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Regional Council
TE RAUHITANGA TAIAO

Price Forecasts for Transport Fuels and other Delivered Energy Forms

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This document supports the development of the Auckland Regional Land Transport Strategy 2010. It is the culmination of work developed by the Technical Advisory Committee (TAC) to support the Auckland Regional Transport Committee. The TAC includes representatives from all local territorial authorities, Auckland Regional Transport Authority, Auckland District Public Health Board and other technical experts.

Reviewed by:

A handwritten signature in black ink, appearing to read 'Don Houghton', written in a cursive style.

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Date: 14 April 2009

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Price Forecasts for Transport Fuels and Other Delivered Energy Forms

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1 Purpose

This report has been prepared to assist the Auckland Regional Transport Committee with preparation of the Auckland Regional Land Transport Strategy 2010.

2 Introduction

The Auckland Regional Council (ARC) commissioned McCormick Rankin Cagney (MRCagney) to model prices of transport fuels and other energy forms in the period 2008-2060. The aim of this research is to assist the ARC to develop and update regional transport and energy strategies.

MRCagney has previously undertaken research for the New Zealand Transport Agency (NZTA) that identified the risk of sustained high oil prices in the period 2008-28, modelled future travel demands in response to a range of socio-economic factors, and recommended transport and land use policies that support both improved energy efficiency and increased economic development (Donovan and Genter, 2008). The ARC subsequently commissioned MRCagney to build on this research by, firstly, extending the time horizon from 2028 to 2060 and, secondly, investigating a wider range of energy forms.

Forecasting energy prices to 2060 is a challenging task that requires a number of major assumptions, the most important of which is that prices for oil are set within a global, free, and liquid market. We have attempted to capture uncertainty around these assumptions through the use of statistical techniques that incorporate sources of variability into the price forecasts. As a result, it is crucial that future oil prices are understood not as a fixed pre-determined trajectory but more in terms of a range of price paths, all of which are possible but some of which are more likely than others. While this research does identify an average price forecast, this average forecast must be viewed in the context of its associated variability.

It is noted that the unfolding global financial crisis and the strengthening United States Dollar (USD) have caused oil prices to fall below the price forecasts modelled in this report. Indeed, the recent unprecedented turmoil in global financial markets has significant implications for near term economic growth and consequent effects on demand for oil. This serves to highlight the complex range of factors that may bring about unexpected movements in oil prices, especially in the short term. This short term volatility is attributable to a combination of low short run elasticities (both on the supply and demand side) along with a high consumer willingness to pay; such that small changes on either side of the economic equation bring about large changes in price.

However, in spite of the recent bottoming out in prices, long term forecasts for oil prices appear largely unchanged. For example in their latest World Energy Outlook the International Energy Agency (IEA) has forecast the real price of oil to reach \$120 per barrel by 2030, on the back of weakening non-OPEC (organisations of petroleum exporting countries) production from existing fields (IEA, 2008b). The relatively insensitive nature of long term forecasts suggests that the primary impact of current economic uncertainty is to change the point from which prices will start rather than affect where prices are headed in the future. As an aside, the global financial crisis may discourage much needed investment

in oil infrastructure and somewhat perversely create an upside risk to prices in the medium to long term.

For these reasons it is considered that the implications of this research, at least insofar as the ARC are concerned, remain unchanged despite recent rapid declines in oil prices. It is considered that oil prices will in general trends upwards and perhaps more importantly exhibit increasing volatility. Although higher prices are expected to drive efficiencies of their own accord, the associated volatility mean that prices alone are a poor proxy for good policy. It is suggested that an increased focus on regional energy security grounded in reduced dependence on oil based transport fuels will be an increasingly important determinant of Auckland's future economic development.

3 Prices for liquid transport fuels

This section modelled future prices for oil in the period 2008-2060. These prices are then used to forecast retail prices for liquid transport fuels (both petrol and diesel). Results indicate that oil prices will increase from current levels to average approximately \$150 USD/barrel by 2015. After this prices are expected to plateau until circa 2025, when growing demand and laggard production is expected to create sustained upwards pressure on prices such that they reach \$400 USD per barrel by 2060. The price of oil based transport fuels is expected to follow a similar trend, although the short to medium term decline in the value of the NZD may be expected to exacerbate the effects of higher oil prices. These factors are expected to result in petrol and diesel prices in the range of \$6 NZD per litre in 2060.

Sustained high prices for liquid transport fuels are likely to motivate gradual but sustained shifts in travel and land use patterns of their own accord characterised by increased demand for alternative transport modes as well as denser and more diverse land use patterns. Adjustments to transport and land use policies may go a long way to preparing the Auckland Region for the risk of sustained high oil prices. It is also noted that substantial socio-economic adjustment to higher fuel prices is likely to occur prior to the widespread adoption of fuel efficient vehicles (whether they be conventional or electric). Responses such as land use consolidation, in-vehicle efficiencies, and mode shift, are expected to help ameliorate the impacts of sustained high oil prices, particularly for low income households and those living in denser and more diverse urban areas.

Alternative transport technologies, such as electric vehicles and bio-fuels, are likely to be deployed in New Zealand within the timeframes considered in this report, and contribute to ameliorating the impacts of sustained high oil prices. Such technologies are however expected to have only marginal effects on global demand for oil.

The following material is broken into the following three sections:

- modelling future oil prices,
- price forecasts for transport fuels,
- technological substitution.

3.1 Modelling future oil prices

MRCagney, in conjunction with Dr. Geoff Leyland, has developed two oil price models for this project. These models are referred to as the Meta model and the Market model.

The Meta model combines a number of reputable forecasts from various agencies to generate a single representative forecast. The methodology underlying the Meta model is discussed at length in the NZTA research report *Managing Transport Challenges when Oil Prices Rise* (Donovan and Genter, 2008). The Market model, by contrast, explicitly models the underlying economic parameters affecting the availability, production, and demand for oil.

Both models provide insight into future oil prices – the Meta model is good for understanding near-term influences on oil prices (such as refining capacity) while the Market model has value in understanding long term trends. Due to the fact that few agencies produce long-term price forecasts, the Meta model is not used to generate forecasts beyond 2028. After this point, our forecasts are provided solely by the market Model. The results of the models are discussed in the following sections. Data tables of the price forecasts are contained in Appendix H.

3.1.1 Results of the Meta model

The underlying forecasts on which the Meta model is based and the resulting Mean forecast are illustrated in figure 1. All oil prices have been adjusted to constant 2008 United States dollars per barrel (USD per barrel).

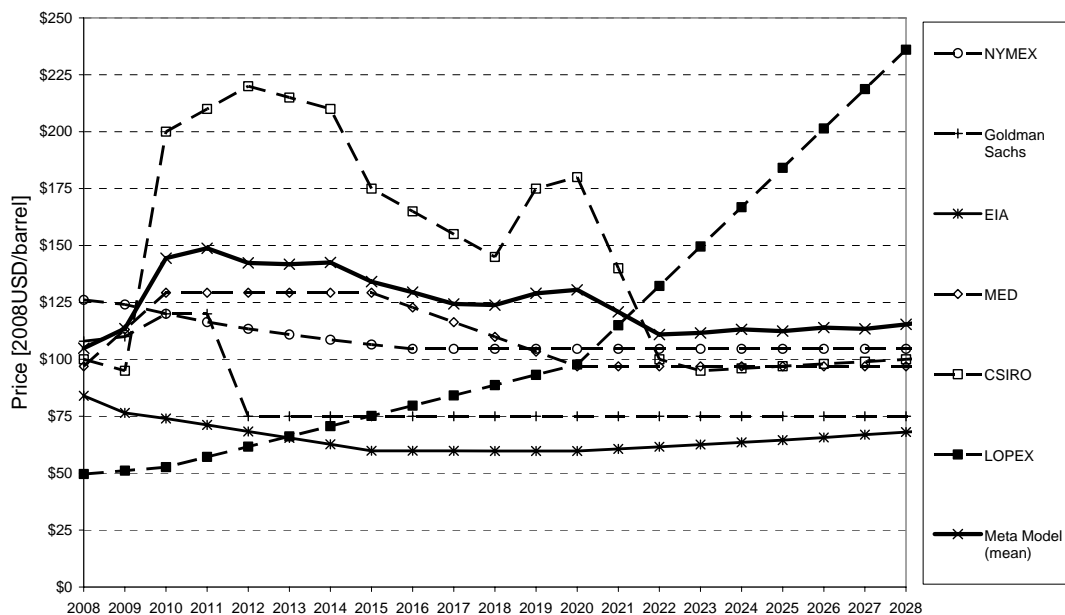


Figure 1: Results of the Meta model 2008-2029

Figure 1 illustrates how the average price is expected to reach \$150 USD per barrel by 2011, after which there is a plateau and a gradual decline to \$110 USD per barrel by 2020. After this time prices are expected to gradually rise to \$120 USD per barrel by 2028.

It is emphasised that the prices generated by the Meta model are not the simple average of the underlying forecasts for any particular year. Instead, a Monte Carlo simulation is used to project a statistically representative distribution of oil prices for each year, from which the average prices may then be calculated.

The general effect of this approach is to capture the large upside risk associated with oil price forecasts i.e. oil prices on the downside are bounded to remain above \$0, whereas they remain unbounded on the upside at least until demand is completely destroyed. The latter is defined by consumer willingness to pay. High value uses for oil such as the production of plastics, therefore, creates the potential for large upwards movements in oil prices.

3.1.2 Results of the Market model

The results from the Market model are illustrated in figure 2. The Market model considered underlying drivers of oil prices, such as resource availability, production capacity, and demand growth. The prices forecast by the Market model are illustrated below.

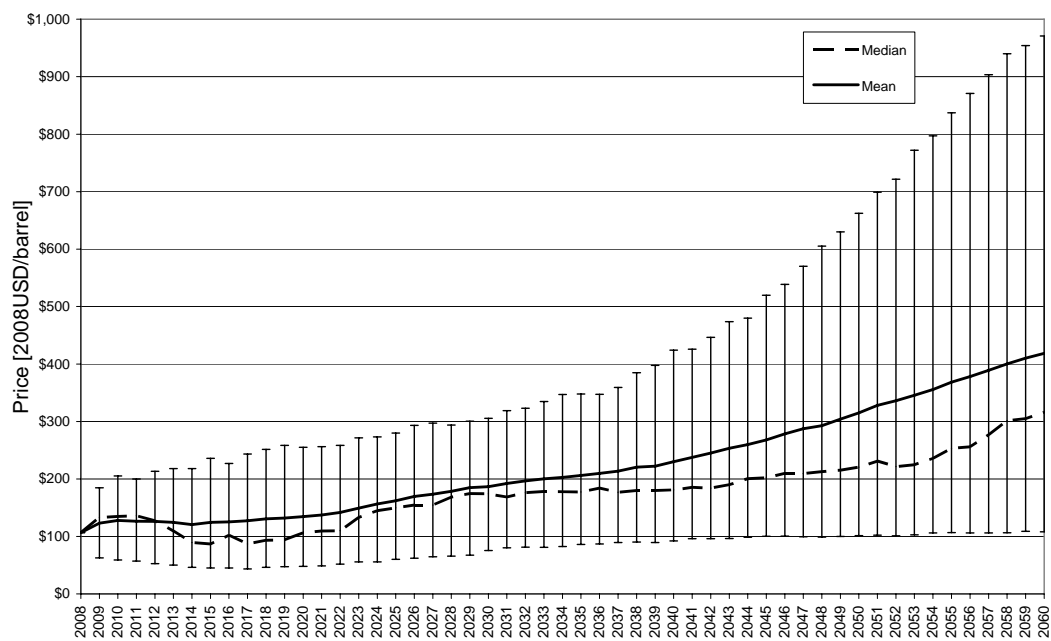


Figure 2: Results of the Market model 2008-2060

Figure 2 illustrates that average prices are expected to plateau at approximately \$120 from 2008-2020 after which there is a sustained ramp up to approximately \$400 USD per barrel by 2060.

It is noted that these results are indicative of average prices and thus infer a greater degree of smoothness than is likely to eventuate. The volatile nature of oil prices is caused by low

supply and demand elasticities, which mean that unforeseen changes in supply and/or demand result in substantial changes in price. Figure 3 presents an example of a scenario generated by the Market model so as to highlight the variability that is typical of oil price trajectories generated by the Market model.

It is worth noting that the relationship between price and demand is modelled through two components – a short term first order elastic response with a lagged second order effect (ie delayed demand response). This allows supply and demand to elastically expand and contract for any given year, while also accelerating or decelerating in response to sustained price trends. This short term response is illustrated by the negative correlation between demand (pink) and price (black) lines in figure 3. Supply (blue) is positively correlated with price (black) – although with a one year delay. The long term response is somewhat more subtle. The sustained period of low prices from 2026-2049 appears to stimulate a gradual ramp up in demand (pink), which subsequently causes a price spike in the period 2050-2055.

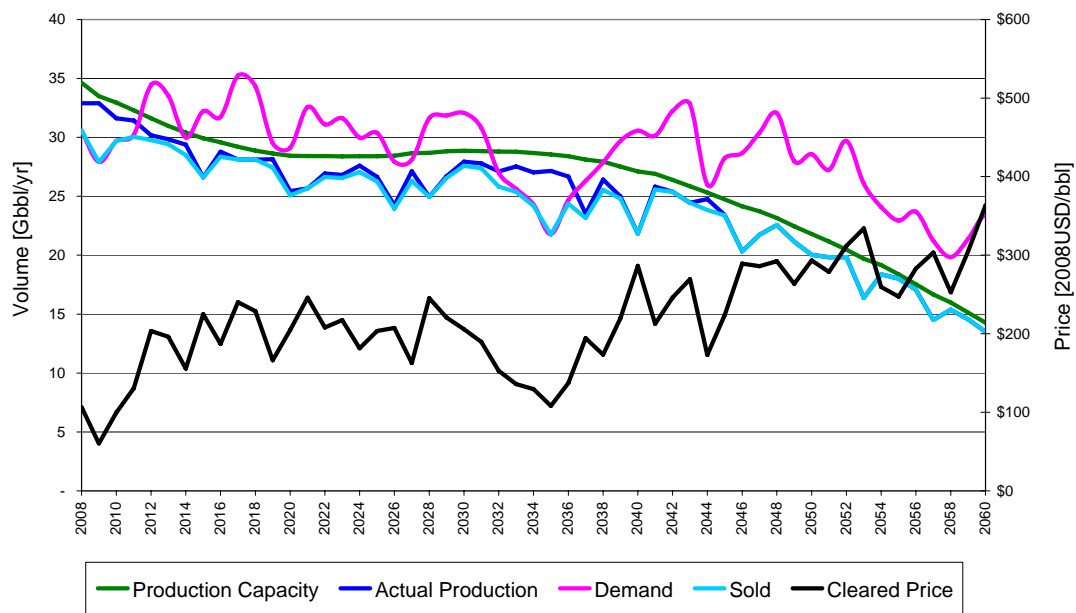


Figure 3: Example of supply and demand scenario for Market model 2008-2060

The price forecast illustrated in figure 3 also reinforces that highly complex and unstable systems are not adequately represented by averages. Uncertainty was accommodated into the model by allowing input parameters to assume a range of values – that is, key parameters were modelled probabilistically rather than deterministically.

This variability leads to large variability in results, and generates the wide confidence intervals shown in figure 2. It is important that the average prices are thus considered within the bounds of these confidence intervals. The following section discusses the sensitivity of the results to large changes in the value of these key parameters.

3.1.3 Key modelling assumptions and sensitivity analysis

Key modelling assumptions associated with the Market model are summarised below.

| Attribute | Parameter | Value | Unit | Source |
|-----------|------------------------------|------------------------------------|-------------|-----------|
| GDP | World total | \$46 trillion | 2008USD | IMF |
| | Annual average growth | 4% | | |
| | Standard deviation of growth | 1.275% | | |
| Reserves | Total reserves | 1500 | Gbbl | Sauner |
| | Standard deviation | 10% | | |
| | Maximum LRMC ¹ | \$225 | 2008USD/bbl | |
| | Reserve stack | Based on SAUNER (2000) data | | |
| Supply | Production unavailability | 5% | | Estimated |
| | Maximum SRMC ² | \$100 | 2008USD/bbl | |
| | Initial production | 33 | Gbbl/year | |
| Demand | Maximum willingness-to-pay | \$1000 | 2008USD/bbl | |
| | Demand stack | Modelled using arctangent function | | |

Table 1: Key parameters in the market model

Sensitivity analyses were undertaken on some of the key modelling parameters identified outlined above. This analysis considered a high and low value for some parameters and calculated the average price variation in comparison to the Base price scenario illustrated in Figure 1. The parameters tested, the range over which they are expected to vary, the average impact on price (as compared to the base case), and the annual average change in price from 2008 to 2060 (the Base scenario experienced annual price increases of 2.6 per cent), is summarised in the table below.

| Parameter | Range | | Average Price [USD/barrel] ³ | | Annual change [%] | |
|--------------------------|-----------|-----------|---|-------|-------------------|------|
| | High | Low | High | Low | High | Low |
| Annual GDP growth | 5% | 3% | +\$47 | -\$32 | 3.0% | 2.1% |
| Total Reserves | 1000 Gbbl | 2000 Gbbl | +\$97 | -\$41 | 3.3% | 2.2% |
| Willingness to pay (WTP) | \$1500 | \$500 | +\$78 | -\$63 | 3.5% | 2.1% |

Table 2: Results of the sensitivity analysis

¹ Long run marginal cost

² Short run marginal cost

³ Price refers to the average price over the time horizon considered

This shows, as expected, that prices are reasonably sensitive to all three input variables. Prices appeared to be particularly sensitive to changes in total reserves. The variation associated with the high scenario is consistently larger than the low variation, again suggesting that the risk profile is skewed to the upside.

It is also noted that in all scenarios tested, the average oil price trended upwards over the time horizon considered. The lowest and highest rate of increase was associated with the low Willingness-to-pay scenario, which saw annual average increases of 2.1 per cent in the low scenario and 3.5 per cent growth in the high scenario.

The sensitivity price paths are illustrated in figure 4.

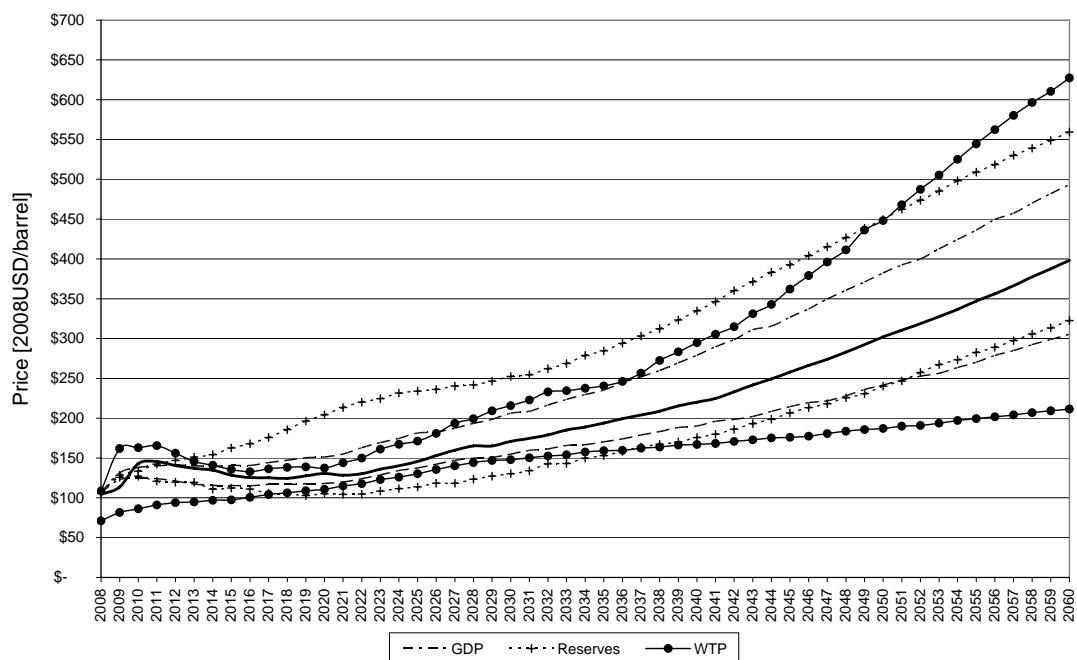


Figure 4: Sensitivity testing of the market model

This illustrates that the high and low price paths generated by these various sensitivity tests are fairly evenly distributed around the mean scenario and more importantly, generally fall within the confidence intervals associated with the mean forecast.

3.1.4 Combining the results of the two models

Both the Meta and Market models provide insight into future oil prices – by drawing on a number of forecasts the Meta Model produces representative forecasts, while the Market model provides additional information on possible long-term trends. For this reason it is recommended the results from both models are combined or knitted together to create a single continuous forecast for the period 2008-60.

This combined forecast has been generated by taking a linear weighted combination of the Meta model and Market model forecasts. The weight attributed to the Meta model starts at 100 per cent in 2008 and reduces to 0 per cent in 2028 and vice-versa for the Market Model. This approach means the Synthesised price is exactly equal to the price generated by the Market Model in 2028. Figure 5 compares the price forecasts generated by the two models for the period 2008-28 as well the combined result.

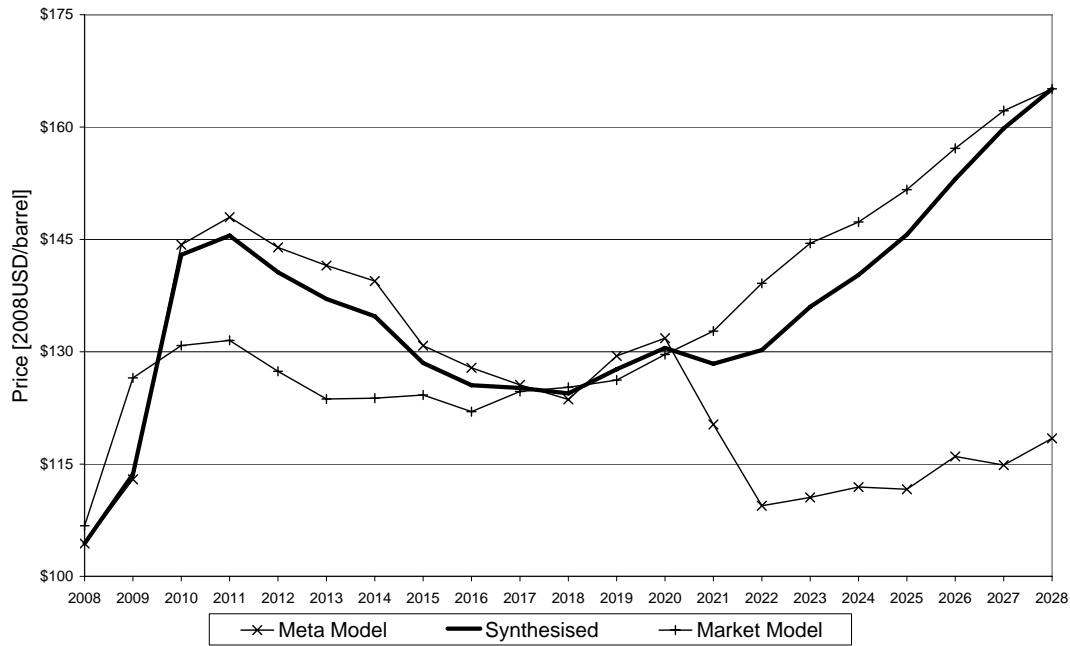


Figure 5: Synthesising the Meta and market forecasts 2008-2020

Figure 6 below illustrates the synthesised forecast in comparison to the CSIRO and LOPEX forecast. The CSIRO forecast incorporates a high degree of technological substitution while the LOPEX forecast considers depletion of oil reserves. In the period 2008-2020 the synthesised prices follow the CSIRO forecast, albeit more subdued. From 2020 onwards the synthesised price moves away from the CSIRO forecast to follow the LOPEX forecast instead.

