Report

New Zealand Oil Security Assessment Update

NZIER Report to Ministry of Economic Development

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Key points

The 2005 *Oil Security Review* provides a sound approach to assessing oil security, by comparing the costs of various disruption risk scenarios with the cost of taking precautions against or mitigating that risk. This is consistent with an economic definition of security as that level of oil supply that minimises the combined cost of disruption and precautionary actions over time.

The costs of major oil supply disruptions can be large and escalate rapidly, but such disruptions do not happen often. Comparing the potential impact costs in probability-weighted expected values provides a means of assessing how much it is worth spending to reduce those potential impact costs.

The 2005 Report also estimates an optimal level of storage for New Zealand and finds existing commercial storage sub-optimal, concluding that market failures in the oil supply sector warrant provision of additional storage. These conclusions are no longer valid. The 2005 Report was prompted by recognition that New Zealand was at risk of failing to comply with its IEA obligations to hold stocks equivalent to 90 days of net imports and has a focus on providing additional domestic storage in New Zealand. Since then:

- Government has achieved IEA compliance since 2007 by taking out ticket contracts with suppliers in other IEA member countries, thus providing volumes of oil that could be released if needed for an IEA intervention
- Domestic production of oil in New Zealand has risen and reduced the net import requirement, although production is now declining again, with fluctuations in additional storage requirements
- The costs of providing new capacity have risen substantially, as demonstrated in the 2010 *Petroleum Reserve Stock Strategy Review*.

IEA compliance is about New Zealand's ability to contribute oil stocks to IEA interventions in the international oil market to dampen serious disruptions. For that purpose it matters little where stocks are held, and holding stocks in other countries is worthwhile as long as it is the most cost effective way of meeting these obligations. But such overseas commitments do little to alleviate domestic disruption or alleviate risks of failures of domestic infrastructure. IEA compliance sits to one side of the oil security issue, which is about minimising the expected value of disruption impacts through cost effective measures of precaution or mitigation of impacts.

The principal components of the economic impacts of oil supply disruption impacts are:

- Consumer losses, from price rises or contraction in consumption
- Loss of taxation revenue for government, due to reduced oil use
- Reduction in external costs of oil use (e.g. environmental externalities).

This review has updated the assumptions from the 2005 Report and applied them to seven revised scenarios of potential disruption impacts. Apart from updating we revise the estimation of externalities which are cost savings to offset against other costs of disruption. In the 2005 Report these were estimated too low, increasing the size of disruption cost. We also estimate impacts on jet fuel using a lower short run price response than in the 2005 Report.

The 2005 Report was confined to the externalities on road-wear and the environment, but two other externalities can be identified at the macro-economic level. These are the effects of shortage or price escalation on GDP and on consequent increases in payments on imports. To illustrate these effects and their distribution we examine the effects of shortage scenarios on an inter-industry economic model.

Six of the scenarios cover domestic infrastructure failures within New Zealand, and include two with nationwide impact, two with primarily Auckland impact, and two with local impact in Wellington and Christchurch regions. These events are relatively short lived and on past experience assumed to not cause either temporary or lasting price changes, as companies would co-ordinate a response to rectify any shortfall while continuing as close as possible with business as usual.

The seventh scenario covers an international disruption event that is likely to disrupt supplies for six months. It is likely to be mediated by market price responses, with a sharp spike in the immediate aftermath of the event, followed by a lower but still elevated price once remedial measures are in place.

We examine three estimates of the impacts of the disruption scenarios. These are:

- An update using the 2005 Report's consumer impact assumption adjusted by consumer price-index
- An update basing consumer impacts on fuel price-elasticity estimates
- An estimate using consumer impacts and other inputs from the 2005 Report.

Results are summarised in the table below.

		Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Low probability of occurring		0.20%	0.50%	0.20%	0.50%	0.15%	0.20%	2.50%
High probability of occurring		0.25%	1.00%	0.30%	1.00%	0.25%	0.30%	2.50%
New scenarios updated input								
Consumer surplus	$m	1,093.6	57.8	452.2	84.6	169.5	183.8	1,971.9
Tax losses	$m	138.0	8.9	65.1	10.9	20.2	22.7	39.8
Externalities	$m	-139.3	-6.0	-50.5	-10.5	-22.7	-23.8	-44.5
Combined	Total $m	**1,092.3**	**60.7**	**466.8**	**84.9**	**167.1**	**182.7**	**1,967.2**
Probability weighted costs								
Low probability	$m/year	2.18	0.30	0.93	0.42	0.25	0.37	49.18
High probability	$m/year	2.73	0.61	1.40	0.85	0.42	0.55	49.18
New scenarios alternative update								
Consumer surplus	$m	815.56	30.93	551.89	49.24	59.73	75.43	1,932.05
Tax losses	$m	137.99	8.86	65.11	10.92	20.18	22.71	39.26
Externalities	$m	-139.3	-6.0	-50.5	-10.5	-22.7	-23.8	-44.5
Combined	Total $m	**814.3**	**33.8**	**566.5**	**49.6**	**57.2**	**74.3**	**1,926.8**
Probability weighted costs								
Low probability	$m/year	1.63	0.17	1.13	0.25	0.09	0.15	48.17
High probability	$m/year	2.04	0.34	1.70	0.50	0.14	0.22	48.17
New scenarios 2005 inputs								
Consumer surplus	$m	896.2	47.4	370.6	69.3	138.9	150.6	1,919.0
Tax losses	$m	127.9	7.9	59.0	10.1	18.9	21.1	34.9
Externalities	$m	-41.1	-1.8	-14.9	-3.1	-6.7	-7.0	-13.1
Combined	Total $m	**982.9**	**53.6**	**414.7**	**76.3**	**151.1**	**164.7**	**1,940.7**
Probability weighted costs								
Low probability	$m/year	1.97	0.27	0.83	0.38	0.23	0.33	48.52
High probability	$m/year	2.46	0.54	1.24	0.76	0.38	0.49	48.52

The international disruption event has by far the largest potential impact, because high prices are paid by suppliers and passed on to all consumers in New Zealand. For domestic disruption the consumer impacts are borne primarily by contraction in fuel consumption at the margin.

The largest results come from the updates where consumer losses have been estimated by scaling up the 2005 estimates by consumer price index, the smallest come from the alternative updates using elasticity-based consumer impacts, and the estimates using 2005 inputs are between the two updates. The externality effects are substantially larger in the updates than in the results with 2005 inputs.

The distribution of impacts is concentrated on the transport sector and distribution sector (wholesale). For other sectors the effect of disruption is very slight, because of the low proportion of transport services in their total costs. Some service sectors may even gain during oil disruption as consumers substitute away from the more transport-reliant goods and services.

The two updated estimates provide a range within which the potential impacts are likely to lie. Because these disruption scenarios are more severe than anything that has been experienced in recent history, their probability-weighted "expected value" costs are relatively low. These expected values provide a basis for comparing against the annualised cost of precautionary and mitigation measures. We use the higher-bound estimates against which to assess mitigation and precaution options.

Options for alleviating the impacts of oil security centre mainly on increasing capacity in infrastructure and distribution on the supply side, or behaviour changing measures for demand side management.

New domestic storage is even less appealing as a remedial measure than in 2005 when compared with the expected value of disruption. The scenarios we model are larger than any disruptions that have been experienced in New Zealand in recent years, yet the expected impacts still fall well short of what would be required to justify new storage. Extra storage would provide some relief from shortages and at large scale could eliminate the shortage entirely in some of the scenarios, but the costs of provision are substantially higher than the expected value of the disruption impact avoided and Benefit-Cost Ratios in this analysis are mostly less than 0.5.

Increasing the capacity of the oil trucking fleet would enable transport of supplies around disruptions in the local supply chain, with the added flexibility of mobility and ability to be redeployed around the country. This is a less costly option than increasing storage. However, our estimates suggest that enlarging the New Zealand trucking fleet to cater for an event that may never happen is less cost effective than relying on shipping additional vehicles and bringing drivers from Australia or elsewhere to meet short term emergencies if they arise.

Building a RAP-WAP connection to by-pass disruption at the Wiri terminal is more likely to provide net benefits, as costs of jet fuel disruption would accumulate rapidly. Again, our estimates suggest that building in advance of an event that may never happen is less cost effective than rapid installation after a disruption occurs.

Various demand side measures could provide reductions in fuel use in times of crisis, but the resources required to achieve such behavioural shifts and maintain that behaviour are uncertain. Consumers will adjust voluntarily in response to changes in prices, in the shadow prices implied by increased queuing, and sometimes for altruistic motives. But there is information failure around the severity of disruptions and the ability of consumers to assimilate risks which could warrant some government intervention to manage events through a disruption.

Our estimates suggest with both the trucking and RAP-WAP connection some pre-emptive spending to speed up the response when needed would be worthwhile. It would also be useful to do further work on what would be required to secure fuel savings from demand side responses that are additional to those that come from unassisted actions.

The analysis in this report draws recommendations on preparatory work that could be done to improve security against disruption:

- Preparation for enlarging trucking capacity through pre-approving routes for over-sized vehicle use (up to $0.7 million)
- Preparation for rapid truck deployment by making arrangements for obtaining additional capacity from Australia (up to $0.2 million)
- Preparation for rapid completion of the RAP-WAP link to by-pass Wiri terminal disruption and restore jet-fuel into Auckland (up to $0.5 million)
- Identification of which demand side management measures deliver most additional demand restraint over the voluntary responses of consumers, and how to apply them in practice.

The analysis in this report is focused on short to medium term responses to potential security disruption. Long term exposure to disruption risk can be reduced by lowering the dependency on oil in sectors such as transport, but this is not examined in this report.

Contents

Appendices

Figures

Tables

1. Introduction

This report provides a review and update of the assumptions, methodology and analysis of an earlier assessment of New Zealand's oil security undertaken in 2004 and completed in 2005 (the "2005 Report").[1] It takes account of more recent studies into the oil security situation in New Zealand, some recent trends and developments in the production, import and consumption of oil in New Zealand, and also some implications from literature on the global oil security situation. It aims to provide recommendations for optimising oil security on the basis of comparison of costs and benefits of options identified for improving oil security.[2]

1.1 Brief context and background

The structure of the oil supply industry in New Zealand is illustrated in Figure 1 below. It is broadly the same as it was at the time of the 2005 Report.[3]

About 75% of New Zealand's oil energy needs are imported as crude oil for refining into petroleum products at the Marsden Point Refinery. From there they are distributed via the Refinery to Auckland Pipeline (RAP) to the terminal at Wiri, or via ship to 10 coastal tank depots, from whence further distribution occurs via road tanker wagons to retail outlets and other direct customers.

Domestic oil production from both onshore and offshore fields around Taranaki is variable but since 1974 has averaged about a third of consumption volume and has sometimes reached half of refinery intake. It is mostly light, sweet crude and is predominantly exported, as the Refinery is geared to using heavier, sourer and cheaper crude feedstocks. The balance of oil product supply is imported as refined product.

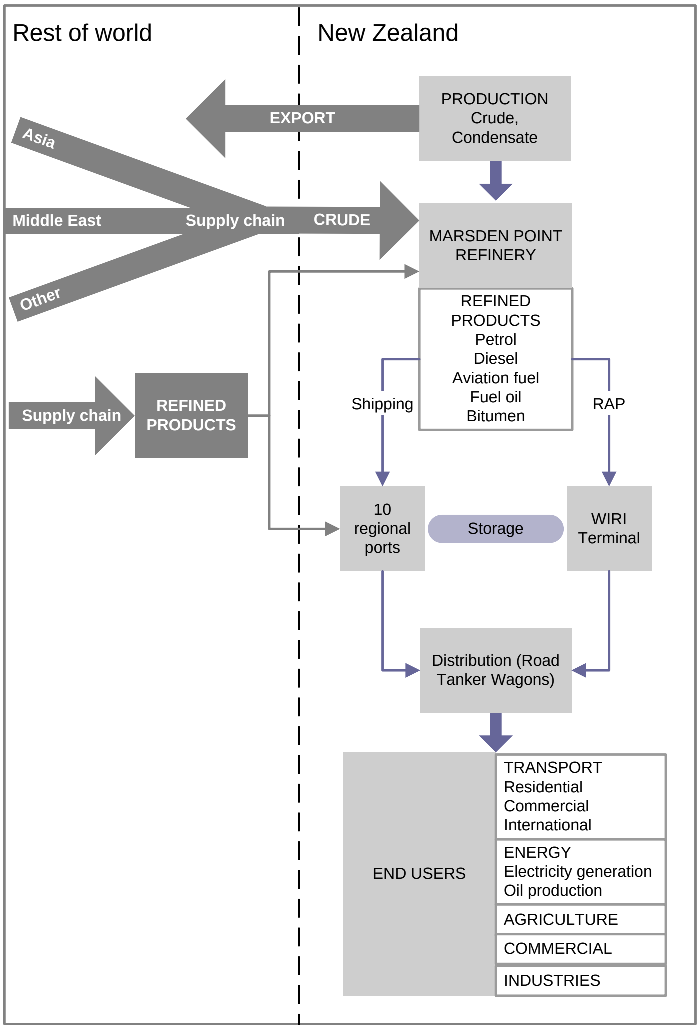
Four multi-national oil companies – Shell, BP, Mobil and Caltex – dominated wholesaling and retailing in New Zealand in 2004. An independent company, Gull Petroleum, imports refined product into Tauranga and has retail outlets in the upper North Island. A change since the 2005 Report is the sale by Shell of its downstream assets (wholesaling and retailing) to New Zealand owned Greenstone Energy, which has rebranded to Z Energy. Z Energy has initially been supplied by Shell, however, and can be expected to have secured supply in contracts and have access to similar response capabilities on overseas supply chains as the multi-nationals. Other changes have been the emergence of supermarket petrol retailing and Gasoline Alley Services, an independent company supplied by BP that has taken over retail outlets abandoned by other companies.

[1] Covec and Hale and Twomey Limited (2005) *Oil Security*, Report prepared for Ministry of Economic Development, Wellington

[2] The report has been prepared at NZIER with collaboration of Hale and Twomey Limited, one of the organisations that co-authored the 2005 Report. However, the economic analysis of that previous report remains with the previous authors, and the framework for that analysis is being reviewed and where necessary recreated in reaching the conclusions of this report. There may be differences in the fine detail of how this report and the 2005 Report analyse the issues and reach conclusions. We specify the principles and assumptions underlying this report so that such differences can be taken into account in interpreting the two reports

[3] The material covered by section 1 in the 2005 Report, describing the structure of the oil supply industry in New Zealand and the nature of New Zealand's obligations under the International Energy Authority's *International Energy Programme*, are out of scope of this review. They are touched on only to the extent necessary to identify significant changes that could affect the security assessment.

Figure 1 Structure of New Zealand oil supply



Source: NZIER

1.2 Outline

This report proceeds by

- Reviewing the 2005 Report and the findings of subsequent reports and international literature on the assessment of oil security
- Setting out a revised framework for analysis for this report, in light of that review, including defining the problem that security policies address
- Estimating the expected value cost of various types of disruption to oil supply, both those caused by international factors and those stemming from domestic supply disruption
- Estimating the expected cost of various measures that could be applied to improve security
- Comparison of the expected value cost of disruptions and the cost of ameliorating measures to identify an efficient or optimal set of policy responses to the security issue.

2. Review of earlier reports

The previous *Oil Security Review* (the 2005 Report) was prepared by Covec and Hale & Twomey Limited (H&T) in 2005. It provided:

- Background on the New Zealand Oil sector and IEA arrangements[4]
- Assessment of various sources of risk to security
- A calculation of the optimal level of storage based on a model for estimating the welfare cost of 5 scenarios of supply disruption, comparing the expected value welfare cost of supply disruption with the cost of storage provision
- Comparison of various options for addressing the shortage of current storage.

That report's findings included that:

- International risks are more likely than risks to the national oil supply chain
- There is market failure that means that the commercially optimal level of storage is less than the nationally optimal level of storage
- New Zealand had less than the optimal level of storage, which in turn was less than the IEA 90 day requirement
- Storage was the most favourable of the available options considered

Following the 2005 study, New Zealand has met its international obligations through ticket contracts held in Australia, Japan and Europe (from 2007).[5] The New Zealand government has offered tenders for additional reserve stocks held in New Zealand to count towards its IEA obligations, but has yet to receive any compliant bids.

2.1 Commentary on the 2005 assessment

The 2005 *Oil Security Review* provides a sound approach to assessing oil security risk that compares estimates of the expected value of disruption risks against the estimated cost of providing amelioration of that risk. That approach is broadly consistent with that proposed in this report's section 3, in that it:

- Aims to estimate the net benefits of amelioration measures
- Applies a welfare framework for estimating changes in economic surpluses to consumers and producers from potential disruptions
- Extends this to consider economic externalities from disruptions to oil supplies to New Zealand.

However, although the framework methodology of the 2005 report is sound, it does not follow that all the conclusions still apply. Some have been overtaken by subsequent events, such as the emergence of off-shore ticket contracts as a cost effective alternative to domestic storage. There are also a number of assumptions and conclusions in that report that could be challenged.

[4] The International Energy Agency (IEA) was established following oil shocks in the 1970s, and has an agreement with most OECD member countries on an International Energy Programme which provides procedures for mitigating future international supply disruptions. New Zealand is a party to this Programme and has obligations to hold 90 days net imports of oil requirement which may be made available to the IEA for responding to major disruption to the global market, and it also has obligations to institute other measures to manage demand in New Zealand during such an event.

[5] Ticket contracts are undertakings to store oil in an IEA member country which can count towards another IEA member's 90-day requirement, established under an agreement between the governments of the respective countries.

2.1.1 Market failure

The 2005 Report concludes that commercial storage is less than a nationally optimal level on the basis of a market failure analysis that contains some rather strong assumptions. It argues that market failure is apparent in the New Zealand oil market due to:

- Market power, as exhibited by the oil companies in NZ preferring quantity constraints to price rationing in times of short-term disruption, although rather confusingly the 2005 Report cites as evidence 1970s speed limits, car-less days and rationing of container sales which were regulatory impositions rather than signs of market players responding in non-competitive ways
- Externalities which arise when oil use decisions are made without consideration of the full range of impacts on third parties to the decision or transaction; and in the case of oil include both
  - Negative externalities, such as adverse environmental effects from oil use that may change in the event of supply disruption
  - Positive externalities that are unrewarded, such as a benefit to third parties from private measures to secure oil supply against disruption
- Oil security is a public good, because the assumed quantitative rationing that spreads fuel allocation restriction without regard to value to the consumer means that security is neither rival nor excludable
- Absence of good information among consumers about probabilities of supply failure may result in under-investment in security, compounded by an expectation that quantity rationing or other intervention provides for security.

There is a reasonable case for the existence of externalities and information asymmetry in oil supply, but the arguments for market power and public good are less compelling.

2.1.1.1 Market power

The four multi-national companies have dominated wholesaling and retailing in New Zealand since well before oil sector deregulation and removal of price controls in the late 1980s, but it is less obvious that such dominance allows exercise of market power to sustain raising prices above a competitive level.[6] Among those four, Shell, BP and Mobil have contended for leadership by market share and that leadership has switched between companies, but no one company has been able to secure and sustain leadership for long so competition may be sufficient to restrain emergence of a dominant supplier. Shell and reputedly at least one other oil major in the period since 2005 have sought to sell their downstream wholesale/retailing businesses on the grounds that they are not sufficiently profitable and distract from their core activities in exploration and production. The new independent entrant, Gull, has not been able to expand its market share much beyond its bridgehead around Tauranga, Auckland and other centres in the upper North Island, which suggests it is not profitable to expand and may indicate that there are not substantial economic rents that can be skimmed off the incumbents exercising market power.

The 2005 Report inferred that the companies preferred quantitative rather than price responses to short term supply disruption in the New Zealand market. The extent to which companies avoid using price rises to respond to localised shortages is a testable

[6] A 2008 review by Hale & Twomey of the competitiveness of the New Zealand's petrol market found business concentration which may be a precursor of market power but did not evaluate profitability or establish its extent.

hypothesis that is not examined here, but it raises the question of why they would forgo opportunities for increasing profit for the benefit of their consumers, particularly as they are less reticent in passing on increases in the price of oil? Localised shortages are mostly due to failures in shared infrastructure which is used by all the main suppliers, so it is possible that quantitative preference reflects brand protection and companies' unwillingness to alienate customers with pricing behaviour that might appear to be exploiting shortages caused by faults in the companies' supply chain. In other words competition is sufficient to make the threat of losing market share palpable and something to be avoided. This is not the exercise of market power in its normal sense. We do not agree with the 2005 Report that market power can be proven as the indicators referred to above are ambiguous and establishing the extent (if any) of market power is beyond the scope of this current report.

