

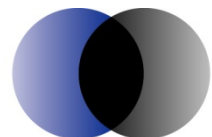


# Liquid fuels vulnerability assessment

A review of liquid fuels vulnerability

Department of Resources Energy and Tourism

October 2011



**ACIL Tasman**

Economics Policy Strategy

## Reliance and Disclaimer

The professional analysis and advice in this report has been prepared by ACIL Tasman for the exclusive use of the party or parties to whom it is addressed (the addressee) and for the purposes specified in it. This report is supplied in good faith and reflects the knowledge, expertise and experience of the consultants involved. The report must not be published, quoted or disseminated to any other party without ACIL Tasman's prior written consent. ACIL Tasman accepts no responsibility whatsoever for any loss occasioned by any person acting or refraining from action as a result of reliance on the report, other than the addressee.

In conducting the analysis in this report ACIL Tasman has endeavoured to use what it considers is the best information available at the date of publication, including information supplied by the addressee. Unless stated otherwise, ACIL Tasman does not warrant the accuracy of any forecast or prediction in the report. Although ACIL Tasman exercises reasonable care when making forecasts or predictions, factors in the process, such as future market behaviour, are inherently uncertain and cannot be forecast or predicted reliably.

ACIL Tasman shall not be liable in respect of any claim arising out of the failure of a client investment to perform to the advantage of the client or to the advantage of the client to the degree suggested or assumed in any advice or forecast given by ACIL Tasman.

## ACIL Tasman Pty Ltd

ABN 68 102 652 148

Internet [www.aciltasman.com.au](http://www.aciltasman.com.au)

### Melbourne (Head Office)

Level 4, 114 William Street  
Melbourne VIC 3000

Telephone (+61 3) 9604 4400  
Facsimile (+61 3) 9604 4455  
Email [melbourne@aciltasman.com.au](mailto:melbourne@aciltasman.com.au)

### Brisbane

Level 15, 127 Creek Street  
Brisbane QLD 4000  
GPO Box 32  
Brisbane QLD 4001

Telephone (+61 7) 3009 8700  
Facsimile (+61 7) 3009 8799  
Email [brisbane@aciltasman.com.au](mailto:brisbane@aciltasman.com.au)

### Canberra

Level 1, 33 Ainslie Place  
Canberra City ACT 2600  
GPO Box 1322  
Canberra ACT 2601

Telephone (+61 2) 6103 8200  
Facsimile (+61 2) 6103 8233  
Email [canberra@aciltasman.com.au](mailto:canberra@aciltasman.com.au)

### Darwin

GPO Box 908  
Darwin NT 0801

Email [darwin@aciltasman.com.au](mailto:darwin@aciltasman.com.au)

### Perth

Centa Building C2, 118 Railway Street  
West Perth WA 6005

Telephone (+61 8) 9449 9600  
Facsimile (+61 8) 9322 3955  
Email [perth@aciltasman.com.au](mailto:perth@aciltasman.com.au)

### Sydney

PO Box 1554  
Double Bay NSW 1360

Telephone (+61 2) 9389 7842  
Facsimile (+61 2) 8080 8142  
Email [sydney@aciltasman.com.au](mailto:sydney@aciltasman.com.au)

## For information on this report

Please contact:

Alan Smart  
Telephone (02) 6103 8201  
Mobile 0404 822 312  
Email [a.smart@aciltasman.com.au](mailto:a.smart@aciltasman.com.au)

### Contributing team members

Ken Willett  
John Söderbaum  
Joel Etchells

Yuan Chou  
Guy Jakeman



## Contents

<b>Executive summary</b>	<b>viii</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Vulnerability assessment 2008</b>	<b>3</b>
2.1 Findings in 2008	3
2.2 Approach taken in this report	4
<b>3 Australia's current liquid fuels situation</b>	<b>5</b>
3.1 Supply	5
3.1.1 Production of crude oil, condensate and naturally occurring LPG	5
3.1.2 Production of petroleum products	8
3.1.3 Imports	9
3.1.4 Demand	10
3.1.5 Liquid fuels self sufficiency	10
<b>4 World oil outlook</b>	<b>15</b>
4.1 Resources and reserves	15
4.2 Production capacity	16
4.3 Demand and supply scenarios	19
4.3.1 Demand	20
4.3.2 Supply	21
4.3.3 Price assumptions	23
4.3.4 Changes since 2008	25
4.4 Refinery capacity	25
4.5 Petroleum markets in Asia	30
4.6 IEA collective response plans	30
4.6.1 Maintaining readiness	34
4.7 Australia's current level of stocks	35
4.8 Petroleum statistics	39
<b>5 Vulnerability to Oil Shocks: New Perspectives Since 2008 Assessment</b>	<b>40</b>
5.1 Introduction	40
5.2 Shocks, Shortages and Market Forces	40
5.3 Disproportionate Price Effects of Oil Shocks	41
5.3.1 Crude Oil	41
5.3.2 Refined Oil Products	43
5.4 Types and Causes of Shocks	45



5.4.1	Crude Oil Shocks	45
5.4.2	Inventories and the Precautionary Demand Concept	46
5.4.3	Historical Crude Oil Shocks	49
5.4.4	Refined Product Shocks	59
5.5	Economic implications of oil shocks	60
5.5.1	Aggregate Demand Shock	61
5.5.2	Oil Supply Shock	61
5.5.3	Precautionary or Speculative Oil-Specific Demand Shock	62
5.5.4	Changes Over Time and Across Countries	62
5.5.5	Refined Products Supply Shocks	63
5.5.6	Compound Shocks	64
<b>6</b>	<b>Analysis of Hypothetical Major Shock: Singapore Petroleum Outage</b>	<b>66</b>
6.1	Introduction	66
6.2	Supply Shock Scenario	67
6.3	Significance of Australian Refined Product Imports from Singapore	67
6.4	Logistical Issues from Disruption of Singapore's Role as a Liquid Petroleum Trading Hub	68
6.4.1	Crude Oil	68
6.4.2	Petroleum Products	70
6.5	Comparison with Hurricanes Katrina and Rita	72
6.5.1	Hurricanes Katrina and Rita	72
6.5.2	Hypothetical Singapore Capacity Outage	76
6.6	Short-Term Price Elasticity of Demand	77
6.6.1	Available Estimates	77
6.6.2	Implications of Estimates of Short-Term Price Elasticity of Demand	78
6.7	Short-Term Price Elasticities of Supply	79
6.8	Potential Price Shocks	84
6.9	Quantitative assessment of economic effects of price shocks	86
6.9.1	Approach	86
6.9.2	Price Shocks	87
6.9.3	Results	87
6.10	Impact of the hypothetical supply shock on adequacy, reliability and affordability	92
<b>7</b>	<b>Vulnerability 2011 -2025</b>	<b>94</b>
7.1	Introduction	94
7.2	Implications of context of the Singapore shock scenario	94
7.2.1	Impact of an aggregate demand shock	95
7.2.2	Impact of a crude oil supply shock	96
7.2.3	Impact of precautionary buying	96
7.2.4	The impact of IEA collective action	97
7.3	Vulnerability to a disruption in oil supplies	98



7.3.1	Immediate term	99
7.3.2	Medium term	99
7.3.3	Longer term	100
<b>8</b>	<b>Affordability 2011 - 2025</b>	<b>101</b>
8.1.1	Definition of affordability	101
8.1.2	Crude oil price trends	102
8.2	Crude oil price forecasts	104
8.2.1	Retail price trends	105
8.2.2	International comparisons	112
8.2.3	Expenditure on liquid fuels	113
8.3	Affordability assessment	115
8.4	Summary	116
8.4.1	Immediate term	116
8.4.2	Medium term	117
8.4.3	Long term	117
<b>9</b>	<b>Conclusions and recommendations</b>	<b>119</b>
9.1	Vulnerability to a disruption	119
9.2	Adequacy of Australian stocks	120
9.3	Petroleum statistics	121
9.4	Recommendations	122
<b>List of boxes</b>		
Box 1	<b>IEA scenarios</b>	20
Box 2	<b>Role of Precautionary/Speculative Demand and Taxes in 'First Oil crisis'</b>	51
Box 3	<b>Energy Security Defined in Terms of Adequacy, Reliability and Affordability</b>	67
Box 4	<b>Katrina and Rita Supply Shocks and Market Forces</b>	76
<b>List of figures</b>		
Figure ES 1	<b>World oil production by source - New Policies Scenario in IEA 2010 Outlook</b>	x
Figure ES 2	<b>Oil price projections by the IEA and the EIA (\$US per bbl)</b>	x
Figure ES 3	<b>Capacity additions in Asia Pacific refineries</b>	xii
Figure ES 4	<b>Asian product demand compared with refining capacity</b>	xii
Figure ES 5	<b>Real versus nominal price of petrol in Australia, September 2001 to May 2011 (cents per litre)</b>	xxiii
Figure ES 6	<b>Real versus nominal price of diesel in Australia, February 2006 to May 2011 (cents per litre)</b>	xxiii
Figure ES 7	<b>Ratio of retail petrol price and crude oil price (left axis) versus the exchange rate of the Australian dollar (right axis)</b>	xxiv
Figure 1	<b>ABARES projections of Australian production of crude oil, condensate and LPG</b>	8



Figure 2	<b>Australian crude oil and other refinery feedstock production and net imports</b>	12
Figure 3	<b>Self sufficiency in crude oil and other refinery feedstock forecasts 2008 and 2010</b>	13
Figure 4	<b>OPEC spare crude oil production capacity</b>	17
Figure 5	<b>World oil supply capacity growth (mbd)</b>	18
Figure 6	<b>Oil demand projections for 2025</b>	21
Figure 7	<b>World oil production by source - New Policies Scenario in IEA 2010 Outlook</b>	22
Figure 8	<b>Oil price assumptions by IEA (\$US/bbl)</b>	23
Figure 9	<b>Figure 32 from IEO2010, World oil prices in three cases, 1980-2035, (2008 dollars per barrel)</b>	24
Figure 10	<b>Regional share of expansion in crude distillation capacity</b>	27
Figure 11	<b>Capacity additions in Asia/Pacific refineries</b>	27
Figure 12	<b>Crude distillation capacity in the Asia-Pacific region</b>	28
Figure 13	<b>Asia-Pacific product demand compared with refining capacity (mbd)</b>	29
Figure 14	<b>IEA Emergency Response System</b>	32
Figure 15	<b>IEA response to hurricanes in the Gulf of Mexico in 2005</b>	34
Figure 16	<b>Share of Australian imports of refined petroleum products by country/region, 2009-10</b>	68
Figure 17	<b>U.S. Weekly Refinery Throughput</b>	72
Figure 18	<b>Singapore Export Petrol Price Movements Compared with Crude Oil Price Movements in 2005-06, Highlighting Effect of Hurricane Katrina</b>	73
Figure 19	<b>Retail Petrol Prices in United States, Australia, and Europe – 2003-04, 2004-05 and 2005-06</b>	74
Figure 20	<b>International refinery throughput in response to Hurricanes Katrina and Rita</b>	75
Figure 21	<b>Illustrative price movements</b>	86
Figure 22	<b>Nominal and real price of Malaysia Tapis Blend crude in US dollars per barrel</b>	102
Figure 23	<b>Nominal and real price of Asia Dubai Fateh crude in US dollars per barrel</b>	103
Figure 24	<b>Weekly nominal price of Tapis Blend crude in US dollars per barrel, January 2007 to April 2011</b>	104
Figure 25	<b>EIA projection of world oil prices in three cases, 1980-2035 (2008 US dollars per barrel)</b>	105
Figure 26	<b>Average national petrol and diesel pump prices by week, February 2006 to May 2011 (cents per litre)</b>	106
Figure 27	<b>Real versus nominal price of petrol in Australia, September 2001 to May 2011 (cents per litre)</b>	106
Figure 28	<b>Real versus nominal price of diesel in Australia, February 2006 to May 2011 (cents per litre)</b>	107
Figure 29	<b>Average monthly capital city unleaded petrol prices, April 2001 to April 2011 (cents per litre)</b>	108
Figure 30	<b>Average monthly capital city diesel prices, April 2001 to April 2011 (cents per litre)</b>	109
Figure 31	<b>Average monthly capital city LPG prices, April 2001 to April 2011 (cents per litre)</b>	109
Figure 32	<b>Retail price of petrol in Australia versus price of Tapis Blend crude, September 2001 to May 2011 (Australian cents per litre)</b>	110
Figure 33	<b>Retail price of diesel in Australia versus price of Tapis Blend crude, February 2006 to May 2011 (Australian cents per litre)</b>	111



Figure 34	<b>Ratio of retail petrol price and crude oil price (left axis) versus the exchange rate of the Australian dollar (right axis)</b>	111
Figure 35	<b>Prices of petrol (left panel) and diesel (right panel) in OECD countries, December quarter 2010 (Australian cents per litre)</b>	112
Figure 36	<b>Comparison of automotive LPG prices in OECD countries, December quarter 2010 (Australian cents per litre)</b>	113
Figure 37	<b>Australia's 'Oil Burden'</b>	114

### List of tables

Table ES 1	<b>Total primary petroleum energy production, consumption and net imports</b>	ix
Table ES 2	<b>Global Crude Distillation Capacity (million barrels per day)</b>	xi
Table ES 3	<b>Percentage price change with current Asian spare capacity</b>	xviii
Table ES 4	<b>Percentage price change with medium term Asian spare capacity</b>	xix
Table ES 5	<b>Projected economic impacts in the short term (in 2010 terms)</b>	xix
Table ES 6	<b>Projected change in sectoral output relative to the reference case in the short term</b>	xix
Table ES 7	<b>Projected economic impacts in the medium term (in 2010 terms)</b>	xx
Table ES 8	<b>Projected change in Australian output by sector, relative to the reference case</b>	xx
Table 1	<b>Australian production of crude oil, by basin – 2004-05 to 2009-10</b>	6
Table 2	<b>Australian production of condensate, by basin – 2004-05 to 2009-10</b>	6
Table 3	<b>Australian production of liquefied petroleum gas, by basin – 2004-05 to 2009-10</b>	7
Table 4	<b>Refinery production in Australia (2008-09)</b>	8
Table 5	<b>Australian production of refined petroleum products</b>	9
Table 6	<b>Australian imports of crude oil and other refinery feedstock</b>	10
Table 7	<b>Australian primary energy consumption of petroleum (PJ)</b>	10
Table 8	<b>Self sufficiency in petrol, automotive diesel oil and jet fuel</b>	11
Table 9	<b>Australia's level of self sufficiency in refined petroleum products</b>	11
Table 10	<b>Australia's level of self sufficiency in crude oil and other refinery feedstock</b>	12
Table 11	<b>Total primary petroleum energy production, consumption and net imports (PJ)</b>	13
Table 12	<b>World oil reserves by country as at 1 January 2010</b>	15
Table 13	<b>IEA primary oil demand scenarios (mbd)</b>	21
Table 14	<b>IEA Projections of oil production (millions of barrels per day)</b>	22
Table 15	<b>Global Crude Distillation Capacity (million barrels per day)</b>	25
Table 16	<b>ABARES' and ACIL Tasman's stockholding calculations (including adjustments)</b>	38
Table 17	<b>IEA Crude Oil Price Differentials – Selected Monthly Averages 2005</b>	81
Table 18	<b>Comparative International Refining Margins, September 2005</b>	82
Table 19	<b>Percentage price change with current Asian spare capacity</b>	87
Table 20	<b>Percentage price change with medium term Asian spare capacity</b>	87
Table 21	<b>Projected change in Australian demand for refined petroleum products by sector, relative to the reference case</b>	88



Table 22	<b>Projected change in Australian output by sector, relative to the reference case</b>	88
Table 23	<b>Projected change in Australian real GDP– Expenditure side (in 2010 terms)</b>	90
Table 24	<b>Projected change in Australian real GDP — Income side (in 2010 terms)</b>	91
Table 25	<b>Projected change in Australian real income (in 2010 terms)</b>	92
Table 26	<b>Projected economic impacts in the short term</b>	99
Table 27	<b>Projected economic impacts in the medium term</b>	100
Table B1	<b>Projections of petroleum production - reference case</b>	1
Table C1	<b>Sectors in the <i>Tasman Global</i> database</b>	4





## Executive summary

### Introduction

The Government has periodically reviewed Australia's vulnerability to interruptions to oil supplies. The most recent was a review undertaken by ACIL Tasman in 2008. This report updates that review.

A number of factors have changed since 2008. In particular, since December 2009, Australia has been in breach of its 90 day stockholding obligation as a Member of the International Energy Agency (IEA).

The terms of reference required us to consider:

- a) the declining ratio of Australia's stocks to net imports and resulting non-compliance with its 90 day stockholding obligation, assessing whether or not this increases Australia's vulnerability to a large scale supply disruption;
- b) recent high and volatile crude oil prices and whether or not this has affected the affordability of liquid fuels in Australia; and
- c) in answering these questions, model and consider the impact of a shock scenario testing Australia's vulnerability to the loss of a major trading hub for oil products for a period of 30 days.

Overall, on the basis of analysis conducted for the preparation of this report, ACIL Tasman found that recent market developments have not resulted in a significant change in Australia's liquid fuels vulnerability since the 2008 review, from the perspective of adequacy, reliability or affordability. Adequacy in terms of suppliers being able to keep up with demand, has generally been maintained. This situation is likely to continue to be the case, despite the planned closure of Shell's refinery at Clyde in Sydney.

With growing net imports, the ratio of stocks to net imports is likely to decline. However, this is not considered to be a concern for supply security reasons in the short term. This is because of the nature of the petroleum market globally and in the Asia-Pacific region, where supply security depends on being able to source petroleum products from a diverse range of refineries that can meet Australian specifications.

The history of oil shocks over the past 38 years has not provided any evidence to suggest that crude oil and refined product markets would not swiftly respond to a supply disruption by eliciting some additional supply, reallocating supply efficiently among users, and reducing the quantity demanded through temporarily higher prices.

A major disruption to global oil supplies could negatively impact on this assessment of liquid fuel security. However, this particular vulnerability has not changed since the 2008 assessment and the probability of a major supply shock is considered to be low.



ACIL Tasman therefore retains its view, as expressed in the 2008 review, that despite growing dependence on imported sources of crude oil and refined petroleum products, adequacy is likely to be maintained to 2020. However, if supply capacity constraints emerge during or beyond this time period and the cost of liquid fuels from new sources of supply increases substantially, this will likely result in upward pressure on petroleum prices and periods of price volatility.

Despite a lack of significant changes to Australia's liquid fuels vulnerability, a number of factors have changed since the 2008 review. In particular, since December 2009, Australia has regularly been in breach of the 90 day stockholding obligation it has as a Member of the International Energy Agency (IEA).

### Outlook for liquid fuels supplies

The most recent projections prepared by the then Australian Bureau of Agricultural and Resource Economics (ABARE) show the proportion of liquid fuel (crude oil and LPG) produced domestically to total consumption of liquid fuels, expressed in primary energy terms, decreasing from 50 per cent to 24 per cent between from 2007-08 and 2029-30 (ABARE, March 2010). The forecasts are summarised in Table ES 1.

Table ES 1 **Total primary petroleum energy production, consumption and net imports**

	Production	Consumption	Net imports	Production to consumption
	PJ	PJ	PJ	
2007-08	1,048	2,083	1,034	50%
2029-30	668	2,787	2,119	24%
Average annual growth	-2.0%	1.3%	3.3%	

*Note:* Consumption and imports include the energy content of both petroleum products and refinery feedstock.

*Data source:* (ABARE, March 2010)

Total consumption of liquid fuels is projected to grow at an annual average rate of 1.3 per cent and net imports are projected to grow at an average annual rate of 3.3 per cent.

### Conventional and unconventional oil supplies

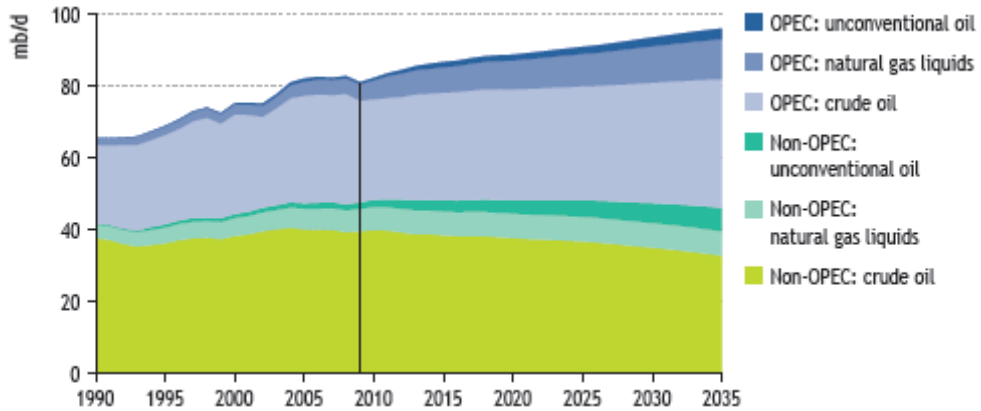
Projections prepared by the International Energy Agency (IEA) and the US Energy Information Administration (EIA) forecast the demand for liquid fuels to increase from around 84 million barrels per day (mbd) in 2009 to around 99 mbd by 2035. OPEC projections are close to the IEA and EIA reference cases.

The IEA World Energy Outlook 2010 New Policies Scenario projections (reference case) suggest that production of liquid fuels will be sufficient to meet demand growth. However, not all of this will come from conventional crude oil reserves. The IEA forecasts that production of conventional crude oil from non-OPEC countries will decline slightly over the period, while



production from OPEC countries will increase. The difference is met by production from unconventional oil and natural gas liquids (see Figure ES 1).

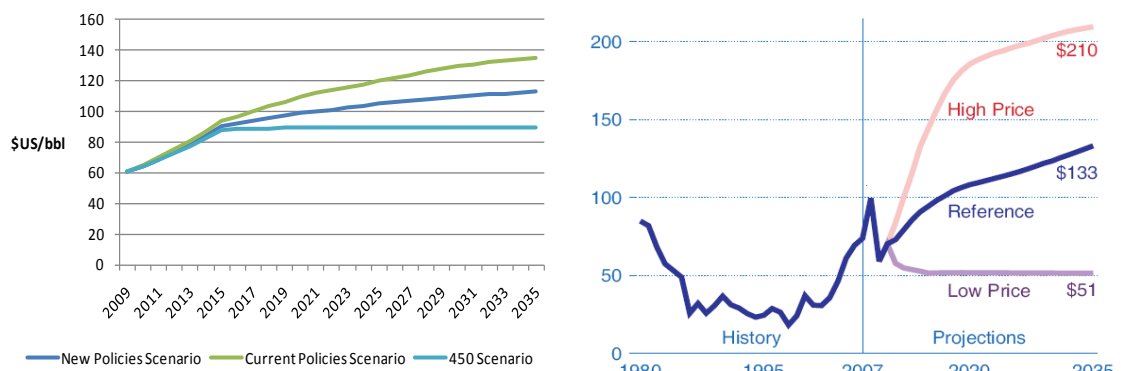
Figure ES 1 World oil production by source - New Policies Scenario in IEA 2010 Outlook



Note: World oil production shown excludes processing gains of 3 mbd by 2035  
Data source: (IEA, 2010)

The marginal cost of production of unconventional fuels is generally higher than from conventional fields. Accordingly, the projections for the reference cases are for rising oil prices over this period. The bands of price projections are, however, very wide. For example the Energy Information Administration (EIA) price projections for 2035 range from \$US50 per barrel (bbl) to \$200 per bbl whereas the IEA price projections span a narrower band (see Figure ES 2).

Figure ES 2 Oil price projections by the IEA and the EIA (\$US per bbl)



Data source: (IEA, 2010)

The IEA's 2011 Medium-Term Oil and Gas Markets Report estimates that global oil production capacity will rise from 94 mbd in 2010 to 101 mbd by 2016. The 6.8 mbd increase comes from OPEC, non-OPEC and natural gas liquids in approximately equal shares (IEA, 2011). These planned additions to capacity are likely to exceed forecast demand growth with potential spare capacity of more than 4 mbd by 2016.



## Refinery capacity

The IEA projects that global refinery crude distillation capacity will increase by 9.6 mbd (see Table ES 2).

Table ES 2 Global Crude Distillation Capacity (million barrels per day)

	2010	2011	2012	2013	2014	2015	2016	2010-2016
OECD North America	21.5	21.4	21.9	22.0	22.0	22.0	22.0	0.6
OECD Europe	15.9	15.7	15.7	15.7	15.7	15.9	15.9	0.0
OECD Pacific	8.6	8.5	8.6	8.6	8.6	8.6	8.6	0.0
FSU	8.1	8.2	8.5	8.6	8.6	8.7	8.8	0.7
China	9.9	10.0	10.6	11.0	11.4	12.3	13.2	3.3
Other Asia	10.7	11.1	11.5	11.8	11.9	11.9	12.0	1.3
Middle East	7.8	8.0	8.1	8.6	9.0	9.8	10.1	2.3
Other Non-OECD	10.6	10.7	11.0	11.3	11.7	12.0	12.2	1.5
<b>World</b>	<b>93.1</b>	<b>93.5</b>	<b>95.9</b>	<b>97.5</b>	<b>98.8</b>	<b>101.3</b>	<b>102.7</b>	<b>9.6</b>

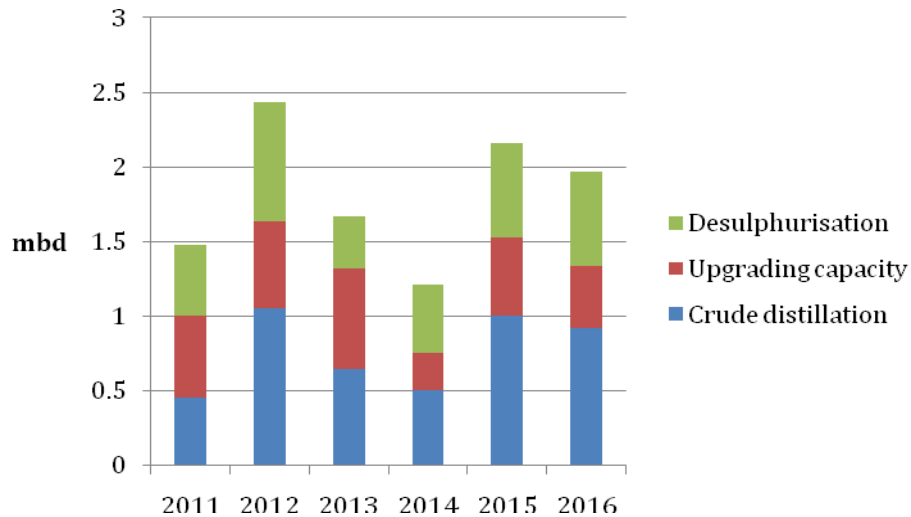
Data source: (IEA, 2011)

Petroleum products are traded globally, and recent evidence suggests that the world market for petroleum products responds quickly to changes in supply or demand regardless of the where these changes occur. Products are traded between regions and the market can respond relatively quickly to temporary shortages in one region providing there is sufficient spare capacity in the system and that price rises are not constrained by regulatory intervention.

From Australia's point of view, spare refining capacity in the Asia-Pacific region is an important factor in the market response. The IEA report projects a net expansion of 4.5 mbd in crude oil distillation capacity in the Asia-Pacific region by 2016. Expansions of 3.0 mbd in capacity upgrades and 3.3 mbd in desulphurisation capacity are also projected for the region (see Figure ES 3).



Figure ES 3 Capacity additions in Asia Pacific refineries

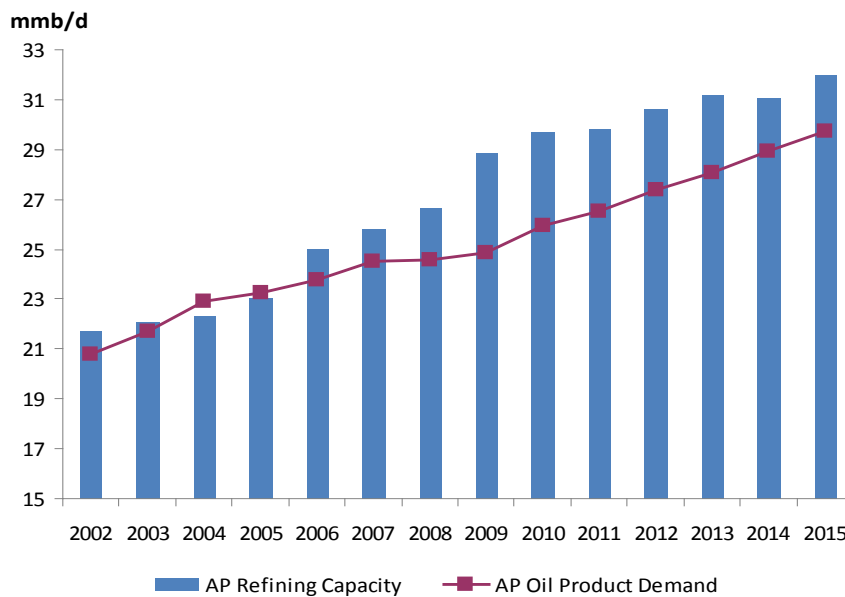


Note: Crude oil distillation separates crude oil into base products such as LPG, petrol, diesel, jet fuel, kerosene and heating oil. Upgrading capacity includes process to upgrade feedstock and earlier products to higher value products. Desulphurisation includes additions to hydrotreating and desulphurisation capacity.

Data source: (IEA, 2011)

A recent paper by Zhang suggests that spare capacity in the Asian region will largely continue out to 2015. Although closure of some older Asian refineries and continued demand growth will reduce this spare capacity around 2014, projected refining capacity will remain in surplus (Zhang, Jan-Mar 2011). Investment in additional capacity is projected over the next 5 to 6 years. This analysis is summarised in Figure ES 4.

Figure ES 4 Asian product demand compared with refining capacity



Data source: (Zhang, Jan-Mar 2011)



Longer term investment in oil production and refining capacity cannot be predicted with certainty. The 2010 IEA World Energy Outlook and the 2011 Medium Term Oil and Gas Markets Report note that investment in upstream and downstream infrastructure has rebounded since the global financial crisis of 2008.

Projected trends in the "New Policies Scenario"<sup>1</sup> in the World Energy Outlook require ongoing investment of around \$US 310 billion per year of which 85 per cent is needed upstream. Investment beyond 2015 cannot be predicted with certainty. The IEA notes that lags in investment responses to price swings tend to result in cyclical swings in investment. However the IEA considers that the policies and regulatory frameworks assumed in their "New Policies Scenario" provide an investment environment consistent with the investment required to 2035. Nevertheless there are likely to be short periods when investment falls below the level required to balance supply with projected demand.

### **Current stock levels and IEA Stockholding**

Australia does not currently meet its IEA obligation to hold oil stocks equal to 90 days of average daily net imports in the previous year.

A review undertaken by ACIL Tasman indicated that even with the addition of some missing stocks and current and planned additions to storage capacity, Australia's stocks of liquid fuels (as calculated according to IEA guidelines) would still only reach 86 days of net oil imports in 2011, less than the 90 days required of Australia as an IEA member.

An interim report prepared as part of this assignment found that there were gaps and discrepancies in the reporting of stocks in Australian Petroleum Statistics (APS), which supports statistical reporting to the IEA. The interim report also concluded that the methodology specified by the IEA to calculate Australia's stocks for the purposes of reporting to the IEA did not fully reflect the Australian situation in a number of areas.

While the planned improvements in the system for collecting APS data should enable a much more accurate picture of existing stocks to be recorded, Australia is still unlikely to meet its 90 day obligation. This situation is likely to worsen as net imports increase.

Furthermore, even if possible changes to the IEA methodology could be agreed, Australia would at best only meet its obligations for a short period of time.

The reporting methodology required by the IEA does not fully reflect the operation and nature of the Australian petroleum market. For example, it excludes oil in tankers destined for Australia, despite the fact that the majority of this oil is contractually committed solely to

---

<sup>1</sup> The New Policies Scenario takes account of the broad policy commitments that have been announced by Governments and assumes cautious implementation of national pledges to reduce greenhouse gas emissions by 2020 and to reform fossil fuel subsidies.



Australian importers. If the calculation were adjusted to take into account Australian market conditions, Australia's current stock levels would be slightly above 90 days of net oil imports.

However, a continuation of current production and consumption trends could see Australia again failing to meet its IEA obligations within a relatively short timeframe, unless additional storage capacity is installed and at a rate faster than the related increase in daily net imports. In recent years significant new storage capacity has been installed by industry in response to growing demand, particularly for diesel. On the basis of ACIL Tasman's consultations and analysis, this additional storage capacity will more than offset the reduction in capacity caused by the closure of Shell's Clyde refinery. However, this will not alter the above conclusion in respect of meeting the 90 day IEA obligation.

Given this situation, there is a strong case for persisting with the planned improvements in the collection of Australian Petroleum Statistics and making reporting mandatory for the liquid fuels industry.

## **Vulnerability to oil shocks**

Australia's vulnerability to a large scale liquid fuel supply interruption has been taken to mean its susceptibility to economic harm from the supply shock. Vulnerability is also considered in terms of adequacy, affordability and reliability.

The history of oil shocks over the past 38 years has not provided any evidence to suggest that crude oil and refined product markets would not swiftly respond by eliciting some additional supply, reallocating supply efficiently among users, and reducing quantity demanded through temporarily higher prices. While most of the earlier literature on oil shocks focussed on disruptions to crude oil supplies, more recent literature has addressed the implications of interruptions to supplies of refined products.

Recent academic work suggests that refined oil product shocks could arise as a result of one or more of the following:

- *crude oil supply shocks* (pass through of crude oil price increases)
- *aggregate demand shocks* (global growth of demand for goods and services generally)
- *precautionary or speculative crude oil demand shocks* (pass through of crude oil price increases)
- *precautionary or speculative refined product oil demand shocks*
- *refined product supply shocks.*

Because refined product prices rise and fall with crude oil prices, crude oil supply shocks and precautionary crude oil demand shocks would also translate into refined product shocks. Aggregate demand shocks affect crude oil prices because demand for crude oil is derived from demand for refined products. Two additional potential shocks apply to refined products - refined product supply shocks separate from crude oil supply issues, and precautionary demand for products, separate from precautionary demand for crude oil.



More than one shock may apply simultaneously and they may also interact.

## Market responses

In economic literature, responsiveness of demand to price changes is measured by price elasticity of demand. This is the proportionate change in quantity demanded divided by the proportionate change in price (a negative number). Responsiveness of supply to price changes is measured by price elasticity of supply. This is calculated as the proportionate change in quantity supplied, divided by the proportionate change in price (a positive number).

Relatively small shifts in crude oil supply can lead to disproportionately large changes in prices. This is because responsiveness of demand and supply to price movements tends to be extremely low (or inelastic) in the short-term. While responsiveness increases over time, it is still very low compared to most goods and services in the long-term. Responses can occur on the supply and demand side:

- On the supply side, crude oil production can only be increased in the short-term in response to a large price increase if there is excess production capacity. With the elapse of time, production capacity can be increased, but the effect of various lags may be a long response time.
- On the demand side, consumers have some ability to respond to short-term price increases by changing consumption. The longer the price increase persists, the greater are the opportunities to reduce consumption.

Price elasticity of demand for products ex-refinery is higher than for crude oil, because the crude oil price accounts for only part of the ex-refinery price of refined products. It is higher again at the point of use because the crude oil price is a smaller proportion of the final price of refined products to users and that price is higher than the ex-refinery price because of distribution and retailing costs and margins and taxes.

## Singapore

For the purposes of assessing the possible costs of a disruption to supplies, ACIL Tasman chose a hypothetical 30 day disruption in Singapore. There is no precedent for a market disruption of the kind modelled in this report, and selection of Singapore does not imply any specific vulnerability in the world oil market. In fact, Australian industry advised that it cannot envisage any credible peacetime scenario, including in Singapore, which would prevent them from sourcing fuel supplies from alternative locations to meet Australia's liquid fuel needs.

Singapore is an important market hub for crude oil and petroleum products and also has refining capacity of around 1.34 mbd. Singapore currently supplies about 51 per cent of Australian imports of petroleum products (around 20 per cent of total consumption) and the main impact of a shutdown in Singapore would be on supplies of petroleum products for the Australian market.





Singapore is also an important logistics centre for crude oil trade. Cargoes from the Middle East, West Africa and Asia are discharged from Very Large Crude Carriers and are broken-up through ship to ship transfer into smaller vessels for shipping to Australian refineries.

Australian refineries would need to seek alternative sources of crude oil to replace any shipments from the Singapore hub. Some crude originally bound for the Singapore hub would become available to the wider market. Industry consultation indicated that the impact of disruption to crude supplies from Singapore would not be felt by Australian refineries for 5 to 6 weeks. After trade in the Singapore hub re-commenced, there would be a gradual return to normal supply arrangements.

### **Impact of a 30 day closure**

The main impact on Australia of a 30-day shutdown of Singapore would be on the source of supply of petroleum products. The impact would typically be felt through an immediate price rise as traders sourced replacement product from the global market.

Economic analysis and historical experience have shown that a supply shock, such as the hypothetical Singapore shut-down scenario would trigger large increases in prices of refined products globally. Prices would rise sufficiently to ration supply in the very short-term, and to re-allocate supply. Indeed, there could be overshooting in the very short-term because of speculative demand. Thereafter, market forces would adjust prices automatically as uncertainty declines, additional supply of products is induced and other circumstances change. In effect, the operation of market forces would translate the supply shock into a price shock that would resolve the supply rationing and allocation problem.

The scale of this price rise would depend on spare refining capacity in the global market in general and in the Asia-Pacific region in particular. It would also depend on the net call on the global spot market for short term supply, as Singapore's product customers hold material stockholdings of petroleum products which they can utilise or run down in such circumstances whilst additional supply is sourced.

The most immediate impact would be on products imported into Darwin and North Western Australia, which are usually supplied from Singapore. Industry consultations indicated that the sailing time from Singapore to Darwin is around 7 days, which means that stocks on the water and in import terminals are likely to be sufficient for about 2 weeks on average. Sailing times from Singapore to import terminals further south on the East and West coasts of Australia are around 14 days. Importers supplying these areas would have up to 2 weeks supply of product on the water and potentially another 1 to 2 weeks in import terminals.

Most Australian cargoes are locked into the Australian market well before tankers sail, which would ensure supply in the first two weeks of the disruption. This, along with storage at import terminals, would provide a buffer period of between 2 to 4 weeks while importers sourced product from other locations to make up for the loss of product normally shipped from Singapore.



In the case of a Singapore disruption, supplies for Australia would be sourced from the spot market in the first instance. This would include diverting cargoes that would otherwise have been exported from the Asia-Pacific region. Refineries in the Asia-Pacific region routinely export surplus production to other regions, notably the Americas and Europe.

Diesel that meets Australian specifications is a fairly fungible grade in Asia and industry consultations suggested that sourcing additional diesel from Asia would not be difficult. Australian-specification petrol (ULP) is less fungible. However, Japanese and Korean refineries can supply ULP to Australian specification, as can newer refineries in India and refineries in the Middle East. Supplies from Japan and South Korea can take 4 to 6 weeks from contracting supply to delivery at Australian ports. Sailing time from India and the Middle East is around 6 weeks. Industry advised that importers would take early action to secure additional supplies from these sources to ensure that the Australian market was supplied in the subsequent weeks.

In summary, stocks on the water and in terminals should be sufficient to supply the Australia market for between 2 to 4 weeks, depending on location in Australia. Additional supply sourced from the spot market would provide the first source of supply to replace that which would otherwise have been supplied from Singapore. Subsequent supplies would be procured from refineries in North Asia and further afield. Arranging these supplies would take 2 to 4 weeks in the first instance according to industry sources. More remote supplies could come on line in subsequent weeks, depending on the duration of the disruption. Together these supplies would be sufficient to meet Australian demand until supplies from Singapore could be fully restored. It is possible that full restoration of normal operations from Singapore could take up to 2 months.

While the disruption would require readjustment and rerouting of cargoes, the general view of the industry and ACIL Tasman's research into recent interruptions to supply is that the market would be able to respond and readjust the supply lines to replace supplies lost from Singapore. Prices would rise in the interim - the extent of the rise would depend on the net amount of product taken out of the market, the extent of precautionary buying by market participants and any release of government-controlled stocks, such as under coordinated responses by IEA member countries.

## **Modelling the impacts**

ACIL Tasman used an analysis of the response of the oil market to Hurricanes Katrina and Rita in 2005 in the Gulf of Mexico to estimate the impact on prices over three months of a 30 day shutdown in Singapore. Hurricane Katrina, which arrived in late August 2005, resulted in an initial loss of around 2 mbd in global refinery capacity and an average loss of refining capacity of 1.57 mbd for the month immediately following. More capacity was taken out following Hurricane Rita in late September 2005. The peak net loss of refinery capacity exceeded 4 mbd by early October 2005. Crude oil production from the Gulf of Mexico was also reduced by around 1.37 mbd.



By comparison, a 30 day shutdown of Singapore would result in the loss of around 1.33 mbd of production of refined petroleum products. There would be no loss in global production of crude oil. However, the role of Singapore as a trading hub for both crude oil and refined petroleum products would be suspended for the duration of the incident.

The supply disruption caused by Hurricane Katrina resulted in an immediate increase in petrol prices in the United States of around 18 per cent. Petroleum product prices in Singapore and Europe increased along with prices in the United States, demonstrating the integrated nature of the international market for crude oil and refined petroleum products. The IEA estimated that ultimately around 0.72 mbd in extra refinery runs globally were induced by market forces arising out of the price rises following the Hurricane Katrina.

The impact of the supply disruption was also muted by collective action by IEA member countries through a combination of release of emergency stocks, increased production and demand restraint measures. The release of refined product stocks offset about a quarter of the peak net loss in capacity, which resulted in the prices of petroleum products falling back within a period of around a week. Crude oil prices were largely unaffected.

Kilian (2010 b) drew attention to the importance of spare refinery capacity for crude oil price movements in response to disruptions in refineries. If there is little spare refinery capacity in the global system, crude oil prices could fall as a result of reduced demand from the remaining refineries. On the other hand if there is spare refinery capacity available, it is likely that other refineries will draw on the available crude oil, reducing downward pressure on crude oil prices.

In estimating price elasticities for a hypothetical Singapore shutdown, the price shocks for the immediate period were based on estimates of spare capacity being available in Asian refineries in 2011. In the immediate term prices are estimated to increase 12.3 per cent per cent initially with a further 5.71 per cent rise due to precautionary buying (Table ES 3). The estimate of the impact of precautionary buying is based on the Hurricane Katrina example. The total price increase is 18 per cent. In the second month the supply response reduces the total response to a price increase of 10.6 per cent.

Table ES 3 **Percentage price change with current Asian spare capacity**

Month	1	2	3
Elasticity of demand	-0.10	-0.15	na
Elasticity of supply	0.04	0.10	na
Change in quantity	-1.72	-1.72	0.00
Percentage change in price	12.3	6.9	0.00
Assumed impact of precautionary demand	5.7	3.7	2.00
Percentage change in price	18.00	10.6	2.00

Data source: ACIL Tasman

The price shocks for the medium-term are based on the lower, but still significant, spare capacity being available in Asian refineries in 2014. Prices are estimated to increase 14.3 per



cent initially with a further 6.7 per cent impact estimated for precautionary buying (Table ES 4). The estimate of precautionary buying is based on estimates drawn from the Hurricane Katrina example. The total increase is 21.0 per cent (Table ES 5). In the second month the supply response reduces the total price increase to 14.0 per cent.

Table ES 4 **Percentage price change with medium term Asian spare capacity**

Month	1	2	3
Elasticity of demand	-0.10	-0.15	na
Elasticity of supply	0.02	0.05	na
Change in quantity	-1.72	-1.72	0.00
Percentage change in price	14.3	8.6	0.00
Assumed impact of precautionary demand	6.7	5.4	3.5
Percentage change in price	21.0	14.0	3.5

Data source: ACIL Tasman

## Results

### 2011

The total loss in real GDP over the four month period following the closure is projected to be \$1,382 million. Loss in real income is projected to be nearly \$2,146 million over four months (see Table ES 5).

To place these numbers in perspective, the loss in real GDP is roughly equal to 0.10 per cent of total (i.e. annual) GDP in 2011, while the loss in real income is equivalent to an average of around \$96 for every Australian.

Table ES 5 **Projected economic impacts in the short term (in 2010 terms)**

	Units	Month 1	Month 2	Month 3	Month 4	Total
Increase in price of petroleum products	%	18.0	10.6	2	0	
Loss in real GDP	A\$ million	-791	-479	-102	-10	<b>-1382</b>
Loss in real income	A\$ million	-1227	-749	-160	-10	<b>-2146</b>

Data source: ACIL Tasman

The projected percentage change in output by sector is shown in Table ES 6.

Table ES 6 **Projected change in sectoral output relative to the reference case in the short term**

	Month 1	Month 2	Month 3	Month 4
	%	%	%	%
2011				
Agriculture	-0.8	-0.5	-0.1	-0.0
Mining	-0.8	-0.5	-0.1	-0.0
Manufacturing	-0.1	-0.0	-0.0	0.0



	Month 1	Month 2	Month 3	Month 4
	%	%	%	%
Transport	-0.4	-0.2	-0.0	-0.0
Other	-0.9	-0.5	-0.1	-0.0

Data source: ACIL Tasman Data source: ACIL Tasman

The modelling indicated that the agriculture and mining sectors are heavily affected by the price rise. In the modelled outcome these sectors reduce their call on road based transport through some switching from road to rail.

### Medium-term

In the medium-term, lower (but still significant) spare refinery capacity in Asia results in a greater price rise. The interruption is estimated to increase product prices by around 21 per cent on average in the first month while prices decline in the second and third months. The total loss in real GDP is estimated to be \$2,210 million over four months and the loss in real income is estimated to be \$3,704 million over four months (see Table ES 7).

To place these numbers in perspective, the loss in real GDP is roughly equal to 0.15 per cent of total (i.e. annual) GDP in 2015, while the loss in real income is equivalent to an average of around \$164 for every Australian.

**Table ES 7 Projected economic impacts in the medium term (in 2010 terms)**

	Units	Month 1	Month 2	Month 3	Month 4	Total
Increase in price of petroleum products	%	21	15	2	0	
Loss in real GDP	A\$ million	-1169	-805	-221	-16	<b>-2210</b>
Loss in real income	A\$ million	-1954	-1359	-374	-17	<b>-3704</b>

Data source: ACIL Tasman

The projected change in output by sector is shown in Table ES 8.

**Table ES 8 Projected change in Australian output by sector, relative to the reference case**

	Month 1	Month 2	Month 3	Month 4
	%	%	%	%
<b>2015</b>				
Agriculture	-0.8	-0.5	-0.1	-0.0
Mining	-1.2	-0.7	-0.2	-0.0
Manufacturing	0.1	0.1	0.0	0.0
Transport	-0.5	-0.3	-0.1	-0.0
Other	-1.2	-0.8	-0.2	-0.0

The impact on the mining sector is also higher in the medium term than the immediate term, reflecting the dependence of that sector on petroleum fuels.



### Longer-term

In the longer-term, Australia's production of refined petroleum products is not expected to increase. This is because the construction of any new refineries in Australia is generally viewed as economically unviable given the cost advantages enjoyed by large scale Asian refineries and also because there will be only marginal ongoing augmentation of existing domestic refinery capacity (e.g. through de-bottlenecking programs) which is expected to be insufficient to keep pace with domestic demand growth for liquid fuels. After the closure of Shell's Clyde refinery in 2013, production of refined product in Australia will also decline by around 11 per cent.