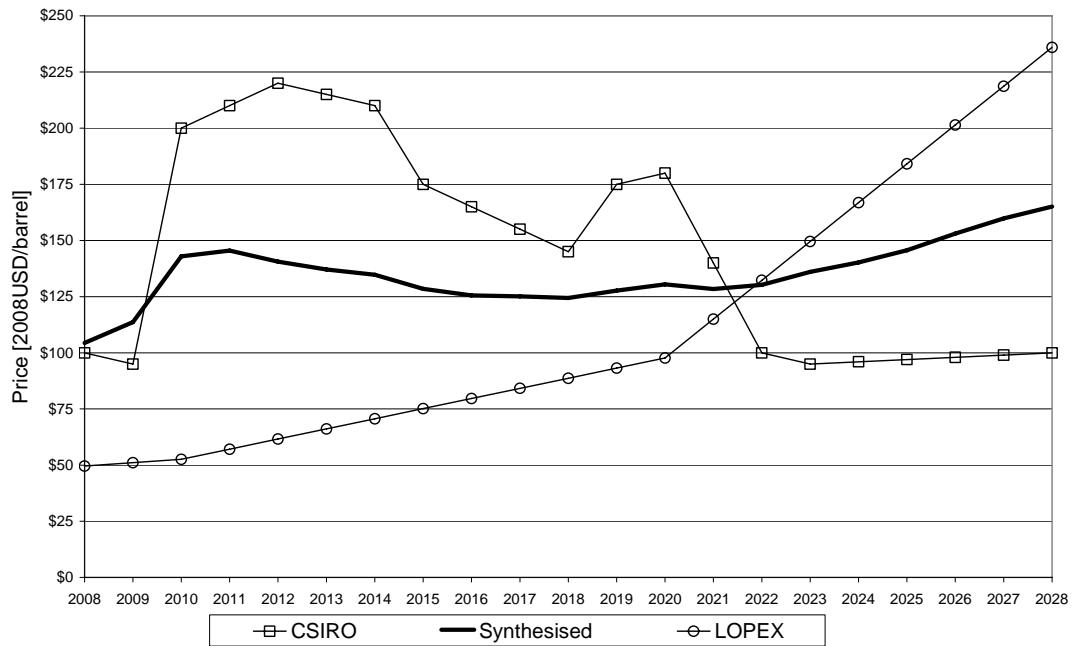


Figure 6: Comparing the synthesised forecast with the CSIRO and LOPEX forecasts 2008-2028

This comparison indicates that the synthesised price falls slightly to the lower end of the range formed by two of the more extreme oil price forecasts incorporated into the Meta model. After 2028 the synthesised forecast was based solely on the Market model forecast. The resulting final price forecast for the entire time horizon is illustrated below in figure 7.

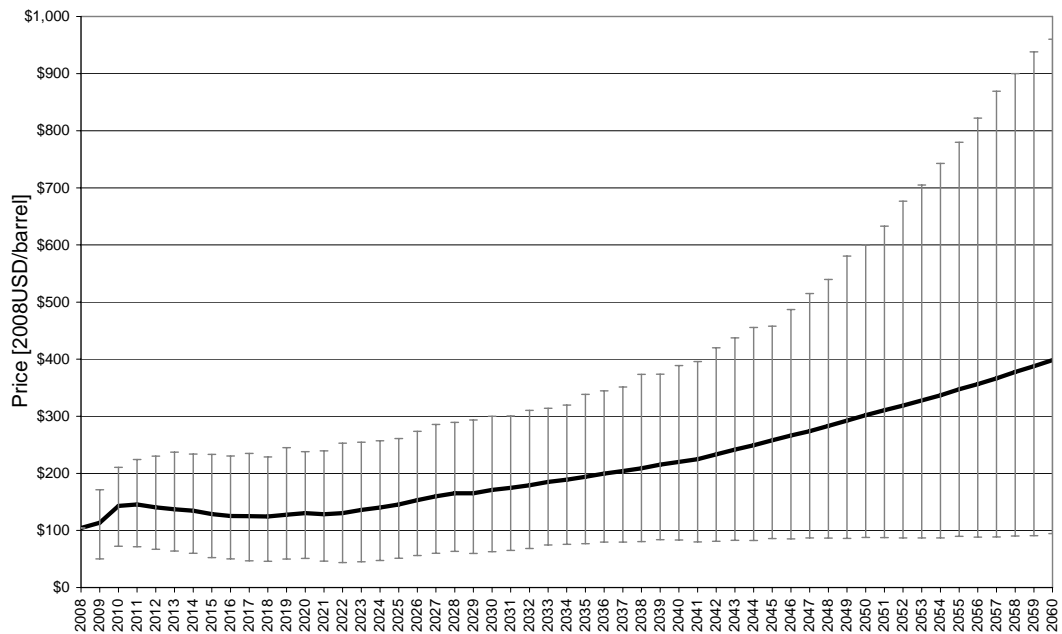


Figure 7: Recommended price forecasts and associated error bounds 2008-2020

This analysis suggests prices will rise over the next three to five years to reach approximately USD150 per barrel - prices that will be sustained until approximately 2020. After this point it is expected that continued demand and limited supply from cost-effective conventional sources will drive oil prices upwards to approximately USD400 per barrel by 2060.

Lower economic growth as a result of the global credit crisis may delay the ramp up in price predicted by these models. This effect, however, should not detract from the apparent trend towards higher prices and increased volatility, and nor should it shift the focus of regional and territorial authorities from developing policy settings that deliver enduring improvements in energy efficiency. The following section discusses some ways that the oil price models may be improved.

3.1.5 How the oil price models may be improved

These models may be improved in one of two ways: refinement of existing parameters, and extension to incorporate additional factors.

Refinement of the Market model should look to more accurately characterise the description of reserves, production, and demand stacks. Such refinement is dependent on gaining access to international surveys of oil availability. Demand stacks are more opaque as these relate to the willingness to pay for access to oil. It may be necessary to develop a banded elasticity stack that applies unique elasticities to suppress demand in different price

bands. It would be expected that as one travels up the demand stack the elasticity reduces, for example, non-essential consumption is destroyed first. Further refinement of the Meta model could focus on refining the estimation of error bounds and weighting the forecasts in respect to their historical accuracy.

Extension of the Meta model could look to incorporate a wider range of forecasts, such as those used in generating consensus forecasts. It may be useful for the ARC to develop a database of unique oil forecasts, so as to inform the continued development of Meta model price forecasts. The Market model could be extended to more explicitly model the oil supply chain. This might lead to a more fine grained analysis of supply factors, such as refining capacity, OPEC production, and investment programmes.

Finally, using annual averages price projections smooth out much of the short time scale variations. As oil reserves and supply becomes more constrained, volatility is expected to increase. This short-term volatility is difficult to predict, although a recent working paper released by the IMF discusses some statistical models that provide some insight into this volatility (Krichene, 2008). Gaining a better understanding of volatility may assist with contingency planning for transport agencies.

3.2 Price forecasts for liquid transport fuels

This section discusses the impact of rising oil prices on retail prices of oil based transport fuels. Prices for transport fuels are primarily a function of oil prices and the value of the New Zealand Dollar (NZD).

The value of the New Zealand Dollar is assumed to drop in relation to the United States Dollar (USD). Detailed discussion on the methodology relating oil prices to fuel prices is contained in Appendix D, with the resulting prices for petrol and diesel illustrated in figure 8 and figure 9 respectively.

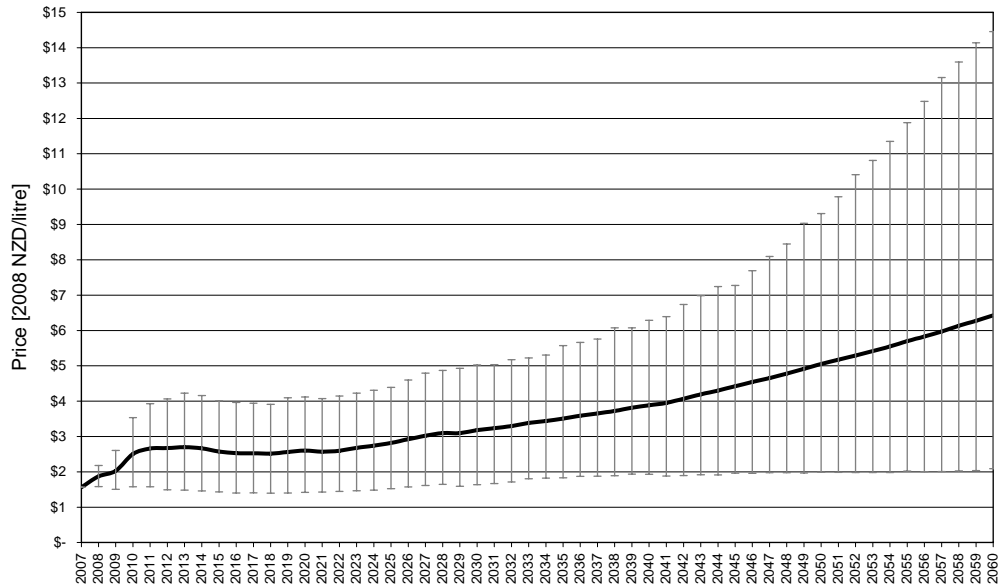


Figure 8: On-road petrol (U91) price forecasts 2008-2060

This suggests prices for petrol and diesel may reach \$6.50 and \$6.00 respectively in 2060. Escalations in price are likely to be most rapid in the period 2008-2011 and from 2025-2060. The period 2011-2025 is expected to see prices for transport fuels stabilise, albeit at historically high levels. These years may thus present a unique opportunity to drive through substantial and sustained reforms designed to improve regional energy efficiency, at a time when the economy is not burdened by general increases in energy costs. The price of fuels for off-road use is calculated by subtracting fuel excise taxes, which is discussed in Appendix D.

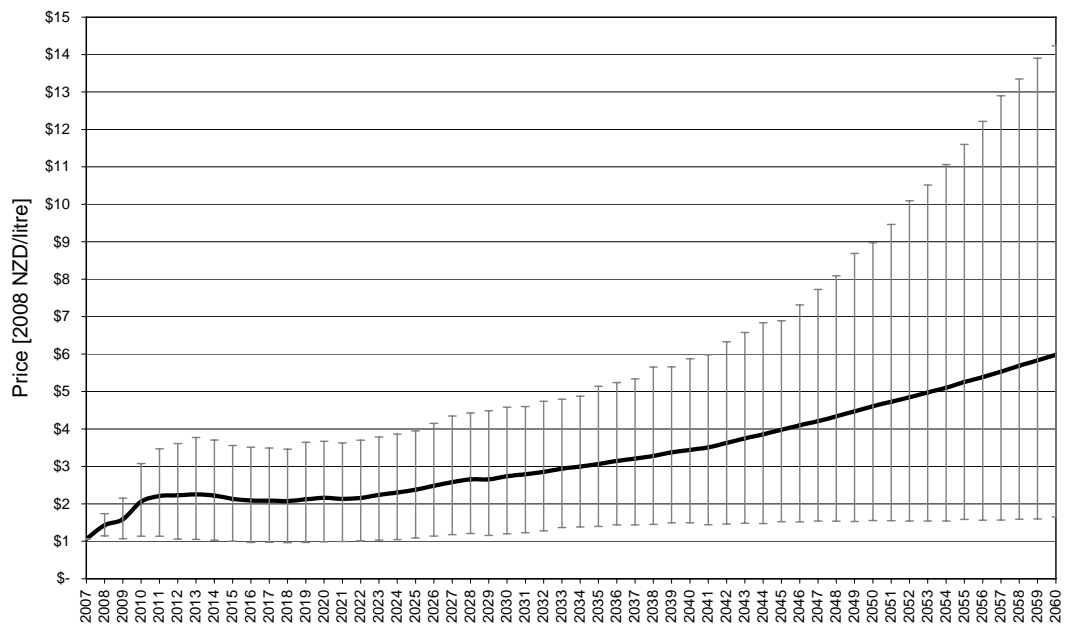


Figure 9: On-road diesel price forecasts 2008-2060

3.3 Technological substitution of transport fuels

Technological substitution has been incorporated into the Market model by way of a short and long demand response to higher oil prices. This assumes that technological substitution is best modelled on a global aggregate level and that technological substitution is both pervasive and gradual.

Some commentators remain optimistic that technological developments in the oil based transport fuels will continue to develop. Such developments, it is argued, will be sufficient to suppress demand growth and therefore mitigate the effects of higher oil prices.

Optimism over the potential for technological developments to offset issues with limited supply and growing demand is not, however, universal; the International Energy Agency (IEA) recently commented on the potential for technological substitution to offset demand as follows (IEA, 2008a):

While bio fuels have made a significant contribution in meeting transport demand growth over the past few years, they will only account for 3.5 per cent of total transportation fuels by 2013. This could obviously change in the case of a major technological breakthrough (second-generation bio fuels based on a wider range of feedstocks), but at this point such progress is uncertain and therefore not envisaged in this report.

In the same vein, even though sales of hybrid vehicles have picked up, notably in the US, they remain a niche market. Meanwhile, the development, and mass commercialisation, of hydrogen and fuel cell vehicles also depends on technological advances that would significantly reduce costs, while the production of non-conventional oil and Fischer-Tropsch synthetic fuels requires considerable amounts of energy and releases large quantities of CO₂. As such, neither of these sources is assumed to have a significant effect within the timeframe of this report.

By contrast, efforts to improve fuel efficiency will likely be more effective. The average light-duty vehicle (LDV) fuel economy is expected to improve in most regions during the forecast period. This will result from policy changes in most OECD countries, and by strong sales of small cars in much of the developing world. The share of sport-utility vehicles (SUVs) is expected to decline in many regions as first-time drivers purchase cheaper, smaller vehicles, with possibly the exception of China, where SUV sales are booming (currently at twice the growth rate of the passenger market as a whole).

This commentary suggests that improvements in the performance of conventional vehicles are likely to deliver greater efficiency gains than alternative vehicle and fuel technologies.

As part of this research, the ARC requested that MRCagney investigate the potential for developments in electric vehicle technology to create a step-change in demand for petroleum based transport fuels.

This research considered to what extent electric vehicles may be expected to:

- provide an economically attractive alternative to conventional vehicle technology,
- be deployed in large numbers (globally) within the timeframes considered in this study.

These points are considered in the subsequent sections. This analysis is intended to provide a preliminary discussion on the merits, or otherwise, of alternative transport technologies. Further more detailed work may be required to determine their regional impacts.

3.3.1 Economics of plug-in hybrid electric vehicles

Plug-in hybrid electric vehicles are generally accepted to be amongst the most promising alternative transport technology. By combining the convenience of a conventional vehicle with the cost-effectiveness of electric engines they appear likely to become available within the timeframes considered in this study. The next question is, then: To what extent are PHEV expected to offset global demand for oil?

The economics of plug-in hybrid electric vehicles (PHEV) were assessed by considering the fuel prices at which electric vehicles became an economically rational alternative to conventional vehicle technology. In general, conventional vehicles (CV) have lower capital costs and higher operating costs; electric vehicles have higher capital costs and lower operating costs. Capital costs are relatively fixed whereas operating costs vary, primarily as a function of distance travelled.

The more specific question that this research attempted to answer was then: At what fuel price and for what travel distances is the higher capital cost of PHEV justified on the grounds of their lower operating costs? This question was answered by considering the payback curves associated with electric vehicles in comparison to conventional vehicle technology. Payback curves compared the lifetime costs (capital and operating) associated with both PHEV and a CV technology.

Payback curves were calculated assuming future operating costs are discounted at 8 per cent per annum, and vehicles were assumed to have a useful life of twenty years. Maintenance costs were assumed to be the same for both vehicle technologies. Detailed discussion on the operating performance, costs, formulae, and assumptions underlying this analysis is contained in Appendix E, much of which is based on a research paper by Simpson (2006). All prices are in New Zealand Dollars.

The resulting fuel price payback curves are illustrated in. The two lines trace payback curves associated with difference in capital costs between the PHEV and current conventional vehicles. Payback curves were traced for PHEV capital costs of \$30,000 and \$40,000 in comparison to a conventional vehicle costing \$25,000. Thus the PHEV is seeking to make up \$5,000 - \$10,000 in additional capital costs over the lifetime of the vehicle. The curves are hyperbolic in shape and demonstrate the increasing attractiveness of PHEV as distance travelled increases. The average annual distance travelled per vehicle per year is illustrated by the dashed black line at approximately 15,000 kms.

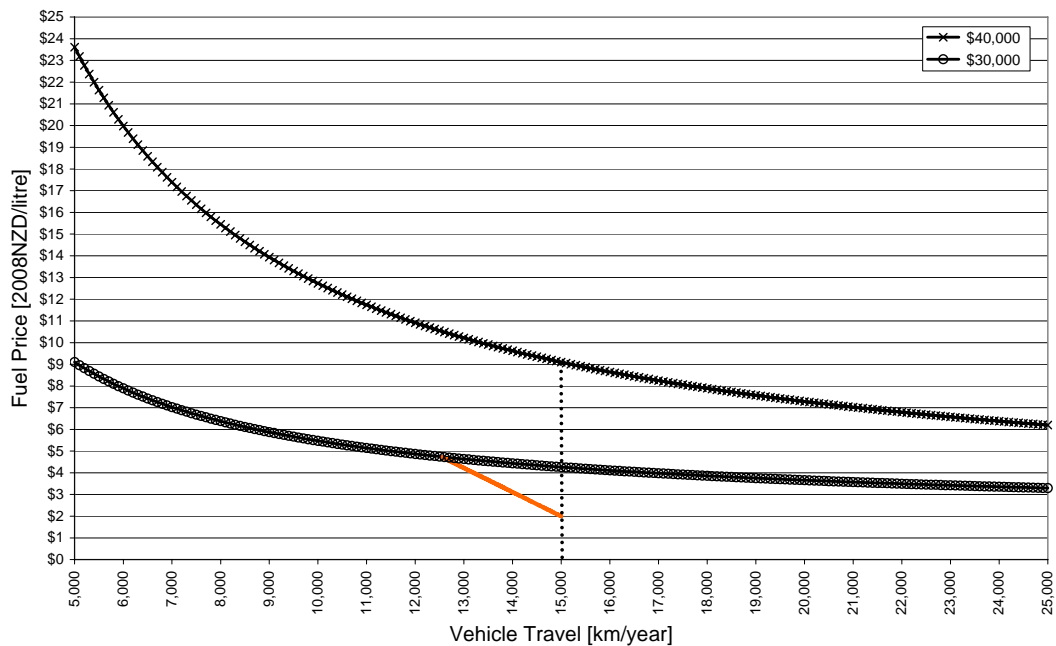


Figure 10: PHEV payback curves as a function of fuel prices and annual distance travelled

This analysis suggests that for the average vehicle fuel prices of approximately \$4 are required to justify the higher capital costs associated with PHEV.

This analysis is conservative given that vehicle travel reduces as fuel prices increase. In other words, should fuel prices increase from their current level then the average vehicle travel would be expected to reduce – further increasing the fuel price required to make PHEV an economically rational investment.

The short-run elasticity of vehicle travel with respect to fuel prices was assumed to be -0.12 (Kennedy and Wallis, 2007). This causes the average vehicle travel to reduce from 15000km per year at approximately \$2 per litre to 12,300km at \$5 per litre. The reduction in vehicle travel associated with higher fuel prices therefore pushes the “breakeven” fuel price further to the left in the above graph and consequently increases the fuel price required for PHEV to be the economically rational fuel price.

It is emphasised that -0.12 is defined as a short-run VKT elasticity. The higher long-run elasticity of -0.24 identified by Kennedy and Wallis (2007) would mean the orange “adjusted VKT” line failed to intersect with the PHEV payback curve. This would correspond with a situation where the rate of reduction in travel demands associated with higher fuel prices, effectively annuls the potential for PHEV to be an economically rational alternative for the average vehicle.

The rate of change in VKT associated with increasing fuel prices are illustrated in figure 11.

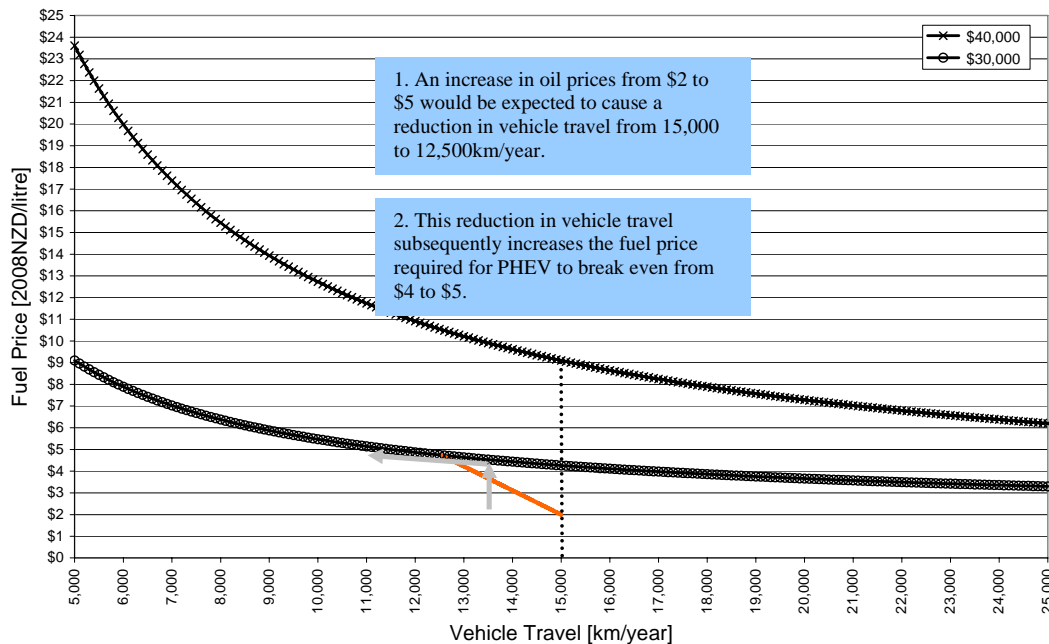


Figure 11: PHEV payback curves with elastic reduction in average VKT

This preliminary assessment suggests the economics associated with PHEV make them an economically questionable investment (from an individual perspective) unless:

- fuel prices exceed \$4-\$5 per litre,
- vehicle capital costs are below \$30,000.

These findings may change should improvements in PHEV technology occur more rapidly than expected.

This analysis suggests PHEV technology is unlikely to cause a step-change in global demand for oil within the timelines considered in this study. This conclusion is further supported by the fact that:

- Developing countries may not have access to stable and cost-effective electricity supplies, such that plugging-in PHEV will not be as convenient as it is in New Zealand.
- Developing countries may have higher discount rates than the 8 per cent assumed in this analysis – which would be consistent with higher wear and tear.
- Current vehicle turn-over (in terms of individual ownership) is approximately seven years. Thus the assumption of a 20 year payback period may be optimistic.

It is noted that central government energy and transport strategies have identified an important role for PHEV. Our analysis suggests that such a role is unlikely to come about without additional incentives and/or direct subsidies. Such incentives must be carefully

tailored so as to not detract from the potential for consumers to adopt more economically efficient and enduring responses to higher energy prices. For more detailed discussion on incentives and subsidies in the transport sector readers are referred to a recent report from the OECD (2008).

3.3.2 Other technologies – pure electric vehicles and alternative fuels

It is acknowledged that aside from PHEV there are other technologies that may emerge to offset demand for oil based transport fuels, such as pure electric vehicles (EV) and alternative fuels.