2.1.1.2 Oil security as a public good

The 2005 Report suggests that oil security is a public good because quantitative rationing spreads fuel allocation evenly across the community, reducing the risk of losing supply for individuals in a way that is indivisible across the community. This argument rests on the non-rival, non-excludable consumption characteristics of public goods. A fundamental characteristic of a public good is that it provides a net social benefit: but as the 2005 Report acknowledges, seeking oil security by spreading quantitative restrictions evenly across the community allocates restricted supply irrespective of where it is valued most. The one thing that is certain from such a response is that oil will not be allocated to its highest valued uses, unless a black market or other secondary trades emerge to reallocate and subvert the initial response. As black market responses and "profiteering" are generally discouraged in such public policy responses, quantitative restriction is likely to be an impediment to allocative efficiency in responding to a disruption. It is quite likely, therefore, that such responses to disruption would not achieve benefits in excess of costs sufficient to be regarded as a public good.

2.1.1.3 Positive externalities of private storage

The 2005 Report argues that those who privately provide for their own oil security also create a positive externality for those around them by increasing the availability of oil that may be reallocated to higher value uses in times of crisis. That is valid in the sense that a community with private reserves is better off than one without it in the event of a crisis. The social value is essentially an option value to access and convert the private reserves under certain contingencies, and depends on the expected value of exercising the option being less than the expected value of dealing with the disruption in the next best way in the absence of the option. Private storage may be at less than the socially optimal level because such positive externality goes unrewarded, but the public option value need is not necessarily large enough to cover expected costs of additional private storage levels.

2.1.1.4 Negative externalities of oil use

The 2005 Report draws attention to negative externalities of oil use that arise from oil-based transport, such as traffic accidents and pollution. In estimating the value of these externalities the report assumes these effects reduce linearly in response to reductions in oil supply and use, with the result that supply disruption has a positive welfare effect in reducing these negative externalities. While this is a pragmatic approach to valuing the effects of a disruption, it is not necessarily realistic: international literature on the relationship between transport activity levels and such negative externalities gives rather mixed results, and it is possible that short term disruptions could increase, rather than reduce, some of these externalities as people revert to second choice or other inferior substitutes for their current transport choices.[7] In relation to total costs of disruption in the 2005 Report these effects are relatively small and unlikely to be critical, but there is a risk that on some of the estimates the sign is pointing the wrong way.

The 2005 Report estimates average accident costs and road wear costs per litre of fuel consumption on an assumed annual consumption of 22,549 million litres in 2003 (page 49). Actual consumption of petrol and diesel in recent years has been more in the region of 6,000 million litres (4-5 million tonnes) per year, so the 2005 Report overstates the consumption and understates the average cost of external effects for estimating changes in consumption levels. This has an appreciable effect on the results of the 2005 Report.

2.1.1.5 Other market failures

Other market failures and externalities that are not in the 2005 Report are sometimes claimed as a reason for promoting oil security. For instance, increased oil consumption increases a country's exposure to risk of disruption and associated GDP losses and macro-economic costs in the event of disruption (Brown 2009). Similarly, increased consumption that raises the level of required imports of oil has effects on balance of payments and exchange rates that have wider impact across the economy than just those making decisions on consumption and import of oil. While individual consumers may internalise the risk to themselves of supply shocks, they are less likely to account for how their demand exacerbates the risk to all other consumers in the economy. Hence there is an element of externality – an adverse effect imposed on the rest of the economy from the actions of a subset within it. Such considerations apply to all market goods, and corrective action with respect to oil alone could distort relative pricing across the economy with perhaps unforeseen consequences.

2.1.2 Other aspects of the 2005 Report

The finding that there is a greater risk of international disruption than of domestic disruption requires some qualification. Disruptions arise regularly in the international oil market and the resulting price variations are spread across the international market, which oil wholesalers pass onto consumers in New Zealand. Most of this is routine market variation and it takes exceptional circumstances to trigger a situation in which the equilibrating function of the market is under real stress. In contrast, domestic disruption due to infrastructure failures is by definition non-routine. The 2005 study found the risk of failure in individual components of the New Zealand oil supply system to be exceptionally low, but there are potential vulnerabilities – a single refinery handling the majority of the country's product, a single pipeline supplying the largest city, a coastal distribution system comprising two ships, storage infrastructure with limited headroom that already involves oil wholesalers sharing capacity and product on a mutual exchange basis.

The 2005 study refers to a limited number of security indicators such as the quality and type of stock available, location of that stock, and alternative means of distribution of stock, and compiles an even shorter national indicator based around days' worth of four specified products in terminals and at the refinery. However, international literature on oil security often uses a wider range of indicators e.g.

- Domestic production capacity

[7] For example, a temporary mode switch to more walking and cycling in mixed traffic streams could increase the exposure to person-vehicle collision risks, and to the extent that such switches reduce road congestion and allow increased vehicle speeds, they can raise the severity of crashes.

- Import dependency
- Import concentration (by source, or specific route)
- Petroleum inventory stocks relative to imports
- Ability to second-source imports in the event of disruption.

Some of these, like import dependency, arise from a confusion of oil security with self-sufficiency, as the risks around import supply are not so much of being unable to access product as with the price that has to be paid for it. Nevertheless a wider indication of security could arise from supplementing days cover with indicators on the ability to second-source imports in the event of disruption of normal supply, and availability of alternative means of distribution to get around local bottlenecks.

2.2 Other reports

2.2.1 Petroleum Reserve Stock Strategy Review

In 2010, Hale and Twomey prepared a *Petroleum Reserve Stock Strategy Review* which was based on the expectation of an increase in reserve stock holding requirement due to domestic production declining (H&T 2010). It gives a detailed estimate of likely stock holding requirements in the period to 2015 and considers the options for meeting that requirement, including storage and the availability of ticket contracts in the future.

Historically New Zealand relied on commercial stocks for compliance with its IEA obligations, but a combination of leaner commercial stockholding practices and variable domestic oil production led to a risk of breach of IEA requirements. Since 2004, total demand has levelled out after a period of strong growth, in face of engine efficiency improvements, rising prices and the effect of recession in curtailing transport activity. But relatively large variations in domestic production drive variability in net import requirement that makes holding additional domestic stock a costly option.

The report found that New Zealand should be able to continue to obtain ticket contracts in the countries it currently uses (Japan, Netherlands and UK), albeit at a higher price because of increased demand from other countries like Australia that may seek to use ticket contracts for their IEA compliance. The UK's dwindling oil exports raise questions over its continuing ability to supply ticket contracts, so the report recommended entering Government to Government agreements with more countries to ensure it always has three or more countries that supply such contracts to choose from. It also found that the costs of additional storage provision in New Zealand were increasing due to both rising infrastructure costs and rising product prices, and it recommended closer examination of the economics of domestic stock holdings in New Zealand.

2.2.2 Refinery to Auckland Pipeline Contingency Options

In 2011 Hale and Twomey prepared a *RAP Contingency Options* report that examined the risks to supply to Auckland via the Refinery to Auckland Pipeline (RAP) and associated Wiri terminal, and also options for re-establishing supply (H&T 2011). This found that in the event of pipeline failure, road tanker wagons from other coastal ports would have sufficient capacity to supply emergency services and a portion of other demand for most fuels, but that Auckland Airport could be deprived of jet fuel with no feasible alternative for making good the supply. It made a number of recommendations, including:

- Regulatory changes to facilitate effective response to disruption, such as:

  - Allowing trucks to over-load for a specified period during an emergency event to supply Auckland from other parts of the country
  - Allowing foreign vessels to trade on the New Zealand coast for an extended period during an emergency
- Provisioning measures to provide capacity to deal with an emergency event, such as:
  - The Wiri Terminal Board and Refining New Zealand to investigate the possibility of connecting the RAP and the Wiri to Airport Pipeline (WAP) and of implementing this contingency within a reasonable timeframe
  - Oil companies put in place arrangements to access drivers and trucks off-shore in the event of a significant disruption

Some of these recommendations are being investigated further by Government and they are reflected in the supply disruption scenarios.

2.2.3 Recent Australian reviews

In Australia in 2011, ACIL Tasman prepared a *Liquid Fuels Vulnerability Assessment* that used a computable general equilibrium (CGE) model of the economy to estimate GDP impacts from supply disruptions, specifically a cessation of available supply from Singapore. While this estimated both national GDP and sectoral impacts – finding agriculture and mining particularly hard hit by price rises – the use of CGE in this way to predict effects of temporary disruptions is unfounded. Such models track the effect of moving from one equilibrium to another in response to price shocks, a process that may take much longer than the length of the short term supply disruptions being considered, so the impact figures can substantially overstate the impact of short term disruptions.

ACIL Tasman found that shifts in crude oil supply lead to disproportionately large price changes because price responsiveness of demand and supply is very low in the short-term, and also low in the long term relative to most other goods and services. On the supply side, short term responses are only possible if there is spare production capacity. On the demand side response depends on the ease of accessing alternatives. Overall it found no significant change in Australia's fuel vulnerability from the previous assessment in 2009, despite Australia regularly breaching its IEA 90 day requirement since then, and it argued that access to a functioning international market was the best security option.

At the end of 2011 Australia issued its *National Energy Security Assessment* (NESA) which had similar findings. It found the ability to bring on adequate investment in future energy infrastructure in future decades will determine levels of energy security. Unlike electricity and gas, it found liquid fuel supply is more dependent on global supply chains and international outcomes than on domestic policies, and geopolitical risks and the length of supply chain are major sources of potential insecurity. Government's role is largely in creating a policy environment in which private sector invests and attracts global capital to energy supply. Like the ACIL Tasman report it found access to well-functioning international markets with robust and flexible supply chains is the key to oil security.

The NESA found no evidence that rising Australian imports that put pressure on the IEA 90 day stock holding requirement is evidence of an emerging domestic security problem. It noted there was upward price pressure from climate change policies, but that that did not change the overall security level.

2.2.4 Demand restraint and other measures in New Zealand

In 2010 the IEA issued a report on oil and gas security in New Zealand, with particular attention to New Zealand's compliance with the IEA stockholding obligations, and its ability to enact other measures in the event of a crisis. It noted that ticket contracts held by New Zealand in other IEA member countries could be readily released for use in IEA interventions, and other measures would be applied domestically in New Zealand to reduce its depletion of remaining oil stocks. The International Energy Agreement Act (1976) sets out the powers and obligations to act in IEA compliance, and the Petroleum Demand Restraint Act (1981) confers other powers for enacting domestic measures.

Other measures identified by the IEA, and which are included in the Oil Emergency Response Strategy (MED 2008a), include:

- Demand restraints, in particular targeting voluntary measures in the transport sector that uses 83% of oil in New Zealand, and which, being voluntary, need no legal enforcement
- Fuel switching, for which there are very limited options, because there are few non-oil powered vehicles and very little use of oil in electricity generation and industrial heating which in other countries offer more substitution possibilities
- Surge domestic oil production, which could not be brought in within 30 days, has modest effect on fuel production and potentially could damage wells
- Relaxing fuel specifications to increase the likelihood of a wider range of offshore sources being acceptable for sale in New Zealand.

The second and third bullet offer little scope for easing disruption, and the fourth may also be of declining significance, as fuel specifications in Asian suppliers are being raised to meet the standards for OECD markets such as EU and USA (and hence also New Zealand). There are also a number of mandatory measures that could be introduced if voluntary demand restraints are not successful.

Such mandatory and voluntary measures were canvassed in another 2005 report on *Oil Demand Restraint Options for New Zealand* (Covec and Hale and Twomey 2005a). This drew on experience of fuel price protests in the UK in 2000, and also an IEA guidance note in 2004 on *Saving fuel in a hurry*. The UK protests, which led to the abandonment of an escalating carbon levy on petroleum fuels, identified the risks of private hoarding in exacerbating shortage and increasing costs through excess queuing for fuel, causing a *prima facie* externality that could warrant intervention such as minimum purchase amounts to deter people from repeated refilling. The report canvassed a range of demand restraint options, from the purely voluntary to mandatory measures like rationing and carless days, some of which are revisited in section 5 of this report.

2.3 Summary

The 2005 Oil Security Assessment Report provides a sound basis for assessing oil security. Specific assumptions will be revisited and updated later in this report. The Report overstates the extent of market failure in oil security, particularly with respect to supposed market power of incumbent suppliers, which has a bearing on the extent of intervention and who pays for it, but that is not a matter addressed by this report.

This current update of domestic oil security comes at a period when global oil production and demand have plateaued after strong growth in the early 2000s, with demand in developing countries offsetting flat or falling demand from recession-hit OECD countries (see Appendix B). New Zealand's supply and demand have also been flat, and with changing vehicle technologies demand may not recover to previous levels once the economy recovers from the current recession.

Much of the literature on oil security makes the point that in the long term, the impacts of oil insecurity depend on how oil dependent the economy is: moves to reduce oil dependency through diversity of fuel use and availability of substitutes will tend to reduce the impact of disruption, but that must be matched against the cost of providing such diversity. In this respect New Zealand does not appear to have diversified in recent years and may even have become more concentrated on oil. The current New Zealand Energy Strategy has a key objective of promoting diverse energy sources.

Some forecasts of potential futures with reduced oil dependency have already been undertaken (MED 2008b). As noted by the IEA (2010) there is little scope for fuel switching because of low use of oil in sectors other than transport, there are low numbers of non-oil using vehicles with limited numbers of gas vehicles and electric vehicles yet to get beyond pilot stage. While biofuel blends are available for land transport and being trialled for aviation, these are being used as fuel extenders rather than substitutes for mineral oil. That may help to minimise the impact of a short-term disruption, but its scale does not yet make significant inroads into the dependency on mineral oils exposed to long global supply chains.

3. Framework for analysis

While this report is an update of the 2005 assessment, from its terms of reference and discussion with officials its scope is rather different. The 2005 report was prompted by the realisation that oil stocks in New Zealand were materially below the levels required for the country to meet its stockholding obligations to the International Energy Agency (IEA). Having identified a shortfall the 2005 report also set about estimating an optimal level of storage, as distinct from the level of storage required for IEA compliance.

For this report IEA compliance is still relevant, but it is not as central to the analysis as it was in 2005. Since 2007 shortfalls in domestic stock-holdings in New Zealand have been met by ticket contracts held overseas, that are available for release in an IEA intervention. These are likely to continue to be available, albeit at increasing price.

Ticket contracts cover New Zealand's international obligations but they are too far removed to add much to oil security in New Zealand in the event of short term disruption of supply. The oil security issue today is more about domestic economic impacts of short term supply disruptions, their scale and likelihood of occurrence.

3.1 What is oil security?

From a review of international literature there does not appear to be a widely accepted definition of oil security. Definitions are often implicit rather than explicit, or built around readily obtained measures without a clear economic rationale. A commonly used measure is net oil import dependency, which may indicate a security problem to the extent that disruptions to imports create costs over and above what would be experienced with a less import dependent oil supply. But despite importing most of its oil for final consumption, New Zealand's oil production and export lowers its net import dependency and provides little basis for determining an economic level of security. Put another way, reducing import dependency may increase the costs of oil supply, replacing periodic price hikes with a continuous exposure to increased domestic supply costs, with all that implies for competitiveness and welfare across the economy.

The Australian NESA (2011) defines energy security as "the adequate, reliable and competitive supply of energy to support the functioning of the economy and social development". This works as a mission statement for energy policy, but is less clear on how energy security is measured and how an adequate level is set.

A more economic definition might be that:

> Oil security is that level of supply that minimises the combined cost of disruption and precautionary measures; or in other words, that level of precautionary measures where the marginal cost of precaution just matches the marginal benefit of avoided disruption cost, so as to maximise the net benefit of precaution over time.

As in the 2005 Report, our approach is to examine the costs of specified scenarios of short term supply disruption and compare these against various measures to lessen their impacts, including storage, alternative sourcing from overseas, fuel substitution and so on. The optimal level of security occurs where the combined cost of precaution and damage is minimised. There is no constant level of security: that will vary over time with changes in price, availability of supplies and so on. The principle however is to maximise the net present value over time obtained from precautions against infrequent shocks, by comparing the expected value cost of shocks and precautions.

In an integrated global market, fluctuations in supply are mediated through the price mechanism, and there is no market failure justifying intervention on such occasions. Very severe price shocks, however, could conceivably create negative externalities if they lead to consumption responses that do not take account of the effects on other consumer groups (such as hoarding or excessive queuing). There is also potential for localised shortages to form around infrastructure bottlenecks and failures.

Accordingly we distinguish two types of shortage and disruption events:

- International supply disruptions, which are principally mediated through the market price mechanism and have limited scope for short term amelioration measures
- Domestic disruptions caused by temporary infrastructure overload or failure, which can cause physical shortage of product due to constraints in the back-up infrastructure, and for which price response is likely to be suppressed by oil companies seeking to minimise undue consumer reaction

3.2 Framework outline

If oil security is defined as a level of precaution in oil supply where the marginal cost of precaution equals the marginal cost of disruption, then it will differ from the current level of security in New Zealand determined by oil wholesalers' commercial management of the supply chain if there are external costs from supply failure that the companies do not take into account. Those most affected by such costs could take out private insurance or other measures to hedge such risks, but may not do so if the cost is prohibitive for individual action or if they are unable to assess the risk they face – a form of information failure. The public policy question is, are there avoidable costs from security risks that could be cost effectively reduced by additional precautionary measures?

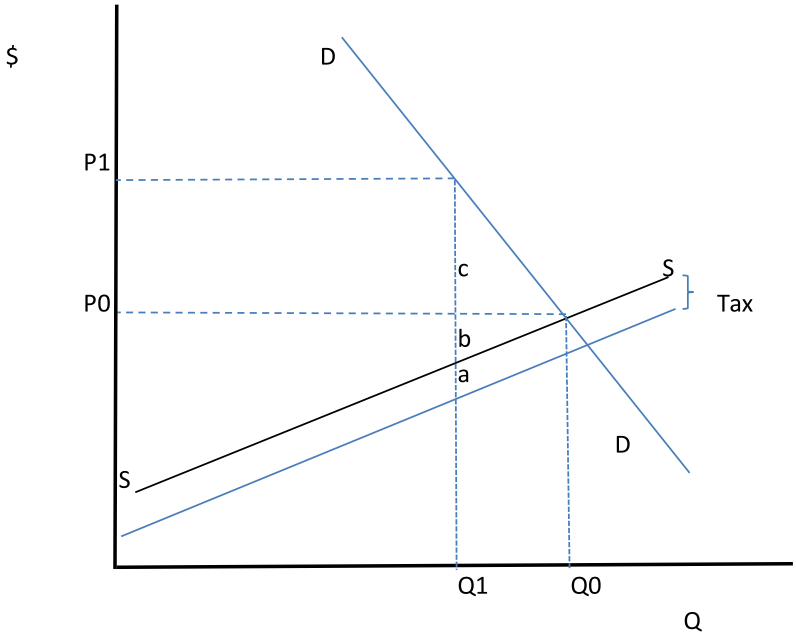
Most shocks to oil security result from a temporary disruption in physical availability. In international markets this leads to price rise and demand response. Deep quantity constraints where customers are unable to obtain supply even if prepared to pay the price occur more rarely. In extreme events the IEA may intervene to reduce the restraint on physical availability, although it has only done so on 3 occasions over the past 35 years, and on those occasions oil and products were still available to consumers who were prepared to pay the price.

As in the 2005 Report, our approach to optimising oil security for New Zealand is to identify various kinds of security event and the costs they cause, to compare against the cost of precautionary measures.

The framework we apply is cost benefit analysis, or applied welfare analysis, in which changes in consumer surplus and producer surplus indicate the welfare effects of a supply disruption and measures to counter it. The principal component of disruption effect is the welfare loss caused when price rises and demand contracts in accord with price elasticity, or if supply contracts with no price adjustment (see Figure 2 below). As in the 2005 report, we take the tax levied on oil products to be a form of economic surplus – it is paid by consumers to government and hence not a net cost to the nation. Any contraction of consumption due to disruption therefore causes a loss in consumer surplus, producer surplus and tax returns to the New Zealand government.

Figure 2 Welfare effects of supply shock

Consumer surplus (c), producer surplus (b) and tax wedge (a)



Source: NZIER

The 2005 report assumed marginal profits would be repatriated to overseas owners of the oil wholesalers so there is no welfare loss to New Zealand from changes in producer surplus. Since then, the sale of Shell's trading businesses to the Z Energy means about 25% of the New Zealand oil wholesaling and retailing is undertaken by this New Zealand owned entity, so changes in its producer surplus do count towards New Zealand's welfare.

