a price set by the costs of alternative supplies in the form of imported liquefied natural gas (LNG). Recent estimates suggest that LNG imports to New Zealand would cost in the order of $8-9/GJ, with an additional distribution cost to industrial sites (c$1/GJ).[66] This has been used as the basis for alternative feedstock costs of up to $10/GJ.

Table 16 Impact of Feedstock Costs on Ethanol Production Costs

Feedstock (Wood) price		Ethanol	Oil @ US$40/bbl		Oil @ US$60/bbl	
($/GJ)	$/t[1]	(c/l equiv)[2]	Total (@ $15/t)	Total (@$25/t)	Total (@ $15/t)	Total (@$25/t)
6.6	44	96.9	92.1	90.2	91.5	89.7
8	53	100.8	95.9	94.1	95.3	93.5
10	67	106.3	101.5	99.7	100.9	99.1

[1] Based on 6.7GJ/t (Source: Carter Holt Harvey); [2] This is a measure of the price of supplying sufficient ethanol to displace a litre of regular petrol

2.6. Distribution of Impacts

Introducing ethanol will result in a distribution of the costs and benefits of policy. The security of supply and environmental benefits will accrue to society as a whole, whereas the additional costs of production (if any) will be borne by the oil industry (depending on the approach taken to policy), albeit passed on to consumers. The effects are shown in Table 17 for biodiesel.

For the data shown, there are net benefits to the oil industry if the oil price is $50/bbl or above as there are reductions in the costs of production. In practice, given the competitiveness of the oil industry, it would be expected that these cost savings would be passed on to consumers in the form of reduced prices.

[65] From a wholesale price of approximately $6/GJ

[66] CAE (2005) Energy Supply in the Post-Maui Era. An Investigation into Thermal Fuel Options and their Contribution to Energy Security. CAE Comments 04.

Table 17 Distribution of Costs and Benefits (cents/litre)

Oil price (US$/barrel)	Diesel	Biodiesel	Oil industry	Society	Total
40	53.0	62.2	-9.2	3.6	-5.6
50	63.5	62.2	1.3	3.9	5.2
60	73.9	62.2	11.8	4.2	15.9
70	84.4	62.2	22.3	4.5	26.7

2.7. Uncertainty

The analysis of costs and benefits above has been based on best available information. However, we are aware that technology is progressing rapidly in biofuels production and also that some firms in New Zealand are experimenting with technologies that may reduce costs substantially, particularly for ethanol production. This has implications for policy as explored in Section 4 below. Specifically, it suggests that any targets used either as a policy objective or as part of the policy instrument, eg as a mandatory sales target, should take account of the possibility that low cost supplies might be available. Flexibility in policy should be used to encourage all possible options.

2.8. Implications for Targets

The analysis suggests that, depending on the future direction of oil prices, that there might be net national benefits of biodiesel supply using tallow but that supply of ethanol does not appear to show net national benefits. Viability of biodiesel production is also sensitive to tallow prices but these are likely to be more stable than oil prices. It is possible that we have over-estimated the costs of ethanol production and we note above that there are new technologies being introduced and trialled in New Zealand that might result in significant reductions in production costs.

The quantities of tallow-based biodiesel available are approximately 130,000 tonnes per annum or close to 150 million litres. This is approximately 5.2 PJ.

However, the limits to supply noted in Table 1 on page 2 are likely to be important in setting targets for policy.

3. Other Issues

3.1. Demand Side Issues

Demand side issues of concern are whether consumers, or the motor industry, will have confidence in the technical and quality standards, because of the potential impacts on engine performance and reliability.

The vehicle impacts discussed in Section 2.3.3 are a major factor in motorists' attitudes to, and acceptance of biofuels. A recent Australian study[67] found that only 25% of Australian motorists were happy to buy ethanol blended petrol, mostly citing the potential engine damage as a reason. The Australian Taskforce report[68] notes concerns with E10 for older vehicles (pre 1986); it reported that 56% of people were not happy or have reservations about buying ethanol fuels (in 2005; down from 63% in 2003). There is far less concern with use of biodiesel although the taskforce noted that this could change easily. The level of concern over ethanol blends in Australia is believed to be related to early experience with high concentration blends (20-30%) and widely published allegations of vehicle damage;[69] there have also been suggestions that there was publicity about vehicles damaged by ethanol that was actually attributable to a single vehicle damaged by fuel contaminated with kerosene.[70]

Some research has been undertaken in New Zealand to assess awareness of biofuels and attitudes towards them.[71] This was after the negative publicity in Australia. Amongst those that had heard of biofuels,[72] only 5% were opposed to its introduction, with 31% unsure and 64% supportive. Provision of additional information led to an increase in those opposed (to 7%) and of those supportive (to 82%); the number of people unsure fell.

Despite these results, consumer confidence will be an issue in New Zealand if the government makes moves to encourage or require the use of biofuels, particularly given the number of older vehicles in the New Zealand market (Figure 10); by 2007 approximately 8% of the fleet would be estimated to be pre-1986. Information from a wide variety of different sources is likely to be presented in the media, with a variety of messages. The positive aspects of biofuels, ie their environmental effects, will be an important aspect of any encouragement of uptake.

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[67] ANOP (2005). Australian Automobile Association: Motorists' Attitudes. 2005 ANOP National Survey. ANOP Research Services. (http://www.aaa.asn.au/documents/opinion%2F2005%2FANOP_exec_05.pdf)

[68] Australian Government Biofuels Taskforce (2005) Report of the Biofuels Taskforce to the Prime Minister. Available at: www.dpmc.gov.au/biofuels/final_report.cfm

[69] [69] Australian Government Biofuels Taskforce (op cit)

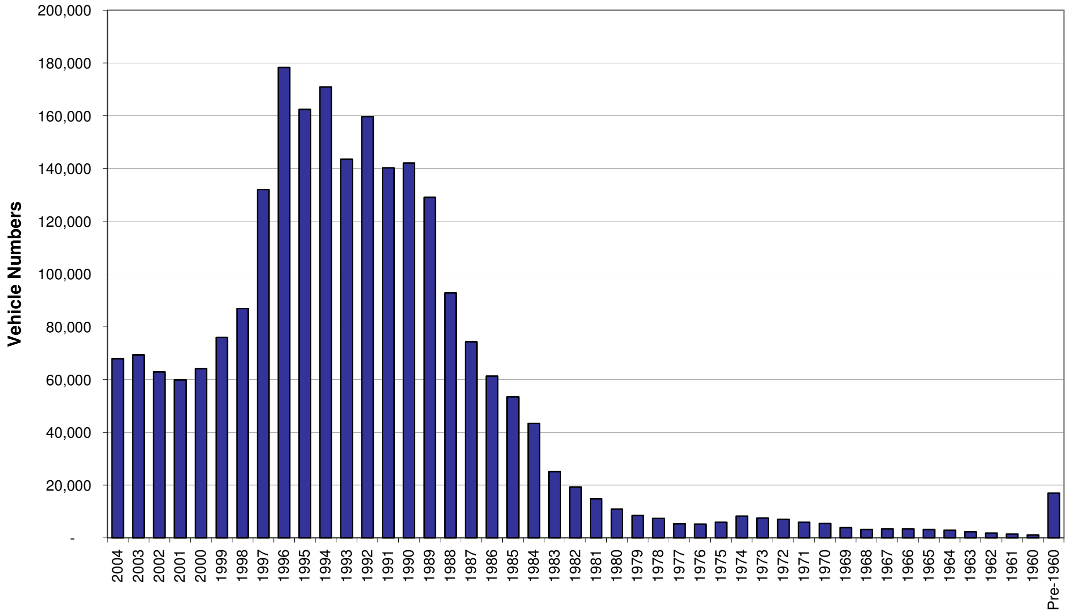
[70] Sheehan P (2003) Ethanol fuel line has motorists labouring under misapprehension. www.smh.com.au/articles/2003/04/27/1051381850427.html

[71] UMR Research (2005) Biofuels Research. A Qualitative and Quantitative Study. EECA.

[72] In the 2005 study, 39% had heard of biofuels; although a higher number (50%) had heard of ethanol as a fuel.

The early experience with high-concentration ethanol blends in Australia also suggests that there is value in starting with low-concentration blends in New Zealand to build consumer confidence.

Figure 10 Year of Manufacture of Petrol Cars in New Zealand (1 January 2005)



Source: Data from Land Transport New Zealand

3.2. Taxation and Fiscal Impact

The government's annual fuel excise income is around $953M from cars, and $105M from trucks.[73] A further $20M comes from buses, motorcycles and other sources. In addition to this, Road User Charges (RUCs) contribute $583.7M to government revenue. This income contributes to the government's funding of a range services in the country, including: road construction, maintenance and depreciation; administration of national and local transport authorities; research; ACC funding; and police, fire, and ambulance funding.

Table 18 explores the impacts for three different biofuel concentrations. It shows the lost revenues from not taxing biofuels and the rates that would have to apply to the conventional fuels to produce the same level of revenue. Alternatively, if biofuels were to be taxed, lower rates could apply to them because there would be greater consumption in litre terms. The final column in the table shows the tax rate that would need to apply if, following the introduction of biofuels, the tax take required was the same. This represents the necessary tax level on the slightly higher quantity of fuel sold (assuming no demand response) to retain the same level of revenues.

[73] "Surface Transport Costs and Charges" A report prepared by Booz Allen Hamilton for the Ministry of Transport, 2005

Table 18 Impacts on Tax Take

	Diesel/Bio-diesel			Petrol/Ethanol		
Consumption (Ml)		1950[1]			3400	
Current tax rate (c/l)		0.355			47.665	
Biofuel mix	3%	5%	10%	3%	5%	10%
Lost revenue if no biofuel tax ($M)[2]	0.2	0.3	0.7	49	81	162
New tax rates on petroleum-based fuels only (c/l)	0.394	0.394	0.394	52.961	52.961	52.961
Biofuel tax rate (c/l)	0.324	0.324	0.324	38.132	38.132	38.132
All fuel tax rate (c/l)	0.354	0.353	0.352	47.310	47.077	46.502

[1] Road use only; [2] Excludes GST

3.3. Trade Issues

3.3.1. TTMRA

Under the Trans-Tasman Mutual Recognition Act (TTMRA), if products can legally be sold in Australia, they can be sold in New Zealand (and vice versa), regardless of any differences in standards. This means, in practice, that for any specific product or issue, the lowest standard can apply.

This does not apply to fuels produced in New Zealand, ie if biofuel was manufactured in New Zealand it would need to be manufactured to New Zealand standards. However, the TTMRA rules would apply to any imported product, eg if Gull Petroleum, that currently imports product to New Zealand, was to import Australian biofuels.