If there are further refinery closures, the diversity of the domestic supply chain will be lower. This would be offset by greater diversity in the international supply chain from new and expanded sources of imported product supply as more neighbouring countries move to producing fuel to Australian standards. Importantly, Australia's overall supply diversity will continue to be very high, including by international standards, given Australia's supply security risks will continue to be spread between domestically produced and various imported sources of product supply.

However, the availability and efficiency of petroleum product import infrastructure will be critical to maintaining an acceptable level of supply security against temporary disruptions in the product supply chain. Any constraints in these capacities will increase the vulnerability of Australia to a disruption such as the Singapore Shock scenario. Constraints will also create problems in the supply chain even without a crisis. Recent history indicates that investment in the supply chain is continuing in response to demand growth and such constraints are not currently envisaged.

While there are no longer-term estimates of investment in refinery capacity in Asia, the investment program over the next 6 years discussed above is expected to increase surplus capacity post-2015.

Disruptions to domestic refineries are likely to be less significant in the longer-term, as the contribution from domestic refineries to total demand will be lower. That said, the continued operation of some Australian refineries will still provide a diversity of supply, which is important for reducing the risks associated with a disruption in the global supply chain. Equally important for supply security will be increased diversity in global refining capacity. For Australia, increased investment in refining capacity in the Asian region represents an important and proximate diversification of potential supplies of petroleum products.

### Vulnerability assessment

Projections by the IEA and EIA support a conclusion that there should be sufficient global oil production and refining capacity to supply the Australian market over the period to 2035. Periodic capacity constraints and interruptions to supplies could however result in volatile and rising oil prices over the period, as would be expected in a normal functioning market.



Vulnerability to a shock, such as the closure of Singapore, has been assessed for the immediate term, medium term (2014-15) and longer term (2020-2025). The analysis of a shutdown of Singapore for a period of 30 days indicates that while there would be a short-term rise in petroleum product prices, there would nevertheless be sufficient petroleum products available to support economic activity - albeit at an economic cost.

- If the shock occurred in the immediate term, product supply would be maintained with product from the existing surplus capacity in other Asian refineries and from product that would normally be arbitrated out of the region. There would be short term price increases as the market adjusted to the shortfall.
- For a shock that occurred in the medium-term, product supply would be maintained but we would expect to see comparatively higher prices because the surplus capacity in Asian refineries would be lower resulting in more precautionary buying in the global product market.
- In the case of a shock that might occur beyond 2015, additional new investment is expected in the Asian refineries. Any such investment would reduce the price impact of a disruption.

Reducing fuel standards during an emergency would allow additional supplies from Asian refineries and additional supply of premium unleaded petrol (PULP) from Australian refineries to be brought on stream after a lag of one to two weeks.

Australia's vulnerability is primarily related to logistical consideration. As long as the global refinery sector has surplus capacity, price movements will ensure that refined products reach users. It is just a question of how long it takes to arrange for and then physically transport those alternative supplies to Australia.

ACIL Tasman therefore retains its view, as expressed in the 2008 review, that despite growing dependence on imported sources of crude oil and refined petroleum products, adequacy is likely to be maintained to 2020. However, given the increasing contribution of higher cost oil supplies in the future there is likely to be upward pressure on oil prices. If supply capacity constraints emerge during or beyond this period and the cost of liquid fuels from new sources of supply are substantially greater than from conventional oil producing fields, higher petroleum prices and periods of price volatility are likely.

## **Affordability**

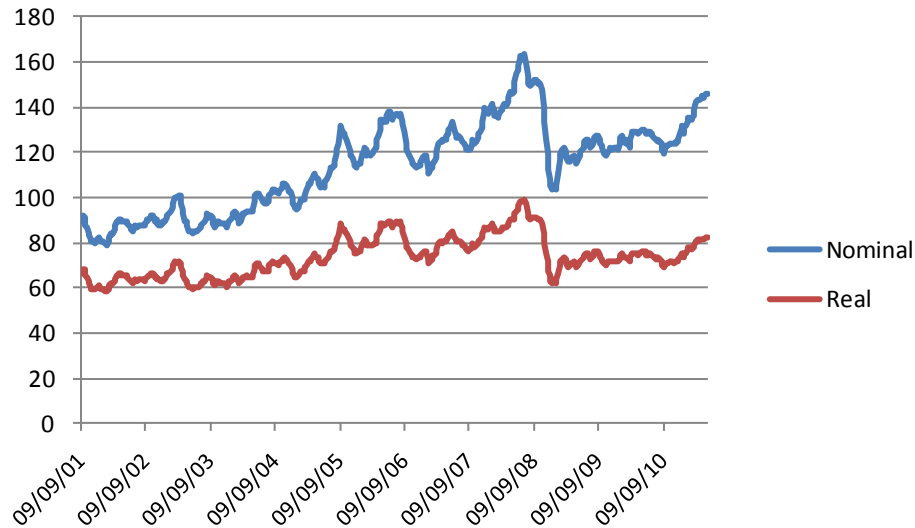
Affordability during periods of disruption, when expressed in terms of international competitiveness, is not expected to deteriorate. However, the impact on affordability will be more significant for some sectors of the economy than others. For example, sectors that are heavily dependent on road transport in particular are likely to be relatively worse off.

Wages in Australia have been increasing at a faster rate than petroleum product prices. From this perspective, the affordability of petroleum fuels has improved.



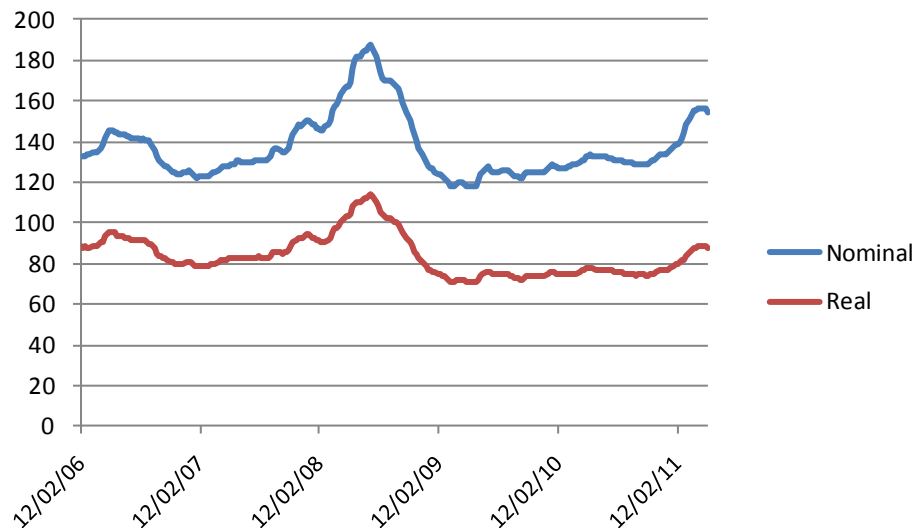
Recent price statistics show that the price of petrol and diesel has not risen dramatically in real terms (as can be seen in Figure ES 5 and Figure ES 6).

Figure ES 5 Real versus nominal price of petrol in Australia, September 2001 to May 2011 (cents per litre)



Data source: AIP, ABS 6401.0 Consumer Price Index

Figure ES 6 Real versus nominal price of diesel in Australia, February 2006 to May 2011 (cents per litre)



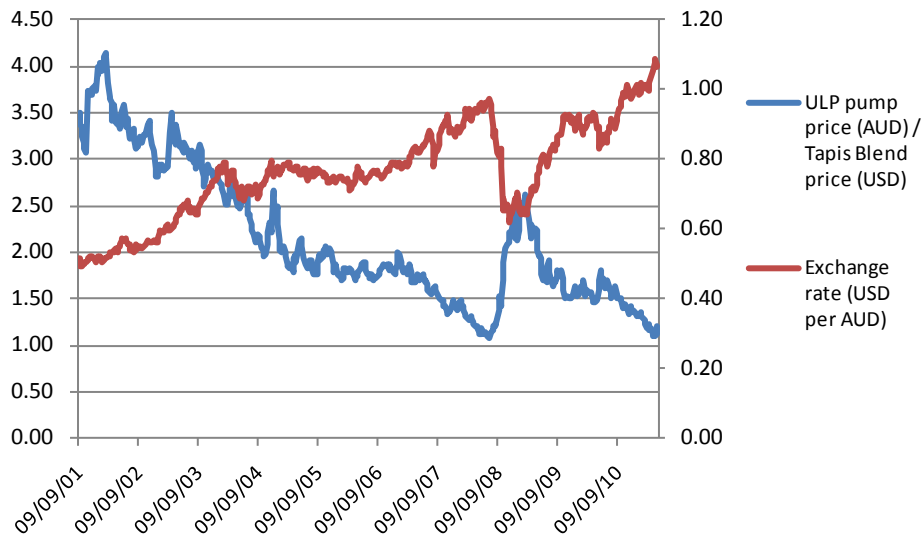
Data source: AIP, ABS 6401.0 Consumer Price Index

The reason for this trend is the impact of Australia's exchange rate on the price of petroleum fuels when prices are expressed in Australian dollars. As the Australian dollar appreciated in value against the US dollar, the pump price of petrol in Australia declined relative to the price of Tapis Blend crude in US dollars (see Figure ES 7)





Figure ES 7 **Ratio of retail petrol price and crude oil price (left axis) versus the exchange rate of the Australian dollar (right axis)**



Data source: AIP, EIA and RBA

Under a scenario of continued demand for Australian minerals and resources in Asia, and corresponding high commodity prices, rising oil prices are not likely to be of fundamental concern for affordability when viewed in terms of maintaining Australia's international competitiveness. This is because a resulting high exchange rate will offset to some extent the price of petroleum products in Australian dollars. However, to the extent that Australia's export industries are more dependent on transport than their competitors, there may be a relative deterioration in competitiveness for those industries.

In most cases, the impact of price spikes during a major disruption such as the Singapore shock is not expected create permanent affordability concerns for most consumers. Nevertheless, any price spike will affect consumers that are heavily dependent on petroleum fuels for transport and have limited access to alternative transport options such as public transport or rail services.

### Implications of growing fuel imports

Growing dependence on imports of petroleum products is not in itself a cause for greater risk of a supply disruption, provided the industry invests in import infrastructure. There is evidence that this is occurring as demand grows.

The potential closure of refinery capacity in Australia will increase imports of petroleum products and reduce the diversity of supply options for the Australian market. This will be offset in the short term by increasing diversity of supply from Asian refineries and the projected ongoing surplus refining capacity in the Asian region.



## **Adequacy of Australian stocks**

With growing net imports, the ratio of stocks to net imports is likely to decline. However this is not considered to be a risk to supply security in the short-term. This is because of the nature of the petroleum market in the Asia-Pacific region, where supply security is reliant on being able to source product from a diverse range of refineries that can meet Australian standards.

The current surplus refining capacity in the region and the fact that a high proportion of cargoes bound for Australia are pre-committed and under contract to Australian buyers provides some confidence that the impacts of a disruption in the short term will be manageable.

If there is any significant decline in excess refining capacity in Asia, there may be a need to look further afield for replacement product in the event of a disruption to supplies. These supplies could take longer to source and transport to Australia and the role of Australian stocks might be more important in moderating price increases. The modelling showed that the price impact of a disruption increased with less spare capacity in the Asia-Pacific Region which resulted in loss in GDP as a result of the hypothetical disruption increasing from \$1,382 million to \$2,210 million.

The current investment plans of the Asian refinery sector suggest that the surplus capacity in the Asian region will continue for many years. This would reduce the economic cost of a disruption. However, noting that investment in new capacity can lag price signals, it is highly likely that there will be cycles when spare capacity will decline before increasing again.

In the longer term, the adequacy of Australian stocks will depend to a significant degree on the structure and operation of the Asian market and in particular the role of the Singapore trading hub. While this structure is not expected to change in the longer term (2020-25), any change would justify a re-evaluation of this conclusion.

Investment in commercial stocks in Australia takes into account a range of factors including shipping logistics, terminal cycles, demand growth, the state of the global and regional product market, and the need to manage unexpected disruptions in imports. Essentially, the key objective of the major commercial fuel suppliers is to reduce the risks and consequences of supply disruptions to an acceptable level, including over the longer term. This involves balancing supply reliability with the cost to consumers. Given that there has been no major disruption to liquid fuels supplies in Australia for decades, as well as Australia's competitive fuel prices by international standards, it would be reasonable to conclude an appropriate balance is being maintained by fuel suppliers.



## Summary of findings

1. There has been no significant change in Australia's liquid fuels vulnerability since the 2008 review. 2020 Adequacy in terms of suppliers being able to keep up with demand has been maintained. This is likely to continue, over the medium term and potentially to 2035 according to the latest IEA World Energy Outlook.
2. The need to develop more remote oil resources or unconventional sources of oil is likely to place upward pressure on prices over the longer term.
3. Australia's growing dependency on oil and petroleum product imports will have limited affordability, reliability and security implications for liquid fuels supply.
4. The market would respond and readjust the supply lines to replace supplies lost in the event of a disruption. Prices would rise and there would be a cost to the economy. However, the impact could be reduced in size and duration in the event of a coordinated response by IEA members designed to increase available supply.
5. Ongoing investment in adequate importing capacity and storage will continue to be important in the future. However, there is sufficient clear evidence of significant recent and planned investments in import capacity to provide confidence that Australia will continue to be able to meet its growing domestic demand for liquid fuels.
6. There are also measures which could improve the monitoring and decision-making surrounding liquid fuels supply, and also contribute to meeting Australia's international stock obligations (see recommendations).

## Recommendations

Given the findings of this vulnerability review it is recommended that:

1. The Government, in consultation with industry, should review the extent and availability of spare crude oil production capacity and spare refining capacity globally and in the Asian region around 2015 to assess whether the assumptions underpinning this vulnerability assessment remain valid.
2. In the light of the importance of industry statistics to ongoing assessment of vulnerability the government should mandate the provision of stocks data through the Australian Petroleum Statistics portal.
3. Responsibility for reporting stocks should remain with the owners of those stocks. Terminal owners should be required to advise importers of their responsibility to report and an annual survey of port authorities should be undertaken to ensure that all new storage is identified by the Department.
4. The Government should communicate its concerns over the calculation methodology to the IEA and seek a review of market arrangements in the Asian region and their impact on the calculation of stocks for Australia.



## 1 Introduction

This report was commissioned by the Department of Resources, Energy and Tourism. It reviews recent assessments of liquid fuels vulnerability undertaken by the Australian Government and others.

Under the terms of the Agreement on an International Energy Program which established the International Energy Agency (IEA) in 1974, the governments of the 28 member countries are committed to undertake joint action in response to oil supply disruptions. At the centre of the emergency response system is the obligation on all member countries to have oil stocks equivalent to at least 90 days of their net oil imports.

Since December 2009, Australia has regularly been in breach of its 90 day stockholding obligations as a member of the International Energy Agency (IEA). The main reason for this has been the increase in net imports of crude oil and petroleum products over the past decade.

Another area of concern has been the accuracy and consistency of the Australian Petroleum Statistics (APS) data which is used to determine Australia's stock position. The Petroleum Statistics Working Group (PSWG) examined the collection and reporting of APS data during 2010 and its recommendations on APS data collection are now being implemented.

In addition, a review of Australia's emergency response measures that was undertaken by the IEA in February 2011 recommended that Australia take action to:

- establish additional emergency oil reserves to ensure that Australia can meet its 90 day stockholding obligation;
- establish a credible mechanism for participation in IEA collective action; and
- establish a mandatory reporting regime for petroleum statistics.

The terms of reference require:

- 1) a broad analysis of current practices around the IEA 90-day stockholding calculation, associated data collection, reporting, maintenance and verification. This will include, but is not limited to, a stocktake of the current data position, an assessment of the accuracy of the data employed and identification of ongoing issues with data quality and coverage that are having an adverse effect on Australia's 90-day calculation. The project will also include recommendations on how current practices can be improved to ensure Australia's petroleum data meets IEA best practice; and
- 2) a review and update of aspects of the Liquid Fuel Vulnerability Assessment (LFVA) 2008, based on the latest available data, with a focus on:
  - a) Australia's vulnerability to a large scale supply disruption;
  - b) current affordability of liquid fuels in Australia; and
  - c) any emerging energy security issues or risks arising in the face of growing liquid fuel imports.



Part 2(a) of the project will include modelling the impacts of an oil shock scenario to be included in the 2011 National Energy Security Assessment.

The full terms of reference are included at Attachment A.

An interim report analysing the 90 day stockholding was delivered in late April 2011. This report updates that document and reports the results for part 2 of the project.



## 2 Vulnerability assessment 2008

In May 2008, ACIL Tasman completed an assessment of Australia's liquid fuels vulnerability to the year 2020. The 2008 assessment extended the vulnerability assessment that was included in the 2004 Energy White Paper.

### 2.1 Findings in 2008

The 2008 review made the following findings:

- Despite a growing dependence on imported sources of oil and refined petroleum products, adequacy in terms of suppliers being able to keep up with demand has generally been maintained. This is likely to continue, although capacity constraints in global oil infrastructure may see continued upward pressure on prices.
- The impact of disruptions in refineries Australia's refineries has increased as higher fuel standards increases the interdependence of refinery units and there is now limited spare capacity in the refining system. This is offset by the ability of the petroleum products market to increase imports during a disruption. However some bottlenecks in import infrastructure were impeding the flexibility to respond in some areas.
- Affordability on an individual and household level had deteriorated while affordability expressed in terms of international competitiveness was not likely to have deteriorated.
- There is unlikely to be a significant constraint on crude oil supplies in the period leading up to 2020.
- Australia will face greater exposure to global crude oil and refined petroleum product markets as the margin between domestic production and domestic demand for both crude oil (from declining domestic production) and refined petroleum products (from increasing domestic demand that outpaces any domestic production expansion) widens over the next 12 years
- Interruptions to supply from domestic refineries or from problems at receiving terminals and pipelines will have a greater impact than in the past due to:
  - less spare capacity resulting in supply interruptions having a greater impact on the market; and
  - replacements of refined petroleum products coming increasingly from imported cargoes rather than diverting cargoes from Australian production, therefore increasing supply chain delays for products by between three to six weeks.
- The major sources of interruption to supplies are more likely to be from:
  - breakdowns at Australian refineries;
  - breakdowns at terminals and associated infrastructure;
  - interruptions to imported crude oil supplies and a possible supply side constraint in the period up to 2015 from a lack of spare capacity rather than a lack of petroleum resources; and



- global problems in crude oil and refined petroleum product markets resulting from natural and/or geopolitical factors.
- Interruptions to global supplies of crude oil and refined petroleum products are likely to lead to price spikes in liquid fuels in the short to medium term.
- The establishment of further refining capacity in the Asian region, such as Reliance Petroleum's mega refinery at Jamnagar in India, will reduce Australia's exposure to interruptions from both world and domestic problems.
- Australia will need more investment in product storage at terminals and associated pipeline infrastructure in response to greater volatility in supplies:
  - to manage commercial and supply risks identified above; and
  - to meet IEA obligations.
- There appears no lack of willingness to invest in new storage capacity for refined petroleum products, however, concerns have been raised in regard to a number of impediments to further investment, such as lengthy and complicated regulatory approval processes, compliance with competition law requirements and land constraints at port locations around the country.
- Alternative liquid fuels to refined petroleum products will not provide material reduction in supply risk management over the period to 2020:
  - LPG will continue to provide a useful complement to petrol as a source of fuel for the passenger vehicle fleet;
  - LNG will probably emerge as a useful complement and alternative to diesel for the heavy duty vehicle fleet leading up to 2020; and
  - Current generation biofuels provide a useful extender of fuel supplies but are limited in their ability to substitute for supplies of conventional.

## 2.2 Approach taken in this report

The terms of reference specifically refer to the need to consider the following factors:

- a) the declining ratio of Australia's stocks to net imports and resulting non-compliance with its 90 day stockholding obligation, assessing whether or not this represents a vulnerability to a large scale supply disruption;
- b) recent high and volatile crude oil prices and whether this has had an effect on the affordability of liquid fuels in Australia; and
- c) Australia's growing liquid fuel imports and any emerging energy security issues and risks arising as a result.

To ensure the independence of advice, the Department also specified that the consultant was free to identify additional high order issues that may have an impact on Australia's liquid fuel security.

ACIL Tasman commenced the analysis by focussing on what had changed since the 2008 assessment, the above issues and what, if any, other relevant issues may have emerged since 2008.



## **3 Australia's current liquid fuels situation**

The 2008 vulnerability assessment drew on Australian Energy Projections to 2029-30 released in 2008 by the then ABARE (ABARE, 2008). For the current work, ACIL Tasman has drawn on the Australian Energy Projections to 2029-30 released in March 2010 by ABARE (ABARE, March 2010). The latter projections include forecasts of liquid fuels self-sufficiency that are higher than was projected in the earlier report. However this is not a result of higher projections of production, instead it reflects more modest estimates of the rate of demand growth.

The following sections review the main changes since the last review.

### **3.1 Supply**

#### **3.1.1 Production of crude oil, condensate and naturally occurring LPG**

The majority of Australia's indigenous production of crude oil, condensate and naturally occurring liquefied petroleum gas (LPG) comes from the Carnarvon Basin, which currently accounts for 72 per cent of total Australian production of naturally occurring petroleum liquids. The mature Gippsland Basin accounts for 24 per cent of total Australian production of naturally occurring petroleum liquids.

Time series of Australian production of crude oil and condensate, by basin, are shown in Table 1 and Table 2.

Australia's crude oil and condensate production has declined by around 1,700 ML or 6 per cent over the period from 2004-05 to 2009-10. One of the largest declines in production was from the Gippsland Basin (around 1,500 ML), which is in line with a trend of declining production in the Gippsland Basin since the mid-1980s. Crude oil and condensate production has also declined in the Cooper- Eromanga Basin in Queensland. The flooding in 2009-10 may have exacerbated the decline in production.





**Table 1 Australian production of crude oil, by basin – 2004-05 to 2009-10**

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
	ML	ML	ML	ML	ML	ML
Adavale	0	0	0	0	0	0
Amadeus	132	53	55	50	55	55
Bonaparte	1,868	1,403	1,470	826	812	1,026
Bowen-Surat	24	23	21	16	19	17
Canning	3	2	2	4	7	7
Carnarvon Barrow Island	448	390	394	364	325	321
Carnarvon North West Shelf	7,859	4,524	5,177	3,799	2,716	2,126
Carnarvon Other	3,831	5,854	7,999	7,817	9,578	9,075
Cooper-Eromanga Qld	529	432	437	512	379	313
Cooper-Eromanga SA	401	489	742	814	1,072	745
Gippsland	4,647	3,681	3,850	3,392	3,922	3,233
Otway	0	0	0	0	0	0
Perth	517	395	816	668	418	320
<b>Total</b>	<b>20,259</b>	<b>17,246</b>	<b>20,963</b>	<b>18,262</b>	<b>19,303</b>	<b>17,238</b>

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

**Table 2 Australian production of condensate, by basin – 2004-05 to 2009-10**

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
	ML	ML	ML	ML	ML	ML
Adavale	0	0	0	0	0	0
Amadeus	0	0	0	0	0	0
Bonaparte	307	394	394	33	0	0
Bowen-Surat	23	20	21	19	21	16
Canning	0	0	0	0	0	0
Carnarvon Barrow Island	120	0	8	0	0	0
Carnarvon North West Shelf	5041	5265	5692	5572	6436	7235
Carnarvon Other	250	202	134	143	44	89
Cooper-Eromanga Qld	270	205	158	81	90	77
Cooper-Eromanga SA	221	208	247	247	216	183
Gippsland	813	770	744	804	738	647
Otway	7	3	2	28	99	86
Perth	1	2	3	2	2	2
<b>Total</b>	<b>7,053</b>	<b>7,069</b>	<b>7,403</b>	<b>6,929</b>	<b>7,646</b>	<b>8,335</b>

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

Production of LPG is shown in Table 3. Total LNG production has declined slightly since 2004-05, although there was a small increase from 2008-9 to 2009-10 to 4096 ML per annum. This is attributable to increased production of LPG from the North West Shelf offsetting a decline in production from the Gippsland Basin.



**Table 3 Australian production of liquefied petroleum gas, by basin – 2004-05 to 2009-10**

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
	ML	ML	ML	ML	ML	ML
Adavale	0	0	0	0	0	0
Amadeus	0	0	0	0	0	0
Bonaparte	0	0	0	0	0	0
Bowen-Surat	24	23	24	24	24	18
Canning	0	0	0	0	0	0
Carnarvon Barrow Island	0	0	0	0	0	0
Carnarvon North West Shelf	1963	2160	2067	1500	1582	1780
Carnarvon Other	0	0	0	0	0	0
Cooper-Eromanga Qld	0	0	0	0	0	0
Cooper-Eromanga SA	663	597	551	557	560	560
Gippsland	1977	1942	1908	1883	1628	1616
Otway	0	0	0	6	136	122
Perth	0	0	0	0	0	0
<b>Total</b>	<b>4,627</b>	<b>4,722</b>	<b>4,550</b>	<b>3,970</b>	<b>3,930</b>	<b>4,096</b>

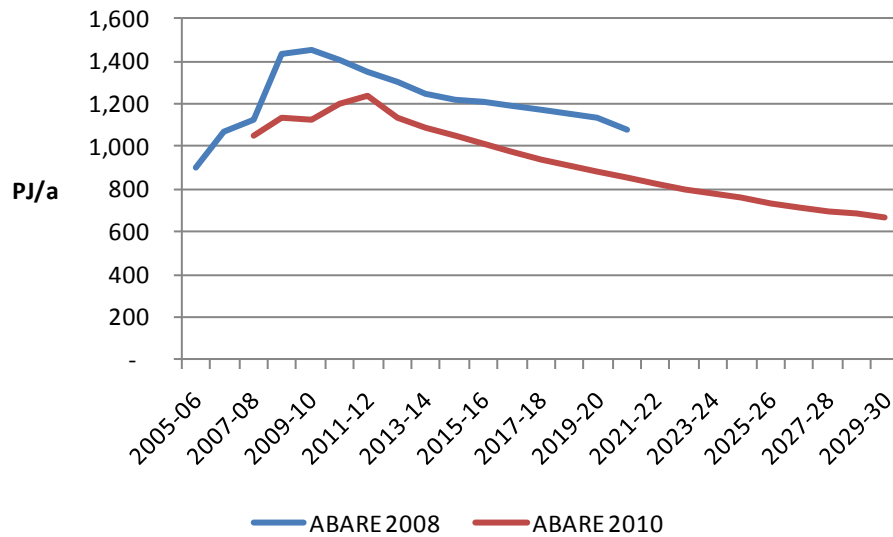
Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

According to ABARES, Australian production of crude oil, condensate and LPG is projected to increase by around 18 per cent from 1,048 PJ in 2007-08 to 1,233 PJ in 2011-12, mainly due to the ramp up of the Pyrenees and Van Gogh fields in the Carnarvon Basin from mid-2010.<sup>2</sup> Production is then projected to decline by around 40 per cent from 1,133 PJ in 2012-13 to 668 PJ in 2029-30, as shown in Figure 1. This decline is driven by a fall in production of crude oil and condensate from 945 PJ in 2007-08 to 425 PJ in 2029-30, which is partially offset by a projected rise in production of LPG from 103 PJ in 2007-08 to 243 PJ in 2029-30.

<sup>2</sup> Note that in 2010 ABARE switched from reporting production in volume terms to reporting in energy terms.



Figure 1 **ABARES projections of Australian production of crude oil, condensate and LPG**



Data source: Syed, Melanie, Thorpe & Penney (2010).

These projections are on average 17 per cent lower than the projections prepared by ABARE in 2008. The lower projections can be attributed to mainly lower projections of production of crude oil, condensate and LPG from the Carnarvon Basin and lower estimates of undiscovered petroleum.

### 3.1.2 Production of petroleum products

Seven major petroleum refineries currently operate in Australia. BP and Caltex have the greatest refining capacities, each with around 32 per cent of total capacity in Australia. The largest petroleum refineries include BP's Kwinana refinery in Western Australia and Caltex's Kurnell refinery in New South Wales.

Table 4 **Refinery production in Australia (2008-09)**

Refinery	ML/a
Bulwer Island - BP Brisbane	5,910
Lytton - Caltex Brisbane	6,300
Clyde - Shell Sydney	4,740
Kurnell - Caltex Sydney	7,810
Altona - Mobil Victoria	4,640
Geelong - Shell Victoria	6,530
Kwinana BP -WA	8,280
Total	44,210

Note: In April 2011, Shell announced that it is considering closing its refinery at Clyde in Sydney.

Data source: (AIP, 2009)



Australia's refineries were generally constructed in the 1950s and 1960s. They were upgraded during the 2005 and 2006 period and are understood to be operating at full capacity. Inquiries made by ACIL Tasman suggest that refinery production could be increased for short periods by around 5 per cent, although this could be subject to relaxation of some specifications, such as allowing higher levels of benzene and olefins in ULP.

On 27 July, Shell announced its decision to stop refining operations at its 79,000 barrel-per-day Clyde Refinery in Sydney, Australia, and convert it and the Gore Bay Terminal into a fuel import facility before mid-2013. The proposal would see the end to refining operations at the site, with Clyde converted to a fuel import terminal to supply the New South Wales market, including the growing western suburbs of Sydney. Australia's refinery capacity would be reduced by around 10 per cent to around 39,470 ML per annum if the Clyde refinery were to close.

A recent time series of Australian production of refined petroleum products, including petrol, diesel, jet fuel, bitumen and LPG, is shown in Table 5. Total annual production of refined products has declined in 2009-10 by around 6 per cent, to 41,893 ML. This was caused by the closure of the Shell refinery at Clyde for around 6 months of that year for maintenance.

Table 5 **Australian production of refined petroleum products**

	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
	ML	ML	ML	ML	ML	ML
Petrol	17,913	16,528	17,732	17,079	17,159	16,771
Automotive diesel oil	12,822	10,154	11,055	12,177	12,231	11,720
Jet fuel	5,325	5,216	5,332	5,182	5,494	5,341
Fuel oil	1,092	1,048	942	979	872	846
Liquefied petroleum gas	995	1,125	1,387	1,515	1,477	1,204
Industrial and marine diesel fuel	22	31	21	3	13	3
Bitumen	1,091	831	1,356	1,452	1,294	690
Lubricants	202	163	146	121	114	74
Aviation gasoline	144	119	119	119	105	104
Heating oil	106	102	86	102	69	35
Other	4,844	5,363	5,475	5,356	5,283	5,105
<b>Total products</b>	<b>44,556</b>	<b>40,680</b>	<b>43,651</b>	<b>44,085</b>	<b>44,111</b>	<b>41,893</b>

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

### 3.1.3 Imports

Australia is a net importer of crude, currently importing around 30 per cent of its refinery feedstock. Imports have increased by around 5 per cent from 26,056 ML in 2004-05 to 27,284 ML in 2009-10, as shown in Table 6.



**Table 6 Australian imports of crude oil and other refinery feedstock**

Source	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
	ML	ML	ML	ML	ML	ML
Indonesia	3,328	3,929	3,391	3,289	3,666	4,178
Malaysia	4,761	3,976	3,730	4,103	4,461	5,319
New Zealand	663	638	635	1,974	2,313	2,569
Other Middle East	158	199	118	43	40	43
Papua New Guinea	1,717	2,386	2,059	2,190	1,349	1,580
Qatar	77	0	106	0	0	0
Saudi Arabia	3,101	1,602	1,151	573	775	478
Singapore	652	830	841	713	555	605
United Arab Emirates	1,917	863	2,971	3,660	2,918	3,846
Vietnam	6,560	6,708	6,677	6,318	5,277	3,904
Other	3,122	3,287	3,665	3,360	2,947	4,762
<b>Total</b>	<b>26,056</b>	<b>24,418</b>	<b>25,344</b>	<b>26,223</b>	<b>24,301</b>	<b>27,284</b>

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

### 3.1.4 Demand

ABARES is projecting that Australian primary energy consumption of crude oil will increase by an average of 1.3 per cent per year, from 2,083 PJ in 2007-08 to 2,787 PJ in 2029-30. This is below the rate of annual growth of 1.6 per cent projected by ABARES in 2007 (see Table 7). The change in the projection is driven by lower expected consumption growth in the manufacturing (including petroleum refining) and transport sectors.

**Table 7 Australian primary energy consumption of petroleum (PJ)**

PJ	ABARES forecast 2010	ABARES forecast 2007
2005-06		2,022
2007-08	2,083	2,083
2011-12		2,274
2019-20		2,528
2029-30	2,787	2,944
<b>Average annual growth 2007-08 to 2029-30</b>	<b>1.3%</b>	<b>1.6%</b>

Data source: Data source: Syed, Melanie, Thorpe & Penney (2010) and Syed, Wilson, Sandu, Cuevas-Cubria, & Clarke (2007)

### 3.1.5 Liquid fuels self sufficiency

Australian refineries produce around 90 per cent of the petrol, 62 per cent of the diesel and 30 per cent of the jet fuel consumed in Australia (See Table 8 ). The level of self sufficiency has been relatively stable for petrol and diesel over the period from 2005-06 to 2009-10. However, the level of self sufficiency for jet fuel has declined by 17 per cent over that period due to a relatively significant increase in demand for jet fuel.



Table 8 Self sufficiency in petrol, automotive diesel oil and jet fuel

Year	Petrol	Diesel	Jet fuel
2005-06	87%	64%	97%
2006-07	92%	65%	91%
2007-08	89%	67%	85%
2008-09	92%	66%	89%
2009-10	90%	62%	80%

Note: Self sufficiency in this table is expressed in volume terms.

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2011)

With the announced closure of the Shell Clyde refinery in New South Wales, Australia's level of self sufficiency in refined petroleum products will drop. However, this will be offset by an increased capacity to import into the Sydney region.

Table 9 shows Australia's level of self sufficiency in refined petroleum products expressed in volume terms. The table shows that in 2009-10 Australia produced 82 per cent of refined petroleum products consumption.

Table 9 Australia's level of self sufficiency in refined petroleum products

	Domestic production of refined petroleum products	Domestic consumption of refined petroleum products	Percentage of domestic consumption satisfied by domestic production
Year	ML	ML	ML
2005-06	40,679	48,234	84%
2006-07	43,652	49,746	88%
2007-08	44,086	50,788	87%
2008-09	44,111	50,614	87%
2009-10	41,892	50,928	82%

Data source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2011)

According to ABARES, Australia's level of self sufficiency in crude oil and other refinery feedstock is projected to fall from 66 per cent in 2009-10 to 41 per cent in 2019-20 and to just 27 per cent in 2029-30 (See Table 10).



**Table 10 Australia’s level of self sufficiency in crude oil and other refinery feedstock**

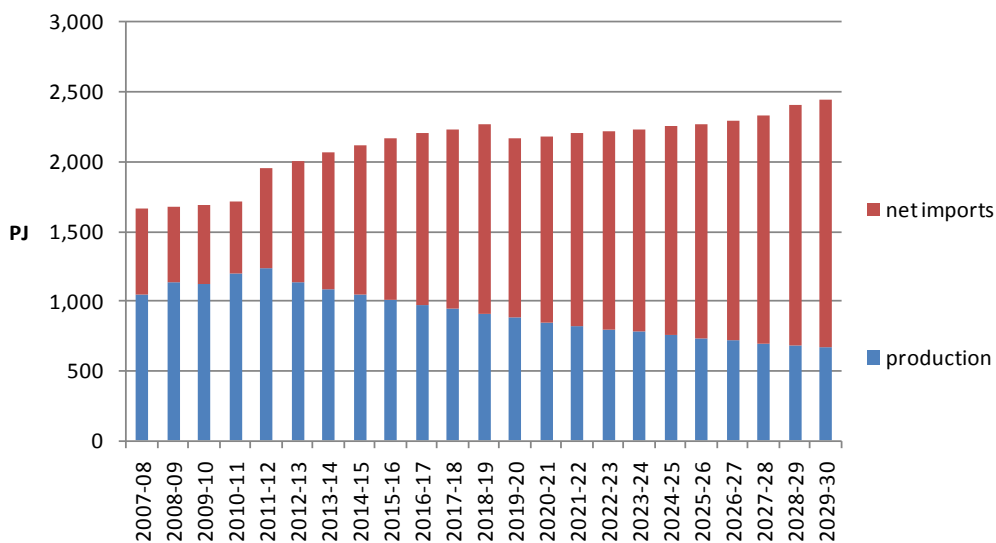
Year	Domestic consumption of crude oil and other refinery feedstock	Domestic production of crude oil and other refinery feedstock	Percentage of domestic consumption satisfied by domestic production
	PJ	PJ	PJ
2007-08	1,667	1,048	63%
2008-09	1,677	1,139	68%
2009-10	1,690	1,121	66%
2010-11	1,718	1,198	70%
2014-15	2,123	1,049	49%
2019-20	2,161	880	41%
2024-25	2,252	756	34%
2029-30	2,443	668	27%

*Note: Self sufficiency is expressed in energy terms in this table.*

*Data source: Syed, Melanie, Thorpe & Penney (2010).*

This declining level of self sufficiency is reflected in Figure 2, which shows the growing gap between domestic supply and demand of crude oil and refinery feedstock.

**Figure 2 Australian crude oil and other refinery feedstock production and net imports**



*Note: Self sufficiency is expressed in energy terms*

*Data source: Syed, Melanie, Thorpe & Penney (2010).*

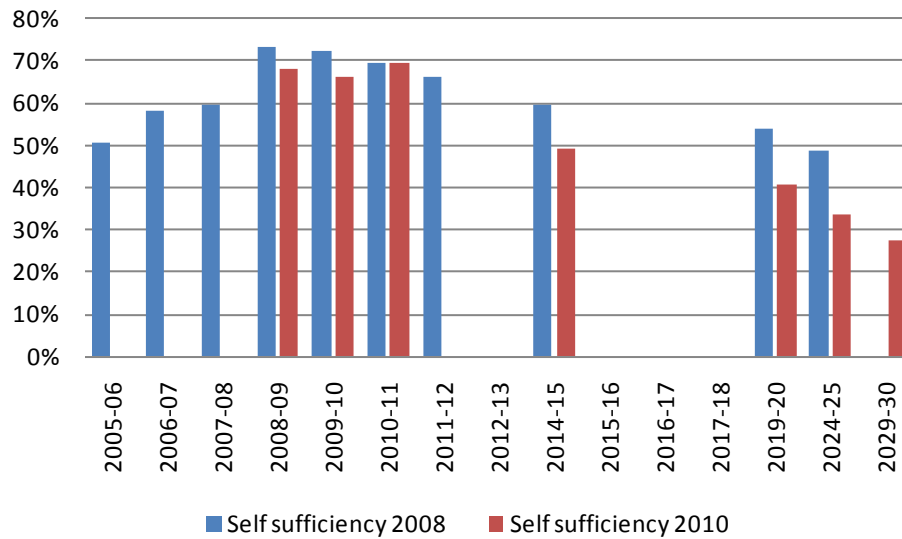
ABARES’ 2010 projections of self sufficiency are lower than the 2008 projections, specifically by:

- around 20 per cent in 2014-15; and
- almost 30 per cent for 2024-25.

This appears largely to be attributable to lower estimates of production of crude oil and condensate in the current forecasts (see Figure 1).



**Figure 3 Self sufficiency in crude oil and other refinery feedstock forecasts 2008 and 2010**



Self sufficiency expressed in energy terms  
Data source: (ABARE, March 2010)(ABARE, 2008)

In energy terms net imports of crude oil and petroleum products are projected to increase from 1,034 PJ in 2007-08 to 2,119 PJ in 2029-30 and average annual increase of 3.3 per cent over the period (Table 11).

**Table 11 Total primary petroleum energy production, consumption and net imports (PJ)**

	Production	Consumption	Net imports	Production to consumption
	PJ	PJ	PJ	
2007-08	1048	2083	1034	50%
2029-30	668	2787	2119	24%
Average annual growth	-2.0%	1.3%	3.3%	

Note: Consumption and imports include the energy value of both petroleum products and refinery feedstock.  
Data source: (ABARE, March 2010)

The percentage of domestic production of petroleum in energy terms to total primary energy consumption was projected to decrease from 50 per cent in 2007-08 to 24 per cent by 2029-30.

It is important from a vulnerability assessment perspective to account for a number of uncertainties in the projections for 2020 and beyond. These include:

- uncertainty with respect to estimates of additional production from existing fields that may become commercial as a result of rising oil prices;
- estimates of yet to be discovered petroleum resources; and
- the impact of petroleum product prices on demand.





Further to this, ABARES' projections do not include estimates of production from non conventional liquid fuels including biofuels, gas-to-oil and other alternative sources of production of liquid fuels.

Nevertheless, the consensus view is that the ratio of Australia's liquid fuels production to demand, expressed in energy terms, is likely to fall over the medium to longer term. This, along with the possible closure of some refining capacity, means that Australia will become increasingly dependent on imported petroleum products in the medium to longer term.



## 4 World oil outlook

### 4.1 Resources and reserves

The IEA reports in its World Energy Outlook 2010 that proven reserves of oil worldwide at the end of 2009 were around 1,354 billion barrels. Around 70 per cent of these reserves are in OPEC. The breakdown of world oil reserves is shown in Table 12.

Table 12 World oil reserves by country as at 1 January 2010

Country	Oil reserves	Per cent of world total
	Billion bbls	%
Saudi Arabia	259.9	19.20
Canada	175.2	12.94
Iran	137.6	10.16
Iraq	115.0	8.50
Kuwait	101.5	7.50
Venezuela	99.4	7.34
United Arab Emirates	97.8	7.22
Russia	60.0	4.43
Libya	44.3	3.27
Nigeria	37.2	2.75
Kazakhstan	30.0	2.22
Qatar	25.4	1.88
China	20.4	1.51
United States	19.2	1.42
Brazil	12.8	0.95
Algeria	12.2	0.90
Mexico	10.4	0.77
Angola	9.5	0.70
Azerbaijan	7.0	0.52
Norway	6.7	0.49
Rest of World	72.2	5.33
World Total	1,353.7	100.00

Data source: Oil and Gas Journal quoted in (IEA, 2010)

This is a marginally higher volume than reported by the IEA in 2008. It is also the highest level of proven reserves ever attained. The IEA notes that reserves have more than doubled since 1980 and have increased by over one third over the past decade. Half of the increase since 2000 is due to revisions in OPEC countries (Iran, Venezuela and Qatar) and half is attributable to Canadian oil sands reserves.



## 4.2 Production capacity

The debate on future production capacity and “Peak Oil” was discussed in some detail in an earlier assessment of Australia’s liquid fuel vulnerability by ACIL Tasman (2008). Strong reservations were expressed regarding the “Peak Oil” thesis that the supply of crude oil will drop rapidly and that this descent will commence soon.

In our earlier report we discussed the arguments put forward by the “Peak Oil” debate. We concluded with the following observation:

While there will be a peak in the world production of crude oil, internationally accepted information from sources such as the IEA, EIA and CERA suggest that this peak is still some decades away and will occur beyond 2020.

In the event that a peak world oil production should occur sooner than is generally predicted, that is in several decades time, then it will most likely result in a dramatic increase in crude oil prices as supply is unable to keep pace with increasing demand. A dramatic and ongoing real increase in the price of crude oil will result in adaptation that will likely manifest itself through four main avenues:

- It should trigger an increase in the technical efficiency of processes using and reliant on liquid fuels.
- It should provide an incentive to a shift to alternative energy sources.
- During the transition process involved in the pursuit of increased technical efficiency and the shift towards alternative energy sources, it should lead to a moderation or short-term contraction in the rate of economic growth.
- It should encourage a transition to a less oil intensive economy. (ACIL Tasman, 2008)

Several recent contributions to the literature on “Peak Oil” have strongly reinforced the view that the propositions of proponents of the concept are based on spurious analysis. For example, Aguilera and others (2009) have substantially upgraded United States Geological Survey estimates of ultimately recoverable petroleum reserves that had earlier cast doubts on propositions of proponents of the “Peak Oil” thesis, while Gordon (2009), Smith (2009), Holland (2008) and Radetzki (2010) have strongly criticised the arguments and logic underpinning the thesis.

In its 2010 outlook, the IEA noted that there are two important aspects that need to be considered in considering the pros and cons of the peak oil debate. The first is the impact of price on demand. In its report the IEA commented:

What is often missing from the debate is the other side of the story — demand — and the key variable in the middle — price. How much capacity is available to produce oil at any given moment depends on past investment. Decisions by oil companies on how much and where to invest are influenced by a host of factors, but one of the most important is price (at least relative to cost). .. In short, if demand rises relative to supply capacity, prices typically rise, bringing forth more investment and an expansion of capacity, albeit usually with a lag of several years.

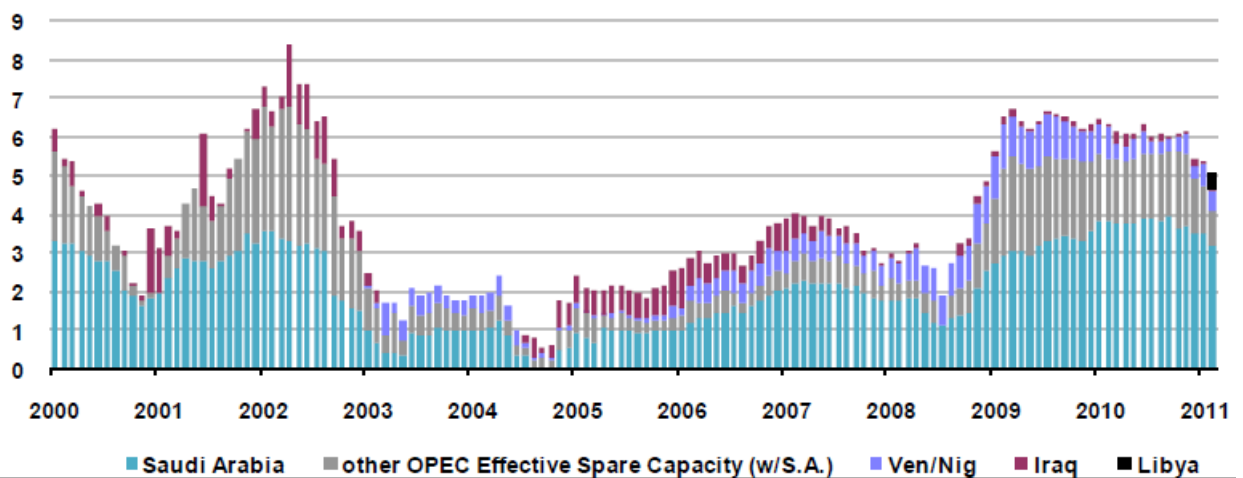
Prior to the Global Financial Crisis the IEA reported constraints in spare production capacity in OPEC. The crisis dampened upstream investment due to lower oil prices and financing difficulties. In its report “Medium Term Oil and Gas Markets 2011”, the IEA notes that



upstream spare capacity and OECD inventories have diminished, reducing supply flexibility (IEA, 2011). Nevertheless the medium term outlook expects that global oil production capacity will rise from 93.8 mbd in 2010 to 100.6 mbd by 2016. The 6.8 mbd increase in supply capacity is expected to arise from equal shares of OPEC, non OPEC and natural gas liquids production. By comparison, global oil demand was 88.0 mbd in 2010 and is projected to rise to 95.3 mbd by 2016.