Current EV technology has only limited range; outside of short-distance urban environments their deployment may be limited – particularly given their longer refuelling times in comparison to conventional vehicles. While there is the potential for innovative battery distribution systems to emerge, no such system is currently available (Djukic, 2008). Moreover, the additional capital investment required to establish and operate such systems may be expected to increase the costs of EV.

Alternative fuels, such as bio-fuels, may also offset demand for oil based petroleum fuels. However, the apparent need to mix such fuels with oil based products, as well as current costs of production (particularly on a calorific basis) mean that they are likely to play only a marginal role in meeting future energy demands. Prices for bio fuels are discussed in more detail in section 5.1.

It is thus not currently clear whether these technologies – while promising – are able to cause a step-change in global demand for oil. It is suggested that their deployment will be at best gradual. For this reason, it is suggested that technological developments will provide a continuous but gradual response to higher oil prices, rather than a step-change.

3.3.3 Conclusions

It is acknowledged that research into new transport technologies is dynamic and ongoing. There is a possibility that developments occur which change the prognosis outlined in this report. There are also valid questions over to what degree future land use and transport policies should plan for the availability of new transport technologies.

We do not recommend that the ARC develop land use and transport policies that bank-on or subsidise emerging transport technologies, for the following reasons:

- The use of vehicles is already highly subsidised. For example, vehicle users currently do not pay for the costs of their impacts on air pollution, noise, and, notably, car-parking.
- Subsidies may lock-in sub-optimal technology, infrastructure, and behaviours that do not provide the most efficient or sustainable use of resources (OECD, 2008).

Instead it is recommended that the ARC:

- maintain a constant watch for viable alternatives to conventional vehicle technology and consider their potential impacts on future energy demands. Where such technologies have real and demonstrable potential to reduce global demand for oil then it may be necessary to revisit regional land use and transport strategies;
- develop economically neutral transport and land use policies that firstly recognise and secondly address historical subsidies for private vehicle use (such as removing minimum parking requirements). Policy settings that allow for and incentivise more intensive and diverse land use development should also be considered.

4 Other Transport Fuels

This section presents prices for the following transport fuels:

- Liquid petroleum gas (LPG)
- Compressed natural gas⁴ (CNG)
- Marine fuel (MFO180)
- Aviation gasoline (Avgas)
- Aviation kerosene (JetFuel)

Prices for these fuels were assumed to be a function of oil as per the relationships outlined in Appendix H. Implicit in these relationships is the assumption that there will be limited substitution of demand from one energy source to another. The projected prices (both in volumetric and net calorific⁵ terms) are highlighted below in Figure 12 and Figure 13 demonstrates prices of the fuels on a per litre basis, including current fuel excise taxes and duties.⁶ Notable trends include the divergence in price for aviation fuels relative to petrol and diesel prices. It is emphasised that the apparent low price for LPG needs to be considered in terms of its energy density, which is approximately 25 per cent lower than unleaded 91. Road user charges for diesel vehicles have been omitted.

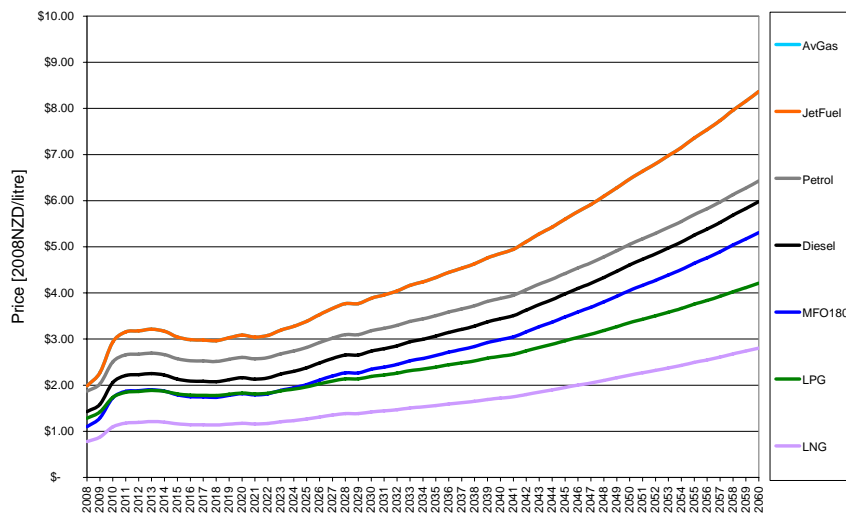


Figure 12: Volume based prices for transport fuels 2008-60 [2008NZD/litre]

⁴ Local sources of natural gas are not considered sufficient to fulfill more than niche applications within the transport sector. There is however potential for importing liquefied natural gas to play a future role in transport demands, for which prices are presented.

⁵ Net Calorific Value (or lower heating value) is equivalent to the gross energy content available for combustion less that required to vaporise water. Vaporising water is an inherent part of the combustion process itself and therefore represents energy that is not available for mechanical processes (http://en.wikipedia.org/wiki/Heat_of_combustion).

⁶ Information on fuel excise duties available at www.med.govt.nz/templates/Page_12961.aspx

Figure 13 considers a subset of fuels, namely petrol, LPG, and LNG. These fuels were selected because of their potential to be used interchangeably for land transport purposes, in comparison to AvGas, JetFuel, and MFO180 that have more specific applications in the aviation and marine industries respectively. Large quantities of LNG are not currently used in New Zealand, and local gas supplies are not sufficient to warrant large scale distribution. For this reason the cost estimates shown are for imported LNG, including estimated costs of shipping, storage, and re-gasification. Distribution costs and wholesale margins were estimated by assuming they are 50 per cent higher than the average margin for liquid transport fuels.

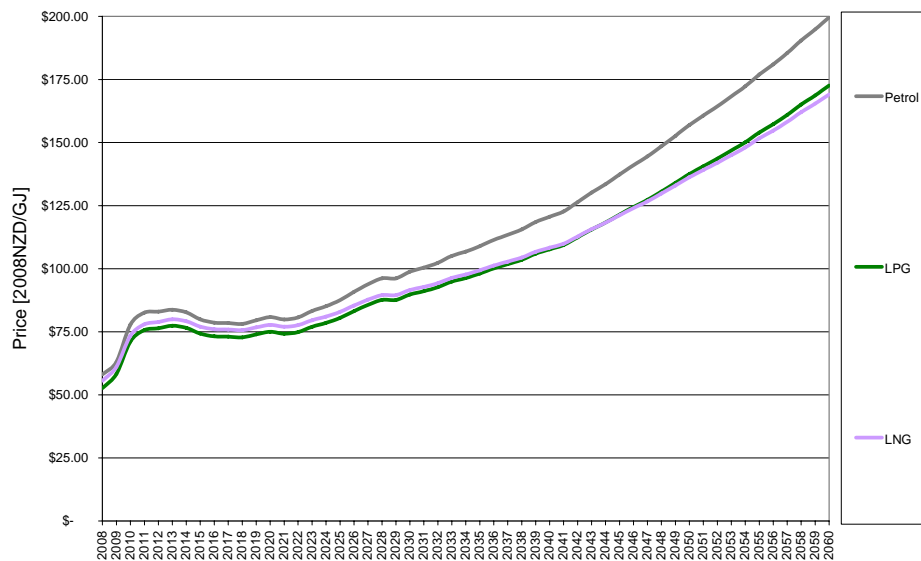


Figure 13: Calorific based price for substitutable transport fuels 2008-60

Figure 13 indicates that LNG may provide a calorific premium over petrol, particularly from 2030 onwards. This viability is affected by two important caveats. Firstly, that LNG infrastructure is capital intensive and thus requires a substantial and sustained price advantage over other transport fuels to justify the scale of investment. Secondly, the price differential between LNG and liquid fuels may not persist, particularly if international demand for LNG continues to grow strongly. Other countries have the added advantage of being able to import LNG via pipelines as opposed to the more costly tankers on which New Zealand's supplies will be reliant.

Diesel was not considered due to the difficulties of comparing road user charges and fuel excise duties. Omitting fuel taxes reveals that diesel was 5-10 per cent more energy dense than petrol on a \$/GJ basis. It is expected that this differential will drive increased uptake of diesel vehicles in the next few decades, as envisaged in the NZES (MED, 2007). This trend is expected to further reduce the potential market for using LNG as a transport fuel. It may be possible to link the transport demands for the use of LNG with electricity generation, although the latter also appears to be financially marginal.

More detailed discussion on the assumptions underlying these prices forecasts are presented in figure 14.

5 Other fuels

This section presents future prices for the following fuels:

- bio fuels
- wood
- coal.

Price forecasts were developed for the period 2008-60 by MRCagney in conjunction with Adam Barker [bio fuels and wood] and Centre for Advanced Engineering (CAE) [coal].

5.1 Liquid bio fuels

Prices for liquid bio fuels were modelled as a function of feedstock, other inputs, production, supplier margin, producer transport costs, and international shipping. Feedstock costs were assumed to reduce by 2 per cent per annum in line with improvements in genetic quality. Other costs were assumed to be constant, aside from transport to port and international shipping (where the latter is based on shipping costs from Brazil). Costs associated with both travel to port and shipping costs were assumed to be a function of oil prices, where oil was assumed to constitute approximately 20 per cent and 15 per cent of total costs for road and sea freight respectively. These costs were subsequently adjusted according to the forecast oil prices outlined in technical report 1, which effectively added an additional 20c per litre to the price of imported bio fuels. Price scenarios for bio fuels were determined as follows: I

- Low - based on expected production costs of sugarcane ethanol.
- Average - based on average production costs of second generation bio fuels.
- High – based on high production costs of second generation bio fuels.

Prices for these three scenarios are illustrated in figure 14 below.

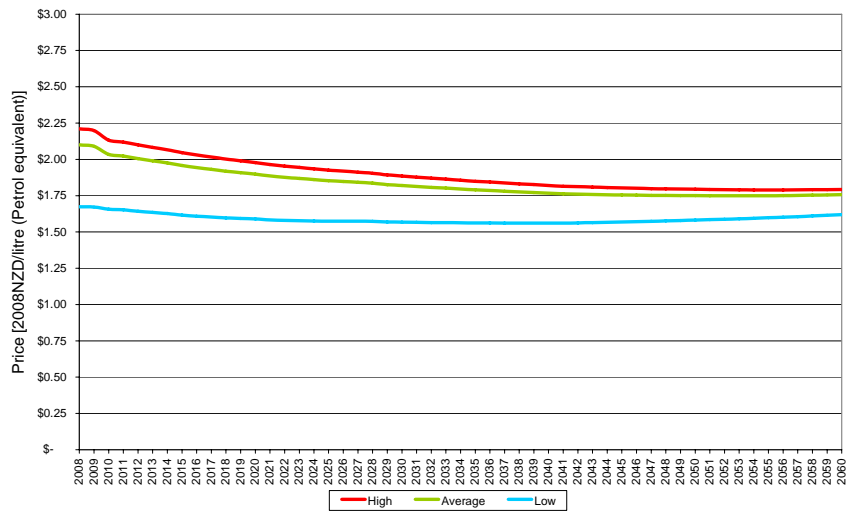


Figure 14: Landed bio fuel prices [2008NZD per litre of petrol equivalent]

Figure 15 shows bio fuel prices including importer margins, distribution costs, and fuel excise taxes (on the assumption that the majority of bio fuels are imported for transport purposes).

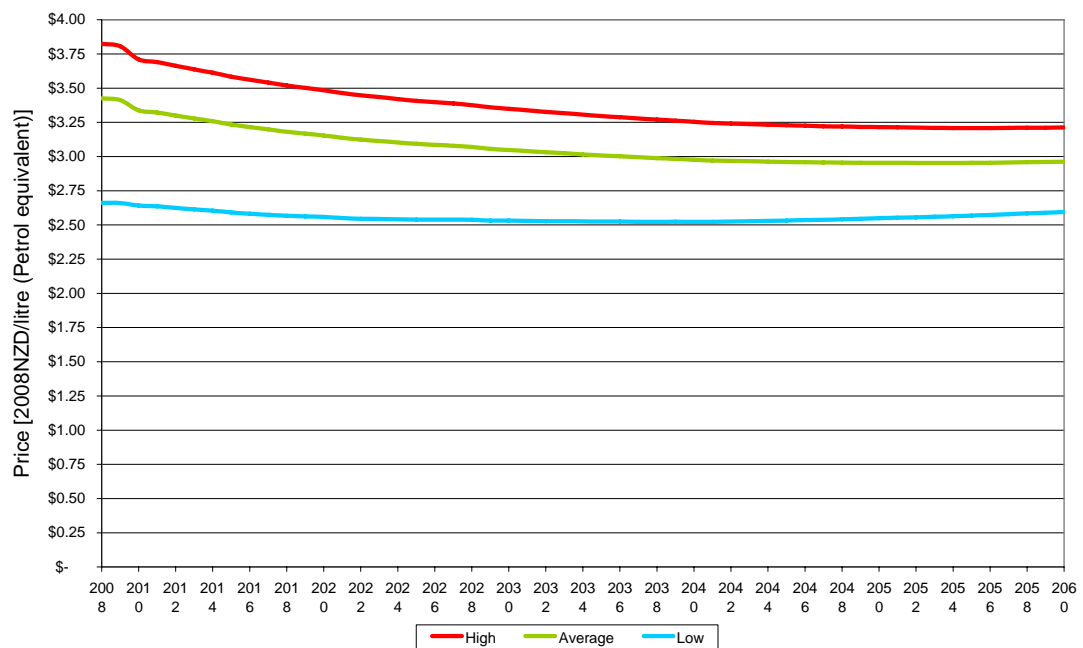


Figure 15: Distributed bio fuel prices [2008NZD/litre of petrol equivalent]

The retail prices for bio fuels illustrated in figure 15 includes high, average, and low importer margins of 20 per cent, 15 per cent, and 10 per cent respectively. Figure 15 illustrates that the low price scenario (ie that defined by imported sugarcane ethanol) is

almost competitive with oil based petroleum fuels. Further discussion on bio fuels is contained in Appendix I.

5.2 Wood prices

Although wood availability changes somewhat over the forecast time period the impact of the changes on delivered costs are relatively minor. The cost to supply wood fuel to the Auckland market is therefore not expected to change significantly over the forecast period.

An expected lower bound on the supplied cost is NZ\$40 per tonne of wood supplied. An upper bound is about NZ\$95 per tonne. The mid-case scenario is approximately \$60 per tonne. Further discussion on wood prices is contained in Appendix J.

5.3 Coal prices

We estimate the cost of coal into the future to be in the range of \$4-\$5 per GJ. This is similar to the figures and projections assumed in the Ministry of Economic Development's Energy Outlook to 2030⁷ but adjusted for a slightly more bullish view of (energy) commodity prices and of higher supply chain costs. A relatively flat outlook for prices reflects coal's ready availability and its increasing unattractiveness as a general energy source.

Coal being the most carbon intensive of all energy types, with sub-bituminous coal emitting 91.2 kg per GJ, will be most disadvantaged by New Zealand's proposed emissions trading scheme. We have assumed carbon prices increase linearly until 2060 in accordance with the parameters outlined in table 3. Carbon trading is expected to begin in 2011, commencing with a price of \$15NZD per tonne.

| Scenario | Feedstock [\$ /GJ] | Carbon Price [\$/tonne in 2060] |
|----------|--------------------|---------------------------------|
| Low | \$4.00 | \$30 |
| Average | \$4.50 | \$45 |
| High | \$5.00 | \$60 |

Table 3: Coal scenario parameters

The coal prices resulting from these assumptions are illustrated in Figure 16.

⁷ www.med.govt.nz/templates/MultipageDocumentTOC_21862.aspx, p29

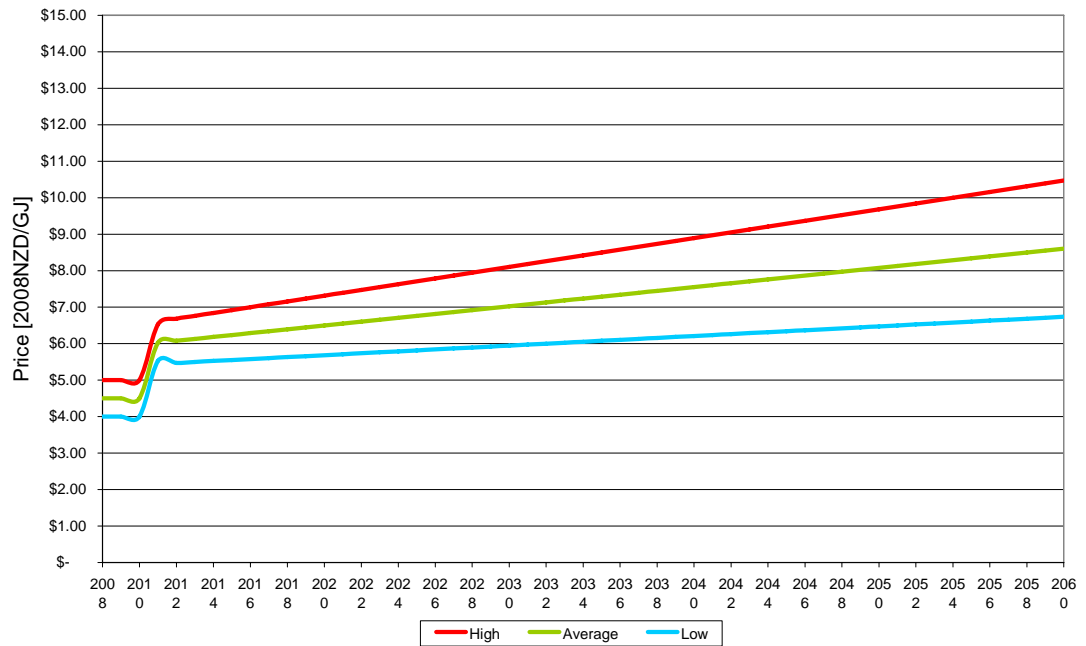


Figure 16: Coal prices [\$/GJ]

A subsequent technical report will discuss the use of coal (and natural gas for that matter) to generate electricity. Further discussion on the estimation of coal prices is contained Appendix K.

6 Electricity prices and consumption

This section discusses future electricity prices and consumption. It presents analyses of prices and a model of future electricity consumption.

Data for this section were sourced from:

- New Zealand Energy Outlook (MED, 2006)
- New Zealand Energy Strategy (MED, 2007)
- Energy Data File – Quarterly Electricity Prices (MED, 2008a)
- New Zealand Energy Information Handbook (CAE, 2008).

6.1 Electricity prices

A model of future electricity prices was developed for the period 2008-60. This model generated annual average prices by considering expected trends in the supply of and demand for electricity. The model considered ongoing growth in conjunction with the supply stack created by both existing and new sources.

The mean annual average prices generated by the model are illustrated in figure 18, where historical prices are in red and future prices shown in black.⁸ These prices represent the wholesale electricity prices, which are broadly equivalent to the price paid for by industrial consumers.

Prices for residential and commercial customers have been estimated on the basis of current margins between the prices paid by these groups in comparison to the wholesale price of electricity. The bumpiness of the wholesale price was smoothed by assuming linear price variations between major inflexion points. This shows three distinct periods characterised by increasing prices in the period 2008-2027 after which prices may be expected to slowly decline to approximately \$250 per MWh and \$200 per MWh for residential and industrial consumers respectively. Obviously, the actual price path for these users will depend largely on the pricing schemes devised by the individual retailers, who may opt for a greater or lesser degree of smoothing than what has been assumed here.

⁸ These are national average prices; prices for Auckland are not expected to vary significantly from the national average over long time periods. The historical price premium paid for electricity in the upper North Island is expected to dissipate as larger amounts of geothermal and wind come on-stream in the central North Island area. It is noted that price separation (ie significant differences between prices at different nodes) may occur in Wellington and South Island due to transmission constraints caused by the removal of pole 1 of the HVDC link.

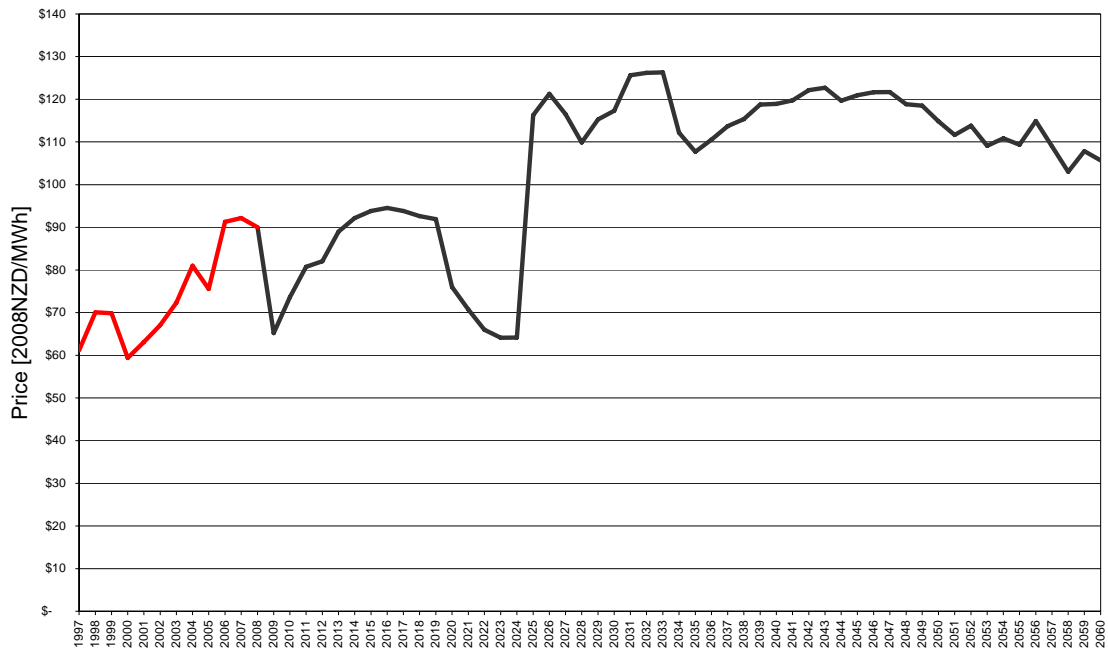


Figure 17: Wholesale, commercial, and residential electricity prices 2008-2060

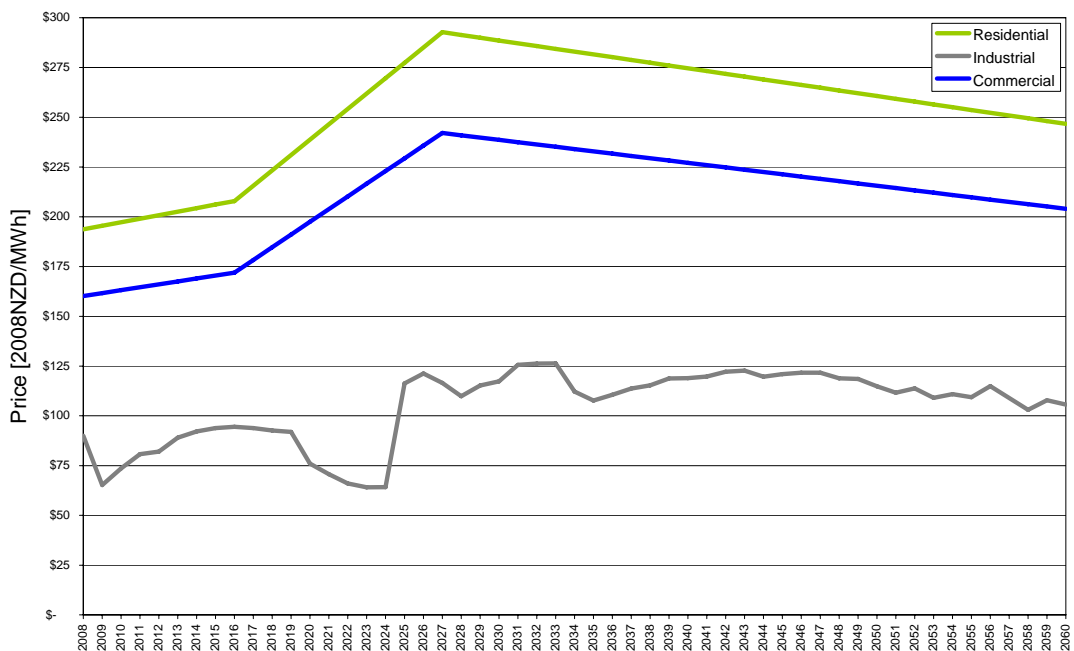


Figure 18: Annual average electricity prices [2008NZD per MWh]

Figure 18 illustrates that prices are expected to drop in 2009 to approximately \$65 per MWh before climbing gradually to reach approximately \$95 per MWh in 2020. This price rise reflects growing demand and expected increases in the domestic price of gas and

coal.⁹ At this point there is a bottoming out in prices to approximately \$65 per MWh as new generation comes on-stream in advance of the retirement of Huntly coal power station, which is programmed to occur in 2025.