Current Australian standards and regulations that apply to biofuels are:

- a 10% ethanol limit which came into force on 1 July 2003 as an amendment to the fuel quality standard for petrol;
- fuel quality standards for use of ethanol up to the 10% limit;
- standards for biodiesel set out in the Fuel Standard (Biodiesel) Determination 2003 (Annex C).

This issue is unlikely to be significant, but it suggests that there is some value in coordinating standards for biofuel use with Australia. There is a potential for compromise of New Zealand's technical specifications for biofuels.

3.3.2. MARPOL

The International Convention for the Prevention of Pollution from Ships (MARPOL) addresses prevention of pollution of the marine environment from ships, including accidental pollution and that from routine operations. It includes six technical Annexes, amongst which, two are relevant for biofuels:

- Annex I - Regulations for the Prevention of Pollution by Oil
- Annex II - Regulations for the Control of Pollution by Noxious Liquid Substances in bulk

When biofuels are moved as products intended for blending with petroleum/mineral product, they are considered as falling under Annex II. However, when being carried as a mixture, the issue of which Annex is relevant is causing confusion within the chemical, vegetable oils and the shipping industries.[74]

Products cannot be shipped under Annex II under the generic names biofuel or biodiesel. Much of the discussion has been around the movement of biodiesel. Currently there are only three fatty acid methyl esters approved for carriage under Annex II:

- Palm oil fatty acid methyl ester (currently in the IBC Code)
- Coconut oil fatty acid methyl ester (currently in the IBC Code)
- Rapeseed oil fatty acid methyl ester (currently in list 1 of MEPC.2 Circ)

Work on this issue is ongoing internationally and is likely to be clarified to better enable the movement of biofuels. It does not appear to be a significant issue.

3.3.3. International Taxes and Duties

Taxes and duties have been used in a number of countries to provide incentives for biofuels. These can distort the market for biofuels in New Zealand.

In Australia, petrol and diesel are subject to a fuel tax of 38.143c/litre. Biodiesel and ethanol are also taxed at this rate, but there is a production grant that is exactly equal to the fuel tax that applies to domestically produced ethanol and imported and domestically produced biodiesel. From 2011 fuel tax will begin to apply to biofuels and imported and domestically produced ethanol will be treated the same, opening domestic ethanol production to international competition.[75]

Thus currently, the Australian tax system would provide incentives for imports of New Zealand biodiesel.

Other countries have similarly provided incentives in the form of exemptions from duty or grants for production.

In some instances these vary with the source, eg in the US, ethanol and biodiesel production receives a tax credit of $0.51 and $1.00 per gallon, respectively (or $0.50 if biodiesel is made from recycled rather than virgin vegetable oil or animal fat).[76]

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[74] International Maritime Organization (2006) Evaluation of Safety and Pollution Hazards of Chemicals and Preparation of Consequential Amendments. Report of the eleventh session of the Working Group on the Evaluation of Safety and Pollution Hazard of Chemicals – Bio-fuels. Sub-Committee on Bulk Liquids and Gases 10th Session. BLG 10/3/9

[75] Australian Government Biofuels Taskforce (2005) Report of the Biofuels Taskforce to the Prime Minister.

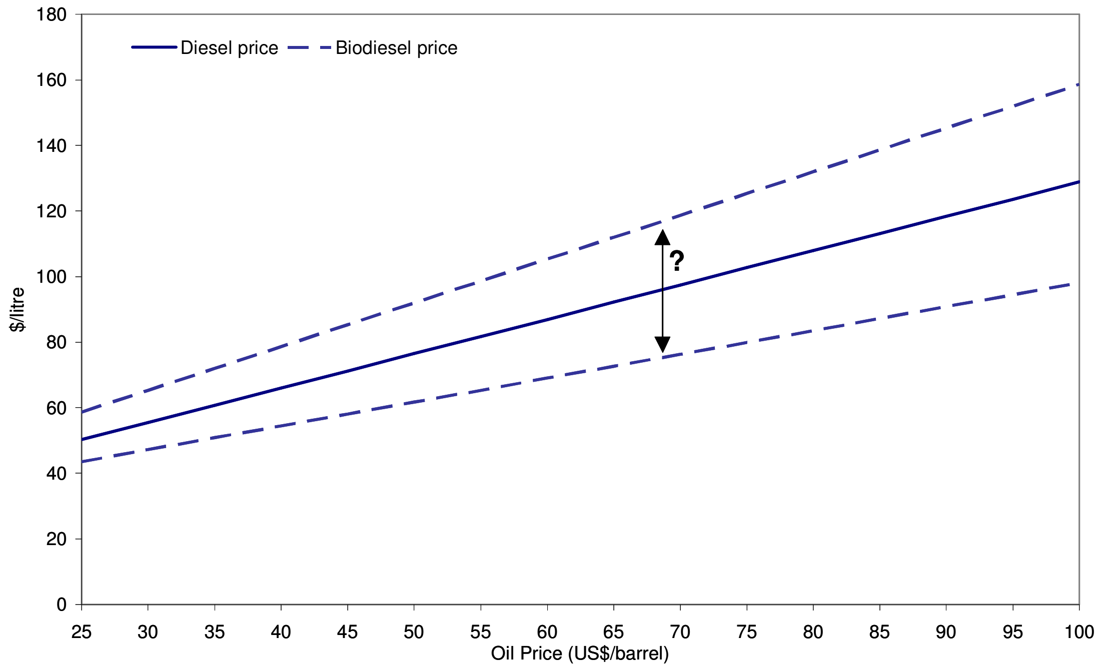
[76] http://www1.eere.energy.gov/biomass/biomass_basics_faqs.html#incentives

One of the potentially significant impacts of these regulations is the effect on markets of feedstocks. For example, as other countries subsidise or otherwise encourage biofuels supply, the demand increases for feedstocks that might be used by New Zealand. This might, for example, affect the costs of tallow supplies.

At this stage, we assume that the distance and transport costs to other markets will be sufficient that production in New Zealand for any given feedstock will be more profitable than exporting it to another country, although this will depend on the level of incentive offered. However, this is part of a more widespread issue, that of arbitrage between the tallow market (and other feedstock markets) and the oil market, because of increasing demand for biofuels.

The issue is illustrated in Figure 11; it shows, under hypothetical assumptions, how the price of biodiesel might be linked to the price of oil and thus varying with the key factor affecting the diesel price. This contrast significantly with the picture presented in Figure 4. New Zealand will be isolated from this effect to some extent because of distance and transport costs, but the future development of price is uncertain, particularly because of the likelihood of increasing policy focus on encouragement of biofuels.

Figure 11 Biodiesel and Diesel Price Relationship



3.4. Investor Issues

The issues that will affect investor willingness to invest in biofuels supply include a number of uncertainties:

- Market uncertainty;
- Regulatory uncertainty; and
- Technological uncertainty.

3.4.1. Market Uncertainty

Investment decisions in biofuels manufacture will be influenced by a number of factors including:

- Economics including incentives available
- Assurance of market demand (eg mandatory targets)
- Scale
- Feedstock supply and costs

Investors are unlikely to make an investment decision until they are confident they have an economic project of suitable scale to make investment worthwhile. Our analysis shows that both ethanol (with tax incentive) and biodiesel (without incentive) are economic under reasonable assumptions of feedstock prices, although exposed to movements in the underlying petroleum fuels prices. And it should be noted that, while oil prices are currently high, industry oil supply development decisions are still done on prices less than US$40/bbl.

An investor will either require an increased incentive (or some incentive in the case of biodiesel) or an assured market in the form of mandatory targets. Therefore investment decisions are unlikely until Government policy (in the form of mandatory targets) is formulated.

Once Government policy is confirmed an investor will then need to secure feedstock supply, progress design, obtain offtake contracts (eg find buyers), arrange finance, obtain resource consents and build and commission the plant. While some of this may be done prior to a Government policy decision it is expected to be two to three years before a plant is producing following the Government policy decision. Therefore if the mandatory targets are set in the 4th quarter 2006 it might be late 2009 before significant volumes are available from domestic manufacture.

In addition for that investment to be of suitable scale (typically at least 50 million litres) the targets in the years following will need to be reasonably significant.

3.4.2. Regulatory Uncertainty

Regulatory uncertainty was noted above as an important element in investment decisions. It is important because of the underlying uncertainties in the market. Regulation can provide investors with certainty that there would be a demand for the product, albeit that it might not provide price certainty. These issues are explored in more detail in Section 4.

3.4.3. Technological Uncertainty

Experimental technologies are often difficult to encourage infrastructure investment in. This is because of the possibility of technological gains that render existing technology uneconomic to run. Despite biofuels having been in existence for some time, new processes and technological improvements continue to be made. This may limit investors' willingness to invest in existing biofuel technology.

However, the analysis of costs suggests that capital costs are a reasonably small proportion of total costs and may mean that the costs of early exit may be less than in other industries. And certainly there is evidence of ongoing investment in biofuels supply in other countries, albeit in response to government policy.

4. Policy Options

4.1. Background and Issues

This section examines policy options that could be used to progress the introduction of biofuels consistent with the findings on net national costs and benefits. In examining options, the analysis below emphasises the economic efficiency impacts of options—either ensuring that biofuels are encouraged to the extent that there are net social benefits, or ensuring that pre-specified targets are achieved at least cost.

However, there are three additional issues that are important considerations in policy design— the need to provide market certainty, dealing with uncertainty in costs and benefits and the timing of any targets. These issues are outlined below.

4.1.1. Certainty

The analysis of costs of biofuels supply suggests that domestic production is lower cost than importing biofuels. This is not to suggest that domestically produced biofuels will not trade at the price of imports (or just below), but that for New Zealand, producing here is lower cost. For New Zealand-owned firms any producer surplus or profit (the difference between the costs of production and the market price) is likely to be retained locally; however foreign-owned investors may repatriate profits.

As noted above, investments in domestic production will require some market certainty. If biofuels are lower cost to produce than petroleum-based product, this certainty might be provided by the market. The cost analysis suggests that biodiesel production is similar in cost to the production of conventional diesel. However, there are a number of uncertainties (see below) that increase risks and are thus a constraint to investment. Government regulation can provide market certainty.

For companies making investments in biofuels production, the decision to invest is based on the comparison of costs of production with the expected revenue stream over the economic life of a plant. Government regulation that requires the use of biofuels, while not removing all market uncertainty (eg other firms can enter the market and produce at lower cost), would provide the market with certainty that there will be demand for the product.

Governments cannot commit future governments on future policy changes, but the likelihood of changes can be reduced through the design of policy, eg those that create property rights are less likely to be overturned such as instruments that create tradable rights (or obligations). This issue is discussed in greater detail under Section 4.5 below.