Spare production capacity in OPEC countries between 2000 and 2011 is shown in Figure 1.

Figure 4 OPEC spare crude oil production capacity



Data source: (Fyfe, March 2011)

The figure shows the cyclical nature of investment by OPEC countries in production capacity and the somewhat volatile levels of spare capacity and their relationship to price and economic events. The spare capacity enabled the market to absorb the loss of around 1mbd of Libyan light, sweet crude in 2011, although this was not without some price impacts.

The IEA outlook also notes that the idea that the amount of recoverable oil is fixed is a misconception:

The amount of oil that was ever in the ground — oil originally in place, to use the industry term — certainly is a fixed quantity, but we have only a fairly vague notion of just how big that number is. But, critically, how much of that volume will eventually prove to be recoverable is also uncertain, as it depends on technology, which will certainly improve, and price, which is likely to rise: the higher the price, the more oil can be recovered profitably. An increase of just 1% in the average recovery factor at existing fields would add more than 80 billion barrels to recoverable resources.

So, the chances are that the volume of resources that prove to be recoverable will be bigger than the mean estimate we use to project production, especially since that estimate does not include all areas of the world. Even if conventional crude oil production does peak in the near future, resources of NGLs and unconventional oil are, in principle, large enough to keep total oil production rising for several decades.

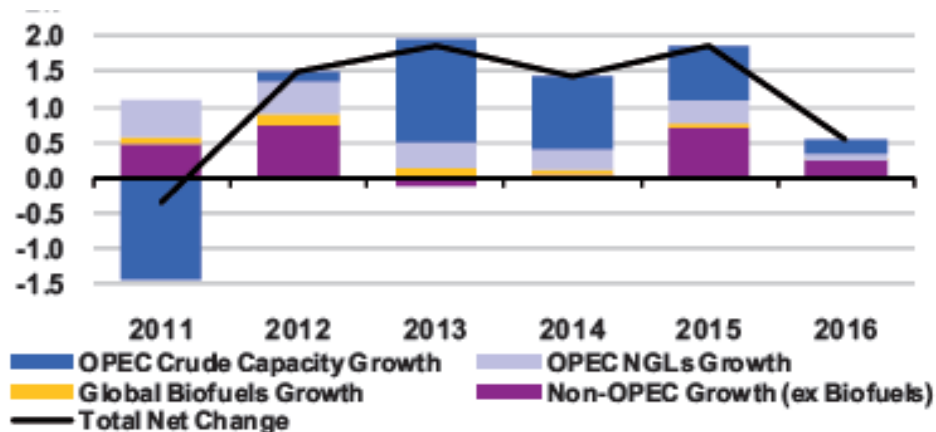


The IEA outlook concludes as we did in our 2008 report, that global oil production will peak one day but that the peak will be determined by factors on both the demand and the supply side. In the IEA scenarios they project a peak in production of conventional crude before 2020 for the New Policies Scenario but after 2035 for the 450 Scenario where policies to address climate change and energy efficiency reduce demand. The Agency concludes:

In the New Policies Scenario, production in total does not peak before 2035, though it comes close to doing so, conventional crude oil production in that scenario holding steady at 68-69 mb/d over the entire projection period and never attaining its all-time peak of 70 mbd in 2006. In other words, if governments put in place the energy and climate policies to which they have committed themselves, as we assume in this scenario, then our analysis suggests that crude oil production has probably already peaked. If governments act vigorously now to encourage more efficient use of oil and the development of alternatives, then demand for oil might begin to ease quite soon and we might see a fairly early peak in oil production. That peak would not be caused by any resource constraint. But if governments do nothing or little more than at present, then demand will continue to increase, the economic burden of oil use will grow, vulnerability to supply disruptions will increase and the global environment will suffer serious damage. The peak in oil production will come then not as an invited guest, but as the spectre at the feast. [(IEA, 2010) p 126].

The most recently available medium term oil market outlook released by the IEA in June 2011 estimates that global oil production capacity is set to rise from 93.8 mbd in 2010 to 100.6 mbd by 2016. The 6.8 mbd increase comes from OPEC, non-OPEC and natural gas liquids in approximately equal shares (IEA, 2011).

Figure 5 World oil supply capacity growth (mbd)



Data source: (IEA, 2011)

These observations do not prompt ACIL Tasman to change its views on the peak oil debate that were expressed in our earlier report. However the discussion highlights the very important interactions between policy responses both on the demand and supply side on the longer term supply and demand outlook. As the IEA notes, under some scenarios oil production could peak because of demand factors rather than resource constraints. The spectre of 'peak oil' should also not be used to panic policy makers into wholesale interventions in the market. It is market responses that will signal to consumers, investors



and producers when and how to respond to the evolving global oil market. This applies as much to longer term supply considerations as it does to short term events that disrupt the market.

Increasingly, it will be policy responses relating to the oil production sector as well as responses to climate change that will influence the timing of a 'peak oil' event. In our view an excessive focus on 'peak oil' would be detrimental to policy formulation over the longer term. With appropriate policies, a peak oil event could pass with little fanfare albeit with a higher oil price and a different energy mix beyond 2030. Vulnerability assessments need to take this into account.

The implications of the peak oil debate for vulnerability are further discussed in section 5.4.3.

### **4.3 Demand and supply scenarios**

The IEA assumes three price projections corresponding to three different scenarios, namely the Current Policies, New Policies and 450 Policy scenarios.

In summary, the Current Policies scenario reflects a no policy change scenario, the New Policies takes into account the commitments countries have already made to policies to mitigate the impacts of climate change and the 450 Policy scenario assumes far stronger policy responses from countries to climate change policies. The assumptions behind these scenarios are described in more detail in Box 1.



**Box 1**      **IEA scenarios**

Three scenarios are presented the IEA 2010 Outlook.

The New Policies Scenario takes account of the broad policy commitments that have already been announced and assumes cautious implementation of national pledges to reduce greenhouse-gas emissions by 2020 and to reform fossil-fuel subsidies.

The Current Policies Scenario (equivalent to the Reference Scenario of past Outlooks) takes into consideration only those policies that had been formally adopted by mid-2010.

The third scenario, the 450 Policies Scenario, assumes implementation of the high-end of national pledges and stronger policies after 2020, including the near-universal removal of fossil-fuel consumption subsidies, with the aim of limiting the concentration of greenhouse gases in the atmosphere to 450 parts per million of CO<sub>2</sub>-equivalent and any global temperature increase to 2° Celsius.

Assumptions about population and economic growth are the same in each scenario. World population is assumed to expand from an estimated 6.7 billion in 2008 to 8.5 billion in 2035, an annual average rate of increase of about 1%. Population growth slows progressively, in line with past trends. The population of non-OECD countries continues to grow most rapidly. Most of the growth occurs in cities. GDP — a key driver of energy demand in all regions — is assumed to grow worldwide by 3.2% per year on average over the period 2008-2035. In general, the non-OECD countries continue to grow fastest. The world economy contracted by 0.6% in 2009, but is expected to rebound by 4.6% in 2010. India, China and the Middle East remain the fastest growing economies.

In the New Policies Scenario, the IEA crude oil import price, a proxy for international prices, is assumed to rise steadily to \$99/barrel (in year-2009 dollars) by 2020 and \$113 by 2035, reflecting rising production costs.

The price rises more rapidly in the Current Policies Scenario, as demand grows more quickly and more slowly in the 450 Policy Scenario, due to lower demand. Natural gas prices are assumed to remain low relative to oil prices in all scenarios, notably in North America, under pressure from abundant supplies of unconventional gas. North American prices nonetheless converge to some degree with prices in Europe and Asia-Pacific over the projection period, as the cost of production climbs. Coal prices rise much less than oil and gas prices, and fall in the 450 Scenario. CO<sub>2</sub> trading becomes more widespread and CO<sub>2</sub> prices rise progressively in the New Policies and 450 Policy Scenarios.

Source: (IEA, 2010)

**4.3.1 Demand**

In the two years since the last assessment was undertaken the IEA has downgraded its 35 year demand forecasts slightly. In its 2008 forecasts it projected world primary oil demand growing from 84.7 mbd in 2008 to 116.3 mbd by 2035 - an average annual growth rate of 1.06 per cent.

In its 2010 projections, the IEA projects primary oil demand to grow from 84.0 mbd in 2009 to 107.4 mbd in 2035 in the current policies scenario - an annual average growth rate of 1 per cent (details of the assumptions behind each scenario are provided in Box 1).

The projections for the three scenarios adopted by the IEA are shown in Table 13.



Table 13 IEA primary oil demand scenarios (mbd)

			New Policies Scenario		Current Policies Scenario		450 Scenario	
	1980	2009	2020	2035	2020	2035	2020	2035
OECD	41.3	41.7	39.8	35.3	40.5	38.7	38.2	28.0
Non-OECD	20.0	35.8	44.1	54.6	45.4	59.4	42.2	46.6
Bunkers**	3.4	6.5	7.5	9.1	7.5	9.3	7.2	7.3
<b>World</b>	<b>64.8</b>	<b>84.0</b>	<b>91.3</b>	<b>99.0</b>	<b>93.5</b>	<b>107.4</b>	<b>87.7</b>	<b>81.0</b>
Share of non-OECD	33%	46%	53%	61%	53%	61%	52%	62%

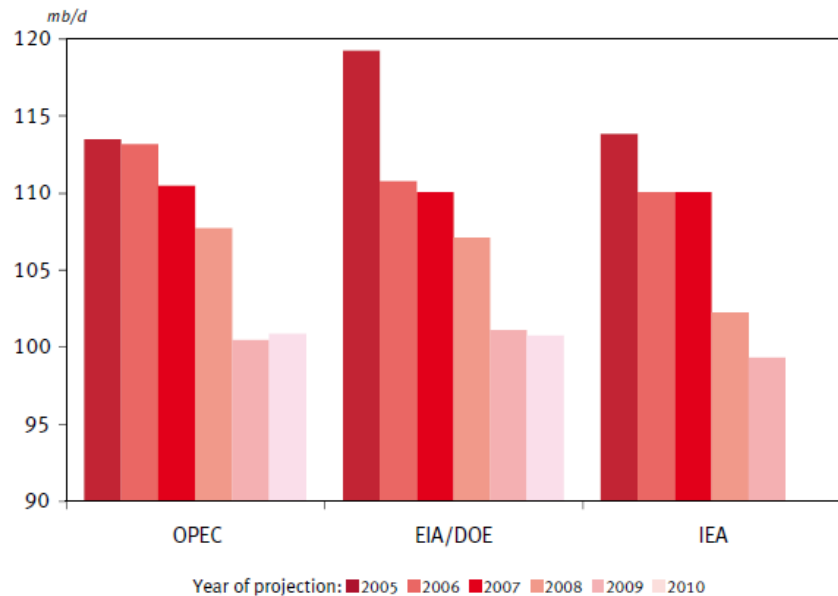
Notes: \* Excludes biofuels demand, which is projected to rise from 1.1mb/d (in energy-equivalent volumes of gasoline and diesel) in 2009 to 2.3 mb/d in 2010 and to 4.4 mb/d in 2035 in the New Policies Scenario.

\*\* Includes international marine and aviation fuel.

Data source: (IEA, 2010)

Over the 5 years between 2005 and 2010, the IEA, the EIA and OPEC reduced their forecasts for demand in 2025 significantly (see Figure 6). There is a growing consensus between the publishers of official forecasts on the level of demand that is likely to occur in 2025 - around 90 mbd to 102 mbd.

Figure 6 Oil demand projections for 2025



Data source: (OPEC, 2010)

### 4.3.2 Supply

The IEA projections for oil production are shown in Table 14. The Current Policies scenario is not dissimilar to the reference scenario assumed by the Energy Information Administration (EIA). The main difference is the in the relative proportion of OPEC production in total production. The IEA assumes around 52 per cent of total production is from OPEC, while the EIA assumes 42 per cent is from OPEC (see Appendix B for the EIA projections).





Table 14 IEA Projections of oil production (millions of barrels per day)

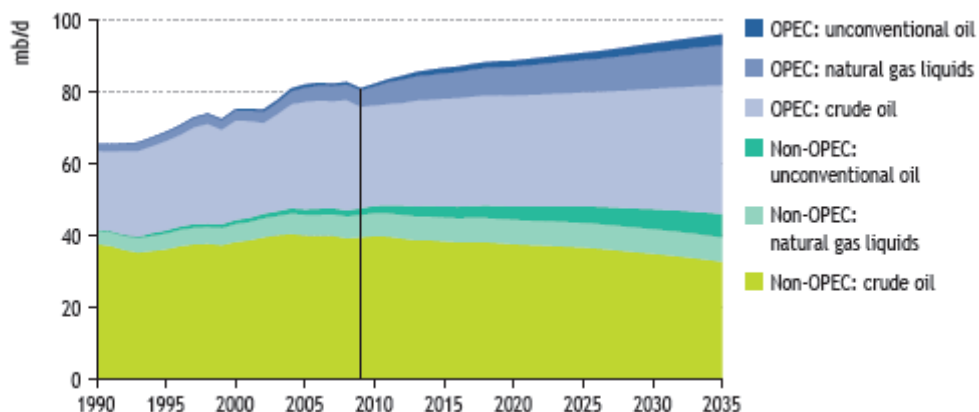
	1980	2009	New Policies Scenario		Current Policies Scenario		450 Scenario	
			2020	2035	2020	2035	2020	2035
OPEC	25.5	33.4	40.5	49.9	41.9	54.2	40.1	41.7
Crude oil	24.7	28.3	30.9	35.8	32.0	38.6	31.4	31.8
Natural gas liquids	0.9	4.6	8.0	11.1	8.2	12.3	7.1	7.6
Unconventional	0.0	0.5	1.6	3.0	1.7	3.2	1.6	2.3
Non-OPEC	37.1	47.7	48.2	46.1	48.9	49.9	45.1	37.6
Crude oil	34.1	39.6	37.6	32.8	38.2	35.0	35.1	25.9
Natural gas liquids	2.8	6.2	6.8	6.8	6.9	7.1	6.5	5.7
Unconventional	0.2	1.8	3.7	6.5	3.9	7.8	3.4	5.1
World production	62.6	81.0	88.7	96.0	90.8	104.1	85.2	78.5
Crude oil	58.8	67.9	68.5	68.5	70.1	73.6	66.5	57.7
Natural gas liquids	3.7	10.8	14.8	17.9	15.1	19.5	13.6	13.3
Unconventional	0.2	2.3	5.4	9.5	5.5	11.0	5.0	7.4
Processing gains	1.2	2.3	2.6	3.0	2.7	3.3	2.5	2.5
World supply	63.8	83.3	91.3	99.0	93.5	107.4	87.7	81.0
World liquids supply	63.9	84.4	93.6	103.4	95.7	110.9	90.3	89.1

Source: (IEA, 2010)

There is a significant difference in the level of conventional crude oil production between the scenarios. In the 450 Policy Scenario for example, production plateaus at 66.5 bbls per annum by 2020 as a result of lower demand, whereas in the Current Policies scenario production increases to 70.1 bbl per annum by 2020 and continues to increase to 73.6 mbls per annum by 2035.

Global liquid fuels production increases in the Current Policies and New Policies scenarios to meet demand. However, there is need for new capacity as production from existing fields in non OPEC nations declines. This is illustrated in Figure 7 for the New Policies Scenario.

Figure 7 World oil production by source - New Policies Scenario in IEA 2010 Outlook



Note: world oil production shown excludes processing gains of around 3 mbd by 2035

Data source: (IEA, 2010)



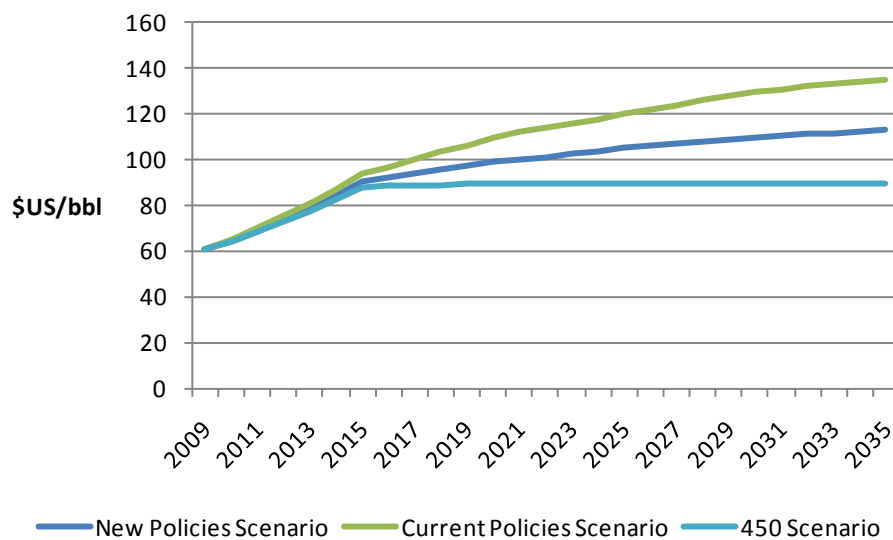
### 4.3.3 Price assumptions

While economic activity is the principle driver of demand, price remains the balancing mechanism between demand and supply. The IEA also argues that price has less of an impact on production of conventional crude oil, as the rate of change in production is largely determined by the decline in output from existing producing fields in non-OPEC countries. This assumption is in our view less relevant to production from new fields, enhanced oil recovery or from non conventional liquid fuels.

Regardless of these points however, the IEA observes that lower prices are expected to be associated with strong climate change responses. While this conclusion might be questioned, it is the range of projections of prices that are of interest from the point of view of the vulnerability assessment.

The IEA assumes three different average crude oil price paths for its scenarios, as shown in Figure 8. In the Current Policies scenarios the IEA assumes that the price of crude rises to \$US 135 per bbl by 2035. In the New Policies Scenario it is assumed that prices rise to \$US 113 per bbl by 2035, whereas in the 450 Policy scenario prices are expected to rise to \$US 90 per bbl by 2035.

Figure 8 Oil price assumptions by IEA (\$US/bbl)



Data source: (IEA, 2010)

This range of prices is far narrower than those assumed for the high, low and medium scenarios explored in the outlook released by the Energy Information Administration.

In its latest outlook the Administration develops three world oil price paths (scenarios):

- Low;
- 'Reference case'; and
- High.



The three price paths are for three distinct scenarios, each reflecting alternative assumptions about the sources and costs of world oil supplies. The Reference case reflects an assumed decision by OPEC members to maintain the organization’s aggregate production at approximately 40 percent of the world liquids supply. To retain that share of world oil supply, OPEC would have to increase production by 12.6 mbd from 2007 to 2035, or about one-half of the projected total increase in world oil supply. Non-OPEC conventional supplies, including production from high-cost projects and from countries with unattractive fiscal or political regimes, account for an increase of 4.8 mbd over the projection, and non-OPEC production of unconventional liquid fuels supplies the remaining 8.4 mbd of the increase (Energy Information Administration, 2011).

The High oil price scenario assumes that several non-OPEC producers further restrict access to, or increase taxes on, production from prospective areas, and that the OPEC members reduce their production substantially below current levels. Oil prices rise above the Reference case levels, dampening demand for liquid fuels and encouraging increased production from those high-cost conventional and unconventional non-OPEC oil resources that still are accessible and attractive for exploration and development.

The Low oil price case assumes greater access to, and more attractive fiscal regimes in, several prospective non-OPEC areas—including Russia and the Caspian region—as well as increased production from OPEC members. Under those conditions, oil prices fall below the Reference case levels, leading to increased demand for liquid fuels and dampening production of conventional and unconventional resources from non-OPEC producers that currently have attractive fiscal regimes but relatively mature or depleted resource bases.

Figure 9 **Figure 32 from IEO2010, World oil prices in three cases, 1980-2035, (2008 dollars per barrel)**



Data source: (Energy Information Administration, 2011)



The range of oil price assumptions assumed by these forecasts is very wide, yet over the past 10 years oil prices have ranged between \$US28 per bbl and \$US140 per bbl. In reality, as the chart in Figure 9 shows, oil prices can be quite volatile from year to year and extremes at each end of the price spectrum cannot be ruled out over the next twenty years.

#### 4.3.4 Changes since 2008

In the 2008 Vulnerability Assessment we noted that there appeared to be sufficient reserves of oil in the world to satisfy demand beyond 2020. This still appears to be the case.

However, we expressed concern that production capacity in the period beyond 2012 would not be sufficient to satisfy demand in the short term without significant price increases arising out of a perceived lack of spare capacity in the system in 2008. Since that time it has become apparent that new investment has come forward following the Global Financial Crisis, which helps increase the capability of the oil supply chain to supply demand at prices within the range experienced over the past five to ten years.

### 4.4 Refinery capacity

Global refinery capacity was around 93 mbd in 2010. According to the 2011 IEA Medium Term Oil and Gas Markets Report, refinery expansion plans are expected to add an additional 9.6 mbd of crude distillation capacity by 2016<sup>3</sup>. Around 95 per cent of these additions are planned in non OECD Asia (Table 15).

Table 15 Global Crude Distillation Capacity (million barrels per day)

	2010	2011	2012	2013	2014	2015	2016	2016-2010
OECD North America	21.5	21.4	21.9	22.0	22.0	22.0	22.0	0.6
OECD Europe	15.9	15.7	15.7	15.7	15.7	15.9	15.9	0.0
OECD Pacific	8.6	8.5	8.6	8.6	8.6	8.6	8.6	0.0
FSU	8.1	8.2	8.5	8.6	8.6	8.7	8.8	0.7
China	9.9	10.0	10.6	11.0	11.4	12.3	13.2	3.3
Other Asia	10.7	11.1	11.5	11.8	11.9	11.9	12.0	1.3
Middle East	7.8	8.0	8.1	8.6	9.0	9.8	10.1	2.3
Other Non-OECD	10.6	10.7	11.0	11.3	11.7	12.0	12.2	1.5
<b>World</b>	<b>93.1</b>	<b>93.5</b>	<b>95.9</b>	<b>97.5</b>	<b>98.8</b>	<b>101.3</b>	<b>102.7</b>	<b>9.6</b>

Data source: (IEA, 2011)

Significant investment in upgrading and desulphurisation capacity are also planned with around 6.9 mbd and 7.3 mbd being added respectively. According to the IEA, the planned additions to capacity are likely to exceed forecast demand growth to 2016. Furthermore, increasing volumes of biofuel, crude for direct combustion, gas and coal to liquids and natural

<sup>3</sup> Crude distillation capacity is often used as an indicator of refining capacity in oil market analysis. Crude distillation separates crude oil into base products such as LPG, petrol, diesel, jet fuel, kerosene and heating oil. Upgrading capacity includes process to upgrade feedstock and earlier products to higher value products. Desulphurisation includes additions to hydrotreating and desulphurisation capacity.



gas liquids will also contribute to meet product demand. The IEA estimates that potential spare refining capacity of up to 4 mbd could arise by 2016.

The IEA notes that product supply balances point to increased tightness in middle distillates by 2016 with demand for diesel, gasoil and kerosene growing strongly.<sup>4</sup>

Petroleum products are traded globally and recent evidence suggests that the world market for petroleum products responds quickly to changes in supply or demand regardless of where these changes occur (see discussion in Section 5.4.4). A temporary supply shortage in one region tends to produce price increases in all regions. Products traded between regions can be redirected in response to temporary shortages in one region, providing there is sufficient spare capacity in the system.

While it is possible for Australian oil companies to source product from as far afield as the Middle East and Scandinavia, from a fuels security perspective, Australian importers source a significant proportion of their products from Asian refineries (this is discussed in more detail in Section 6.3).

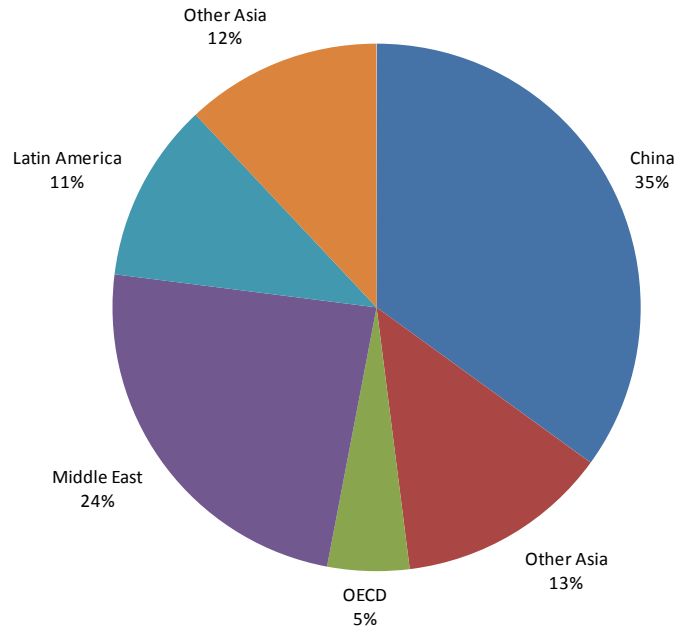
An important feature of the IEA's medium-term outlook for supplies to Australia is therefore the significant increase in refinery capacity in Asia. Expansion in China and other Asian regions comprise around 48 per cent of global refinery expansion.

---

<sup>4</sup> Petroleum products are grouped into three categories: light distillates (LPG, gasoline, naphtha), middle distillates (kerosene, diesel), heavy distillates and residuum (heavy fuel oil, lubricating oils, wax, asphalt). Gasoil is a product generally burned directly in furnaces with a boiling range and viscosity between kerosene and lubricating oil.



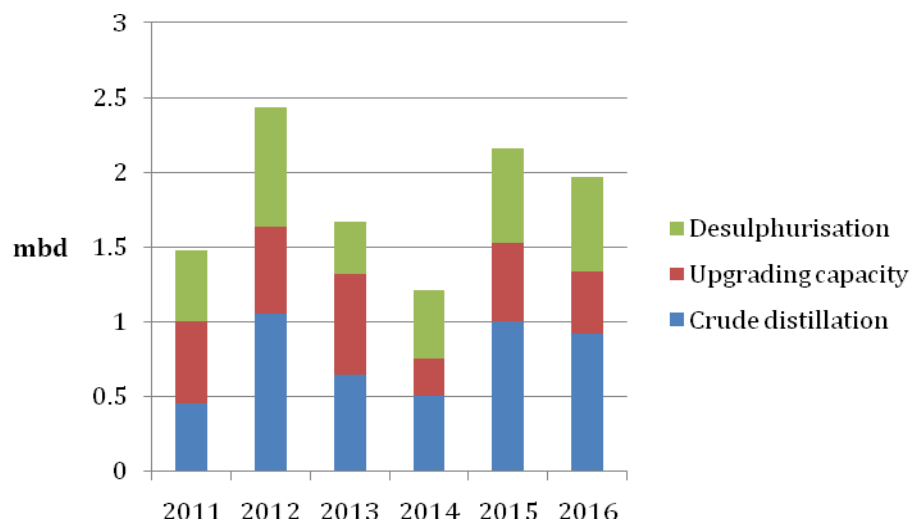
Figure 10 Regional share of expansion in crude distillation capacity



Data source: (IEA, 2011)

The IEA projections include total net additional expansion in crude oil distillation capacity of 4.5 mbd by 2016. Expansions of 3.0 mbd in capacity upgrades and 3.3 mbd in desulphurisation capacity are also projected. Capacity additions in the Asia-Pacific region are shown in Figure 11.

Figure 11 Capacity additions in Asia/Pacific refineries



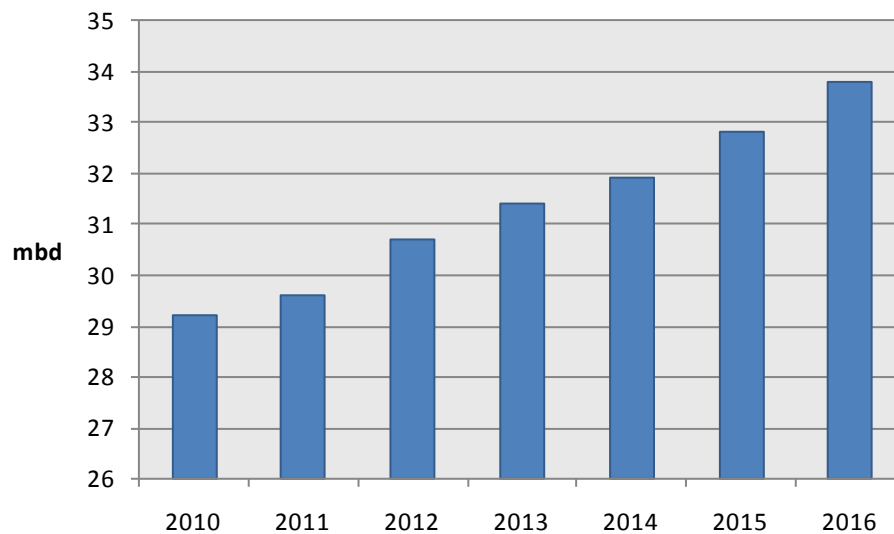
Note: Crude oil distillation separates crude oil into base products such as LPG, petrol, diesel, jet fuel, kerosene and heating oil. Upgrading capacity includes process to upgrade feedstock and earlier products to higher value products. Desulphurisation includes additions to hydrotreating and desulphurisation capacity.

Data source: (IEA, 2011)



Expansion in refineries in the Asia-Pacific region is offset to some extent by closures of older refineries in the region, notably in Japan, China and Australia. Regardless of these closures, the figure shows that the capacity additions are positive in all years, despite a decline in the period from 2012 to 2014, before increasing again in 2015<sup>5</sup>. Total crude distillation capacity for the Asia-Pacific region from the IEA projections is shown in Table 15.

Figure 12 Crude distillation capacity in the Asia-Pacific region



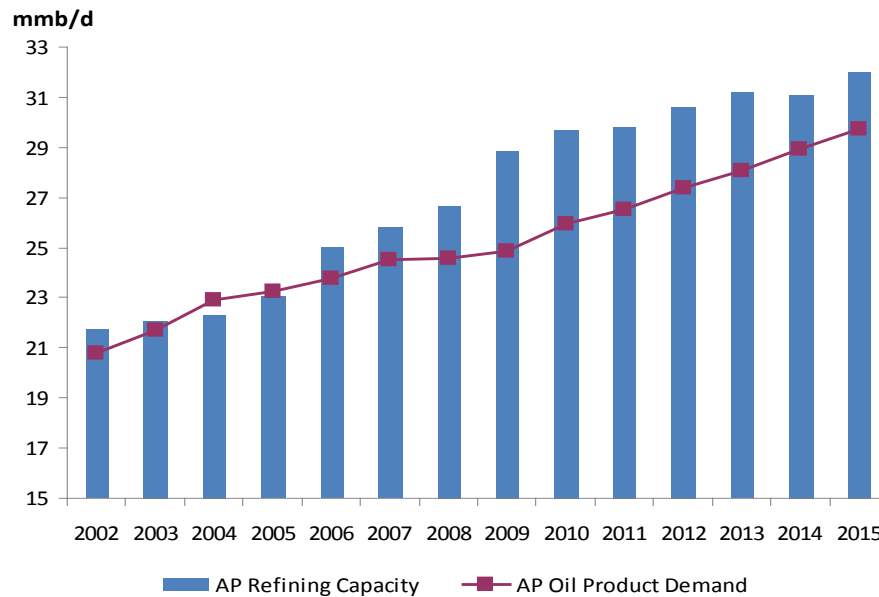
Data source: From Table 15

An analysis of the availability of spare capacity for the Asia-Pacific region has been undertaken by Liutong Zhang of Facts Global Energy in Singapore (Zhang, Jan-Mar 2011). Zhang's provides slightly lower projections for refinery capacity in the Asia-Pacific region than the IEA, possibly as a result of differences in countries included in the region. However, with these lower projections he suggests that significant investment in new capacity over the past five years has created a surplus that is projected to continue (see Figure 13). The surplus capacity in each year will be dependent on the rate of closures of older refineries. On his estimates, the surplus may reduce around 2014 before increasing again in subsequent years. This appears broadly consistent with the IEA's analysis of additional capacity summarised in Figure 11 above.

<sup>5</sup> The Asia-Pacific for this discussion includes China, Japan, India, South Korea, Singapore, Taiwan, Indonesia, Australia, Malaysia, Pakistan, Philippines, Vietnam and New Zealand



Figure 13 Asia-Pacific product demand compared with refining capacity (mbd)



Note: Includes China, South Korea, Japan, India, Singapore, Taiwan, Thailand, Indonesia, Australia, Malaysia, Pakistan, Philippines and Vietnam

Data source: (Zhang, Jan-Mar 2011)

These recent additions to capacity mean that petroleum product supply now exceeds demand in the region. In 2009 and 2010 for example, an additional 3 mbd of refining capacity was added in the region, while demand growth was only 1.4 mbd. Around 8 mbd capacity is expected to be added over the next ten years. Around 64 per cent of the additions will be by national oil companies, while an additional 29 per cent will be semi-government organisations. These organisations include Sinopec, PetroChina, CNOOC and Sinochem in China as well as state owned refiners in India. Some investment is expected to be undertaken in joint venture by other Asian National Oil Companies and with some Middle Eastern national oil companies. Around 76 per cent of the additions will occur in China and 15 per cent in India. India will pass Japan as the second largest refiner in Asia by 2012.

These additions will be offset by some closures in Japan and China. These closures will be mainly older and smaller refineries that are being phased out as larger and more efficient refineries are built in these countries. Likely closures will amount to around 1.4 mbd and be split equally between Japan and China. With these closures and some demand growth, the overall surplus capacity is expected to decline slightly around 2014 but still be significant with new capacity additions.

An issue for Asian refiners is competition from Middle Eastern refineries as they come on line over the next ten year period. Securing crude supplies from the Middle East will be important for them to maintain a competitive product slate.

The Asia-Pacific region is expected to have a surplus of gasoline, diesel and jet fuel. Not all Asian refineries can supply product that meets Australian specifications. However refineries in Japan and Korea and new refineries in India have the capacity to do so. That was not the





case when the 2008 review was undertaken. This has significantly increased the options for Australian importers to source transport fuels for Australia, particularly diesel and jet fuel.

Spare capacity in the Asia-Pacific region provides further confidence that responses to a supply disruption in the Asia-Pacific region will be effective and timely.

#### **4.5 Petroleum markets in Asia**

The past five years has seen an evolution in the operation of markets for petroleum in Asia. This has been driven in part by expansion of refinery capacity in China and India in particular. As noted above, this is very important for the Australian market as it increases the availability of products that meet the Australian specifications for ULP, PULP and 10 ppm diesel. The Asia-Pacific region refineries now have surplus capacity in transport fuels and a deficit in fuel oil.

Singapore plays an important role in trade in crude oil and petroleum products as a marketing hub. Traders in Singapore play an important role in helping the region's refineries sell their surplus products into end markets. There is considerable arbitrage of this surplus into markets in Europe, the USA and South America.

The current surplus in transport fuels in Asian refineries provides opportunities for Australian importers to tap into the arbitrage market for surplus transport fuels. This has important implications for liquid fuels supply security.

Singapore is not a source of crude other than for some crudes cargoes from the Middle East and West Africa, which are discharged from Very Large Crude Carriers (VLCCs) and broken up (ship to ship transfer) onto smaller vessels for shipping to Australian refineries and other small regional refineries which cannot receive VLCC's (2 mbbls). Petroleum products from the region are also transferred and blended in Singapore through local storage and ship to ship transfer.

The markets in Asia differ from those in Europe in important ways. Established markets such as Australia depend more on cargoes that are contracted well before loading and are therefore committed to Australian customers. ACIL Tasman estimates, on the basis of interviews, that spot cargoes make up less than 30 per cent of Australian imports of petroleum products. The percentage for crude imports is probably significantly less than this.

By comparison, trade in crude oil and petroleum products in Europe is characterised by a higher percentage of cargoes that are destined for more than one country and a larger role for the spot market.

#### **4.6 IEA collective response plans**

Under the terms of the Agreement on an International Energy Program which established the International Energy Agency (IEA) in 1974, the governments of the 28 member countries are committed to undertake joint action in response to oil supply disruptions. The IEA regards the



development of collective response capabilities to mitigate the negative impacts of sudden oil supply shocks as being one of its core objectives.

In order to meet this objective, the IEA has developed an emergency response system that is designed to both suppress demand and increase supply in the event of a disruption to oil supplies. If a disruption does occur, there are a number of measures that members can collectively use to mitigate any negative consequences. These include a coordinated drawdown of stock holdings, demand restraint measures, increasing local production and fuel switching (see Figure 14). We note that the capacity to switch fuels in power generation is decreasing as the share of oil used for generation has declined. Similarly, the ability to switch to alternative fuels for transportation is relatively limited, at least in the short term. Consequently, these response measures may have less impact now than they might have had in the past and there is therefore more reliance on stockdraw (see Figure 15).

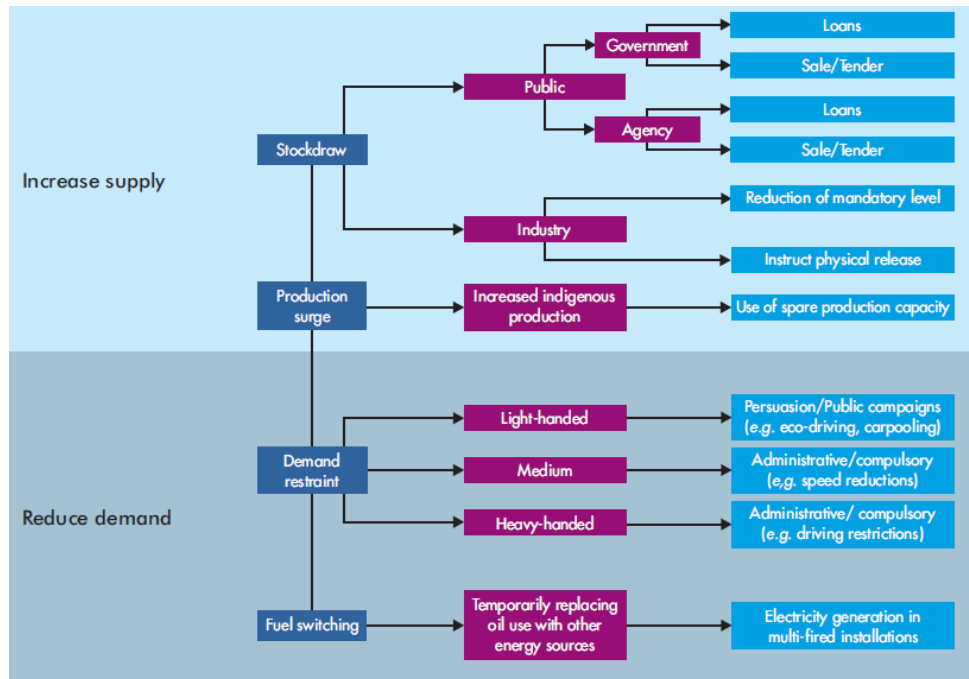
At the centre of the emergency response system is the obligation on all member countries to have oil stocks equivalent to at least 90 days of their net oil imports. The IEA minimum stockholding requirement does not stipulate the composition of oil stocks that must be held, only that the aggregated value of crude oil equivalent stock covers at least 90 days of net imports. Member countries can meet this requirement through holdings of commercial reserves, government emergency reserves, specialised stockholding agencies or minimum stockholding obligations on industry. Most IEA Member countries opt for a mix of commercial and government owned stocks.<sup>6</sup>

---

<sup>6</sup> Australia is currently the only IEA member country (that is not a net exporter of oil) that does place any minimum stockholding requirements on industry.



Figure 14 IEA Emergency Response System



Source: IEA Response System for Oil Supply Emergencies, IEA/OECD, 2011

According to the IEA, as at the end of 2010, total oil stocks in IEA member countries totalled some 4.2 billion barrels.<sup>7</sup>

It is important to note that an increase in oil prices is not in itself a trigger for a collective action. Rather an actual physical supply shortfall is required before any collective response action can be considered. Of course, there will normally be price movements in response to changes in the balance between supply and demand and when a collective response is initiated one of the likely consequences will be changes in the prevailing price.

The IEA describes the sequence of events following a disruption to oil supplies as follows:

- In the event of an actual or potentially severe oil supply disruption, the IEA Directorate of Energy Markets and Security assesses the market impact and the potential need for an IEA co-ordinated response.
- This market assessment includes an estimate of the additional production oil producers can bring to the market quickly, based on consultation with producer governments.
- Based on this assessment, the IEA Executive Director consults with and advises the IEA Governing Board, which is comprised of senior energy officials from member countries who determine the major policy decisions of the IEA. This consultation process to determine the need for an IEA co-ordinated action can be accomplished within 24 hours, if necessary.
- Once a co-ordinated action has been agreed upon, each member country participates by making oil available to the market, according to national circumstances. An individual member country's share

<sup>7</sup> IEA Response System for Oil Supply Emergencies, IEA/OECD, 2011



of the total response is generally proportionate to its share of the IEA member countries' total consumption.

- Throughout this decision-making process and the implementation stage of a decision, industry experts, through the IEA Industry Advisory Board, provide advice and consultation on oil supply/demand and emergency response issues.<sup>8</sup>

As we see from the above, when assessing the need for a co-ordinated response to an oil supply disruption, the IEA considers a number of factors beyond merely the loss of supply caused by an event. Factors such as the expected duration and severity of the oil supply disruption, and the amount of additional oil which might be available to put on the market by producer countries are other important factors.

Since its creation, the IEA has implemented a co-ordinated response to bring additional oil onto the market on three occasions. The first time was in response to the 1991 Gulf War that followed the invasion of Kuwait by Iraq. The second was in response to the hurricanes in the Gulf of Mexico in 2005. On 23 June 2011, the IEA initiated a third collective action in response to the disruption for crude oil exports from Libya. This action is outside the scope of this report.

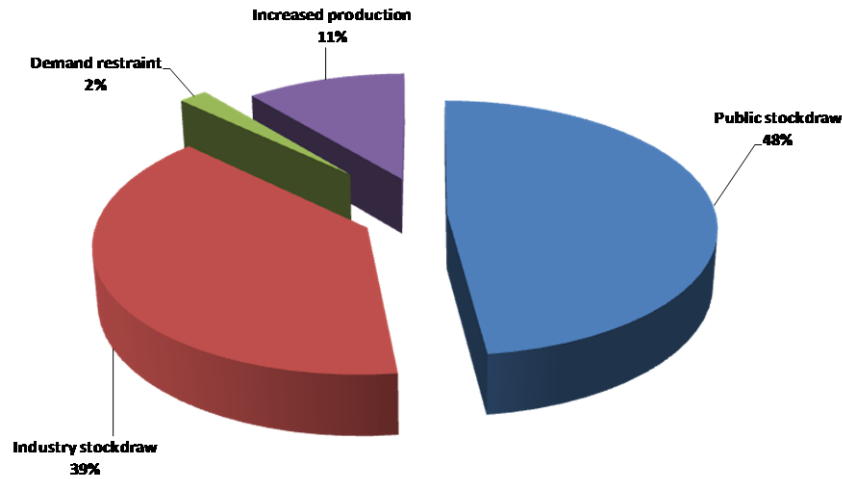
In the latter case, on 2 September 2005, all 26 IEA member countries (the IEA has since expanded) agreed to make available to the market the equivalent of 60 million barrels through a combination of emergency response measures, including the use of emergency stocks, increased indigenous production and demand restraint. The relative contribution of each measure to this effort is shown in Figure 15. We see that public and private stockdraw contributed around 87 per cent of all the additional oil brought into the market.

---

<sup>8</sup> Ibid.



Figure 15 IEA response to hurricanes in the Gulf of Mexico in 2005



Data source: IEA Response System for Oil Supply Emergencies, IEA/OECD, 2011

#### 4.6.1 Maintaining readiness

The IEA uses a number of mechanisms to maintain its members' readiness (as well as its own) to respond to an oil emergency. These mechanisms include:

- *Monitoring the market* - The IEA statistics division collects and provides monthly data on oil supply, demand, balances and stocks for OECD and non-OECD member countries for use by IEA oil market analysts. That analysis is used to prepare the monthly Oil Market Report.
- *Emergency Response Exercises* - Every two years, the IEA carries out a series of workshops and exercises to train and test policies, procedures and personnel. The objective is to review and practice emergency procedures and policies, to ensure all parties are ready to make rapid decisions and act quickly and effectively.
- *Emergency Response Reviews* - IEA member countries' emergency preparedness is peer reviewed every few years. The review team (composed of IEA Secretariat representatives and experts from other member countries) check the individual country's procedures and institutional arrangements and prepare a report with recommendations for discussion with all member countries.
- *IEA emergency stock levels* - Member countries are required to provide a monthly report to the IEA on their stocks of oil. The performance of each IEA member country in meeting the requirement to have a minimum of 90 days of net imports is assessed and reported on the IEA's web site each month.

The current status of Australia's obligation to hold stocks equivalent to 90 days of net oil imports is discussed in section 4.7.



## 4.7 Australia's current level of stocks

The Report for the first component of this project presented the results of a broad analysis of current practices for calculating and reporting the 90 day stock position. It examined current data collection, reporting, maintenance and verification methods and related issues and procedures. It probed the adequacy of the Australian Petroleum Statistics (APS) and examined the processes currently undertaken by ABARES in reporting the APS data to the IEA.

ACIL Tasman concluded that, in the past Australia had easily met its 90 day stock obligations because of the high level of domestic production of petroleum relative to demand. However, declining domestic production of oil coupled with steadily growing demand has changed that situation and Australia has regularly been in breach of its 90 day stock holding obligations since December 2009.

### *Methodology for determining stocks*

ACIL Tasman's audit of the methodology used by ABARES in order to report Australia's monthly stock levels to the IEA found that it was correctly applying the methodology required by the IEA. Using that methodology, and based on the data as reported in the January APS, provides a figure for Australia's stockholdings that is over a week short of the required 90 days.

The first report argued that a number of the standard adjustments that are made to arrive at this figure may not be entirely appropriate in Australia's case. For example, we believe that the standard deduction made by the IEA for naphtha is inappropriate in Australia's case. Removing this deduction would have increased the number of days of stocks held by just over a day and a half.

Similarly, the IEA's calculation of the stock obligation also includes a 10 per cent reduction for unavailable stocks at the bottom of storage tanks. ACIL Tasman believes that there would be merit in carrying out a comprehensive assessment of existing tank technology in use in Australia, as modern tank storage can access a much higher proportion of the contents of the tank. It is possible that a lower reduction may better match the actual circumstances in Australia. Reducing the deduction from 10 per cent to 5 per cent would have added a further 4.6 days of stock holdings in January 2011.

Finally, we considered the IEA's treatment of stocks on the water. At any point in time there will be a considerable amount of Australia controlled stocks on the water being shipped to Australia to refill storage tanks. There will also be movement of stocks between Australian coastal ports. Currently, the IEA definition of eligible stocks excludes stocks on vessels at sea. It does allow stocks on coastal tankers to be included, but it is unclear if they are being accurately recorded at this time.

It is likely to be very difficult to gain the IEA's acceptance that all of the crude oil and product at sea could be counted in Australia's emergency stock calculation. However, ACIL Tasman believes that it would be possible to argue that a proportion of the stock on the water should



be counted, such as the portion that has entered into Australia's exclusive economic zone (EEZ). The proportion could be determined by an annual survey of the average amount of petroleum contracted for delivery to Australia that is within our EEZ at any particular time.

We do not have the information we would need to be able to estimate the impact that a change in approach in the treatment of stocks on the water along the lines of that discussed above might have.