The retirement of Huntly is exacerbated by increased demand from electric vehicles – these two factors creating a large escalation in price to \$125 per MWh around 2025.¹⁰ Prices are expected to oscillate after this point but gradually decline to approximately \$105 per MWh. The decline reflects the gradual addition of second tier renewable electricity generation – including Class II wind and geothermal, as well as substantial amounts of tidal, wave, and ultimately solar. This investment is expected to be supported by wholesale prices in the order of \$100-\$115 per MWh.

It should be noted that the model incorporated a number of probabilistic parameters – in other words, many inputs and outputs were allowed to vary across a range of values, including weather, demand, and the amount of new supply constructed in any particular year. This allowed the model to capture not only the expected, or average, electricity prices but also the range of variability that may be expected around this average.

Variability was encapsulated into supply and demand in a number of ways. The most important variation affecting supply was the determining examples of wet and dry years, where the latter tend to curtail generation from both hydro and wind thereby driving up prices. In order to capture a range of potential outcomes a large number (5000) individual price forecasts were made, as illustrated in Figure 19. This generated a wedge shape price distribution that is typical of systems characterised by upside risk factors.

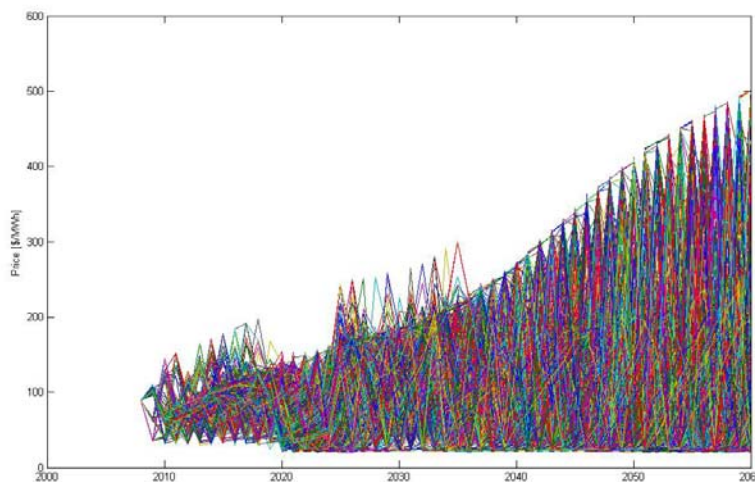


Figure 19: Price distribution

⁹ EnergyHedge prices at Otahuhu are \$85/MWh in 2009, but it is our view that these contract prices are not robust due to thin volumes, small number of market participants who offer contracts, incentives for participants to “manage” prices, and an added risk premium from the increased risk of a dry year next year.

¹⁰ The effects of plug-in hybrid electric vehicles (PHEV) are phased in from 2016 – which is discussed in more detail in subsequent sections.

Figure 19 demonstrates increasingly volatile electricity prices. This volatility reflects the combined effects of must run renewable generation backed up in dry years by increasingly expensive gas generation. In this context the supply stack essentially steepens, such that in the event of a dry year and/or unexpected demand, growth prices flick from a low price band into a high price band. The issue of the steep supply stack is exacerbated by the fact that electricity consumption is relatively insensitive – or inelastic - to changes in prices. Rates are often fixed in advance such that demand suppression is that much more muted. For this reason, demand side management (based around increased price exposure) will be an important component of preparing for a future of increasing volatile electricity prices.

6.2 Modelling approach

Intuitively the factors affecting future electricity prices are encapsulated in concepts of supply and demand. More importantly, however, is the rate of growth in demand and the price of additional supply. It is the changes in demand and supply at the margin that determines future electricity prices. The following sections outline the key assumptions made in the model, under the sub-headings of supply and demand. The model architecture is discussed in more detail in Appendix L.

6.2.1 Supply

Supply is characterised by a stack of potential generation arranged in order from lowest to highest price. This stack consists of two primary parameters; the price at which the supply becomes available as well as the amount of energy that it is able to generate. The current supply stack consists of large amounts of cost-effective generation from renewable wind, geo, and run-off-river hydro. This is backed up with stored hydro and large thermal (such as Huntly) for the inter-day peaks. Combined cycle gas turbines (CCGT) become base load in a dry year with additional peaking thermal plant, typically gas being used during times of high demand and plant outages. The prices and quantities associated with the base supply stack are illustrated in table 4.

| SRMC [\$/MWh] | Energy [GWh] | | | Notes |
|------------------|--------------|-------|-------|-----------------------------|
| | Wet | Mean | Dry | |
| 0 | 0 | 0 | 0 | |
| 25 | 34400 | 29600 | 25400 | Must run renewables – wind, |
| 30 | 39700 | 34900 | 30700 | Base load thermal – mainly |
| 60 | 45500 | 40700 | 36500 | Daily peaking thermal – gas |
| 65 | 48000 | 43000 | 39000 | |
| 70 | 48500 | 43500 | 39500 | |
| 80 | 49000 | 44000 | 40000 | |
| 120 | 50000 | 45000 | 41000 | Back up supply |

Table 4: Base supply stack

As discussed above, marginal supply growth is expected to come primarily from renewable energy forms. The cost of new generation is described by the long run marginal costs (LRMC), which essentially represents the price at which the generation becomes economically efficient. Once built, however, renewable sources effectively have a short run marginal cost (SRMC) of \$0, such that the cost of generating electricity from renewables is minimal once they have been constructed.

This based supply stack was expanded to meet growing demand by selecting new generation from the “pool” summarised in table 5.

| LRMC [\$/MWh] | Generation Pool [GWh] | | | Notes |
|------------------|-----------------------|------|-------------------|---|
| | Hydro | Geo | Ren ¹¹ | |
| <80 | 900 | 6500 | 6000 | First tier projects as identified in MED (2006) and other research |
| <100 | 0 | 1000 | 56500 | Assumes major new sources of renewables, such as tidal, wave, and solar are developed, alongside large amounts of Tier 2 wind |

Table 5: New generation pool

We estimate that there is limited capacity for additional hydro generation, due to very few large rivers left to dam, the largest schemes are politically unsuitable, and finally difficulties in obtaining resource consent in face of multiple users of the water resource (eg kayakers and other recreational interest groups).

Geothermal is by far the most cost-effective technology. New generation is limited by resource availability; where the resource is present it is generally lower cost (hence why there is not an abundance of geothermal resource over \$80 LRMC). Higher cost generation will typically involve smaller, lower temperature resource. There is known moderate capacity for additional geothermal generation – government and industry scientists have accurately mapped the central North Island hotspots and the most likely resources have already been identified. The main limits on fully utilising the known resources are: potential negative effects on tourism landmarks and potential negative effects on conservation sites.

Wind is a widely available and cost-effective energy source that provides the potential to meet a significant proportion of New Zealand’s future energy needs. There is some debate over the maximum amount of wind which can be incorporated into the New Zealand electricity grid, with the debate ranging from 15-25 per cent of total electricity supply. We have assumed a maximum 25 per cent of mean year energy demand could be produced from wind on the grounds that improved grid management and technological developments will facilitate a relatively high level of wind penetration. The main technical system issues with wind are related to short-term fluctuations in output and the fact that

¹¹ Incorporates sources such as tidal, wave, and solar which are unlikely to be correlated with wind and hydro. Note that correlations between wind and hydro may be important for determining generating capacity in dry years.

wind turbines have low spinning inertia, such that a higher incidence of wind may increase electricity grid instability (voltage and frequency problems).

The process for adding new generation is summarised as follows:

- Demand pushes up electricity prices up to the point where additional generation would be economic.
- Generators make investment decisions based on trend prices, so new generation becomes available after some time lag.
- Generators also make investment decisions based on foreseeable events, such as the retirement of Huntly coal in 2025.
- Additional renewable generation is added to the supply stack as “must-run” – ie has a SRMC of \$0.

In this way new generation was added to the supply stack at such time as demand and ensuing prices made it economic. It is noted that wind was allowed to only make up approximately 25 per cent of mean year energy demands, which is considered to represent its maximum market penetration based on existing technologies. It was assumed that hydro, wind, and other renewables were positively correlated.

The resulting supply scenarios are shown in figure 20.

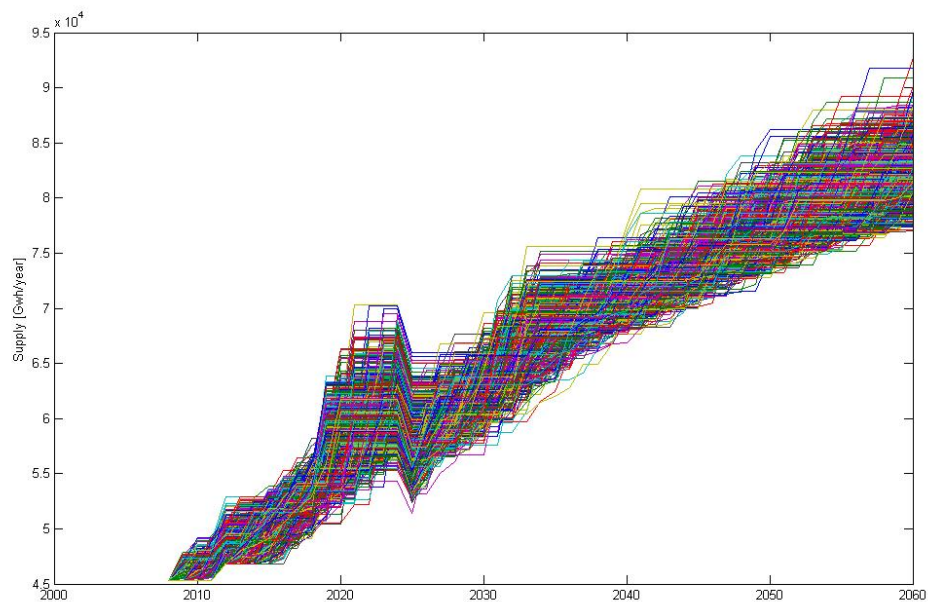


Figure 20: Supply scenarios

6.2.2 Demand

The demand side model consisted of the following three components:

- Annual demand growth – assumed to be a constant compounding growth rate.
- Demand responsiveness – assumed to be a function of prices from the previous year and a small initial demand response elasticity of -0.06.
- Additional demand – assumed to primarily derive from uptake of electric vehicles, although domestic heating (such as heat pumps) may also be a factor.

Firstly, annual demand growth was assumed to be normally distributed with a mean of 1.31 per cent. Secondly, demand responsiveness was assumed to be a function of prices from the last year and an assumed elasticity starting from -0.1. This elasticity increased over time on the assumption that time-of-use metering would deliver increased responsiveness from the residential sector.

Finally, additional demand was characterised on the basis of uptake of electric vehicles. Demand levels were based on modelling undertaken by the Electricity Commission (EC) and Ministry of Transport (MOT). However, this modelling assumed oil prices of approximately \$60USD per barrel, which are substantially lower than that modelled in earlier work on this project (EC, 2008). For this reason, the uptake of electric vehicles (and their associated demand for electricity) was factored up in proportion to higher oil prices. It is important to note that the price effects of this additional demand may depend on whether the load is able to be spread to times of low demand. The resulting demand scenarios are illustrated in figure 21.

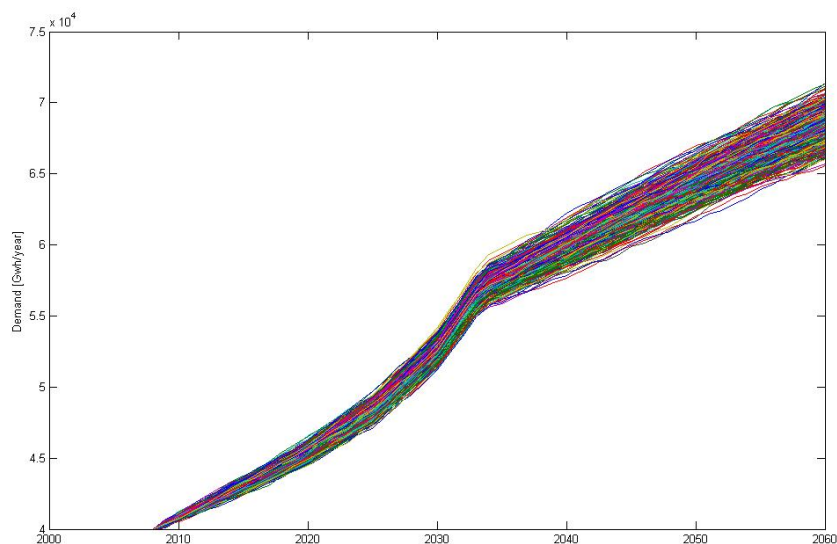


Figure 21: Demand scenarios

6.3 Discussion

The following sections discuss some of the finer points of the electricity price model.

6.3.1 Relative importance of supply and demand

The relative bumpiness and larger range associated with the supply curve in comparison to the demand curve, suggests that the timing and cost of new generation will be the primary determinant of future electricity prices. This model attempts to model the decision making processes of the electricity generators as a function of average price and the costs of new supply. If these assumptions do not hold, such that generators actually take a different view on the timing of new generation, then the price forecasts presented above are unlikely to eventuate.

6.3.2 Trends in generating capacity

Figure 22 illustrates that the relative ratio of potential supply to demand varies around 85 per cent, with obvious distortions in the build up and aftermath of 2025 when the retirement of Huntly is expected to present challenges to generating capacity. While the effective spare capacity appears to increase over time (as would be expected with a supply stack characterised by an increasing proportion of positively correlated renewables) it is cautioned that this figure does not account for additional plant retirement above and beyond Huntly; in other words it is assumed that existing gas generation is replaced by new gas generation at the same price.

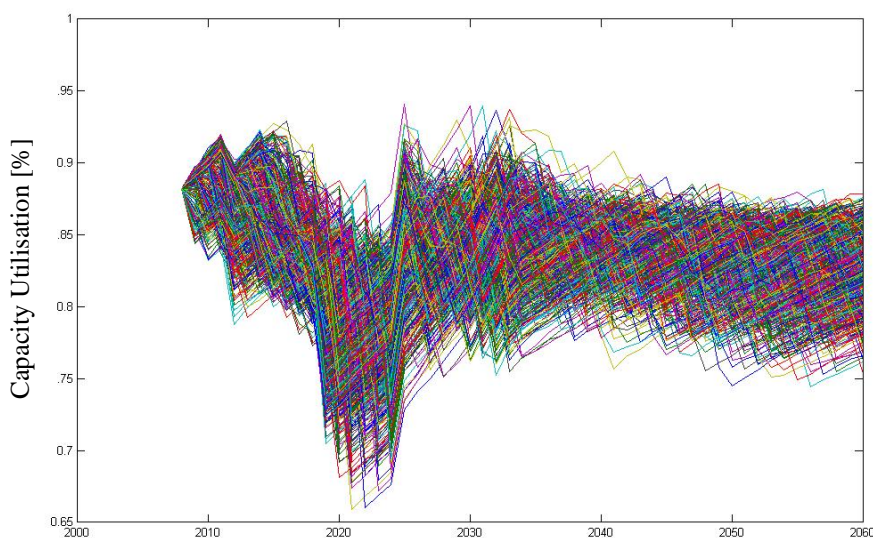


Figure 22: Demand versus supply

6.3.3 Opportunities for new coal technologies

The high prices in figure 19 illustrate the effects of high international gas prices. In this context new coal technologies may become increasingly attractive. Figure 23 shows the mean price, superimposed with the estimated costs of new coal generation.

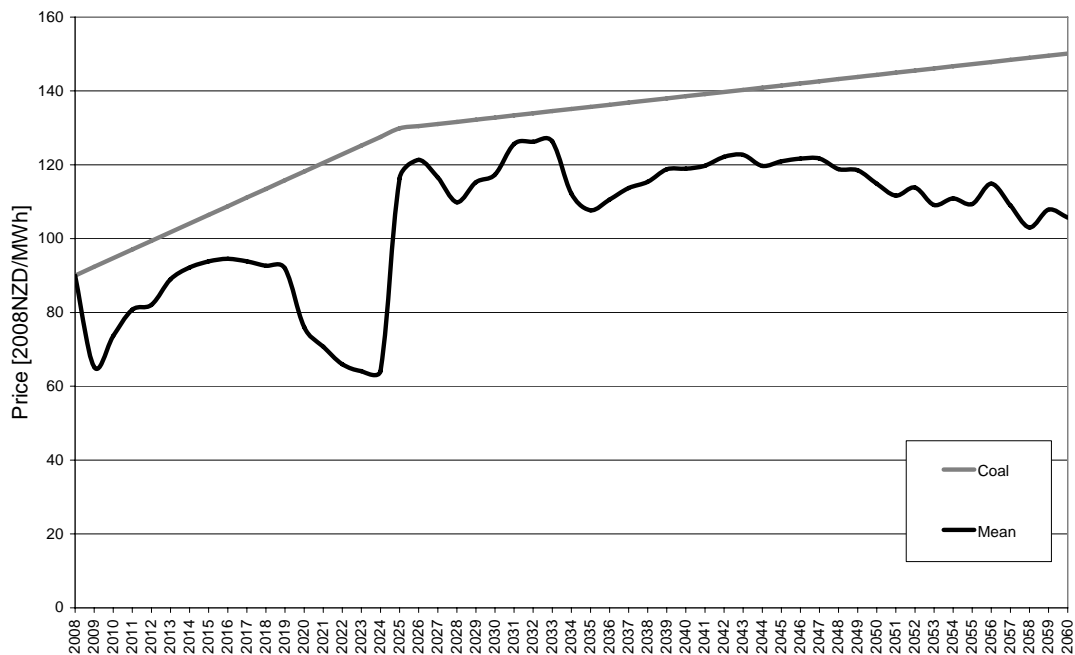


Figure 23: LRMC of coal generation in comparison to modelled electricity prices

This suggests the role of dry year back-up and peaking plant may be filled by coal at a lower price than can be achieved with gas, with the important caveat that this price is strongly dependent on the carbon price. We have assumed that new coal technologies will be approximately \$50 per MWh more expensive than current coal generation – reflecting additional costs associated with mitigating their greenhouse gas effects. While a renewable dominated system is on average more cost effective, it appears that there remains substantial potential for new coal technologies to insulate consumers from the combined effects of dry years and escalating international gas prices.

6.3.4 Impact of electric vehicles

Additional demand from electric vehicles added approximately 2.6 per cent to electricity prices in the period 2027-33, when the rate of demand growth is expected to be the greatest. This result may be conservative given the potential for smart charging technologies (such as time of use meters) to spread this demand to off-peak times. In this event, electric vehicles will primarily utilise electricity associated with base load thermals and must-run renewables, such as geothermal and wind.

6.3.5 Reactive power and voltage support

The other important electricity consideration for the Auckland region is a potential shortfall in reactive power and the requirement for voltage support. Ongoing growth in demand for appliances such as air conditioners and heat pumps increases the need for reactive power and voltage support. Without these, brownouts such as those recently experienced in Perth could potentially be expected in summer and winter peaks.

Reactive power is needed to power inductive loads such as lightly loaded induction motors (found in appliances such as air conditioners) and ballasts in fluorescent lights. At a system level this can be provided by adding capacitor banks to switchyards or adding synchronous condensers:

- The use of capacitors is limited by the fact that during low voltage events such as short circuits, the reactive power produced by the capacitors is dramatically reduced. This characteristic can promote voltage instability under some conditions.
- Synchronous condensers such as those at Otahuhu A, Southdown, and Marsden produce reactive power when required, even during low voltage events, enhancing voltage stability and voltage support over a wide range of conditions. Local thermal generation also acts in the same way as synchronous condensers.

The location of new thermal generation (such as gas-fired and diesel-fired power generators) in the Auckland region would thus enhance voltage stability and voltage support and produce the reactive power required to underpin growing demand for appliances such as air conditioners, heat pumps, and compact fluorescent lights.

6.3.6 Limitations of this model

The main limitation of this model is that in considering only annual average prices it operates at a relatively coarse temporal level. This means the model is unable to account for potential trends in demand across the day or season. Such trends may see, for example, greater short-term variability as a result of increased wind generation. This variability may also hasten the implementation of demand side management measures. While these measures may initially seek to shift load – there is the potential for them to also reduce total energy consumption in the long term, as technology develops to enable consumers to adapt to price variability.

6.4 Policy considerations

Building consents: ARC may wish to consider reducing impediments to building consents for energy efficient improvements, such as double glazing and solar hot water and buildings with solar PV cells.

Resource consents: Consider policy settings that enable electricity consumers to install local electricity generation so as to provide price security and incremental gains in electricity grid stability through voltage support, reactive power, and frequency/reserves.

6.5 Electricity consumption

This section considered regional electricity consumption in more detail. It develops per capita models of historical demands in the industrial, commercial, and residential sectors as functions of economic growth, time, and price. This model is used to forecast future electricity consumption.

Historical electricity demands for the industrial, residential, and commercial sectors are shown below.

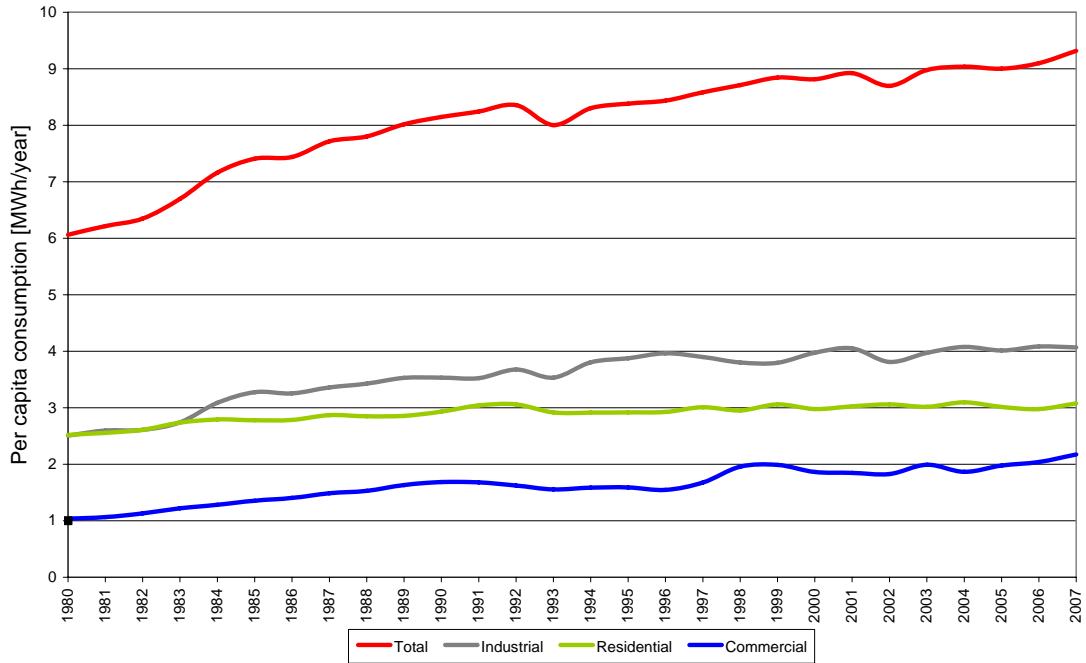


Figure 24: Per capita electricity consumption 1980-2007

Figure 24 illustrates electricity consumption for the period 1980-2007. Historical demand was assumed to be a function of economic growth, time, and price. The predictive ability of these models is illustrated in Figure 25 while the formulation of the models themselves is discussed in Appendix M.