4.1.2. Uncertainty

There are uncertainties in the future costs and benefits of biofuels use. The costs of biofuel production relative to that of conventional fuels will vary with the price of oil, for example. Thus if biofuel production was encouraged by government subsidy, an estimated subsidy level might not be sufficient if the price of oil were to drop. In contrast, other types of instrument do not rely on ex-ante estimates of prices, eg mandatory obligations (with or without trading); rather, such an instrument would pass the cost uncertainty on to industry.

For government, if pursuing a subsidy approach, the existence of uncertainty may require the rate of subsidy to be set at a high level to ensure that it would provide incentives even under low oil prices. This passes cost risk on to tax payers.[77] In contrast, the mandatory approach does not change the certainty of achieving environmental outcomes (provided compliance penalties are sufficiently large), but passes cost risk on to consumers.

4.1.3. Timing

Regulations can be designed to ensure investment and the achievement of any targets set. A key design issue is timing—how hard and fast does the government push the requirements for introduction of biofuels. This also needs to take account of issues to do with uncertainty.

Industry will require some time to build plant if a mandatory requirement is introduced. If encouragement of domestic production is an objective, timing needs to be taken into account. Imports of biofuels are a possibility before domestic production facilities are established but there is a risk that, in the short run, the only fuel available might be ethanol. Biodiesel is available in small volumes internationally but there is a more active international market in ethanol. Importing ethanol could encourage or require the establishment of ethanol infrastructure, that might become stranded assets if biodiesel is used once domestic production is established.

Policy can respond to these uncertainties.

- Policy could be designed with a slow start, allowing companies to plan for a future with biofuels use. This requires that the government liaises closely with industry in estimating the necessary timing.

- Instruments might be designed that were consistent with a slow start but that rewarded and encouraged an early start if that was possible.

- Policy could be designed to start "hard and fast" such that imports were a possibility, and accepting the risk of stranded assets.

4.2. Options

Options that can be introduced to encourage the use of biofuels include those that target production (supply) or consumption (demand). They can be introduced as incentive-based or mandatory programmes. Here we examine the following broad policy options:

[77] Assuming that it is funded out of central funds

- Price incentive programmes
- Mandatory sales targets
- Mandatory sales targets with trading
- Reverse auctions

All options considered would require the introduction of standards for the use of biofuel. These would set out fuel specifications in the same way as is done now for conventional fuels.

Additional complementary measures could include those that ensure the vehicle fleet is capable of using biofuels. For example, standards might be applied to imported vehicles to restrict entry to those that could use biofuels.

Before examining the policy options in more detail, we discuss two general issues—the value of the market-based approach to policy and the use and definition of targets.

4.2.1. Market-Based Instruments versus Command and Control

Market-based or economic instruments are defined here in broad terms to include all instruments that make use of market incentives to achieve objectives. They affect the monetary costs or benefits of private actions, either through directly changing market prices (charges or subsidies) or introducing markets where previously there were none, eg through introducing sales obligations for biofuels, requiring certificates of compliance with these obligations and allowing owners to trade these certificates.

Market-based instruments (MBIs) are generally lower cost than command-and-control instruments that are more specific in their requirements, because MBIs provide greater flexibility. For example, the costs of a mandatory sales obligation are reduced through allowing trading because it provides incentives for the firm that can supply or consume biofuel at least cost to do more, and the firm with high costs to do less. Trading might also be used to limit costs for allowing firms to shift requirements to meet obligations forwards or backwards in time.

4.2.2. Targets

Targets are integral to some or most policy approaches that could be adopted. It is possible to introduce policy which does not set biofuels targets; rather the market decides how much is delivered. For example, an incentive, either via a subsidy for biofuels or a charge on petrochemical-based fuels might be introduced. The quantity of biofuels actually produced would then reflect the difference in production costs between the two fuel types, adjusted for the incentive. Such an approach could be used, for example, with an incentive based on an estimate of the differences in external costs,[78] to produce an optimal level of biofuels.[79]

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[78] Costs that are not priced in the market, such as differences in environmental effect

[79] This approach is consistent with the so-called Pigouvian tax, a charge equal to marginal damage. Most efficiently it would ensure that the difference in tax between fossil-fuel based and biofuels reflected the difference in external costs.

However, if the government were to target a particular level of use, then the policy approach might be different, eg introducing an incentive approach set at a level expected to achieve the target, or through using the target as an integral part of the policy, eg in the form of a mandatory sales target. These different approaches to policy are discussed below.

In August 2005, the Government agreed in principle to the introduction of a mandatory biofuels sales target for transport biofuels. The analysis in this report has examined the costs and benefits to New Zealand of biofuels production versus the ongoing supply of petrochemical-based fossil fuels. This approach can be used to define an optimal target. This is explained below in reference to the way that it is specified, the level and the timing.

Specification

There are two issues—fuel specificity and the energy specification.

The underlying objectives of the introduction of biofuels are associated with the environmental and security of supply benefits. These benefits accrue regardless of whether bio-diesel or ethanol is the fuel type used. Thus the government is indifferent to the fuel used; it is purely an issue of costs.[80] Targets specified in biofuel terms, rather than as separate biodiesel and ethanol targets give greater flexibility to how the targets are achieved and thus, in theory, can result in lower costs.

The way the target is specified needs to take account of the differences in energy value of the different fuels. Thus if a target is specified in litres of fuel sold, there would need to be a multiplier used to estimate the equivalent benefits of ethanol and biodiesel. Rather than using such a system, the target could simply be stated in terms of the outcome desired, ie a reduction in the quantities of petroleum-based fuel used. Consistent with this, a target might be specified in terms of the quantity of petroleum-energy displaced.

Level and Timing

The analysis suggests that, under reasonable assumptions, there is a national net benefit (at current oil prices) of using biodiesel produced from tallow. Net national benefits are less clear for biodiesel produced from other feedstocks, eg palm oil,[81] or production of ethanol.

There are some other restrictions on the use of biofuels for purely practical reasons, as noted in Table 1 on Page 2. This suggests that an optimal target would be 1.3PJ by 2008 and 2.5PJ by 2010, specified in terms of PJs of petroleum-based product displaced.

[80] To some extent the issue of costs is defined by the practical difficulties for oil companies in introducing the different fuel types.

[81] Even ignoring any concerns over the sustainability of supply, ie the environmental costs of production of palm oil

Targets set need to be sufficiently high to encourage efficient plant sizes, and over a time frame that allows plants to recover costs.

4.3. Incentive Programmes

The starting place for examining policy instruments is that of a monetary incentive to introduce biofuels. There are two ways to approach this:

- An effective incentive—the level of incentive that is required to ensure a targeted level of biofuel use is achieved;
- An optimal incentive—an incentive defined on the basis of an estimate of the differences in external costs between biofuels and petroleum-based fuels

4.3.1. Effective Incentives

Incentive programmes would provide financial rewards to producers to introduce biofuels to the market. These would need to bridge the gap between the costs of biofuel production and the costs of alternatives—diesel and petrol.

The analysis of the relative costs of production of biofuels and conventional fuels suggests the required level of incentive. This level differs with the expected values of a number of input assumptions and chiefly the oil price and the feedstock costs. On the basis of the analysis in Section 2, we can estimate a range of possible incentive requirements.

Three issues arise:

- How it would be specified;
- The need for equivalence; and
- How to deal with uncertainty.

Specification
An incentive might be introduced as a subsidy payment to biofuels or a charge on conventional fuels. The approach chosen is complicated by the differences in the existing system of charges in which there is a significant set of government taxes on petrol, but an insignificant level of tax on diesel—the equivalent charge on diesel is paid through Road User Charges (RUCs).

So, for example, ethanol might be incentivised through removing the petroleum excise duties. To obtain the same level of total tax revenue would require the tax on petroleum-based fuels to be increased, although the extent of this would depend on the level of penetration of ethanol use. In addition, there would need to be some caution in the way in which the system was designed so that there was not a dynamic one-for-one relationship between the use of ethanol and the extent to which the tax was increased on the other fuels, otherwise the incentive effect would be removed. For example, if ethanol was not taxed but the level of tax on any given entity did not change, then the benefits of using ethanol—reduced tax—are exactly offset by the penalty for doing so—increased tax on the other fuel with which the ethanol was mixed. The system would need to be designed such that there was no dynamic relationship, ie removal of tax on ethanol and an increase in the tax on petroleum-based fuel, based on an expectation of the impact on ethanol sales.

For biodiesel, there is no equivalent tax level that can be used. The tax level on diesel is currently 0.355 cents per litre; its removal would provide little to no incentive effect. For diesel, an alternative approach would need to be used to provide the equivalent incentive. This would either involve introducing a charge on diesel, and presumably replacing the RUCs, or providing a subsidy to biodiesel.

There is a possibility of mixing ethanol with diesel which has not been explored in the accompanying technical reports, largely because it is believed to be technically difficult and unlikely. However, the possibility of this technical option raises the potential for double taxation—ethanol subject to excise duty and to RUCs. If there was no exemption of ethanol from excise duty, a rebate system might be required to avoid possible distortion.

Equivalence

Any system of incentives, to be efficient, would need to provide the same level of incentive, on an energy equivalent basis, for biodiesel and ethanol use. If the incentives used were set at different levels, eg reflecting the estimated required sum to incentivise introduction, the levels of use of the individual fuels would be unlikely to be optimal. For example, the analysis in Section 3 shows that the necessary incentive to encourage use of ethanol would need to be greater than that used to incentivise biodiesel use. However, if, as a result, a greater incentive was provided for ethanol, then there is a risk that too much ethanol is used and too little biodiesel. On environmental grounds we are indifferent between a GJ of biodiesel and a GJ of ethanol,[82] but the analysis suggests that obtaining a GJ of ethanol has a higher net national cost.

The incentive payment or penalty on conventional fuels should thus be the same, allowing market participants to decide whether to respond through supplying biodiesel or ethanol. Note, this suggests that removing the excise duty on ethanol is not optimal in the absence of a similar level of support to biodiesel. To explain: if an oil company with an obligation to purchase biofuels faced a cost of biodiesel and ethanol, both without excise duty, if it purchased ethanol it would save the higher level of excise duty on the petrol that was displaced. In contrast it would save very little excise duty from the diesel displaced. It means that removing the excise duty from ethanol without a corresponding subsidy of the same amount for biodiesel is distorting purchases at the margin towards ethanol.

Currently LPG and CNG have a lower rate of duty than other transport fuels. This provides a precedent for a lower tax rate for individual fuels and reflects lower environmental effects of these fuels compared with petrol. If tax (duty) rates are used as the only policy instrument to encourage fuel switching, then ideally the level of duty would differ amongst fuels only with respect to the relative environmental effects.