### *Data for determining stocks*

ACIL Tasman also reviewed the data collected through the APS. We identified a number of discrepancies and gaps in that data and concluded that it was likely that stocks are being under-reported. There may also be a possibility of some under- or over-reporting of upstream stocks due to estimation of data<sup>9</sup>. While individually the gaps and discrepancies are not large, collectively they could add a significant number of days of net import coverage.

The most important gaps were:

- stocks held in storage tanks owned by mining companies;
- storage capacity upgrades since the 2008 audit; and
- additional storage capacity under construction as advised by AIP.

Table 16 shows the impact of progressively adding the additional storage capacity identified in these three areas. The explanation for the data shown in the last five columns in the table is as follows:

- Column A – this is the original ABARES calculation.
- Column B – this contains the data in Column A plus the estimated stocks held by mining companies. It also includes estimates of stocks likely to be held at the end of 2011 by independents (i.e. Marstel, Neumann, Kleenheat and Blue Diamond).
- Column C – this includes the data in Column B plus announced storage capacity upgrades since the 2008 audit.
- Column D – this includes the data in Column C plus additional information on construction of further storage capacity provided by AIP in 2011.
- Column E - this includes the data in Column D plus Shell's advice to us on the likely changes to their storage capacity as a consequence of the closure of the Shell refinery at Clyde.<sup>10</sup>

---

<sup>9</sup> The Petroleum Statistics Working Group Final Report released on 1 September 2010 concluded that there were some oil and gas producers that do not report to the APS and some figures are extrapolated from past data.

<sup>10</sup> These changes include the decommissioning of crude oil storage tanks and the construction of additional product storage tanks. Note that some of the increases in product storage capacity were included in the information provided earlier by the AIP. Thus the loss of crude oil storage is the dominant change to the data in Column D, resulting in a two day reduction in days of net import coverage.



In all the above cases we have assumed that the storage tanks are at 50 per cent capacity.

We see from Table 16 that the cumulative net effect of these adjustments is to add approximately three days of net import coverage to Australia's stocks position. However, Australia's estimated stock holdings would still be four days short of the 90 day obligation. If Australia was able to convince the IEA of the merits of the proposed changes to the methodology for calculating stocks in relation to naphtha and tank bottoms as discussed above, then the combined effect of this and addressing the gaps in the data collection would probably bring Australia's stock holdings above 90 days of net oil imports.

ACIL Tasman's view is that even if Australia does manage to increase its stock holdings above the 90 day obligation that outcome is unlikely to persist for long in view of the expected decline in Australia's crude production and increase in product demand.





**Table 16 ABARES' and ACIL Tasman's stockholding calculations (including adjustments)**

		A	B	C	D	E
ktoe						
<b>Net Import Coverage Calculation</b>		Jan-11	Jan-11	Jan-11	Jan-11	Jan-11
<b>Crude Component</b>						
S	Crude Oil Stocks	1831	1831	1831	1831	1753
T	Refinery Feedstock Stocks	548	548	548	548	531
U	Total Crude Oil & Feedstock Stocks	2379	2379	2379	2379	2284
V	Crude, NGL and Feedstock Closing Stocks (U x 0.96)	2284	2284	2284	2284	2193
<b>Product Component</b>						
W	LPG Stocks	222	242	242	242	242
X	Naphtha Stocks	28	28	28	28	28
Y	Motor Gasoline Stocks	600	607	611	611	632
Z	Biogasoline	0	0	0	0	0
AA	Avgas Stocks	18	18	18	18	18
AB	Avtur Stocks	206	207	207	207	235
AC	Other Kerosene Stocks	5	5	5	5	5
AD	Total Diesel Stocks	743	821	930	978	988
AE	Total Fuel Oil Stocks	80	80	80	80	22
AF	Petroleum Coke Stocks	0	0	0	0	0
AG	Other Products Stocks	688	741	741	741	724
AH	Total Products Stocks	2590	2749	2862	2910	2893
AI	Total Products Stocks (AH*1.065)	2758	2928	3048	3099	3081
AJ	Gasoline Closing Stocks (Y+Z+AA)	618	625	629	629	650
AK	Kerosene Closing Stocks (AB+AC)	211	212	212	212	240
AL	Gasoil/Diesel Closing Stocks (AD)	743	821	930	978	988
AM	Residual Fuel Oil Closing Stocks (AE)	80	80	80	80	22
AN	Stocks of 4 Main Product Groups (AJ+AK+AL+AM)	1652	1738	1851	1899	1899
AO	Stocks of 4 Main Product Groups (AN x 1.2)	1982	2085	2221	2278	2279
<b>Total Emergency Reserves</b>						
AP	Method 1 (AI + V) x 0.9	4538	4690	4799	4845	4747
AQ	Method 2 (AO + V) x 0.9	3840	3932	4054	4106	4025
<b>Net Import Coverage (Fixed 12 month calculation)</b>						
AR	Adjusted Daily Net Imports	55	55	55	55	55
AS	Days Current Net Imports Method 1 (AP / AR)	83	85	87	88	86
AT	Days Current Net Imports Method 2 (AQ / AR)	70	72	74	75	73

Note: This table does not include storage of LPG at Kwinana (total capacity around 40 kilo tonnes)

Data source: ACIL Tasman and ABARES analysis of RET data, ACIL Tasman analysis of 2008 Petroleum Import Infrastructure Audit data and data provided by AIP in personal communication



## 4.8 Petroleum statistics

During the course of this work it was found that there were discrepancies in the collection of Australian Petroleum Statistics. The main concerns were:

- incomplete reporting of production and trade;
- some double counting for LPG;
- incomplete reporting of stocks mainly by independents and some LPG; and
- lack of coordination in the collection of some supply and demand statistics leading to duplication in reporting (and some inconsistencies in approach).

ACIL Tasman agrees with the IEA recommendation of the review team that a mandatory reporting mechanism for Australian Petroleum Statistics should be implemented. In this respect, ACIL Tasman notes:

- The administrative demands of mandatory reporting could to some extent be offset by improved coordination of collections.
- Mechanisms need to be put in place to ensure that the administrators of the APS are informed when new terminal capacity is brought into service by independent importers.

We have revised our recommendation in the interim report with respect to allocation of responsibility for reporting stocks to recognise the value of retaining the current arrangement where stocks are reported by their owners. A suitable definition could be along the following lines:

Any 'corporation':

- producing, importing and manufacturing material volumes of crude oil or finished petroleum products (including diesel, petrol, jet fuel, LPG, CNG, LNG, heating oil, fuel oil, lubes etc.), biofuels and biofuel blends, must report fuels data (including stocks and flows) to the APS each month for the stock that the corporation owns and controls;
- storing material volumes of petroleum products and biofuels (e.g. in terminals which they own and/or operate) must also report data to the APS each month for the stock they control or own, and advise the data authority of any changes to the entities using the corporation's storage or terminal facilities.

To ensure that all owners report to the system it would be necessary for the Department to be aware of any new import terminals. We propose that this be done by an annual survey of port authorities of any new terminal construction and requirement that terminal operators advise new importers of the requirement to report stocks.



## **5 Vulnerability to Oil Shocks: New Perspectives Since 2008 Assessment**

### **5.1 Introduction**

The terms of reference required a review and an update of some aspects of a liquid fuels vulnerability assessment for Australia completed in November 2008.<sup>11</sup> The review and update were to include an assessment of Australia's current and projected vulnerability to a large scale disruption of supply of crude oil or refined products, including analysis of a specific hypothetical disruption to supply of refined products from all of Singapore's refineries.

The focus was to be on matters involving noticeably changed circumstances since the 2008 assessment. The terms of reference specifically nominated three matters for investigation (see Attachment A), but advised that those undertaking the assignment could identify other high order issues considered to affect Australia's liquid fuel security or vulnerability to a liquid fuel shock.

This chapter provides a qualitative, high level assessment of Australia's current and projected vulnerability to a large scale disruption of supply of crude oil or refined products. Chapter 6 sets out results of qualitative and quantitative analyses of a specific hypothetical disruption to supply of refined products from all of Singapore's refineries.

Australia's vulnerability to such a large scale liquid fuel supply interruption has been taken to mean its susceptibility to economic harm from the supply shock. In addition, it is important to recognise that some sections of the Australian community may be more susceptible to harm than others. In other words, it is appropriate to consider distributional effects as well as economic effects.

### **5.2 Shocks, Shortages and Market Forces**

Large scale interruptions to supply of crude oil and refined oil products would create fear of shortages and consequent disruption of economic and social activity. These fears would induce responses through markets. Because crude oil and refined products are traded in highly integrated global markets, market responses and effects would be global in scope.

A major supply interruption would induce users of crude oil and refined products that are likely to be affected by the event to bid up prices to ensure that they can obtain supplies from alternative sources of supply in integrated international markets. Existing purchasers from these sources would compete to retain supply. Sellers would seek higher prices for their scarcer supply. Higher prices would reduce demand, effectively rationing available supply. Higher prices would also call forth some additional supply from sources with spare capacity.

---

<sup>11</sup> See ACIL Tasman (2008).



Supply made available in these ways would be reallocated to those prepared to pay higher prices.

If a fear of shortages was caused by a major demand surge, rather than a supply interruption, the responses of market participants would again push up prices. Higher prices again would ration existing supply, call forth some additional supply, and reallocate existing and new supply in accordance with willingness to pay.

Certainly, the history of oil shocks over the past 38 years has not provided any evidence to suggest that crude oil and refined product markets would not swiftly ration and reallocate supply efficiently to avoid shortages. The scale of the price change that is required to clear the market following the initial effect of the shock on supply or demand is discussed in the next sub-section.

The position would change in the event of government intervention to regulate prices for some or all uses. In such a situation, shortages would persist, with scarce supply rationed by queuing or some administrative device. This occurred when the United States Government implemented price controls in response to the 'first oil crisis' in October 1973.

Market-determined prices are far superior at rationing supply and allocating resources efficiently, than queuing and administrative allocation. The market system allocates resources to their highest valued users. Queuing and administrative allocation do not. Queuing is biased towards users with lower time values. Administrative allocation is inefficient because the information requirements for efficient centralised allocation are extremely demanding and arbitrariness is inevitable.

### 5.3 Disproportionate Price Effects of Oil Shocks

#### 5.3.1 Crude Oil

Large scale disruptions to supply of crude oil tend to cause proportionate increases in prices that are much higher than proportionate reductions in supply. Conversely, large supply increases tend to cause price reductions that are proportionately much larger. Shifts in crude oil supply lead to disproportionately large price changes because responsiveness of demand and supply to price movements tends to be extremely low (or inelastic) in the short-term, and still very low compared to most goods and services in the long-term.

In the economics literature, responsiveness of demand to price changes is measured by price elasticity of demand, the proportionate change in quantity demanded divided by the proportionate change in price (a negative number). Responsiveness of supply to price changes is measured by price elasticity of supply, which is calculated as the proportionate change in quantity supplied divided by the proportionate change in price (a positive number).

The importance of very low price elasticities is illustrated by the following. A hypothetical supply shock removing or adding  $S$  per cent of global crude oil production would require a proportionate increase in price of  $\Delta$  to clear the market, eliminating a shortage or surplus



caused by the supply shock at the price applying before the shock. This market-clearing process would be accomplished by a combination of a proportionate change in quantity demanded of  $\Delta \times \mathbf{Ed}$  and a proportionate change in quantity supplied of  $\Delta \times \mathbf{Es}$ , where  $\mathbf{Ed}$  and  $\mathbf{Es}$  represent short-term price elasticity of demand and short-term price elasticity of supply, respectively. The changes in quantity demanded and quantity supplied are in opposite directions. Therefore, the supply shock,  $\mathbf{Ss} = \Delta \times \mathbf{Ed} - \Delta \times \mathbf{Es}$ , and the proportionate change in price,  $\Delta = \mathbf{Ss}/(\mathbf{Ed} - \mathbf{Es})$ .

If the supply shock,  $\mathbf{Ss} = -0.02$  (2 per cent reduction in supply) when  $\mathbf{Ed}$  is  $-0.05$  and  $\mathbf{Es}$  is  $0.05$ , the proportionate change in price,  $\Delta = 0.2$ . So, a 2 per cent reduction in supply leads to a 20 per cent increase in price. Conversely, a supply increase of 2 per cent, with the same values of  $\mathbf{Ed}$  and  $\mathbf{Es}$  leads to a reduction in price 20 per cent. Smith (2008, p. 155) observed that values of  $-0.05$  and  $+0.05$  for short-term price elasticities of demand and supply for crude oil, respectively were indicative of estimates in the economics literature on the crude oil market.

Revising the calculation with the values of  $\mathbf{Ed}$  and  $\mathbf{Es}$  suggested by Kilian and Murphy (2010),  $-0.26$  and  $0.02$ , respectively, indicates a 2 per cent reduction in supply would cause a price increase in excess of 7 per cent.

Price elasticities of demand and supply tend to rise over time as opportunities expand for economic entities to adjust consumption, production, exploration, investment, and research and development in respect of fuel-saving, extraction, and exploration technologies and techniques.

On the demand side, in response to a large fuel price increase resulting from higher crude oil prices, car owners might switch to public transport for trips to and from work and/or reduce discretionary driving in the very short-term. Of course, some individuals will respond sooner and to a greater extent than others. The longer the fuel price increase persists, the greater such responses would be in aggregate. If the large fuel price increase persists, individuals and businesses might switch to vehicles with lower fuel consumption, when vehicles are scheduled for replacement or sooner. They may even seek information and participate in educational programmes showing how fuel can be saved by changing driving and maintenance practices. Manufacturers might increase emphasis on improving fuel economy in planning for their new models. They may accelerate research and development activities focused on better fuel consumption through improvements to internal combustion engines, transmissions, tyres and vehicle mass without loss of safety. In addition, they may accelerate research and development activities in respect of petrol-electric and diesel-electric hybrids, electric vehicles, and hydrogen fuelled vehicles. The longer the large price increase persists, the greater would be the range of opportunities to reduce consumption of liquid petroleum fuels. Therefore, with the passing of time, price elasticity of demand (ignoring the negative sign) increases. That is, demand becomes more elastic.

On the supply side, crude oil production can be increased in the short-term in response to a large price increase only if there is excess production capacity. In addition, there would have to be no effective constraints on utilisation of that excess capacity. Such constraints have been



applied in OPEC countries, particularly in the largest producing OPEC country, Saudi Arabia, for lengthy periods during the past 38 years. This has resulted in crude oil producers elsewhere operating close to capacity.

It takes time and investment to activate increases in crude oil production capacity. With time, various investments can be made to increase the production rate and extent of extraction from producing reservoirs. With more time, other known deposits, which were previously sub-marginal, can be brought into production. In longer time-frames, new deposits can be discovered, assessed, and brought into production, but this could take a decade or more because of various lags in the investment process, even if increased exploration activity yields to relatively early, positive outcomes. Of course, exploration may not produce positive results relatively quickly, because better-than-marginal deposits are scarce and the degree of scarcity increases with the economic surpluses they can yield.

The various lags in the investment process that delay commissioning of new production capacity include lags in:

- perceiving trends and opportunities and deciding to respond
- planning and undertaking exploration programmes
- assessment and investment decision processes
- planning and design activities
- government regulatory processes
- arrangement of funding
- construction and commissioning of projects.<sup>12</sup>

For reasons outlined above, the long-term can be a long time coming, and long-term price elasticity of supply can be expected to be very low, albeit significantly higher than in the short-term.

Extremely low price elasticities of demand (ignoring the sign) and supply in the short-term, and elasticities that are still very low relative to most other goods and service in the long-term are important explanatory factors for pronounced price effects of oil shocks that seem proportionately much larger than the shock to supply or demand.

### **5.3.2 Refined Oil Products**

Price elasticity of demand tends to be very low for refined petroleum products in the short-term, although higher than for crude oil. Price elasticity of demand for products ex-refinery is higher (ignoring the negative sign) than for crude oil, because the crude oil price accounts for only part of the ex-refinery price of refined products. It is higher again at the point of use because the crude oil price is a smaller proportion of the final price of refined products to

---

<sup>12</sup> The significance of such lags in commissioning new extraction capacity was highlighted by Radetzki and others (2008).



users and the latter price is higher than the ex-refinery price because of taxes and distribution and retailing costs and margins.

Price elasticity of demand for refined products tends to rise during the transition from the very short-term to the long-term because opportunities expand for economic entities to adjust their usage of fuel. These opportunities include offerings of vehicles and other equipment that use less fuel by manufacturers seeking to take advantage of fuel-users desire to economise in the expectation of persistence of high prices. Price elasticity of demand for refined products still tends to be low in the long-term compared to most other goods and services.

Price elasticity of supply for refined products in the short-term depends on the existence of spare production capacity. This in turn depends on the level of global economic activity, the amount of capacity available, the short-term availability of suitable crude oil feedstock, the timing of scheduled maintenance, re-scheduling flexibility, occurrences of unscheduled downtime, and inventories.

As time passes, capacity of existing refineries may be expanded and new refineries built, so that price elasticity of supply rises over time. Of course, the rate of increase of supply elasticity over time is limited by lags related to perception, design, planning, investment decision, regulatory, funding, construction, and commissioning requirements and issues. Construction of new refineries in advanced economies has been severely impeded by regulatory processes in some cases.

Low price elasticities of demand (ignoring the sign) and supply in the short-term are important explanatory factors for pronounced short-term price effects of refined oil product shocks that are proportionately much larger than the shock to supply or demand. For example, a supply shock of a 1.5 per cent reduction in global supply of refined products would translate into a market clearing price increase of 10 per cent, using the formula in the previous sub-section, and assuming a short-term price elasticity of demand of  $-0.1$  and a short-term price elasticity of supply of  $0.05$ .

The proportionate short-term price effects of refined product shocks could be expected to be smaller than for equivalent crude oil shocks, because price elasticity of demand would be more elastic or higher (ignoring the negative sign) than for crude oil as explained above, and price elasticity of supply typically would not be any less than for crude oil.

In the long-term, price elasticity of demand and price elasticity of supply could be expected to be higher for refined products than for crude oil. The former would apply because of the gap between crude oil and refined product prices. The latter would result from the scarcity of above-marginal deposits which increases with the economic surplus they can yield.

Short-term price elasticities of demand and supply for refined products are discussed in more detail in sub-sections 6.6 and 6.7.



## 5.4 Types and Causes of Shocks

The economic literature on oil shocks has focused mainly on shocks in the market for crude oil and dates back to the mid-1970s. Relatively little attention has been given to shocks in the market for refined products, and the limited literature available on this topic is recent.

Crude oil shocks appear to have attracted much greater attention than refined product shocks for two reasons. First, there has been a series of high profile events during the 30-year period from 1973 to 2003, which have been associated with crude oil supply disruptions and/or fears of supply loss. Second, the short-term price elasticities of demand and supply of crude oil are extremely low compared to those for most other goods and services and lower than corresponding elasticities for refined products.

Until the last four years, supply shocks attracted much more attention than demand shocks for three reasons. First, supply shocks tended to be associated with high profile or dramatic events. Second, aggregate demand shocks have tended to affect prices gradually, rather than abruptly. Third, oil-specific and refined product-specific demand shocks have tended to be entangled with, and difficult to distinguish from supply shocks and aggregate supply shocks.

### 5.4.1 Crude Oil Shocks

Economic analysis of shocks in the crude oil market was initiated following the severe oil shocks of 1973-74 (the Arab-Israeli war) and 1979-80 (the Iranian revolution, then the Iran-Iraq war) and revitalised as a result of the sharp oil price drop in 1986 (the collapse of OPEC support for the oil price). Interest in the economic effects of oil shocks was renewed by upward spikes in oil prices in 1990-91 (Iraq's invasion of Kuwait), in 2002-03 (the Venezuelan crisis and the Iraq war), although these price movements were much smaller than the price spikes associated with the 1970s oil shocks.

Over the past four years, there has been a significant quantity of new economic literature on crude oil shocks, and there has been a substantial shift in focus. The recent literature has been concerned with:

- causes and effects of the extraordinary rise in oil prices after 2003 and prior to October 2008, the subsequent oil price slump in late-2008, which continued in 2009, and the strong oil price revival in 2010 and 2011;
- distinguishing between types of oil shock and their causes;
- reconsideration of causes of pre-2004 shocks; and
- contrasting of effects of different types of oil shocks and underlying causes.

Lutz Kilian, with and without co-authors (for example, Kilian, 2009a; Kilian, Murphy, 2010) and some other analysts (for example, Dvir, Rogoff, 2010; Baumeister, Peersman, Van Robays, 2010) have explained that crude oil price shocks can arise from:

1. *oil supply shocks* – shocks to physical availability of crude oil;





2. *aggregate demand shocks* – shocks to demand for crude oil arising from changes to global economic activity; and
3. *precautionary or speculative oil-specific demand shocks* – shocks resulting from speculative or precautionary buying or selling of oil in response to “expectations shifts” or changes in perceptions of uncertainty in relation to supply and demand imbalances at prevailing prices.

They have observed that more than one type of shock may exert influence on crude oil prices around the same time. However, different types of shock tend to influence prices with different degrees of rapidity and for different periods of time. In addition, they have explained that different shocks have different economic effects and these can vary greatly between economies in accordance with differences in their industrial structures.

#### 5.4.2 Inventories and the Precautionary Demand Concept

In recent years, the relative importance of the various sources of price shocks in explaining major oil price events over the past 38 years, and the extent to which they have interacted with each other have been keenly scrutinised and debated.<sup>13</sup> The presence and role of precautionary or speculative oil demand shocks and their interaction with other sources of price shocks have been the main sources of controversy, with a central issue being the role played by inventories or stocks.

Changes to speculative or precautionary demand for crude oil refer to buying or selling of oil in response to “expectations shifts”. These shifts involve adjustments to perceptions of uncertainties relating to future supply and demand and consequential future imbalances at prevailing prices.

Increases in speculative or precautionary demand reflect a collective desire to hold larger stocks/inventories of crude oil because of a perceived increase in uncertainty regarding future market conditions or perceived probability of higher prices because of actual or anticipated supply disruptions or other reasons. A positive precautionary demand shock causes an increase in the oil price.

Decreases in speculative demand reflect a collective desire to reduce crude oil inventories because of a perceived reduction in oil market uncertainty or an anticipated increase in the likelihood of lower prices because of changes to supply or demand conditions. A negative precautionary demand shock causes a decrease in the oil price.

Precautionary oil-specific demand shocks are more likely to occur when there has been little spare capacity. Then, an event raising doubts about adequacy of supply at current prices is more likely to induce precautionary buying. Conversely, an event relieving concerns about

---

<sup>13</sup> For example, see Kilian, 2008c, 2009a,b; Hamilton, 2009a, b; Smith, 2009a; Dvir, Rogoff, 2010; Kilian, Murphy, 2010; Balke, Brown, Yücel, 2010; Baumeister, Peersman, Van Robays, 2010.



supply adequacy at current prices is more likely to result in an unwinding of any build-up of stocks for precautionary purposes in the context of earlier lack of spare capacity.

When negative supply shocks and increases in precautionary demand overlap with each other, the inventory effects of these shocks tend to work in opposite directions, while the price effects tend to be in the same direction. The same applies when positive supply shocks and precautionary demand reductions overlap. The net change in inventories in the event of overlapping shocks can be up or down and it can change over time.

The behaviour of inventories is the key to the presence and importance of precautionary demand shocks (Hamilton, 2009a,b; Dvir, Rogoff, 2010; Kilian and Murphy, 2010). However, different interpretations of historical behaviour of inventories have been used in support of, and against the precautionary demand concept.

Hamilton (2009a,b) claimed that inventory movements tended to moderate price shifts following shocks, rather than exacerbate them. He also argued that historical inventory movements did not support the existence of precautionary demand shocks.

The main purpose of inventories is to mitigate shocks. If an upward demand or downward supply shock effect applies to a commodity, its price rises. If the shock and price rise are perceived to be short-lived, stocks of the commodity are run down at the higher price to be replenished at the “normal”, lower price later. In effect, stocks of the commodity are transferred from a time of adequacy to a time of shortage. If a downward demand or upward supply shock is perceived to be temporary, inventories would build up, effectively transferring commodity stocks from a time of surplus and relatively low price to a time of “normal” adequacy and price. Therefore, inventory movements tend to moderate price shifts from temporary demand or supply shocks.

Dvir and Rogoff (2010) explained that this behavioural pattern was dependent on the shock being perceived to be temporary and supply not being restricted. The importance of these conditions can be illustrated as follows.

When an upward aggregate demand shock occurs, existing and potential market participants would be caught between two contradictory forces. The reduction in relative availability and rise in price of the commodity following the shock would indicate an inventory run-down in the short-term, to the extent the shock is temporary. However, if it is thought the aggregate demand shock could persist or there could be a series of such shocks, and if supply is restricted, the expectation or fear of continuation of high or rising prices would induce higher or rising demand for inventories. If enough market participants anticipate that the aggregate demand shock or series of shocks is likely to persist, and that supply restrictions would continue, the influence of stock-building would dominate the tendency to run-down inventories. Then, the net speculative demand influence would add to the effects of shocks on price.

The supply restriction condition should not be overlooked. To the extent that supply was perceived to be flexible, the expectation or fear of high or rising future prices would be



moderated, reducing demand for inventories and the exacerbation of the effects of shocks on price via the influence of speculative demand. Dvir and Rogoff (2010) highlighted the importance of concurrence and interaction of shocks. Moreover, they emphasised the role of persistent artificial supply constraints, such as OPEC's restrictions on production capacity. Supply shocks are not confined to occasional events associated with wars, civil unrest, and natural disasters.

Adelman (1995) stressed the importance of precautionary/speculative demand shocks in the context of supply side constraints and threats of such constraints by Middle Eastern oil producing countries at the time of the 'first and second oil crises'. He also explained how these shocks interacted. Indeed, he argued that Middle Eastern producing countries deliberately encouraged precautionary/speculative demand and then exploited that demand shock to raise their production-linked taxes and official prices to sustain prices caused by precautionary/speculative demand at new, higher levels.

Kilian and co-authors have discussed in depth the role of precautionary demand effects in the context of various aggregate demand and supply shock events in specific periods ranging from a year or two to five years since 1972. However, they have not focussed on the role of prolonged periods of production capacity constraint by OPEC members as either a persistent supply shock or a contextual matter from 1973 to the present time.

Because of controversy regarding the implications of inventory movements for identification of causes of oil price shocks, Kilian and Murphy (2010) formulated a structural vector autoregressive (VAR) model of the global crude oil market that for the first time explicitly included a role for shocks to oil inventories or stocks, in addition to roles for shocks to demand and supply (flows) in the market for crude oil.

The model allowed for negative oil supply shocks or supply disruptions (flow supply shocks) to cause the draw-down of inventories to smooth consumption of refined products, as well as for the price of oil to rise in response to the supply reduction. It also allowed for reverse outcomes from positive oil supply shocks.

The model also allowed for precautionary or speculative oil demand to rise in response to a supply disruption (negative supply event) and consequent price rise, for the purpose of building inventories. This could be pursued by attempting to re-build above ground stocks, including storage in tankers at sea, or by leaving oil below ground in anticipation of price increases (Frankel, Rose, 2010; Kilian, Murphy, 2010).

Symmetrically, the model allowed for precautionary or speculative demand to fall to reduce crude oil stocks following a positive supply event and consequent price fall. Again, the inventory effects of the supply event and the change in precautionary demand are in opposite directions, the price effects are in the same direction, and the net change in inventories could be up or down and vary over time.



The model also allowed for aggregate demand shocks (a shock to flows) to raise or lower the price of crude oil, depending on the direction of the shift in the level of economic activity. It allowed for a lagged draw-down of inventories and then a build-up to support higher usage.

In addition, the model allowed for the existence of a residual shock that could include weather shocks, unexpected changes to strategic reserves, and changes to companies' inventory technologies or preferences for inventories.

Kilian and Murphy (2010) used the model to disaggregate or decompose movements in the real oil price and oil inventories from June 1978 to August 2009. Intuitive explanations of model results for oil market shocks during this period of 31 years have been outlined, along with contextual information on each shock, in the next sub-section. For completeness, the concepts have also been applied to explain the roles of various types of shock in the 'first oil crisis' in 1973-74.

### **5.4.3 Historical Crude Oil Shocks**

There are several high profile examples of major oil shocks over the past 38 years. Analysis of the circumstances reveals how different types of oil shock may combine to influence prices or may act in isolation on some occasions. Historically, combinations of different types of oil shock appear to have been the most common occurrence.

#### ***1973-74: Arab-Israeli War and Repudiation of Government-Company Agreements***

During the "first oil crisis" of 1973-74, the nominal price of crude oil quadrupled and the real price more than tripled in a period of a few months. For many years thereafter, it was common for commentators to attribute this price shock to production cuts by Middle Eastern producers and an oil embargo against the United States and some other countries following the Arab-Israeli (Yom Kippur) war in October 1973. This perception was buttressed by data showing a drop in production, as well as the spectacular price increase. However, important circumstances were overlooked in forming this view. In 1972, prices of other mined commodities surged in real terms in response to strong growth of global aggregate demand. Crude oil prices did not experience similar growth. The existence of substantial excess supply of crude oil was one reason. Another constraint was the 5-year Tehran/Tripoli agreements between oil companies and Middle Eastern producing countries, which provided a moderate improvement in government receipts per barrel of crude oil extracted in exchange for assurances that governments would allow oil companies to extract as much oil as they saw fit. Nevertheless, nominal crude oil prices rose faster than provided under the agreements, because governments increased their take through taxes effectively linked to quantity produced and took part ownership of production or "participation" (Adelman, 1995). However, the nominal crude oil price increases were more than offset by rising inflation and,



in the case of prices denominated in United States dollars, by depreciation of that currency (Kilian, 2008b, 2010c; Radetzki, 2006, 2008).<sup>14</sup>

With demand for petroleum products and therefore crude oil growing strongly in response to the strong growth of global economic activity, oil companies expanded oil production from spare capacity with moderate increases in payments per barrel to host governments. By the beginning of 1973, many Middle Eastern countries were producing at levels close to nominal capacity, with the exception of Saudi Arabia. Output from Saudi Arabia increased further in early 1974 (Adelman, 1995; Kilian, 2008b).

While consumption of crude oil continued to grow in 1973, the rate of growth slowed. However, growth of demand remained strong because of inventory building to avoid anticipated increases in the government take through higher taxation and “participation”. This build-up of inventories extended beyond crude oil to refined products. As demands from Middle Eastern countries for higher “takes” from taxation and “participation” increased during 1973, fear of higher government “takes” and consequent higher prices caused increased precautionary/speculative demand for inventories of crude oil and refined products. This led to higher prices, which were followed by concerted increases in government “takes”, which then supported prices at higher levels. The Tehran/Tripoli agreements had been effectively repudiated before the Arab-Israeli war in October 1973 (Adelman, 1995).

The Arab-Israeli War commenced on 6 October 1973. On 17 October 1973, the Organisation of Arab Petroleum Exporting Countries (OAPEC) agreed on production cuts of 5 per cent per month, commencing immediately and continuing until Israel withdrew completely from Arab land occupied in June 1967, particularly Jerusalem, and restored legal rights of Palestinian people. A few days later, Saudi Arabia and Kuwait applied larger cuts. OAPEC also announced an embargo against the United States and the Netherlands, and reduced shipments to some other countries (Adelman, 1995). The pattern of ratcheting-up crude oil prices, which was established before the war, continued during the remainder of 2003. The announcements regarding production cuts created fear, inducing precautionary/speculative demand, which drove up the price. The floor price was set by the tax “take”, which was nearly doubled on 16 October and more than doubled from the 16 October level in late December 1973. Morris Adelman’s description of the mechanism in the period October-December 1973 has been reproduced in Box 2.

On 4 December, Saudi Arabia announced, without explanation, cancellation of the additional production cut of 5 per cent scheduled for the month. By mid-December 1973, it was becoming clear that production shortfalls were not as severe as had been feared (Adelman, 1995). The reduction in the global production rate during the period October 1973 to March

---

<sup>14</sup> Radetzki (2006, 2008) pointed out that the acceleration of inflation was not caused solely by strongly growing aggregate demand. The boom in commodity prices had been preceded by two consecutive years of widespread crop failures.



1974 was 4 per cent. The real crude oil price increase approached 200 per cent (Hamilton, 2009b). The peak output reduction by OPEC countries was about 2.67 mbd in November and December 1973. In January and February 1974, the size of the output reduction compared to pre-October 1973 shrank to 0.8 mbd and 0.57 mbd, respectively (Kilian 2008b).

## Box 2

**Role of Precautionary/Speculative Demand and Taxes in 'First Oil crisis'**

"Over the three months October through December, total lost output was about 340 million barrels, which was less than the inventory build-up earlier in the year. Considering as well some additional output from other parts of the world, there was never any shortfall in supply. It was not loss of supply but fear of possible loss that drove up the price. Nobody knew how long the cutback would last or how much worse it would get. Additional cuts were scheduled.

Precautionary demand was driven by the fear of death. Oil might be only a small fraction of a buyer's total cost of operation, but without it, a factory, or a power plant, or a truck fleet would stop dead. The loss was so great that it paid to take out expensive insurance against even a minor probability. Panic aside, it made sense for refiners and users to pay outlandish prices for oil they did not need.

Speculative demand included those seeing a quick turnover profit or crude oil buyers trying to buy sooner rather than later. But an additional factor may have been even more important: oil product prices were largely controlled by contract or government. Every buyer and seller at the much lower mainstream prices knew that if the production cuts continued, those prices would also rise. Moreover, OPEC had nearly doubled the per barrel tax in October and would again.

Thus, buyers and sellers could hold crude oil or products with little downside price risk. Their increased demand raised prices all the more. "The spot crude oil market dropped dead last week ... as sellers decided to hang on to every barrel." [Petroleum Intelligence Weekly Special Report, October 1990]. Those with stocks of oil or products sold as little as possible. Some sought to buy for an immediate resale gain, others to hold for higher prices soon. Thus the effects were out of all proportion to a loss of at most 9 percent for a month.

Not the amount of cutback or 'shortfall' but the fear of dearth did the damage."

Source: Adelman, 1995, pp. 110, 112.

By mid-January 1974, crude oil was in substantial excess supply. If crude prices had been ruled by supply and demand in a competitive market, the price surge of 1973 would have been reversed. However, the market was not competitive, the OPEC countries collectively had substantial market power and they exercised it to raise prices further, with surplus capacity also growing. By August 1974, surplus capacity in OPEC countries had risen to about 20 per cent. During 1974, the relevant governments raised their "take" through tax and "participation" arrangements by more than 50 per cent. The governments raised their taxes and sales prices of their "participation" oil in concert and generally refrained from offering lower prices to sell more oil. This raised contract prices. Meanwhile, open market crude oil and refined product prices typically rose through precautionary/speculative demand in anticipation of the government action pushing up official prices. By the end of 1974, crude oil and product storage tanks everywhere were full. With prices set in these ways, the market determined quantity demanded, and production was adjusted to match that quantity (Adelman, 1995).

Analysis of the circumstances of the 1973-74 oil crisis has revealed that the price spike was attributable not just to an oil supply shock. Two other types of shock also played roles.



Specifically, aggregate demand and oil-specific precautionary demand shocks also contributed to the price spike. In addition, the nature of the supply side shock was more complicated than just loss of production.

Kilian (2008b, 2010c) argued that a comparison of the spike in the oil price and the earlier spike in prices of other mined commodities suggested that up to 75 per cent of the increase in the real price of crude oil could be explained solely by strong growth of demand for crude oil driven by growth of global economic activity. Moreover, analysis of the change in supply indicated that less than 25 per cent, and probably only about 20 per cent of the oil price spike could be attributable to an oil supply shock, leaving 75 per cent to 80 per cent of the price spike to be explained by growth of aggregate demand and oil-specific precautionary demand (Kilian, 2008b; 2010c).

Radetzki (2006, 2008) perceived contributions from aggregate demand, precautionary demand and supply shocks to the spike in crude oil prices in 1973-74. He pointed out that crude oil prices rose much more than other mined commodity prices. He attributed this to the supply management actions of OPEC, large sales of metals from the United States Government's strategic stockpiles between mid-1973 and mid-1974, and sales in late-1974 of excess stocks of metals held by Japanese companies. Radetzki was not as definitive as Kilian on relative contributions of different types of shock to the crude oil price spike.

Hamilton (2009b) acknowledged that an aggregate demand shock contributed to the crude oil price spike, but considered the supply shock to be more important. He doubted that precautionary demand contributed to the spike because inventories of crude oil and refined products declined for 3-4 months from October 1973. He argued that if precautionary or speculative buying had been occurring, it should have been evidenced by a build-up of inventories.

However, this does not indicate the absence of a significant precautionary or speculative demand shock. The initial decline in inventories may simply mean the expected run-down in inventories in response to the supply shock outweighed the influence of precautionary demand for 3-4 months. The later build-up of inventories to levels above those prevailing before the shock is consistent with the existence of a precautionary demand shock. This view is consistent with the analysis of Dvir and Rogoff (2010).

In any event, Morris Adelman explained that there was a substantial build-up of inventories from the beginning of 1973 January to the beginning of October 1973. He estimated that the increase in crude oil inventories was substantially in excess of 552 million barrels (2 mbd), compared to lost output of 340 million barrels in the three month period, October to December 1973. In addition, he argued that outside the oil industry there had been substantial build-up of inventories of refined products during 1973 prior to October. Then, inventory levels climbed again to the capacity of available storage during 1974 (Adelman, 1995).



The embargo on oil supplies to the United States and the Netherlands, and reduced shipments to some other countries was rendered ineffective by diversion of shipments from country to country. The embargo was not responsible for queues more than 1.5 kilometres long at fuel service stations in the United States. This queuing was the result of controls on fuel prices in the United States and administrative allocation of supplies (Adelman, 1995, 2004; Kilian, 2008b). Morris Adelman, (2004, p. 19) commented:

“We ought not blame the Arabs for what we did to ourselves.”

### ***1978-80: Iranian Revolution and the Iran-Iraq War***

The ‘second oil crisis’ involved another huge increase in the real price of crude oil. The peak was more than double the real price level established as a result of the ‘first oil crisis’ (Hamilton, 2009b). During and after the ‘first oil crisis’, Middle Eastern and North African countries progressively took over oil company producing assets. This process commenced before the ‘first oil crisis’. As this process continued, governments transitioned from use of production-based taxes to selling oil to collect their take. The transition made it more difficult to maintain a floor under the crude oil price following spot price surges caused by precautionary/speculative demand increases resulting from fears regarding supply, that they had sought to create or exploit. With the companies, they could raise their production-based taxes in concert and let the companies compete above the floor set by cost plus tax. Without the companies, governments had to set production and market shares and rely on others not to cheat (Adelman, 1995).

The traditional view is that the initial price surge of the ‘second oil crisis’ was driven by disruptions to oil supply associated with the Iranian revolution in late-1978 and early-1979. These disruptions occurred during the period, December 1978 to February 1979. Restoration of Iranian production was well advanced by April 1979. However, the big surge in the real oil price did not commence until May 1979.

Kilian (2008b, 2010c) and Kilian and Murphy (2010) attributed the price surge to a resurgence of global economic activity (aggregate demand) combined with speculative demand driven by fears of military conflict in the Persian Gulf and consequential oil supply interruptions, in the context of high oil production capacity utilisation rates in OPEC countries and worldwide. Inventory behaviour was consistent with this explanation, falling sharply initially and then rising above pre-shock levels by May 1979. Adelman (1995) provided a more detailed explanation.

Adelman pointed out that there was adequate spare capacity in late 1978 and the first half of 1979 to cover disruption of supply from Iran. However, it was widely expected that OPEC would increase official prices at its December 1978 meeting, and fear of supply disruption was strong. Precautionary buying occurred and inventories rose contra-seasonally. Loss of Iranian production in November was covered by other producers. However, OPEC announced price rises for each quarter of 1979 at its December meeting. The annual rate of increase was 14.5 per cent.





Iran was out of the world market again in January until early March 1979, when exports recommenced, but at a reduced rate. In late January 1979, Saudi Arabia announced a cut in production of 2 mbd. Major oil companies had already been involved in heavy precautionary buying of crude oil, pushing up spot prices. Governments raised official prices towards spot levels.

Spot prices eased in March following resumption of exports from Iran, but surged in May following production cuts by Saudi Arabia in April. Official prices took-off in pursuit. While the rise in spot prices temporarily ceased after Saudi Arabia raised output in July 1979, other governments cut production and OPEC governments continued raising official prices. Spot prices surged again late in 1979, following production cuts by some governments and renewed fears about supply. Spot prices turned down early in 1980, but official prices continued to rise, albeit more slowly through to August 1980. Meanwhile, inventories accumulated (Adelman, 1995).

Following the break-out of war between Iran and Iraq in September 1980, the supply of oil suffered a major disruption. Their combined capacity dropped from 11 mbd to 6 mbd, where it remained until 1990. The real oil price climbed further, with some resurgence of speculative demand. Official prices climbed behind the spot price. Inventories again fell initially before climbing above pre-stock levels, but only partly because of speculative demand. Inventories also grew because of unexpected increases in oil production, including growth of production outside of OPEC. This dampened the oil price. Some selling of inventories occurred because of high holding costs. By July 1981, spot prices were back at levels prevailing before the Iran-Iraq war, with spot and official prices approximately the same (Adelman, 1995; Kilian, Murphy, 2010).

### ***1986: Collapse of OPEC Support for Oil Price***

In late-1985, Saudi Arabia abandoned its attempts to support the crude price by curtailing its own production. The result was a major increase in oil supply. This positive oil supply shock translated into a sharp fall (about 50 per cent) in the real crude oil price.

Kilian and Murphy (2010) argued that a speculative demand drop, represented by reduction of stocks, reinforced the oil price fall. They explained that this shift in speculative demand was caused by changes in price expectations as a result of altered perceptions of OPEC's market power. They pointed out that while inventories rose initially as expected because of the increase in Saudi Arabian production, they subsequently declined consistent with a downward speculative demand shock.

### ***1990-91: Iraq's Invasion of Kuwait***

Oil supply was disrupted following Iraq's invasion of Kuwait in August 1990. The average global reduction in the oil production during the August-October 1990 period was 2.9 per cent. The real crude oil price spiked to around double the level before the invasion, which was around the real price prevailing before Saudi Arabia abandoned its pre-1986 support for the



oil price through cuts to its own production. The upward price movement was quicker than in 1973 and 1979, and the downturn commenced much sooner, less than three months after the invasion. (Adelman, 1995; Hamilton, 2009b). The traditional view is that the supply shock was responsible for the price spike. This seems to be supported by an initial decline in inventories, but that reduction was small in the context of the size of the supply shock. However, the reality was more complicated.

The disruption occurred at a time of excess crude oil supply and weak prices. The amount of excess capacity in the Persian Gulf region at the time, about 5 mbd (excluding Iraq and Kuwait), exceeded the combined production rate of Iraq and Kuwait before the conflict by about 1.5 mbd. While the spare capacity could not be brought into use instantly, inventories of crude oil and refined products were at high levels and could cover the disruption on an interim basis (Adelman, 1995).

According to Adelman (1995, p. 293):

“Thus, the 1990 oil crisis was like the others: there was no shortage, but the *threat* of shortage generated precautionary demand for more inventories, which raised prices, which brought additional speculative demand. Expectation of a higher price is a self-fulfilling prophecy.”

Kilian and Murphy (2010) argued that a speculative demand shock was operating simultaneously with the supply shock. The speculative or precautionary demand shock was tending to increase inventories, while the supply shock was causing them to be run down. Meanwhile, both shocks contributed to the sharp increase in real crude oil prices. Their modelling results suggested that the supply shock was responsible for about two-thirds of the price spike.

Kilian and Murphy (2010) suggested that the speculative demand increase commenced 2-3 months before the conflict, because of increasing tension in the Middle East. However, the potential price effects of this demand shock were offset by rising crude oil production.

They explained that the decline in real oil prices from late October 1990 was caused almost entirely by a decline in precautionary/speculative demand, rather than increased oil production. This was reflected by a decline in inventories. The underlying shift in expectations was attributed to removal of a previously perceived threat to Saudi Arabian oil fields in the context of conflict in the Middle East (Kilian, Murphy, 2010).

Adelman (1995, p.296) argued that additional factors contributed to the short duration of the oil price surge and the decline in precautionary/speculative demand to other factors. Of particular importance was the behaviour of Saudi Arabia:

“After a month’s silence let the price rise, they (Saudi Arabia) increased output and let it be known they would keep it high. That was far cry from 1979-1980, when their prolonged refusal to ensure more supply kept driving up the price for over a year.”

Adelman (1995) argued that knowledge in the market that strategic petroleum reserves in the United States, Germany and Japan might have been used to address the ‘crisis’ moderated the



surge of precautionary/speculative demand. One way in which it did this was by helping to quell panic in governments.

Adelman (1995) noted that some “token sales” were made from strategic petroleum reserves after crude oil prices had turned down and sales from strategic reserves were no longer needed. He commented that if large or unlimited amounts had been offered for sale or if options for future sale had been offered when the ‘crisis’ began, the price upheaval could have been prevented.

### ***2002-03: Venezuelan Oil Supply Crisis and the Iraq War***

Civil unrest in Venezuela was followed by a sharp, well-defined reduction in crude oil production from December 2002. Then, in early-2003, Iraqi oil production ceased temporarily as a result of war with the United States and its allies. The combined supply shock was similar in magnitude to the 1970s supply cuts (Kilian, 2008b; Kilian, Murphy, 2010).

The real oil price rose in response to the Venezuelan event and inventories fell. An increase in speculative demand because of the potential of conflict between the United States and Iraq dampened the decline in inventories, but reinforced the oil price rise.

However, the combined Venezuelan and Iraqi supply shocks did not generate a large oil price spike, because they were more than offset by an unexpected increase in global oil production early in 2003 - a countervailing positive supply shock. The positive oil shock led to inventory accumulation, and induced a reversal of the speculative demand shock. The speculative demand shock worked in the opposite direction to the positive oil shock in respect of inventories, and in the same direction in the case of the oil price (Kilian, Murphy, 2010).

### ***2004-08: Strong Global Economic Expansion***

Kilian and Murphy (2010) found that the surge in the real price of oil between mid-2003 and September 2008 was caused mainly by shifts in demand for crude oil associated with growth of global aggregate demand, powerfully underpinned by growth of economic activity in China, India and other rapidly developing Asian economies. Their modelling did not find evidence of a contribution from increases in precautionary or speculative demand, even during 2007-08 when the real crude oil price rose sharply. They said that this was confirmed by analysis of oil inventory data. Their findings were consistent with those of several other respected economic analysts (for example, Radetzki, 2008; Hamilton, 2009a,b; Smith, 2009a,b; Kesicki, 2010).

It is important to view this finding in the context of the supply position. After global oil production rose in 2003, 2004 and into 2005, it stagnated until the second half of 2007. One contributing factor was a 23 per cent decline in non-OPEC production, the first significant decrease in non-OPEC production since the ‘first oil crisis’. In addition, Saudi Arabian production was about 0.85 mbd lower in 2007 than in 2005 (Hamilton, 2009a,b; Smith, 2008; Kilian, 2009b, 2010a). From August 2007, growth of oil production began to outstrip non-speculative demand growth, with new production coming on line (Maugeri, 2009).



The supply situation prevailing in the 2004-2007 period neatly fitted the circumstances in which Dvir and Rogoff (2010) argued speculative demand would add to price increases resulting from a persistent aggregate demand shock (see sub-section 5.4.2 above). Therefore, the attribution of responsibility for the substantial surge in crude oil (and other mined commodity prices) to potential causes in this period is problematic.