The 2005 report also calculated changes in additional social externality costs, specifically greenhouse gas emissions, local air pollution, accidents and road damage (although not congestion, which could also change with an event that reduced the availability of transport fuels). These externalities provide a component of social benefit from oil disruption, which in the 2005 Report were assumed to reduce linearly with reduction in oil consumption and transport activity. However, such linear reduction is not necessarily valid for short term disruptions.

Our analysis takes a national perspective in measuring changes in economic surpluses arising from a security shock. It also includes a national input output table to trace the effect of oil shocks through first and subsequent round effects across the sectors of the economy, and a similar input output table for the Auckland regional economy, to examine the regional effects of disruption scenarios that primarily affect Auckland.

Our analysis is set at a high level and does not explicitly model the distribution of stocks of different fuel types at locations across New Zealand. Rather it treats New Zealand as a single pool, regards storage capacity as inter-changeable for use with different fuels, and focuses on only the three largest oil products – petrol (combining regular and premium), diesel and jet fuel - which in total comprise about 90% of petroleum consumption.

4. Costs of disruption

Costs of oil supply disruption are a function of the scale and timing of the event and result from price rises and production losses, covering both first round and secondary effects in consuming sectors. These costs also need to be assessed relative to the probability of occurrence. Combining costs and the probability of occurrence yields the expected cost of disruption against which the costs of policy options for improving security can be measured.

The 2005 Report approached this by postulating a range of most likely disruption events and estimating changes to economic surpluses and welfare caused by these events, for comparison against the cost of additional storage. We adopt a similar approach here, with the addition of some explicit inter-industry modelling of the effects on outputs and incomes for affected sectors in the economy.

The shortage and disruption event scenarios are drawn from a separate report by Hale and Twomey (2012) Limited. That report describes in more detail these scenarios and remedial measures that could be put in place. There are two groups of disruption risks: domestic disruption due to infrastructure failures that would not prompt a price response, and disruption to international supply chains that would be mediated through the market price mechanism.

An outline of the disruption scenarios is provided in the table below:

Table 1 Disruption scenarios

	Scenario 1 Long term Refinery Outage	**Scenario 2** Short term Refinery Outage	**Scenario 3** Long term RAP/Wiri Disruption	**Scenario 4** Short term RAP/Wiri Disruption	**Scenario 5** Long term Wellington Disruption	**Scenario 6** Long term Christchurch Disruption	**Scenario 7** International Disruption Event
Disruption period (days)	42	21	60	9	60	60	183
Shortage over period							
Petrol/diesel	24%	2%	12%	17%	15%	15%	0%
Jet fuel	48%	24%	65%	33%	0%	25%	0%
Total shortfall kilo litres							Demand chg
Petrol/diesel	172,750	7,416	62,608	13,080	28,113	29,567	55,226
Petrol	88,463	3,798	32,061	6,698	14,396	15,141	16,619
Diesel	84,287	3,618	30,547	6,382	13,717	14,426	38,607
Jet fuel	70,720	17,860	101,907	7,761	0	7,500	22,926
Petrol/diesel tonnes	136,706	5,869	49,545	10,351	22,247	23,398	43,703
Jet fuel tonnes	56,576	14,288	81,526	6,208	0	6,000	6,000
Petrol/diesel tonnes/day	3,255	279	826	1,150	371	390	239
Petrol tonnes/day	1,667	143	423	589	190	200	72
Diesel tonnes/day	1,588	136	403	561	181	190	167
Jet fuel tonnes/day	1,684	850	1,698	862	0	125	125
	4,939	1,130	2,524	2,012	371	515	364
Low probability	0.20%	0.50%	0.20%	0.50%	0.15%	0.20%	2.50%
High probability	0.25%	1.00%	0.30%	1.00%	0.25%	0.30%	2.50%

Source: NZIER drawing on Hale & Twomey Ltd (2012)

4.1 Domestic disruption events

Included in Table 1 are a number of internal risks to supply caused by infrastructure failures, which would be felt either nationally or regionally. As these are all relatively short term events, the assumption is that the oil companies will act to find ways around the disruption without raising price to ration demand. Nevertheless shortages of product do occur, the cost of shortages will be apparent in queues at petrol stations and the "shadow price" of oil products increases as users forgo some of the use that they would otherwise have made of oil products. The quantity restriction effectively shifts consumption back up the demand curve even in the absence of a nominal price rise, giving rise to a welfare loss.

Six scenarios cover these domestic disruption events, with two having nationwide impact, two particularly affecting Auckland, and a further two affecting each of Wellington and Christchurch. The impacts have been defined by H&T and are described in more detail in a separate report. The analysis in this report focuses on the consequences of the scenarios, the extent of physical shortage of different fuels, the duration of disruption, and the probability of such events occurring in view of the record of similar infrastructure in New Zealand and elsewhere.

4.2 International disruption event

The international disruption scenario has been derived by Hale and Twomey (2012) and informed by international reports assessing various forms of risk to the international energy supply system. Further details of this process are contained in Hale and Twomey's report on *Information for NZIER Report on Oil Security*. With hindsight viewing the source data referred to in the 2005 Report, it appears that the 2005 Report in common with other contemporary literature may have rather overestimated the risks to the system at that time.

For this updated assessment Hale & Twomey (2012) assume a 10% market disruption (~8.5 MMBD disruption) with a probability of 2.5%. This disruption volume takes account of current spare capacity in the system but not release of emergency stocks.

While the normal supply to the market is disrupted by 10%, the actual shortage will be less as:

- The market price for crude oil will rise substantially in response to the disruption having the effect of rationing demand as lower value uses are switched to other fuels or avoided altogether
- Release of many countries strategic reserves (both IEA countries and other countries with reserves such as China) will help minimise the shortage although it will also mitigate the price rise somewhat. Based on partial release of the strategic reserves we estimate that the physical shortage would reduce to 5% (i.e. strategic stocks offset half the disruption).

Once these changes are allowed for, an international disruption of this magnitude would raise international crude prices by an expected 37% over the 6 months affected after an event. This would add 46c/litre to price of refined products in New Zealand, specifically rises of 21% for petrol, 32% for diesel and 36% for jet fuel, the different proportions being caused by the differing levels of taxes in the market price of these fuels.[8]

[8] The NZ price increases are estimated with an assumed exchange rate of US$0.82 to NZ$1, as detailed in H&T 2012. The exchange rate and fuel price assumptions were both taken in March-April 2012,

These higher prices in New Zealand cause demand to contract and create a consumer welfare loss, tax losses and externality effects as in the case of the domestic shortages. But in addition, all consumers pay more for their oil products, which ultimately returns as revenue to overseas producers and is lost to New Zealand. This is evaluated by calculating a "price excess" on existing consumption, as well as the welfare loss on contraction of consumption, only for the international disruption scenario (scenario 7).

Our modelling assumes the expected price effect lasts through the duration of the affected 6 month period, then reverts to pre-disruption levels. There will be an initial price spike when the disruption occurs (approximately double the above increase), followed by settling on a less extreme price rise once measures have been enacted to calm the market, such as releasing stocks or stepping up of short term production. Our estimates use this post-spike price as the expected value of price increase caused by the disruption.

4.3 Updating the 2005 Report's estimates

The 2005 Report estimated the costs of a range of scenarios of disruption impact similar to those which we update here. The three principal components of those estimates were the consumer welfare loss, the loss of tax revenues to government, and reductions in externalities associated with the use of oil, such as environmental emissions and accident costs. In general it calculates an average value per litre of product consumed as a basis for estimating the loss of value from reduced product availability for consumption.

Table 2 summarises main changes to updated input assumptions described below.

which by historical standards was a period when both were relative high. Movement in one tends to temper the effect of the other. Movement in both would change the NZ price impact, but not by enough to significantly change this analysis.

Table 2 Update and changes to input assumptions

Prices in nominal dollar terms

	Item	2005 study $/litre	2012 update $/litre
Consumer surplus estimates	Premium petrol	$ 7.16	$ 8.74
	Regular petrol	$ 6.82	$ 8.32
	Diesel	$ 2.90	$ 3.54
	Jet fuel	$ 0.60	$ 0.73
Tax loss estimates	Tax on net margin - Petrol	$ 0.035	$ 0.035
	Tax on net margin - Diesel	$ 0.023	$ 0.023
	Tax on net margin - Jetfuel	$ 0.006	$ 0.006
	FED and Local authority petrol tax	$ 0.420	$ 0.591
	Taxes on diesel (excl RUC)	$ 0.0036	$ 0.0038
	RUC revenue	$ 0.2567	$ 0.2268
Externalities			
Greenhouse gas emissions	Pre 2008, 0; post 2008, $15/t CO2	$ 0.038	$ 0.038
Local air pollutants	Standard measures of life time exposure to pollution not applicable to temporary disruptions	<$0.01	$ 0.01
Accidents	Assume marginal reductions in consumption lead to savings	$ 0.16	$ 0.58
Road damage	Transfund budgeted maintenance costs averaged over fuel consumption	$ 0.03	$ 0.17
Traffic congestion	Not covered		
All externality costs	Pre 2008	$ 0.200	
	Post 2008	**$ 0.238**	**$ 0.806**

International Price impact	Pre-shock price $/litre	Shock $/litre	%
Petrol	$2.19	0.46	21%
Diesel	$1.44	0.46	32%
Jetfuel	$1.28	0.46	36%

Source: NZIER

The main changes are in the assumptions for consumer surplus impacts and some of the items in the externalities. Reasons for these changes are discussed in more detail below.

4.3.1 Welfare loss

The 2005 Report estimated the welfare loss of reduced consumer surplus by calculating demand functions for each of regular and premium petrol, diesel and jet fuel, drawing on data and price elasticity estimates from the MED's *Energy Outlook* 2003. The report does not specify the derivation of these functions and we have not been able to replicate them here. *Energy Outlook* is no longer published in the same format with elasticities for different oil products. The most straight forward means of updating is therefore to apply a suitable price index to the 2005 estimates of consumer surplus per litre consumed.

Possible indexes to use are the RBNZ's Consumer Price Index for all goods, which increased by 22% between December 2004 and December 2011, or a specific CPI for petrol which increased by 74% over the same period. Because we are interested in the loss of consumer surplus, i.e. the value loss to other spending rather than the value loss to spending on oil products, we use the all goods index in the first instance but examine the effect of using other values in the sensitivity analysis (see s 4.4.1 and Appendix E).

The 2005 Report ignored changes to producer surplus caused by loss of product sales and additional costs incurred by oil companies during the disruption, on the grounds that the marginal profits would be expropriated from New Zealand by the multinational oil companies and would not constitute a loss of New Zealanders' welfare. Strictly that situation has changed slightly as a New Zealand company, Z Energy, will now collect some of the profit that would formerly have accrued to Shell. But as there is no practical way of attributing a share of producer surplus losses to a single company we retain the practice of the 2005 Report in not counting producer surplus changes. [9] Similarly, although H&T identify costs for companies in trucking fuel into areas suffering shortage which amount to almost $3 million in scenarios 3, 5 and 6, we assume these costs are primarily taken out of the company's profits and producer surplus and do not account for them here.

4.3.2 Taxation losses

The losses of taxation revenue associated with oil supply disruption were estimated in the 2005 report as revenue costs per litre, using the posted rates of fuel excise duty in the MED's *Energy Data File* which can be readily updated. It also calculated Road User Charge revenue on diesel vehicles as a value per litre of diesel consumed, and we have done the same with reference to the National Land Transport Programme 2009-2012. As in the 2005 Report jet fuel does not attract specific taxes.

The 2005 Report also estimated loss of income tax from reduced margins on sales for retailers and wholesalers. We have no recent data on net margins with which to update these estimates, so use the same ones as the 2005 Report.

4.3.3 Externalities

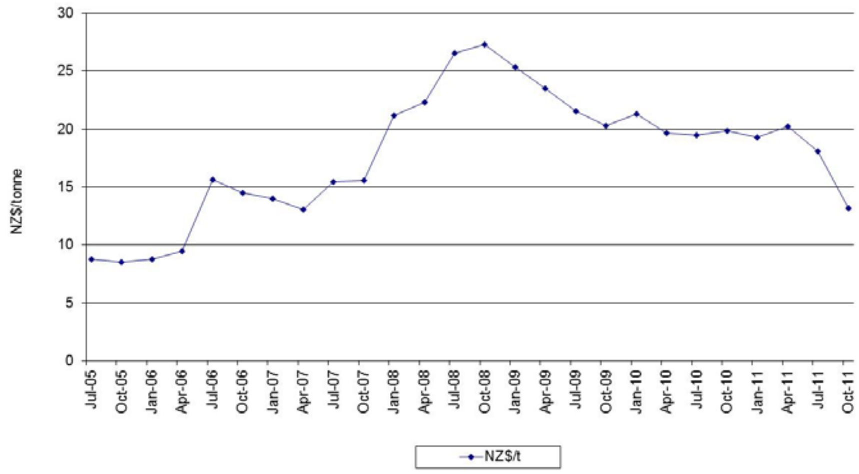
The 2005 Report took account of greenhouse gas emissions, local air pollution, accidents and road damage. Some of these estimates were understated by overstating the volume of litres consumed in calculating the averages, so we have changed some (but not all) these estimates.

4.3.3.1 Emissions costs

The greenhouse gas emission cost in the 2005 Report was split between $0 before the start of the Kyoto Commitment Period in 2008 and $15/tonne CO_2e after it. There is no longer a need for this split as under New Zealand's Emission Trading Scheme all greenhouse emissions in New Zealand incur a liability to hold carbon credits or emission allowances, resulting in a cost for New Zealanders, either for private parties where the emission obligation has been fully devolved, or for government to the extent that it has not. The critical issue now is what value to ascribe to greenhouse gas emissions?

[9] Z Energy is 50% owned by the Guardians of the New Zealand Superannuation Fund, and 50% by Infratil Ltd, which currently has 80% New Zealand shareholders and, according to Infratil's annual report, returns a profit of about 3 cents per litre. While a figure of 2.7 cents a litre could be used to estimate impact on producer surplus, uncertainty around market share makes this impractical.

Figure 2 Carbon prices in New Zealand since 2005



Source: NZIER from Ministry for the Environment data

In the long term emission credit prices are expected to rise as more countries take on binding commitments to reduce emissions and their target reduction levels get tighter, but the current recession has pushed back the likely timing of these price rises. In the short term there is substantial over-supply of emission units relative to recession-hit demand in both the New Zealand and European Emissions Trading Schemes which provide much of the focus for international trade, and prices fell further in late 2011 under the influence of the currency crisis in the Euro zone. This is apparent in Figure 2's time series of carbon prices as recorded by the Ministry for the Environment. With recent carbon credit prices around €7/tonne, NZ$15/tonne may appear on the high side, but on the assumption that prices will recover at some time in the future we retain $15 as the value used here.

The 2005 Report placed a low value of 1c/litre on emissions that create local air pollution, on grounds that most of the adverse effects of air pollution are cumulative over lifetime exposure and hardly affected by temporary disruption. This is a reasonable assumption which we retain in the update.

4.3.3.2 Road accidents

Accident costs were considerably understated in the 2005 report on account of being averaged across a 22 billion litre annual consumption, instead of the actual consumption of petrol and diesel that was nearer to 6 billion litres. We have corrected this error and updated the accident value with reference to the MOT's 2010 update of the social cost of road crashes and injuries. As a value per litre this changes from 16c in the 2005 Report to 58c in the current update.

4.3.3.3 Road wear and repair

The 2005 Report assumed a road damage cost of 3 cents per litre would be saved as a result of reduced traffic and wear and tear on the roads. This figure was derived by dividing the expenditure on road repair and maintenance from the National Roads Programme by the number of litres consumed.

Comparing figures from the respective National Land Transport Programmes, the cost per litre rises from 3 cents in the 2005 report to 17 cents in the current update. This is partly due to the overstatement of litres and understatement of the average in the previous report as mentioned above, but partly it also reflects an increase in road funding in recent years following the hypothecation of all fuel tax revenues to transport purposes in 2007. The current estimate covers operations, maintenance and renewals expenditure funded by both the NZTA and local authorities, but excludes capital upgrades and new roads. We retain this item in the analysis with the caveat that given the way budgets and maintenance cycles are met, and the likelihood that truck movements would rebound after the end of disruption, it is highly questionable whether short term disruptions would lead to savings in road wear and maintenance expenditure.

4.4 Results of welfare estimates

The results of the update with initial settings and assumptions are presented in Table 3, broken down into consumer surplus, tax loss and externality components. Across the scenarios the externalities avoided come close to cancelling out the taxation losses. As it is not clear that the largest components of externalities, accident costs and road damage, would necessarily reduce in linear fashion with reduced fuel use during disruptions, they could be removed from the estimate. That would leave consumer surplus accounting for about 89% of the total and taxation losses for 11% in the six domestic disruption scenarios, and 93% and 7% respectively across all seven scenarios including the international disruption.

The table shows the largest potential impact costs from domestic disruption arise with Scenario 1, which affects national fuel supply, and Scenario 3, which particularly affects supply to Auckland, Northland and Waikato. The potential costs for disruption to Wellington and Christchurch are substantially less than those of long term Auckland disruption, but still more than the costs of short term events at national level or in Auckland. The potential impact of the international disruption is almost twice that of Scenario 1, reflecting its long duration, price induced demand contraction and payment by all remaining consumers of higher prices to overseas oil suppliers.

The bottom of the table gives the expected value impacts per year by applying the assessed probabilities of each event. The largest expected value applies to the international disruption of Scenario 7, reflecting its higher probability. Of the domestic scenarios, 1 and 3 remain the largest, but a short term disruption to the RAP/Wiri terminal has a larger expected value than either the disruptions to Wellington and Christchurch, because a higher probability applies to disruption of the single facilities serving the Auckland region than to the multiple facilities in the other cities.

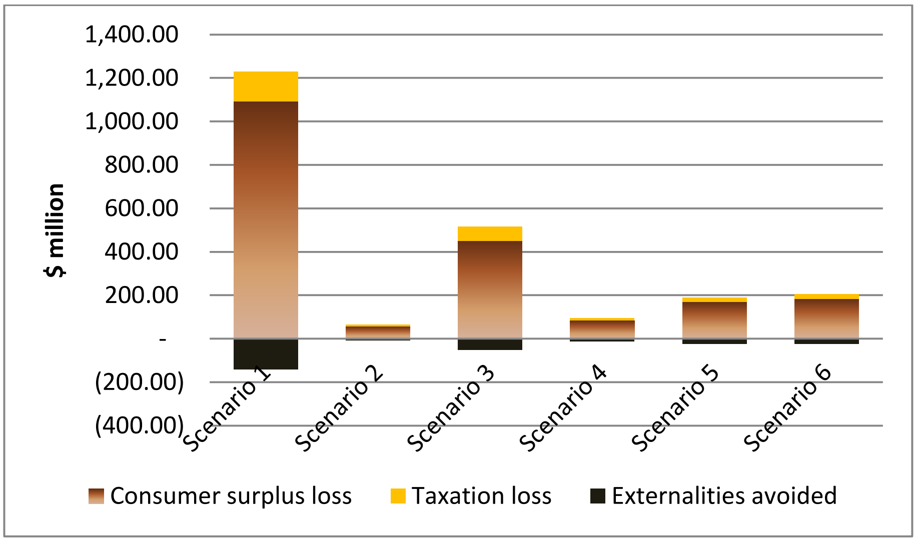
Table 3 Update of cost impacts of disruption scenarios

			Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Consumer surplus loss									
Petrol	$	8.40	743.53	31.92	269.47	56.30	121.00	127.26	860.13
Diesel	$	3.54	298.26	12.80	108.10	22.58	48.54	51.05	812.57
Jetfuel	$	0.73	51.78	13.08	74.61	5.68	-	5.49	299.19
	Total $m		1,093.57	57.80	452.18	84.56	169.54	183.80	1,971.88
Taxation loss									
Inc Tax Petrol	$m		3.07	0.13	1.11	0.23	0.50	0.52	0.58
Inc Tax Diesel	$m		1.95	0.08	0.71	0.15	0.32	0.33	0.89
Inc Tax Jetfuel	$m		0.44	0.11	0.64	0.05	0.00	0.05	0.14
Petrol FED&LAPT	$m		52.31	2.25	18.96	3.96	8.51	8.95	9.83
Diesel FED&LAPT	$m		0.32	0.01	0.11	0.02	0.05	0.05	0.14
RUC	$m		19.12	0.82	6.93	1.45	3.11	3.27	8.76
Jetfuel FED	$m		0.00	0.00	0.00	0.00	0.00	0.00	0.00
GST (all)	$m		60.80	5.45	36.65	5.06	7.69	9.52	19.50
	Total $m		137.99	8.86	65.11	10.92	20.18	22.71	39.84
Externalities avoided									
GHG	$m		-6.34	-0.27	-2.30	-0.48	-1.03	-1.09	-2.03
Air pollutants	$m		-1.73	-0.07	-0.63	-0.13	-0.28	-0.30	-0.55
Accidents	$m		-101.00	-4.34	-36.60	-7.65	-16.44	-17.29	-32.29
Road damage	$m		-30.20	-1.30	-10.94	-2.29	-4.91	-5.17	-9.65
	Total $m		-139.26	-5.98	-50.47	-10.54	-22.66	-23.84	-44.52
Combined	Total $m		**1092.30**	**60.68**	**466.81**	**84.94**	**167.05**	**182.67**	**1967.20**
Expected value impacts $m/year									
Low probability			2.18	0.30	0.93	0.42	0.25	0.37	49.18
High probability			2.73	0.61	1.40	0.85	0.42	0.55	49.18

Source: NZIER

The relative magnitudes of domestic scenarios are illustrated in Figure 3. Scenario 7's impact is much larger and has been omitted to focus on the domestic scenarios.