[82] Or more exactly, a GJ of diesel displaced by biodiesel or a GJ of petrol displaced by ethanol

However, because of the distortions noted above, if such an economic incentive is used to encourage biofuels, it would need to operate as a reduced level of duty on ethanol and an equivalent subsidy on biodiesel. If, in contrast, a mandatory sales target is introduced, then distortion of behaviour between CNG/LPG and biofuels is not the issue, but distortion of behaviour amongst biofuels is. Retaining duty on ethanol ensures against distortion of effect between those two fuels, as would reducing duty on ethanol and providing an equivalent subsidy to biodiesel. However, the latter results in some loss of revenue to the government that might need to be made up somewhere else.

Uncertainty

Uncertainty in prices of feedstocks and oil means that the required level of incentive is uncertain. To be certain that targets were met, the level of incentive would need to be set such that biofuel would be supplied under low oil prices and high NZ dollar values. This passes market risk on to the government and tax payers.

If the system worked via a subsidy payment, over-payment (ie a high subsidy to ensure the biofuels are supplied under all market outcomes), might be reflected back in a competitive market as lower prices of fuel. This would mean that consumers, in aggregate, were not harmed, but there would be a net transfer from tax payers to fuel consumers, such that those consumers that used more fuel benefited the most. Also, a net result of such a system might be that average fuel prices went down below the level without biofuels; this would have consequent impacts on demand.

There is also considerable volume uncertainty, ie will the quantity of biofuel be much less than targeted or, will the required subsidy be much greater than anticipated.

If the system worked via a tax differential, ie reduced tax for ethanol, then the main problem is the potential over-rewarding of ethanol relative to biodiesel (as discussed above). The tax issue is different. If a reduced tax on ethanol is met by an increased tax on petroleum-based product, total revenues are maintained. If the tax reduction reward is too great, then there is a potential revenue problem if the quantity of ethanol used is higher than anticipated, but not if the expected volume is simply delivered at a lower price. In that circumstance, costs are simply lower; as are prices.

Design

An incentive payment (subsidy) or tax differential approach is not an ideal instrument to achieve specified targets for biofuel use. There are too many price uncertainties in the market that would mean a high level of incentive was needed.

4.3.2. Optimal Incentive

An optimal incentive simply introduces a marginal incentive that reflects the difference in environmental effect. This most simply would be a tax on diesel to reflect its environmental costs and security of supply impacts (requirement for additional storage) and a lower but positive tax rate on biodiesel. For ethanol, this could be reflected by imposing the existing petrol tax on ethanol, less an amount that reflected the difference in external costs of ethanol and petrol.

The impacts of this approach would be a market-defined level of investment and supply of biofuel. However, the estimated benefits of biofuel supply may not be sufficient to overcome the market risks, particularly those associated with current oil price movements. For example, the environmental and security of supply benefits of biodiesel are approximately 4 cents per litre whereas the difference in diesel price between US$40 and US$60/bbl of oil is more than 20 cents per litre. This dominates the investment decision.

4.4. Mandatory Sales Targets

A mandatory sales target requires companies to sell biofuels. In simple terms it would be introduced as a requirement that, for each oil supplier, a specified minimum percentage of its sales averaged over a year, were biofuels. So, if the target was 3%, this could be met through all fuel sold having a 3% biofuel content or 50% of fuels having a 6% biofuel content (all specified in energy equivalent terms).

Such a system provides certainty to biofuel producers that there would be demand for the product. The costs of meeting the obligation are borne initially by the oil companies and would be expected to be passed on to consumers in sales prices.

Mandatory sales targets ideally would be specified in flexible terms, allowing companies to use either ethanol or biodiesel sales to meet the target. The difficulties and potentially high costs of the system are introduced because of issues of distribution and competition.

Biofuel plants may be located in regional locations close to feedstock resources. These may be better suited to some suppliers than others.

4.4.1. Competition

Competition issues may be an important element of the mandatory sales target approach. If biofuel supplies are in the hands of one or a very small number of suppliers, they will hold market power in offering supplies to those with obligations. This means that prices of biofuel supplies might rise to:

- The price of imports of biofuels; or
- The costs of the penalty of not providing biofuels.

Because of these issues, the market might respond, eg through the oil companies investing in biofuels supply, or at least in control of some element of the supply chain such as the feedstock supplies. Alternatively, policy might be introduced to limit the costs of the target, such as the approach used in the UK Renewables Obligation (RO) and the more recently proposed Renewable Transport Fuels Obligation (RTFO).

The UK Renewables Obligation requires electricity suppliers to supply 10% of demand from approved renewable sources in 2010, with lower annual targets in years prior to this date.[83] Proof of compliance is via holdings of Renewables Obligation Certificates (ROCs), which are allocated to renewable generators for every MWh generated from an approved source.

The RO introduces a means for firms with obligations to avoid that obligation if the cost is too high.[84] The RO allows electricity suppliers to choose whether to supply electricity from renewables (as evidenced through holding ROCs) or to pay into a buy-out mechanism at a rate of 3p/kWh. As part of the policy design it is equivalent to saying that the UK government wishes to meet a renewable electricity target, but not at any cost.

A similar mechanism could be provided for a biofuels mandatory sales target. It would require a company to sell a specified percentage of transport fuels as biofuels, that would be translated into, eg MJ of fuel, or to pay a sum of $x/MJ of obligation not met through sales.

The UK system has a recycling mechanism attached to the buy-out fund in which the total revenue collected from the buy-out fund is redistributed to those that have met the obligation, in proportion to their contribution to total supplies. Thus, at the extreme, if only one kWh of renewable electricity was supplied and a buy-out price was paid for the remainder of the obligation (a large amount of money), the total revenue would be paid to the supplier of the single kWh. This provides considerable incentive for early action.

Some of the cost problems of a mandatory sales target can be reduced through adding the ability to trade. This is addressed in more detail below.

4.5. Mandatory Sales Targets plus Trading

Adding trading to a mandatory sales target allows those that are only able to meet the obligation at high cost to trade with companies that could meet it at lower cost. This improves the economic efficiency of the sales target. A mandatory sales target of say 2% of fuels can be translated into an obligation to supply a specified quantity of fuel in energy terms. So, for 195PJ of road transport fuel, this would be equivalent to 3.9PJ of obligation. Under a trading system compliance with this obligation could be met through holding (or surrendering) some form of (electronic or other) certificates that demonstrated sales of biofuels; in aggregate the total number held, or surrendered to a compliance authority, would need to equal 3.9PJ. Developing a trading scheme such as this requires the following elements:

- a binding obligation on specified parties;
- a defined unit of trade (eg, a certificate to discharge responsibility for sales of 1GJ of fuel);[85]

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[83] Department of Trade and Industry (2001), 'New and Renewable Energy: Prospects for the 21st Century. The Renewables Obligation Statutory Consultation.'

[84] The Renewables Obligation also introduces the potential for trading of obligations – see Section 4.5

[85] 1 million GJ = 1PJ

- a system for initial distribution of obligations;
- a penalty system for non-compliance;
- a compliance period.

In addition to these issues, we discuss below some additional design issues: banking & borrowing and market function.

4.5.1. Basic Design Issues

Obligation

This is the same as for the mandatory sales target and would be specified for each obligated firm as a percentage of sales. It would be translated into energy equivalent supplies.

Unit of Trade

The unit of trade would be some form off certificate that verified that a unit of biofuel had been sold. The traded units would be created when the biofuel was sold. Independently verified, they would state the quantities sold and by whom. Verification would need to ensure that the biofuels could be sold once only.

Distribution of Obligations

Most simply the set of obligation would be the same for each oil company.

Penalty System

There are a number of elements of the trading system that might be covered by the compliance regime, but chiefly insufficient holding of certificates and inadequate monitoring.

Effective compliance penalties are an essential component of any trading system. The compliance penalty creates the value of the certificates. It therefore needs to be sufficiently high to deter non-compliance and certainly in excess of any expected certificate price.

In the economics literature, non-compliance is viewed as a rational act that weighs the costs and benefits of compliance and non-compliance—a firm will comply if the probability of being caught times the fine is greater than the value of non-compliance.[86] The implications are that the penalty for non-compliance must be at least as great as the marginal costs of compliance, but must also reflect an additional amount because of the possibility of not being caught. The US SO_2 trading system has established a penalty regime in which the fine for non-compliance is ten times the expected costs of coming in to compliance (ie, the costs of allowances).[87]

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[86] Hargrave, T., Kerr, S., Helme, N. and Denne, T. (2000), 'Treaty Compliance as Background for an Effective Trading Program', in S. Kerr (ed.) *Global Emissions Trading. Key Issues for Industrialized Countries*, Edward Elgar, pp. 43–83.

[87] It is probably less as a multiplier of the expected costs of compliance at the time the programme was designed.

A number of other elements of the compliance system improve its effectiveness, including certainty of the size of the penalty and automaticity (ie, firms know that if they do not comply they will face the penalty).

The compliance regime for sales that are below certificate holdings should involve the following two elements:

- a financial penalty per GJ of missing certificates, set at a value several times the expected certificate price;
- additional percentage sales requirement in the following compliance period to make up the difference.

If it was not possible to develop a GJ-based financial penalty, eg the level were simply decided by the courts, the deduction rate might be used to be more punitive. The deduction in the next year would need to be greater than 1:1 to take account of discounting and a punitive element. In the UK greenhouse gas emissions trading scheme, a rate of 1.3:1 was used (ie, if the company had 100 fewer allowances than required, 130 would be deducted from the subsequent year's allocation). These sums would be equivalent to a discount rate of 30% (ie, a company would be indifferent between purchasing 100 allowances now and 130 in the subsequent year). However, as companies will be operating with lower discount rates, this represents an effective penalty.[88]

Penalties will also be required for failure to have a good monitoring system, or to report sales to an adequate standard. Provided that there was an adequate compliance system for holding too few certificates, non-compliance with data requirements could be achieved through adjustments to the monitoring data such that a deflated estimate of sales was used instead of the missing or inadequate data. This would then require the firm to purchase additional certificates to meet obligations. Deflated figures could continue to be used until an adequate monitoring system was established.

Under international rules on emissions trading, being developed under the Kyoto Protocol, suspension of rights to buy and sell emission permits is included as a penalty for poor data systems. However, such an approach passes costs on to other market participants by reducing supply and/or demand.[89] Suspension of purchasing should never be used as a penalty as it makes compliance more difficult. Suspension of rights to trade can be evaded to some extent by trading derivatives—eg, selling futures (a promise to deliver an allowance in the future when it might be expected that the company would be in compliance with data system requirements).

Compliance Period

The compliance or budget period is the length of time at the end of which those with obligations must reconcile their obligation with holdings of certificates. The choice of

[88] The same 1:3 rate is proposed for compliance under the Kyoto Protocol, but this is for a five-year compliance period, in which case the penalty is equivalent to a discount rate of only 5%, providing little disincentive to over-emitting.