Some respected oil market specialists have argued that the effects of the aggregate demand shock on the crude oil price were exacerbated by speculative demand in the 2007-08 period. Econometric analysis by Frankel and Rose (2010) found evidence of destabilising speculative effects arising from actions based on 'bandwagon expectations' – forecasts of future commodity prices that extrapolated recent trends – during the 2007-08 period. They explained that prices for crude oil and other mined commodities continued to rise despite a series of downgrades of forecasts economic growth.

ENI Vice President Leonardo Maugeri (2009) also argued that expectations based on recent trends had influenced strong increases in oil prices in 2007-08. He said that this would not have occurred without inadequate data provision, and misleading analysis and forecasts by high profile organisations that distorted perceptions of market fundamentals. He stated that inventories grew as supply growth outstripped non-speculative demand growth. Maugeri claimed that the accumulation of inventories was not included in official statistics until later.

However, it should be noted that the form of speculative demand that Frankel and Rose (2010) and Maugeri (2009) argued was influencing prices in 2007-08 appears to be conceptually different to the concept discussed by Kilian and co-authors (for example, Kilian and Murphy, 2010) and by Dvir and Rogoff (2010). The former was based on extrapolation of past prices, while the latter was based more fundamentally on uncertainty regarding the future demand and supply balance.

### ***2008-10: Global Financial Crisis and Partial Recovery***

Kilian (2010a,b) argued that the collapse of the oil price in late 2008 and 2009 was caused mainly by unexpected changes in global activity combined with "unprecedented expectations shifts" triggered by the global financial crisis. The expectations shifts, through speculative demand reductions, exacerbated the reduction in demand for oil resulting from the shift in global economic activity.

Hamilton (2008b) also suggested that the economic reversal was unexpected. However, Frankel and Rose (2010) argued that the signs of an impending downturn were clearly evident and publicised.

Hamilton (2008) commented that the sharp global economic decline in response to the global financial crisis was not enough by itself to explain the magnitude of the dramatic decline in the oil price. He suggested that the effect of the severe economic reversal was reinforced by delayed responses to high oil prices in 2007-08.



Kilian (2010c) and Kilian and Murphy (2010) attributed the subsequent partial recovery of the crude oil price primarily to a recovery of global real economic activity. As in the 2004-2008 period, the recovery was underpinned by growth of economic activity in China, India and other rapidly developing Asian economies.

### **Aggregate Demand Shocks: Cycles and Structural Shifts**

The economic literature focusing on the relative importance of crude oil supply shocks, aggregate demand shocks and precautionary demand shocks has abstracted from a growing body of literature focused on analysis of demand side influences on movements of prices of mined commodities (including petroleum). This parallel body of analytical work has sought to distinguish between influences on mined commodity prices of:<sup>15</sup>

- cyclical changes in the level of global economic activity (the economic or business cycle)
- speculative activity
- “structural shifts” in markets for mined commodities at various times over the past 140 years
- “super cycle” phenomena.

It is apparent that behaviour of prices of petroleum and other mined commodities over the past decade has been influenced by each of the first, second and third of these phenomena. The fourth is different perspective on the third.

Detailed discussion of these influences on mined commodity prices is beyond the scope of this study.

### **Supply Shocks: Peak Oil and OPEC Cartel**

The discussion of supply shocks in the study has focused on major supply disruptions that have occurred abruptly. There are two other potential sources of major supply disruption that should be mentioned, “Peak Oil” and the behaviour of the OPEC cartel over the past decade.

Our current assessment of the “Peak Oil” issue is discussed in section 4.2 of this report. As indicated in this earlier discussion, the analysis put forward by the proponents of this thesis is not considered valid for the medium to long term (ACIL Tasman, 2008). The latest IEA World Energy Outlook supports the assessment in the 2008 vulnerability assessment that

“Even if conventional crude oil production does peak in the near future, resources of NGLs and unconventional oil are, in principle, large enough to keep total oil production rising for several decades.” (IEA, 2010)

A potential source of supply shocks with more substance is the ongoing behaviour of the OPEC oil cartel.

---

<sup>15</sup> For example, see Humphreys (2009, 2010), Roberts (2009), Radetzki, others (2008), Radetzki (2006), Cuddington, Jerrett (2008), Cuddington, others (2007), and Roberts, Rush (2010).



Although the volume of proved reserves in OPEC countries doubled over the period 1973-2008, OPEC's production capacity has remained virtually unchanged since 1973. OPEC's installed production facilities are sufficient to extract just 1.5 per cent of its proved reserves each year. Non-OPEC producers have invested in production facilities able to extract 5.6 per cent of their proved reserves each year. It seems OPEC has limited oil production by avoiding provision of new production capacity (Smith, 2009).

It appears that from 1973 to 1985, and from 1991 to 2005, Saudi Arabia had adjusted its production to support prices at times of slack demand and raised production to moderate price increases resulting from supply disruptions elsewhere (Hamilton, 2009a; Kilian, Murphy, 2010). However, Saudi Arabian production was not increased in response to strongly rising crude oil prices from 2005. Indeed, it fell. Hamilton (2009a) suggested that Saudi Arabian may no longer have spare capacity or it may have moved to a new price policy.

Artificial capacity constraints in OPEC could be regarded as a form of persistent supply shock. Adelman (2004) described this, not "Peak Oil" as "the real oil problem". In a similar vein, Dvir and Rogoff (2010, p. 3) observed that taking a long-term view of the oil market served to enrich the debate in the literature on sources of oil shocks because:

"...shocks to the oil market may have remarkably different effects on the real price oil across historical periods, not only due to their origin on the supply or the demand side, but also because of the ability (or lack thereof) of key players in the market to restrict access to supplies. In particular, in periods when the ability to restrict access to supplies was lacking, the oil market showed remarkable flexibility and relative price stability, even in the face of massive disturbances in both supply and demand."

#### **5.4.4 Refined Product Shocks**

Recently, Kilian (2010b) began to extend the categorisation of shocks to include shocks to supply of automotive fuel, exemplified by refinery (refined product supply) shocks. He suggested that the concept of precautionary or speculative oil demand shocks in response to "expectations shifts" could be extended to oil products, but did not develop this line of analysis, focusing mainly on comparison of the effects of refinery shocks and his three categories of oil price shocks on refined product prices.

Economic modelling by Kilian (2010b) indicated that an unanticipated disruption of U.S. refinery output would cause an immediate and highly statistically significant increase in the real price of automotive fuel that would remain statistically significant for three months. He explained that the modelling results were consistent with the petroleum product price effects of damage to oil refineries caused by Hurricane Katrina, which hit the United States Gulf (of Mexico) Coast in late August 2005. This severe weather event, and Hurricane Rita, which hit the Gulf Coast a month after Hurricane Katrina, caused the largest refined product supply shock in the world over the past few decades.

Obviously, a major refined product supply shock would result in considerable uncertainty regarding its duration and significance. It would also cause changes in perceptions of uncertainty regarding future shortfalls that could persist even after supply had been restored



to pre-shock levels. It is difficult to assess how much a precautionary oil demand shock arising from such 'expectations shifts' would add to the price increase from the short-term oil product supply shock, and how long the effects on real refined product prices would persist.

In view of the preceding analysis, refined oil product price shocks could result from:

- *crude oil supply shocks* (pass through of crude oil price increases);
- *aggregate demand shocks* (global growth of demand for goods and services generally);
- *precautionary or speculative crude oil demand shocks* (pass through of crude oil price increases);
- *precautionary or speculative refined product oil demand shocks*; and
- *refined product supply shocks*.

Because refined product prices rise and fall with crude oil prices, crude oil supply shocks and precautionary crude oil demand shocks would also translate into refined product shocks. Aggregate demand shocks affect crude oil prices because demand for crude oil is derived from demand for refined products. Two additional potential shocks apply to refined products:

- refined product supply shocks separate from crude oil supply issues; and
- precautionary demand for products, separate from precautionary demand for crude oil.

As for crude oil, more than one shock may apply simultaneously. Again, contemporaneous shocks may also interact.

## **5.5 Economic implications of oil shocks**

The distinction between types and causes of oil shocks has great economic importance. The economic consequences of an oil shock depend crucially on its cause or causes. There are important differences between the economic effects of oil and refined product price increases resulting from aggregate demand shocks, oil and refined product supply shocks, and precautionary (speculative) demand shocks.

The economic effects of oil shocks also vary between countries in accordance with differences in economic structures. These effects have changed over time as economic structures have changed.

The differences between economic effects of the various types of oil shock have important implications for formulation of macroeconomic policy responses. Appropriate responses will differ according to the causes of the shocks. A complication for formulation of policy responses is that more than one type of shock may be operating around the same time.

The different economic effects of different types shocks and implications for policy for various categories of country are discussed below. Further discussion linked to economic modelling results can be found in articles by Baumeister, Peersman and Robays (2010) and Kilian (2009a, 2010a).



### 5.5.1 Aggregate Demand Shock

A shock to prices of crude oil and products caused by an unexpected increase in global economic activity would result in a transitory increase in real national income and inflationary pressures in all countries, as well as an increase in crude oil and refined product prices. If the unexpected increase in the rate of growth of global economic activity unexpectedly persists, the higher rate of growth of real national income and inflationary pressures would persist. Monetary authorities could be expected to intervene to dampen inflationary pressures.

Such an aggregate demand shock would cause relatively large increases in prices of all mined commodities and other natural resource-based commodities, such as food and fibres. This would occur because to varying degrees, these natural resource based commodities are characterised by relatively low price elasticities of demand and supply. Because Australia is a large producer of a diverse range of commodities, it would tend to be particularly affected by such an aggregate demand shock. This has been exemplified by the commodity price boom of 2004-2008 and its revival in 2010 and 2011.

The particularly strong increase in inflationary pressures in a major commodity producer like Australia would be ameliorated by a floating currency. An increase in the nominal exchange rate (the value of the Australian dollar relative to other currencies) could be expected to ameliorate the inflationary pressures. An interest rate response could also be invoked.

### 5.5.2 Oil Supply Shock

An oil supply shock would cause markedly different effects in net oil-importing countries than in countries that are net exporters of oil, net exporters of oil and other energy, and net exporters of energy but not oil.

Net oil-importing countries would experience a permanent fall in real economic activity and an increase in inflationary pressures. Monetary authorities might respond with an interest rate increase to address inflation or a reduction to address the decline in economic activity. This would be influenced by exchange rate movements.

Net exporters of oil and other forms of energy, such as Norway and Canada, could be expected to experience a permanent rise in real economic activity, because of the expansionary effects of higher prices for the oil and other energy products that they produce. Exchange rate appreciation would tend to offset inflationary pressures from higher oil product prices and increased economic activity.

Countries which are net oil exporters, but net importers of other forms of energy, could experience effects on economic activity working in opposite directions. Any reduction in economic activity would tend to be transitory. Inflationary pressures would tend to increase because of higher prices of energy products. The relative importance of net oil exports and net imports of other energy forms would determine the extent to which exchange rate





movements offset or exacerbate inflationary pressures and the likely intervention of monetary authorities to adjust interest rates.

In countries like Australia that are net exporters of energy, but net importers of oil, there would be effects on economic activity working in opposite directions. Higher oil prices would tend to cause a contraction of national income, while higher prices for energy commodities in general would tend to be expansionary for net exporters of energy. Again, any reduction in economic activity would tend to be transitory, depending on the relative importance of the opposing forces. These same opposing forces would also determine the direction and magnitude of movements in the exchange rate and the nature and extent of monetary intervention. The economic effects of an oil supply shock on Australia could be insignificant or positive overall. As Australia's net energy export balance increases because of large increases in exports of coal and liquefied natural gas and coal seam methane, the likelihood of positive overall economic effects on Australia increases.

### **5.5.3 Precautionary or Speculative Oil-Specific Demand Shock**

It is likely that an increase in precautionary/speculative oil-specific demand would cause a temporary reduction in real national income and a temporary increase in the price level.

Intuitively, however, one would expect that there would be countervailing effects for countries that are net oil exporters or net energy exporters. Higher prices for these products would be stimulatory, countering to some degree the effects of higher prices of energy products on economic activity. Similarly, these higher export prices would tend to cause exchange rate appreciation.

Surprisingly, this intuition was not supported by results of modelling by Baumeister, Peersman and Van Robays (2010). They found that net oil exporters and net energy exporters would experience temporary reductions in real national income, although not as large as for net energy importing countries. For Australia, they found the reduction would be less than in comparable countries, Canada, Norway, and the United Kingdom. Also, their modelling indicated that exchange rates in net energy-exporting countries would not respond significantly to a precautionary demand increase and inflationary effects would not differ greatly from those in net energy importing countries. For Australia, they found a larger effect on the price level than other developed net energy-exporting countries and net energy-importing countries, but a relatively small exchange rate movement. Baumeister, Peersman and Van Robays (2010) did not provide an intuitive explanation for these modelling results.

### **5.5.4 Changes Over Time and Across Countries**

Baumeister, Peersman and Van Robays (2010) have argued that the potential economic effects of oil shocks of a particular type and magnitude have changed fundamentally over time, and that the changes in potential economic effects have varied across countries.

They have estimated that short-term price elasticity of demand for crude oil becomes significantly more inelastic or lower (ignoring the negative sign) from the mid-1980s. In



addition, they observed that short-term price elasticity of supply had become highly inelastic over time. This means an oil shock of a particular type and magnitude would lead to a much larger oil price change now than at the time of the 'first oil crisis' and 'second oil crisis' of the early 1970s to early 1980s.

The economic implications of potentially greater price shifts now have been moderated somewhat by noticeable reductions of oil intensity and energy intensity in all developed countries since the 1970s. However, the differences between countries are substantial, particularly in respect of oil intensity.

In addition, net oil-importing/exporting and net energy-importing/exporting positions have changed over time to varying degrees across countries. Norway, Australia, Canada and the United Kingdom (in that order) have significantly improved their positions since the 1970s and early 1980s. In contrast, the United States has improved its position only slightly, with European countries and Japan making moderate improvements that see them significantly better placed than the United States but significantly less so than Norway, Australia and Canada.

An important relevant policy change for Australia was the move to a floating exchange rate in 1983. This meant that changes in the nominal exchange rate could occur automatically in response to shocks, allowing changes to the real exchange rate to occur without high inflation and allowing more moderate adjustments in monetary and fiscal policy to stabilise the economy.

These changes have implications for Australia's vulnerability to oil shocks. Australia's vulnerability would now be greater than at the time of the first and second oil crises to the extent that price elasticity of demand and supply for crude oil have declined during the intervening period. On the other hand, Australia's susceptibility to economic harm from oil shocks has declined since the time of the first and second oil crises because of lower oil intensity, improvements to Australia's position as a net exporter of energy, and the floating exchange rate.

#### **5.5.5 Refined Products Supply Shocks**

The world's largest refined product supply shock over the past few decades was associated with temporary loss of refining capacity along the United States Gulf Coast because of Hurricanes Katrina and Rita in late August 2005 and late September 2005, respectively.

The increase in refined product prices resulting from this sort of shock would tend to cause a temporary reduction in national income and an increase in the price level in countries around the world. Obviously, there would be an additional hit to national income in the country hosting the disabled refining capacity. In countries with spare refining capacity, there would be a temporary stimulus to economic activity helping to offset the effects of higher refined product prices in other parts of the economy.



Net energy-exporting countries, such as Australia, would not gain from higher prices of other energy products as they would in the case of a crude oil supply shock, because crude oil prices would not rise and induce increases in prices of other energy products. When refining capacity is lost, demand for crude oil from that source disappears. The previous demand level can be restored only to the extent that there is spare refining capacity elsewhere. Consequently, crude oil prices could fall or remain unchanged (Kilian, 2010b).

The economic effects in Australia of refined product supply shock in the form of a loss of refined capacity elsewhere would be a temporary loss of real national income and higher price level. The loss of national income from the increase in product prices following the shock would be offset only to the extent that Australian refineries could expand production.

### 5.5.6 Compound Shocks

Analysis of past oil shocks has shown that more than one type of shock and underlying cause may be operating around the same time. Several historical examples of such occurrences have been discussed in sub-section 5.4.3 above. However, in that sub-section the focus was on crude oil shocks only.

Oil shocks may take the form of refined oil product shocks, as well as crude oil shocks. The persistent aggregate demand shock in the period, 2004-2008, was obviously a refined oil products shock, as well as a crude oil price shock, because demand for crude oil derives from demand for products. The early period of this prolonged shock coincided with a refined oil products supply shock caused by Hurricanes Katrina and Rita in late 2005. The latter was accompanied by a precautionary demand increase (shock) for refined products.

If a major refined petroleum products shock occurred in mid-2011, the context would be multiple interacting sources of shock. Because of the aggregate demand shock of the substantial slump in global economic activity associated with the global financial crisis, there is significant spare refining capacity globally. However, this spare capacity is diminishing following another aggregate demand shock, the unexpectedly rapid resurgence of growth in China, India and other rapidly developing Asian economies. The run-down of spare capacity is being hastened by scheduled closures of inefficient refineries. The latest aggregate demand shock has raised crude oil prices to relatively high levels (but not to third quarter 2008 levels) in the context of ongoing constraints on production capacity (but not reserves) in OPEC countries. Consequently, refined product prices have climbed to relatively high levels. Spare global refining capacity means short-term price elasticity of supply is higher than when there is little spare capacity. With product prices already high because of high crude oil prices, short-term price elasticity of demand would be higher than when product prices are lower, according to some analysts (for example, Hymel, Small, Van Dender, 2010), but a survey of hundreds of estimates by Dahl (2011) suggested that there would be little difference.

If a major refined products shock occurred at various other times in the future, the context could be quite different.



For example, if Chinese and Indian demand for mined commodities unexpectedly strengthened (another aggregate demand shock), crude oil prices would climb higher, and spare refinery capacity could disappear, pending lagged investment responses. In the context of little spare refining capacity and high product prices before the refined products shock, precautionary demand increases could exacerbate a spike in prices of refined products arising from the refined products supply shock. The height of the spike would be exacerbated by an extremely low price elasticity of supply of refined products. How low price elasticity of demand (ignoring the sign) would be in these circumstances would depend on the tendency of higher prices to increase this elasticity and higher incomes to lower it. Some analysts have identified such tendencies (for example, Hymel, Small, Van Dender, 2011), but others have not (Dahl, 2011).

An alternative example could involve a major refined products supply shock in the context of a downward aggregate demand shock (say, a recession in China and India), when there is substantial spare refining capacity, lower crude oil prices, relatively low refined product prices before the shock, and relatively low crude oil prices. Then, the impact of the shock on product prices would be moderated by a higher short-term price elasticity of supply. In this set of circumstances, price elasticity of demand would tend to be higher because of lower incomes, but lower as a result of lower refined product prices, according to some analysts (see Hymel, Small, Van Dender, 2010). According to results of a review by Dahl (2011) effects of price and income changes on price elasticity of demand could not be discerned.

When different types of shocks occur around the same time, the combined economic effects of the shocks and their underlying causes would have to be taken into account when considering policy responses. These deliberations should include consideration of the economic implications of interactions between causes. Good analysis will not be simple.



## 6 Analysis of Hypothetical Major Shock: Singapore Petroleum Outage

### 6.1 Introduction

The terms of reference stipulated that ACIL Tasman's assessment of Australia's vulnerability to a large scale liquid fuel supply disruption should include analysis of a specific hypothetical supply shock scenario. The scenario nominated in the terms of reference was an interruption to the shipping of crude oil to, and refined oil products from, a major oil hub for about 30 days.

Australia's vulnerability to such a large scale liquid fuel supply interruption has been taken to mean its susceptibility to economic harm from the supply shock. This economic harm could result from the price response to the shock. Alternatively, if there are impediments to the price rising sufficiently to clear the market, the economic harm would be caused by some combination of a limited price shock and physical shortages, requiring some rationing mechanism other than automatic rationing by price movements.

An important issue is that some sections of the Australian community may be more susceptible to harm than others. Therefore, it is appropriate to consider distributional effects as well as overall economic effects of the hypothetical supply shock.

In this chapter, qualitative analysis has been applied to determine an indicative market-clearing price response to the supply shock and to consider possible overshooting because of precautionary or speculative buying triggered by uncertainty associated with the supply shock. This qualitative investigation includes comparative analysis of the hypothetical Singapore refined products supply shock and a similar historical episode in the Gulf of Mexico in 2005, as well as a review of the literature on supply and demand shocks in the affecting the crude oil and refined oil products industries.

The qualitative analysis has been complemented by the application of economic modelling tools. The indicative price shock was entered into ACIL Tasman's computable general equilibrium (CGE) model in order to assess the economic consequences of the price spike for Australia.

As required by the terms of reference, impacts of the hypothetical supply shock have been analysed with respect to the concepts of "adequacy", "reliability" and "affordability" underlying the concept of "energy security" in the *National Energy Security Assessment 2009* (Department of Resources, Energy and Tourism, 2009). The definitions of these concepts in energy security document have been reproduced in Box 3.



## Box 3

**Energy Security Defined in Terms of Adequacy, Reliability and Affordability**

In the Australian context, energy security is defined as the adequate, reliable and affordable supply of energy to support the functioning of the economy and social development, where:

- adequacy is the provision of sufficient energy to support economic and social activity;
- reliability is the provision of energy with minimal disruptions to supply; and
- affordability is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.”

*Source:* Department of Resources, Energy and Tourism, National Energy Security Assessment 2009, p. 5.

Consistent with the requirements of the terms of reference, a broader concept of “affordability” has been applied in this Chapter and in Chapter 8.

## 6.2 Supply Shock Scenario

The hypothetical supply shock scenario nominated by the Department of Resources, Energy and Tourism was a temporary interruption to the supply of oil products from a major regional oil trading and refining hub. Specifically the scenario selected involved interruption of shipping of crude oil and petroleum products into and out of Singapore for about 30 days.

After allowing for the time it takes to ship crude oil to Singapore, refine crude oil, store and blend sufficient oil products, break-up cargos, and ship crude oil and refined products to Australia, the interruption of supply from Singapore to Australia could last for 45 to 60 days.

As discussed below, such an incident would temporarily remove around 1.72 per cent of world refinery capacity from the market. To place this in context, a recent study suggested that the probability of a disruption of 10 per cent or more in world oil supplies could be of the order of 2.5 per cent or around 1 in every 40 years (Covec, February 2005). A disruption of around 1.72 per cent therefore could be expected to occur more frequently. Indeed the history of disruptions discussed in Section 5.4.3 above and in the following sections indicates that a disruption of this magnitude might occur at least once a decade.

## 6.3 Significance of Australian Refined Product Imports from Singapore

Singapore is an important trading hub for petroleum liquids in the Asia Pacific regions. Singapore plays multiple important roles with respect to imports of crude oil and refined product into Australia. First, Singapore refineries supply Australian-specification products to augment production from Australian refineries. Second, Singapore stores, blends and tranships products from different sources for shipping to Australia. Third, Singapore performs similar functions in respect of crude oil.

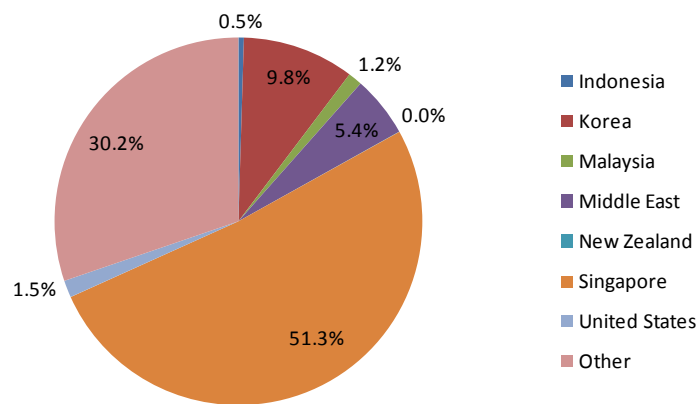
Singapore has three oil refineries with combined capacity of about 1,336,000 barrels per day (77,530 million litres per year). This is about 1.72 per cent of global capacity. It is 1.75 times the combined capacity of Australia’s 7 refineries, before the planned closure of Shell’s Clyde



refinery, and 1.96 times the combined capacity of Australia’s refining industry after the possible closure of the Clyde refinery<sup>16</sup>.

Australian imports of refined petroleum products from all sources in 2008-09 and 2009-10 represented more than 42.25 per cent of Australian consumption plus exports expressed in energy terms, excluding LPG, up from 32 per cent in 2005-06. Net imports (imports less exports) of refined petroleum products represented around 30 per cent of total Australian consumption, excluding LPG, in 2008-09 and 2009-10<sup>17</sup>.

Figure 16 Share of Australian imports of refined petroleum products by country/region, 2009-10



Source: DRET, Energy in Australia 2011

Singapore provided over 51 per cent of Australian imports of refined petroleum products in 2008-09 and 2009-10 (see Figure 16), down from 59.6 per cent in 2005-06. Therefore, imports from Singapore in 2008-09 and 2009-10 supplied more than 15 per cent of Australian consumption (excluding LPG), and nearly 18 per cent of Australian consumption (excluding LPG) plus exports of refined petroleum products.

## 6.4 Logistical Issues from Disruption of Singapore’s Role as a Liquid Petroleum Trading Hub

### 6.4.1 Crude Oil

Singapore is an important logistics centre for crude oil trade. Cargoes from the Middle East, west Africa and Asia are discharged from Very Large Crude Carriers (VLCCs) and are broken-up through ship to ship transfer into smaller vessels for shipping to Australian refineries that

<sup>16</sup> At the time of writing a proposal had been tabled with the Shell boards which recommended that refining at Clyde Refinery cease and that Clyde and Gore Bay Terminal be converted to a dedicated fuel import terminal. The boards have not made a decision on whether or not to accept the proposal.

<sup>17</sup> If LPG exports are included the figure falls to 27 per cent.



cannot receive VLCCs. Australia's seven refineries typically do not take large percentages of Middle Eastern high sulphur crude.

A major Singapore disruption would not have a significant impact on crude availability for Australian refineries.

The impact on crude availability for Australian refineries of Singapore being closed-down would be mainly due to logistical issues arising from the need to redirect crude straight to Australian refineries or via another hub. This could involve delays of up to one week.

However, some crude oil cargos would have to be sought from further afield in Asia, the Middle East and North Africa to replace crude oil temporarily isolated in storage in Singapore. This could involve delays of 3-6 weeks for longer hauls.

There should not be any loss of crude oil supply to Australia for two reasons. First, crude oil destined for Australia via Singapore would still be available. Some of this would be on ships in transit to Singapore, providing seaborne inventories that could be drawn down. Second, higher product prices globally would reduce global requirements for crude oil.

With Singapore refineries closed down, there would be some more proximate, additional crude available for Australian refineries, providing them with the opportunity to increase their run rates in the short term, capacity permitting. There would be some delays as crude originally destined for Singapore was traded and redirected to Australian refineries. The delay could be up to one week. In addition, crude oil might also be diverted from Europe and the United States as well as other areas, through interregional arbitrage deals.

However, available advice suggests that it is unlikely that Australian refineries could increase production significantly even on a temporary basis. Therefore, a high proportion of crude oil previously destined for Singapore would be traded and re-directed to refineries with spare capacity.

It might be argued that the loss of Singapore as a hub for crude oil could increase delivered prices of crudes to Australian refineries, because of longer hauls in smaller tankers due to the loss of a cargo break-up centre. Also, rebidding crude cargos might result in price increases. On the other hand, higher product prices globally would reduce crude oil requirements, resulting in a short-term surplus of crude-oil and lower prices. Experience from the disruption of Gulf of Mexico refinery production by Hurricane Katrina suggests that the net effect on crude oil prices would be either a reduction or no change in prices.

The impact of disruption to crude supplies from Singapore would not be felt by Australian refineries for 5 to 6 weeks.

The refineries in New South Wales, Queensland and Western Australia depend on imported crude and would need to seek alternative sources of crude oil to replace shipments from the Singapore hub after about three weeks. However, as discussed above, the main impact is likely to be on logistics. After trade in the Singapore hub re-commenced, there would be a gradual return to normal supply arrangements.





### 6.4.2 Petroleum Products

The greatest impact of a 30-day loss of Singapore is likely to be on the source of supply and price of petroleum products for Australia. Not only does Singapore have refining capacity of around 1.34 mbd, but also it is an important market hub for petroleum products. Products from Singapore refineries and refineries in other countries are blended in Singapore. Products from refineries elsewhere are transferred from large tankers to Medium Range tankers suited to Australian ports.

Petroleum products are subject to considerable inter-regional trade. The eastern Asian region (India to South Korea and Japan) is long on refined products at the present time, and refineries from this region export products to other regions, including Europe, the west coast of the United States, South America, the United States Gulf Coast and the Caribbean.

Australia is predominantly short on diesel and jet fuel, which are generally imported from north Asia. Independent importers also source petrol from north Asia.

While the situation is different for each importer, in general terms, imports of diesel and jet fuel are important for southern and south-eastern Australia, where a high proportion of the demand for petrol can be met from local refineries. Melbourne is long on petrol, but would need to import jet fuel and diesel. Adelaide is dependent on imports of all products.

Further north, there would be pressure on prices of supply of diesel and petrol, with demand for the former being more critical as a result of strong growth of demand from mining, and to a lesser extent agriculture.

Economic analysis and historical experience have shown that a supply shock, such as the hypothetical Singapore shut-down scenario, would trigger large increases in prices of refined products globally. Prices would rise sufficiently to ration supply in the very short-term, and to re-allocate supply. Indeed, there could be overshooting in the very short-term because of speculative demand. Thereafter, market forces would adjust prices automatically as uncertainty declines, additional supply of products is induced, and as other circumstances change. In effect, the operation of market forces would translate the supply shock into a price shock that will resolve the supply rationing and allocation problem.

The scale of this price rise would depend on spare refining capacity in the global market in general, and in the Asia-Pacific region in particular. It would also depend on the net call on the global spot market for short term supply, as Singapore's product customers hold material stockholdings of petroleum products which they can utilise or run down in such circumstances whilst additional supply is sourced.

The most immediate impact would be on product imported into Darwin and North Western Australia, which is usually supplied from Singapore. Industry consultations indicated that the sailing time from Singapore to Darwin is around 7 days, which means that stocks on the water and in import terminals are likely to be sufficient for about 2 weeks on average. Sailing times from Singapore to import terminals further south on the East and West coasts of Australia are



around 14 days. Importers supplying these areas would have up to 2 weeks supply of product on the water and potentially another 1 to 2 weeks in import terminals.

Most Australian cargos are locked into the Australian market well before tankers sail, which would ensure supply in the first two weeks of the disruption. This, along with storage at import terminals, would provide a buffer period of between 2 to 4 weeks while importers sourced product from other sources to make up for the loss of product normally shipped from Singapore.

In the case of a Singapore disruption, supplies for Australia would be sourced from the spot market in the first instance. This would include diverting cargoes that would otherwise have been exported from the Asia-Pacific region.

Diesel that meets Australian specifications is a fairly fungible grade in Asia and industry consultations suggested that sourcing additional diesel from Asia would not be difficult. Australian-specification petrol (ULP) is less fungible. However, Japanese and Korean refineries can supply ULP to Australian specification, as can newer refineries in India and refineries in the Middle East. Supplies from Japan and South Korea can take up to 4 to 6 weeks from contracting supply to delivery at Australian ports. Sailing time from India and the Middle East is around 6 weeks. Industry advised that importers would take early action to secure additional supplies from these sources to ensure that the Australian market was supplied in the subsequent weeks.

In summary, stocks on the water and in terminals should be sufficient to supply the Australia market for between 2 to 4 weeks, depending on location in Australia. Additional supply sourced from the spot market would provide the first source of supply to replace that which would otherwise have been supplied from Singapore. Subsequent supplies would be procured from refineries in North Asia and further afield. Arranging these supplies would take around 2 to 4 weeks in the first instance according to industry sources. More remote supplies could come on line in subsequent weeks, depending on the duration of the disruption. Together these supplies would be sufficient to meet the Australian demand until supplies from Singapore could be fully restored. It is possible that full restoration of normal operations from Singapore could take up to 2 months.

While the disruption would require readjustment and rerouting of cargoes, the general view of the industry and ACIL Tasman's research into recent interruptions to supply, is that the market would be able to respond and readjust the supply lines to replace supplies lost from Singapore. Prices would rise in the interim - the extent of the rise would depend on the net amount of product taken out of the market, the extent of precautionary buying by market participants and any release of government-controlled stocks, such as under coordinated responses by IEA member countries.



## 6.5 Comparison with Hurricanes Katrina and Rita

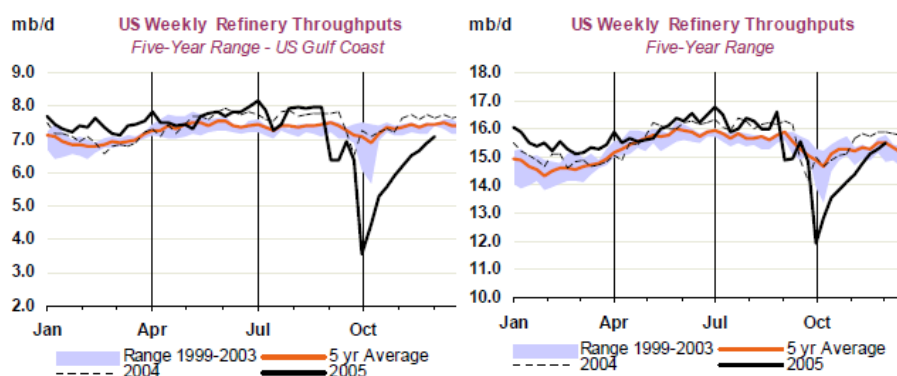
It is useful to compare the “shock scenario” of a hypothetical temporary loss of supply of 1,336,000 barrels per day of refined petroleum products from Singapore with the supply disruption caused by Hurricanes Katrina and Rita in the Gulf of Mexico in late-August 2005 and late-September 2005, respectively. The value of this comparison derives from the fact that Singapore’s refinery capacity is of a similar order of scale to the temporary loss of oil refinery production in the Gulf of Mexico.

### 6.5.1 Hurricanes Katrina and Rita

Following Hurricane Katrina, refined petroleum production capacity in the Gulf of Mexico fell initially by about 2 mbd, with some production resuming after 1-2 weeks and other capacity not being available for more than three months (U.S. Congressional Research Service, 2005). In the month immediately following Hurricane Katrina, the average loss of refinery throughput was 1.57 mbd. North American refinery throughputs for September 2005 were approximately one million barrels a day lower than the same period in 2004 (Energy Information Administration, 2010).

More capacity was taken out of service following Hurricane Rita. The peak net loss of capacity exceeded four mbd in early-October 2005. Throughput of Gulf Coast refineries was down by over three million barrels a day around that time.

Figure 17 U.S. Weekly Refinery Throughput



Data source: IEA Oil Market report - December 2005

August is typically the summer peak period for refinery throughput in the United States, while September and October are normally months characterised by depressed refinery throughput, about one million barrels a day less, as maintenance takes place. Figure 17 clearly depicts that this usual seasonal drop in refinery crude runs was amplified by the strong hurricane season.

The Hurricane Katrina supply shock was more complicated than the hypothetical Singapore refined product supply shock. In the Gulf of Mexico, crude oil output fell, as well as refined commodity production. Gulf of Mexico crude oil production was reduced by more than 1.37

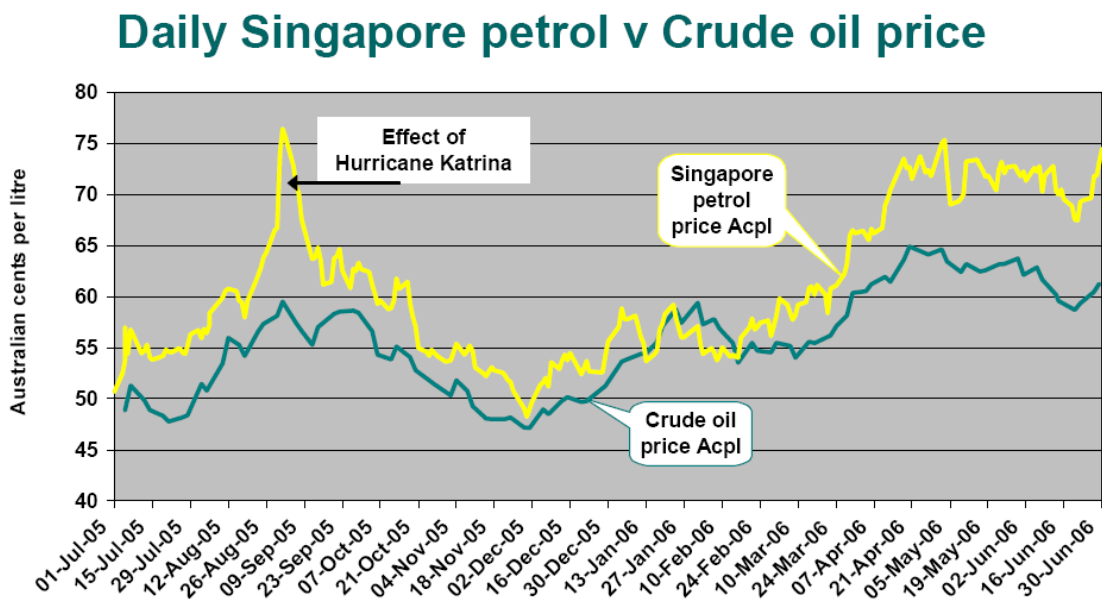


mbd (U.S. Energy Information Administration, 2005). In addition, there was an International Energy Agency (IEA) emergency supply response (discussed briefly below).

The supply disruption caused by Hurricane Katrina resulted in an increase in United States petrol prices of about 18 per cent over the following days. Because there is an integrated international market for crude oil and refined petroleum products, this substantial supply loss affected prices globally. This is illustrated by Figure 18 and Figure 19.

A striking feature of Figure 18 is that export petrol prices from the refining and trading hub of Singapore, the benchmark for Australian retail prices, rose substantially relative to crude oil prices. Figure 19 shows clearly that retail petrol prices in Australia and Europe have moved with prices in the United States, with the price shifts associated with the effects of the Hurricane Katrina supply disruption from late-August 2005 clearly evident.

Figure 18 **Singapore Export Petrol Price Movements Compared with Crude Oil Price Movements in 2005-06, Highlighting Effect of Hurricane Katrina**

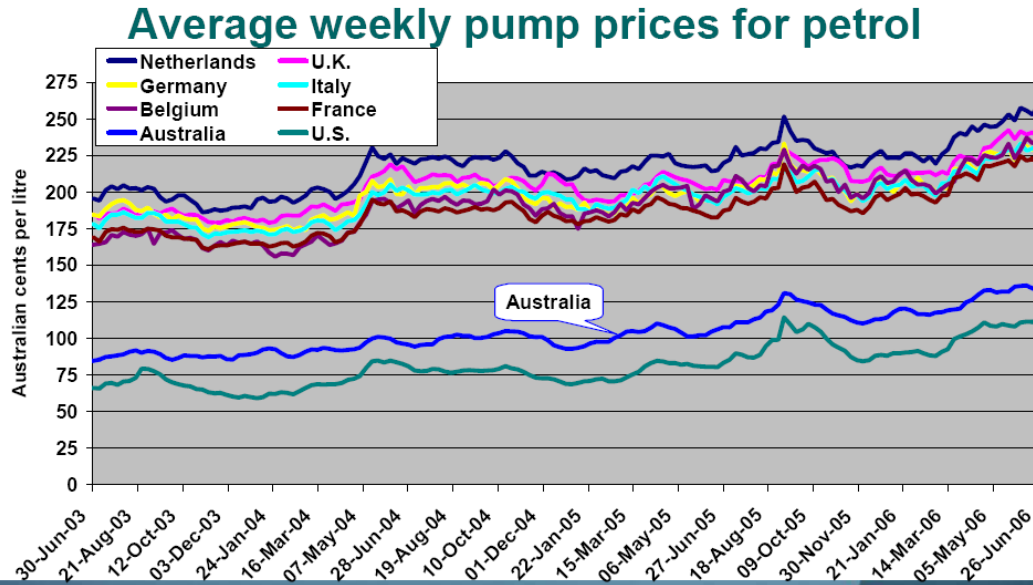


<sup>a</sup> Acpl – Australian cents per litre

Data source: Caltex Australia (2006).



Figure 19 Retail Petrol Prices in United States, Australia, and Europe – 2003-04, 2004-05 and 2005-06



<sup>a</sup> Acpl - Australian cents per litre

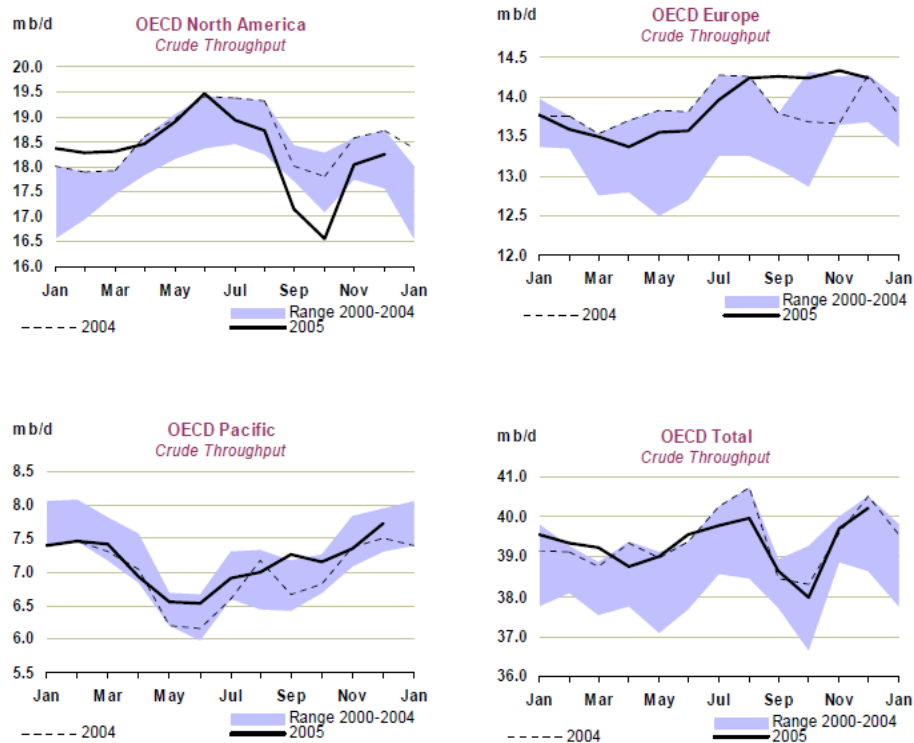
Data source: Caltex Australia (2006).

It is important to note that the integrated market not only resulted in prices moving together around the world, but also moderated the effect that the supply disruption would have caused in the United States if that economy had not been open to imports from the rest of the world.

OECD refinery throughputs in September 2005 rose by 59 thousand barrels a day, relative to the same month in the preceding year. This increase was achieved despite the disruption to U.S. Gulf Coast refinery operations. Runs in OECD Europe increased by 0.427 million barrels a day, and in the OECD Pacific runs increased by 0.625 mbd, compared to the previous year (see Figure 20). The IEA explained that approximately 0.33 million barrels a day of this 1.05 million barrel a day increase in throughput outside the US could be attributed to lower scheduled refinery maintenance in Europe and the Pacific, suggesting that the remaining 0.72 million barrels a day of the extra refinery runs were induced by market forces. These are reflected by increases in refining margins shown in Figure 18.



Figure 20 International refinery throughput in response to Hurricanes Katrina and Rita



Data source: IEA Oil Market Report – February 2006

It should be noted that the effects of the supply disruption caused by Hurricane Katrina were muted by IEA action. All 26 IEA members agreed on 2 September 2005 to make available 60 million barrels through a combination of emergency response measures, including use of emergency stocks, increased production, and demand restraint. Nearly 29 million barrels of crude oil and products were drawn from government stocks, and an additional 23 million barrels were made available by reducing private sector stockholding obligations. Refined products represented almost half of the 52 million barrels of emergency stock releases (IEA, 2008).

The IEA action would have reduced the period of time the refined product price spike lasted. By increasing supply it would have caused a drop in product prices. By reducing uncertainty regarding supply, it would have induced a reversal of precautionary or speculative demand buying in response to the supply shock. This reversal may also have prevented a higher product price peak.

The price impact of the Hurricane Rita supply disruption was much less than for Katrina (see Figure 18 and Figure 19), for at least two reasons. First, IEA action helped offset supply losses. Second, imports of refined products induced by the Katrina price spike arrived at record rates during the three weeks following Cyclone Rita (see Box 4)

**Box 4 Katrina and Rita Supply Shocks and Market Forces**

“The Katrina-generated spike in gasoline prices sent a signal heard around the world. .... gasoline tankers raced to the U.S. and in particular to the highest priced market, the Gulf Coast. ‘The cavalry came in the form of the surge in gasoline imports’, summarised the Energy Information Administration, ‘setting all-time records in three successive weeks ..... that was critical in helping to keep gasoline prices from going higher following Hurricane Rita and to help them start dropping substantially thereafter.’”

Source: Bradley, Tanton (2007), p.6.

By the end of November 2005, refinery throughput rates for the US petroleum refining industry overall were back to normal levels for that time of year, although Gulf Coast throughput rates still had not fully recovered to normality (see Figure 17 and Figure 20). As US refinery throughput rates recovered, imports of refined products declined (Bradley, Tanton, 2005).

**6.5.2 Hypothetical Singapore Capacity Outage**

The integrated international market for refined petroleum products and the size of the hypothetical Singapore supply shock would mean that the loss of supply of refined products from Singapore for 30 to 60 days would be important globally, not just regionally, just as the supply interruption in the Gulf of Mexico caused by Hurricane Katrina had been from late-August 2005.

Such a supply disruption would induce customers of Singapore’s petroleum refining industry to bid up prices for refined products to obtain supplies from alternative sources. Users of refined products elsewhere in the integrated international market would have to pay higher prices to retain supply. Higher prices would ration available supply by reducing quantity demanded. Higher prices would also call forth some additional supply from sources with spare capacity. Supply made available in these ways would be reallocated to those prepared to pay higher prices to replace output lost from Singapore’s refineries.

The increases in prices of refined products globally would be smaller than the regional price increases would have been if countries supplied by Singapore were unable to source products elsewhere and take advantage of the effect of higher global prices on quantities demanded and supplied throughout the world.

Because price elasticity of demand and supply for refined petroleum products (responsiveness of demand and supply to price changes) tends to be very inelastic or low (ignoring the negative sign) in the short-term, the percentage increase in price required to clear the market following a temporary supply reduction is likely to be much higher than the percentage reduction in supply. Very inelastic demand and supply characteristics in the short-term mean shocks that do not seem large from a global perspective can still have large price effects.



For example, a short-term price elasticity of demand of  $-0.05$ , combined with a price elasticity of supply of  $0.05$  in the short-term, would mean that a 10 per cent increase in price would result in a one per cent reduction in quantity demanded. Alternatively, a one per cent reduction in supply would lead to a price increase of 10 per cent.

There is no logical reason why price in an unfettered market would not rise quickly and sufficiently enough to clear the market quickly, following an important supply shock, such as the hypothetical Singapore petroleum refining industry outage. This remains true even when short-term price elasticities of demand and supply are very low. Such elasticities simply mean that the market clearing price change has to be substantial. Moreover, precautionary/speculative demand increases could push the price even higher.