Figure 3 New domestic scenarios, updated assumptions



Source: NZIER

Assuming all six domestic disruption scenarios could occur in the same year – which is highly unlikely – and using the updated estimates, the expected value per year of all the domestic disruptions would range from about $4.5 million at the low probability of occurrence to $6.5 million at the high probability of occurrence. The expected value of international disruption dwarfs these domestic impacts, but there is little New Zealand can do to ameliorate these impacts, other than contributing to the IEA's efforts to moderate impacts. The expected value of domestic disruption defines a limit to the annual costs that it would be worth incurring to avoid those disruptions.

4.4.1 Varying assumptions

The low annualised value of disruption cost raises the question of whether the updates have sufficiently reflected the value changes since the earlier report. Updating the consumer surplus loss with the petrol-only CPI rather than the all goods index would see the disruption costs increase by almost 50%, so the summation of the expected values of the six domestic scenarios would rise to a range of $6.34 million to $9.3 million.

However, it is possible that the consumer surplus loss in the 2005 Report from which these estimates are based is over-estimated rather than under-estimated. When supply disruption occurs but suppliers do not raise their prices, users still face limits and less certainty than normal of replenishment of any fuel they use. The consumption that gets shed first will be discretionary, least valuable uses, valued at a marginal shadow price. The 2005 Report's description of calculating an average consumer surplus per product from market demand curves calculated from the intercepts with each axis (p 55) suggests it may have calculated an average across the whole demand curve, which would be higher than the marginal value of use averted.

As an alternative to the approach used in the 2005 report we have estimated the welfare triangle loss directly using price elasticities to estimate the slope of the demand curve and the implicit price under constraint.[10] The method is explained more fully in Appendix E and results are summarised in Table 4 below.

In its *Energy Outlook* (2003) MED used short run elasticities of 0.05 for petrol and 0.08 diesel, but it now uses input from a Ministry of Transport model with respective elasticities of -0.07 and -0.057 in 2006. Using these later elasticities and an elasticity of -0.10 for jet fuel, yields expected values across the scenarios markedly smaller than the update in Figure 2 above[11]: between $0.09 and $0.14 million for the Scenario 5 disruption in Wellington and between $1.63 and $2.04 million for the Scenario 1 refinery outage.[12] The summation of expected values across all scenarios ranges from $3.4 to $4.9 million.[13]

[10] This estimation process treats the supply contraction over the disruption period as a reduction in demand, and uses price elasticity for each fuel to estimate the increase in the implied shadow price, from which the welfare triangle or loss of consumer surplus can be calculated (see Appendix E).

[11] The 2005 Report and the update have low expected welfare losses for jet fuel, due to a low consumer surplus per litre consumed and low tax losses. That model puts most impact value on petrol, rather less to diesel and much less to jet fuel, which implies elastic jet fuel demand. But there is literature to suggest that the demand for jet fuel is actually very price inelastic, in the short-run at least – and it is the short-run response that is relevant for this analysis. For example, we found reports of short-run price elasticity of demand of –0.06, –0.07, –0.09, –0.10, –0.10 and –0.15 for six US airlines and an estimate of near perfect inelasticity in Israel. A recent study of transport and fuel use in New Zealand suggests demand may have become slightly more price elastic, with elasticities of -0.15 which, would result in no scenario having an expected value that exceeds $1 million if applied to all fuels (Kennedy & Wallis 2007), but that same elasticity across all fuels would not be realistic.

[12] The consumer surplus loss per litre ranges from $3.03 for diesel (up from $2.90 in 2005) to $3.76 per litre for petrol (down from $6.89 in 2005). The largest proportional change in loss per litre is on jet fuel, which rises to $3.23 (from $0.60 in 2005).

[13] Results are similar when using the MED's 2003 elasticities, slightly larger and with heavier impact on petrol consumers and lighter impact on diesel consumers.

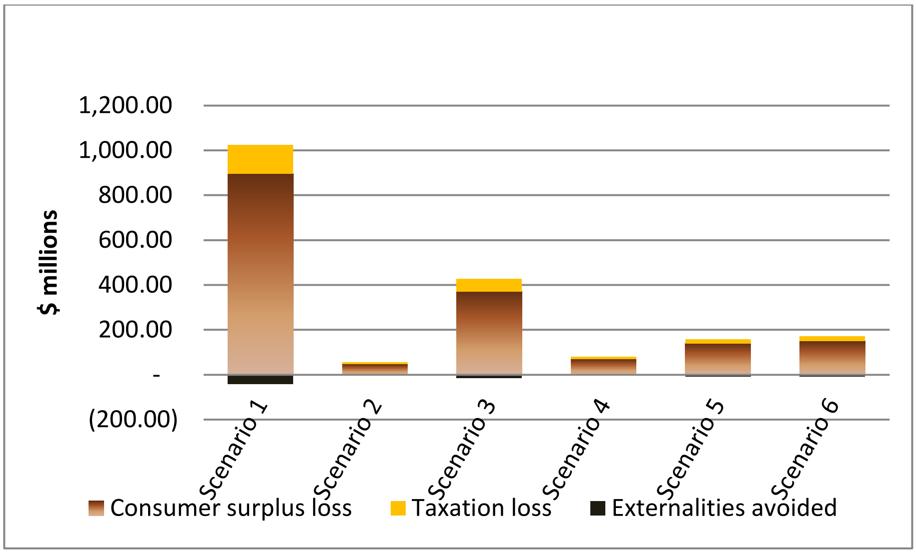
Table 4 Alternative estimate of updated disruption scenarios

			Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Consumer surplus loss									
Petrol	$	3.76	332.19	1.19	60.20	18.11	33.79	35.53	782.85
Diesel	$	3.03	255.08	0.91	46.22	13.91	25.94	27.29	792.79
Jetfuel	$	3.23	228.29	28.83	445.47	17.22	-	12.61	356.41
	Total $m		815.56	30.93	551.89	49.24	59.73	75.43	1,932.05
Taxation loss									
Inc Tax Petrol		$m	3.07	0.13	1.11	0.23	0.50	0.52	0.00
Inc Tax Diesel		$m	1.95	0.08	0.71	0.15	0.32	0.33	0.89
Inc Tax Jetfuel		$m	0.44	0.11	0.64	0.05	0.00	0.05	0.14
Petrol FED&LAPT		$m	52.31	2.25	18.96	3.96	8.51	8.95	9.83
Diesel FED&LAPT		$m	0.32	0.01	0.11	0.02	0.05	0.05	0.14
RUC		$m	19.12	0.82	6.93	1.45	3.11	3.27	8.76
Jetfuel FED		$m	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GST (all)		$m	60.80	5.45	36.65	5.06	7.69	9.52	19.50
	Total $m		137.99	8.86	65.11	10.92	20.18	22.71	39.26
Externalities avoided									
GHG		$m	-6.34	-0.27	-2.30	-0.48	-1.03	-1.09	-2.03
Air pollutants		$m	-1.73	-0.07	-0.63	-0.13	-0.28	-0.30	-0.55
Accidents		$m	-101.00	-4.34	-36.60	-7.65	-16.44	-17.29	-32.29
Road damage		$m	-30.20	-1.30	-10.94	-2.29	-4.91	-5.17	-9.65
	Total $m		-139.26	-5.98	-50.47	-10.54	-22.66	-23.84	-44.52
Combined	Total $m		**814.29**	**33.81**	**566.53**	**49.62**	**57.25**	**74.30**	**1926.79**
Expected value impacts $m									
Low probability			1.63	0.17	1.13	0.25	0.09	0.15	48.17
High probability			2.04	0.34	1.70	0.50	0.14	0.22	48.17

Source: NZIER

We also estimate the current disruption scenarios by substituting the 2005 input assumptions for the 2012 assumptions (see Table 2) and inputting into our updated model, to compare against the updates. Results are shown in Figure 4, and in Table 5. The updated results have a noticeably larger externality component, which largely offsets the tax losses and pulls down the net impact costs. Overall, however, the net impact estimated from the main update with index adjusted welfare inputs is slightly higher than the same scenarios estimated on 2005 assumptions, because the index adjustment of consumer surplus dominates other update changes. The alternative update with elasticity-based welfare inputs is rather lower than the results with 2005 assumptions. These results suggest the main update with index-adjusted welfare inputs is unlikely to understate the costs of impacts or precautions that would be worthwhile to mitigate them.

Figure 4 New scenarios estimated on 2005 assumptions



Source: NZIER

Table 5 Results of updated scenarios using 2005 inputs

		Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Consumer surplus loss								
Petrol	$ 6.89	609.33	26.16	220.83	46.14	99.16	104.29	834.92
Diesel	$ 2.90	244.43	10.49	88.59	18.51	39.78	41.84	787.91
Jetfuel	$ 0.60	42.43	10.72	61.14	4.66	-	4.50	296.16
	Total $m	896.20	47.37	370.57	69.30	138.94	150.63	1,918.99
Taxation loss								
Inc Tax Petrol	$m	3.07	0.13	1.11	0.23	0.50	0.52	0.58
Inc Tax Diesel	$m	1.95	0.08	0.71	0.15	0.32	0.33	0.89
Inc Tax Jetfuel	$m	0.44	0.11	0.64	0.05	0.00	0.05	0.14
Petrol FED&LAPT	$m	52.31	2.25	18.96	3.96	8.51	8.95	6.98
Diesel FED&LAPT	$m	0.32	0.01	0.11	0.02	0.05	0.05	0.14
RUC	$m	19.12	0.82	6.93	1.45	3.11	3.27	9.91
Jetfuel FED	$m	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GST (all)	$m	50.66	4.54	30.54	4.22	6.41	7.94	16.25
	Total $m	127.86	7.95	59.00	10.08	18.90	21.12	34.88
Externalities avoided								
GHG	$m	-6.56	-0.28	-2.38	-0.50	-1.07	-1.12	-2.10
Air pollutants	$m	-1.73	-0.07	-0.63	-0.13	-0.28	-0.30	-0.55
Accidents	$m	-27.64	-1.19	-10.02	-2.09	-4.50	-4.73	-8.84
Road damage	$m	-5.18	-0.22	-1.88	-0.39	-0.84	-0.89	-1.66
	Total $m	-41.11	-1.77	-14.90	-3.11	-6.69	-7.04	-13.14
Combined	Total $m	**982.94**	**53.55**	**414.67**	**76.27**	**151.15**	**164.71**	**1940.72**
Expected value impacts $m/year								
Low probability		1.97	0.27	0.83	0.38	0.23	0.33	48.52
High probability		2.46	0.54	1.24	0.76	0.38	0.49	48.52

Source: NZIER

These results retain the practice of the 2005 Report of excluding effects on producer surplus of foreign oil suppliers from the welfare impact calculation. Z Energy is 90% New Zealand owned and claims 3 c/litre profit, so if it bore disruption impact in proportion to its market share of the three fuels – assumed to be 25% - it would add to the total impact cost $1.6 million in Scenario 1, $1.1 million in Scenario 3, $0.5 million in Scenario 7 and less in all other scenarios. In expected value terms this translates to additional welfare cost of $4,000 in Scenario 1, less in all other scenarios. Omitting producer surplus effects of Z because of uncertainty over market shares does not significantly affect these results, and the same applies to Gasoline Alley and other minor New Zealand suppliers.

These estimates assume that for the domestic disruptions, oil companies do not respond by raising prices. This may have been the practice in the past but is not necessarily so for the future in face of potentially larger disruptions than have been previously experienced. Companies have an established methodology for translating international price movements into domestic markets, but there is no transparent method for adjusting prices in domestic disruptions. If companies adjusted prices to manage demand during domestic disruption, the main effect would be a price rise on remaining consumption during the disruption that siphons some consumer welfare loss into the pockets of mostly foreign owned producers, with the macro-economic effect of increasing payments to foreign suppliers that are ultimately expropriated as profits. If companies do not price for scarcity during disruptions, the stocks they hold are also worth less, reducing the incentive for companies to build more capacity. The assumption, if correct, would tend to reinforce the 2005 Report's conclusion that private storage provision is sub-optimal.

4.5 Estimating economy-wide effects

4.5.1 Determining the distribution of welfare impacts

The total welfare impact can be measured through changes in the market for fuel, subject to some assumptions.[14] That is what has been done in previous sections and the following analysis does not modify that or imply any additional welfare impacts. Rather, we investigate the distribution of changes in welfare across the economy. In particular, it would be interesting to know which industries are most affected by the fuel shortage.

We cannot directly estimate the welfare impact across markets, but we can gain some idea of the changes in output. That can indicate the level of concentration of output impacts, which has some correlation to the welfare impact.

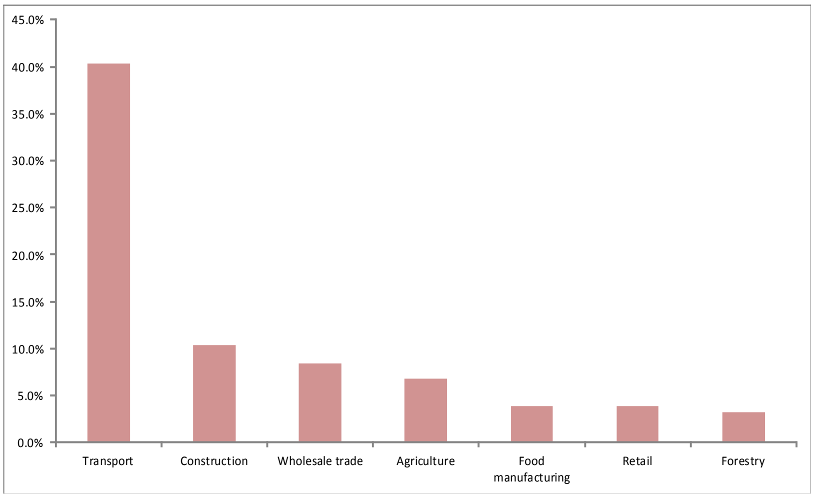
4.5.2 Use of fuel across industries

An important element of the overall cost of a supply disruption is the effect on downstream industries. Firms that use oil-based products will be forced to reduce their output, which then has effect upon firms who use their products. For example, the road freight industry is heavily dependent upon diesel and transports goods to market for many other industries (see Figure 5).

[14] The key assumptions are that empirically estimated fuel demand elasticities are used, and that markets are perfectly competitive. See Boardman et al (2006) p113-118 for a technical explanation.

Figure 5 Percentage of fuel used by each industry

Percentage of total fuel sales in New Zealand (2010), selected industries



Source: Statistics New Zealand, NZIER

Direct and indirect channels

The effect of the shortage is felt through two channels:

- **Directly through the availability of fuel**. The importance of this channel depends on how important fuel is to the industry and how available substitutes are. We have assumed that substitutes are unavailable at such short notice, so the importance of petroleum fuels to the industry is central to the impact
- **Indirectly through the effect on upstream and margin industries**. If an industry relies upon inputs that are produced by a fuel-intensive industry then it will be indirectly affected. Similarly, if it uses a lot of road or rail transport to move its products then it will be affected by the reduction in fuel available to those margin industries.

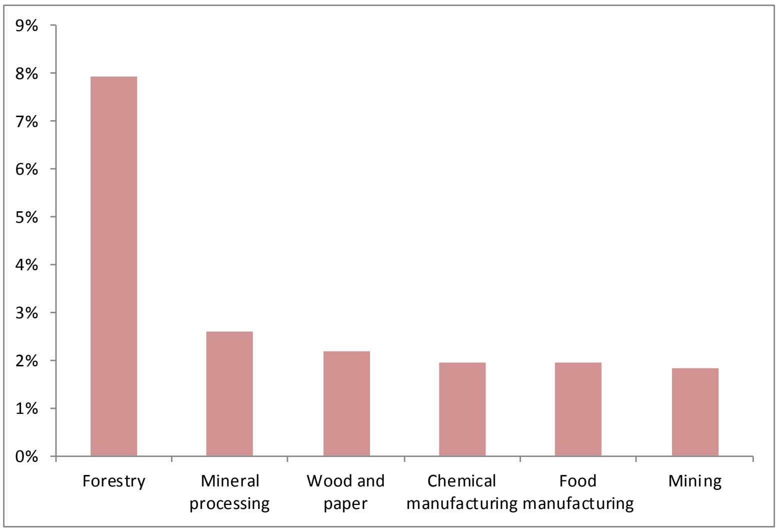
The main contributor to the distribution of direct effects is the extent to which industries use petroleum products. The largest fuel user, by far, is the transport industry (see Figure 5). Because transport is a 'margin' industry that enables others to trade we expect it to have a significant impact on the sales of any firm that relies upon it for moving or storing either inputs or outputs. The wholesale and retail trades are also margin industries that enable the sale of goods and services. Together, margin industries account for over half of all fuel use in New Zealand.

The importance of fuel to the transport industry is shown by its percentage of industry costs. For the transport industry fuel is 9% of total cost. For most industries the direct cost of fuel is less than 1% of their costs. Beyond margin industries the construction, agriculture, forestry and food manufacturing industries use the greatest quantity of fuel.

Figure 4 shows the percentage of each industry's costs that are attributable to their use of transport. Only the largest users are shown for brevity.

Figure 6 Percentage of industry costs attributable to transport

Percentage of industry total cost (2010), non-margin industries with greatest transport intensity[15]



Source: Statistics New Zealand, NZIER

The first notable aspect of the figure is that forestry and food manufacturing are exposed to both direct and indirect risk from an oil shock. The second notable element is how little of most industries' costs are attributable to transport. For most, transport comprises less than 3% of their total costs.

To determine the relative size of these effects we conducted some indicative modelling work, detailed in Appendix D.

4.5.3 Conclusions from modelling

4.5.3.1 Effects are concentrated

Using an input-output model we find that the oil shortage's primary effect is concentrated around the transport sector. Transport uses close to half of New Zealand's oil supply, by value, and could contract by up to 20% during a national oil supply shortage of 24%.

That contraction indirectly affects goods traders who rely on the transport sector for shipping their goods to market. However, because transport accounts for only about 1% of industry costs, a reduction in its volume does not have overly dramatic consequences for the wider economy. Our estimates suggest that goods manufacturers might reduce their output by around 0.5% in response to a 24% reduction in the supply of oil, as in Scenario 1.

The results are calculated at an extremely aggregated level and do not take into account the sensitivity of particular businesses to the shortage. There are likely to be some firms who suffer far more than that, as well as some who feel very little impact. For example, if milk trucks are reduced in frequency then farmers may have to dump milk, which would noticeably affect their revenues. It is likely that such sensitive industries would take some action to secure the supply of transport that they require, drawing from industries that

[15] Margin industries have been excluded from this figure for clarity. In fact, the transport industry is one of the largest users of transport in the database. That is due to aggregation of the numerous distinct transport sectors within a single category.

have less need. We have not modelled those re-allocations of supply, but they are likely to reduce the overall impact of the shortage.[16]

In sum, we can conclude that the calculated welfare effects are likely to be concentrated in a small number of industries that are heavily dependent upon the transport sector.

4.5.3.2 Household behaviour is important

The second finding of our modelling is that the impact on industries not directly affected depends largely on consumers' response to the shortage. An unanticipated shortage causes output in New Zealand to drop, which reduces national income for the duration of the shortage. There are two possible scenarios for the resulting change in household spending.

Households may choose to reduce spending commensurate with the drop in income during the period of the shortage. That would cause the output of retail and service industries to drop during the shortage.

However, some consumers with reduced incomes may instead borrow against future income, or reduce their saving. To the extent that consumption remains constant throughout the shortage, spending less on fuel would allow them to spend more on other goods and services. That would cause an increase in purchases among service and retail industries.[17]

In reality, the behavioural response will be somewhere in between. Consumers may defer purchase of large, durable items, while depleting savings to continue purchasing day-to-day goods and services at their usual rate or more.[18] What we can conclude from our modelling is that the response of consumer spending is far more important to service industries than the change in the cost of transport.