[89] Adjustments do, too, by increasing total demand for allowances and thus their price; however, suspension of sales and purchases is expected to have a more significant impact.

budget period will reflect the environmental limits on trading (see below). Other trading systems have quite different budget periods:

- proposals for international greenhouse gas emissions trading have a budget period reflecting the compliance period under the Kyoto Protocol (ie, five years from 2008–12). Parties to the Protocol must limit their emissions aggregated over the whole five-year period;

- NOx trading in the US Ozone Transport Commission (OTC) region applies to the summer (May–September) months because it is aimed at reducing ambient concentrations of tropospheric ozone, a largely summertime phenomenon;

- RECLAIM (the Californian NOx trading scheme) and a proposed Dutch NO_X trading system both use overlapping annual compliance periods, ie they introduce annual obligations but have some parties with January to December year and others with a July to June year; they allow trading between the two types of allowance.

For biofuels obligations the compliance period could be consistent with the first commitment period under the Kyoto Protocol, for example; or could be annual.

4.5.2. Banking and Borrowing

Banking and borrowing offer considerable advantages to a trading system by providing flexibility in sales over time in addition to flexibility over space.

Banking allows firms that hold more certificates than they need in any year to retain the excess for use or sale in later years. Borrowing allows firms to use a certificate from a future year to cover an obligation in the current year. Banking and borrowing reduce price volatility in the certificate market and limit the costs of over- or under-compliance, but at the possible expense of sales being below the annual target in some years.

Unlimited banking has been included in the US SO_2 trading system. Coupled with stringent penalties for non-compliance, this has led to banking of considerable quantities of allowances. Firms have managed their allowance holdings to limit the risks of non-compliance, and banking has limited the costs of over-compliance. In a system involving a two-step cap (with step reductions in total allowed emissions in 1995 and 2000), banking has led to a relatively smooth, downward-sloping emissions path.

Banking and borrowing enable firms to smooth the price curve of allowances. Under unlimited banking and borrowing, and perfect information, firms might be expected to act in such a way that the price of allowances increased over time at a rate equal to the discount rate. If less than this rate, firms would have an incentive to borrow allowances from the future, as prices next year discounted to the present day would be less than prices this year. Borrowing has the effect of reducing future availability (supply) of allowances, thereby increasing expected future prices, and of increasing current supply, thereby reducing current prices. Borrowing would occur until discounted prices were equal. Likewise, with banking, if prices were expected to rise faster than the discount rate, firms would reduce emissions more now, and transfer allowances to future time periods. Again, this would occur until discounted prices were equal in all time periods. In the absence of banking and borrowing, allowance prices are likely to be much more volatile; at the end of a compliance period, they may rise to very high levels (if there are shortages in supply), or fall to low levels (if there is excess supply).

The system of tradeable Packaging Recovery Notes (PRNs) currently used in the UK to ensure compliance with recycling and recovery obligations has no banking and borrowing, and is subject to end-of-year price spikes, for example.

Banking improves compliance. Because it ensures that certificates have a value at the end of the compliance period, it limits the costs of over-compliance: excess certificates can be retained for use in the following year. In the absence of banking, firms will weigh up the risks of non-compliance with the costs of holding excess allowances. They will seek to maintain certificate holdings at the end of the compliance period very close to their expected emission levels. Depending on the stringency of compliance penalties, some may hold too few allowances. In contrast, if banking is allowed, the cost of holding excess certificates is the difference between their price this year and their discounted value next year. This difference in value will depend on factors including the level of the obligation next year and expected activity levels.

Eventually, it is assumed that certificates in the bank will be used and sales will fall below the target. However, the ability to bank means that certificate holdings are always likely to be above required levels.

Borrowing allows sales below the obligation early in the programme and, while providing many of the cost-reduction advantages of banking, can reduce public confidence. The efficiency advantages of borrowing can be built into a trading system using an obligation that increases over time. This simulates the behaviour of firms when borrowing is possible and cost-effective—ie, more sales are made later and fewer now. The efficient use of certificates and an efficient pricing outcome over time can still be achieved, provided that there is access to unlimited banking and that the rate of increase of the cap is as steep as the maximum that the market would derive.

4.5.3. Market Function

Price Information

Markets work most efficiently if all participants have good access to information regarding the price of certificates. It would be expected that the trading market would commence through a series of simple bilateral trades. In the US markets, although these trades have been managed by brokers, they have provided information to the market (and the public) regarding the price of allowances and the volume of trades. However, in a market as thin as a New Zealand biofuels obligation market might start, transparency regarding trades (eg, the size of the trade in addition to the value) may reveal the buyer and seller, and provide useful information to competitors regarding expected market behaviour. In these circumstances, it is not certain that the market will provide price transparency. However, the government cannot guarantee access to good price data through, for example, compulsory reporting of price, as firms would have little incentive for accurate reporting.

Liquidity
Market liquidity is a measure of the rate of trading and the number of transactions. The more liquid the market, the lower total costs are expected to be. Liquidity is best achieved by limiting transaction costs, maximising price information and maximising the number of market participants. Market liquidity might also be increased through more frequent reconciliation of sales and certificate holdings (eg, making firms balance their books on a quarterly or monthly basis).

4.5.4. Competition Issues

A market amongst the oil companies operating in New Zealand is small and unlikely to be highly competitive. However, introducing the possibility of trading can only be an efficiency improvement over a sales obligation without trading. There is no compunction to trade; those with obligations will only do so if it reduces their costs.

We have considered and discounted the possibility of Commerce Act implications arising from allowing obligations to be tradable. The only possible parts of the Commerce Act that we consider might be relevant are those relating to agreements between competitors, specifically section 27 which prohibits "contracts, arrangements or understandings" that substantially lessen competition. This section does not preclude competitors from trading with each other, provided that doing so does not substantially lessen competition in some market. We see the trading of obligations as being very similar to the current intra-industry trading of tankage capacity. In both cases, commercial imperatives lead firms to seek cost efficiencies and these can sometimes be obtained by trading with each other. Allowing tradability of biofuel obligations will promote (rather than lessen) competition in the supply of biofuels.

4.6. Reverse Auctions

Incentive schemes provide price certainty in the market (although they do not remove the substantial uncertainty of oil price movements). Mandatory targets introduce volume certainty but cost uncertainty, although this can be limited through using a buy-out mechanism. A final policy option is an auction based system that provides greater certainty of costs and outcomes, but requires industry to undertake considerable pre-feasibility planning.

It would be a system in which the government offered to pay subsidies for the supply of biofuels and invited bids for that supply. The bids would be in the form of MJs of supply over different years. The government could then choose, with considerable price and volume information, what it was willing to purchase.

This has the downside of requiring the government to pay the (additional) cost of biofuel supply, unlike the mandatory sales target, but has the advantage over the incentive payment scheme of introducing more certainty over the outcome. The system could be accompanied by penalties for failure to meet the agreed volume sales.

This is similar in approach to the government's current tender system for oil storage to meet the national's IEA storage obligations.

4.7. Combinations of Instruments

Instruments can be combined. A mandatory sales target (with or without trading) could be combined with tax incentives, such as removal of excise duty on ethanol. The mandatory sales target is what is binding and this ensures that targets are met. However, if the tax incentive is sufficiently large, firms may go beyond the target. If it is the sales target that is the binding measure, the issues that need to be considered relate to the fiscal effects and the fuel choice.

If the measure is to be fiscally neutral, ie if the total tax-take from transport fuels needs to be the same, the tax would need to be increased on other fuels. The consumer would not notice any difference; the tax measure merely shifts the tax from biofuels to conventional. The actions of firms would not change either, because the mandatory sales target would be the measure that led to the use of biofuels.

There is an impact where both ethanol and biodiesel are used. Here the tax measure would benefit ethanol over biodiesel and lead to a shift towards use of ethanol as the means for meeting the biofuels target. This suggests that, if a mandatory sales target is introduced, ethanol should be taxed at the same rate as petrol, as discussed in Section 4.3.1.

Reverse auctions can also be combined with tax measures. Here the effect will be simply to change the quantity bid. If there is a tax incentive on ethanol use, firms will bid for a lower subsidy amount to supply ethanol. As above, care needs to be taken in the evaluating bids for subsidy for ethanol versus biodiesel if ethanol is provided with a tax incentive also. The two fuels can be treated equally through not providing (removing) tax incentives for ethanol or through weighting bids to take the existing incentive into account.

5. Conclusions and Policy Implications

The analysis of costs and benefits of biofuel supply suggest that:

- Replacement of diesel with biodiesel from a tallow feedstock would have positive net benefits for New Zealand under reasonable assumptions regarding future oil and feedstock prices;
- Supplies of biodiesel from other feedstocks or directly imported would not be expected to produce net benefits for New Zealand;
- Limits to the total potential supplies of biodiesel are set by the distribution system;
- Replacement of petrol with ethanol is not expected to produce net national benefits;
- Currently there are limits to the potential supply of ethanol as a petrol mix, particularly because of the limited number of service stations with double containment to reduce pluming of fuels.

However, there is considerable uncertainty in the economic analysis, associated with the costs of feedstocks and oil prices, and also because of the rapid development of the technologies. We are aware that there are companies developing alternative supply technologies, particularly for ethanol, which may have lower costs. Any policy to support and encourage the supply of biofuel should provide incentives for both biodiesel and ethanol supplies.

Policy options include incentive payments (subsidies) or tax breaks (no excise duty on biofuels). These approaches have a number of difficulties because of the price uncertainty, passing price risk on to government and consumers.

Instruments based simply on the internalisation of estimated external costs would not be expected to provide sufficient incentive for investment in biofuels supply, because of the significant uncertainties in current market prices, particularly for oil.

Mandatory sales obligations would provide certainty to the market, while passing cost risk on to industry and, in turn, consumers. The cost uncertainty could be limited through the introduction of a buy-out mechanism as include in the UK's Renewables Obligation (RO).

Adding a trading element to the mandatory sales target would provide more flexibility and reduce costs. Trading could be introduced to allow sales between firms within a time period and could be extended to include trading over time, either via multi-year compliance periods or formalised banking and/or borrowing.

Reverse auctions allow the government to estimate how much subsidy it would be willing to provide to obtain supplies. It provides considerable price and volume certainty but still requires government expenditure to obtain biofuels. It also has less up-front certainty for industry; it needs to undertake considerable pre-planning to ensure that it bids at the right price. It also requires industry to commit some time in advance as to the amount it would supply over time; there is considerable cost risk associated with this approach that may limit bids or mean bids are high in price.

A mandatory sales target with trading would be the least cost instrument to meet a specified target for biofuels supply. If introduced, to avoid inter-biofuel distortions, excise duties on ethanol should be raised to equal that on petrol.

Annex A: Carbon Damage Costs

The science of climate change is characterised by uncertainty. There is a high degree of certainty surrounding the existence of an enhanced greenhouse effect and increasing certainty of anthropogenic causes. There is a high level of confidence in estimates of the impacts on global mean temperatures. However, the impacts will depend on local and regional changes in climate combined with current distribution of ecosystems, populations and land uses. Regional and local impacts are much less certain.