IEA intervention could be expected to reduce the period of time for which the price spike lasts, for reasons outlined in the previous sub-section. The extent to which it would reduce the height of the price spike would depend upon the time lag between the revelation of the shock and announcement of a response. Government intervention to regulate refined product prices in some or all uses would have perverse consequences. Then, shortages would persist, with scarce supply rationed by queuing or some administrative device.

## 6.6 Short-Term Price Elasticity of Demand

Sub-sections 6.6.1 and 6.6.2 below add to the discussion of price elasticity of demand in sub-section 5.3.2.

### 6.6.1 Available Estimates

There are many widely cited estimates of short- and long-term price elasticity of demand for automotive fuel covering various OECD countries.<sup>18</sup> Invariably, estimated long-term elasticities have been substantially higher (ignoring the negative sign) than short-term elasticities, because opportunities to adjust fuel-use tend to increase with time.

A recent review by Dahl (2011) of hundreds of studies, relating to about 65 countries, found that the range of price elasticities of demand for diesel tended to be slightly higher (ignoring the sign) than those for petrol, although the median elasticity estimate for petrol was about double that for diesel. Unfortunately, Dahl focused on long-term elasticities, rather than short-term elasticities, which are relevant to the analysis of short-term shock in this chapter. Estimates of elasticities for petrol were substantially more numerous than those for diesel.

In contrast, Chesnes (2009) indicated price elasticity of demand for diesel could be double or more (ignoring the negative sign) the price elasticity of demand for petrol. On the other hand, the Bureau of Infrastructure Transport and Regional Economics (2008) suggested that price

---

<sup>18</sup> For example, see Espey (1998), Graham and Glaister (2002), Hughes, Knittel and Sperling (2008), Brons, Nijkamp, Pels, Rietveld (2008), Breunig and Gisz (2009), Hymel, Small and Van Dender (2010), and Dahl (2011).





elasticity of demand for diesel fuel in trucks was less in the long-term than for petrol and diesel in light vehicles.

Because the focus of the “shock scenario” is a short-term supply interruption, estimates of short-term price elasticity of demand are relevant for ascertaining product price changes in response to a short-term supply loss. Estimates of short-term price elasticities of demand vary widely between analysts, countries and categories of countries. Among OECD countries, estimates tend to be considerably lower for Australia, Canada and the United States than for European countries (Breunig, Gisz, 2009; Brons, Nijkamp, Pels, Rietveld, 2008; Graham, Glaister, 2002; Espey, 1998). Also, Dargay, Gamely and Huntington (2007) have estimated that price elasticities are much lower in countries outside the OECD that are growing relatively quickly, including China, than in OECD countries overall. A review of estimates by Dahl (2011) confirmed that elasticities were lower for rapidly developing economies than OECD countries, but the difference was not large.

Since a short-term supply interruption from Singapore would affect product prices globally, it would be appropriate to use elasticity estimates representative of global demand, not those relating to one country or region. For OECD countries, surveys by Espey (1998) and Graham and Glaister (2002) have suggested estimates of short-term price elasticity of demand around  $-0.25$ . A different survey approach used by Brons, Nijkamp, Pels and Rietveld (2008) suggested short-term price elasticity of demand estimates around  $-0.35$ .

In contrast, Breunig and Gisz (2009) estimated the short-term price elasticity of demand for Australia to be in the range  $-0.1$  to  $-0.14$ . Graham and Glaister (2002) reported a short-term price elasticity of demand of  $-0.05$  for Australia.

Hymel, Small and Van Dender (2010) estimated short-term price elasticities of demand for the United States of  $-0.054$  to  $-0.075$ , depending on the data set used. Hughes, Knittel and Sperling (2008) provided comparable United States estimates. In contrast, Kilian and Murphy (2010) claimed these estimates were too low (ignoring the negative sign), because they did not take into account endogeneity of the price of crude oil and products. They provided an estimate of about  $-0.26$ .

Allowing for price elasticities of demand in China and other rapidly growing non-OECD economies that are less than those for the OECD overall, and price elasticities of demand for products that are no less than and up to twice those for crude oil, suggests short-term price elasticities of demand in the range  $-0.1$  to  $-0.17$  for rapidly growing non-OECD countries, and an indicative overall global range of  $-0.15$  to  $-0.25$ .

### **6.6.2 Implications of Estimates of Short-Term Price Elasticity of Demand**

Since a short-term loss of supply of products from Singapore would represent a cut in world supply of around 1.72 per cent, the price increases suggested by indicative estimates of global short-term price elasticity of demand cited above would be as shown below (assuming completely inelastic supply):



-0.15	→	11.5 per cent price increase
-0.25	→	6.9 per cent price increase.

The sensitivity of price increases to the short-term price elasticity of demand is obvious. To further illustrate this point, a short-term price elasticity of demand of  $-0.1$  would result in a price increase of 17.2 per cent, and an elasticity of  $-0.3$  would mean a 5.7 per cent price increase.

Estimates of short-term price elasticity of demand typically relate to a concepts of “short-term” that are considerably longer than the period of the hypothetical Singapore supply shock of 30 days nominally, and 45 to 60 days effectively. Therefore, it would be reasonable to consider lower elasticities (ignoring the negative sign) than those above. An indicative range could be:

-0.05	→	34.4 per cent price increase
-0.1	→	17.2 per cent price increase
-0.15	→	11.5 per cent price increase.

A supply shock removing 1,336,000 barrels per day of refined products (Singapore’s refining capacity, which is about 1.72 per cent of global capacity) from the integrated world market would require a proportionate increase in price of 11.5 per cent to clear the market if short-term price elasticity of demand is  $-0.15$  and supply is completely inelastic in the short-term (price elasticity of supply is zero).

Price increases based on short-term price elasticities of demand would be moderated to the extent that higher prices induce supply of additional quantities of products in the short-term. The larger the price elasticity of supply (responsiveness of quantity supplied to price changes), the more muted the price increase would be following a supply reduction.

## 6.7 Short-Term Price Elasticities of Supply

Price elasticity of supply (responsiveness of quantity supplied to price changes) is likely to be relatively low in the very short-term, when opportunities to adjust quantity supplied are particularly limited. It typically increases over time as more and more opportunities to adjust quantity supplied become available. In the long-term, additional import facilities and petroleum refineries can be built and new crude oil sources can be discovered and tapped. Of course, commissioning of new facilities can take several years because of various lags in the investment process, as explained in sub-section 5.3.2.

Price elasticity of supply is likely to be positive, not zero, even in the short-term. To the extent that refineries have spare capacity or even if they can make minor adjustments to squeeze out some extra output, short-term price elasticity of supply (**Es**) will be positive, and the price increase from the supply shock will be moderated. For example, if **Es** is assumed to be 0.05, and short-term price elasticity of demand (**Ed**) is  $-0.15$ , the proportionate price change is an increase of 0.086 (8.6 per cent). If **Es** is assumed to be 0.05, and **Ed** is  $-0.05$ , the proportionate



price change is an increase of 0.172 (17.2 per cent). Alternatively, if **Es** is assumed to be 0.3, and **Ed** is -0.05, the proportionate price change is an increase of 0.049 (4.9 per cent).

It is important to estimate price elasticities of supply and demand on a consistent basis and avoid using elasticities calculated on different bases when estimating the price shock resulting from a supply shock. Ex-refinery prices and final sales prices differ because of fuel taxation, GST (or other consumption taxes outside of Australia), shipping, storage and distribution costs and wholesale and retail margins. Therefore, estimates of elasticities will differ at retail and ex refinery price levels. If both elasticities relate to the final point of sale, the price shock estimated to result from a supply shock will be the price change at the retail level. If both elasticities are linked to the ex-refinery prices, the price shock will be the price shift at the refinery gate. If the elasticities are calculated at different reference points in the supply chain, the resulting estimate of the price movement will be spurious.

In addition, estimation of short-term price elasticities of supply is problematic. It will vary with the availability of spare refining capacity, flexibility in respect of timing of programmed maintenance, time required for adjustments to production, and flexibility relating to regulation of product specifications, other aspects of refining operations, private sector stockholdings, government emergency stockholdings and pricing of releases, and regulatory constraints on use of inventories.

For example, it is understood that prior to the disruption of petroleum refinery production in the Gulf of Mexico by Hurricanes Katrina and Rita, there was little spare refining capacity available globally (Kilian, 2010b; Zhang, 2011). This would have meant that short-term refinery supply was very inelastic (price elasticity of supply very low). However, the disruptions occurred when demand normally declined and maintenance was undertaken. Moreover, the IEA agreement on 2 September 2005 partly bypassed the problem of very inelastic short-term supply by ratifying releases of government stocks and adjustments to mandated private sector stockholding requirements to provide about 25 million barrels of refined products. These arrangements would have effectively created significantly more elastic supply conditions in the very short-term to the extent that stock releases were not made at prices fully reflecting the opportunity cost of the market value of crude oil and refined products at the time.

Kilian (2010b) pointed out that if there is little spare refining capacity before a major loss of capacity, such as occurred following Hurricane Katrina, crude oil prices could fall as a result of reduced demand from remaining refineries. Of course, if there is sufficient spare refining capacity to make up for the shock of loss of refining capacity, and that capacity can be quickly utilised, crude oil prices would not change.

In the case of Hurricane Katrina, the circumstances were complicated by a disruption to crude oil supply as well as refined products, and by the IEA action. The stock releases by IEA members largely offset the temporary loss of crude oil production, but only partly offset (around 50 per cent) the initial loss of refined products capacity. The refined product stock releases offset only about one quarter of the peak net loss of capacity caused by Hurricanes



Katrina and Rita. Crude oil price rises were avoided (see Table 17), because of reduction of refining capacity and throughput, and release of crude oil stocks.

**Table 17 IEA Crude Oil Price Differentials – Selected Monthly Averages 2005**

	Jul	Aug	Sep	Jul-Sep	Jul-Sep	Week Commencing				
	\$/bbl	\$/bbl	\$/bbl	Change	%	5 Sep	12 Sep	19 Sep	26 Sep	3 Oct
<b>Crudes</b>										
Brent Dated	57.58	64.12	62.91	-1.21	-1.9	63.22	61.12	63.57	62.31	59.03
WTI Cushing 1mth (adjusted)	58.68	64.96	65.52	0.56	0.9	64.84	63.86	66.15	66.07	63.05
Urals (Mediterranean)	55.02	58.61	58.38	-0.23	-0.4	58.07	56.32	59.59	58.50	56.54
Dubai 1mth (adjusted)	52.83	56.60	56.54	-0.06	-0.1	56.69	55.50	56.81	56.15	55.31
Tapis	59.70	67.26	67.64	0.38	0.6	68.47	66.75	67.46	66.54	64.52
<b>Differential to Dated Brent</b>										
WTI Cushing 1mth (adjusted)	1.10	0.84	2.61	1.77		1.62	2.73	2.58	3.76	4.00
Urals (Mediterranean)	-2.56	-5.5	-4.53	0.97		-5.15	-4.81	-3.98	-3.81	-2.79
Dubai	-4.75	-7.52	-6.37	1.14		-6.53	-5.63	-6.76	-6.17	-3.71
Tapis	2.12	3.14	4.73	1.59		5.25	5.63	3.89	4.22	5.49
<b>Prompt Month Differential</b>										
Brent 1mt-2mth (adjusted)	-0.72	-0.45	-0.68	-0.23		-0.71	-0.64	-0.84	-0.65	-0.65
WTI Cushing 1mth-2mth (adjusted)	-1.21	-0.63	-0.33	-0.23		-0.56	-0.06	0.01	0.23	0.23

Note: Weekly data for Brent and WTI 1<sup>st</sup> month and 2<sup>nd</sup> month are unadjusted

Source: IEA Oil Market Report - October 2005.

In the United States and Europe, refining margins rose to record levels. Asian margins improved significantly, though gains proved relatively modest compared to the United States. These changes in refining margins are shown in Table 17. The change in Singapore refining margins is evident in Figure 14, as well as being documented in Table 17.

The IEA stated that the regional differences were a function of proximity to, and product arbitrage opportunities with, the United States. US Gulf Coast refining margins on domestic grades peaked at record highs in September, driven by surging gasoline prices (see Table 18).

Substantial surplus petroleum refining capacity appeared as a result of reduced economic activity following the global financial crisis in the second half of 2008 and during 2009 (IEA, 2009; Zhang, 2011). Despite significant additions of new capacity commissioned in 2009 and smaller subsequent additions, the surplus has been shrinking and is expected to continue doing so, at least until 2015, because of demand growth and refinery closures. In 2015 and 2016, major additions of refining capacity are scheduled to be commissioned in the Middle East and Asia (Zhang, 2011).



Table 18 Comparative International Refining Margins, September 2005

Selected Refining Margins in Major Refining Centres (\$/bbl)										
		Monthly Average			Change			Week Ending:		
		Jul 05	Aug 05	Sep 05	Sep05- Aug05	02 Sep	9 Sep	16 Sep	23 Sep	30 Sep
<b>NW Europe</b>	Brent (Cracking)	4.74	4.28	10.82	6.54	13.84	9.93	6.86	8.88	12.99
	Urals (Cracking)	5.98	8.02	12.76	4.74	16.54	11.78	8.94	10.63	14.37
	Brent (Hydroskimming)	-0.89	-2.44	4.10	6.54	4.96	3.15	1.34	3.09	6.41
	Urals (Hydroskimming)	4.97	7.10	11.75	4.64	14.71	10.60	8.28	10.31	12.65
<b>Mediterranean</b>	Es Sider (Cracking)	4.34	7.19	12.17	4.98	15.24	10.74	9.14	10.47	13.33
	Urals (Cracking)	4.34	7.19	12.17	4.98	15.24	10.74	9.14	10.47	13.33
	Es Sider (Hydroskimming)	-0.36	0.12	4.87	4.78	5.72	4.00	2.67	3.91	5.82
	Urals (Hydroskimming)	-3.27	-2.17	2.68	4.85	3.64	1.30	1.57	1.31	3.96
<b>US Gulf Coast</b>	Brent (Cracking)	0.23	3.89	17.71	13.85	17.38	10.50	3.20	19.50	27.57
	LLS (Cracking)	3.02	6.77	19.07	12.30	19.99	11.97	4.75	20.11	30.93
	Mars (Cracking)	0.05	3.98	12.95	8.97	13.88	8.35	0.01	15.31	21.07
	Mars (Coking)	6.49	12.55	24.05	11.50	25.52	17.69	7.10	26.12	34.98
	Maya (Coking)	11.57	18.40	29.63	11.23	31.93	23.82	12.92	31.52	37.59
<b>US West Coast</b>	ANS (Cracking)	4.22	6.22	12.21	5.99	15.23	8.86	8.52	11.96	15.01
	Kem (Cracking)	3.70	3.30	9.13	5.83	7.15	7.46	6.18	8.03	11.60
	Oman (Cracking)	4.33	8.54	14.07	5.53	16.17	10.06	8.56	12.64	17.11
	Kem (Coking)	18.45	20.52	25.32	4.80	28.27	21.38	18.44	22.13	26.90
<b>Singapore</b>	Dubai (Hydroskimming)	-1.89	-1.96	2.64	4.60	4.76	2.61	1.87	2.11	3.83
	Tapis (Hydroskimming)	-2.32	-5.40	-1.95	3.45	-0.99	-2.37	-2.86	-2.07	-0.85
	Dubai (Hydrocracking)	2.67	3.18	7.78	4.60	10.45	7.86	6.58	6.82	8.77
	Tapis (Hydrocracking)	-0.26	-3.05	0.99	4.05	2.79	0.57	-0.21	0.65	2.15
<b>China<sup>a</sup></b>	Cabinda (Hydroskimming)	-0.52	-4.02	0.26	4.28	-0.36	0.20	1.32	0.92	1.52
	Daqing (Hydroskimming)	-1.52	-2.52	-0.68	1.84	-2.23	-0.90	-0.80	-0.67	-0.28
	Dubai (Hydroskimming)	-2.33	-2.26	2.36	4.59	4.37	2.31	1.64	1.75	3.52
	Daqing (Hydrocracking)	1.64	1.96	4.87	2.95	5.28	4.91	4.32	4.16	4.74
	Dubai (Hydrocracking)	2.25	2.91	7.52	4.61	10.09	7.61	6.40	6.49	8.47

<sup>a</sup> The China refinery margin calculation represents a model based on spot product import/export parity, and does not reflect internal pricing regulations

*Note:* For the purposes of this Report, refining margins are calculated for various complexity configurations, each optimized for processing the specific crude in a specific refining centre on a "full-cost" basis. Consequently, reported margins should be taken as an indication, or proxy, or changes in profitability for a given refining centre. No attempt is made to model or otherwise comment upon the relative economics of specific refineries running individual crude slates and producing custom product sales, nor are these calculations intended to infer the marginal values of crudes for pricing purposes.

Source: IEA Oil Market Report - October 2005 Interacting Oil Price Shocks

Important issues that must be taken into account when developing an oil products supply shock scenario are that there may be more than one shock influencing prices simultaneously, and that these shocks may interact with each other. The shocks may reinforce or moderate the effects of others. They may influence prices at different speeds and to apply for different periods.

As explained in sub-section 5.4.4, oil product price shocks could arise from:



- *crude oil supply shocks* (pass through of crude oil price increases);
- *aggregate demand shocks* (global growth of demand for goods and services generally);
- *precautionary or speculative crude oil demand shocks* (pass through of crude oil price increases);
- *precautionary or speculative refined product oil demand shocks*; and
- *refined product supply shocks*.

A refined products supply shock scenario, such as a temporary loss of refinery production from Singapore, could trigger a precautionary refined product demand shock. Obviously, a refinery supply shock of the magnitude of a short-term loss of supply of refined products from Singapore would result in considerable uncertainty regarding its duration and significance. It would also cause changes in perceptions of uncertainty regarding future shortfalls. Therefore, it may persist even after supply had been restored to pre-shock levels.

It is difficult to assess how much a precautionary oil demand shock arising from such “expectations shifts” would add to the price increase from the short-term oil product supply shock, and how long the effects on real refined product prices might persist. The magnitude and timing of effects would depend on the broader economic context, including the contemporaneous existence of other types of shock. The complexities of compound shocks have been discussed in sub-section 5.5.6 above.

Of course, it is important to reiterate another important contextual matter. In the short-term, price elasticities of demand and supply for refined products tend to be very low, as explained above. As the time-frame increases, price elasticities of demand and supply typically increase because of the availability of more and more opportunities to make adjustments to usage and production.

Price elasticity of supply for products in the short-term will vary according to the extent there is spare capacity.<sup>19</sup> This will vary with economic conditions including the co-existence of other shocks, as discussed sub-section 5.5.6. It is possible that short-term price elasticity of demand might also vary with economic circumstances, including the concurrent influence of other shocks. Specifically, changes in prices and incomes might affect short-term price elasticity of demand, although there is some debate about this matter, as indicated in sub-section 5.5.6.

---

<sup>19</sup> Inventories can be drawn-down in the very short-term, but this does not necessarily mean high price elasticity of supply in the very short-term, because inventories have an opportunity cost. They could be sold at the higher market price following a cut in supply or increase in demand.



## 6.8 Potential Price Shocks

The preceding analysis indicates that estimation of the potential refined product price shock resulting from a temporary shut-down of liquid petroleum trade with Singapore requires consideration of:

- any pass-through of changes in crude oil prices;
- price elasticity of demand for refined oil products in the shut-down period;
- price elasticity of supply for refined products in the shut-down period; and
- precautionary or speculative demand effects.

As explained above, it is expected that crude oil prices would either fall slightly or not change if liquid petroleum trade between Singapore and the rest of the world was temporarily suspended. For the purposes of the modelling in this study, it has been assumed that crude oil prices do not change.

It was assumed that Singapore would re-enter the crude oil market in month 2, but lags associated with inward and outward shipping times and production processes mean that Singapore product would not be available internationally in month 2. For month 3, it was assumed that supply from Singapore to the international market would return to pre-shock levels.

In the very short-term, the price elasticity of demand for refined petroleum products is extremely low (ignoring the negative sign), and rises over time as opportunities expand for economic entities to make adjustments. This has been explained above. In view of the available estimates in the economics literature, it has been assumed that price elasticity of demand globally in the first month from commencement of a disruption in 2011 averages  $-0.1$ . In the second month, it has been assumed to average  $-0.15$ .

For reasons explained in sub-section 5.3.2 above, price elasticity of supply for refined petroleum products is also extremely low in the very short-term and increases only slowly over time as opportunities to make adjustments increase. Even when there is significant spare capacity globally, practical issues discussed in sub-section 6.4.2 above mean very short-term price elasticity of supply would be extremely low.

Therefore, for illustrative purposes, it has been assumed that price elasticity of supply for refined products in the current context of significant spare refining capacity averages  $0.04$  in the month following commencement of the oil product supply shock and averages  $0.1$  in the second month, recognising that the passing of time increases opportunities for refiners and transport and logistical service providers to respond. On the basis of these assumptions, the average price increase required to clear the market would be about  $12.3$  per cent in the first month, around  $6.9$  per cent in the second month, and zero in the third month after the supply shock in the current (2011) refining capacity context. A speculative or precautionary demand surge could be expected in response to a temporary shut-down of petroleum trade with Singapore. This would be prompted by uncertainty regarding the length of the shut-down and



logistical issues. Having regard to market behaviour following refining disruptions to petroleum refining in the Gulf of Mexico following Hurricane Katrina in 2005, the IEA response in that case (but not Singapore), the greater initial uncertainty regarding duration of the Singapore outage,<sup>20</sup> and the smaller amount of spare global refining capacity in 2005 than in 2011, it has been assumed for illustrative purposes that speculative demand would add 5.7 percentage points in 2011 to the price increase in the first month following the Singapore supply shock, falling to 3.7 percentage points in month 2, and to 2 percentage points in month 3.

These assumptions and consequential price increases from a Singapore supply shock in 2011 are summarised in Table 18 below. Price increases for month 1, month 2, and month 3 relative to pre-shock prices are 18 per cent, 10.6 per cent and 2 per cent respectively.

In the case of a 2015 Singapore supply shock, lower price elasticities of supply of petroleum products were assumed than in 2011, because current surplus refining capacity is expected to gradually decline at least until 2015, when major additions of refining capacity are scheduled to be commissioned in the Middle East and Asia (Zhang, 2011). In that context, it has been assumed that price elasticity of supply averages 0.02 in the month following the hypothetical Singapore shut-down and 0.05 in the next month. Consequently, the price increase would average around 14.3 per cent in month one, about 8.6 per cent in month 2, and zero in month 3.

Uncertainty and therefore, the speculative demand increase would be greater in the context of little spare refining capacity expected globally in 2015. Therefore, it has been assumed that speculative demand lifts the price increase in the month following the shock by 6.7 percentage points, falling to 5.4 percentage points in month 2, and 3.5 percentage points in month 3.

These assumptions and consequential price increases from a Singapore supply shock in 2015 are summarised in Table 19 below. Price increases for month 1, month 2, and month 3 relative to pre-shock prices are 21 per cent, 14 per cent and 3.5 per cent respectively.

The price movements resulting from a supply shock and an accompanying consequential precautionary or speculative demand shock are illustrated in Figure 21. It should be noted that the supply and demand curves have been depicted as flatter than would be consistent with low elasticities for illustrative purposes.

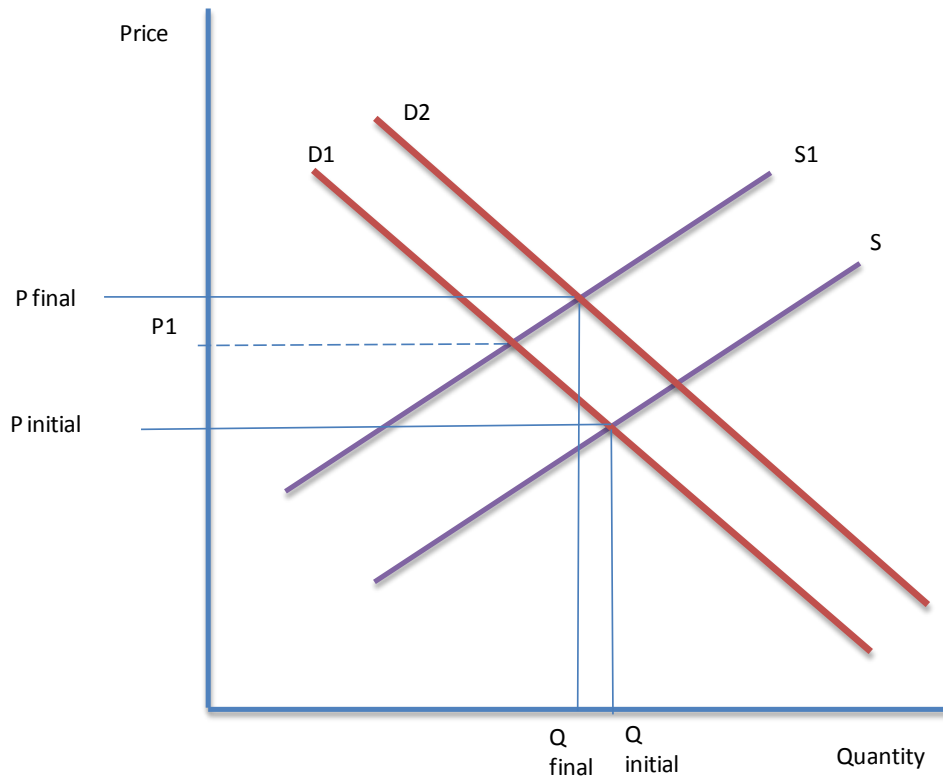
---

<sup>20</sup> In the days following Hurricane Katrina information was available on which refineries were affected and to what degree. In the hypothetical Singapore case, it is unlikely that there would be any indication in month 1 as to when Singapore will re-enter the market.





Figure 21 Illustrative price movements



Note: Both the supply and demand curves will be significantly steeper than depicted in this diagram. Flatter curves have been presented to illustrate the impact of price movements on supply and demand.

Source: ACIL Tasman

Before the shock, the equilibrium quantity of petroleum products sold in the global market is **Q initial** and the price is **P initial**. The shock reduces supply in the market to the supply curve **S1** and the price rises to **P1** in line with the price elasticity of demand and supply effects. Precautionary/speculative buying then raises the demand curve from **D1** to **D2** and the price rises to **P final**. The net reduction in quantity supplied is **Q initial - Q final**.

## 6.9 Quantitative assessment of economic effects of price shocks

### 6.9.1 Approach

Assumptions regarding global short-term price elasticities of supply and demand for refined petroleum products, the proportion of total traded petroleum product lost from the market in the event of Singapore's removal from the market, and precautionary demand assumptions were used to generate the expected global price impact of the hypothetical shock. The price shocks were calibrated to ACIL Tasman's computable general equilibrium (CGE) model to analyse the market response and its sectoral and macroeconomic implications. Details of the model are provided in Appendix C. For this analysis, the model was converted to solve on a monthly basis to better characterise the scenario and to enable better estimation of the economic impacts.



### 6.9.2 Price Shocks

The formulation in sub-section 6.9 of the price shocks used in the CGE modelling is summarised in Table 19 and Table 20.

**Table 19 Percentage price change with current Asian spare capacity**

	Month 1	Month 2	Month 3
Elasticity of demand	-0.10	-0.15	na
Elasticity of supply	0.04	0.10	na
Percentage change in quantity	-1.72	-1.72	0.00
Percentage change in price	12.3	6.9	0.00
Assumed impact of precautionary demand	5.7	3.7	2.00
Percentage change in price	18.00	10.6	2.00

Note: na = not applicable

Data source: ACIL Tasman analysis.

**Table 20 Percentage price change with medium term Asian spare capacity**

	Month 1	Month 2	Month 3
Elasticity of demand	-0.10	-0.15	na
Elasticity of supply	0.02	0.05	na
Percentage change in quantity	-1.72	-1.72	0.00
Percentage change in price	14.3	8.6	0.00
Assumed impact of precautionary demand	6.7	5.4	3.5
Percentage change in price	21	14	3.5

Note: na = not applicable

Data source: ACIL Tasman analysis.

### 6.9.3 Results

Refined petroleum products are an important source of fuel used in production processes throughout the economy. The ability to substitute alternative fuels in the short-run in many sectors is limited by technological and capital constraints. Thus, any significant rise in refined petroleum product prices would be expected to have an adverse impact on production in economy, which will in turn have flow-on consequences for aggregate demand.

#### Sectoral impacts

Table 21 shows the projected change in demand for refined petroleum products by sector in response to the oil price shock relative to the reference case occurring either now or in 2015. The results indicate that in general, the manufacturing and transport industries have the greatest ability to substitute across alternative fuel sources in response to a hypothetical shock in the short-term supply of refined petroleum products. This substitution effect can be seen by comparing the projected changes in petroleum demand in Table 21 with the projected percentage change in sectoral output in Table 22 (relative to the reference case).



Consumption of liquid fuels by the agriculture and mining sectors falls by around 2.1 per cent and 2.7 per cent in the first month respectively. This is achieved mainly by a modal shift from road to rail transport. Hence petroleum fuel use in transport falls by around 4.2 per cent at the same time.

Output in agriculture and mining falls by around 0.8 per cent in the first month whereas transport falls by around 4 per cent in part as a result of this switch.

**Table 21 Projected change in Australian demand for refined petroleum products by sector, relative to the reference case**

	Month 1	Month 2	Month 3	Month 4
	%	%	%	%
<b>2011</b>				
Agriculture	-2.1	-1.3	-0.2	-0.0
Transport	-4.2	-2.6	-0.5	-0.0
Mining	-2.7	-1.6	-0.3	-0.0
Manufacturing	-4.3	-2.7	-0.6	-0.0
Other	-2.1	-1.3	-0.2	-0.0
<b>2015</b>				
Agriculture	-2.5	-1.7	-0.4	-0.0
Mining	-3.3	-2.2	-0.5	-0.0
Transport	-5.1	-3.5	-0.9	-0.0
Manufacturing	-5	-3.6	-1.0	-0.0
Other	-2.6	-1.8	-0.5	-0.0

Data source: ACIL Tasman analysis.

**Table 22 Projected change in Australian output by sector, relative to the reference case**

	Month 1	Month 2	Month 3	Month 4
	%	%	%	%
<b>2011</b>				
Agriculture	-0.8	-0.5	-0.1	-0.0
Manufacturing	-0.1	-0.0	-0.0	0.0
Mining	-0.8	-0.5	-0.1	-0.0
Transport	-0.4	-0.2	-0.0	-0.0
Other	-0.9	-0.5	-0.1	-0.0
<b>2015</b>				
Agriculture	-0.8	-0.5	-0.1	-0.0
Mining	-1.2	-0.7	-0.2	-0.0
Manufacturing	0.1	0.1	0.0	0.0
Transport	-0.5	-0.3	-0.1	-0.0
Other	-1.2	-0.8	-0.2	-0.0

Data source: ACIL Tasman analysis



### **Wider economic impacts**

Table 23 and Table 24 decompose the projected changes in Australia's GDP as a result of the Singapore outage, relative to the reference case, for the four months following a hypothetical price shock occurring either now or in 2015. Table 23 presents the components of GDP calculated from the expenditure side of the economy: the sum of total private expenditure, government expenditure and the value of imports minus exports. Table 24 provides the breakdown of GDP into its components calculated on the income side: the sum of the value added (returns to factors in the form of wages and profits), tax revenues and the change output attributed to the productivity changes.

It is projected that, at the end of the first month, the price shocks associated with Singapore's exclusion from the petroleum product market will reduce Australia's real GDP by approximately \$791 million if it occurred in 2011 and by \$1,168 million if it occurred in 2015, relative to the reference case.

The greater loss in growth in 2015 is a product of the higher price spike associated with the projected reduced spare refinery capacity on the global market that is available to replace the product that had been supplied by Singapore. To place these numbers in perspective, the projected change in Australia's real GDP in 2011 and 2015 is equivalent to around 0.06 per cent and 0.07 per cent of annual GDP in those years (or approximately 0.72 per cent and 0.89 per cent of monthly GDP, respectively).

As would be expected, the results show that the impact of the shock is transitory, and once the announcement that Singapore has re-entered the market at the end of month 1, only a lag in the time taken for shipments to recommence and the assumed impact of lingering precautionary demand constrain output in the Australian economy at the end of month 4.



**Table 23 Projected change in Australian real GDP– Expenditure side (in 2010 terms)**

	Month 1	Month 2	Month 3	Month 4
	A\$ million	A\$ million	A\$ million	A\$ million
<b>2011</b>				
Change in private consumption	-706.87	-431.79	-93.42	-7.02
Change in government consumption	-241.30	-147.83	-31.73	-1.98
Change in investment	-152.54	-91.43	-19.16	-1.46
Change in real exports	-181.03	-103.50	-17.93	0.25
Contribution of change in real imports	490.29	295.36	60.06	0.68
<b>Total change in GDP (expenditure side)</b>	<b>-791.45</b>	<b>-479.19</b>	<b>-102.17</b>	<b>-9.55</b>
<b>2015</b>				
Change in private consumption	-1122.27	-781.28	-217.06	-12.68
Change in government consumption	-375.04	-261.55	-72.75	-3.69
Change in investment	-222.31	-151.62	-40.56	-1.87
Change in real exports	-193.69	-120.89	-26.34	0.46
Contribution of change in real imports	744.81	510.74	136.12	1.81
<b>Total change in GDP (expenditure side)</b>	<b>-1,168.51</b>	<b>-804.61</b>	<b>-220.59</b>	<b>-15.97</b>

Data source: ACIL Tasman

The total loss in GDP over the 4 months is \$1,382 million if the shock occurs in short term and \$2,210 million if it occurs in the medium term (around 2014). The difference between the two impacts reflects the fact that greater spare capacity in Asian refineries in 2011 results in a lower price impact.

On the expenditure side of the GDP equation, the decline in the growth of private consumption at the end of month 1 in 2011 and 2015 is projected to be \$706 million and \$1,122 million respectively. Since imports are a major component of private consumption, real imports also fall thereby offsetting the reduction in real GDP to some extent. However, the decline in international economic activity also means Australia experiences a decline in the demand for its exports and a decline in investment as the pool of global savings falls.

Projected changes in value added are shown in Table 24.



Table 24 Projected change in Australian real GDP — Income side (in 2010 terms)

	Month 1	Month 2	Month 3	Month 4
	A\$ million	A\$ million	A\$ million	A\$ million
<b>2011</b>				
Change in value added	-502.38	-304.41	-65.19	-6.44
Change in productivity	24.40	13.93	1.54	-1.65
Change in tax revenue	-313.47	-188.70	-38.53	-1.43
<b>Total Change in GDP (income side)</b>	<b>-791.45</b>	<b>-479.19</b>	<b>-102.17</b>	<b>-9.53</b>
<b>2015</b>				
Change in value added	-739.62	-509.84	-140.51	-11.15
Change in productivity	35.48	23.61	4.92	-1.99
Change in tax revenue	-464.36	-318.38	-85.00	-2.84
<b>Total Change in GDP (income side)</b>	<b>-1,168.51</b>	<b>-804.61</b>	<b>-220.59</b>	<b>-15.97</b>

Data source: ACIL Tasman

The projected change in value added in Table 24 is driven by the assumption that, in short run, real wages are rigid while demand for labour is flexible. Consequently, most of the adjustments on the productive side of the economy occur by reducing the quantity of factors of production employed.

Although the projected change in real GDP is a useful measure of the amount that the output of the Australian economy will change by, changes in the welfare of Australian residents are more important. In the modelling, changes in welfare are measured by the changes in real income which, at a national level, are synonymous with real gross national disposable income as reported by the Australian Bureau of Statistics (ABS).

The changes in real income are equivalent to the changes in real GDP, plus changes in net foreign income transfers plus the change in terms of trade (which measures changes in the purchasing power of a region's exports relative to its imports). The impact of the change in the terms of trade is of particular importance in this scenario, given that Australia is a net importer of petroleum products and the average price of imported commodities rises significantly under the scenarios.

The impact on real income is shown in Table 25. Real income at the end of the first month following the Singapore outage is projected to fall by \$1,127 million and \$1,954 million relative to the reference case in 2011 and 2015, respectively.

As with the projected changes in real GDP, the decline in the growth of Australia's real income is proportionate to the magnitude of the change in oil price for each month. Consequently, by the fourth month (when the price is only 2 per cent higher than it was prior to the shock) the reduction in Australian real income falls to \$10 million and \$17 million, relative to the reference case.

A large proportion of the projected loss in real income arises from a decline in Australia's relative purchasing power, shown by a decline in the terms of trade of \$503 million and \$900



million in 2011 and 2015 respectively. This is a result of Australia's dependence on imported petroleum products and the relatively inelastic demand for petroleum products in the short run.

Table 25 Projected change in Australian real income (in 2010 terms)

	Month 1	Month 2	Month 3	Month 4
	A\$ million	A\$ million	A\$ million	A\$ million
<b>2011</b>				
Change in GDP	-791.45	-479.19	-102.17	-9.53
Changes in terms of trade	-502.79	-313.72	-66.81	0.06
Changes in net foreign income transfers	67.50	44.07	9.41	-0.08
Total change in GNP	-1226.74	-748.84	-159.57	-9.55
<b>2015</b>				
Change in GDP	-1168.51	-804.61	-220.59	-15.97
Changes in terms of trade	-900.23	-638.78	-177.84	-0.80
Changes in net foreign income transfers	114.88	84.64	24.80	-0.63
Total change in GNP	-1953.86	-1358.75	-373.63	-17.40

Data source: ACIL Tasman analysis.

The total loss in real income in 2011 is estimated to be \$2,145 million, and in 2015 it is \$3,704 million.

## 6.10 Impact of the hypothetical supply shock on adequacy, reliability and affordability

The terms of reference required analysis of the impact of the hypothetical supply shock by reference to "adequacy", "reliability" and "affordability" of supply of liquid fuels. The *National Energy Security Assessment 2009* defined adequacy, reliability and affordability as follows (Department of Resources, Energy and Tourism, 2009, p. 5).

- **Adequacy** is the provision of sufficient energy to support economic and social activity.
- **Reliability** is the provision of energy with minimal disruptions to supply.
- **Affordability** is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.

The preceding analysis in this chapter indicates that, in response to a supply shock, such as a hypothetical temporary loss of supply of refined petroleum products from Singapore, the market system would ration and re-allocate reduced supply, and call forth some additional supply and allocate it, through price shifts. This would occur globally. Prices would change swiftly not only to deal with the initial supply shock, but also in response to adjustments to quantity supplied by refiners and others further downstream in the supply chain, and price-prompted adjustments to quantity demanded by refined product users and traders. These



automatic adjustments would continue as temporarily unavailable supply sources came back on line.

This automatic market-based adjustment process would, in conjunction with inventories, avoid shortages during the period until full restoration of supply. Avoidance of shortages appears to be central to the “reliability” criterion and an important aspect of the “adequacy” criterion.

The automatic market-based adjustment process would re-allocate supply of liquid fuels from other sources to markets normally supplied partly or wholly by Singapore. This would support economic and social activity in Australia, as prescribed in the “adequacy” criterion, but at a lower level than before the supply shock, because of adjustments to quantity demanded in response to higher prices. Fuel-using activities valued less than the fuel cost would be reduced, while activities afforded a higher value by the market would continue. For example, some owners of private vehicles would cut discretionary driving, such as weekend trips, and could reduce other discretionary spending to maintain highly valued driving.

A liquid fuels supply shock, such as temporary loss of supply of refined petroleum products from Singapore, would affect fuel prices globally, not just in countries normally supplied by Singapore. Therefore, the automatic market-based adjustment process would affect Australian competitiveness only to the extent that its trade exposed sectors are more liquid fuels-intensive than competing industries in other countries. Any such differential effect is likely to be minimal.

Unfettered operation of the refined products market in Australia would not interfere with investment in refining, import and storage facilities, including additional investment considered following a supply shock.

Higher liquid fuel prices would have other effects that many would consider to be “affordability” impacts, although they are outside the definition of “affordability” in the *National Energy Security Assessment 2009*.

These impacts could include disadvantage to those who tend to drive longer distances to work, own older vehicles with inferior fuel economy, and have inferior access to public transport. Typically, this disadvantage would be concentrated in the less well off sections of the community.

“Affordability” impacts outside the definition in the *National Energy Security Assessment 2009* could also include fiscal consequences of higher fuel prices. Costs of running diesel-powered public transport systems would rise and switching from private vehicles to public transport would add to these costs. Because these systems are subsidised by governments, additional costs would be incurred by State and Territory governments. However, given the period of the price rise for diesel, additional costs would be of relatively short duration.





## **7 Vulnerability 2011 -2025**

### **7.1 Introduction**

This chapter addresses vulnerability from the adequacy and reliability perspective. It draws together the findings of the previous research and analysis into a reassessment of vulnerability over three time frames:

- immediate - being 2011 to 2013
- medium term - being the period around 2015
- longer term - being the period 2020 to 2025.

Australia's vulnerability to liquid fuel supply interruption has been taken to mean its susceptibility to economic harm as a result of the supply shock. In addition, it is possible that some sections of the Australian community may be more susceptible to harm than others. In other words, it is appropriate to consider distributional effects as well as general economic effects.

The terms of reference for this project focus particularly on the vulnerability to a large scale disruption and to affordability in the light of:

- the declining ratio of Australia's stocks to net imports and resulting non-compliance with its 90 day stockholding obligation, assessing whether or not this represents a vulnerability to a large scale supply disruption
- recent high and volatile crude oil prices and whether or not they have had an effect on the affordability of liquid fuels in Australia
- growing liquid fuel imports and any emerging energy security issues and risks arising in the face of this.

The following discussion addresses these factors. However, as discussed earlier in this report, consideration of vulnerability is also dependent on the nature of a shock, whether it is demand- or supply-side initiated, and whether the shock occurs in circumstances of high or low world economic growth. It is necessary to discuss these matters briefly first to place the overall vulnerability assessment in context.

### **7.2 Implications of context of the Singapore shock scenario**

An important finding of the analysis in Chapters 5 and 6 is that the context of a major supply shock, such as the hypothetical refined products supply shock investigated in Chapter 6, is that the economic consequences for Australia of the shock will depend critically on the prevailing economic circumstances, including the existence of other forms of shock around the same time. For example, the analysis highlighted the impact of the availability of spare capacity globally at the time of the shock, and the impact of other events on the capacity situation. The hypothetical Singapore shock was essentially a refined product supply shock.



However, it could be considered in a period of strong growth in aggregate demand with significant spare global capacity, as at the present time, or with little spare capacity. Alternatively, it could be considered in the context of quite different global economic conditions, such as a global recession, and accompanying substantial excess capacity. The review of more recent literature, consultations with the industry and our economic analysis provided some indication of how the impacts of a shock would vary under different assumptions.

### **7.2.1 Impact of an aggregate demand shock**

An aggregate demand shock would arise from global growth or recession. The last decade has provided examples of positive and negative aggregate demand shocks.

Rapid growth of China, India and other rapidly developing economies, combined with solid growth in OECD countries in the period from 2003 to mid-2008, created a major aggregate demand shock. This led to strong growth in derived demand for refined petroleum products and crude oil. Spare capacity for production of crude oil and refined products was whittled down and strong price rises occurred as growth of demand continued in conjunction with lagged or constrained supply responses, particularly in the case of crude oil.

The global financial crisis was associated with a substantial negative aggregate demand shock. The resulting reduction of derived demand substantially reduced prices of crude oil and refined products and created significant excess production capacity.

Resurgence of growth in China, India and other rapidly developing economies in 2010 and 2011 has provided another aggregate demand shock, although it is not as strong as the one prevailing from 2003 to mid-2008 because of weak recoveries and ongoing economic uncertainties in the United States, Europe and Japan. This aggregate demand shock has again whittled down spare production capacity for crude oil and refined products, and revived prices, albeit not to levels achieved in mid-2008. Under a scenario where demand is growing faster than supply capacity, history has shown that there would be a significant rise in the price of crude oil - prices as high as the high scenario in the current EIA projections discussed in Chapter 3 could not be ruled out (i.e. US\$200 per bbl). While it would be tempting to conclude that such prices would have major adverse economic impacts in Australia, this is not necessarily the case. In such a scenario, other commodity prices are also likely to be high because the growth in global aggregate demand underpinning increases in crude oil and refined product prices would have increased derived demand for Australia's diverse range of mined and other commodities.

As commodity prices rose, so would the value of the Australian dollar against the US dollar and other currencies. As oil prices are denominated in US dollars, the higher Australian dollar would offset to some extent price increases for petroleum products in Australian dollars. In addition, incomes in Australia are also likely to have risen, albeit with regional differences. Australian consumers of petroleum products would in general be better placed to afford any resulting price increases.



At the same time, revenue from royalties, other resource taxes, income tax and other taxes would also increase. This additional revenue would help finance any government assistance to those in the community that have not benefited from the higher resource revenues (e.g. those communities dependent on trade exposed industries such as manufacturing and tourism) should this be considered necessary at the time.

An aggregate demand-induced oil shock may not therefore result in the same economic costs as the Singapore shock scenario. In some circumstances, Australia and Australian consumers could be better off. This does not diminish the problems that such a shock would create for other economies or even some regions of Australia. However, from a vulnerability perspective the impacts are likely to be very different.

### **7.2.2 Impact of a crude oil supply shock**

A negative crude oil supply shock would push up the price of crude oil, and therefore prices of refined products. The extent of the rise would depend on the size of the shock, the amount of spare capacity available to cover the shortfall, the degree uncertainty concerning the shock, and any opportunistic exercise of market power by OPEC producers. These conditions would be influenced by aggregate demand conditions. Obviously, the effects of a negative crude oil supply shock would be very different in the context of a positive and negative aggregate demand shocks.

The likelihood of a major disruption in crude oil supplies is not known. In the absence of war, an extended total shutdown of production in say the Middle East or in Africa is of low probability - at least over the next 15 years. Smaller, but still significant interruptions are more likely, but as long as there is spare capacity in the system, the world oil market has demonstrated an ability to respond to any shortfalls with additional production, provided the signals provided by price increases are not impeded by governments. The impact of the loss of Libyan production during much of 2011 has provided the most recent example of the ability of the market to ration, re-allocate and call forth supply through price signals.

In the absence of a globally significant war, the main impact of a crude oil supply shock over the next 10 to 15 years is more likely to be higher oil prices, perhaps as high as the US\$140 per barrel experienced immediately prior to the global financial crisis. As with past disruptions, it is likely that the price would fall within a few months of the resolution of such an event.

It is important to recall that the price of crude oil has ranged between US\$10 per barrel and US\$140 per barrel over the past 12 or so years. Therefore, positive supply shocks that drive down the price of oil, as in 1986, are possibilities, as well as negative supply shocks that drive it up.

### **7.2.3 Impact of precautionary buying**

The analysis in Chapters 5 and 6 discussed the implications of precautionary/speculative buying by market participants in fear or anticipation of potential shortfalls and higher prices



with the onset of any problem in crude oil or product markets. The impact of precautionary/speculative demand is an initial higher price spike than might have otherwise occurred followed by a return to a more measured price rise as uncertainty is reduced. The extent of precautionary/speculative buying appears to be positively correlated with the extent of uncertainty and negatively correlated with the amount of spare global crude and refined product production capacity.

The economic impact of an interruption to crude or product supplies is therefore likely to be more severe when there is greater uncertainty and less spare capacity in the system. As the presence of spare capacity tends to be negatively related to the economic cycle, vulnerability will tend to positively related to the economic cycle.