[16] The reason for excluding reallocation from our modelling is that the extent and direction of the allocation is difficult to determine without using a price signal. In the event of short-term shortages it is unlikely that all prices would adjust across the country, so accounting for the limited and partial reallocations that will occur is extremely challenging.

[17] This is the assumption made in the detailed results included in the appendices.

[18] Determining the exact response would require more sophisticated modelling techniques that consider people's intertemporal consumption decisions. Some form of rational expectations model would likely be required.

5. Costs of precaution

There are various precautions a country could take to soften the impact of supply disruptions when they arise.

The Government's Oil Emergency Response Strategy (2008) describes measures that would only be used if required to either fulfil New Zealand's obligations under the IEA, or respond to a disruption to oil supplies in New Zealand in circumstances where an industry response is unlikely to be sufficient. The measures in the Strategy would not be activated just for price management or to assist suppliers. The strategy outlines responsibilities and triggers for interventions on the supply side (stock drawdown, surge production, relaxing product specifications) and the demand side (voluntary restraint, mandatory restraint, fuel switching), and refers to energy efficiency campaigns that could assist in this process.

The types of responses to disruption are outlined in the table below. New Zealand is too small a player to have any influence on the international market on its own, so it must rely on co-operative action through the IEA to ameliorate the impact of extreme international events, and manage the consequences. For disruption due to domestic infrastructure the responses are determined by market players within the existing policy setting. To the extent there is demonstrable market failure or other policy outcomes affected by the disruption, government may intervene to promote certain responses or even provide them, either by tax-provision or regulation of private parties.

Table 6 Responses to different types of disruption

<table>
<tr><td colspan="3"><u>International disruption</u></td></tr>
<tr><td rowspan="4">Those triggering IEA response</td><td>Price spikes</td><td></td></tr>
<tr><td rowspan="2">Release of stocks</td><td>Offshore contracted stocks</td></tr>
<tr><td>Domestic storage</td></tr>
<tr><td>Demand restraints</td><td></td></tr>
<tr><td rowspan="3">Those below IEA trigger</td><td>Price spikes</td><td rowspan="3"></td></tr>
<tr><td>Unilateral stock release</td></tr>
<tr><td>Demand restraints</td></tr>
<tr><td colspan="3"><u>Domestic infrastructure failure</u></td></tr>
<tr><td rowspan="6">Any infrastructure disruption</td><td rowspan="3">Demand restraints</td><td>Voluntary</td></tr>
<tr><td>Promoted</td></tr>
<tr><td>Mandatory</td></tr>
<tr><td rowspan="3">Supply response</td><td>Voluntary</td></tr>
<tr><td>Promoted</td></tr>
<tr><td>Mandatory</td></tr>
</table>

Building on the previous studies we have examined:

- Increases in domestic storage
- Demand restraint, which the IEA 2010 identified as capable of delivering up to 6% reductions in consumption
- Other supply side measures to improve management of security
  - Provision of additional trucking capacity to expedite restoration of supplies after local disruptions in Auckland and elsewhere

– Provision of a pipeline to by-pass Wiri terminal to supply Auckland airport and alleviate vulnerability for jet fuel.

These measures contain a mix of one-off responses and long lived infrastructure headroom, the costs of which can be estimated for comparison against the expected value of disruption losses. We look at annualised costs and expected values of disruption, which provide a measure of annual risk over a period, rather than attempting to forecast variation in expected demand growth and future prices which increases the range of assumptions that need to be made.

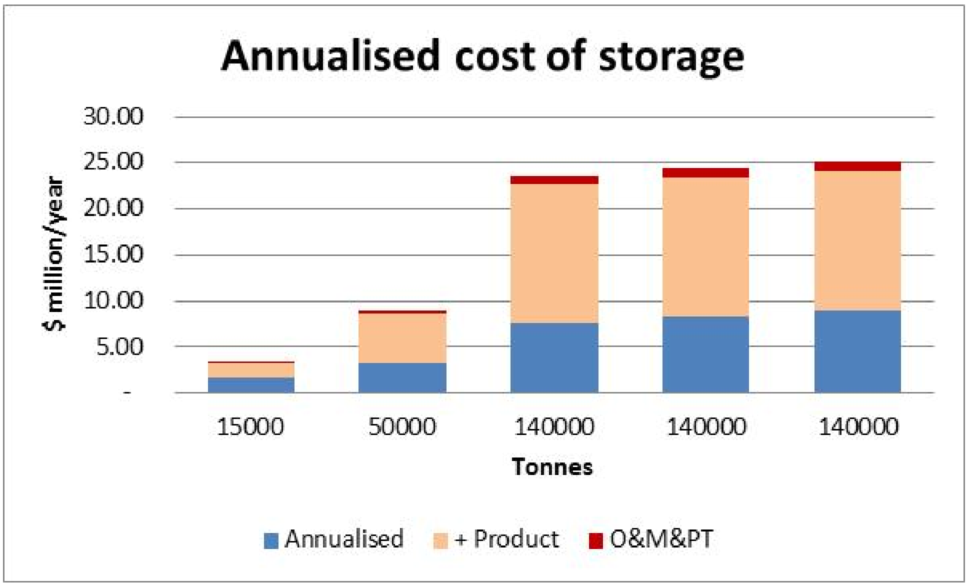
5.1 Supply side precautions

5.1.1 Increasing domestic storage

Domestic storage is one of the options for supply response, but there may be other ways of incentivising the oil supply industry to better manage security risks, for instance by requiring some of the economic rents earned in periods of shortage to be returned to consumers through other measures. Updated tank storage costs were provided in the *Petroleum Reserve Stock Strategy Review* 2010 and which form the basis of analysis here.

Figure 7 Annualised costs of new storage

Annualised over 40 years at Treasury's public sector discount rate of 8% real

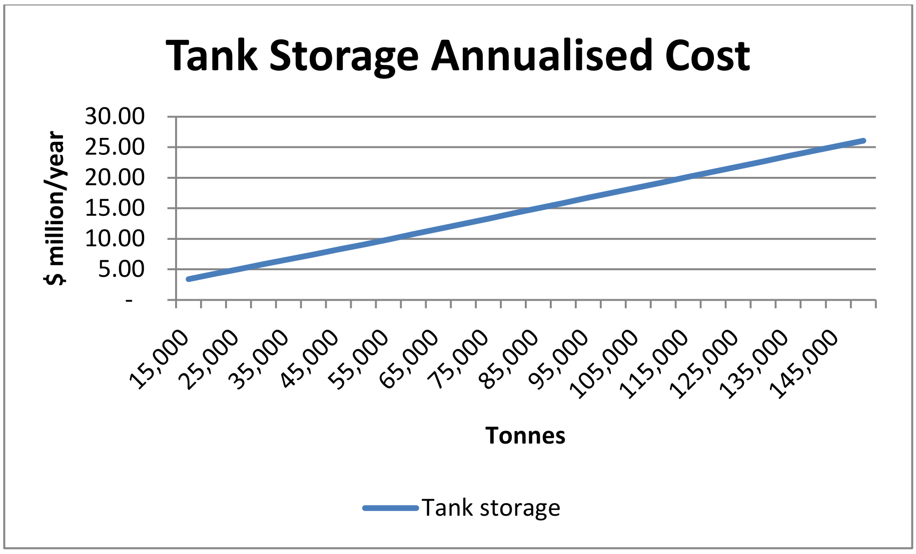


NB: the graph covers the annualised cost of capital for tanks, the interest cost on holding additional product stock, and the annual cost of operations, maintenance and product turnover management. The three 140,000 tonne options refer (from lowest cost to highest cost) to product tank farms at Marsden Point, Auckland and crude storage at NZRC.
Source: NZIER, from data in H&T 2010

The 2010 report identified substantial increase in costs of providing new storage, through estimates of five different installations of different sizes. A substantial proportion of the annual cost of increased storage is the cost of the fuel held, as illustrated in figure 7 below. This explains oil companies' reluctance to increase their domestic storage, when most of the time a just-in-time replenishment from elsewhere is more efficient for them.

We have used this information to construct a supply curve for new storage, interpolating between the size bands of the different tank farms to derive annualised costs of new storage provision. The results are not trivial and indicate that, even more than in the 2005 report, large disruption costs would be required to make new storage appear economic on an annualised cost basis

Figure 8 The cost of new storage supply



Source: NZIER, from data in Hale & Twomey 2010

The estimates range from $3.4 million per year for the 15,000 tonne tank farm to $24.3 million per year for a 140,000 tonne tank farm. In terms of cost per tonne these range from $228 to $174 per year.

The 2011 RAP report included cost estimates for a 44,000 tonne back-up terminal at Wiri, concluding that with annualised cost of $10.9 million per year that would be an unjustified insurance cost for a risk that was very low. That assessed the annual terminal cost or required rate of return at 10% of capital cost over a 20 year return period. If these requirements are relaxed by using a notional public sector rate of return of 8% over a 40 year tank life, the overall net annual cost would fall to $9.3 million. This remains well above the expected value of any of the domestic scenarios in this report, and greater than the expected value of all scenarios combined ($4.5 million at low probability, $6.6 million at high probability). The expected value of the international disruption in Scenario 7, at $49 million, is much higher but domestic storage does not provide relief against the price impacts of an international disruption: the fuel stored domestically will rise in value in line with the international price, so the benefits accrue principally to the international suppliers of the oil and New Zealand welfare is still negatively affected. A 44,000 tonne terminal would provide sufficient days cover to meet four out of the six domestic scenarios, but the expected value plus the cost of distributing oil to meet shortages if they occur indicate the cost or precaution is likely to exceed the welfare cost of the disruption.

Another issue with storage is the location of new capacity should it be provided. It would seem reasonable to locate this either near the largest market (Auckland) or near the main point of production/importation (Marsden Point), but either of those locations would add little security to risks elsewhere in the country. There is also a risk that additional capacity in those locations may be taken out by disruption risks in those locations.

5.1.2 Other supply side measures

Other supply side measures to alleviate disruption risks include investment in specific infrastructure to overcome vulnerabilities in the current system. These include

- modifications to the Wiri to Auckland Pipeline link, to reduce the risks of jet-fuel shortage for Auckland's air services, as identified in the RAP Options report (2011)
- Other adjustments to the RAP/Wiri complex, which as identified in Scenario 3 has the second highest potential cost of all the domestic disruption scenarios
- Enhancing the capacity of the fleet of road tanker wagons to enable faster response to distribute around any infrastructure failings.

The *RAP Contingency Options* report in 2011 identified additional trucking capacity to provide relief for localised shortages to meet RAP contingencies, and the building of pipeline link between the RAP and the Wiri to Airport Pipeline to by-pass the Wiri terminal in the event of its disruption. These are examined in the next section.

5.2 Demand side measures

A range of measures have been identified as having potential to reduce fuel use in times of shortage (Covec et al 2005a, IEA 2010). Compared against the fuel supply contraction in the domestic scenarios, some of these would make an appreciable contribution to reducing the shortage. These sources provide no cost estimates for these measures, and they range from purely voluntary measures such as discretionary trip reduction, with no explicit cost implications (although there will be hidden welfare costs for those depriving themselves) to those requiring regulatory mandate with associated costs of implementation and enforcement.

In combination these measures could make a substantial contribution to relieving shortage on some of the disruption scenarios. But with all such behaviour changing options, there are critical questions about how much to invest in supporting them:

- How quickly and widespread would be the uptake of the measures?
- How assiduously do participants adhere to them, and how much enforcement or other reinforcing actions would be required to keep up the desired response?
- How much of the response to promotion will be additional to what would happen anyway, given that implicit in the welfare response calculation in this report is some reduction in oil consumption in face of price rise, perceived shortage and increase in the shadow price caused by queuing and uncertainty of supply?

Both the volume of saving and the speed with which it could be put into effect in the event of a crisis are open to question, but could be examined through sensitivity analysis of changing assumptions on these variables if the costs of detailed implementation are defined.

Table 7 Demand side measures and disruption alleviation

		Scenario 1 Long term Refinery Outage	Scenario 2 Short term Refinery Outage	Scenario 3 Long term RAP/Wiri Disruption	Scenario 4 Short term RAP/Wiri Disruption	Scenario 5 Long term Wellington Disruption	Scenario 6 Long term Christchurch Disruption	Scenario 7 International Disruption Event
Kilotonnes per day		13.4	13.4	6.7	6.7	2.4	2.6	13.4
Disruption duration		42	21	60	9	60	60	183
BAU Kilotonnes during disruption		561.4	280.7	399.3	59.9	144.3	154.8	2,446.0
Kilotonnes short during disruption		134.7	5.6	47.9	10.2	21.7	23.2	0.0
Responses		kilotonnes	kilotonnes	kilotonnes	kilotonnes	kilotonnes	kilotonnes	kilotonnes
Drop 10% trips	2.16%	12.1	6.1	8.6	1.3	3.1	3.3	52.8
More efficient veh	0.43%	2.4	1.2	1.7	0.3	0.6	0.7	10.5
Car-pooling	1.23%	6.9	3.5	4.9	0.7	1.8	1.9	30.1
Telecommuting	0.40%	2.2	1.1	1.6	0.2	0.6	0.6	9.8
Compressed work week	0.17%	1.0	0.5	0.7	0.1	0.2	0.3	4.2
Tyre pressure	1.40%	7.9	3.9	5.6	0.8	2.0	2.2	34.2
Mandatory speed reduction	1.42%	8.0	4.0	5.7	0.9	2.0	2.2	34.7
Driving bans/carless days	4.00%	22.5	11.2	16.0	2.4	5.8	6.2	97.8
Total combined		62.9	31.5	44.8	6.7	16.2	17.4	274.2

Source: NZIER

Some of these measures could entail virtually no cost. Less obvious ones would require active promotion through publicity campaigns and information at points of sale, and could be justified by market failure and information asymmetry around the likely scale and duration of disruption. At the bottom of Table 5 are regulatory or mandatory requirements, which would entail public agency costs in implementation and enforcement.

Demand side measures do not require much investment in infrastructure that would remain unused except in disruption, so their costs are low. But they do require some contingency planning and provisions in place so that they can be enacted when required. Much of this can be handled at a national level, with implementation devolved and costs varying with the scale of localised events which would trigger their use.

The existence of public conservation campaigns could act as substitutes for, rather than complements to, supply side measures if they result in a lower private provision of spare capacity in the system such as storage. That would implicitly transfer wealth from New Zealand taxpayers to mostly foreign owned oil companies. The extent to which that would happen for the measures described here is an empirical question beyond the scope of this study. So too is the question of how much additional restraint would be delivered by promotional campaigns over that which would emerge voluntarily in face of perceived shortage.

6. Options for improving New Zealand's oil security

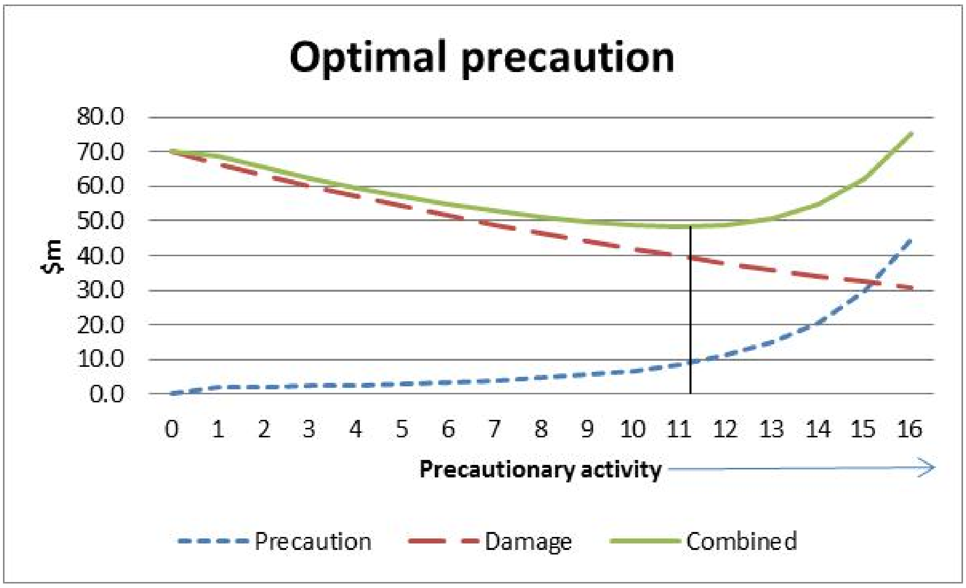
This section examines a selection of options for improving New Zealand's oil security and asks the question of whether any of the identified options could be implemented to provide greater oil supply security. The options are:

- Additional storage capacity in New Zealand – which on current estimates is unlikely to be a cost effective means of alleviating risk of domestic disruption or of complying with IEA requirements, given the existence of ticket contracts in other countries at much lower costs per tonne
- Additional truck capacity to alleviate supply disruption for petrol and diesel into Auckland, which would clearly be cost effective if a disruption occurred, but it would not be cost minimising to expand capacity in advance, given the ability to import additional trucks and drivers when the disruption occurs
- Building a link between the RAP and the WAP to by-pass major disruption at the Wiri terminal should it occur, which would be cost effective in restoring supply to the Auckland International Airport quickly but may not be cost minimising if installed in advance; however, if such a major disruption occurs, it would be beneficial to install the link as quickly as possible
- Demand side measures, which could have relatively low cost per tonne of consumption restraint, but has some major uncertainties over the rate of uptake and the degree of additionality delivered by any promotional activity.

Explanation of these options is provided below.

Optimal oil supply security for New Zealand depends on finding a level of security against disruption at which the marginal cost of additional security equals the marginal benefit of disruption avoided, which will maximise the present value of net benefits over time. That can be found by looking at the combined cost of disruption and precautionary activity and locating the point where they are minimised.

Figure 9 Combined costs of impacts and precaution



Source: NZIER

Expected values provide a way of comparing the average risk with the annual cost of precautions. But very large but low probability disruption events could lead to above-average costs being incurred at any time. Over-providing precautionary measures relative to average risk could then be useful in reducing some of those costs and the uncertainty caused by the possibility of very large impact costs. This can be likened to an insurance policy, paid on the expectation it will not be needed in order to soften the impact of extreme low probability adverse events. This kind of policy comes with a security premium, and whether or not it makes sense fo the public to pay such a premium depends on the level of pubic risk aversion.

In the estimates of options we use the main update based on index-adjusted welfare inputs. These give the largest impact estimates, so an option that fails to clear the hurdle of expected impact on these estimates will not do so with other estimates in this report.

6.1 Cost benefit comparisons of selected options

Numerical estimates of the costs and benefits of different precautionary measures are described below. These compare the annualised cost of the different measures against the benefit of reduced or avoided impact of disruption.

6.1.1 New Storage

Table 6 below compares the benefits and costs of additional 15,000 tonne and 44,000 tonne terminals for each of the disruption scenarios. Details for the 44,000 tonne terminal are drawn with minor updating from the 2011 RAP Options report. Small adjustments have been made, in particular discounting at a public sector rate of 8% real over a 40 year tank life time rather than 10% over 20 years from the 2011 report. The estimate accounts for a saving in ticket contract costs for IEA purposes of $20 per tonne.

As in the 2011 report, the table confirms that the annual costs of new storage options are very high relative to the potential savings in impact costs. The 44,000 tank farm would provide more days' cover than is required for each of Scenarios 2, 5 and 6, and the 15,000 tonne farm provides more than is required for Scenario 2, so there is substantial spare capacity built into such additional storage. This shows up in the cost per tonne shortage averted. The annualised cost of capacity per tonne is $228 for the 15,000 tonne option and $213 for the 44,000 tonne option, but the cost per tonne averted is substantially higher for those scenarios with excess cover.

Table 8 Cost benefit comparison of storage options

Additional Storage		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
15,000 t	Days cover	5	21	18	13	40	38
Benefit $m/yr							
	Low probability	0.24	0.31	0.29	0.62	0.17	0.24
	High probability	0.30	0.61	0.43	1.24	0.28	0.35
Cost $m/yr		3.42	3.42	3.42	3.42	3.42	3.42
Mid-range BCR		0.08	0.13	0.10	0.27	0.07	0.09
Cost $/tonne averted		$ 228.07	$ 582.93	$ 228.07	$ 228.07	$ 228.07	$ 228.07
44,000t	Days cover	14	21	53	9	60	60
Benefit $m/yr							
	Low probability	0.71	0.31	0.84	0.43	0.25	0.37
	High probability	0.88	0.61	1.26	0.85	0.42	0.55
Cost $m/yr		9.39	9.39	9.39	9.39	9.39	9.39
Mid-range BCR		0.08	0.05	0.11	0.07	0.04	0.05
Cost/tonne averted		$ 213.41	$ 1,600.00	$ 213.41	$ 907.15	$ 422.07	$ 401.31

Source: NZIER

These comparisons are made against each of the scenarios individually. In practice tank farms have to be located somewhere and will not provide cover to all these scenarios simultaneously. The most likely location would be at the main importation/production point (Marsden Point) or near the main market (Auckland). Additional storage would address the localised shortages that could arise in those locations, but provide no practical assistance to shortages in Wellington or Christchurch where other existing facilities would be brought in to remedy shortages.