Comprehensive assessments of the social costs of CO_2 have been undertaken in the UK. In January 2002, a Government Economic Service working paper[90] suggested £70/tC (NZ$49/t CO_2)[91] (within a range of £35 to £140/tC or NZ$25-99/t CO_2) as an illustrative estimate for the global damage cost of carbon emissions. A recent UK analysis that built on this earlier work in applying a cost of carbon to policy analysis, has used a range from £35 - £220/t C (£10-60/t CO_2 or NZ$25-155/t CO_2).[92]

Most of the damage estimates come from Integrated Assessment Models (IAMs) that combine scenarios of climate change and its damage effects with an economic model of activity and output. These models have been used to estimate total and marginal damage costs of climate scenarios. There have been a number of reviews of the damage cost estimates resulting from IAMs, and recently a useful review of reviews for the UK government-sponsored international seminar on the social costs of carbon. It provided the following summary[93]:

- In 1996, the Intergovernmental Panel on Climate Change (IPCC's) Working Group III published a range of US$5 - $125 per tonne of carbon (in 1990 prices, or $6 - $160/tC in 2000 prices) based on a review of existing studies and relating to carbon emissions in the period 1991-2000. For the period 2001-2010, the representative range was estimated to increase to $7 - $154/tC (in 1990 prices, or $9-$197/tC in 2000 prices);
- On the basis of a review of 8 major studies, the UK Government Economic Service[94] suggested $101.5/tC (within a range of $51 to $203/tC) as an illustrative estimate for the global damage cost of carbon emissions. It also suggested that these figures should be raised in real terms by $1.45/tC per year as the costs of climate change are likely to increase over time.

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[90] Clarkson R and Deyes K (2002) Estimating the Social Cost of Carbon Emissions. HM Treasury & DEFRA. www.hm-treasury.gov.uk/media/209/60/SCC.pdf

[91] Converted using £1:NZ$2.59 (average over the last year – to April 3rd 2006) and 3.67t CO_2/t carbon

[92] AEA Technology (2005) The Social Cost of Carbon. The Social Costs of Caron (SCC) Review – Methodological Approaches fro Using SCC Estimates in Policy Assessment.

[93] Department for Environment, Food and Rural Affairs (2003) The Social Cost of Carbon Review. Background Paper.

[94] Clarkson R and Deyes K (2002) Estimating the Social Cost of Carbon Emissions. Government Economic Service Working Paper 140. HM Treasury, Department for Environment, Food and Rural Affairs.

- Pearce (2003)[95] lists 24 estimates from 12 studies in his review, some of which have been published or peer-reviewed following the publication of the GES paper. Pearce's survey of the SCC literature leads him to conclude that a more appropriate range would be \$6 to \$39/tC.
- In a recent working paper that probably constitutes the most complete survey of the literature to date, Tol (2003)[96] counts 88 estimates from 22 published studies. The mode of these estimates is \$5/tC, the mean \$104/tC and the 95th percentile \$446/tC, the right skewed distribution reflecting the presence of a few estimates that place the SCC at a few hundred of dollars (and in one case more than a thousand of dollars) under pessimistic scenarios. After weighting the estimates, Tol concludes that "[…] for all practical purposes, climate change impacts may be very uncertain but is unlikely that the marginal costs of carbon dioxide emissions exceed \$50/tC and are likely to be substantially smaller than that."

There are a number of key parameters that affect the results including[97] discount rates—greenhouse gases, particularly CO_2, are very long lived and many of the effects will have substantial time-lags. Thus discount rates matter. There is a substantial literature growing on the use of low and declining discount rates[98]; time varying discount rates could roughly double damage estimates.

Taking account of Tol's recent and comprehensive analysis, would suggest a figure of less than US\$50/t of carbon (US\$13.6/t CO_2 equivalent to NZ\$23/t CO_2).

[95] Now published as: David Pearce (2003) The Social Costs of Carbon and its Policy Implications. Oxford Review of Economic Policy, 19(3): 362-384

[96] Tol, RSJ (2003) The Marginal Costs of Carbon Dioxide Emissions: an Assessment of the Uncertainties. Working Paper FNU-19, Hamburg University, Germany. http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/margcostunc.pdf

[97] Taken from: Pearce D (2003) International Seminar on the Social Cost of Carbon: Rapporteur's Summary

[98] When there is uncertainty about future state of the economy/levels of relative consumption or of changes in time preference, it can be demonstrated that discount rates should decline over time. See: OXERA (2002) A social time preference rate for use in long-term discounting. The Office of the Deputy Prime Minister, Department for Transport, and the Department of Environment, Food and Rural Affairs.

Annex B—Costs of Particulates

There is a very considerable literature on the costs of particulates, including studies in New Zealand.[99, 100] The impacts are dominated by the effects on morbidity (respiratory illness) and mortality (premature death). Epidemiological studies have correlated numbers of deaths and hospital admissions for a range of symptoms to pollutant concentrations, while accounting for factors such as season, temperature and day of the week. The results have been highly consistent and have withstood criticism.[101]

The studies have resulted in a series of risk estimates that correlate changes in pollutant concentration to impacts including asthma attacks, restricted activity days, bronchitis episodes, respiratory hospital admissions and total mortality. An example is given in Table 19.

Table 19 Impacts of 10μg/m^3 increase in concentration of PM_{10}

Health outcome	Relative risk	(±95% confidence interval)
Total mortality (adults ≥30 years)	1.043	(1.026-1.061)
Respiratory hospital admissions (all ages)	1.0131	(1.001-1.025)
Cardiovascular hospital admissions (all ages)	1.0125	(1.007-1.019)
Chronic bronchitis incidence (Adults ≥25)	1.098	(1.009-1.194)
Bronchitis (children <15)	1.306	(1.135-1.502)
Restricted activity days (adults ≥20)	1.094	(1.079-1.102)
Asthma attacks (children <15)	1.044	(1.027-1.062)
Asthma attacks (adults ≥15)	1.039	(1.019-1.059)

Source: Künzli N, Kaiser R, Medina S, Studnicka M, Chanel O, Filliger P, Herry M, Horak F jr, Puybonnieux-Texier V, Quénel P, Schneider J, Seethaler R, Vergnaud J-C and Sommer H (2000) Public-health impact of outdoor traffic-related air pollution: a European assessment. *The Lancet*: 356: 795-801

In New Zealand, detailed medical studies have been undertaken in Christchurch. These have shown an association between 24-hour concentrations of fine particulates (PM_{10}) and mortality and hospital admissions; the results are consistent with overseas studies.

A 2002 report for the Ministry of Transport[102] notes the lack of data but uses what is available making "realistic assumptions … to arrive at the current best estimate for public health effects". It used the exposure data to estimate the expected mortality impacts of elevated PM_{10} concentrations. The authors describe the methodology as being published in the well-respected medical science journal, the Lancet (see Table 19), and

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[99] Fisher GW, Rolfe KA, Kjellstrom T, Woodward A, Hales S, Sturman AP, Kingham S, Petersen J, Shrestha R and King D (2002) Health effects due to motor vehicle air pollution in New Zealand. Report to the Ministry of Transport
[100] Fisher G, Kjellstrom T, Woodward A, Hales S, Town I, Sturman A, Kingham S, O'Dea D, Wilton E, O'Fallon C, Scoggins A, Shrestha R, Zawar-Rewa P, Epton M, Pearce J, Sturman J, Spronken-Smith R, Wilson J, McLeod S, Dawson R, Tremblay L, Brown L, Trout K, Eason C, Donnelly P (2005) Health and Air Pollution in New Zealand: Christchurch Pilot Study. Prepared for Health Research Council, Ministry for the Environment, Ministry of Transport. Available at: www.hapinz.org.nz/
[101] Samet et al, 1996 in: Fisher GW, Rolfe KA, Kjellstrom T, Woodward A, Hales S, Sturman AP, Kingham S, Petersen J, Shrestha R and King D (2002) Health effects due to motor vehicle air pollution in New Zealand. Report to the Ministry of Transport
[102] Fisher et al (op cit)

derived from long term studies. It used a 4.3% increase in background mortality rate for each 10μg/m^3 annual average increase in PM_{10} concentrations above a 7.5 μg/m^3 threshold as a chronic mortality impact. Others have assumed no health effect threshold, including the US EPA[103] and the recent studies coordinated by the European Commission.[104] The World Health Organisation[105] examines a number of studies that report a range of chronic impacts from 3-18% increase per 10μg/m^3 increase in PM_{10} concentrations, with a mid value of 10%. The most recent work coming out from the European Commission[106] uses an approach described by Arden Pope and others[107] that recommends a total mortality impact of a 6% increase in death rates per 10μg/m^3 increase in $PM_{2.5}$.

There are two significant issues involved in moving from concentrations to estimate damage costs:

- The delay in the mortality impact;
- The quantification of the value of lives lost.

Delay in Impact

The mortality studies include[108]:

- Time series studies of acute exposure, ie the impacts of short term spikes in concentrations; and
- Cohort studies of chronic (long term) exposure that result in changes to age-specific death rates.

The impacts across a wide range of studies are dominated by the chronic effects. These studies show the impact on death rates, or more correctly life expectancy, of long term exposure to elevated levels of pollution. However, the results need to be interpreted with some caution.

The long and short term impacts can be explained using a two by two matrix (Table 20). Susceptibility to death may be increased because of air pollution or some other cause, eg

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103 Hubbell BJ, Koman T, Fox TJ, Possiel MS, Stella G and Timin B. Health benefits of reducing particulate air pollution from heavy duty vehicles. USEPA (www.epa.gov/ttn/ecas/workingpapers/hddben.pdf)

104 AEA Technology Environment (2005) Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment

105 World Health Organisation (2000) Air Quality Guidelines for Europe (www.euro.who.int/document/e71922.pdf)

106 AEA Technology (op cit)

107 Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American medical association, 287: 1132 - 1141. In: AEA Technology (op cit)

108 AEA Technology Environment (2005) . Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. .Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment.

illness, and the event of death may be triggered by air pollution or another cause. The long term studies that demonstrate a linkage between rates of death and long run exposure to pollution, do not separate out causes A, B and C.

Table 20 Long-term Frailty and Trigger of Death

Long-term frailty	Event of death	
	Related to air pollution	Not related to air pollution
Related to air pollution	A	B
Not related to air pollution	C	D

Source: Seethaler, RK, Künzli N, Sommer H, Chanel O, Herry M, Masson, S, Vergnaud J-C, Filliger P, Horak F Jr, Kaiser R, Medina S, Puybonnieux-Texier V, Quénel P, Schneider J, Studnicka M and Heldstab, J (2003) Economic Costs of Air Pollution Related Health Impacts: An Impact Assessment Project of Austria, France and Switzerland. Clean Air and Environmental Quality, 37/1: 35-43

While a reduction in emissions may reduce the number of deaths immediately related to air pollution (A and C), average levels of long term frailty in the population will change slowly over time.