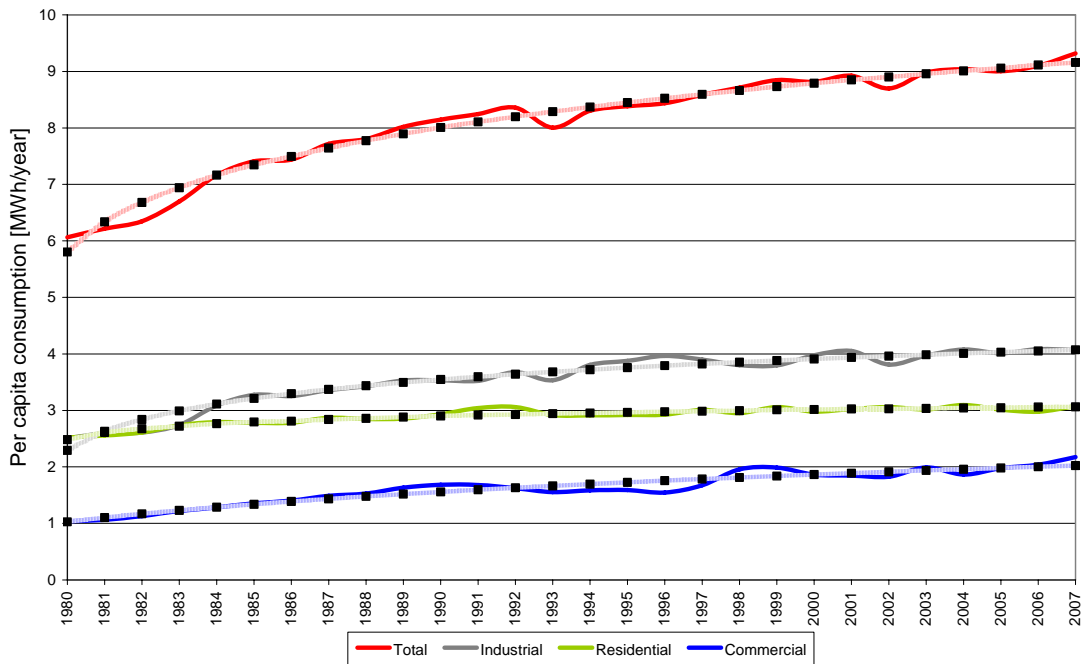


Figure 25: Modelled electricity demands 1980-2007

Both linear and logarithmic functions were investigated. Table 6 shows that the model of total electricity consumption has an R-squared of approximately 99 per cent. This is higher than what was found using more simple linear growth models.

| Consumption Model | R-squared |
|-------------------|-----------|
| Industrial | 95.1% |
| Residential | 89.1% |
| Commercial | 93.5% |
| Total Demand | 99.3% |

Table 6: Summary of model statistical performance

The electricity consumption model (ECM) is formulated as follows:

$$C(t) = C_{Industrial}(t) + C_{Residential}(t) + C_{Commercial}(t)$$

$$C(t) = (A_I \ln(t - T_I) + K_I) + (A_R \ln(t - T_R) + E_R P_R(t) + K_R) + (A_C \ln(t - T_C) + K_C)$$

Electricity consumption is therefore a function of time and price – where price responsiveness is evident only in the residential sector. The constants used in the formulation of the ECM were determined using a linear least squares regression model which is discussed in more detail in Appendix M.

6.5.1 Future demand for electricity

Allowance was made for additional demands from electric vehicles. Forecasts from the Ministry of Transport and the Electricity Commission provide indicative rates of uptake of electric vehicles, although these were factored up in light of higher than expected oil prices. The net effect of electric vehicles is to add approximately 10 per cent to total energy demands by 2034.

Demand management measures, such as time of use meters, were assumed to facilitate peak spreading as opposed to reduced consumption. For this reason these technologies are not expected to reduce future electricity demands but instead spread consumption to periods with low prices.

Electricity savings associated with, for example, improved building standards, energy efficient lighting, and solar water heating were assumed to be reinvested in increased consumption for space heating purposes. Such demands are likely to result from increased use of heat pumps as opposed to gas and solid space heaters.

In addition to electric vehicles, it is likely that higher prices for fossil based fuels may drive additional shifts in energy demands to electricity. This has been accounted for by adding 200MWh of additional electricity consumption per year from 2035 onwards. Further work could seek to refine this approach by disaggregating additional demand factors.

6.5.2 Forecast consumptions

The ECM and additional demand from technological developments were used to forecast national electricity demands, as illustrated in Figure 26.

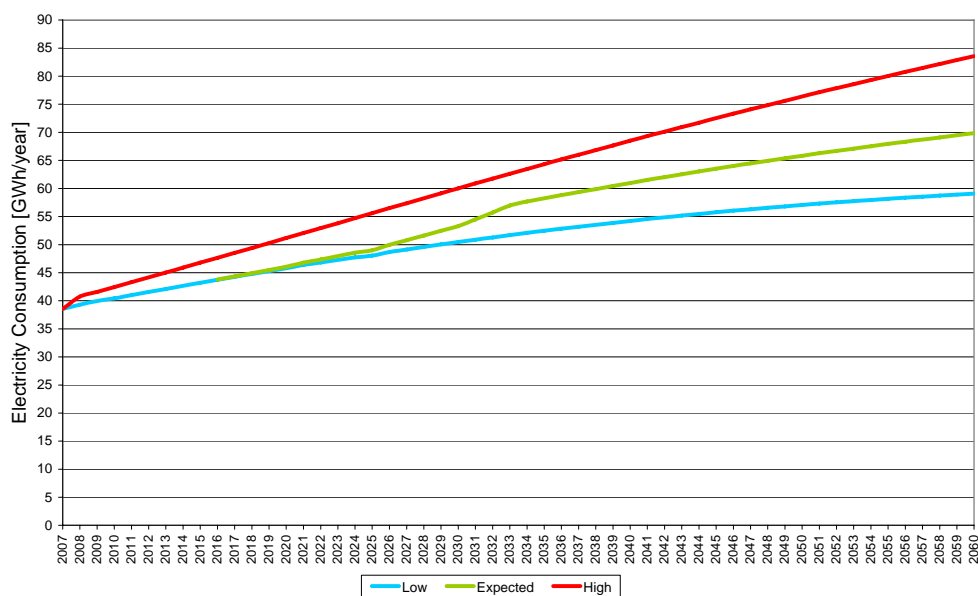


Figure 26: Electricity demands in New Zealand 2008-2060

This shows electricity consumption almost doubling from its current level of 38.6 GWh per year to approximately 70 GWh per year. It is noted that electricity consumption is distinct from electricity generation in that the former does not include transmission losses which typically account for 5 -10 per cent of electricity generated.

Consumption for the Auckland Region was estimated on the basis of relative population projections sourced from Statistics New Zealand, as illustrated in Figure 27.

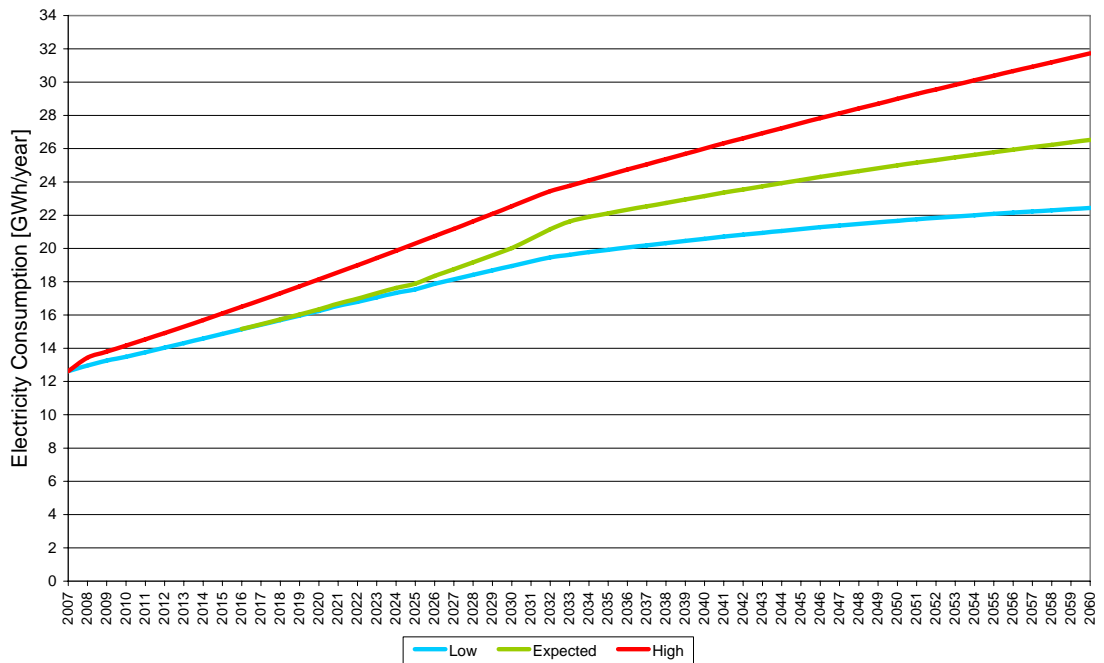


Figure 27: Regional electricity demands 2008-2060

It is expected commercial consumption will continue to grow at a faster rate than industrial and residential consumption.

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8 Appendix A: Methodology of the Meta Model

This section outlines the methodology underlying the Metal model. This model essentially sought to combine multiple oil price forecasts (these are discussed in Appendix E) to generate a statistically representative view of future oil prices.

None of the mainstream forecasters offers a confidence interval on their results, and few make their past predictions or model details freely available. However, Energy Information Association (EIA) forecasts are available from the early 1980s and Reserve Bank of New Zealand (RBNZ) from 2004. These are shown (in log form), along with the actual price of oil, in Figure 28.

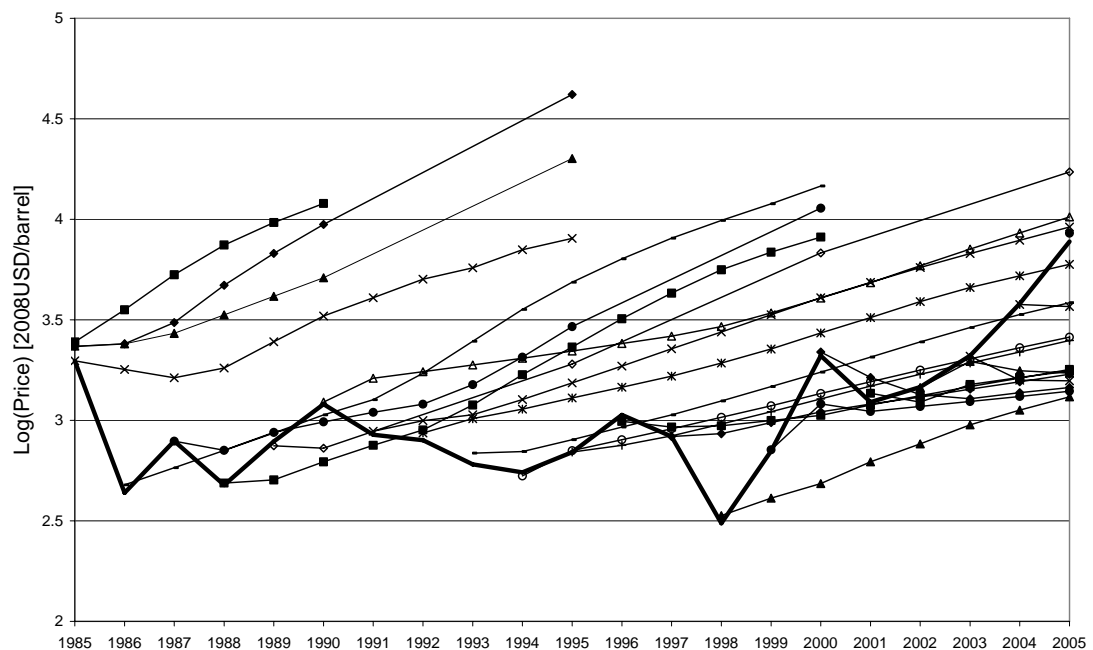


Figure 28: EIA forecasts 1985-2005

Given the shortage of data, the EIA history was used to generate synthetic error bounds for all forecasts by assuming that the true oil price lay within the 95 per cent error bounds of past EIA forecasts. For scale invariance and to avoid negative prices, the logarithm of years after the prediction and the error in the prediction of the logarithm of price was compared, as shown in Figure 29.

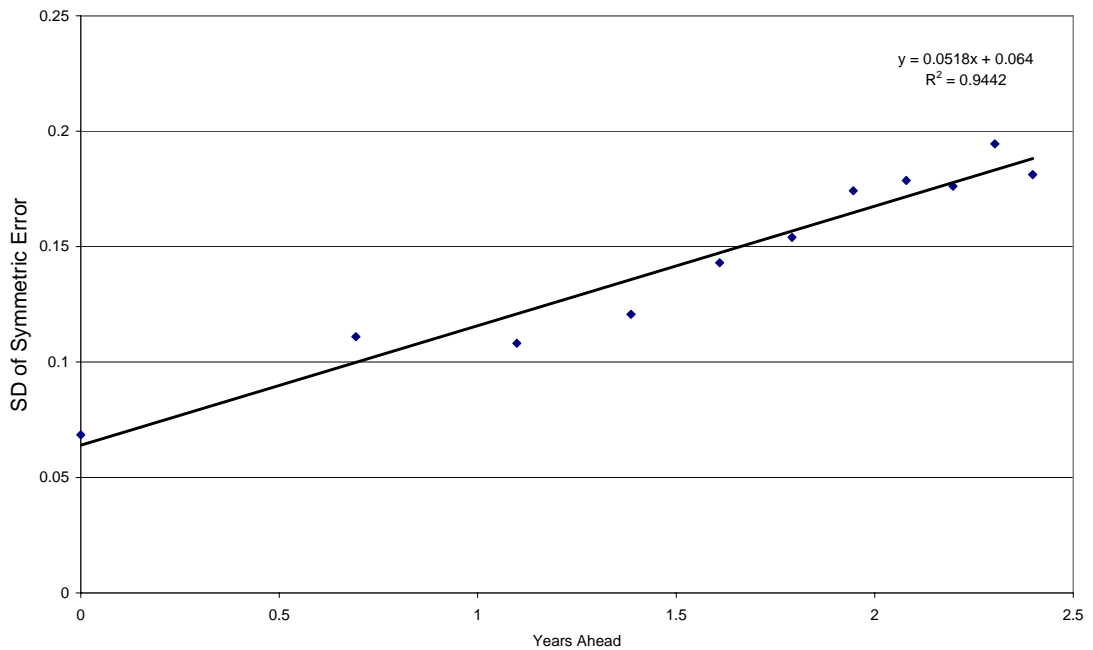


Figure 29: SD of symmetric error versus log time for EIA forecasts

The forecasters seem to predict on a business as usual basis; various non-economic risk factors are not taken into account, even though they clearly have a significant effect on the price of oil.

In order to generate an expected forecast, and error bounds on that forecast, a large number of candidate forecasts were generated by sampling for each year from the set of forecasts, the error distribution for that year, and non-economic risk factors, which were assumed to add approximately 5 per cent to the underlying price forecast. That is, for a single trajectory t , the prediction in year y , the price $P_t(y)$ is:

$$P_t(y) = e^{\ln[f_{U_t}(y)]N[1, a+b\ln(y-y_0)]} \prod_{Risks} Z_r$$

Where f_U is the U the forecast, U_t is a randomly chosen forecast used for the whole trajectory, N is a normal random variable sampled every year, a and b are parameters of the error correlation, and Z_r is a random variable for each risk element that is fractional change in cost with the probability that the modelled event occurs, and 1 otherwise.

The merits of this modelling approach rest broadly on the robustness of the various forecasts used and to a lesser degree the magnitude of the risk premium added by non-economic risk factors. Most forecasts are made on an annual basis and will therefore not incorporate the most recent price trends. In particular, it is likely that the recent prices and

IEA warnings of a supply crunch in 2015 will not as yet have been accounted for in the older price forecasts.

9 Appendix B: Methodology of the Market Model

Overall structure

The model generates a price trajectory by calculating an oil price from supply and demand, and then moving forward a period (one year) by changing the supply and demand by some function of price. The model treats key input parameters as random variables and uses a number of runs to generate statistically representative oil price scenarios.

The in-period price problem compares supply and demand stacks, (supply is separated into price bands) to generate an oil price. Current and past price behaviour suggests that oil demand and supply are relatively inelastic to price, and this can be modelled by having little or no overlap between the two stacks. This suggests that shortfalls in supply will catalyse large jumps in price.

Once the price of oil is determined for a period, the supply and demand stacks are altered in some manner as a function of the oil price, and these new stacks are used to determine the price in the following period. Intuitively, we can assume that a higher price of oil may result in a slower growth in oil demand, and a lower oil growth may result in less effort in increasing or maintaining supply. Both of these effects may operate in a lagged or integral sense. Empirical data to support these assumptions is limited however. This reflects that demand, in particular, is relatively inelastic in the short term, and that information on the world's production capacity is unreliable, particularly for some of the larger oil-producing nations.

Oil reserves are modelled as a reserve stack, specifying how much oil is available to be brought to market in each price bracket. The reserve stack contains all available oil, not just proven reserves. Discovery is not modelled, other than as part of making reserves available for supply.

The output from the model is not a single trajectory or scenario, but a summary of several thousand scenarios. The expected price path is an average of the full set of the scenarios, and the high and low paths are confidence intervals for the sample of generated scenarios.

Reserves

The reserve stack for each period specifies the total amount of oil remaining in the world in each price band. The user enters the initial stack, and subsequent stacks are calculated by subtracting usage in each period. Figure 30 shows an example reserve stack.

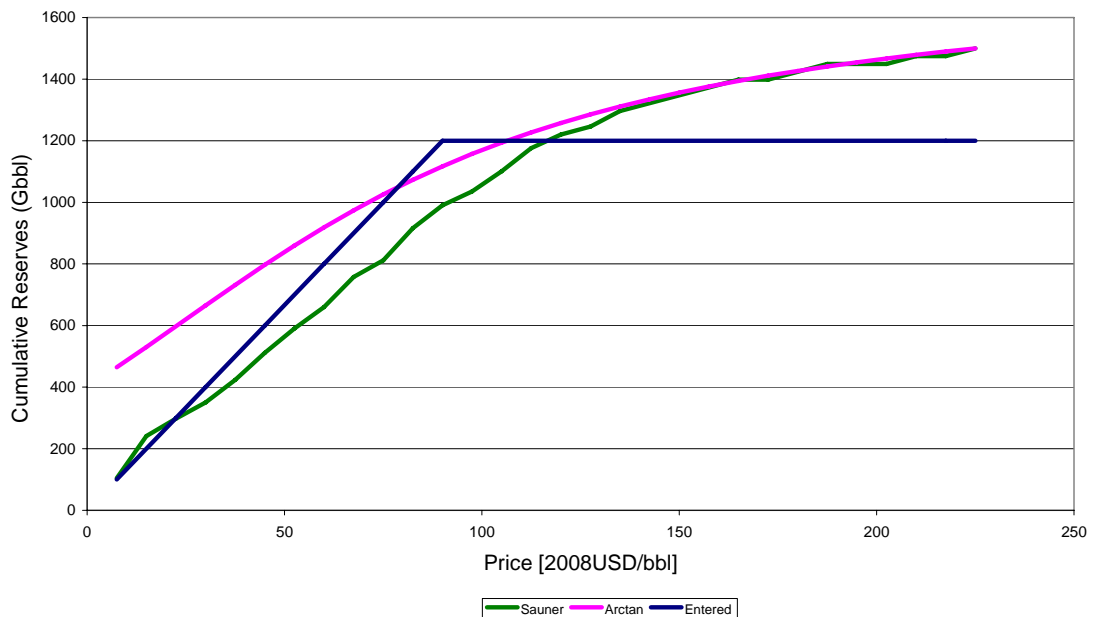


Figure 30: Reserve price stack

Some guidance for the initial reserve stack is available from SAUNER data and the BP Statistical Review data, which contains a view on total reserves but no discussion of the stack (SAUNER, 2000, BP, 2007).

The SAUNER data should be used with caution. It suggests a total reserve of 6000 Gbbl of oil, a larger number than most studies, and presumably the shape of the stack has changed from subsequent use of oil in its lower price brackets.

For the initial reserve stack the user can choose between a scaled SAUNER stack, a user entered stack or a stack interpolated with an arctangent.¹² The user enters both the shape of the reserve stack and total reserves. The shape of the reserve stack is fixed for a simulation run, while the total reserves are modelled as a random variable.

Supply

The supply stack determines what fraction of remaining reserves in each price band can be brought to market in a period. This model, combined with the reserve stack means that, given a constant supply stack, actual supply will reduce over time. In each price bracket

p , the supply S_p , changes as:

$$\frac{dS_p}{dt} = -a_p S_p$$

¹² Arctan is a useful function for approximating stacks.

where a_p describes the intensity of development of supply.

The response of the supply to the market price P is to change a_p . We assume that the second derivative of a_p is proportional to the difference between P and P :

$$\frac{d^2 a_p}{dt^2} = b(p - P)$$

Each segment of the stack responds differently to the price signals, and high prices have a cumulative effect on supply.

As with the reserve stack, the initial supply stack is entered by the user, however, there is only scant information on what it looks like. The user can enter a maximum price for oil on the market today and choose from a couple of simple supply profiles, or enter one manually. The user also enters b which is modelled as a random variable.

Supply availability (or withdrawal) is also modelled as a random variable specifying the fraction of supply capacity that is not available to the market in each period. Alternatively, supply could be modelled with a logistic function as per Rehl and Friedrich (2005), however a per-price-band logistic reserve model considerably complicates the model for little change in results, and provides little new insight into the initial conditions, which are the defining characteristics of this model.

Demand

Demand is measured as barrels of oil required to produce a dollar of global GDP (this figure is currently about 0.7 barrels per \$1000 of GDP), with GDP growth modelled as a random variable with a mean of about 4 per cent. Historical figures for oil usage and price were taken from the BP statistical review and GDP by country from the World Bank and investigated for a price/demand model.