6.1.2 Responding to disruption to RAP or Wiri Terminal

Scenario 3 identifies two distinct types of impact resulting from long term disruption to the RAP or Wiri Terminal:

- Disruption to petrol and diesel supplies, that could be restored to normality in 2 months by trucking in supplies from elsewhere with sufficient augmented trucking capacity
- Disruption to jet fuel supplies, that is not feasibly resolved by trucking because of the lack of both loading facilities and trucking capacity to move the volume required. Restoration of supply through the existing route could take up to 18 months in the event of a major explosion at Wiri terminal requiring extensive repair; or more likely 3-6 months to install a direct link to the Wiri-Airport Pipeline (WAP) to divert jet fuel from the RAP, avoiding the terminal disruption.

The solutions to these two impacts are different because of the volumes to be moved relative to the capacity of the existing truck fleet to source alternative supplies. With changes to how the existing truck fleet is deployed[19] for moving petrol and diesel, along with additional truck and driver resources, the volumes required could be supplied from neighbouring terminals. There are no neighbouring terminals that have jet fuel available and a limited jet fuel-capable trucking fleet. While a temporary terminal could be installed at Marsden Point and significant trucking resources imported, the assessment in the 2011 *RAP Contingency Options* report is that a pipeline connection to by-pass the terminal is a more practical option for dealing with jet fuel disruption in Auckland.[20]

6.1.2.1 Augmented trucking to relieve petrol and diesel disruption

The 2011 *RAP Contingency Options* report identified two options for restoring petrol and diesel supplies to Auckland in 60 days: expanding the capacity of the New Zealand domestic trucking fleet to meet such a contingency, or bringing new trucks in from Australia if and when required. Each option entailed a number of other measures to raise the capacity for moving fuel into Auckland: over-loading trucks above their normal level, bringing spare truck capacity in New Zealand into full service (10 trucks), importing new truck and trailer units (12 trucks) and adjusting supply chain practices to free up more volume (e.g. closing some service stations). The 2011 RAP report estimated the costs to be $26.6 million for expanding New Zealand capacity and $27.2 million for augmenting with imported vehicles.

With the augmented New Zealand trucking fleet option there is an on-going annual cost for holding increased capacity in New Zealand, comprising costs of capital, storage of vehicles and maintenance. The 2011 RAP report estimated this to be $1.9 million per year, so the operational costs of trucking fuel if required would be $24.7 million. With the alternative of importing vehicles in the event of disruption, the operational costs are essentially the same, leaving $2.5 million as the logistical cost of bringing trucks in when required. As the $1.9 million would be incurred every year with the New Zealand fleet augmentation, but the $2.5 million is only incurred in the event of disruption which has a low likelihood in any year, it is less costly to rely on rapid importation than expand the fleet in readiness.

The welfare costs for consumers, lost tax revenues and reduced externalities of a 60 day disruption with 12% reduction in petrol and diesel supplies are estimated to be around $291 million. That amounts to about $4.9 million a day, so the alternative of not adjusting capacity to restore supplies could be much more costly, as illustrated in Table 8. This shows the disruption volumes and costs for three variants on Scenario 3:

- Response constrained by current loading restrictions, requiring import of more additional trucking units (29) and longer period (90 days) before restoring petrol and diesel supplies
- Response following the RAP report recommendations, restoring supplies in 60 days
- Response with more rapid deployment of trucks, restoring supplies in 30 days

[19] These are detailed in the H&T report published along with this report.

[20] H&T RAP Contingencies Review

Table 9 Costs and benefits of a truck solution to RAP/WIRI disruption

		No overload, more trucks	Overloading, supply chain changes & more trucks	Overloading, supply chain, more trucks more quickly
Days of disruption		90	60	30
Total shortage	Kilolitres	371,425	187,825	135,175
	Tonnes	97,976	49,545	35,657
Petrol	Tonnes	50,172	25,371	18,259
Diesel	Tonnes	47,804	24,174	17,397
Disruption cost	$m	577.2	291.9	210.1
Incremental gain	$m		285.3	81.8
Expected value of increment				
Low probability	$m		0.571	0.164
Mid range	$m		0.713	0.205
High probability	$m		0.856	0.245
Disruption cost/day	$m/day	6.4	4.9	7.0
Incremental gain	$m/day		9.5	2.7
Additional trucks used				
NZ Spare capacity		10	10	10
Imported new capacity		29	12	12

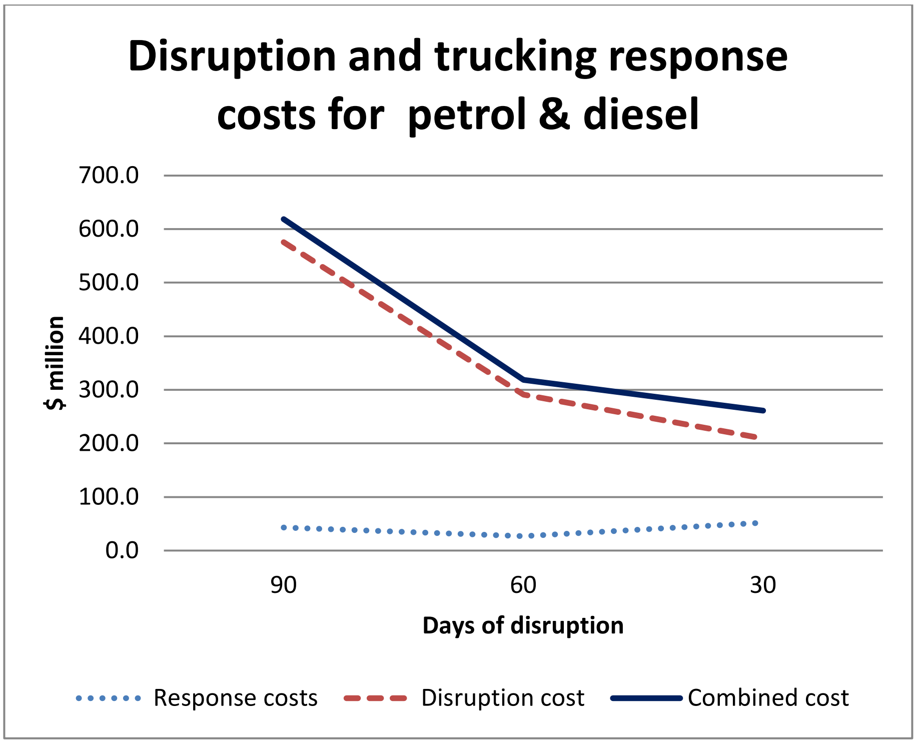
Source: NZIER

The table shows that reducing the time to full restoration from 90 days to 60 days almost halves the disruption cost, with an incremental saving of $285.3 million. Against that either of the response options in the 2011 RAP report would deliver substantial net benefits, with a saving in disruption cost of about $9.5 million a day. If the additional trucking resources could be secured more quickly to restore normality in 30 days, the volume reduction would be lowered to 9% over the 60 day period and the welfare loss would be reduced to $210.1 million, with a saving of $82 million compared to the 60 day option The incremental reduction in shortage falls, with an average saving of $2.7 million per day.

With disruption costs accruing at up to $7 million a day there is advantage in restoring supply sooner rather than later. Comparing the 90 day option with the 60 day option, assuming the operational costs increase in proportion to the extra days of operation and the holding costs increase in proportion to additional vehicles, the cost of responding in 90 days would be around $42 million, resulting in a combined cost of disruption and response of about $619 million compared to just under $320 million for the 60 day option. Expediting the deployment of trucks to restore supplies in 30 days will cost more than the 60 day option, but the response costs would need to be more than 4.3 times those of the

60 day option for 30 day restoration not to be the option that minimises the combined cost of disruption and response. If the response costs of restoring in 30 days are just double those of the 60 day option, the results are as illustrated in the diagram below.

Figure 10 Cost minimising position for trucking



Source: NZIER

The probability of a RAP/Wiri disruption of this scale is assessed to be 0.2-0.3% per year, so the expected value of savings made by responding in 60 days rather than 90 is around $0.57 million to $0.85 million per year, and the additional expected value of reducing from 60 to 30 days for restoration is around $0.16- $0.25 million per year. As these benefit values are substantially lower than the annualised cost of the augmented New Zealand truck capacity, that option would be more costly than relying on rapid import and deployment of extra capacity if needed when such an event occurs.

Augmenting New Zealand's trucking capacity confers an additional advantage in that it could be deployed in the event of other similar sized disruption events. There are three such scenarios in this analysis – Scenarios 3, 5 and 6 – with combined probability of occurrence between 0.55% and 0.85%. This would raise the expected value of benefit – from around $0.16-$0.25 million to between $0.5 and $0.7 million for the 30 day restoration option - but still not enough to outweigh the $1.9 million annual cost for additional New Zealand trucks. The risk with augmenting New Zealand's trucking capacity is that an event of such size may never occur in the economic lifetime of the vehicles, in which case substantial cost will have been incurred for essentially no benefit other than the peace of mind of knowing the capacity to deal with such an event exists.

Given the record of New Zealand's oil distribution infrastructure in avoiding disruptive events of such scale in the past, relying on rapid import of trucks and drivers from

Australia if such an event should occur is likely to be less costly. The risk to this option is the shipping time of 3-5 days and constraints on shipping capacity and schedules to bring vehicles over for a timely response. This option requires only 12 additional truck and trailer units, so the risk of impediment by such shipping constraints is small. The value per day of saving from reducing restoration from 60 to 30 days is about $2.7 million, so if the import of required trucking capacity is delayed beyond the first month, additional disruption costs of similar magnitude could accrue on successive days until the full capacity augmentation is in place. Such potential delay costs provide a justification for having a plan and arrangements in place to expedite such truck import in case the need should arise.

As both the 60 and 30 day options require changes in truck operations and regulations, in particular around overloading trucks above normal operating levels, there may be additional costs in regulating that activity such as pre-approval of roads that can accommodate the heavier trucks. We have no details of what that might entail or what the costs would be. However, the expected value of the costs avoidable puts a limit on the costs that can be incurred with expectation of positive return. So, using the mid-range of the expected values, it would be reasonable to spend up to $0.7 million per year on preparatory measures such as heavy route pre-approval that enabled the 60 day option to be implemented, and around $0.2 million on preparatory measures that enabled rapid import and deployment of trucks to achieve supply restoration in 30 days.

6.1.2.2 RAP/WAP connector

The 2011 *RAP Contingency Options* report highlighted particular vulnerabilities with respect to jet fuel in the Auckland region. One option to counter disruption at the Wiri terminal would be to provide a link between the existing RAP and Wiri to Airport Pipeline to by-pass the risk of disruption at the Wiri terminal. The 2011 report identified from industry sources that such a connector could be built for around $5-$15 million and would be sufficient to eliminate any shortage of jet fuel in the event of a Wiri disruption. At the time of writing the 2011 Report, oil companies suggested a RAP-WAP link could be installed in an emergency within 3-6 months. On the assumption that for jet fuel it is impractical to build up a dedicated truck fleet sufficient to eliminate the shortfall, supply may not be restored for up to 18 months in the case of a major terminal outage, so a RAP-WAP connection built in 3-6 months would still provide relief for jet supplies.

Table 7 examines this in the context of Scenario 3, using the annualised mid-point cost estimate of $10 million. Compared against the expected value of disruption, the result is relatively cost effective, although costs may still exceed benefits on the base assumptions depending on the counterfactual. Compared against the strict do-minimum option of waiting 18 months for the Wiri terminal to be repaired from major damage, pre-installing a RAP-WAP connector would be net beneficial, with a benefit cost ratio of 2. On the assumption that a more likely counterfactual would be the building of the by-pass after an outage occurs, with avoidable costs of up to 180 days disruption in supply, the cost benefit ratio of pre-installing the connector drops to 0.67. The figures in Table 7's right hand column indicate an annual cost that would apply if the link were built pre-emptively to avert such disruption and avoid 60 day loss of jet fuel, which would achieve a benefit cost ratio of 0.22. If the cost of building the RAP-WAP link were at the low end of range at $5 million the benefit cost ratios of all options would double, lifting that of the 180 day option to 1.33.

Table 10 Costs and benefits of a RAP-WAP connection

Excluding airline costs	Scenario 3	Scenario 3	Scenario 3
To eliminate jet shortage in	*540 days*	*180 days*	*60 days*
Benefit $m/yr			
Low probability	1.34	0.45	0.15
High probability	2.01	0.67	0.22
Cost $m/yr	0.84	0.84	0.84
Mid-range BCR	2.00	0.67	0.22
Cost/tonne averted	$ 1.14	$ 3.43	$ 10.29
Including assumed airline costs	**Scenario 3**	**Scenario 3**	**Scenario 3**
To eliminate jet shortage in	*540 days*	*180 days*	*60 days*
Benefit $m/yr			
Low probability	1.88	0.63	0.21
High probability	2.82	0.94	0.31
Cost $m/yr	0.84	0.84	0.84
Mid-range BCR	2.81	0.94	0.31
Cost/tonne averted	$ 1.14	$ 3.43	$ 10.29

Source: NZIER

If instead of building the by-pass link pre-emptively it is built only when needed in a disruption, the cost is lower but the benefits depend on the delay in getting it running. Once a disruption has occurred, the welfare cost on jet fuel alone accrues at about $37.2 million a month, or about $1.2 million a day. If the link could not be built for 180 days the lost value of the shortage would be $219 million in present value terms. If the installation could be expedited to 150 days, the disruption cost would drop to $183 million, and if brought back to 60 days, the lost value would be about $74 million. There is substantial net benefit in installation as soon as possible.

The benefits of this could be understated, as the welfare impact estimate does not include full costs for airlines in adjusting and maintaining their operations in the absence of fuel at Auckland, bunkering in fuel from other airports or changing schedules and planes to use those that carry sufficient fuel to pick up supplies elsewhere. Such costs affect the producer surplus for New Zealand owned aircraft and the potential benefit of a RAP-WAP link. In the absence of information from airlines on these potential costs, assuming this is in the order of $0.5 million a day and mostly incurred by New Zealand owned airlines, the monthly welfare cost on jet fuel would rise from $37m to about $52 million. Then the welfare cost of disruption over 6 months would rise to PV$308 million, and there would be a reduction in this disruption cost of about PV$50 million for each month that completion of the RAP/WAP by-pass is brought forward. An airline cost of this scale would also raise the benefit cost ratio of the 180 day option to 0.94, as shown in the bottom half of Table 7.

Once a disruption has occurred and welfare costs of that magnitude are accumulating, on this analysis it is clearly net beneficial to build the link if its costs are in the range of $5 - $15 million, and build it sooner rather than later. If the counterfactual is installing the by-pass in 180 days, the value of lost supply would be PV$219 million excluding airline costs (or $308 million including them), but the disruption cost reduces by about PV$36 million ($50 million) for each month the completion of repair is brought forward. Compared to a 6 month supply restoration, building the link in 90 days would save PV$110 million ($155 million).

As there is a benefit in expediting the building of the RAP/WAP link there is some benefit in preparing the way for swift installation, tempered by the probability of the event occurring. This is illustrated in Table 8, which shows the benefits of avoided disruption from early completion of the link, and their probability weighted expected values. With the probability of such disruption between 0.2% and 0.3%, the net benefit of completing the link at the end of 2 months instead of 6 would have an expected value of $0.29-0.44 million ($0.41-0.61), but that expected value falls the closer to 6 months it takes to commission the link. It would be worth spending pre-emptively around half a million dollars a year to enable 2 month completion, but not so much for lesser shortening of installation times.

Table 8 Costs and benefits of expediting a RAP-WAP connection

	Excluding airline cost				Including airline cost			
Disrupted Days	Disruption Cost $m	Early Benefit $m	Expected values Low prob $m/yr	Expected values High prob $m/yr	Disruption Cost $m	Early Benefit $m	Expected values Low prob $m/yr	Expected values High prob $m/yr
60	74.2	145.4	0.29	0.44	104.1	204.0	0.41	0.61
90	110.9	108.7	0.22	0.33	155.6	152.5	0.30	0.46
120	147.3	72.2	0.14	0.22	206.7	101.3	0.20	0.30
150	183.6	36.0	0.07	0.11	257.6	50.5	0.10	0.15
180	219.5				308.1			

Source: NZIER

Even though the expected value of disruption may not warrant building pre-emptively, as the costs are relatively low, it could be viewed as an insurance premium against the risk of disruption, particularly if there is wide uncertainty around what those risks might be. The benefits might also be understated if there are other operational advantages in having the link, for instance improving flexibility around routine maintenance of the terminal. Conversely the benefits could be overstated to the extent that scenario 3 impacts are not based on failure of the Wiri terminal alone, but also include failure of the RAP which would not be alleviated by a terminal by-pass.

During the development of the RAP contingency work there was considerable uncertainty as to the cost estimate for this link, particularly what would need to be spent in advance and what would be spent at the time when construction occurred. Given these uncertainties in the cost estimates and the welfare savings from faster implementation, it is recommended that more work is done on the cost of specific actions to speed the implementation of the RAP/WAP link. Including airlines in discussion on this would reveal the value of benefit and risk assessment of the parties most heavily affected.

6.1.3 Demand side measures

As indicated in section 5.2 above, demand side measures could make an appreciable contribution to relieving consumption during supply constraints, but there is uncertainty about how quickly they would be taken up, how long they would be sustained, and how much it would cost to implement them. Some demand restraint will emerge at no visible cost during a shortage, as uncertainty about supplies and the perceived costs of queuing encourage consumers to conserve their own supplies and cut back on discretionary consumption. Some trip reduction, car-pooling, telecommuting and switching to more efficient vehicles by those who already have them could emerge spontaneously, but they and the options of compressed work weeks and tyre pressure tuning would require promotion for widespread uptake. Mandatory speed reduction could face substantial cost around changing existing road signs, and is likely to result in increased resources spent on enforcement. Driving bans and carless days would involve greater implementation costs, both for those administering the system and those complying with it, and in view of the ineffectiveness of carless days introduced in the 1970s they are not considered here.

The introduction of each of these options would require more detailed scrutiny than is possible in this report, but an illustration of the likely scale of effect is outlined in Table 8. These cover implementation of all the demand measures in section 5.2, including mandatory speed reduction to 80 kph but excluding bans and carless days.[21] The costs comprise:

- $200,000 per region per month of disruption duration spent on public information campaigns
- A one off cost of $125,000 per event per region on signage and other facilities
- $250 per region per day on additional enforcement activity
- A one-off cost of $50,000 per region affected in administration by public authorities.

Table 11 Potential costs of demand side measures

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Costs	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*
Publicity campaign	4.5	2.2	1.2	0.2	1.6	0.4
Signage etc	2.0	2.0	0.4	0.4	0.5	0.1
Enforcement	0.2	0.1	0.2	0.0	0.2	0.2
Administrative adjustments	0.8	0.8	0.8	0.8	0.8	0.8
Total $m	7.4	5.1	2.6	1.4	3.1	1.6
$/tonne	$ 184.02	$ 253.20	$ 90.83	$ 322.09	$ 301.72	$ 140.23

Source: NZIER

The results suggest promoting demand side management could have relatively low cost per tonne of consumption averted. As these costs would only be incurred in the event of a disruption they can be compared against the costs of potential impacts, which for petrol and diesel to which these measures apply is in the vicinity of $7,500 - $8,000 per tonne across the different scenarios. On these cost assumptions, therefore, demand side measures would be well worth implementing, and the difference between cost and benefit is so great that costs could be substantially higher and welfare impacts considerably lower before the measures cease to be worthwhile. However, that result depends crucially on:

- The cost of campaigns necessary to cover the affected area
- The effectiveness of campaigns in inducing additional restraint that relieves the disruption period.

[21] We have not found detailed costings for close analogies to the conservation campaigns required in an oil disruption, where there is more opportunity to disseminate messages through points of sale than in electricity campaigns which place heavy emphasis on media campaigns. Estimates here draw on policy dissemination and implementation estimates and vary with geographical extent and duration of disruption.