#### **7.2.4 The impact of IEA collective action**

The effect of IEA collective action, particularly a stock draw, could be highly significant if undertaken promptly and if the response is commensurate with the supply shock. The Hurricane Katrina incident showed that as soon as the stock draw commenced, refined product prices stopped rising and turned down significantly. The effect of the stock draw was to provide additional crude to replace loss of production of crude oil in the Gulf of Mexico and to partly offset loss of refined product production along the Gulf Coast. Surprisingly, the crude oil supply response was larger than the refined product response, when the loss of refined products capacity was significantly larger than the loss of crude oil production capacity.

A drawdown of stocks of crude is only likely to be effective if there is spare capacity in the global refining system. Where spare refining capacity is small, provision of additional crude into the market will probably reduce the price of crude on world markets, but it will do little to address the availability of refined product in the short term. The net effect might be to either moderate the rise in product prices or more likely, increase refinery margins.

There is no question that IEA collective action to release refined product stocks can significantly calm the market and hence reduce the likelihood of extreme price outcomes in the event of a refined products supply shock. However, its effectiveness is also influenced by spare capacity in the refining system. It is likely to be more effective when there is little spare refining capacity and less so in cases of substantial spare capacity.

The effectiveness of IEA collective action in response to a crude oil or refined products supply shock would also be dependent on and other government interventions. Some interventions, such as price controls, could undermine the effectiveness of collective action, supply rationing, re-allocation and enhancement functions of price signals through markets.

The above factors can only be examined qualitatively for this report. However, it is possible to draw broader conclusions using the disruption scenario modelled in Chapter 6 as a starting point. This is discussed further in the sections that follow.



### **7.3 Vulnerability to a disruption in oil supplies**

In the 2008 assessment, we concluded that supplies of petroleum products should be sufficient to meet growing demand over the period to 2020. The assessment noted, however, that capacity constraints in global oil infrastructure, including production capacity in OPEC countries, could see continued upward pressure on prices (ACIL Tasman, 2008).

The 2008 assessment also noted that the introduction of higher fuel standards a few years ago had increased the impact of disruptions in Australian refineries.

We still consider that this assessment is appropriate to 2020. However, analysis in the literature, as well as experience since 2008, suggests that there are additional subtleties to vulnerability. The impact on Australian society will vary depending on global economic conditions as well as levels of spare production capacity for crude oil as well as refined products.

The capacity of petroleum import infrastructure is gradually increasing. A second deepwater berth in Sydney has been commissioned. Construction of additional import terminal capacity is either underway or planned in areas of demand growth such as Newcastle and north Queensland. There is now surplus refining capacity in the Asian region that can supply product that meets Australian specifications. The impact of a refinery shutdown is now likely to be less severe than earlier in the last decade. For example, when the Shell refinery was shut down for around 6 months in 2008-2009, there was little impact on the market.

The global financial crisis caused a temporary lull in investment by the petroleum industry, which resulted in reduced supply flexibility. However, the IEA medium term outlook expects a 6.8 mbd increase in oil production capacity by 2016, which will go some way to redressing the tightness in supply.

While there is some tightness in the market, there is now a surplus in OPEC production capacity, as well as in refining capacity in the Asia-Pacific region. The former helps moderate the price impacts of crude oil supply shocks, provided it is utilised, and the latter minimises the impact of interruptions to supply of petroleum products in Australia.

The analysis of the Singapore shock scenario demonstrated that supplies to Australian consumers could be maintained as a result of a 30 day shut-down of the Singapore trading hub. In the absence of multiple shocks of the magnitude of that modelled, or a major global disaster, we consider that supply would be sufficient to support economic and social activity for the short, medium and longer term.

As discussed in Section 6.9, this would not be without economic cost owing to the induced price spikes that would accompany a disruption. However, the impact for the economy and for society will vary over the assessment period.



### 7.3.1 Immediate term

In the immediate term, the impact of the shutdown of Singapore would be less severe because the surplus refining capacity in the Asia-Pacific region provides scope for sourcing alternative supplies from other refineries.

From the viewpoint of adequacy and reliability, we would not change our earlier assessment. In fact, the impact of a temporary shutdown in an Australian refinery is likely to be less because of the increase in capacity to import product from surplus capacity in Asian refineries.

The possible permanent closure of the Shell refinery in Sydney reduces the diversity of supply in New South Wales. To the extent that diversity of supply reduces the risk weighted damage of a given disruption, vulnerability could be considered to be slightly higher than it would otherwise have been. However, with the surplus refining capacity in Asia and investment in import infrastructure in NSW and Queensland, this impact is not considered to be a material shift in vulnerability in the immediate term. Indeed, vulnerability is likely to be less.

The interruption is estimated to increase product prices by an average of around 18 per cent in the first month, while prices decline in the second and third months. The total loss in real GDP is projected to be \$1,382 million over four months and the loss in real income is projected to be \$2,146 million over four months (see Table 26). To place these numbers in perspective, the loss in real GDP is roughly equal to 0.1 per cent of total (i.e. annual) GDP in 2011, while the loss in real income is equivalent to an average of around \$96 for every Australian.

Table 26 **Projected economic impacts in the short term**

	Units	Month 1	Month 2	Month 3	Month 4	Total
Increase in price of petroleum products	%	18	13	2	0	
Loss in real GDP	A\$ million	-791	-479	-102	-10	<b>-1382</b>
Loss in real income	A\$ million	-1227	-749	-160	-10	<b>-2146</b>

Data source: ACIL Tasman

The transport and manufacturing sectors of the economy are less affected than are agriculture and mining sectors that have fewer options for substitution and reducing consumption in the short term.

### 7.3.2 Medium term

Supplies are considered adequate in the medium term to meet the economic needs of the nation in the event of the Singapore disruption. However, because there is likely to be a decline in refining capacity in the Asian region leading up to 2014, replacement products would need to be sourced from further afield, including the Middle East and even Europe, where refineries that can produce Australian product specifications can be found. This would



lead to higher transport costs and longer delivery cycles during the disruption, as well as higher global refined product prices.

The interruption is estimated to increase product prices by around 21 per cent (excluding any transport cost effect) on average in the first month, while prices decline in the second and third months. The total loss in real GDP is projected to be \$2,210 million over four months and the loss in real income is projected to be \$3,704 million over four months (see Table 27). To place these numbers in perspective, the loss in real GDP is roughly equal to 0.17 per cent of total (i.e. annual) GDP in 2015, while the loss in real income is equivalent to an average of around \$164 for every Australian.

**Table 27 Projected economic impacts in the medium term**

	Units	Month 1	Month 2	Month 3	Month 4	Total
Increase in price of petroleum products	%	21	15	2	0	
Loss in GDP	A\$ million	-1169	-805	-221	-16	<b>-2210</b>
Loss in income	A\$ million	-1954	-1359	-374	-17	<b>-3704</b>

Data source: ACIL Tasman

The same relative impacts occur in the economy with transport and manufacturing faring better than agriculture and mining.

### 7.3.3 Longer term

In the longer term, Australia's self-sufficiency in liquid fuels will decline. With less domestically produced product available from Australian refineries, the length of the supply chain will be greater than it is today. The availability and efficiency of petroleum product import infrastructure will be critical to maintaining an acceptable level of supply security against temporary disruptions in the product supply chain. Any constraints in these capacities will increase the vulnerability of Australia to a disruption such as the Singapore Shock scenario.

Disruptions to domestic refineries are likely to be less significant as the contribution from domestic refineries to total demand will be lower. That said, the continued operation of some Australian refineries will still provide a diversity of supply which is important to reducing the risks associated with a disruption in the global supply chain.



## **8 Affordability 2011 - 2025**

This chapter assesses the current and short term level of affordability of liquid fuels in Australia. The analysis is placed in a historical context to assess how current price levels and expenditure on liquid fuels compare with past experience.

### **8.1.1 Definition of affordability**

The 2009 NESAs defines affordability as the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.

This definition encompasses two aspects:

- First, that the provision of energy is at a price that is competitive enough to support continued economic activity, rather than so high that it inhibits activity.
- Second, that the price paid by final end users is sufficient to earn energy suppliers a rate of return on their projects that makes ongoing investment to provide for future energy requirements sufficiently attractive.

Since the first and second world oil crises, in 1973 and 1979 respectively, preceded worldwide global economic downturns, it is recognised that significant increases in world oil prices can affect economic activity and growth. Rising oil prices and oil price volatility can affect investment, economic growth and inflation. A central bank's response to the inflation problem can in turn result in economic contraction in some or all sectors of the economy. In extreme cases, a perceived lack of 'affordable' fuel has raised public and political concern. The history of disruptions discussed earlier in this report indicates that the extent of concern can be transitory and that the economic impacts are not always negative in the longer term.

Rising oil prices are also an important signal to consumers. Nevertheless, the global market for petroleum product is subject to inconsistent government taxation and subsidy policies that mask the real resource costs of petroleum products. For example, a significant component of the price of petroleum products is attributable to excise taxes in Europe, while other emerging economies, such as Indonesia, still subsidise petroleum fuels. It is only recently that the Queensland Government removed a subsidy for petrol.

A universal definition of affordability therefore is not a simple matter. As discussed above, it is different from, but complements, the notion of affordability as the capacity of purchasers to acquire products within their budget/financial constraints. Jan Kalicki and David Goldwyn have defined affordable energy as the ability to buy supply at relatively stable as well as reasonable prices (Kalicki & Goldwyn, 2005, p. 9).

Regardless whether a broad or narrow definition is adopted, affordability is arguably a subjective notion. Another dimension of affordability could be consideration of how much one is prepared to pay to achieve a certain level of energy security. One may be prepared to pay





considerably more for liquid fuels if continuity of supply and ongoing access to the product could be guaranteed and the possibility of a supply disruption avoided.

The definition of affordability related to the competitiveness of an economy may not be the most appropriate criterion upon which to assess energy security. This is because the relative competitiveness of an economy is never likely to be adversely affected in the event of a sudden increase in energy prices where economies are open and energy products are freely traded on world markets as is generally the case in the world today as all countries would likely be paying similar prices for their energy products.

To place the discussion in context therefore, the following sections review past trends in petroleum product prices and explore the changes over the years to provide an indication of how future price movements might affect the ability of the Australian economy and community to respond to oil price movements and maintain economic and social activity.

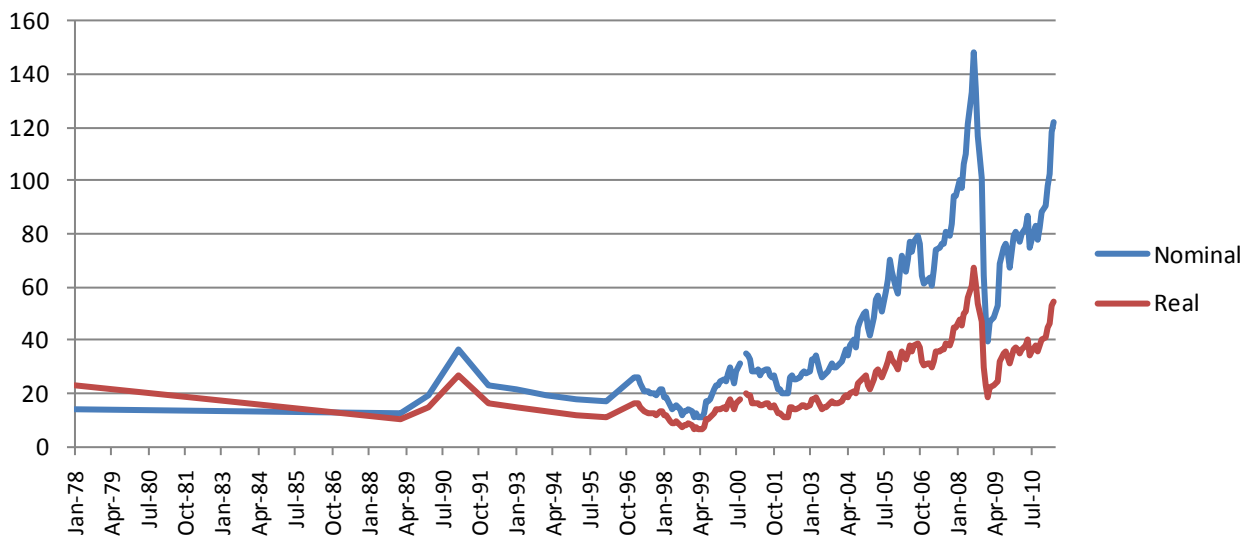
### 8.1.2 Crude oil price trends

#### Changes in key benchmark crude oil prices

Key crude oil pricing benchmarks for the Asia-Pacific market (including Australia) are Tapis, Dated Brent and Dubai.

The real spot price and nominal spot price of Malaysia Tapis Blend crude in US dollars per barrel between January 1978 and April 2011 are shown in Figure 22. The real price was obtained by adjusting the nominal price using the US Bureau of Labor Statistics CPI-U index, with the value of the index set to 100 in 1982. The monthly data series commences in January 1997.

Figure 22 Nominal and real price of Malaysia Tapis Blend crude in US dollars per barrel





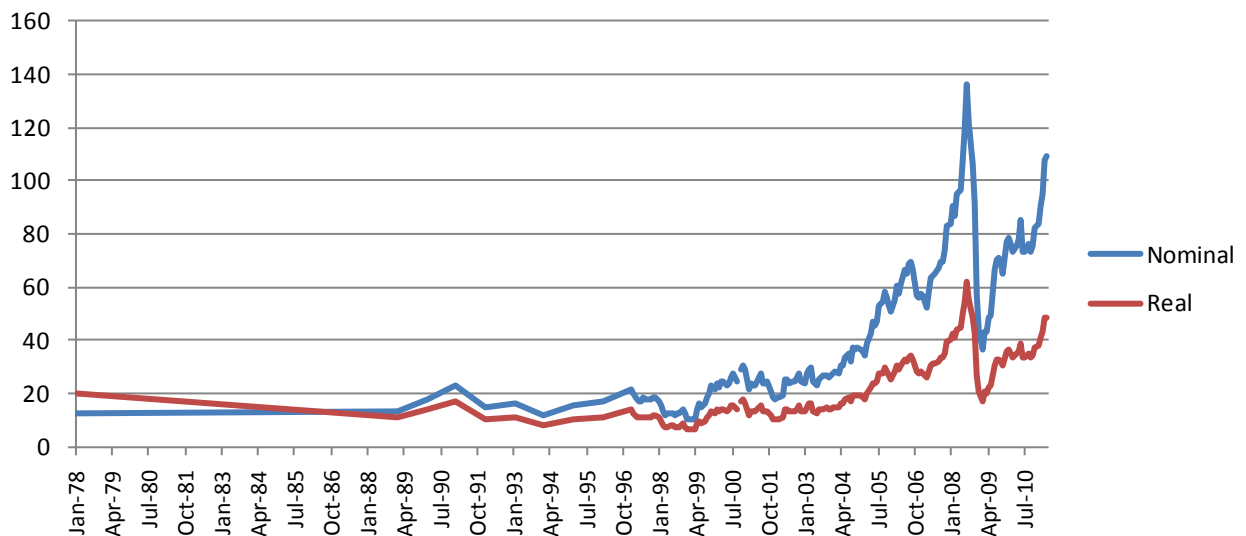
Note: The real price was obtained by adjusting the nominal price using the US Bureau of Labor Statistics' CPI-U price index (where the 1982 level of the index was 100)

Data source: EIA, US Bureau of Labor Statistics

The data shows that the real price of crude oil moved largely in the \$US 10-25 range (in 1982 dollars) between 1978 and early 2005 before rising steadily to nearly \$US 70 (in 1982 dollars) in July 2008. The global financial crisis depressed oil prices in 2009 while recent conflicts in North Africa in particular have in part led to prices rising again.

The real spot price and nominal spot price of Asia Dubai Fateh crude in US dollars per barrel between January 1978 and April 2011 are shown in Figure 23. As in the case of Malaysia Tapis Blend crude, the real price was obtained by adjusting the nominal price using the US Bureau of Labor Statistics CPI-U index, with the value of the index set to 100 in 1982.

Figure 23 Nominal and real price of Asia Dubai Fateh crude in US dollars per barrel



Note: The real price was obtained by adjusting the nominal price using the US Bureau of Labor Statistics' CPI-U price index (where the 1982 level of the index was 100)

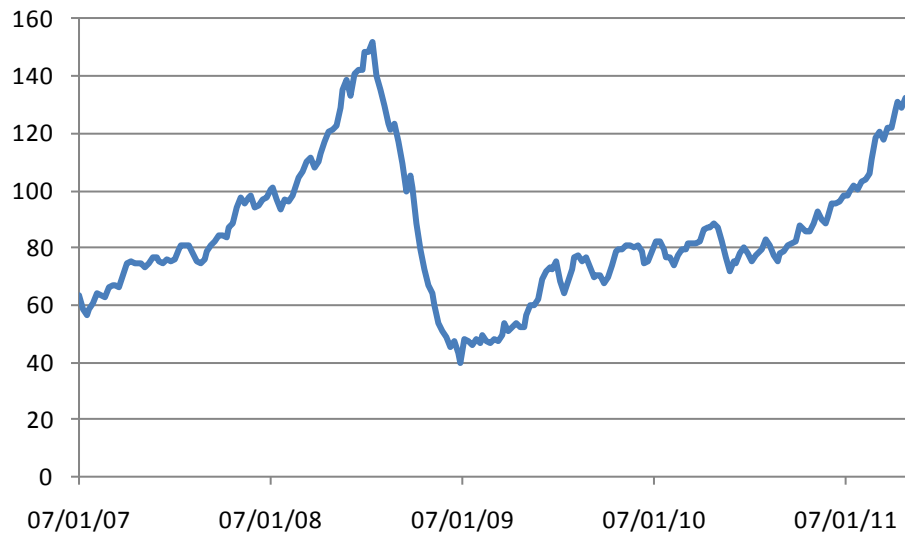
Data source: EIA, US Bureau of Labor Statistics

As can be expected, the movements in the spot price of Asia Dubai Fateh crude mirror those of the spot price of Malaysia Tapis Blend crude.

The volatility in crude oil prices over the last four years can be seen in Figure 24, which shows the nominal price of Malaysia Tapis Blend crude in US dollars per barrel by week between January 2007 and mid-May 2011.



Figure 24 **Weekly nominal price of Tapis Blend crude in US dollars per barrel, January 2007 to April 2011**



Data source: EIA

The price of Tapis Blend crude spiked prior to the onset of the Global Financial Crisis at just over USD 150 per barrel in July 2008, with the price bottoming out at approximately USD 40 per barrel in January 2009. The price has since steadily recovered and appears to be heading back to the mid-2008 peak sometime later in 2011.

## 8.2 Crude oil price forecasts

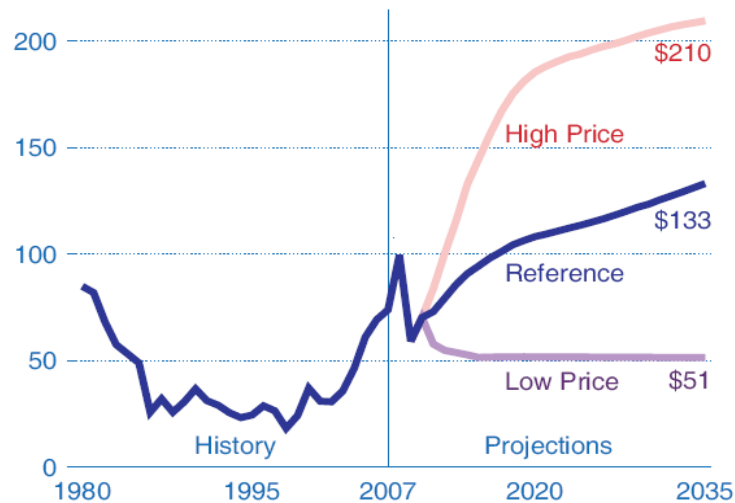
Price projections included in longer term energy projections released for 2010 by the IEA and the EIA were discussed in Chapter 4. In the May 10, 2011 release of its *Short-Term Energy Outlook*, the US Energy Information Administration (EIA) expects that West Texas Intermediate spot prices, which averaged \$79 per barrel in 2010, will average \$103 per barrel in 2011 and \$107 per barrel in 2012.

According to the EIA, based on WTI futures and options prices, the probability that the monthly average price of WTI crude oil will exceed \$120 per barrel in December 2011 is about 31 per cent. Conversely, the probability that the monthly average December 2011 WTI price will fall below \$90 per barrel is about 21 per cent.

The EIA released its *International Energy Outlook 2010* publication in July 2010. In this publication, it forecast the real price of oil out to 2035 (see Figure 25).



Figure 25 EIA projection of world oil prices in three cases, 1980-2035 (2008 US dollars per barrel)



Data source: EIA International Energy Outlook 2010

In addition to the Reference case, High Oil Price and Low Oil Price cases illustrate the range of the inherent uncertainty in long term oil price forecasts, although they do not span the complete range of possible price paths.

In the Reference case, the world oil price in real terms (that is, in 2008 dollars) increases from US\$59 per barrel in 2009 to US\$70 per barrel in 2010 and then rises to US\$95 per barrel in 2015 and \$133 per barrel in 2035 (\$224 per barrel in nominal terms). In the High Oil Price case, the world oil price increases to US\$210 per barrel in 2035 (US\$289 per barrel in nominal terms). In the Low Oil Price case, the world oil price falls to US\$51 per barrel in 2035 (US\$72 per barrel in nominal terms).

In its 2010 World Energy Outlook report, the IEA indicated that the oil price needed to balance oil markets is set to rise, reflecting the growing insensitivity of both demand and supply to price. The growing concentration of oil use in transport, and a shift of demand towards markets where subsidies are most prevalent, is limiting the scope for higher prices to choke off demand and encourage fuel switching.

At the same time, constraints on investment mean that higher prices will lead to only modest increases in production. In the central scenario, the average IEA crude oil price reaches US\$113 per barrel (in 2009 dollars) in 2035 – up from just over US\$60 in 2009.

### 8.2.1 Retail price trends

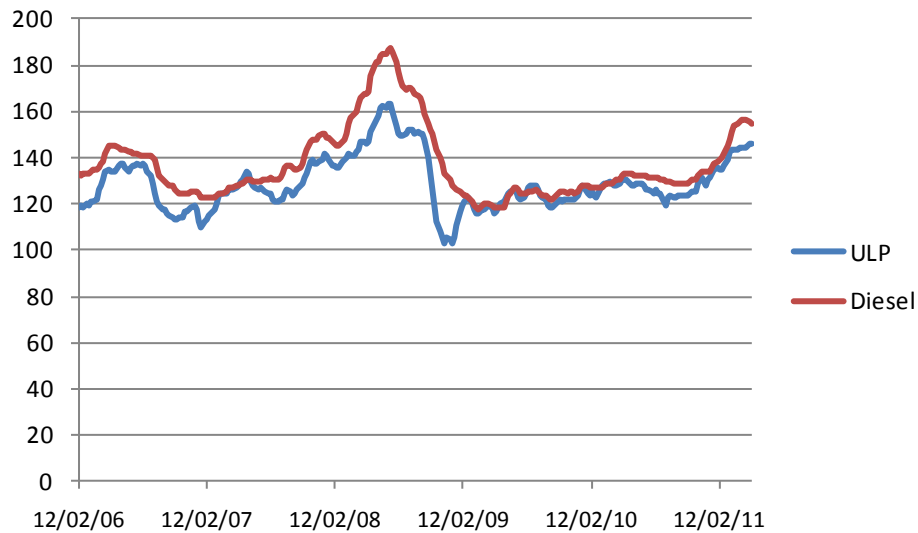
#### Average national real and nominal retail prices

The average national nominal pump prices for unleaded petrol and diesel between February 2006 and May 2011 are shown in Figure 26. The data show that diesel was generally more expensive than petrol in Australia over this period, except between February 2009 and May 2010 when the difference became much smaller. This is probably attributable to the decline in



global demand for diesel in non-transportation uses as a result of the Global Financial Crisis. ACIL Tasman is aware that Japanese refiners in particular were long on middle distillates at that time.

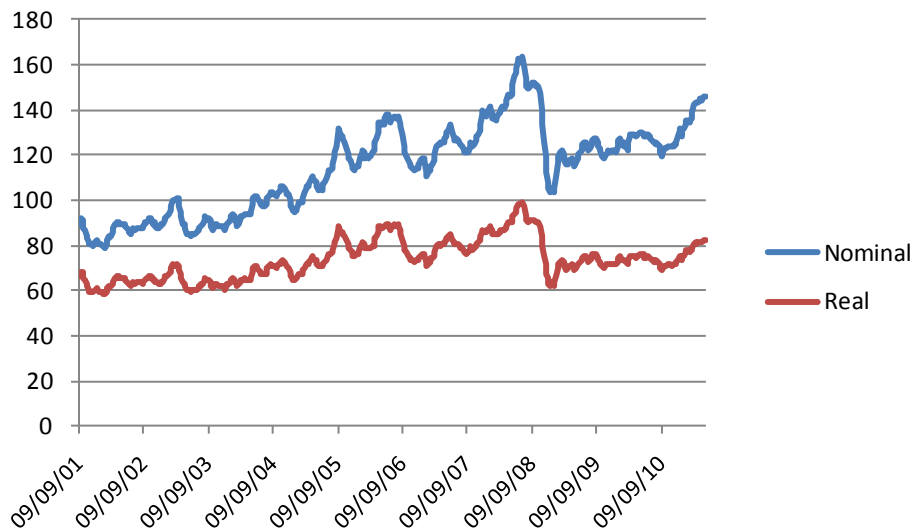
Figure 26 Average national petrol and diesel pump prices by week, February 2006 to May 2011 (cents per litre)



Data source: AIP

The real retail price of petrol in Australia between September 2001 and May 2011 (in 1990 dollars) is shown alongside the nominal price in Figure 27. The data show that the real price of petrol has varied between 60 to 100 cents per litre (in 1990 dollars), averaging at 74 cents per litre, in that period.

Figure 27 Real versus nominal price of petrol in Australia, September 2001 to May 2011 (cents per litre)

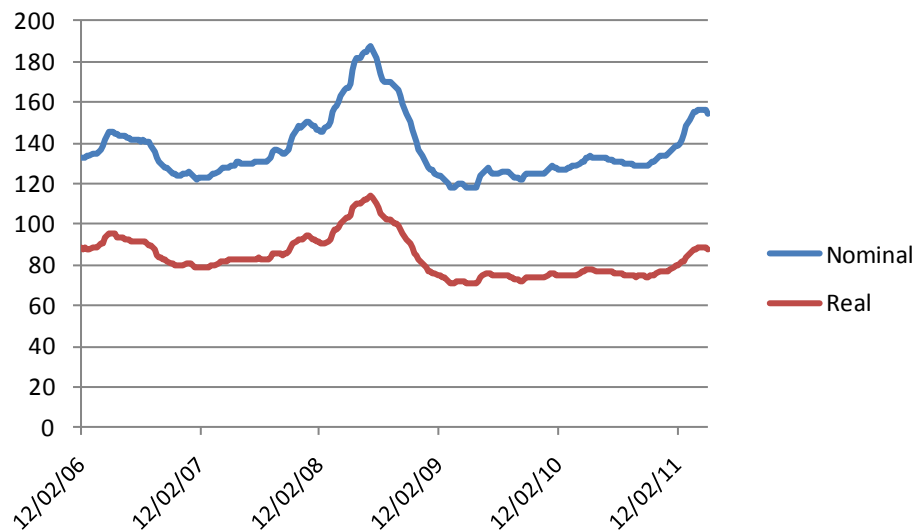


Data source: AIP, ABS 6401.0 Consumer Price Index



The real retail price of diesel in Australia between September 2006 and May 2011 (in 1990 dollars) is shown alongside the nominal price in Figure 28. The data show that the real price of diesel in Australia stayed relatively flat between early 2009 and late 2010, following a steep decline from the peak reached in July 2008. The real price of diesel has begun rising again since the end of 2010.

**Figure 28 Real versus nominal price of diesel in Australia, February 2006 to May 2011 (cents per litre)**



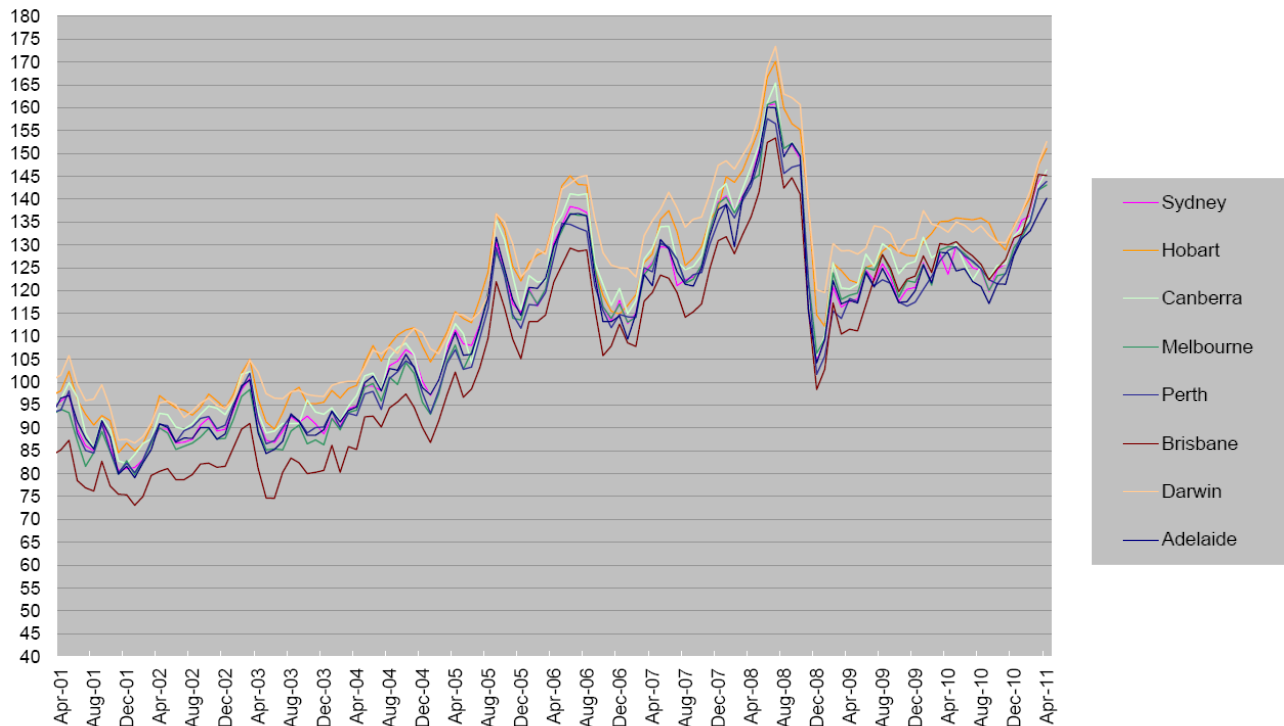
Data source: AIP, ABS 6401.0 Consumer Price Index

### **Nominal retail prices in capital cities**

The average monthly price for unleaded petrol by capital city between April 2001 and April 2011 is shown in Figure 29. For most of this period, petrol prices were the highest in Hobart and Darwin and lowest in Brisbane.



Figure 29 Average monthly capital city unleaded petrol prices, April 2001 to April 2011 (cents per litre)

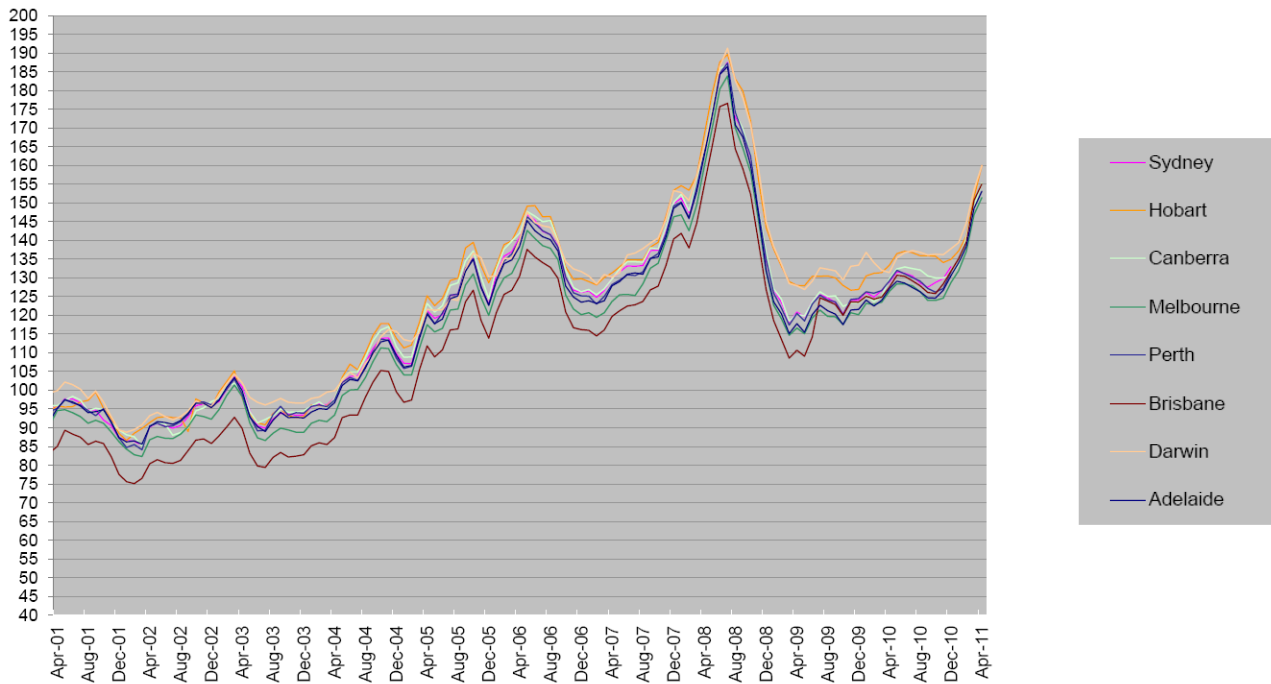


Source: Australian Automobile Association (based on FuelTrac data)

The average monthly price for unleaded petrol by capital city between April 2001 and April 2011 is shown in Figure 30. The data show that, between mid-2008 and late-2010, diesel prices were significantly higher in Hobart and Darwin than in other capital cities. The data also show that diesel prices were consistently lowest (and often by a significant margin) in Brisbane.



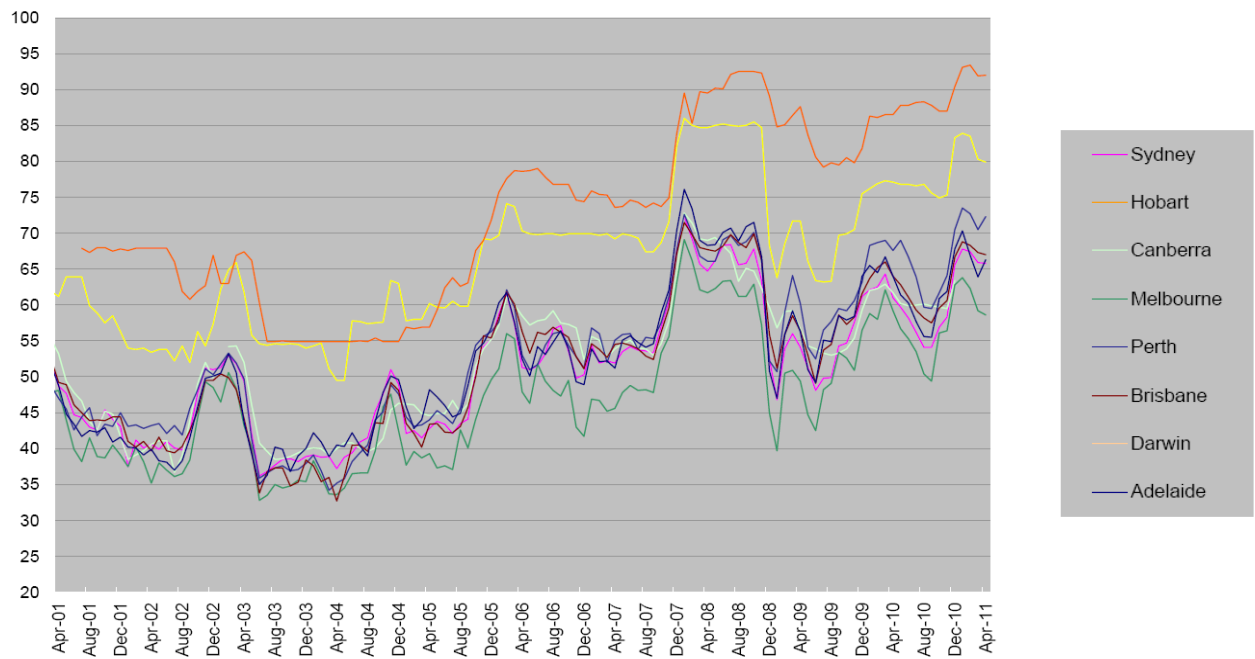
Figure 30 Average monthly capital city diesel prices, April 2001 to April 2011 (cents per litre)



Source: Australian Automobile Association (based on FuelTrac data)

The average monthly price for automotive LPG by capital city between April 2001 and April 2011 is shown in Figure 31. The data show that LPG prices were far higher in Darwin and Hobart (especially the latter) than they were in the other capital cities.

Figure 31 Average monthly capital city LPG prices, April 2001 to April 2011 (cents per litre)





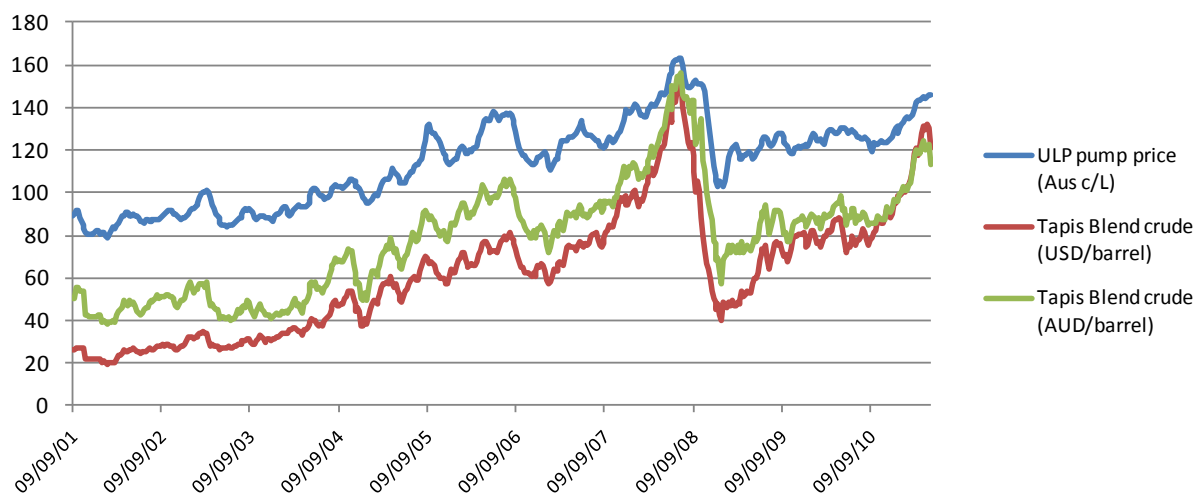


Source: Australian Automobile Association (based on FuelTrac data)

### Retail petroleum product prices versus crude oil prices

A comparison of the retail price of petrol in Australia against the price of Tapis Blend crude (in both Australian and US dollars) between September 2001 and May 2011 is presented in Figure 32. The data show a strong correlation and co-movement between the retail price of petrol and the price of crude oil in Australian dollars.

Figure 32 Retail price of petrol in Australia versus price of Tapis Blend crude, September 2001 to May 2011 (Australian cents per litre)

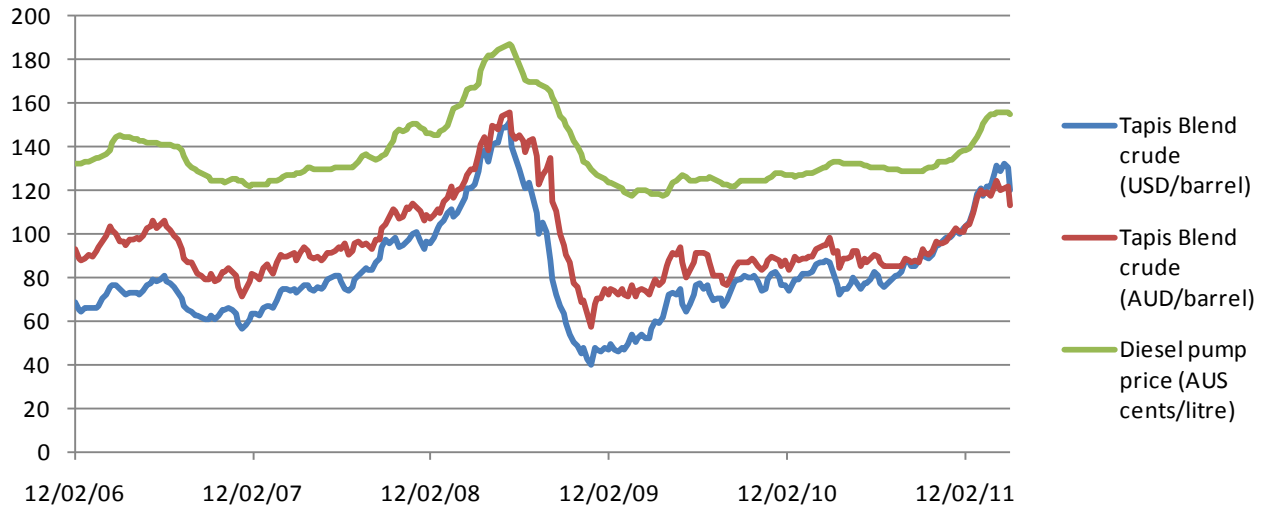


<sup>a</sup> Data source: AIP, EIA, US Bureau of Labor Statistics

A comparison of the retail price of diesel in Australia against the price of Tapis Blend crude (in both Australian and US dollars) between February 2006 and May 2011 is presented in Figure 33. As in the case of petrol, the data show a significant correlation between the retail price of diesel and the price of crude oil in Australian dollars. However, the retail price series for diesel appears considerably smoother than that for petrol.



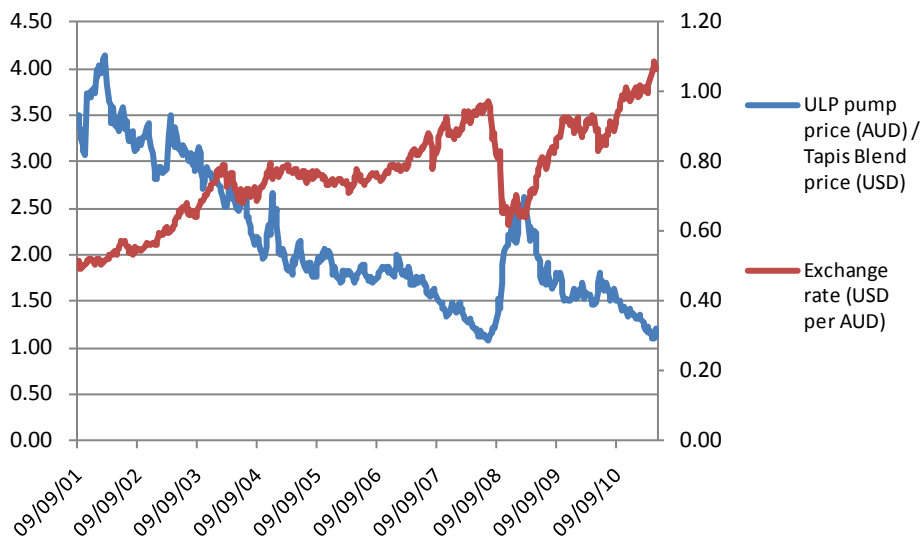
Figure 33 Retail price of diesel in Australia versus price of Tapis Blend crude, February 2006 to May 2011 (Australian cents per litre)



Data source: AIP, EIA, US Bureau of Labor Statistics

The inverse relationship between the ratio of the petrol retail price in Australia to the crude oil price (in US dollars per barrel) and the strength of the Australian dollar is clearly evident in Figure 34.

Figure 34 Ratio of retail petrol price and crude oil price (left axis) versus the exchange rate of the Australian dollar (right axis)



Data source: AIP, EIA and RBA

In the absence of the rise in the exchange rate of the Australian dollar, the rise in the petrol pump price in Australia following the gradual recovery of the world economy from the Global Financial Crisis would have been much steeper. This effect was canvassed in general terms in Chapter 7.

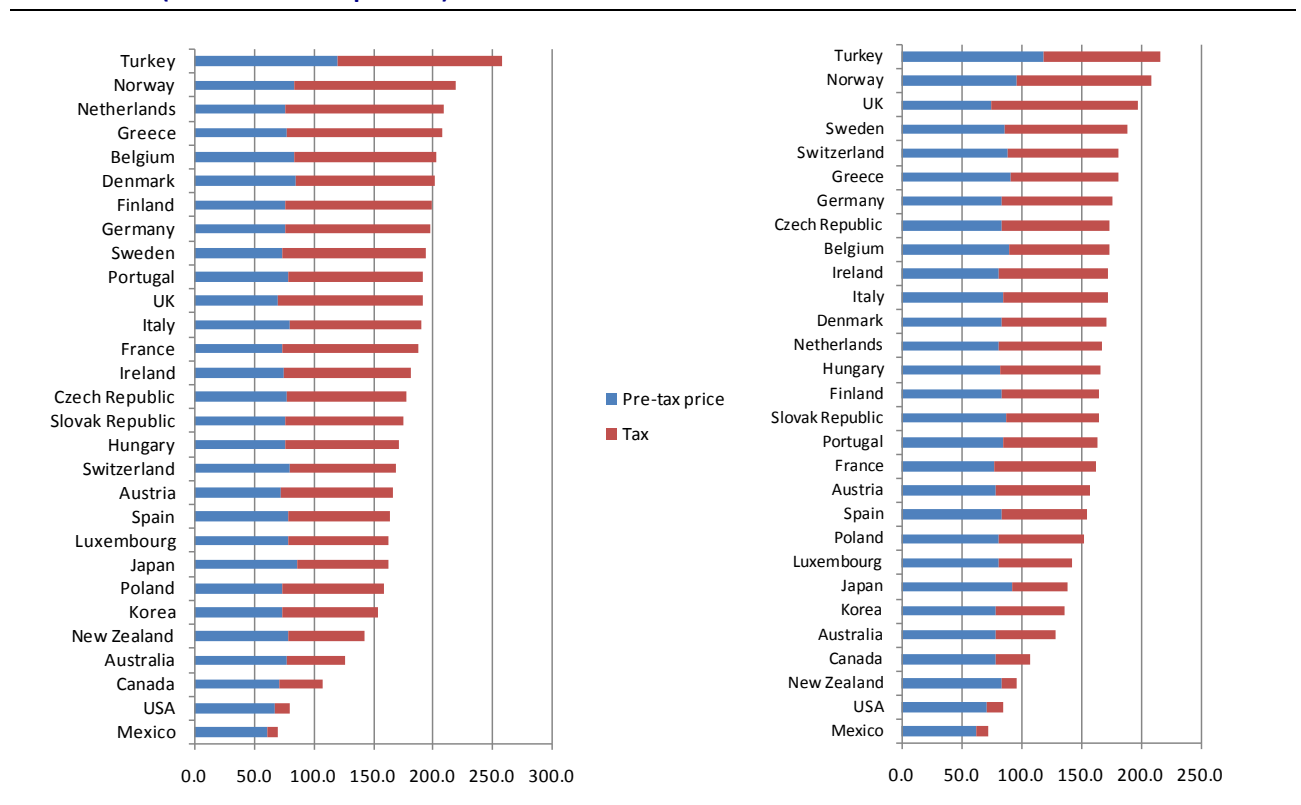


### 8.2.2 International comparisons

Official statistics from the Department of Resources, Energy and Tourism (Australian Petroleum Statistics) and the International Energy Agency (IEA) show that Australia has among the lowest petrol, diesel and LPG prices of all OECD countries.