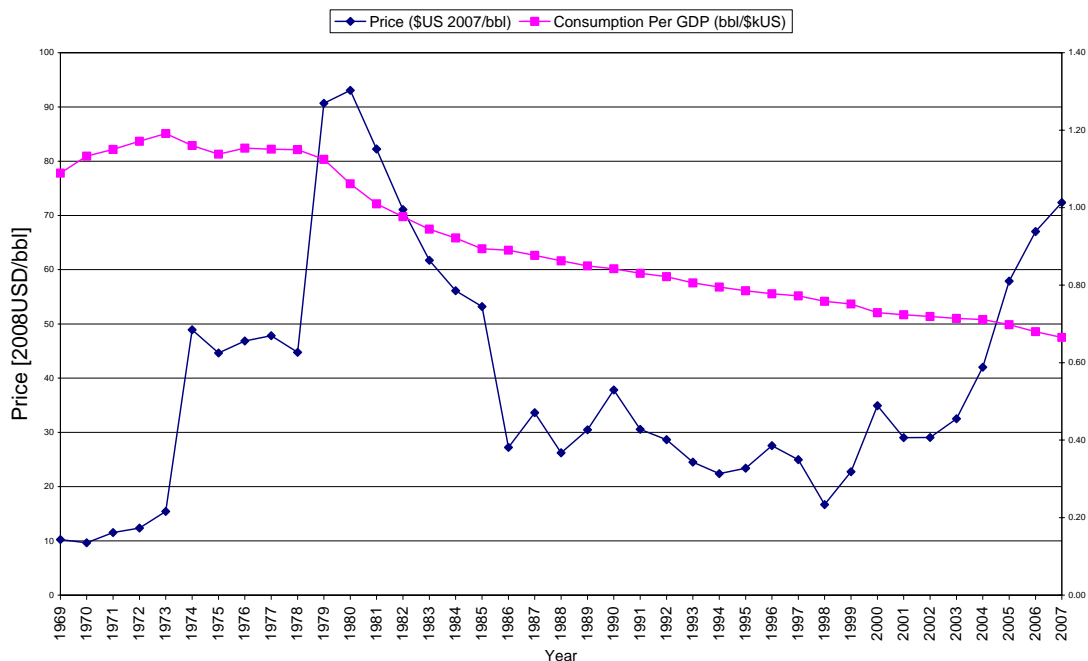


Figure 31: Relationship of oil consumption per unit of GDP 1970-2006

To keep correlations scale invariant, logs of both price and demand (log models also offer better correlations than non-log models) and models that might induce second-order behaviour, were investigated:

$$\frac{d \ln(D)}{dt} = a \ln(f(P)) + c$$

Where c could be a constant or other correlations with time, GDP or past demand (ie

multiple regression models) and where $f(P)$ was P , $\frac{dP}{dt}$ or the total cost of oil divided by GDP. The best model found had a single variable regression with an R^2 of 0.5, a very low probability that either coefficient is zero and a good f-statistic. This model took the following form:

$$\frac{d \ln(D)}{dt} = a \ln(P) + c$$

The strength of this relationship is shown below in Figure 32.

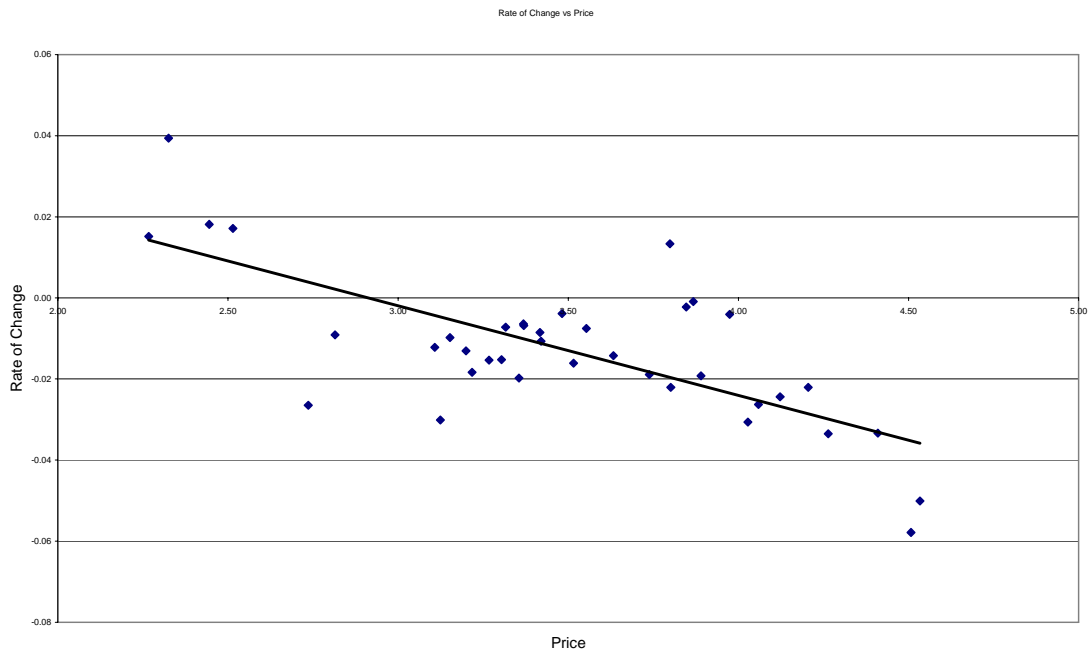


Figure 32: Relationship between demand acceleration and price (log)

Another model adding time and GDP got a higher R^2 , but as GDP growth is fairly constant, time and GDP are highly correlated, and their large coefficients were set to more or less cancel out each other's gross effects. This model is available in the spreadsheet and gives similar results.

The model holds reasonably well (R^2 above 0.2) for a quick survey of individual countries. In Saudi Arabia oil per GDP goes up as price goes up, but the model is complicated in oil exporting countries. It even holds (with an R^2 of 0.5) in China with price controls, but hardly at all in India.

Total oil demand is determined from the product of oil use per GDP multiplied by total GDP. The demand stack defines what proportion of the total use falls into each price band, and so a demand stack in barrels of oil can be constructed. This means that, unlike the supply stack, the shape of demand stack remains unchanged throughout a run.

Discussion

The goal is for the model to be as simple as possible, while capturing the behaviour of the oil market to the best extent possible. Price elasticity is modelled by two separate features of the model; short-term elasticity is offered by the supply and demand stacks, while long-term elasticity by the supply and demand responses. Very low short term elasticity of oil can be modelled by having disjoint supply and demand stacks. As illustrated in Figure 33, at low total demand, price is determined by the supply stack. As the demand stack grows, the price increases up the supply stack, until demand equals

supply. Just before this point, the price is determined by the last barrel of oil to come into production, just after, by the first use to be priced out of the market. If, say, all producible oil is at or below \$80 per barrel, and all uses are economic at \$120, the jump can be significant. Note that the following figures are presented to illustrate how the model functions rather than to communicate results.

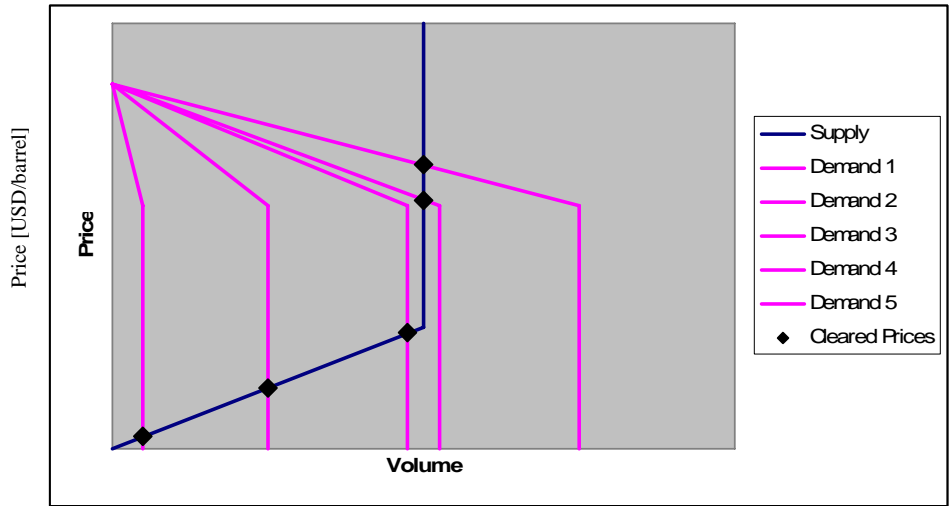


Figure 33: Changing total demand with fixed supply and disjoint stacks

Figure 34 shows the resulting price trajectory as a function of total demand, where the black rectangle indicates the area of the trajectory illustrated in Figure 33.

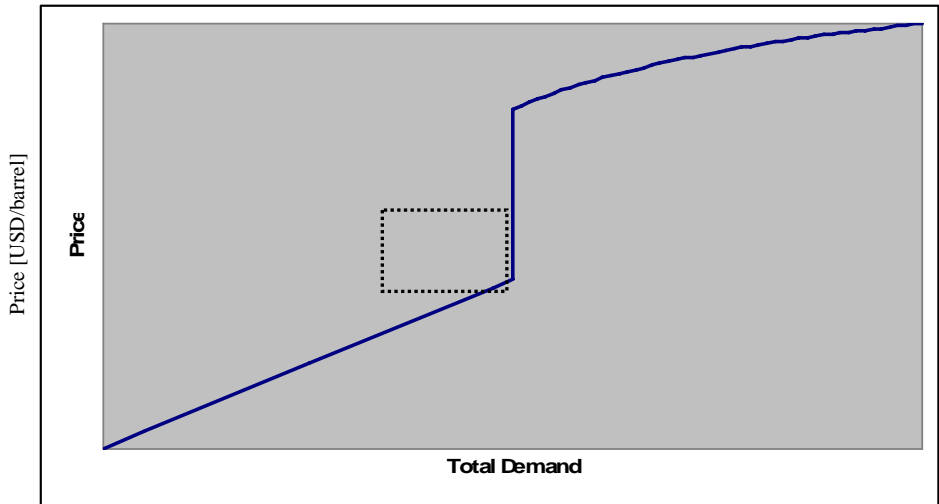


Figure 34: Retail fuel price data versus the price of crude oil 2003-08

Note that the total demand does not reflect what is delivered, which is constrained by supply at the jump. If supply is changing and we assume that it will at some stage decrease as oil is depleted, then if demand response is faster than the decrease in production we will see a drop in oil use as prices remain stable. If demand response is slower than the decrease, then oil prices will quite rapidly walk up the supply stack.

If supply response is strong, then high prices will lead to oversupply (if it's feasible), which will in turn suppress prices, and in turn suppress any reduction in supply, the end result being that when prices do hit the wall, they will be that much more extreme.

Because the depletion of supply effectively means the strength of the absolute demand response will diminish over time, there may well be a period where demand and supply responses are quite well matched. However, because they are driven by opposite ends of the price scale, this relationship will be short-lived, and we'll get periods of high prices (in the demand stack) followed by periods of low prices (in the supply stack).

Aspects of the oil market that are not modelled include:

- Unforeseen major technological improvements that may impact the relationship between price and demand, above and beyond what has happened in the past,
- No cartel behaviour, thereby assuming economically rational supply and demand scenarios. This potential underestimates the effects of OPEC production quotas, which effectively limit the oil coming to market at any given time. Withdrawal of capacity from the market is taken into account in the model. There's evidence (James D. Hamilton, Understanding crude oil prices, UCEI 2008) that OPEC isn't acting as a very effective cartel,
- Discovery of new oil sources is not modelled – rather, estimates of total available resources and the associated costs of extraction are used to define when production comes on stream,
- Political influences – recent price rises have generally been driven out of surging and subsidised demand in developing countries, such as India and China. Subsidies dull the elastic response of consumption to price.

10 Appendix C: Foreign Exchange Assumptions

| Year | Exchange | |
|------|----------|---------|
| | NZD:USD | USD:NZD |
| 2008 | 0.79 | \$1.27 |
| 2009 | 0.75 | \$1.28 |
| 2010 | 0.69 | \$1.30 |
| 2011 | 0.65 | \$1.31 |
| 2012 | 0.62 | \$1.33 |
| 2013 | 0.60 | \$1.35 |

The NZD:USD cross rate was factored in accordance with Treasury's forecast TWI trend (Treasury, 2008). From 2013 onwards the exchange rate was assumed to be 0.60 USD:NZD, which represents the approximate long term historical average.

11 Appendix D: Fuel Price Relationships

The MED data (MED, 2008b) was used to investigate the relationship between the price of crude oil and retail prices for petrol and diesel. The data sets and associated linear regressions are illustrated in figure 35; coefficients are presented in table 7.

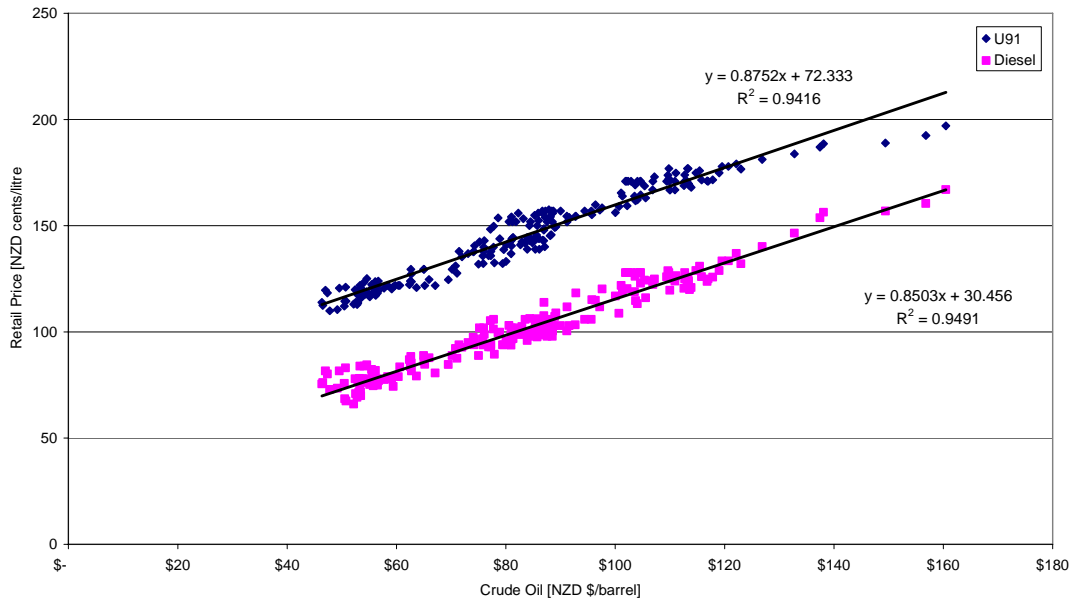


Figure 35: Retail fuel price data versus the price of crude oil 2003-08

| Fuel | R ² | Linear Regression | |
|---------|----------------|-------------------|------|
| | | m | c |
| Regular | 94% | 0.8752 | 72.3 |
| Diesel | 95% | 0.8503 | 30.5 |

Table 1: Linear regressions relating the price of oil [NZD per barrel] to the transport fuels [NZD per litre]

There is the potential for escalating fuel costs to also flow through in increased distribution costs, both internationally and domestically. Analysis of the data revealed no indication of this effect. However, the inflationary impacts of higher fuel prices may take time to flow through. For this reason the use of linear relationships is likely to be conservative.

Premium petrol accounts for approximately 25 per cent of New Zealand’s petrol consumption and retails for approximately 6c per litre more than Regular Petrol. For this reason $0.25 \times 6 = 1.5c$ per litre was incorporated into the modelled Regular Petrol price to account for the additional cost of Premium Petrol. Note that these fuel price relationships

apply only to on-road fuel use only, including excise taxes and GST. Carbon charges are not included. The inclusion of bio-fuels is only expected to add a minimal cost component to the price of fuel and is thus disregarded (West, 2007).

Off-road fuel costs are simply determined by subtracting the fuel excise tax of \$0.51 and \$0.004 for petrol and diesel respectively.

12 Appendix E: Oil Price Forecasts

The following forecasts were incorporated into this model:

- NYMEX Futures Forward Contracts (NYMEX, 2008)
- Goldman Sachs Global Investment Research (Goldman-Sachs, 2008)
- Annual Energy Outlook 2008 (EIA, 2007)
- NZEO "High" scenario (MED, 2006)
- CSIRO (CSIRO, 2008)
- LOPEX (Rehrl and Friedrich, 2005)

Forecasts are shown in figure 36 including adjustments for inflation and various grades of oil.

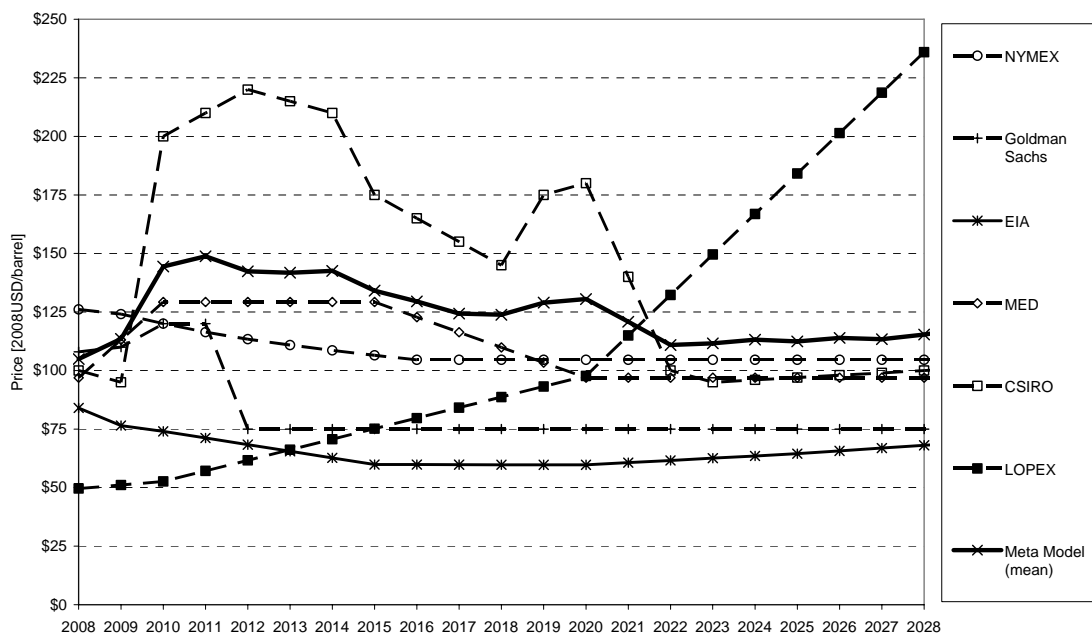


Figure 36: Summary of price forecasts

Recent experience has demonstrated the uncertainty around oil price forecasts. For example, the US Energy Information Administration's official 2007 prediction indicated that even in the high-price scenario, oil prices would not exceed \$100 per barrel until 2030, and in early 2008 predicted that oil prices would not exceed \$100 per barrel until 2018 (EIA, 2007). Recently there has been a shift from forecasts that assume a sufficient supply of oil in the long term to those that explicitly model known reserves, discovery and depletion. The older forecasts often have some kind of mean-reverting shape, while the newer ones

have price profiles that seem to increase exponentially – their modelling of the substitution of oil with alternative technologies tends to be limited. There is little consensus among forecasters - the forecasts we chose vary in their predictions of the price of oil in 2028 from a low of \$70 2008USD/barrel to a high of \$220 2008USD/barrel. Goldman Sachs currently predicts oil hitting \$130 USD/barrel by 2010; the EIA 2008 forecast, made in late 2007, never has the price exceeding \$90 per barrel (EIA, 2007, Goldman-Sachs, 2008).

13 Appendix F: The Economics of PHEV

Calculating the plug-in hybrid electric vehicles (PHEV) payback curves involved finding the fuel price at which the capital and discounted operating costs were equivalent to conventional vehicles (CV) technology. The payback curve represents the fuel price at which PHEV become more economically efficient, that is:

$$Cost_{PHEV} = Cost_{CV}$$

Where "Cost" is a function of capital and operating costs. Expanding the above equation yields:

$$Cap_{PHEV} + Op_{PHEV} = Cap_{CV} + Op_{CV}$$

Operating costs are a function of:

- discounted value of time,
- distance travelled,
- fuel efficiency,
- the price of fuel.

Note that in the case of PHEV the fuel efficiency and price parameters have different components for conventional and electrical operation. Expanding the operating cost components of the previous equation yields:

Equation 1: Capital and Operating Cost Balance for PHEV and CV

$$Cap_{PHEV} + W * d * (Feff_{PHEV} * F + Eeff_{PHEV} * E) = Cap_{CV} + W * d * (Feff_{CV} * F)$$

Where:

- W = the weight allocated to operating costs for a discount rate of $r = 8\%$ summed over

$$W = \sum_{y=1}^L \frac{1}{(1+r)^y} = \sum_{y=1}^{20} \frac{1}{(1+0.08)^y} = 10.6$$

the lifetime $L=20$ years of the vehicle, ie

- D = vehicle distance travelled in km per year
- $Feff_{PHEV}$ and $Feff_{CV}$ = fuel efficiency of PHEV and CV respectively in litre/km
- F = fuel price in \$/litre
- $Eeff_{PHEV}$ = electrical efficiency of PHEV
- E = electricity price in \$/kwh

Rearranging Equation 1 in terms of F yields the fuel price at which the total costs of PHEV and CV are equal as a function of distance, as illustrated in equation 2.

Equation 2: “Payback” fuel price as a function of annual distance driven per vehicle

$$F(d) = \frac{Cap_{PHEV} - Cap_{CV} + E_{eff_{PHEV}} * E}{W * d} \cdot \frac{1}{Feff_{CV} - Feff_{PHEV}}$$

Values assumed for the parameters in Equation 2 are illustrated in

Table 2.

| Parameter | | Vehicle technology | | Notes |
|------------------|--------|--------------------|---------|---|
| Notation | Unit | PHEV | CV | |
| Cap | \$ | \$30k- \$40k | \$25k | Sourced from Simpson (2006) and Honda New Zealand (2008) |
| Feff | l/km | 3.7/100 | 5.0/100 | Sourced from Simpson (2006) and Honda New Zealand (2008) |
| W | | 10.6 | | Calculated as per above – weight has no dimensions |
| E _{eff} | kwh/km | 0.120 | N/A | Sourced from Simpson (2006) |
| E | \$/kwh | 0.200 | N/A | Assumed average residential electricity price over lifetime of the vehicle (has only minor effect on results) |

Table 2: Performance assumptions for PHEV and CV

Note that the values sourced for PHEV from Simpson (2006) represent the expected state of PHEV technology in 2020 – that is, they allow for continued improvements in battery and drive train technology. In this respect the analysis is inherently biased towards PHEV as it compares existing CV technology (i.e. the Honda Jazz) with future PHEV technology.