There are other demand side measures, such as modal switch from private to public transport in the main urban areas, which could have an appreciable effect on the scenarios with more localised impacts. That would depend on the capacity and flexibility of the services to accommodate increased demand during shortage, which is specific to each locality and not estimated in this report. Constraints on the public transport capacity in some areas, both vehicles and staff, may limit the ability to switch modes.

It would be useful to undertake more detailed investigation into:

- The international experience of the form and effectiveness of campaigns promoting demand side restraints
- The applicability of such measures to New Zealand conditions
- The costs of such a campaign should it be required in New Zealand, consistent with the agency responsibilities laid out in the Oil Emergency Response Strategy
- The evidence for the disincentive to private security provision from such conservation campaigns with respect to oil products.

6.2 Aligning incentives

The rationale for intervening to align incentives is that there are market failures in the supply chain that are creating a socially sub-optimal situation and exacerbating the cost of disruption impacts. There are likely to be information failures in the ability of consumers to assess the risks to their fuel supply and the level of security they face. There are also other market failures around the creation of externalities. Any intervention would require more detailed assessment than provided here of its justification and design.

6.2.1 Incentivising oil demand restraint

Demand restraint in the face of shortage may also need to be encouraged to reduce the potential impact of disruption. Overseas experience indicates disruptions can produce some inefficient consumer responses – excessive queuing, hoarding of fuel (which can have safety implications as well as reduce availability of fuel) and impeding the allocation of fuel to its highest valued use (e.g. those who queue longest are those with lower opportunity cost of time).

A number of measures could be considered to realign the incentives on consumers to more socially optimal choices. One might be a temporary tax to raise the price and curtail demand during a shortage. Revenues raised could either be used to fund complementary demand restraint measures, or returned to consumers after the disruption has passed. Another would be to institute minimum purchase on fuel – say $30 – to discourage the pattern of continuous refilling that adds to queues and puts pressure on available stocks. These would provide some price incentive for demand restraint in situations where suppliers are reluctant to do so.

6.2.2 Incentivising industry supply security

Aside from infrastructure investments, another option for alleviating disruption impacts would be to influence behaviour in the oil supply system by encouraging companies to tighten up their supply security systems. Disruptions to oil supply create spillovers for the wider community and economy, so if the companies have inexpensive ways of reducing the risk of disruption still further, it could be nationally advantageous to encourage them to find them.

There are various ways in which the incentives on companies to find such improvements could be changed. Taking the lead from the electricity system, where supply disruptions can cause price spikes that benefit generator-retailers participating in the spot market, new rules from the Electricity Authority have been introduced to return some of the economic rent created by such events and give suppliers less of an interest in seeing such disruptions occur. Disruption-induced price rises appear of lower frequency in the oil market than in electricity, but may occur in the event of bigger disruption events than have hitherto been experienced. Whether companies could cost effectively provide greater security to New Zealand's supply is a question that could be examined more deeply.

6.3 Multiple and compounding risks

In this report we have assumed the oil supply system faces a set of disruption scenarios with known risks in order to estimate the expected value of potential impacts and the costs of alleviating measures. There are other potential disruption risks. Generally the larger the potential impact, the lower probability of it occurring. Similarly, the risk of more than one bad event happening at the same time, which could overwhelm systems responses, depends on the combined risk from multiplying the probability of each event, which is also very small

Nevertheless bad events can happen and risk cannot be eliminated. There is a risk, for instance, that more than one port could be disrupted simultaneously, which would undermine the ability of response measures, storage, distribution fleets to effectively respond. Such a king hit could arise with a tsunami which could afflict multiple ports. However, not all ports are equally at risk, the probability is very small. The expected value of such events less than that of any single scenarios considered here, and the uncertainty around quantification is such that it is not studied separately.

6.4 Key Sensitivities

The estimates in this report depend on a number of assumptions drawn from previous reports or more recent sources. Clearly variation in any of these assumptions would change the results. However, the estimated values of costs and benefits for various response options in this report are so large that it would require radical changes in the assumptions to alter the results. For most inputs it is not illuminating to conduct a sensitivity analysis around most of the input assumptions.

In general it can be seen that the welfare estimates would need to be seriously underestimated, and costs seriously overestimated, to change the conclusions of the cost benefit comparisons. Even if the welfare cost estimates were doubled it would not change the CBA results: among the storage options the best BCR of 0.54 applies to a 15,000 tonne tank farm in Scenario 4, and most of the others are very much lower.

One attribute of the 2005 Report that is carried through into this analysis is variation in welfare cost of shortages across fuels, with the cost on petrol more than double that on diesel and more than 8 times that on jet fuel. In view of the implied elasticities and evidence from overseas studies we believe that may be understating the potential impacts of disruption to jet fuel supplies. Raising the welfare impact for diesel and jet to a similar level to that for petrol would not make benefits of new storage options greater than their costs, but it would make the RAP-WAP link net beneficial with a BCR of 2.67. On the current mid-range cost assumptions the RAP-WAP as a precautionary measure against

Scenario 3 would break-even with a welfare loss of $3.29 per litre, 4.5 times the central estimate in the updated oil security assessment.

Raising the discount rate used to annualise costs in the analysis from the current 8% to 10% or higher would tend to raise the costs of intervention relative to the impacts avoided. The other principal variable affecting the expected value of risk is the probabilities of disruption. These probabilities are already high in relation to the historic record of risk in New Zealand, and doubling them makes no appreciable difference to the cost benefit results.

One critical assumption in the modelling of domestic infrastructure disruptions is that oil companies absorb the costs of finding alternative supply and do not take the opportunity of domestic shortage to raise prices. While that may have been true in the past, it may not be true in future should there be a disruption much larger than any experienced in the past, as depicted by the scenarios in this report. In the construction of the welfare model used here and in the 2005 Report, the welfare costs of domestic disruption could increase appreciably because, in addition to the deadweight loss of reduced consumption, there would also be an extra price on remaining consumption transferred to overseas suppliers of fuel.

To illustrate this we calculate the extra cost for remaining consumption on the assumption that prices rise by 46 cents a litre, the same as for the international disruption scenario. This would raise the value of potential impact of each scenario, most particularly by around 30% in the case of Scenario 1 and 60% in the case of Scenario 3, the two domestic scenarios with the largest impacts. The expected values of these impacts would still remain modest, with Scenario 1 ranging from $2.8 million to $3.5 million with other things held constant.

Nevertheless that illustration shows there could be substantial outflow of funds from New Zealanders to foreign suppliers in the event of a domestically induced price rise. Under such circumstances, there may be national benefit in government instigating the price rise with a temporary tax to encourage demand restraint, the revenues being used to support other demand response measures or returned to fuel consumers with lower taxes at the end of the crisis. That would avoid increasing import costs during a disruption and also assist an industry reluctant for reputational reasons to take advantage of shortages.

There are a number of limitations to this report, around the scale of the welfare effects and the cost and effectiveness of some of the response options. In estimating welfare losses it has not distinguished between permanent loss and displacement or deferral of fuel uses to periods when disruption has passed, so, other things held constant, the impact estimates may be rather larger than the long term welfare cost of disruption.

7. Summing up

This report has reviewed and updated the 2005 *Oil Security Review*. That 2005 Report provides a sound approach to assessing oil security, in that it provides a way of enumerating the costs and risks of disruption impacts and comparing them with costs of precautionary and mitigation measures. But some of its conclusions are no longer valid.

The 2005 Report was instigated by the realisation that New Zealand was at risk of failing to comply with its IEA obligations to hold 90 day's net import supply of oil and oil products in stock. Consequently it was focused on the optimal level of storage. Subsequently the emergence of ticket contracts for overseas stocks with costs per tonne of fuel substantially less than the cost of new storage in New Zealand has shifted the focus of oil security to finding cost effective measures to mitigate the impact of potential disruptions.

The principal components of the economic impacts of disruption impacts are:

- Consumer welfare loss, caused either by price rises and the consequent increase in payments to overseas oil suppliers, or by contraction in consumption caused by shortage of supply availability within New Zealand
- Loss of taxation revenue for government, due to reduction in oil use over the duration of the security event
- Reduction in externalities due to reduction in oil use, which is a source of welfare benefit from disruption to be offset against other losses.

This updated report applies the same welfare framework to six scenarios of disruption caused by domestic infrastructure failures, and one scenario of international disruption. An assessment of the physical risks of disruption events and their consequences for fuel availability are provided in a companion report (Hale and Twomey 2012).

This report focuses on the domestic scenarios and options to alleviate the impacts, as these are the risks that are most amenable to influence by domestic policy responses.

7.1 Findings and recommendations

As in the 2005 Report, this update finds the potential impacts of international disruption far greater than those of domestic infrastructure failure. Price increases get passed through to customers, and storage provides little insulation from such shocks as the value of oil in storage in New Zealand rises with the international value.

The largest domestic disruptions come from long term refinery outage (Scenario 1), and long term RAP/Wiri terminal disruption (Scenario 3). Impacts from disruptions to supplies at Christchurch, Wellington and short term RAP/Wiri events are substantially smaller, and in probability-weighted expected value terms, the short term Wiri/RAP event is more costly than those in the other cities.

For domestic disruptions it is assumed that local prices do not move, as companies absorb the costs of maintaining supply during disruptions to their local infrastructure. There is still some contraction of availability and a rise in the implied shadow price of fuel, as consumption contracts up the supply curve. The welfare effects are based on an aggregate demand curve that encompasses all oil-use impacts across the economy, so there is no additional impact from flow-on effects across the economy.

We have examined the flow on effects of disruptions across an inter-industry model to examine the distribution of those impacts across the New Zealand economy. This modelling found that adverse impacts are concentrated in the transport and wholesale industries. For most industries oil is too small a proportion of input costs to have a significant adverse effect on output.

While the potential impacts of some scenarios are substantial (up to around $1 billion in the case of Scenario 1) their probabilities are low so the expected value of occurrence each year is in the order of up to a couple of million dollars. Options for alleviating the potential costs are compared against these expected values.

Additional storage was a major focus of the 2005 Report, but its costs have since increased and are now in the order of $200/tonne per year. This is substantially higher than recent prices of ticket contracts held in other countries, so storage is not a competitive option for complying with New Zealand's IEA obligations.

The variability of local oil production also affects the utilisation of additional storage for IEA compliance purposes. Additional storage could provide sufficient capacity to meet the shortages of most of the disruption scenarios, but it would need to be fixed to one location – most likely in the main market Auckland – with additional cost in dealing with supply reductions elsewhere.

Additional trucking capacity could be used to alleviate shortages of petrol and diesel in Auckland, but it would be less cost effective to enlarge New Zealand's trucking fleet than to import new capacity and drivers as and when a disruption occurs. We estimate:

- Disruption costs accrue at $2.7 million a day or more at various stages through a disruption
- It would be worth spending up to $0.7 million per year on preparatory measures like pre-approval of routes for over-sized loads to enable restoration of full supply to reduce from 90 days to 60 days
- It would be worth spending a further $0.2 million per year to enable more rapid truck deployment to reduce full restoration from 60 to 30 days.

Building a RAP-WAP link for $5 – $15 million to by-pass disruption at the Wiri terminal would be beneficial in the event of major disruption at the terminal, but if provided pre-emptively it may provide no tangible benefit if no substantial disruption occurs.

- It could be worth spending $0.5 million per year to enable rapid completion of the RAP-WAP connector in 2 months instead of the expected 6 months, given the value of disruption costs that could be saved over that period
- We recommend that more work be done on the specific actions that could be taken to expedite completion of the pipeline when required.

Various demand side response measures have been identified that could yield savings in fuel use during a disruption, but there is little evidence of how cost effective these are likely to be in practice.

- We recommend further investigation of the international experience of promoting demand side measures at times of disruption, and of their applicability to New Zealand's oil market conditions
- We also recommend further work on the likely requirements and costs of promotion activity to induce fuel savings additional to what would happen voluntarily and spontaneously during a disruption.

Appendix A Bibliography

Baumeister, C., & Peersman, G. (2011). *The role of time-varying price elasticities in accounting for volatility changes in the crude oil market* (Working Paper No. 11-28). Bank of Canada. Retrieved from http://ideas.repec.org/p/bca/bocawp/11-28.html

Beccue, Philip C & Huntinton, Hillard G (2005) An assessment of oil market disruption risks, Report to US Department of Energy, Energy Modelling Forum, Stanford University

Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer (2006) *Cost-Benefit Analysis: Concepts and Practice, 3rd Edition*. Upper Saddle River, New Jersey: Prentice Hall.

Brown, Stephen (2009) “Reassessing oil security”, Resources for the Future, Washington DC, www.rff.org/Publications/WPC/Reassessing-oil-security.pdf

Brown & Huntington 2010 "Reassessing the oil security premium" DP 10-05 Resources for the Future, Washington DC

Burke, P. J., & Nishitateno, S. (2011). *Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries* (Departmental Working Paper No. 2011-15). Australian National University, Arndt-Corden Department of Economics. Retrieved from http://ideas.repec.org/p/pas/papers/2011-15.html

Considine, T.J. (2003) *An Energy Demand Forecasting Model for Israel and the Market Potential for Natural Gas*, Pennsylvania State University

Covec, & Hale & Twomey (2005) *Oil security:* prepared for Ministry of Economic Development (Final report) February.

Covec and Hale & Twomey (2005a) *Oil demand restraint options for New Zealand* Report to Ministry of Economic Development, Wellington, June

Dargay, J. M., Gately, D., & Huntington, H. G. (2007). *Price and income responsiveness of world oil demand, by product*.

De Veirman, E., & Labbe, F. (2011). Estimating the effects of permanent oil price shocks consistent with optimal factor allocation. Presented at the New Zealand Association of Economists.

Hale & Twomey (2008). *P2007 ACCC report into Australian petrol prices - Review of applicability to the New Zealand petrol market:* Wellington N.Z.: Ministry of Economic Development.

Hale & Twomey (2010). *Petroleum Reserve Stock Strategy Review*. Wellington N.Z.: Ministry of Economic Development.

Hale & Twomey Ltd (2011) *RAP Contingency Options*, Report prepared for Ministry of Economic Development, Wellington

Hale & Twomey Ltd (2012) *Information for NZIER Report on Oil Security*, Report prepared for Ministry of Economic Development, Wellington

IEA (2010) Oil and Gas Security - Emergency Response of IEA countries; International Energy Agency

Kennedy, D., & Wallis, I. (2007). *Impacts of fuel price changes on New Zealand transport* (Land Transport New Zealand Research Report 331). Wellington, N.Z.: Land Transport New Zealand.

Leiby PN (2007) "Estimating the energy security benefits of reduced US oil imports" paper for US Department of Energy, Oak Ridge National Laboratory

MED (2003) *New Zealand Energy Outlook to 2025*, Ministry of Economic Development, Wellington, New Zealand

MED. (2008a). Oil emergency response strategy - government response to an oil supply disruption. Ministry of Economic Development, New Zealand. Accessible via http://www.med.govt.nz/sectors-industries/energy/pdf-docs-library/energy-security/780059-2.pdf

MED (2008b) New Zealand's Energy Outlook 2009/2010: Changing Gear http://www.liquidbiofuels.org.nz/documents/home/eenergy-outlook_changing-gear-scenario.pdf

MOT (2011) *The social cost of road crashes and injuries* - June 2010 Update; Ministry of Transport, Wellington

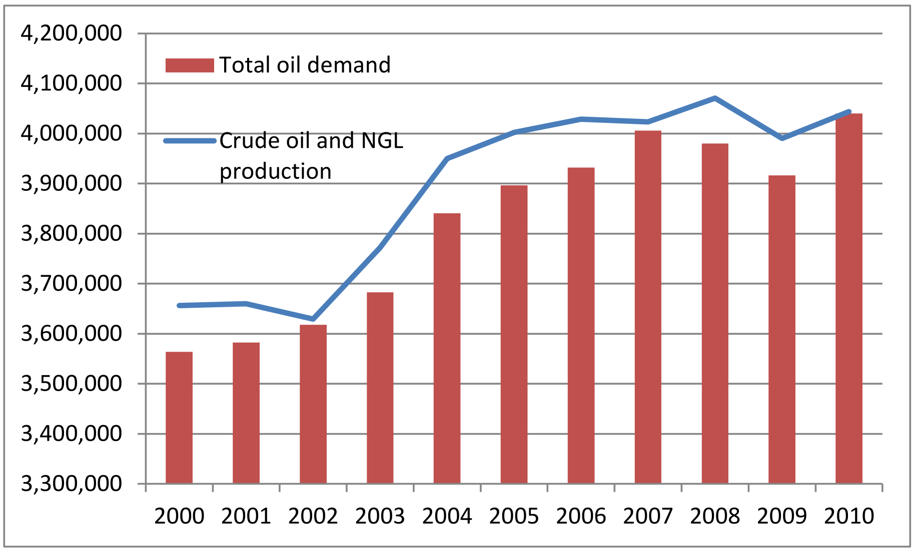
Nordhaus, William (2009) “The economics of an integrated world oil market” Keynote address to International Energy Workshop, Venice, Italy, June 17-19

Pindyck, R.S. and Rubinfeld, D.L. (2004) *Microeconomics*, sixth edition

Appendix B Backdrop

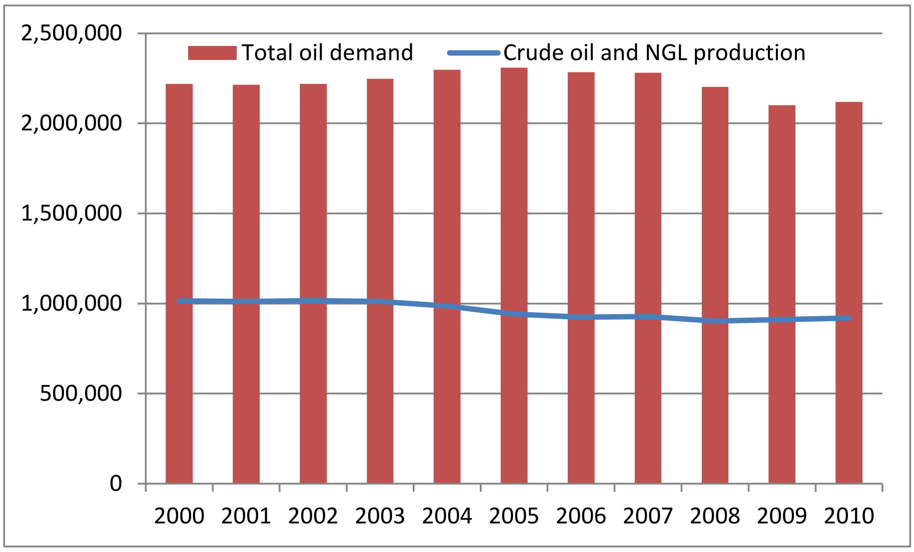
This current oil security review comes at a period when oil production and demand have plateaued after strong growth in the early 2000s. Much of the supply continues to come from the Middle East, where political instability risks supply disruptions Strong oil demand from developing countries, such as China and India, which seek energy security to support their economic growth, has offset flat or falling demand from recession-hit OECD countries. Oil remains the dominant source of global primary energy accounting for about a third, but it has been losing market share, particularly to coal.