However, despite this, the results of studies used to estimate current premature mortality owing to air pollution have been used to estimate marginal effects of reducing pollution levels, eg as an input to the development of national environmental standards for air quality.[109] The approach used in New Zealand is consistent with numerous overseas studies but misleading as a measure of the expected effect, principally because it assumes that reductions in emissions or concentrations will have an immediate and proportional reduction in the number of premature deaths, but also because of the approach used to measure damage (as discussed in the next section).

The cohort studies used to establish the chronic effect suggest that people are frail as a result of a lifetime living in air pollution. Given this, even if air pollution is cut to zero tomorrow, these people will still be frail and many will die prematurely because of this frailty. The reduction in pollution stops additional frailty and allows some repair, however even if all pollution is cut, it will take many years and probably decades for the full benefits to be realised.

This is recognized by a number of current workers. For example, Nino Künzli notes that emission reduction will bring about the total benefit as suggested by the studies, but that the full mortality benefit will not result next year; he suggests that the answer to when it results is not known.[110] Arden Pope suggests that the pollution damage effects will persist for years or even decades.[111]

[109] Ministry for the Environment (2004) Proposed National Environmental Standards for Air Quality. Resource Management Act Section 32 Analysis of the costs and benefits.
[110] Nino Künzli, personal communication
[111] Arden Pope, personal communication.

These effects are beginning to be taken into account as they are vital for an understanding of the marginal effects of reductions in pollution.

A recent report published by the US EPA and including advice by a Health Effects Subcommittee (HES) notes the importance of this issue and that, to date, a weighted 5-year time course of benefits has been assumed in which 25% of the PM-related mortality benefits were assumed to occur in the first and second year, and 16.7% were assumed to occur in each of the remaining 3 years.[112] The EPA noted that it was considering use of a range of lag structures from 0 to 20-30 years, with 10 or 15 years selected as the mid-point value until more definitive information becomes available. The HES endorsed the consideration of these alternative approaches that took account of long lags.

In response to this cumulative advice, the EPA has stated that it intends to further analyse the cessation lag question, but in the interim, it intends to use an alternative lag structure, which assumes 20% of the incidence reduction occurs in the first year of a reduction in PM exposure, another 50% is evenly spread among years 2 through 5 (ie 12.5% each year), and the remaining 30 percent of the incidence reduction is evenly spread out among years 6 through 20 (ie 2% each year)[113].

In contrast, the work for the European Commission continues to assume no lags[114], although as sensitivity analysis researchers have examined the effects associated with a 1-year pulse change, ie a sudden reduction in pollution for one year. Here, in contrast to a 6% increase in mortality for a 10μg/m^3 increase in $PM_{2.5}$ concentrations, they assumed a 2.4% increase in year 1, followed by 0.36% increases in years 2 to 11, followed by reversion to the original mortality rate.

The need for new research is clear when we think through the impacts as marginal effects. If there is a reduction in emissions of a single tonne (or even a single tonne per annum), there is a lesser risk of an acute effect but the chronic effect involves a very slight delay in the build up of frailty.

All of the researchers that are starting to take account of these effects are using assumptions in the absence of studies that have truly examined a marginal effect. However, they demonstrate that the assumptions of an instantaneous response greatly over-estimate the measured impact.

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[112] US EPA (2004) Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis—Benefits and Costs of the Clean Air Act, 1990-2020. Advisory by the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis. (www.epa.gov/sab/pdf/council_adv_04002.pdf)

[113] www.epa.gov/sab/pdf/comments_on_council_adv_04001.pdf

[114] AEA Technology Environment (2005) Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. .Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment.

Quantification of Value
Many studies have sought to quantify the damage attributable to air pollution in monetary terms. They are dominated by the health effects and the impacts on life expectancy.

The morbidity effects are typically estimated using the costs of treatment and there is little controversy about these.

There are a number of issues that are not fully resolved related to the measurement of the valuation of mortality impacts.

Recent work to examine the impact of pollution in New Zealand has used a simple approach to analysis involving the following calculation:

annual death rate x population size x %increase per $\mu g/m^3$ PM_{10} x change in PM_{10}

This results in an estimated number of attributable deaths. Using a 4.3% increase in death rate, as discussed above, Fisher and others[115] estimated 970 additional deaths per annum attributable to PM_{10}, 399 of which were attributable to transport emissions. These have then been multiplied by an estimate of the value of a statistical life (VSL), eg to estimate the costs of damage due to air pollution from traffic.[116]

This simple approach is described by the recent European team as easy to do and to communicate but wrong![117] There are a number of issues of concern. The European team notes the simplifications involved relative to an approach that uses life tables in which the impacts of extra deaths in one year affect the structure of the population in future years.

Other issues relate to the nature of delay and the characterisation of the deaths.

Firstly, taking the New Zealand example above, the results do not mean the premature deaths of 970 (or 399) distinct individuals. The research on which this work is based shows only that the death rate increases under pollution; it might be caused by the measured increase as discrete deaths, but it is more likely that it is an outcome of the reduced lifespans of thousands of individuals so that deaths are squeezed into fewer years and the total annual death rate changes by this amount.

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[115] Fisher GW, Rolfe KA, Kjellstrom T, Woodward A, Hales S, Sturman AP, Kingham S, Petersen J, Shrestha R and King D (2002) Health effects due to motor vehicle air pollution in New Zealand. Report to the Ministry of Transport
[116] Fisher G (2002) The cost of PM_{10} air pollution in Auckland: a preliminary assessment. NIWA Discussion Paper.
[117] AEA Technology Environment (2005) Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme.

AEA Technology notes[118]:

> *…in the long run everybody dies, and dies once only, the aggregate number of deaths in a birth cohort … or in the currently-alive population … will be exactly everybody in that birth cohort or population, irrespective of the effects of pollution on mortality. This highlights the possibly obvious fact that information about pollution and mortality does not reside in the fact of death — this is taken as being certain but rather in its timing: how soon will death occur?*

Aggregate deaths will always be the same. What differs is lifespan.

It is increasingly being recognized that reporting the effect as a number of premature deaths is not an appropriate metric for total mortality.[119, 120] Rather, the appropriate metric is the loss of life expectancy (LE).

And the lifespan impact might only be felt in the long run. For example, if the impact of pollution reduction is as described in the previous section—a reduction in frailty—the result might be seen as life extended at its end. For some individuals this may be many years in the future.

For valuing the mortality effects there are two main approaches that are used in the literature:

- Estimating the number of premature deaths and multiplying by a value of statistical life (VOSL or VSL). This is the approach described above as used in New Zealand. The VSL is typically measured using willingness to pay studies, eg through observing the behaviour of individuals and the amount that they are willing to pay to reduce the risk of death, eg through safer cars or wage rates in risky jobs; and

- Reductions in life expectancy, combined with a value of life years lost (VOLL) or values of life years (VOLY). VOLLs/VOLYs have been measured either as a proportion of VSL or through studies which ascertain the willingness to pay for changes in life expectancy.

Given that the impact is better typified as changes in life expectancy rather than "additional deaths", a VOLY based approach appears to be a better approach. However, the VSL approach has been widely used because it is simple, and because VOLYs are often derived from VSLs anyway. As no empirical data on VOLYs were available, the

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[118] AEA Technology Environment (2005) Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme.

[119] Desaigues B, Rabl A, Ami D, Boun My K, Masson S, Salomon M-A and Santoni L (2004) Monetary Valuation of Air Pollution Mortality: Current Practice, Research Needs and Lessons from a Contingent Valuation (www.arirabl.com/papers/MortalVal-Desaigues%20et%20al04.pdf)

[120] Rabl A 2003. "Interpretation of Air Pollution Mortality: Number of Deaths or Years of Life Lost?" *J Air and Waste Management*, Vol.53(1), 41-50 (2003).

ExternE team calculated the VOLY on theoretical grounds by assuming that VSL is the sum of discounted annual VOLY over 30 to 40 years. [121]

To illustrate the difference in result, AEAT provides the results using VSLs and VOLYs. Because they estimate that each premature death represents a loss of one life year on average, ie people die one year earlier as a result of air pollution, the results are comparable. They note that the saving in life years is approximately 1 year per death. The results are shown in Table 21 converted to New Zealand dollars.

Table 21 Values of Lives Lost from Air Pollution (NZ$)

	VSL	VOLY
Median	$1,781,818	$90,909
Mean	$3,636,364	$218,182

Source: AEA Technology Environment (2005) Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme. Methodology for the Cost-Benefit Analysis for CAFE: Volume 2: Health Impact Assessment Converted to NZ$ at NZ$1:€0.55

The recent cost benefit analysis for the air quality strategy used a VSL approach and a value of $1.88million, very close to the median value above. This was derived from work by Transfund on the value of life for accidents, adjusted to reflect the older population likely to die from air pollution.[122]

However, even the VOLY approach is likely to be an over-estimate for the marginal effects because there is an assumption of divisibility of effect. For example, we might assume that as a result of baseline levels of air pollution, those that die prematurely do so one year earlier than otherwise they would. Using a full VOLY value to estimate the effects of a small reduction in pollution and thus an extension in life of a few days or months assumes that the value of an extra day is worth one 365th of a VOLY. However, the studies that exist do not suggest this.

The first survey, to our knowledge, that asked explicitly about the valuation of a gain in life expectancy was by Swedish researchers Johannesson & Johansson. They administered a telephone survey and asked the following question "*The chance for a man/woman of your age to become at least 75 years old is x percent. On average, a 75-year old lives for another 10 years. Assume that if you survive to the age of 75 years you are given the possibility to undergo a medical treatment. The treatment is expected to increase your expected remaining length of life to 11 years. Would you choose to buy this treatment if it costs y and has to be paid for this year?*"[123] The resulting VOLY values are very low, in the range of NZ$1,000 to $2,000.

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[121] Desaigues B, Rabl A, Ami D, Boun My K, Masson S, Salomon M-A and Santoni L (2004) Monetary Valuation of Air Pollution Mortality: Current Practice, Research Needs and Lessons from a Contingent Valuation (www.arirabl.com/papers/MortalVal-Desaigues%20et%20al04.pdf)

[122] Ministry for the Environment (2004) Proposed National Environmental Standards for Air Quality. Resource Management Act Section 32 Analysis of the costs and benefits.

[123]Johannesson M & P-O Johansson 1997. "Quality of life and the WTP for an increased life expectancy at an advanced age". *J Public Economics*, 65, 219-228 in: Desaigues B, Rabl A, Ami D, Boun My K, Masson S, Salomon M-A and Santoni L (2004) Monetary Valuation of Air Pollution Mortality: Current

Values for Analysis
In the analysis of the value of reduction in emissions a number of issues need to be considered based on the analysis above.