14 Appendix G: Oil Price Data Tables

Prices in 2008 NZD

| Year | Petrol | | | Diesel | | |
|------|--------|---------|-------|--------|------|-------|
| | Upper | Mean | Lower | Upper | Mean | Lower |
| 2008 | \$ | \$ 1.87 | \$ | \$ | \$ | \$ |
| 2009 | \$ | \$ 2.03 | \$ | \$ | \$ | \$ |
| 2010 | \$ | \$ 2.51 | \$ | \$ | \$ | \$ |
| 2011 | \$ | \$ 2.66 | \$ | \$ | \$ | \$ |
| 2012 | \$ | \$ 2.67 | \$ | \$ | \$ | \$ |
| 2013 | \$ | \$ 2.70 | \$ | \$ | \$ | \$ |
| 2014 | \$ | \$ 2.66 | \$ | \$ | \$ | \$ |
| 2015 | \$ | \$ 2.57 | \$ | \$ | \$ | \$ |
| 2016 | \$ | \$ 2.53 | \$ | \$ | \$ | \$ |
| 2017 | \$ | \$ 2.53 | \$ | \$ | \$ | \$ |
| 2018 | \$ | \$ 2.52 | \$ | \$ | \$ | \$ |
| 2019 | \$ | \$ 2.56 | \$ | \$ | \$ | \$ |
| 2020 | \$ | \$ 2.60 | \$ | \$ | \$ | \$ |
| 2021 | \$ | \$ 2.57 | \$ | \$ | \$ | \$ |
| 2022 | \$ | \$ 2.60 | \$ | \$ | \$ | \$ |
| 2023 | \$ | \$ 2.68 | \$ | \$ | \$ | \$ |
| 2024 | \$ | \$ 2.74 | \$ | \$ | \$ | \$ |
| 2025 | \$ | \$ 2.82 | \$ | \$ | \$ | \$ |
| 2026 | \$ | \$ 2.92 | \$ | \$ | \$ | \$ |
| 2027 | \$ | \$ 3.02 | \$ | \$ | \$ | \$ |
| 2028 | \$ | \$ 3.10 | \$ | \$ | \$ | \$ |
| 2029 | \$ | \$ 3.10 | \$ | \$ | \$ | \$ |
| 2030 | \$ | \$ 3.18 | \$ | \$ | \$ | \$ |
| 2031 | \$ | \$ 3.23 | \$ | \$ | \$ | \$ |
| 2032 | \$ | \$ 3.30 | \$ | \$ | \$ | \$ |
| 2033 | \$ | \$ 3.38 | \$ | \$ | \$ | \$ |
| 2034 | \$ | \$ 3.44 | \$ | \$ | \$ | \$ |
| 2035 | \$ | \$ 3.51 | \$ | \$ | \$ | \$ |
| 2036 | \$ | \$ 3.59 | \$ | \$ | \$ | \$ |
| 2037 | \$ | \$ 3.65 | \$ | \$ | \$ | \$ |
| 2038 | \$ | \$ 3.72 | \$ | \$ | \$ | \$ |
| 2039 | \$ | \$ 3.82 | \$ | \$ | \$ | \$ |
| 2040 | \$ | \$ 3.88 | \$ | \$ | \$ | \$ |
| 2041 | \$ | \$ 3.95 | \$ | \$ | \$ | \$ |
| 2042 | \$ | \$ 4.07 | \$ | \$ | \$ | \$ |
| 2043 | \$ | \$ 4.19 | \$ | \$ | \$ | \$ |
| 2044 | \$ | \$ 4.30 | \$ | \$ | \$ | \$ |
| 2045 | \$ | \$ 4.42 | \$ | \$ | \$ | \$ |
| 2046 | \$ | \$ 4.54 | \$ | \$ | \$ | \$ |
| 2047 | \$ | \$ 4.65 | \$ | \$ | \$ | \$ |
| 2048 | \$ | \$ 4.78 | \$ | \$ | \$ | \$ |
| 2049 | \$ | \$ 4.92 | \$ | \$ | \$ | \$ |
| 2050 | \$ | \$ 5.05 | \$ | \$ | \$ | \$ |
| 2051 | \$ | \$ 5.17 | \$ | \$ | \$ | \$ |
| 2052 | \$ | \$ 5.29 | \$ | \$ | \$ | \$ |
| 2053 | \$ | \$ 5.42 | \$ | \$ | \$ | \$ |
| 2054 | \$ | \$ 5.55 | \$ | \$ | \$ | \$ |
| 2055 | \$ | \$ 5.70 | \$ | \$ | \$ | \$ |
| 2056 | \$ | \$ 5.83 | \$ | \$ | \$ | \$ |
| 2057 | \$ | \$ 5.97 | \$ | \$ | \$ | \$ |
| 2058 | \$ | \$ 6.13 | \$ | \$ | \$ | \$ |
| 2059 | \$ | \$ 6.27 | \$ | \$ | \$ | \$ |
| 2060 | \$ | \$ 6.43 | \$ | \$ | \$ | \$ |

Prices in 2006 NZD

| Year | Petrol | | | Diesel | | |
|------|---------|------|-------|---------|------|-------|
| | Upper | Mean | Lower | Upper | Mean | Lower |
| 2006 | | \$ | | | \$ | |
| 2007 | | \$ | | | \$ | |
| 2008 | \$ 2.05 | \$ | \$ | \$ 1.63 | \$ | \$ |
| 2009 | \$ 2.45 | \$ | \$ | \$ 2.03 | \$ | \$ |
| 2010 | \$ 3.32 | \$ | \$ | \$ 2.89 | \$ | \$ |
| 2011 | \$ 3.69 | \$ | \$ | \$ 3.26 | \$ | \$ |
| 2012 | \$ 3.82 | \$ | \$ | \$ 3.39 | \$ | \$ |
| 2013 | \$ 3.97 | \$ | \$ | \$ 3.55 | \$ | \$ |
| 2014 | \$ 3.91 | \$ | \$ | \$ 3.48 | \$ | \$ |
| 2015 | \$ 3.77 | \$ | \$ | \$ 3.35 | \$ | \$ |
| 2016 | \$ 3.73 | \$ | \$ | \$ 3.30 | \$ | \$ |
| 2017 | \$ 3.71 | \$ | \$ | \$ 3.28 | \$ | \$ |
| 2018 | \$ 3.68 | \$ | \$ | \$ 3.25 | \$ | \$ |
| 2019 | \$ 3.85 | \$ | \$ | \$ 3.43 | \$ | \$ |
| 2020 | \$ 3.87 | \$ | \$ | \$ 3.45 | \$ | \$ |
| 2021 | \$ 3.83 | \$ | \$ | \$ 3.41 | \$ | \$ |
| 2022 | \$ 3.90 | \$ | \$ | \$ 3.48 | \$ | \$ |
| 2023 | \$ 3.98 | \$ | \$ | \$ 3.56 | \$ | \$ |
| 2024 | \$ 4.05 | \$ | \$ | \$ 3.63 | \$ | \$ |
| 2025 | \$ 4.13 | \$ | \$ | \$ 3.71 | \$ | \$ |
| 2026 | \$ 4.32 | \$ | \$ | \$ 3.90 | \$ | \$ |
| 2027 | \$ 4.50 | \$ | \$ | \$ 4.08 | \$ | \$ |
| 2028 | \$ 4.58 | \$ | \$ | \$ 4.16 | \$ | \$ |
| 2029 | \$ 4.63 | \$ | \$ | \$ 4.22 | \$ | \$ |
| 2030 | \$ 4.72 | \$ | \$ | \$ 4.31 | \$ | \$ |
| 2031 | \$ 4.73 | \$ | \$ | \$ 4.32 | \$ | \$ |
| 2032 | \$ 4.86 | \$ | \$ | \$ 4.46 | \$ | \$ |
| 2033 | \$ 4.91 | \$ | \$ | \$ 4.50 | \$ | \$ |
| 2034 | \$ 4.99 | \$ | \$ | \$ 4.58 | \$ | \$ |
| 2035 | \$ 5.23 | \$ | \$ | \$ 4.83 | \$ | \$ |
| 2036 | \$ 5.32 | \$ | \$ | \$ 4.93 | \$ | \$ |
| 2037 | \$ 5.41 | \$ | \$ | \$ 5.02 | \$ | \$ |
| 2038 | \$ 5.71 | \$ | \$ | \$ 5.32 | \$ | \$ |
| 2039 | \$ 5.71 | \$ | \$ | \$ 5.32 | \$ | \$ |
| 2040 | \$ 5.91 | \$ | \$ | \$ 5.52 | \$ | \$ |
| 2041 | \$ 6.01 | \$ | \$ | \$ 5.63 | \$ | \$ |
| 2042 | \$ 6.33 | \$ | \$ | \$ 5.95 | \$ | \$ |
| 2043 | \$ 6.57 | \$ | \$ | \$ 6.18 | \$ | \$ |
| 2044 | \$ 6.81 | \$ | \$ | \$ 6.43 | \$ | \$ |
| 2045 | \$ 6.84 | \$ | \$ | \$ 6.47 | \$ | \$ |
| 2046 | \$ 7.23 | \$ | \$ | \$ 6.87 | \$ | \$ |
| 2047 | \$ 7.61 | \$ | \$ | \$ 7.26 | \$ | \$ |
| 2048 | \$ 7.94 | \$ | \$ | \$ 7.61 | \$ | \$ |
| 2049 | \$ 8.49 | \$ | \$ | \$ 8.17 | \$ | \$ |
| 2050 | \$ 8.75 | \$ | \$ | \$ 8.44 | \$ | \$ |
| 2051 | \$ 9.20 | \$ | \$ | \$ 8.89 | \$ | \$ |
| 2052 | \$ 9.78 | \$ | \$ | \$ 9.49 | \$ | \$ |
| 2053 | \$ | \$ | \$ | \$ 9.88 | \$ | \$ |
| 2054 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2055 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2056 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2057 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2058 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2059 | \$ | \$ | \$ | \$ | \$ | \$ |
| 2060 | \$ | \$ | \$ | \$ | \$ | \$ |

15 Appendix H: Price Formulae for Other Transport Fuels

Liquid petroleum gas

Currently, LPG is sourced mostly from NZ gas fields, with a small amount being imported from Australia in small tankers of around 3000 - 4000 tonnes capacity. With the imminent arrival of the Kupe gas and condensate field, the LPG produced will substantially replace the tranche lost with the decline of the Maui field and New Zealand should be able to supply all its LPG demand for the foreseeable future.

International prices are set by the Saudi Aramco contract price FOB AG. Freight differential for NZ estimated at US\$75 per tonne or US\$6.37 per barrel. No price series has been available for NZ since 2000. NZ LPG prices are set relative to international LPG prices, both for imports and domestic production. As a general trend, we would expect the relative price of LPG to decline into the foreseeable future as more associated LPG is produced from the development of gas fields for LNG production.

Based on current transport LPG price of NZD1.35 per litre at the pump, the following price expression developed using correlation between Dubai crude and Saudi Aramco LPG contract price:

$$\text{LPG NZc per litre} = [(\text{Dubai US\$ per barrel} * 0.60 + 8.60) + 6.37 \text{ freight}] * \text{FX US\$: NZ\$} + 41.95$$

Compressed natural gas

New Zealand has a history of compressed natural gas (CNG) use dating back to the late 1970s.

The industry arose out of the quest for improved energy security and energy diversification resulting from the oil crises of the late 1970s. Conversion of internal combustion engine (ICE) vehicles to CNG were subsidised by the government as was the fuel itself (the price of CNG was indexed to 60 per cent of petrol). Consumption peaked around 1984 at almost 6 PJ pa. At CNG's peak, there was an estimated 62,000 CNG capable vehicles on New Zealand roads, up from just 700 in 1979.

With the deregulation of the New Zealand economy that began with the Rogernomics of the fourth Labour government in 1984, subsidisation of economic activity of this type became anathema. The CNG industry, which had become a (relative) world leader declined rapidly, such that it is basically extinct in New Zealand.

Due to its superior environmental properties, CNG is used for transportation in a number of cities and countries, notably in lesser developed countries. Cities such as New Delhi, Shanghai and Bangkok are examples. Iran had a target of having 1 million cars, around 13 per cent of total cars and trucks, running on CNG by March 2008. However, the number

achieved was less than half of the target.¹³ In the developed world, natural gas vehicles are common in Germany and Italy.

Notably, all the users of CNG in the lesser developed countries subsidise the use of the fuel to below that of conventional liquid fuels, even where these are also subsidised.

CNG is a possible fuel for transport use, primarily because of its lower level of pollutants (around 79 per cent of CO², on an energy basis). In a world of (perceived) oil shortages, natural gas is also seen as relatively more abundant (the world has an estimated 41.6 years of proven oil reserves and 60.3 years of natural gas reserves as at the end of 2007¹⁴).

However, the conversion of natural gas to CNG as a consumer fuel, including compression, international transport, storage re-gasification, and distribution, does not come without cost. Earlier this decade, there was still significant (research) interest in large-scale manufacture and transportation of CNG, almost as a niche market between conventional pipeline natural gas and liquefied natural gas (LNG). However, due to the rampant interest in LNG, and improving technology that exploits a wider range of gas fields for the manufacture of LNG, interest in CNG in this context has waned considerably.

A clear example of this was OilSearch Ltd's interest in supplying CNG to New Zealand from its Papua New Guinea gas reserves around 2003/04 in addition to supplying natural gas via a long distance pipeline to Queensland. The latter project was abandoned in 2006 after many years of consideration and the former has also been overtaken. We are not aware of any continuing interest in CNG developments. Rather, OilSearch is currently advancing the development of an LNG export plant which seems quite likely to go ahead.

Essentially, we do not see an economic case for the importation of CNG. Supply would be from indigenous gas fields. These can be separated into (i) the specific manufacturing of CNG for transport use and (ii) the monetising of, say, small coal bed methane deposits remote from gas pipelines, which would otherwise be stranded resources.

In the former case, the cost of natural gas would be at market prices. In the latter case of coal bed methane resources, the resource owner would simply aim to obtain the highest price possible, which given limited deployment options, will likely be below the (wellhead) cost of conventional natural gas. In both cases, the costs of CNG manufacture, transportation and storage are additional. These post-wellhead or post-pipeline costs are likely to be comparatively high, although we have not been able to obtain any figures.

Since the downstream costs, transportation and storage, are comparatively high, the key is to obtain low cost gas. At an international level, LNG production is likely to be much more attractive than CNG.

¹³ Fesharaki, F., Iran's Energy Sector: Domestic Issues and International Implications, presented at Iran: Energy, Politics and Society Conference, Princeton, New Jersey, USA, April 2008.

¹⁴ BP Statistical Review of World Energy 2008, www.bp.com

As a rough approximation, some indicative costings are available from 2004, with some updating to the significantly different market conditions of today, namely, much higher resource value and also much higher supply chain, notably, infrastructure, costs.¹⁵

- Shipping \$3.00
- NZ storage, etc \$2.00
- Total US\$5.00 per GJ + gas cost (discussed in LNG section)
- The gas cost could be somewhat below that for LNG if the gas is sourced from otherwise stranded reserves.

In summary, given New Zealand's prior experience with CNG, and albeit most of this experience and expertise having now been lost, there are existing overseas cases upon which to model any implementation. The technology is relatively well understood. However, the economics are likely to be somewhat doubtful. Thus, we see CNG, again, as a niche application. Its application in New Zealand will likely arise out of conversion of indigenous gas resources rather than from imports.

Liquefied natural gas

LNG is discussed here because:

- It is a possible transport fuel
- It provides a suitable proxy for determining the longer term price of natural gas.

Liquefied natural gas (LNG) is enjoying rapid growth as a method of monetising otherwise stranded natural gas reserves. It has a history going back to the 1930s but its current incarnation dates from large scale production and export from the mid-1960s and accelerated by the emergence of Japan as a major importer from the late 1960s.

In recent years, the growth of LNG trade has grown by around seven to eight per cent per annum, much higher than natural gas overall at around two to three per cent per annum, and is projected to grow at least at this rate into the foreseeable future. Currently, LNG comprises around 7.5 per cent of the world's gas consumption and around 28 per cent of gas trade.

New Zealand cannot import pipeline natural gas and so must consider LNG or CNG. The latter seems unlikely as described above. The importation of natural gas into New Zealand has had serious consideration as a result of the downwards revision of Maui gas reserves in 2003. A CAE report focused on this issue.¹⁶ Contact Energy Ltd, in association with

¹⁵ Centre for Advanced Engineering, New Zealand's Thermal Fuels Markets - the Post-Maui Era, 2004.

¹⁶ Centre for Advanced Engineering, New Zealand's Thermal Fuels Markets - the Post-Maui Era, 2004.

Genesis Energy Ltd, has also investigated the issue in some depth from the commercial perspective of importing LNG for electricity generation.¹⁷

There are established methods for the pricing of LNG in international markets. While these are evolving over time, we consider them applicable for the foreseeable future. One of the authors of this report summarised this in 2006 and is currently updating that work. The discussion follows from the 2006 report and developments since then.¹⁸

LNG pricing in Asia (-Pacific) markets, which comprised around 65 per cent of world consumption in 2007, has historically taken the form of an S-curve based on a formula of the form:

$$P(\text{LNG}) = ax + b \quad (1)$$

where x is the price of a basket of crudes imported into Japan, the JCC. Although not as easy to follow as other benchmark crudes such as WTI or Brent, it is a public domain price.¹⁹ More conveniently, for the purposes of this study, the Dubai price serves as a close approximation for the JCC. Thus:

$$\text{US\$JCC} \sim \text{US\$Dubai} \quad (\text{per barrel}) \quad (2)$$

a and b are negotiated slope and intercept respectively, specific to each contract.²⁰

There are usually less linear tails in a formula, resulting in an S curve to mitigate for price extremes, effectively providing for floors and caps on the LNG price. A floor price may effectively protect the producer's investment, whereas a price cap provides a quid pro quo for the LNG buyer, particularly as long-term off-take contracts, typically of 10-20 years duration are required to underwrite the considerable capital that is required to build the LNG liquefaction trains and other supply infrastructure. There are also specific meet and discuss clauses in any contract to take account of unusual or unanticipated conditions or situations.

At issue, is (i) the slope, a, of the curve, a reflection of the correlation of LNG prices to oil prices, and (ii) the inflexion points at which the correlation is weaker than a. The world, in recent years, has entered a bull phase for commodity prices, including oil and natural gas. Further, scarcity in natural gas supply, especially LNG in this context, has led to LNG prices more closely following the price of oil.

¹⁷ www.contactenergy.co.nz

¹⁸ G Eng, A Formula for LNG Pricing, report prepared for Ministry of Economic Development, May 2006, www.med.govt.nz/templates/MultipageDocumentTOC_23939.aspx

¹⁹ For example, see www.paj.gr.jp/statis/excel/epaj-7.xls or www.bloomberg.com

²⁰ One reason is that these contracts are generally on a CIF basis.

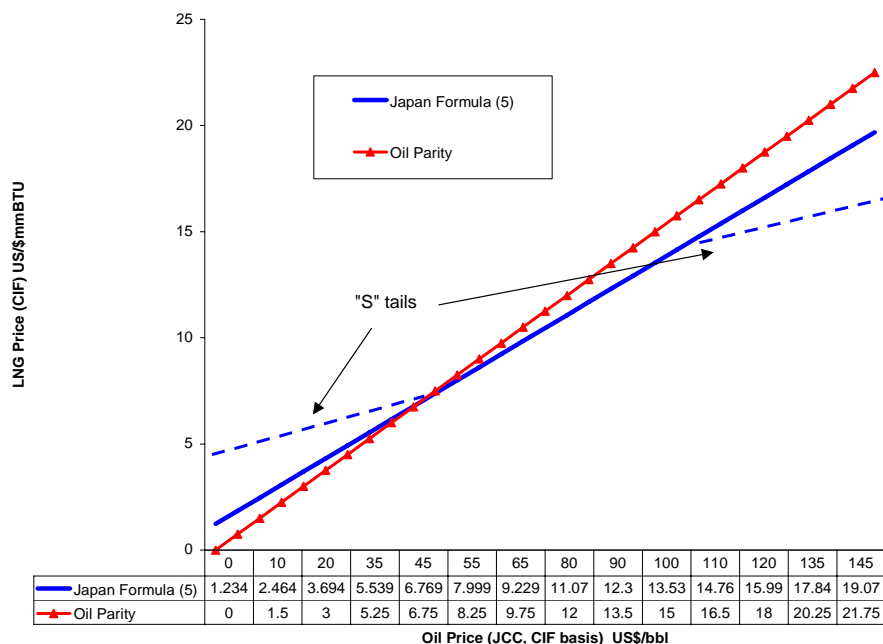


Figure 37: LNG Pricing Formulae (as a proxy for imported gas price)

At full oil price parity, the coefficient, a , of (1) is around 0.15 or a little higher with an intercept, b , close to or at zero. Thus since LNG prices are likely to be a little below oil prices, on an energy content basis, we have derived:

$$P(\text{LNGcif}) = 0.145 P(\text{Dubai}) + 0.2 \quad \text{per mmBTU} \quad (3)$$

Or

$$P(\text{LNGcif}) = 0.1374 P(\text{Dubai}) + 0.19 \quad \text{per GJ}^{21} \quad (4)$$

There are those who would argue for a lower correlation between the LNG price and oil prices, of around 85 per cent. The "traditional" Japan formula is close to that, viz

$$P(\text{LNGcif}) = 0.1226 P(\text{Dubai}) + 1.2367 \quad \text{per mmBTU}^{22} \quad (5)$$

This relationship evolved from when Japan began large scale LNG importation in 1969 – hence the origin of the JCC. Equivalently,

$$P(\text{LNGcif}) = 0.1162 P(\text{Dubai}) + 1.1722 \quad \text{per GJ} \quad (6)$$

We recommend the application of (4). By way of discussion, we note that natural gas is a very low density form of energy. Although it can vary, CNG is around a third of the energy density of petrol on a volumetric basis. In turn, LNG has twice the energy density of CNG on a volumetric basis, ie two-thirds the energy density of petrol. Although currently less

²¹ 1.055 mmBTU per GJ

²² LNG price data from IEA Energy Prices & Taxes.

common than CNG, the use of LNG in transportation, in specific situations, could well be an emerging application.²³

Marine Fuel

Grades available at Auckland:

- Marine gas oil: same as automotive diesel ex NZRC, RAP pipeline.
- Marine fuel oil 180: same as industrial 180 cSt heavy fuel oil ex NZRC by ship.
- Marine fuel oil 40: same as industrial 40 cSt heavy fuel oil ex NZRC by ship (blend of gas oil and HFO).

Prices provided in this report are defined for MFO180 which is delivered in Auckland by pipeline, truck or barge and stored at Wynyard wharf. Prices obtained from MED website, assuming marine prices similar to industrial as they are the same products. Price relationship developed, using correlation between Dubai and Singapore 180 cSt postings:

$$\text{MFO 180 NZc/litre} = [(\text{Dubai US\$/bbl} * 0.80 + 0.98) * (1 + 0.10 \text{freight})] * \text{FXUS\$:NZ\$} + 9.66.$$

This relationship is shown in figure 4.

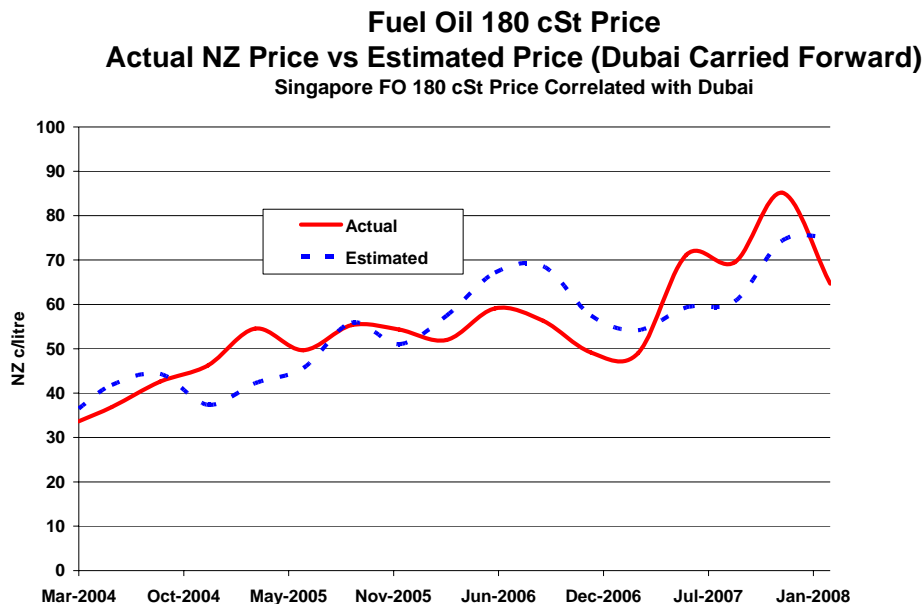


Figure 38: MFO180 actual and forecast prices March 2004 to January 2008

²³ For example, see "Santos to supply Wesfarmers LNG plant", www.petroleumnews.net, 27 September 2006

Aviation gasoline

Avgas is imported into New Zealand from Australia as NZRC operations do not permit the necessary addition of lead nor can it produce the low volatility and high octane components which characterize avgas. As no posted prices exist for avgas in the Australia-New Zealand region, a proxy has been developed by determining a multiplier between premium gasoline and avgas using US market data published by the EIA. This relationship is shown in figure 39.