Figure 11 World oil production and demand (kt/year)



Source: IEA

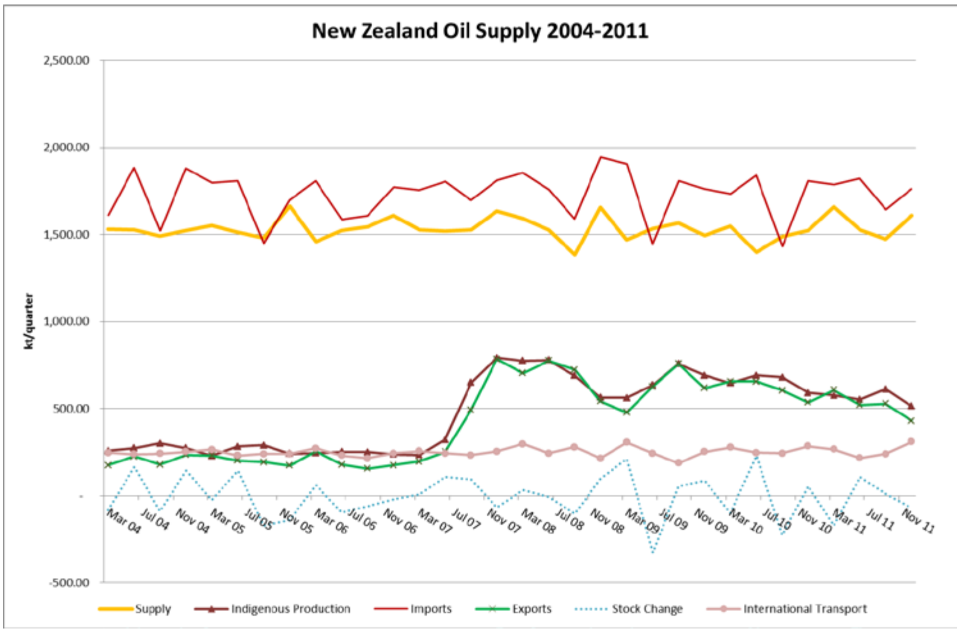
Figure 12 Total OECD oil production and demand (kt/year)



Source: IEA

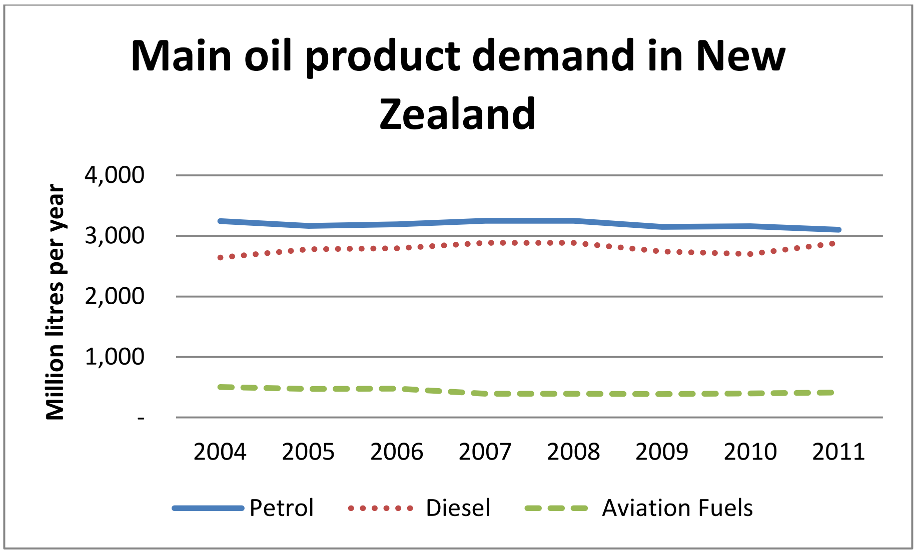
In New Zealand, oil supply has been relatively flat since 2004, but there has been a marked increase in indigenous production, closely matched by exports, since 2007. This has reduced the net import requirement for calculating IEA stockholdings. However, production has begun to tail off, increasing the likely volume of stockholding requirement to be met by ticket contracts or other means. Demand is also flat in face of recession, with only diesel showing slight increase reflecting changes in the vehicle fleet.

Figure 13 New Zealand Oil Supply



Source: NZIER, from MED Energy Data File

Figure 14 New Zealand refined product consumption



Source: NZIER, from MED Energy Data File

Appendix C IEA obligations

As a member of the IEA, New Zealand needs meet IEA's obligation to hold stocks for 90 days net import requirement under the 1974 Agreement on an International Energy Program (IEP Agreement). Oil reserve takes account of commercial oil stock holding by oil companies and contracts for reserve oil stocks from other member countries.

New Zealand initially discovered the shortage in oil reserve in 2004. Since then, a number of studies have assessed different aspects of this issue.

Table 12 Actions on domestic oil reserve

Time	Actions
Mid 2004	MED identified petroleum reserve shortage
Feb 2005	Covec and H&T assessed oil security in New Zealand and suggested to have 190,000 tonnes oil reserve stock for New Zealand(Covec & Hale & Twomey, 2005)
March 2005	Cabinet agreed to meet its stocking obligation through tenders with costs to be met by levy on petroleum sales
April 2006	Government agreed to New Zealand holding tickets in Europe and other IEA countries but did not agree to always hold 190,000 tonne reserve stock in New Zealand. Levy on petroleum sales not agreed
September 2006	Government-to-Government agreement concluded with Australia, Netherlands and United Kingdom. First tender held
2007	New Zealand became compliant with stockholding requirement. Japan is part of the tender.
July 2008	MED published its oil emergency response strategy
December 2010	Hale & Twomey conducted a review on petroleum research stock strategy and
October 2011	Hale & Twomey prepared a report on RAP contingency options

Source: (Hale & Twomey 2010), NZIER

Since 2007, New Zealand has been meeting IEA's obligation through both domestic stock holding and purchased oil tickets.

Changes in following factors had impacts for NZ in meeting its IEA obligation

- Total demand climbed up steadily after 2004, but it had a sharp dip during 2008-2010.
- Commercial stock levels
- indigenous production increased sharply after 2007

Table 13 Commercial stocks

	Commercial Stock		
	Crude oil Stock		Product Stock
Domestic production	Crude		Stocks on shops that have arrived in New Zealand but not yet fully discharged or that are travelling between two New Zealand ports
	Condensate		
	Naphtha		
Feed stock at NZRC	Crude and condensate	NZRC	Intermediate component (e.g., half-finished petrol, diesel, jet fuel etc. which is stored at the refinery)[22]
	Residual feedstocks, blendstocks		Finished product stock
Terminals			Commercial Stock

Source: Hale & Twomey 2010; NZIER

In 2008, MED prepared oil emergency response strategy, outlining the measures to be considered when an industry response is considered to be insufficient. (MED, 2008). Short term security is covered by the oil emergency strategy; mid to long term security is covered by the New Zealand Energy Strategy.

Although ticket contracts have provided a useful mechanism for New Zealand to meet IEA compliance they have recently become more expensive. The average price of tickets has recently increased and reversed successive reductions from 2008-2011 (Figure 7).

Hale & Twomey (2010) conclude that the prices of oil reserve tickets should remain stable but that may no longer hold. The volatility of price would depend on market structure/ compulsory requirements and market demand. The ticket market is a lot more unstable now than when the oil reserve stock review was conducted. Potentially, fewer countries can supply oil reserve tickets: Australia found it was IEA non-compliant and stopped supplying oil ticket contracts to New Zealand in 2009. According to Hale & Twomey 2010, UK will be the next country to announce insufficient in oil reserve.

As the cost of holding oil tickets overseas potentially becoming more expensive, there is a question if the government is willing to pay those prices or have better incentives for encouraging more commercial stocks.

Currently, New Zealand mainly purchases oil tickets from Japan, Netherland and UK. Twomey and West 2010 suggest outsourcing more oil ticket supply countries and to have at least 3 countries, to eliminate the concentration of suppliers and potential risk/event of rushing into buy tickets at high price. Recent ticket contracts have averaged around $20/tonne/year, and the expected value would have to rise considerably to sustained higher levels to make new domestic storage provision a competitive alternative.

[22] This was allowed to counting towards IEA 90 days' obligation since 2004. They are normally around 70 000 tonnes. (From BF's email)

Appendix D Approach to modelling flow-on effects

Estimation of flow-on effects is often accomplished using computable general equilibrium (CGE) modelling techniques that account for the way that price changes flow through the economy. However, as noted in the 2005 Report, that technique is unsound when applied to short-term supply disruptions. During supply disruptions people tend not to adjust prices and behaviours significantly. That is partly because many prices, such as wages, take some time to adjust. It is also partly because there is an expectation that things will return to 'normal' following a small disruption. Consequently, nobody wants to significantly change their behaviour to adjust to the new level of supply. CGE models assume that most prices fully adjust, which will tend to overestimate behavioural responses to an oil disruption. Nonetheless, there are few better techniques for accounting for the links between various industries and the commodities that they produce.

D.1 Modifying the model

We have used a modified CGE model to estimate the flow-on effects through the economy of a reduction in the supply of oil.[23] To account for the lack of likely price movement during a supply disruption we have constrained the model to prevent firms from substituting between production methods and technologies. We have also prevented the cost of capital and wages from changing during the oil disruption. By constraining those elements, we have brought the outcome of the model closer to the stylised facts of an oil disruption. For example, we have eliminated the possibility that people will switch to local producers to account for the increased cost of road transport. However, we have also eliminated the possibility that the road freight industry could pay more to secure a greater supply of fuel. Clearly the true outcome will be somewhere in between but, with the available data, it is not possible to pinpoint the extent to which prices are likely to adjust.

We have used a database drawn from Statistics New Zealand's 2007 supply and use tables, scaled up to 2011 levels. It separates 28 different industries within the economy, but does not split out the different oil-based products. Consequently, our estimation pertains to all petroleum products rather than splitting petrol, diesel, and jet fuel – although product differences are captured to some extent by the industries that use them and implicit in variation of product values.

D.2 Scenarios estimated

Of the six domestic scenarios in this report we have quantified two that are representative of the flow-on impacts we can expect to see. The first is Scenario 1, which pertains to a long-term refinery outage of greater than 42%. Hale and Twomey (2012) estimate a reduction in the supply of petrol and diesel of 24% for this scenario. Scenario 2 is a scaled down version of Scenario 1 and we do not explicitly estimate it. The impact of a 2% reduction in petrol and diesel availability nationally is unlikely to have a significant macroeconomic impact and the distributional spread will be identical to Scenario 1.

[23] The model used is modified from an ORANI variant specifically developed for New Zealand by NZIER and the Monash University Centre of Policy Studies. We modified the closure and elasticities to replicate many of the behaviours of a standard input-output model.

The second Scenario we quantify is Scenario 3, which relates to a long-term disruption of the RAP/Wiri supply infrastructure into Auckland. Hale and Twomey (2012) estimate that it would cause a 12% reduction in the availability of petrol and diesel within the Auckland region. For this scenario we constrain our GE model to estimate the impact on the Auckland region alone. Scenarios 4-6 will have a similar distributional spread to Scenario 3.

Table 14 Modelled impacts of each scenario

	Scenario 1	Scenario 3
Description	Long term refinery outage	Long term RAP/Wiri disruption
Scope of effect	National	Auckland region
Size of supply reduction (petrol and diesel only)	24%	12%

Source: Hale and Twomey (2012), NZIER

D.3 Results

D.3.1 Interpreting the results

The results are split into two parts. First, we examine the channels through which the effects of the shortage act. Secondly, we provide estimates of the net impact on each sector from our modelling.

Two factors are important to bear in mind when interpreting the results. First, the model used focuses on aggregate, distributional outcomes and does not capture the details of each individual industry. For example, it cannot capture the loss of output suffered by dairy farmers if trucks are not able to visit as regularly and milk is lost. These industry-specific effects should be considered additional to the analysis provided below; however, unless there is a breakdown in perfect competition, they affect only the distribution of welfare, rather than the estimated level.

Secondly, we have assumed that the shocks do not affect total household spending. The reason for that assumption is that the shortages are not expected to persist for more than 60 days. At the same time it is likely that there will be some reduction in household income as businesses face lower sales volumes or seek to reduce labour costs. Since people know that it is temporary they are likely to maintain their consumption levels and borrow against future income, rather than cutting consumption during the shortage. In the language of economic impact studies, we are assuming that there are no 'induced' effects resulting from the shortage. That is an extremely important assumption and makes a large difference to the level of the results. If we were to assume people cut back on their total consumption spending then the losses to businesses would be far greater.

D.3.2 Scenario 1: Long term refinery outage

The first scenario is a national shortage due to a refinery outage that lasts around 42 days and reduces the fuel supply by 24% over that time. That is reflected in a large drop in the activity of the refining industry, which has little to do when its products cannot be sold.

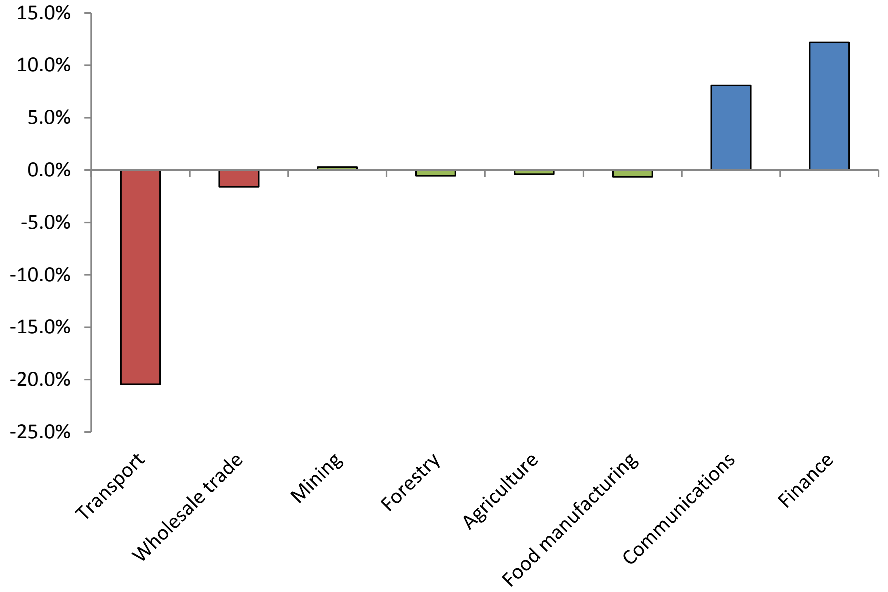
That has a direct effect on the industries that use significant amounts of fuel, particularly the transport sector.

The impact of the shortage is distributed over three classes of industries:

- **Fuel intensive, margin industries** are most affected. The transport sector, for example, sees a 20% fall in activity during the period of shortage (Figure 15) because of its reliance on fuel supplies.[24] These industries are represented by the group in red on the chart.
- **Goods traders** require transport services and suffer from the shortage of fuel because they struggle to maintain sales volumes. However, their losses are still far smaller than the margin industries since they do not have the same direct reliance on fuel. For example, the forestry industry sees only a 0.3% reduction in its activity for the duration of the shortage.
- **Service industries** would suffer from the fall in household incomes, but we have assumed that household spending remains constant. Consequently, service industries receive the benefit of consumers' borrowing to boost their sales as less is spent on goods and transport. This result is slightly counter-intuitive. We might expect that, as firms feel the pinch of reduced cashflow during the shortage they would choose to reduce the hours of their casual and contract staff during the period of low sales. However, if households borrow against future income to maintain current levels of consumption then the two phenomena are not incompatible, although our assumption is likely to overestimate the gains to service industries.

Figure 15 Impact of shortage on industries

Change in activity due to oil shortage



Source: NZIER

[24] Remember that we have excluded the possibility of the industry paying a premium to obtain supplies of fuel on the basis that price competition would be unlikely to happen over such short timeframes.

There are a few caveats to be aware of when interpreting these results. Most importantly, they do not take into account the effect on employees of potentially not being able to access fuel. While the disruptions described in the scenarios are not so large as to put at risk fuel for critical demands such as emergency services or even supermarket distribution, they could impact the availability of fuel for the general public for either leisure or work purposes, and increase the implicit cost (through queuing) of obtaining fuel.

D.3.3 Scenario 3: Long term RAP disruption

The second scenario modelled here, Scenario 3, describes a long-term disruption of the RAP/Wiri. That is estimated to create a 60-day disruption with Auckland and Northland being 12% short of fuel for the duration.

Estimating the regional impact

The crucial element of this scenario is to describe the effect upon the Auckland region. The disruption of supply occurs in Auckland and Northland, but that does not mean that the effects are isolated to those regions. For example, a reduction of fuel in Auckland and resulting contraction of the transport industry will have an impact on every region that imports from Auckland. Because of the size of the Auckland economy, those effects on the rest of the country could be marked.

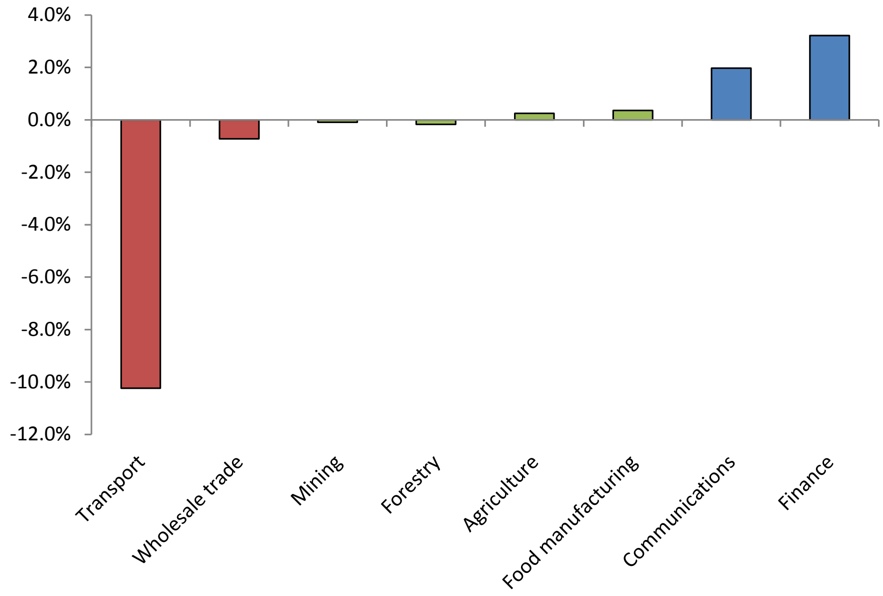
The channels for the impact are largely the same as previously. Although Auckland's industry composition is slightly different from the rest of New Zealand, the industries using the most fuel are largely the same.

Magnitude and distribution of the impact

As in the previous section, we can split the effect into the margin industries, goods traders and service providers. Figure 16 shows the percentage change in output of selected Auckland and Northland industries. The direct impact is half the size of that in Scenario 1 and the distribution of impacts is fairly similar. Note that these are percentage impacts for the Northland and Auckland area, which means that the absolute impact is far smaller than in Scenario 1, even if the percentage impact is close to half the size.

Figure 16 Impact of shortage on Auckland and Northland industries

Change in activity due to oil shortage



Source: NZIER

The previously described effects upon margin industries, goods traders, and service industries remain in the Northland/Auckland region. In addition, there is the complication of 'leakage' from the region: some of the direct effects of the shortage seep out of the region and affect the rest of New Zealand. This is particularly the case for the transport industry, and other industries that sell products across the country. Some of the reduction in their output is transmitted to the rest of the nation, dampening the effect upon the Northland/Auckland region. By contrast, some local, service industries buy and sell only in the local market.

Appendix E Estimating consumer welfare changes

As illustrated in Figure 2, a supply shock that restricts the availability of oil over a period necessitates consumers to change their consumption and avoid or defer their discretionary uses of fuel until normal availability is restored. In a competitive market this would be achieved by price rises and consumption moving back up the demand curve. But if, as is assumed for the domestic disruption scenarios in this report, oil suppliers suppress price responses for short term domestic infrastructure malfunctions, there is still an implicit price increase to the extent that not all normal demand can be met.

The consumer welfare loss is represented by area c in Figure 2 and it can be calculated by the "rule of a half" as:

$$\text{Consumer Welfare Loss} = (P_1\text{-}P_0) \times (Q_0\text{-}Q_1) \times 0.5$$

This is the deadweight welfare loss attributable to reduced consumption. In a market situation there is a larger consumer loss created by increased prices on infra-marginal consumption which is collected as increased revenue for producers, and hence a transfer from consumers to producers. Where there is no price change no such transfer occurs, so the consumer loss is confined to the welfare triangle on reduced production.

We estimate this for each fuel using price elasticities and the assessed reduction in physical quantity of fuel availability during the disruption period. As price elasticity of demand is a ratio of percentage changes in price and quantity, we use the elasticities to calculate the percentage change in implied price of each fuel, then apply these percentage changes to physical quantities and prices to obtain the components of the Consumer Welfare Loss equation above.

$$P_{ED} = \%\ \Delta Q/\ \%\Delta P$$

$$\%\Delta P = \%\Delta Q/\ P_{ED}$$

This procedure is used to estimate an alternative set of disruption costs to those used in our main analysis. The main analysis updates by price index the consumer welfare costs per litre of fuel availability reduction that were used in the 2005 Report. That Report appears to have calculated a demand curve across the whole range of consumption, calculated an average consumer surplus per litre consumed, and applied this as the welfare cost per reduction in fuel availability. That approach results in higher consumer welfare costs of disruption, but may overstate the welfare loss by applying an average rather than marginal value per litre of reduced availability. We provide the directly estimated welfare loss as an alternative and lower bound of a range of estimates.

A corollary of the direct welfare loss calculation is that the implicit demand curve is an aggregate demand curve – it reflects the reduction in consumption across the whole economy for the duration of the disruption until restoration of normality. That means that all changes in welfare across different consuming sectors are subsumed within that demand curve. The economy wide modelling in this report identifies the distribution of that impact across productive sectors, but this does not amount to an additional welfare loss. The modelling identifies the impact is concentrated in a few sectors in which oil is a significant part of input costs, but has less impact on the majority of sectors.