For analysis of the costs of emissions we take a marginal approach, ie we measure the impacts of one more tonne of pollution. The research on causes of death shows that there are some acute (sudden) impacts of pollution, but the greatest effects are chronic as a result of increased frailty. So when one more tonne is emitted, the main effect is that people are less frail and will live longer. The effect of small changes in pollution levels is some more life, many years in the future for many people.

In this context, the approaches used to derive VSLs, such as in the cost benefit analysis of the air quality standard, are an inappropriate basis for valuing this effect. Even if a VSL was available specifically for air pollution, it would be appropriate only for acute mortality, which is a small component of the total impact.[124]

The VOLY approaches come closer to an estimate of the actual effect but even these do not take proper account of the nature of delay and are typically based on VSLs derived from other studies, eg accident costs, which are inappropriate. The Johannesson & Johansson study above is one of the only studies that has directly asked willingness to pay questions that approximate the real impact, and it resulted in a very low estimate.

For analysis here we employ a range of estimates, from the AEAT VOLY estimates at the high end and the Johannesson & Johansson values as an alternative estimate. However, we note that even these may be over-estimates for marginal effects that result in small changes in life expectancy rather than whole years of life saved.

We start with the estimates of damage published by AEAT.[125] Its work on damage costs provides costs on a per tonne basis for a range of pollutants, using the VSL and VOLY data listed in Table 21.

AEAT provides results for each EU member state. The same VOLY value is used for each country but damage cost estimates differ per tonne of pollutant reflecting population density and the geographical spread of the pollutants.

For comparison Figure 12 shows population density of New Zealand and EU Member States. New Zealand has a lower density than all member states. In addition, it is more

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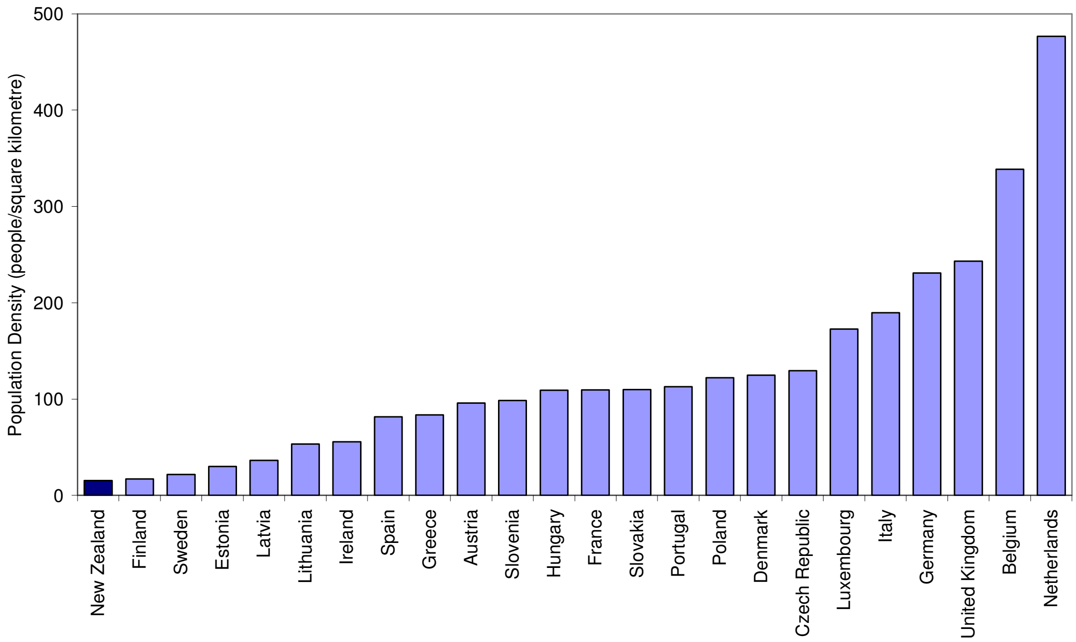
Practice, Research Needs and Lessons from a Contingent Valuation (www.arirabl.com/papers/MortalVal-Desaigues%20et%20al04.pdf)

[124] Desaigues B, Rabl A, Ami D, Boun My K, Masson S, Salomon M-A and Santoni L (2004) Monetary Valuation of Air Pollution Mortality: Current Practice, Research Needs and Lessons from a Contingent Valuation (www.arirabl.com/papers/MortalVal-Desaigues%20et%20al04.pdf)

[125] AEA Technology Environment (2005) Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme.

remote than these countries from surrounding countries. For comparative purposes we use the Finland data as the basis for New Zealand estimates; this is confirmed as appropriate by the EU researchers.[126]

Figure 12 Population Density - NZ and EU Member States



Values of damages for Finland are shown in Table 22.

Table 22 Marginal Damage Costs per Tonne of Emission based on VOLY Estimates (NZ$/t)

	VOLY median	VOLY median Health sensitivity
PM	9818	20000
SO_2	3273	6545
NOx	1364	2727

AEA Technology Environment (2005) Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas. Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme

These numbers are based on assumptions that do not seem credible based on the discussion above. We use two approaches to alter them.

- We spread the effect over a number of years reflecting the delay in impact. For analysis we use the US EPA assumptions.
- We use a value of a life year based on the Johannesson & Johansson work in Sweden, ie a value of $2,000 as opposed to $90,909 (median value).

[126] Paul Watkiss, AEA Technology, personal communication

The modifications apply to the mortality costs of air pollution. The morbidity costs would not change to the same degree. We use AEAT's baseline analysis to estimate the percentage of total costs attributed to mortality versus morbidity; mortality is estimated at 68% of total costs with 28% being morbidity, the remainder includes effects related to ozone and are ignored in our analysis.

Starting with the lower (VOLY median) values above, and taking 28% of these values plus the revised analysis for the mortality effect produces the low estimates shown in Table 23. Alongside this, our high estimate is based on the higher VOLY median with additional health sensitivity from Table 22 above, but with the costs spread over twenty years using the EPA methodology. This gives a very wide spread of possible costs of the different pollutants from $2,383-$15,622 for particulates, $794-5,113/t for SO_2 and from $331-2,130/t for NOx. Our estimate is that costs are likely to be closer to the low value used here and might be less than this, given the uncertainty in the approach used to delay the benefits.

Table 23 Impacts of Pollutants (NZ$/tonne)

	Low			High		
	Mortality	Morbidity	Total	Mortality	Morbidity	Total
PM	147	2236	2383	11066	4556	15622
SO_2	49	745	794	3622	1491	5113
NOx	20	311	331	1509	621	2130

Annex C: Australian Fuel Standard for Biodiesel

AUSTRALIA

Fuel Standard (Biodiesel) Determination 2003

I, DAVID ALISTAIR KEMP, Minister for the Environment and Heritage, make this Determination under section 21 of the *Fuel Quality Standards Act 2000*.

Dated 18 September 2003

DAVID KEMP
Minister for the Environment and Heritage

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1 Name of Determination

This Determination is the *Fuel Standard (Biodiesel) Determination 2003*.

2 Commencement

This Determination commences on gazettal.

3 Definitions

In this Determination:

ASTM International means the standards development organisation of that name.

biodiesel means a diesel fuel obtained by esterification of oil derived from plants or animals.

European Committee for Standardisation (CEN) means the standards development organisation of that name.

4 Fuel standards for biodiesel

(1) Biodiesel that contains a substance mentioned in the following table must not contain more than the amount mentioned for the substance from the date mentioned for the substance.

Item	Substance	Amount	Date
1	Sulfur	50 mg/kg	18 September 2003
2	Sulfur	10 mg/kg	1 February 2006
3	Sulfated ash	0.020% mass	18 September 2003
4	Carbon residue — 10% distillation residue; or	0.30% mass	18 September 2003
	Carbon residue — 100% distillation sample	0.050% mass	18 September 2003
5	Water and sediment	0.050% vol	18 September 2003
6	Phosphorus	10 mg/kg	18 September 2003
7	Free glycerol	0.020% mass	18 September 2004
8	Total glycerol	0.250% mass	18 September 2004
9	Metals — Group I (Na, K)	5 mg/kg	18 September 2004
10	Metals — Group II (Ca, Mg)	5 mg/kg	18 September 2004
11	Alcohol	0.20% (m/m)	18 September 2004

(2) A property of biodiesel mentioned in the following table must meet the specification mentioned for the property from the date mentioned for the property.

Item	Property	Specification	Date
1	Density at 15°C	860 to 890 kg/m^3	18 September 2003
2	Distillation T90	360°C (max)	18 September 2003
3	Viscosity	3.5 to 5.0 mm^2/s @ 40°C	18 September 2003
4	Flashpoint	120.0°C (min)	18 September 2003
5	Copper strip corrosion (3hrs @ 50°C)	No. 3 (max)	18 September 2003
6	Ester content	96.5% (m/m) (min)	18 September 2003
7	Acid value	0.80 mg KOH/g (max)	18 September 2003
8	Total contamination	24 mg/kg (max)	18 September 2004
9	Cetane number	51.0 (min)	18 September 2004
10	Oxidation stability	6 hours @ 110°C (min)	18 September 2004

5 Testing methods

(1) Compliance with the standard set out in section 4 for the substance or property is determined by the testing method for the substance or property in the following table:

Item	Substance or property	Testing method
1	Acid value	ASTM D664
2	Alcohol	prEN 14110
3	Carbon residue — 10% distillation residue	EN ISO 10370
4	Carbon residue — 100% distillation sample	ASTM D4530
5	Cetane number	EN ISO 5165 or ASTM D613
6	Contamination (total)	EN 12662 or ASTM D5452
7	Copper strip corrosion	ASTM D130
8	Density	ASTM D1298 or EN ISO 3675
9	Distillation T90	ASTM D1160

Item	Substance or property	Testing method
10	Ester content	prEN 14103
11	Flashpoint	ASTM D93
12	Glycerol (free)	ASTM D6584
13	Glycerol (total)	ASTM D6584
14	Metals — Group I (Na, K)	prEN 14108 and prEN 14109
15	Metals — Group II (Ca, Mg)	prEN 14538
16	Oxidation stability	prEN 14112 or ASTM D2274 (as relevant to biodiesel)
17	Phosphorus	ASTM D4951
18	Sulfur	ASTM D5453
19	Sulfated ash	ASTM D874
20	Viscosity	ASTM D445
21	Water and sediment	ASTM D2709

(2) For subsection (1):

(a) ASTM followed by an alphanumeric code means the testing method developed by ASTM International under the alphanumeric code; and

(b) prEN, EN and EN ISO followed by a number means the testing method developed by the European Committee for Standardisation (CEN) under the code and number.