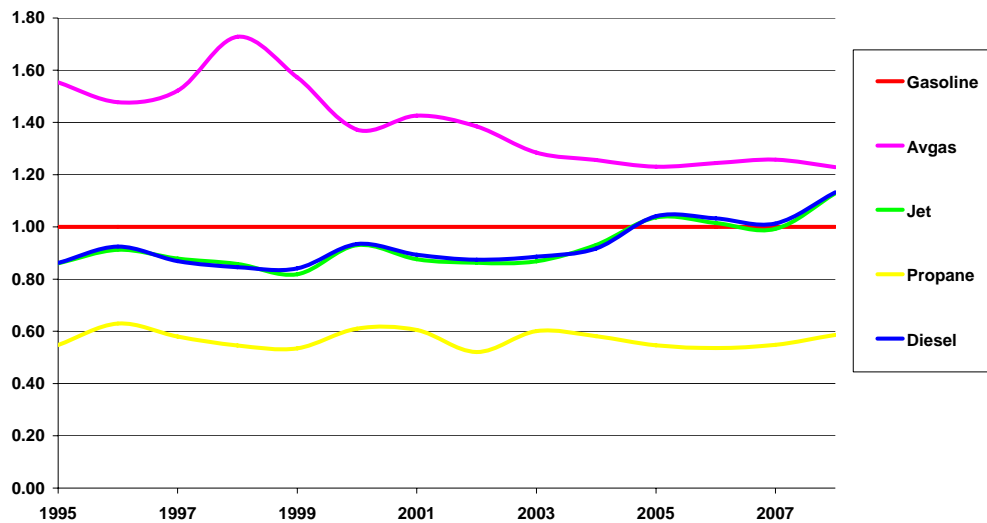


Figure 39: US refiners wholesale price wrt gasoline

New Zealand avgas prices have been developed from a survey of prices at an airport in the Auckland region. Using the methodology described above, the following expression describes the relationship between the avgas price and that of Dubai crude:²⁴

$$\text{AvgasNZc/litre} = [(\text{DubaiUS\$/bbl} * 1.01 + 11.33) * (1 + 0.10\text{freight}) * 1.25\text{avgas proxy}] * \text{FXUS\$/NZ\$} + 38.57$$

The match between this expression and actual avgas prices is shown in figure 40.

²⁴ The correlation coefficients have been developed between Dubai crude prices and Singapore gasoline prices

Avgas Price Actual NZ Price vs Estimated Price (Dubai Carried Forward) Singapore Gasoline Price as Proxy for Avgas

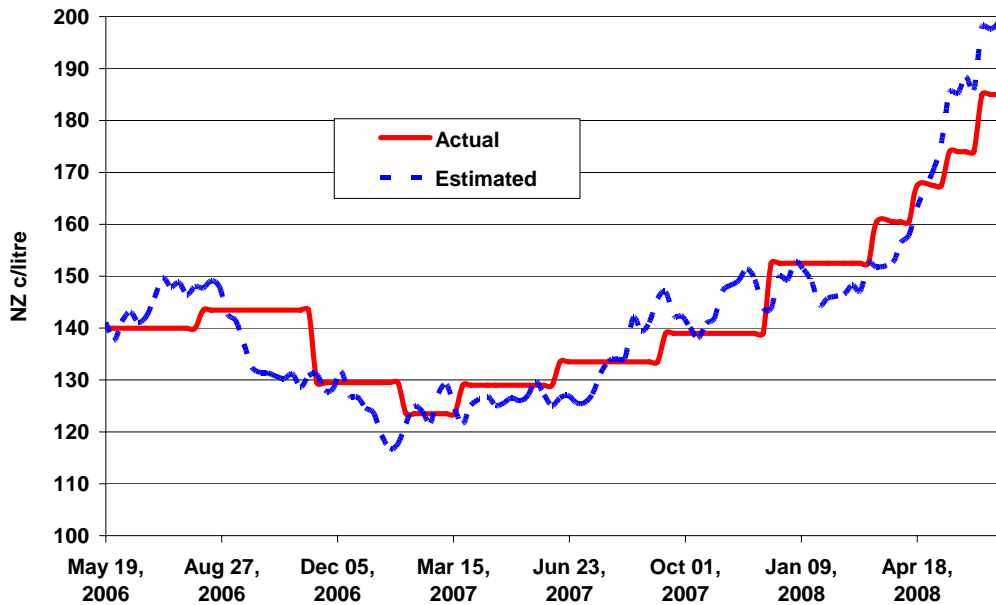


Figure 40: Avgas price actual NZ price vs estimated price

Aviation kerosene

Jet fuel is manufactured at NZRC and delivered to the Auckland region by pipeline to the oil terminal at Wiri. It is transported to Mangere airport by pipeline and to the minor airports in the Auckland by road. Some imported jet fuel is trucked into Auckland from Tauranga. As a kerosene middle distillate, international jet fuel prices tend to be close to those of diesel, which recently have been somewhat higher than gasolines. Both these trends are illustrated in figure 2 for US prices. New Zealand jet fuel prices have been developed from a survey of prices at regional airports and are shown in figure 3. These prices apply to smaller commercial and private aviation operators. Prices to the major commercial operators such as Air New Zealand will be somewhat lower but are subject to considerable commercial sensitivity and are not available for publication. The relationship between New Zealand jet fuel prices and Dubai crude is described by the following expression which incorporates a correlation between Dubai crude and Singapore jet fuel prices:

$$\text{JetNZc/litre} = [(\text{DubaiUS\$/bbl} * 1.21 + 5.69) * (1 + 0.10\text{freight})] * \text{FXUS\$/NZ\$} + 40.59$$

The fit between this expression and historical jet fuel prices is shown in figure 41.

Singapore Jet Price Correlated with Dubai

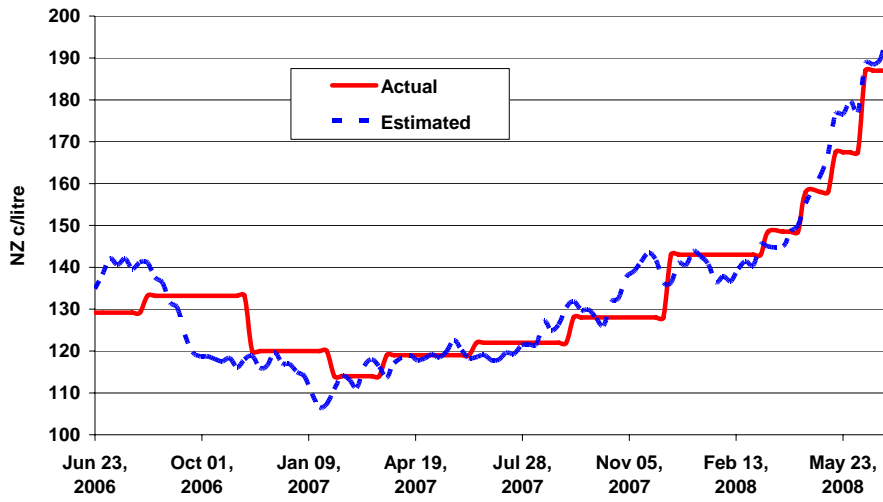


Figure 41: Jet fuel price – Actual NZ price vs estimated price (Dubai carried forward)

16 Appendix I: Background to Bio fuels Prices

Modelling work was undertaken to derive cost estimates for liquid bio fuel supplied to industrial users in New Zealand. The term liquid bio fuels encompasses a number of different fuel types (ethanol, biodiesel, butanol etc.) made using a range of different technologies. Manufacturing technologies used today may not be the dominant technologies used in the timeframe of the forecast. It would be a large task to develop forecasts that account for all of these variables. In order to make some progress, two approaches have been taken. The cost to produce ethanol using sugarcane is considered, as is the cost of producing bio fuels using so called second generation technologies.

Sugarcane ethanol

Of available fuels, technologies, and feedstocks, ethanol produced from sugar cane is the most cost-effective. Further reductions in production costs are likely to make this fuel an interesting benchmark to consider as a candidate for a lower bound on pricing. Estimates of the cost to manufacture sugarcane ethanol today vary between sources; NZ\$0.50 per litre is a typical value. This cost seems likely to reduce as the productivity of sugarcane production improves, dominantly through genetic gain. For modelling purposes genetic gain of 2 per cent per year has been assumed. This value is similar to productivity gains realised in crops such as soy and maize, which have benefitted from sustained genetic improvement programme over long timeframes.

Second generation technologies

A number of second generation technologies are also being developed. Assuming that feedstock costs remain comparable to those today²⁵ future prices would depend largely on the extent to which technical advances drive down the cost to convert biomass into liquid bio fuels. Apart from the claims of individual companies, forecasts of the cost to produce bio fuels using second generation technologies are scarce. Data that we have been able to find are summarised in

Table 3. The data in this figure refer to some future cost when the technology is mature – say 20-40 years from now.

²⁵ If bio fuels were to capture a significant part of the global market for liquid fuel this assumption may not hold. However, modelling feedstock availability would be a much more involved task than this initial analysis allows for. Consequently this simplifying assumption is required.

| Source | Biofuel | Low estimate | High estimate |
|---------------|-------------------------|--------------|---------------|
| Royal Society | Cellulosic ethanol | 0.50 | 1.29 |
| NREL | | 0.60 | 0.60 |
| Mascoma | | 0.53 | 0.79 |
| Royal Society | Syngas ethanol | 1.39 | 1.69 |
| NREL | | 0.57 | 0.57 |
| Coskata | | 0.79 | 0.79 |
| Royal Society | Vegetable oil biodiesel | 0.78 | 1.25 |

Table 3: Bio fuel prices for second generation ethanol technologies (NZ\$ per litre of PE²⁶)

Summary

We assume that bio fuel prices will track the cost of production of the marginal bio fuel producer and not the price of alternative fuels.²⁷ If this assumption is not valid then forecasts relating to bio fuel specifically cease to become interesting – the forecast defaults to the price of the alternative fuel. It is conceivable that the global demand for bio fuel could be met using the production technology of a single low cost production method. Equally, however, it is conceivable that, at the margin, higher cost manufacturing methods are employed.

Potential extensions

There is a lot that could be done to expand the analysis behind the forecasts presented above. Steps could include:

- Consideration could be given to the potential of the so called third generation and fourth generation manufacturing technologies.
- The impact of bio fuel demand on feedstock prices could be considered, where price becomes driven by demand as opposed to supply chain costs.

The interplay between bio fuel pricing and other liquid fuel prices could be modelled. This would require more detailed knowledge of the potential for energy substitution.

²⁶ Ethanol has 67% the energy content of petrol while biodiesel is almost exactly 100%.

²⁷ It seems logical to think that ethanol pricing would track oil prices as ethanol can be used as a substitute for petrol up to a limit. However, during the year to July 2008 Brazilian ethanol prices did not appear to follow the spike in international oil prices. It is debatable whether this lack of correlation would be sustained in the long term if oil prices caused petrol to be more expensive than ethanol on a mileage-equivalent basis. On the evidence of the last year though, it has been assumed that bio-fuel prices are not set by oil prices.

17 Appendix J: Background to wood prices

Modelling work was undertaken to derive cost estimates for wood fuel supplied to industrial users in Auckland. The Auckland location is significant as transport costs between wood sources and users form a major component of the supplied cost. Consequently, costs will vary significantly by location depending on the distance to the wood source. It may be worth noting an implication of this at the outset. If wood does become widely used as an industrial fuel (displacing, for example, natural gas) then industrial users located closer to forests, mainly the Central North Island forest are likely to adopt it first. Combined with finite availability, this means that it is plausible that even if wood becomes an economically attractive fuel, it may not be widely deployed in Auckland.

The model considers both forest residues and pulp logs as fuel sources. A further source of wood fuel – wood processing residues, is not considered here as these are almost entirely utilised within the wood processing industry itself and there seems no reason to expect that this will change in the forecast period.

The cost of wood residue to an end user is made up of the cost to harvest and process offcuts from the forest floor, the cost to chip (or hog) them and the cost to transport the chips to the use location. Currently New Zealand forest owners do not charge for the costs of the residues taken and for this forecast it has been assumed that this situation would continue.

Scion (previously Forest Research) has developed a comprehensive model of the availability, cost to harvest wood from forests and the cost to transport forestry residues. Their model supplied cost estimates for different locations over a 30 year time frame. The cost to harvest residues depends mainly on the type of terrain that the forest was grown on. Publically available summaries prepared using their model form the basis for this analysis.

At any given location the transport cost is a function of availability and demand (as more wood is required the sourcing radius increases and the average distance increases). If total demand for residues in the Auckland area exceeds a certain level, the sourcing radius and hence transport cost is such that it is cheaper to source and transport pulp logs (the lowest grade of whole logs) than it is to transport low density wood chips.

Low, mid and high cost scenarios are developed by considering different inputs for:

- the type of terrain that wood must be sourced from,
- upper and lower limits of Scion's cost estimates to source from different terrains,
- the price of pulp logs,
- total Auckland market demand,

- oil price (which impacts transport cost).

18 Appendix K: Background to Coal Prices

Coal consumption in New Zealand is currently around 90 petajoules per year. Most of it, around 70PJ in 2007, is burned for energy transformation purposes, dominantly at the 1000MW Huntly power station for generating electricity (around 50PJ per year). This amount can be quite volatile depending on electricity demand, the amount of hydro generation available and the amount of natural gas available for electricity generation. As far as the latter is concerned, coal is quite price competitive against gas (at current prices) and could be more so into the foreseeable future depending on carbon prices.

The balance of coal is consumed in the industrial sector. Solid Energy, the dominant coal miner in New Zealand announced in September 2004 that, for environmental reasons, it would no longer sell coal to the residential sector²⁸. We assume that coal consumption in the residential sector will, therefore, decline to negligible amounts and it is not further considered in this note.

Broadly speaking, coal comes in three grades or types, in declining quality, bituminous, sub-bituminous and lignite. Around 50 per cent of New Zealand's production is of the high grade bituminous coal. It is almost all (usually around 95 per cent) exported for industrial purposes such as steel making. Less than 5 per cent of production is of the low grade lignite. Because of its lower quality, economic use of lignite often needs to be close to its source. It has a value of less than \$2 per gigajoule (GJ), less than \$1 per GJ for many suitable and potential applications. The balance, around 45 per cent of New Zealand's coal production is of the sub-bituminous grade. Almost all is consumed domestically. We, therefore, focus on the pricing of sub-bituminous coal in the remainder of this note.

Even for bituminous and sub-bituminous coals, New Zealand has an estimated 3.5 billion tonnes of in-ground reserves, of which over 1 billion tonnes is considered economically recoverable. At production levels of five to six million tonnes per year, resource availability is therefore not currently an issue. Availability is also, therefore, not a strong driver of domestic prices now or into the future. Import (about 50 per cent of Huntly's coal use is imported) and export parity are weak drivers because of the high cost of transporting coal over long distances.

Actual prices of coal are difficult to determine for a number of reasons. Chief amongst these is that there are a small number of large consumers and commercial confidentiality is the order of the day. The cost of transportation from mine to the point of consumption is significant and can vary substantially. Internationally, coal prices have, in the last few years, surged in unison with most other forms of energy and mineral commodities. This has been more so for the higher than lower grades.

We estimate the cost of coal into the future to be in the range of \$4-5 per GJ. This is similar to the figures and projections assumed in the Ministry of Economic Development's

Energy Outlook to 2030²⁹ but adjusted for a slightly more bullish view of (energy) commodity prices and of higher supply chain costs. A relatively flat outlook for prices reflects coal's ready availability and its increasingly unattractiveness as a general energy source. The New Zealand price outlook is also broadly consistent with thermal coal prices projected by the US Energy Information Administration in its June 2008 projections of around US\$1.80-2.00 per mmbtu (or US\$1.70-1.90 per GJ) between now and 2030 – see figure 42.

Coal for industrial use, such as steelmaking, dairy or timber processing and cement manufacture would be at a lower price than for commercial use, such as in hospitals, which, in any case, comprise only around 1-2 per cent of overall demand. Economies of scale would be a key driver in this regard.

Inter-fuel competition would appear to be limited, especially in the short-term. However, it clearly exists for electricity generation where coal at Huntly competes with natural gas at New Zealand's gas combined cycle stations and possibly even at Huntly, which is a dual coal/gas station. Competition between coal and gas would also exist for some industrial applications.

Coal being the most carbon intensive of all energy types, with sub-bituminous at 91.2 kg per GJ, will be most disadvantaged by New Zealand's proposed emissions trading scheme.

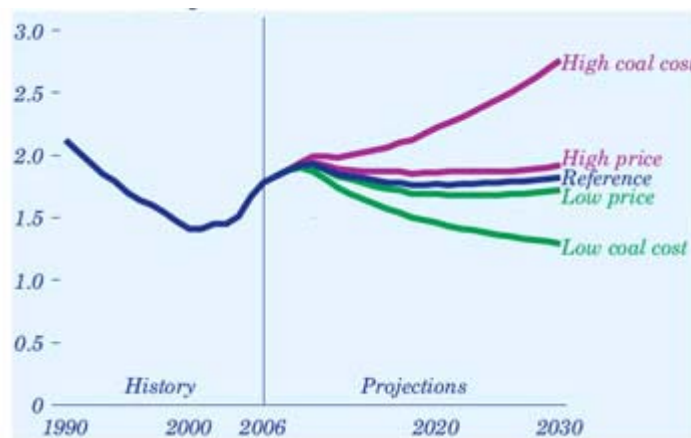


Figure 42: USA delivered (sub-bituminous) coal prices³⁰

Transport costs are more like a "minehead in New Zealand" or "landed" price for imported coal. Imported coal might be landed at Port of Auckland. Coal used at Huntly is imported through Port of Tauranga, as far as we can ascertain. If coal was landed at Tauranga or obtained from Huntly mines (or Taranaki) then transport costs would be expected to add about \$0.40 +/- \$0.10 per GJ land transport. This relatively small amount reflects the fact that coal is often transported in bulk by relatively fuel efficient modes such as rail and

²⁸ <http://www.coalnz.com/index.cfm/1,210,504,0,html/Solid-Energy-confirms-progressive-withdrawal-from-home-heating-market>

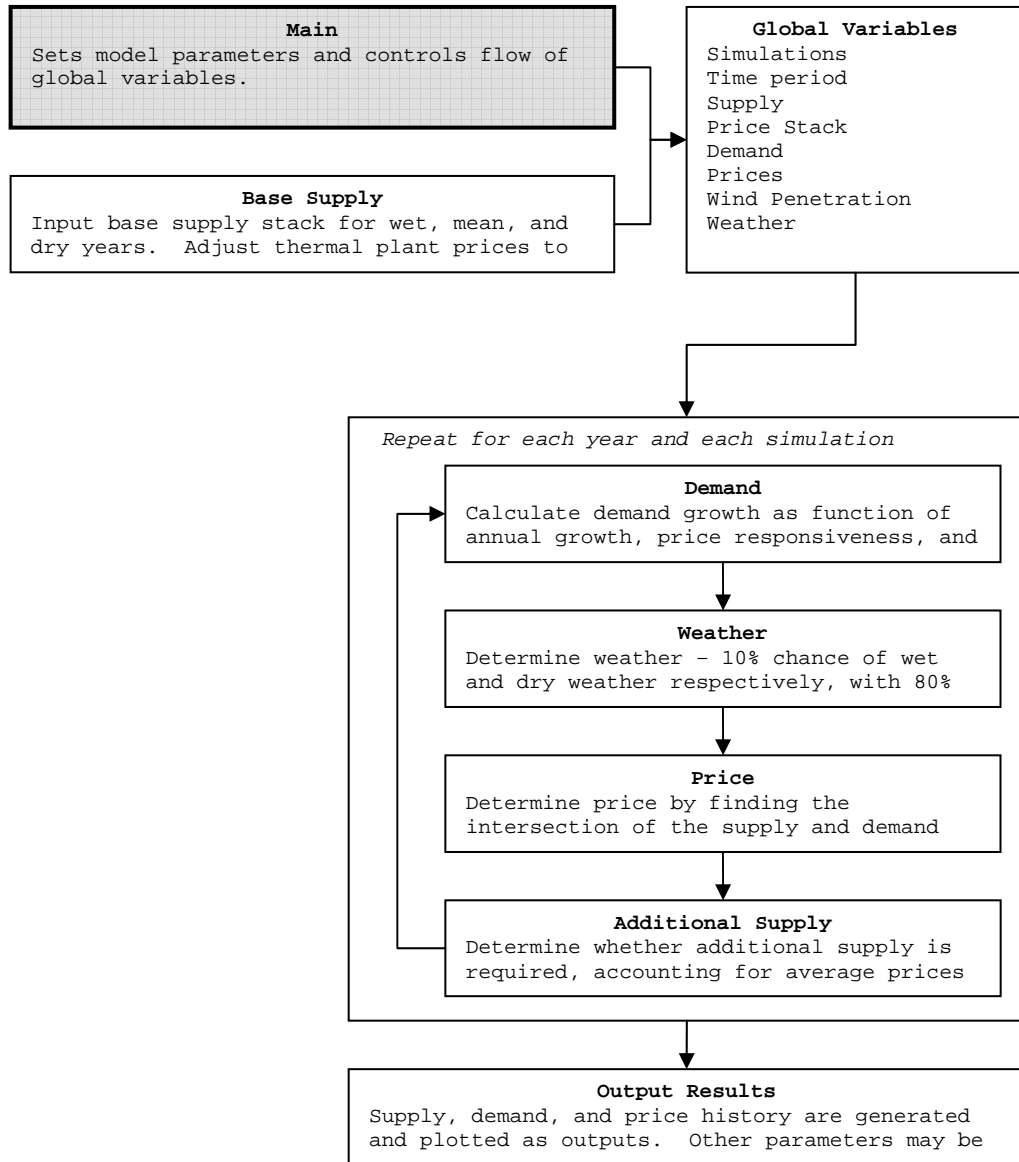
²⁹ www.med.govt.nz/templates/MultipageDocumentTOC_21862.aspx, p29

³⁰

US Energy Information Administration, www.eia.doe.gov/oiaf/aeo/coal

coastal shipping. For this reason, higher fuel prices are likely to have only negligible impacts on coal prices paid by consumers.

19 Appendix L: Electricity price model architecture



20 Appendix M: Electricity consumption model

The Electricity Consumption Model (ECM) was developed by considering historical trends in electricity consumption for the industrial, commercial, and residential sectors.

This analysis revealed a logarithmic relationship between consumption and time for all sectors, as well as a linear relationship between consumption and price for residential consumption. In other words, electricity consumption tends to increase with time, notwithstanding economic growth and prices.

A related observation is that historical prices have not been a major determinant of trends in industrial and commercial consumption, at least in the short term. This is likely to reflect the fact that electricity, albeit essential, is a relatively small expenditure item for most businesses and thus not likely to factor into short term decisions. Contracts may also insulate industrial and commercial customers from short term prices.

A linear least squares regression model was used to identify the following ECM model:

$$C(t) = C_{Industrial}(t) + C_{Residential}(t) + C_{Commercial}(t)$$

$$C(t) = (A_I \ln(t - T_I) + K_I) + (A_R \ln(t - T_R) + E_R P_R(t) + K_R) + (A_C \ln(t - T_C) + K_C)$$

Values for these parameters are summarised in Table 4.

Table 4: Parameters of the ECM model

| Parameter | Sector | | |
|-----------|----------------|-----------------|----------------|
| | Industrial (I) | Residential (R) | Commercial (C) |
| A | 0.570040854 | 0.179108437 | 0.749430327 |
| T | 1978.75598 | 1978.752818 | 1970.246738 |
| K | 2.167926629 | 2.468995086 | -0.67817353 |
| P | 0 | -0.06300499 | 0 |

This model was found to have excellent explanatory abilities for historical data in the period 1980-2007, with an R-squared of 99 per cent.