Figure 35 shows the comparison of Australian petrol and diesel retail prices (in Australian cents per litre) with those of other OECD countries for the December quarter of 2010. The data show that Australia has the fourth lowest petrol price (both pre-tax and post-tax) and the fifth lowest diesel price in the OECD, and that the tax rate on both fuels is relatively low in Australia.

Figure 35 Prices of petrol (left panel) and diesel (right panel) in OECD countries, December quarter 2010 (Australian cents per litre)

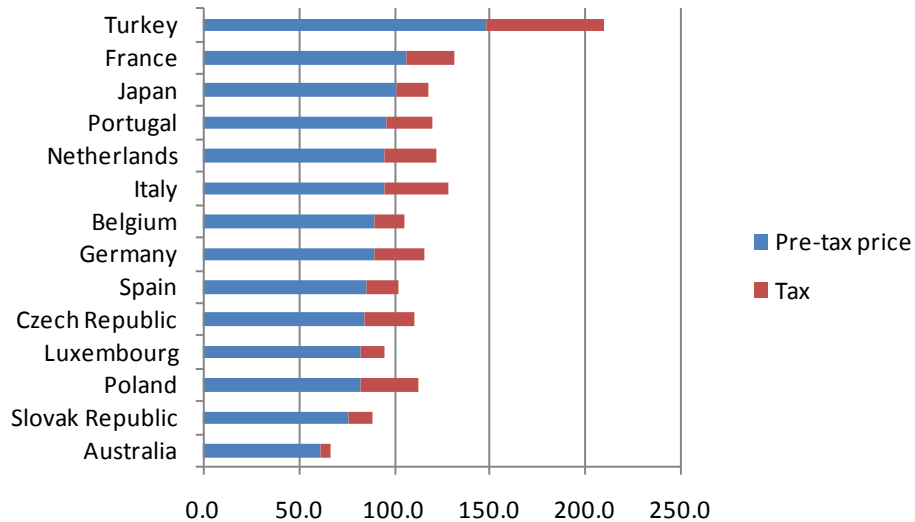


Data source: (DRET, 2011)

Figure 36 shows the comparison of the retail price of automotive LPG in Australia with those of other OECD countries (all in Australian cents per litre) for the December quarter of 2010. The data show that the Australian price (both pre-tax and post-tax) is the lowest in the group. The tax rate on LPG is by far the lowest in Australia



Figure 36 Comparison of automotive LPG prices in OECD countries, December quarter 2010 (Australian cents per litre)



Data source: DRET, Australian Petroleum Statistics

### 8.2.3 Expenditure on liquid fuels

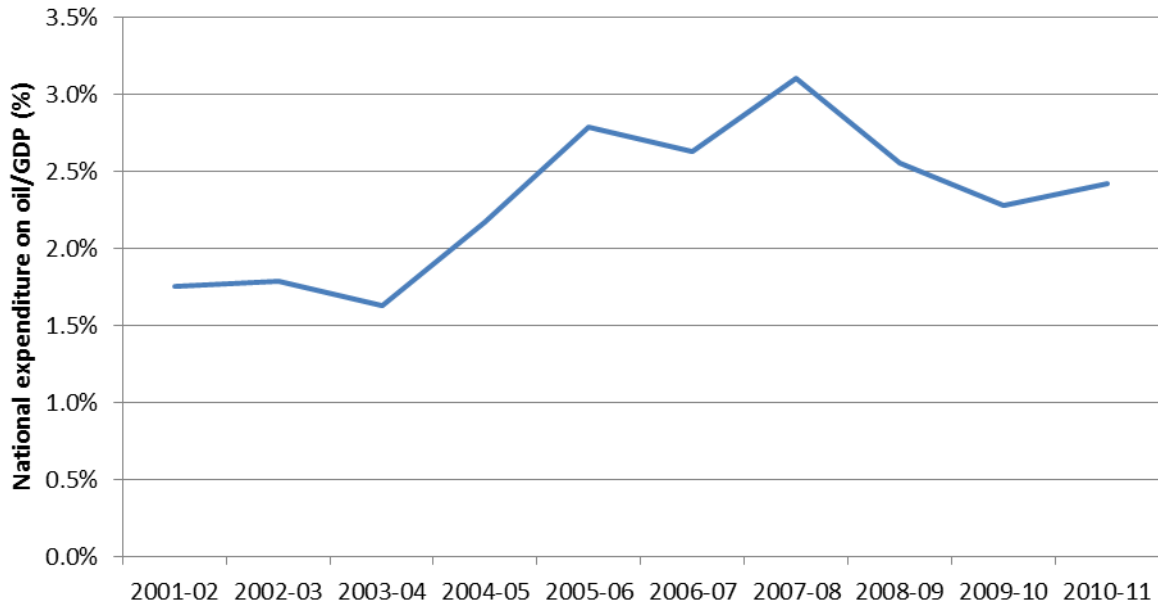
#### National "Oil Burden"

The IEA defines the "Oil Burden" as equal to nominal oil expenditures as percentage of GDP. To calculate this number, the following is needed: a) oil demand, b) real oil prices and c) real GDP. This parameter is used for comparison between countries to compare the dependence of member countries' economies on liquid petroleum fuels and to gauge the impact of changing prices.

Australia's national 'oil burden' over the last decade is shown in Figure 37.



Figure 37 Australia's 'Oil Burden'



Data sources: Monthly EIA prices for Tapis crude were multiplied by the RBA exchange rate and then averaged over 12 months. Annual GDP data is taken from ABS 5206.0 Australian National Accounts: National Income, Expenditure and Product. Oil consumption data is taken from Australian Petroleum Statistics (note that product consumption has been converted to oil equivalent).

### Household expenditure on liquid fuel

According to the 2003-04 Household Expenditure Survey by the Australian Bureau of Statistics (ABS Cat 6530.0), the average Australian household spent \$29.72 per week on petrol in 2003-04. This translates to around 32.7 litres on average a week for capital city motorists in that year.

Based on the national metropolitan average price for petrol in the week ended 15 May 2011, purchasing 32.7 litres of petrol would have cost \$47.64, representing a 55 per cent increase over average 2003-04 prices but only a 3.26 per cent increase over the price in mid-April 2008 when ACIL Tasman produced its previous assessment of Australia's liquid fuel vulnerability.

The recently released 2009-10 Household Expenditure Survey shows that the average Australian household spent \$1,236 per week on goods and services in 2009-10, an increase of 38 per cent (\$343 per week) from the previous 2003-04 survey. In contrast, prices as measured by the consumer price index (CPI) increased by 19 per cent, indicating a rise in real living standards over the intervening period. This survey also shows that in 2009-10 petrol accounted for 3 per cent of total household weekly expenditure, down from 3.23 per cent in 2003-04.

According to the ABS, full time male ordinary time average weekly earnings have risen from a year average of \$995.30 in 2003-04 to \$1,175.40 in November 2007 to \$1,380.80 in February 2011, an increase of 18.1 per cent between 2003-04 and November 2007 and a further increase of 17.5 per cent between November 2007 and February 2011.



That is, between ACIL Tasman's previous assessment of Australia's liquid fuel vulnerability and today, average income has risen by about 18 per cent, while petrol pump prices have only risen by about 3 per cent. By this measure, the affordability of transport fuels by Australian households has increased considerably over this period.

### **8.3 Affordability assessment**

As noted in the previous section, since the previous assessment of Australia's liquid fuel vulnerability in 2008, the affordability of transport fuels from the household perspective has increased due to robust economic growth and a strengthening of the Australian currency which makes petroleum products cheaper in Australia for a given world price of crude oil.

However, a great unknown at this point in time is how much more, and how quickly, will oil and petroleum product prices rise in the next several years and what will be the impact on liquid fuel affordability for Australian households. As pointed out earlier, oil price projections are fraught with uncertainty.

If affordability is defined in terms of maintaining the competitiveness of the economy, then affordability is unlikely to be significantly affected by a change in the level of liquid fuel prices or by their volatility. This is because crude oil and refined petroleum products are internationally traded commodities and prices paid in Australia for petroleum based liquid fuels, setting aside changes in the exchange rate, closely follow movements on world markets. For example, the 2007 inquiry into petrol pricing by the ACCC found that Australia's domestic oil refiners set the price of petrol with reference to an import parity price, the landed price of obtaining refined product from an overseas refiner (Australian Competition and Consumer Commission, 2007). This is generally translated into a price ex Singapore for the purposes of pricing.

On this basis, an increase in the price of crude oil, which is the major input into refined petrol products, as well as any changes in refining margins, which is the difference between the price of crude oil and refined petroleum products, would translate into higher prices for petroleum based liquid fuels for everyone, including overseas competitors. As long as oil and refined petroleum products remain commodity products traded on international markets and affordability is defined in terms of maintaining international competitiveness, then affordability is unlikely to change significantly.

It should be noted that the structure of the Australian economy adds another layer of complexity to the analysis of the economic impact of increases in liquid fuel prices. As the increase in oil and refined petroleum product prices since early 2009 is associated with the recovery of the world economy (and the robust growth of China and India, in particular), the volume and prices of Australian mineral exports have also increased significantly.

This increase in Australia's terms of trade and the demand for (and hence the exchange rate of) the Australian dollar has not only reduced the increase in international crude oil prices in AUD terms but also increased the average income of many Australians and their ability to



afford transport fuels. Of course, not every Australian has shared in the general rise in prosperity due to the mining boom. The impact of rising oil prices will have differential effects in different sectors of the economy and in different regions. Those segments of the population that have not captured the benefits of the current mining boom will feel the impacts more. This may be exacerbated for people who live in areas with poor public transport that are also remote from centres of employment.

In particular, those sectors of industry that are dependent on long road transport linkages, such as agriculture or mining, will be more negatively affected than industries in countries where transport distances are less.

## **8.4 Summary**

Affordability is examined through the prism of the impact of a Singapore shock in the first instance. A qualitative discussion is provided to canvass the impact of other shocks.

### **8.4.1 Immediate term**

A Singapore type shock is unlikely to significantly reduce affordability in the immediate term. The ability of the supply chain to source replacement product, the relatively modest initial price rise and the relatively fast attenuation of the shock as alternate supplies reach the market, suggest that price rises are unlikely to affect competitiveness. As the economic analysis shows, the impact differs between industries.

The current strong economic outlook for China and India and consequently for Australia will also help to reduce the impact on affordability. The high Australian dollar will moderate the impact of price rises and current high levels of employment would help most consumers manage through the period of price rise. As noted above, wages have risen faster than fuel prices and most consumers are spending less of their disposable income on fuel.

There would clearly be some consumers who could experience financial problems. These are more likely to be those experiencing mortgage stress in areas remote from employment and lacking public transport, as well as those dependent on welfare.

This conclusion may well be different in the event of a global recession or a slowdown in the Chinese or Indian economies. However, this is also likely to be accompanied by a fall in demand for petroleum fuels, as occurred in 2008-09 in response to the global financial crisis. Such a fall is likely to also lead to a fall in oil prices, which would help offset any increases in fuel prices caused by a Singapore type disruption.

The impact of a disruption to crude oil production is more difficult to predict. With considerable spare production capacity in OPEC nations, the removal of one producing area on oil prices is likely to be similar to that now occurring in response to the loss of Libyan production and reduced output from Iraq. It is likely that it would require a major war or shutdown of production in a whole region, such as the Middle East or Africa to create this scenario.



#### **8.4.2 Medium term**

A Singapore type shock is likely to have a greater impact on affordability in the medium term around 2014-15. This is because spare refining capacity is likely to be less than in the 2010-2011 period. The price impact is higher and longer for reasons discussed earlier.

The relative impact on affordability will depend on levels of global growth, particularly in China. If growth is strong and commodity prices are strong, it is more likely that the impact of a Singapore disruption will be of the same order as in the short term.

If growth has collapsed and commodity prices fall, the oil price will also fall as a result of lower global demand. This will be offset to some extent by a fall in the Australian dollar exchange rate.

A major disruption in crude oil supplies in a producing region would have broadly the same impact as a disruption to Singapore. Crude oil prices would rise which would feed through into product prices. The lack of spare refining capacity in Asia would be irrelevant as there would be constraints on crude availability.

However, it is difficult, but not impossible, to see this scenario emerging in the medium term.

Overall the medium term outlook for affordability is that while the price impacts would be higher than in the short term, the price rises are unlikely to lead to Australia's economy becoming uncompetitive and in most cases Australian society could adjust. However, there would be regions where communities remote from public transport and under financial stress might be more adversely affected.

#### **8.4.3 Long term**

In the long term, around 2010-2025, the likelihood that crude oil prices will rise as a result of the run down in production from lower cost producing fields and replacement by higher cost production. However this is also very much dependent on government policies on climate change and energy efficiency as well as future levels of global economic growth.

The 2010 IEA World Energy Outlook actually projects lower oil prices under strong climate change policies because of lower demand for petroleum products due to its substitution in transport, and growth in fuel efficiency in motor vehicles. Most of these effects would be policy induced. However, if they were successful, affordability would be improved for most consumers.

Given the difficulties encountered in international negotiations on climate change policy response, and the rapid growth of emerging economies where transport demand is projected to increase significantly, it would seem more prudent to assume that oil prices will be higher in the longer term than they are now.

Temporary interruptions to supply of either products or crude oil are likely to cause price spikes at a higher base. If recoverable reserves turn out to be lower than currently projected





for policy induced reasons such as environmental concerns or adverse resource taxation policies in non-OPEC countries, or because of much higher costs of resources than currently understood, then higher volatility in oil prices are likely and at a higher level.

As discussed above, because oil is globally traded, these higher price levels and higher volatility will be being experienced by all countries. Therefore the impact on competitiveness is likely to be similar for all countries. Industries in Australia that depend more heavily on road transport, such as agriculture or mining may be more affected than in other countries where the transport task is not as significant. However it is difficult to form firm conclusions at this point.



## 9 Conclusions and recommendations

This report reviewed and updated Australia's liquid fuels vulnerability for the immediate, medium and longer term. The findings of the research and analysis are summarised in the following terms.

### 9.1 Vulnerability to a disruption

#### Vulnerability

The analysis of a shutdown of Singapore for a period of 30 days indicates that while there would be a short term rise in petroleum product prices, there would nevertheless be sufficient availability of petroleum products to support economic activity.

- If the shock occurred in the immediate term, product supply would be maintained with product from the existing surplus capacity in other Asian refineries and from product that would normally be arbitrated out of the region. There would be short term price increases as the market adjusted to the shortfall.
- For a shock that occurred in the medium-term, product supply would be maintained but we would expect to see comparatively higher prices because the surplus capacity in Asian refineries would be lower resulting in more precautionary buying in the global product market.
- In the case of a shock that might occur beyond 2015, additional new investment is expected in the Asian refineries. Any such investment would reduce the price impact of a disruption.

There would be differential impacts on industry sectors in the economy caused mainly as a result of rising prices.

- The price rises in the immediate term would be more modest than in the medium term. The reason for this is the proximity of surplus capacity in the Asian region that currently exists but which is expected to be decline by 2014 as a result investment patterns and demand growth.
- Price rises in the longer term would depend on the maintenance of spare capacity in the Asia-Pacific Region as well as globally. There is the possibility that the availability of spare capacity will be cyclical as a result of lags in investment in response to price signals.

Reducing fuel standards during an emergency would allow additional supplies from Asian refineries and additional supply of PULP from Australian refineries to be brought on stream after a lag of one to two weeks.

#### Affordability

Affordability during periods of disruption, when expressed in terms of international competitiveness, is not expected to deteriorate



- However the impact on affordability will be more significant for some sectors of the economy than others. For example, sectors that are heavily dependent on petroleum fuels or road transport, such as agriculture and mining, are likely to be relatively worse off.

Wages in Australia have been increasing at a faster rate than petroleum product prices and in this respect affordability of liquid fuels has improved. In most cases, the impact of price spikes during a major disruption, such as the Singapore Shock, would not raise affordability concerns as consumers have some scope to adapt their fuel consumption in the short term.

- However, some consumers could be more seriously affected - notably those where alternatives to private road transport are not available.
- This impact is likely to be more evident in the medium term - around 2014 - for reasons explained above.

### **Implications of growing fuel imports**

Growing dependence on imports of petroleum products is not in itself a cause for greater risk of a supply disruption, provided the industry invests in import infrastructure.

- There is evidence that this is occurring as demand grows.

The potential closure of refinery capacity in Australia reduces the diversity of supply options for the Australian market.

- This will be offset in the short term by increasing diversity of supply from Asian refineries.
- The offset will reduce as surplus capacity in Asian refineries declines with the most risky period expected to be around 2014, after which time the risk will subside again as new capacity comes on stream around 2015.

## **9.2 Adequacy of Australian stocks**

With growing net imports, the ratio of stocks to net imports is likely to decline. However, this is not considered to be a concern for supply security reasons in the short to medium term. This is because of the nature of the petroleum market in the Asia-Pacific region, where supply security depends on being able to source product from a diverse range of refineries that can meet Australian standards, and the fact that a high proportion of cargoes bound for Australia are pre committed and under contract to Australian buyers.

While surplus capacity in Asian refineries is expected to decline around 2014, current investment plans suggest that it will recover after new capacity is brought on stream from about 2015.

In the longer term, the adequacy of Australian stocks will depend on the structure and operation of the Asian market, and in particular the role of the Singapore trading hub. While this structure is not expected to change in the longer term (2020-25), any change would justify a re-evaluation of this conclusion.



## **IEA requirements**

The current method of calculating stocks for the purposes of reporting to the IEA is under-reporting the number of days by a small margin.

For example, the IEA methodology for calculating stocks does not recognise the very different petroleum market that operates in the Asia-Pacific region. A high proportion of crude oil and product being shipped to Australia at any one time is fully committed to the Australian market for commercial as well as shipping logistics reasons. This is very different to the situation in Europe where cargoes can be destined for more than one country.

In addition, the method of calculating deductions for unrecoverable petroleum in storage tanks and for naphtha is not appropriate to the Australian situation. If these inconsistencies were recognised in the calculation the resulting stock cover would exceed 90 days in 2011.

There are also a number of gaps and discrepancies in the data that is collected and used to determine our level of stockholding. For example, there is new storage capacity under construction or being re-commissioned that is currently not being captured in the statistics. If this was included in the APS then Australia's 2011 cover could increase to around 88 days in terms of the IEA calculation. However, even if this storage capacity was added, stocks are not likely to be consistently above the 90 day requirement for any great length of time, as net imports rise with declining production from Australia's traditional oil fields, mainly the Gippsland and Cooper Basins, exceeding new production of crude oil, condensate and LPG from the Carnarvon Basin.

The expected closure of the Shell refinery at Clyde will to some extent be offset by increased investment in import infrastructure elsewhere in NSW and Queensland.

Regardless of whether the IEA would accept Australia's arguments in relation to these facts or not, the ability to source product from other refineries in Asia, and from further afield, means that the current levels of stocks should be adequate to maintain reliability of supply in the event of major disruptions of the order of the Singapore Shock examined.

## **9.3 Petroleum statistics**

During the course of this work, it was found that there were discrepancies in the collection of Australian Petroleum Statistics. The main concerns were:

- incomplete reporting of production and trade;
- some double counting for LPG;
- incomplete reporting of stocks mainly by independents and some LPG; and
- lack of coordination in the collection of some supply and demand statistics leading to duplication in reporting (and some inconsistencies in approach).



ACIL Tasman agrees with the recommendation of the IEA review team that a mandatory reporting mechanism for Australian Petroleum Statistics should be implemented. In this respect ACIL Tasman notes:

- The administrative demands of mandatory reporting could to some extent be offset by improved coordination of collections.
- Mechanisms need to be put in place to ensure that the administrators of the APS are informed when new terminal capacity is brought into service by independent importers.

We have revised our recommendation in the interim report with respect to allocation of responsibility for reporting stocks to recognise the value of retaining the current arrangement where stocks are reported by their owners. A suitable definition could be along the following lines:

Any 'corporation':

- producing, importing and manufacturing material volumes of crude oil or finished petroleum products (including diesel, petrol, jet fuel, LPG, CNG, LNG, heating oil, fuel oil, lubes etc.), biofuels and biofuel blends, must report fuels data (including stocks and flows) to the APS each month for the stock that the corporation owns and controls; and
- storing material volumes of petroleum products and biofuels (e.g. in terminals which they own and/or operate) must also report data to the APS each month for the stock they control or own, and advise the data authority of any changes to the entities using the corporation's storage or terminal facilities.

To ensure that all owners report to the system it would be necessary for the Department to be aware of any new import terminals. We propose that this be done by an annual survey of port authorities of any new terminal construction and requirement that terminal operators advise new importers of the requirement to report stocks.

## **9.4 Recommendations**

Given the findings of this vulnerability review it is recommended that

1. The Government, in consultation with industry, should review the extent and availability of spare crude oil production capacity and spare refining capacity globally and in the Asian region around 2015 to assess whether the assumptions underpinning this vulnerability assessment remain valid.
2. In the light of the importance of industry statistics to ongoing assessment of vulnerability the government should mandate the provision of stocks data through the Australian Petroleum Statistics portal.
3. Responsibility for reporting stocks should remain with the owners of those stocks. Terminal owners should be required to advise importers of their responsibility to report and an annual survey of port authorities should be undertaken to ensure that all new storage is identified by the Department.



4. The Government should communicate its concerns over the calculation methodology to the IEA and seek a review of market arrangements in the Asian region and their impact on the calculation of stocks for Australia.



## **A Terms of reference**

### **A.1 Background**

Beginning in December 2009, Australia has regularly been in breach of its International Energy Agency (IEA) 90-day oil stockholding obligation. This treaty level commitment requires IEA member countries to establish a common emergency self sufficiency in oil supplies, with each country maintaining emergency reserves equivalent to at least 90 days of daily net imports.

These breaches of the 90 day stockholding obligation are thought to be the result of three factors: a structural shift in Australia's imports of oil and petroleum products; inaccuracies in Australia's data; and short-term industry movements.

A significant increase in Australia's net imports over the last decade is a key factor. This is being driven by increasing domestic consumption and declining domestic production of crude oil and therefore reduced exports. These trends are forecast to continue over the long term.

Another major issue known to be affecting Australia's compliance figures is inaccurate and incomplete petroleum data collection processes. In 2010, the Petroleum Statistics Working Group (PSWG) was formed to consider options to enhance the future collection, analysis, reporting, forecasting and submissions of Australia's liquid fuel data and 90-day reserves. The final internal report of the PSWG, delivered in September 2010, highlighted a number of issues with data coverage, quality and processing, and found that these issues were impacting on Australia's 90-day net import coverage.

In addition to these issues, the International Energy Agency (IEA) conducted an Emergency Response Review (ERR) of Australia in February 2011. A key interim finding from this review was that Australia take action to ensure compliance with its obligations under the Agreement on An International Energy Program (IEP) 1974. This includes:

- establishing additional emergency oil reserves to ensure Australia meets its 90 day stockholding obligation;
- establishing a credible mechanism for participation in an IEA collective action; and
- establishing a mandatory reporting regime for petroleum statistics.

In addressing these recommendations, the central question for Australia is whether recent and potentially ongoing non-compliance with the IEA 90 day stockholding obligation represents a decline in Australia's energy security or is best framed as an issue of compliance with an international treaty commitment. Determining the appropriate policy response rests on answering this question.



Recent Australian Government and independent assessments considered Australia's liquid fuel security arrangements to be stable and robust.<sup>21</sup> This is backed up by the long history of the Australian petroleum industry adequately supplying the market. However, in light of the recent 90 day breaches, and forecasts for continued non-compliance over the long term, it is necessary to re-consider aspects of these assessments.

The main method for doing this will be the second National Energy Security Assessment (NESA) currently being produced by the Department of Resources, Energy and Tourism (RET). The NESA is a factual assessment of the security of the liquid fuels, gas and electricity sectors in the short, medium, and long term, and will be released to the public in the second half of 2011.

To assist in this process RET requires an independent review and update of aspects of the *Assessment of Australia's Liquid Fuel Vulnerability* (Liquid Fuel Vulnerability Assessment or LFVA) released in November 2008. Advice and recommendations from this update will feed into the NESA process and will assist RET in assessing whether Australia's non-compliance with its 90 day stockholding obligation represents an energy security problem.

## **A.2 Objectives**

This project is intended to review and update aspects of the LFVA 2008 based on latest available data and forecasts. The focus will be on issues related to Australia's compliance with its 90 day stockholding obligation and whether non-compliance, as a result of growing oil imports, is indicative of a new vulnerability in Australia's liquid fuel security arrangements.

## **A.3 Project Description**

The project will consist of two main parts:

- 1) a broad analysis of current practices around the IEA 90-day stockholding calculation, associated data collection, reporting, maintenance and verification. This will include, but is not limited to, a stocktake of the current data position, an assessment of the accuracy of the data employed and identification of ongoing issues with data quality and coverage that are having an adverse effect on Australia's 90-day calculation. The project will also include recommendations on how current practices can be improved to ensure Australia's petroleum data meets IEA best practice;
- 2) a review and update of aspects of the LFVA 2008, based on the latest available data, with a focus on:
  - a) Australia's vulnerability to a large scale supply disruption;
  - b) current affordability of liquid fuels in Australia; and
  - c) any emerging energy security issues or risks arising in the face of growing liquid fuel imports.

Part 2(a) of the project will include a shock scenario to be included in the 2011 NESA.

---

<sup>21</sup> Recent assessments of Australia's liquid fuel security are the 2009 National Energy Security Assessment (RET) and 2008 Liquid Fuel Vulnerability Assessment (ACIL Tasman).





Full Descriptions of Part 1 and Part 2 of this project are outlined below.

## **A.4 Part 1– Data Stocktake**

### **A.4.1 Objective**

Part 1 of this project will focus on Australia’s current petroleum data collection and reporting practices. This will involve a broad analysis of current practices around the IEA 90-day stockholding calculation, associated data collection, reporting, maintenance and verification. The aim will be to stocktake the current data position, including assessing the accuracy of the data employed and identifying ongoing issues with data quality and coverage that are having an adverse effect on Australia’s 90-day calculation. The project will also include recommendations on how current practices can be improved to ensure Australia’s petroleum data meets IEA best practice.

### **A.4.2 Stakeholders**

- RET – Energy & Environment division; Resources division; Corporate division
- ABARES
- AIP
- Data providers
- IEA

### **A.4.3 Deliverables**

#### 1) Document 90-day Calculation

Provision of a clear documentation of the IEA 90-day calculation, including how the IEA calculate Australia’s emergency stockholding, what data is required for the calculation and what products can be included/ are excluded from the calculation.

- Outcome: Documentation of IEA calculation methodology.

#### 2) Stocktake current data position

A stocktake is required of the data currently used in reporting to the IEA on Australia’s 90-day stockholding obligation. This includes assessing the quality of the data, specifically to determine whether the data has accuracy, consistent timing, is meaningful and complete. In addition, as part of this stocktake, it is necessary to audit Australia’s internal calculation process to determine its accuracy and consistency.

A large portion of the data reported to the IEA as part of Australia’s 90-day compliance is collected as part of the Australia Petroleum Statistics (APS). An assessment needs to be conducted on the APS data relevant to the 90-day compliance calculation to ascertain the current level of data quality. Particularly with consideration on what data is captured (i.e. what products are reported), the amount of this data that is estimated, the amount of data missing (i.e. companies not reporting), when the data is reported and whether this is consistent across all data sets.

ABARE is currently engaged by the Australian Government to deliver Australia’s Monthly Oil and Gas Questionnaire to the IEA. The data from this questionnaire is used by the IEA to check



compliance with the 90 day stockholding obligation. As part of this process, ABARE receives data from the APS collection, however due to the unknown reliability of data quality ABARE prefers to calculate some of the data used in the IEA stockholding reporting. This process needs to be audited to determine how ABARE calculates the data for IEA reporting. In addition, there is a need for an examination of how various data sets used by ABARE align (i.e. timing of reporting periods) and how much of the data is estimated.

- Outcome: Audit of PSIMS data used in 90-day calculation; Audit of ABARE methodology in producing stockholding reports for IEA.

### 3) Identify data gaps

Applying the outcomes from the data stocktake and audit process, assess the current position and quality of Australia's 90-day stockholding calculation. Particularly, identify if all relevant and allowable data (i.e. products) is included in Australia's 90-day calculation, and determine whether any data currently included in the calculation reports would be excluded by the IEA.

There are discrepancies in the 90-day figure produced using direct APS collected data, ABARE calculated data and the official compliance result published by the IEA. As part of this process, determine where the discrepancies lie and how they can be resolved, in order to provide Australia with a clear and definitive 90-day figure that aligns with the IEA produced measure.

- Outcome: Identification of discrepancies between the IEA data calculation of Australia's stockholding position and the calculation conducted in Australia; Identify possible discrepancies between calculation inclusions allowed by the IEA and that provided by Australia; Identify data gaps in the data collection for the 90-day calculation.

### 4) Recommendations

In conclusion to the data stocktake, provide recommendations to address: changes that are required/ recommended to improve Australia's 90 day stockholding calculation; and ways to improve the internal reporting and calculation process to achieve an enhanced understanding of Australia's stockholding position. Also address how the interim findings from the IEA ERR align with this analysis.

- Outcome: Recommendations to improve Australia's 90-day stockholding calculation and methods to address calculation discrepancies.

## **Timeline**

This part of the consultancy to be completed and provided in an interim report – due Friday 29 April.

## **A.5 Part 2 – Update to the Liquid Fuel Vulnerability Assessment (LFVA)**

### **A.5.1 Objective**

The objective of Part 2 of this project will be to review and update aspects of the LFVA focusing on issues that have changed since the last report published in November 2008. The focus will be on three areas that have seen noticeable change since the last assessment, namely:



- a) the declining ratio of Australia's stocks to net imports and resulting non-compliance with its 90 day stockholding obligation, assessing whether or not this represents a vulnerability to a large scale supply disruption;
- b) recent high and volatile crude oil prices and whether this has had an effect on the affordability of liquid fuels in Australia; and
- c) growing liquid fuel imports and any emerging energy security issues and risks arising in the face of this.

To ensure the independence of advice, the consultant may also choose to identify additional high order issues that may be affecting Australia's liquid fuel security.

The key aims of this update are to: provide RET with independent input into the current NESAs process; and to assist RET in determining whether Australia's ongoing non-compliance with the IEA 90 day stockholding obligation is indicative of a vulnerability in Australia's liquid fuel security arrangements.

This part of the project will also provide recommendations on the most appropriate actions to ensure Australia complies with its obligations under the IEP Agreement.

#### **A.5.2 Part 2(a) – Vulnerability to a Large Scale Supply Disruption**

##### **Deliverables**

The deliverables for this part of the project will be a final report that includes:

- 1) An assessment of Australia's current and projected vulnerability to a large scale supply disruption, giving regard to:
  - Australia's current and projected level of imports and exports of crude oil and key refined products, and domestic consumption (overall and by key sectors);
  - reliability of international crude oil and refined product supplies;
  - the role of global spare production capacity and oil inventories (industry and public);
  - the role of market responses;
  - the role of the IEA's collective emergency response system; and
  - the level of stocks held in the commercial supply chain.
- 2) Modelling of a "shock scenario" testing Australia's vulnerability to the loss of a major trading hub for oil products as outlined below. The report shall include the following information:
  - modelling and analysis methodologies, including a description of the modelling tools used;
  - basis of the modelling;
  - description of the reference case;
  - assumptions made;
  - discussion of findings regarding the impact of key factors specified in the scenario description below;
  - assessment of how adequacy, reliability, and affordability of the liquid fuel sector are impacted by the scenario;
  - discussion regarding vulnerabilities to Australia's energy security that were identified;
  - recommendations of mitigation strategies that reduce the energy security vulnerabilities identified; and
  - conclusions.



## Shock Scenario

RET will include “shock scenarios” as part of the 2011 NESAs. These shock scenarios are physical or market-based disruptions to the liquid fuels, gas and electricity markets that will provide insights into the vulnerabilities, risks, influences and impacts that such significant disruptions may have on Australia’s energy security. The scenarios will analyse energy security impacts under current market conditions and over the medium and long term. The analysis of the impact that each scenario would have under future conditions is important to allow identification of emerging issues, and possible solutions to such issues.

The scenario for the liquid fuels sector is described below. The exact nature of the scenario shall be agreed with RET following engagement of the consultant.

## Background

There is a major trading hub for oil and petroleum products in the Asia Pacific region that is crucial to Australia’s involvement in oil and petroleum product trade and national oil security. As many oil traders are based in this hub, restrictions on movement could potentially extend to everyday business, disrupting the ability of key traders to participate in the Asia-Pacific oil market.

This hub is also a significant producer of refined petroleum products in the region. While the interruption of this proportion of refinery production would not necessarily be great enough to trigger an International Energy Agency (IEA) global collective action, it might be considered significant enough to warrant the declaration of a regional fuel emergency by the IEA.

## Scenario

The scenario to be modelled is a major interruption to an Asian regional supply hub affecting the ability to trade oil and petroleum products with Australia.

This scenario will occur through the temporary closure of shipping to and from a major supply hub. The interruption would be modelled to last for a period of about 30 days, and impacts would be assessed under present conditions, i.e. a reference case, and then around tighter global market conditions forecast for the medium and long term.

### Factors to be held constant across the scenario:

- AUD/USD exchange rate;
- Domestic refining capacity in Australia. Domestic refining capacity should be as at 1 January 2011;
- No significant new discoveries in Australian oil fields;
- A carbon reduction target of 5 per cent below 2000 levels by 2020; and
- A renewable energy target of 20 per cent by 2020.

### Key factors to be modelled in the scenario:

- Impact on adequacy, reliability and affordability of liquid fuels;



Specifically:

- Temporarily increased competition from other nations that import significant volumes of petroleum products from this hub;
- Potential for crude oil shipments en route to this hub to be diverted to other refining nations, including Australia;
- The potential for a temporary reduction in Australian fuel standards to assist surge production;
- Price elasticity of Australian demand for oil products;
- Ability of Australian refineries to surge production (albeit with sub-optimal refinery input and output); and
- Spare capacity and surge capacity of Asian refineries.

**Forecast conditions for medium and long term:**

- Increased Asia-Pacific refinery capacity;
- Tighter global supply/demand balance for oil and petroleum products;
- Higher global oil prices; and
- Increased Australian demand for oil and petroleum products.

The exact nature of the conditions at present, in the medium term, and in the long term shall be developed by the consultant and agreed with RET following signing of the order.

### **A.5.3 Part 2(b) – Assessment of Affordability**

#### **Background**

The NESAs define affordability as the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.

The 2009 NESAs assessed affordability as 'moderate' for all time periods.

Since the release of the last NESAs, crude prices have steadily risen following the crash in prices that occurred after the GFC, and talk of high and volatile crude prices has been prominent in the media recently, as well as in international forums such as the G20.

Therefore, there is a need for an assessment of the current affordability of liquid fuels in Australia and how this may have changed since the release of NESAs 2009.

Such an assessment should be done in:

- global market terms;
- comparative international terms;
- trade weighted terms;
- real terms; and
- consumer terms.



## Objective

The purpose of this project is to assess the current and short term level of affordability of liquid fuels in Australia. This will need to be done historically to assess how current price levels and expenditure on liquid fuels compares to past experience.

## Deliverables

The deliverable for this part of the project is a final report that includes:

- a) an analysis of recent trends, and forecast changes in the short-term, in key benchmark crude oil prices (in nominal, real and trade weighted terms) relevant to Australia in comparison to historical levels since 1970;
- b) an analysis of recent trends in crude oil price volatility;
- c) an assessment of the current levels of retail prices (in nominal and real terms) for petrol, diesel and LPG in Australia in comparison to historical levels since 1970. This should also include a comparison of recent movements in retail prices in relation to key crude benchmarks and an assessment of the impact of recent changes in the Australian dollar exchange rate;
- d) a comparison of Australian retail fuel prices (pre-tax and post tax) to other OECD countries;
- e) an analysis of current liquid fuel expenditures per dollar of GDP (including discussion of the current “oil burden” on the Australian and global economies), current liquid fuel expenditures per household and as a percentage of household disposable income in comparison to historical levels since 1970; and
- f) an overall assessment of current and short term liquid fuel affordability for individuals or households, and for the economy as a whole.

## Part 2(C) – Growing Import Reliance and emerging risks

Taking note of issues already covered in Part 2(a), this section will identify any emerging energy security risks associated with Australia’s increased import dependence since the last vulnerability assessment and with the forecast for continued growth in imports over the long term. This will give consideration to:

- increasing market share of independent terminal operators and the independent distributor network;
- changes to Australia’s fuel standards and ability of regional refinery capacity to meet these standards; and

other issues identified by the consultant.



## B Energy Information Agency projections

Table B1 Projections of petroleum production - reference case

Source	2007	2015	2020	2025	2030	2035	Average annual percent change, 2007-2035
<b>OPEC</b>							
Conventional liquids*	33.8	36.4	37.5	39.7	42.3	45.3	1.0
Extra-heavy oil	0.6	0.8	1.1	1.2	1.3	1.4	3.1
Bitumen	0.0	0.0	0.0	0.0	0.0	0.0	-
Coal to liquids	0.0	0.0	0.0	0.0	0.0	0.0	-
Gas to liquids	0.0	0.2	0.2	0.3	0.3	0.3	15.4
Shale oil	0.0	0.0	0.0	0.0	0.0	0.0	-
Biofuels	0.0	0.0	0.0	0.0	0.0	0.0	-
<b>OPEC total</b>	<b>34.4</b>	<b>37.4</b>	<b>38.8</b>	<b>41.2</b>	<b>43.9</b>	<b>47.0</b>	<b>1.1</b>
<b>Non-OPEC</b>							
Conventional liquids*	47.7	46.2	47.0	48.8	50.8	52.5	0.3
Extra-heavy oil	0.0	0.0	0.0	.01	0.1	0.1	-
Bitumen	1.4	2.4	2.9	3.5	4.2	5.2	4.8
Coal to liquids	0.2	0.3	0.5	0.8	1.1	1.4	7.9
Gas to liquids	0.0	0.1	0.1	0.1	0.1	0.1	-
Shale oil	0.0	0.0	0.0	0.1	0.2	0.4	15.6
Biofuels	1.2	2.4	2.8	3.2	3.5	4.1	4.6
<b>Non-OPEC totals**</b>	<b>50.4</b>	<b>51.3</b>	<b>53.3</b>	<b>56.5</b>	<b>60.0</b>	<b>63.6</b>	<b>0.8</b>
<b>World</b>							
Conventional liquids*	81.4	82.6	84.5	88.5	93.1	97.7	0.7
Extra-heavy oil	0.6	0.8	1.1	1.2	1.4	1.5	3.3
Bitumen	1.4	2.4	2.9	3.5	4.2	5.2	4.8
Coal to liquids	0.2	0.3	0.5	0.8	1.1	1.4	7.8
Gas to liquids	0.1	0.3	0.3	0.3	0.4	0.4	7.3
Shale oil	0.0	0.0	0.0	0.1	0.2	0.4	15.6
Biofuels	1.2	2.4	2.8	3.2	3.5	4.1	4.6
<b>World total</b>	<b>84.8</b>	<b>88.7</b>	<b>92.1</b>	<b>97.6</b>	<b>103.9</b>	<b>110.6</b>	<b>1.0</b>

\* Includes conventional crude oil and lease condensate, natural gas plant liquids (NGPL), and refinery gain.

\*\* Includes some US petroleum product stock withdrawals, domestic sources of blending components, other hydrocarbons, and ethers

Source: (Energy Information Administration, 2011)



## C The *Tasman Global* model

ACIL Tasman's computable general equilibrium (CGE) model *Tasman Global* is a powerful tool for undertaking economic impact analysis at the regional, state, national and global level.

There are various types of economic models and modelling techniques. Many of these are based on partial equilibrium analysis that usually considers a single market. However, in economic analysis, linkages between markets and how these linkages develop and change over time can be critical. *Tasman Global* has been developed to meet this need.

*Tasman Global* is an analytical tool that can capture these linkages on a regional, state, national and global scale. *Tasman Global* is a large-scale computable general equilibrium model which is designed to account for all sectors within an economy and all economies across the world. ACIL Tasman uses this modelling platform to undertake industry, project, scenario and policy analyses. The model is able to analyse issues at the industry, global, national, state and regional levels and to determine the impacts of various economic changes on production, consumption and trade at the macroeconomic and industry levels.

### C.1 Monthly model

For the analysis in this report, the model, database and assumptions were converted to solve on a monthly basis rather than the more usual annual basis. All else equal, the value and quantity flows solved using the monthly version sum to the standard annualised version.

To better characterise the short-term dynamics of the scenarios the elasticities governing the ability for non-technology bundle firms to substitute between fuels or between fuels and factors were reduced by a factor of four from the standard elasticities. All other parameters and elasticities were the same as the standard model. The other key assumption for the policy scenarios was that real wages were fixed relative to the reference case and that labour supply was flexible (reflecting short term wage rigidities).

### C.2 A dynamic model

*Tasman Global* is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

In applications of the *Tasman Global* model, a reference case simulation forms a 'business-as-usual' basis with which to compare the results of various simulations. The reference case provides projections of growth in the absence of the changes to be examined. The impact of the change to be examined is then simulated and the results interpreted as deviations from the reference case.





## The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the latest Global Trade Analysis Project (GTAP) database which was released in 2008. This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities.

The GTAP model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

*Tasman Global* builds on the GTAP model's equation structure and database by adding the following important features:

- dynamics (including detailed population and labour market dynamics);
- detailed technology representation within key industries (such as electricity generation and iron and steel production);
- disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG;
- the ability to repatriate labour and capital income;
- a detailed emissions accounting abatement framework;
- explicit representation of the states and territories of Australia; and
- the capacity to explicitly represent multiple regions within states and territories of Australia.

Nominally the *Tasman Global* database divides the world economy into 120 regions (112 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Tasman regularly models projects or policies at the statistical division (SD) level, as defined by the ABS, but finer regional detail has been modelled when warranted.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 70 industries (Table C1). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, diesel and iron and steel sectors are modelled using a 'technology bundle' approach. With this approach, different known production methods are



used to generate a homogeneous output for the ‘technology bundle’ industry. For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which have their own cost structure.

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.



Table C1 Sectors in the *Tasman Global* database

Sector		Sector	
1	Paddy rice	36	Paper products, publishing
2	Wheat	37	Diesel (incl. nonconventional diesel)
3	Cereal grains nec	38	Other petroleum, coal products
4	Vegetables, fruit, nuts	39	Chemical, rubber, plastic products
5	Oil seeds	40	Iron ore
6	Sugar cane, sugar beef	41	Bauxite
7	Plant- based fibres	42	Mineral products nec
8	Crops nec	43	Ferrous metals
9	Bovine cattle, sheep, goats, horses	44	Alumina
10	Animal products nec	45	Primary aluminium
11	Raw milk	46	Metals nec
12	Wool, silk worm cocoons	47	Metal products
13	Forestry	48	Motor vehicle and parts
14	Fishing	49	Transport equipment nec
15	Brown coal	50	Electronic equipment
16	Black coal	51	Machinery and equipment nec
17	Oil	52	Manufactures nec
18	Liquefied natural gas (LNG)	53	Electricity generation
19	Other natural gas	54	Electricity transmission and distribution
20	Minerals nec	55	Gas manufacture, distribution
21	Bovine meat products	56	Water
22	Meat products nec	57	Construction
23	Vegetables oils and fats	58	Trade
24	Dairy products	59	Road transport
25	Processed rice	60	Rail and pipeline transport
26	Sugar	61	Water transport
27	Food products nec	62	Air transport
28	Wine <sup>a</sup>	63	Transport nec
29	Beer <sup>a</sup>	64	Communication
30	Spirits and RTDs <sup>a</sup>	65	Financial services nec
31	Other beverages and tobacco products	66	Insurance
32	Textiles	67	Business services nec
33	Wearing apparel	68	Recreational and other services
34	Leather products	69	Public Administration, Defence, Education, Health
35	Wood products	70	Dwellings

<sup>a</sup> A detailed alcohol database and model structure covering 30+ alcohol sub-categories is also available.

Note: nec = not elsewhere classified

### Detailed energy sector and linkage to *PowerMark* and *GasMark*

*Tasman Global* contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to



bottom-up models such as ACIL Tasman's *GasMark* and *PowerMark* models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies twelve different electricity generation technologies:

- 1) brown coal (with and without carbon capture and storage);
- 2) black coal (with and without carbon capture and storage);
- 3) petroleum;
- 4) base load gas (with and without carbon capture and storage);
- 5) peak load gas;
- 6) hydro;
- 7) geothermal;
- 8) nuclear;
- 9) biomass;
- 10) wind;
- 11) solar; and
- 12) other renewables.

To enable more accurate linking to *PowerMark* the generation cost of each technology is assumed to be equal to their long run marginal cost (LRMC) while the sales price in each region is matched to the average dispatch weighted prices projected by *PowerMark* – with any difference being returned as an economic rent to electricity generators. This representation enables the highly detailed market based projections from *PowerMark* to be incorporated as accurately as possible into *Tasman Global*.

### **Factors of production**

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates through investment (less depreciation) in each period. Land is used only in agriculture industries and is fixed in each region. *Tasman Global* explicitly models natural resource inputs as a sector specific factor of production in resource based sectors (coal mining, oil and gas extraction, other mining, forestry and fishing).

### **Population growth and labour supply**

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for the 112 international regions and for the 8 states and territories of Australia represented in the *Tasman Global* database is projected using ACIL Tasman's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.



For each of the 120 regions in *Tasman Global*, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc.). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Tasman's demographics module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

### **The Australian labour market**

*Tasman Global* has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations;
- changes to participation rates (or average hours worked) due to changes in real wages;
- changes to unemployment rates due to changes in labour demand;
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour; and
- limited labour mobility between states.

*Tasman Global* recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms who hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.



Labour supply in *Tasman Global* is presented as a three stage process:

1. labour makes itself available to the workforce based on movements in the real wage and the unemployment rate;
2. labour chooses between occupations in a state based on relative real wages within the state; and
3. labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

### Greenhouse gas emissions

The model has a detailed greenhouse gas emissions accounting, trading and abatement framework that tracks the status of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF<sub>6</sub>). Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled but can be accounted for in policy analysis.

The greenhouse modelling framework not only allows accounting of changes in greenhouse gas emissions, but also allows various policy responses such as carbon taxes or emissions trading to be employed and assessed within a consistent framework. For example, the model can be used to measure the economic and emission impacts of a fixed emissions penalty in single or multiple regions whether trading is allowed or not. Or, it can be used to model the emissions penalty required to achieve a desired cut in emissions based on various trading and taxation criteria.

### Model results

*Tasman Global* solves equations covering industry sales and consumption, private consumption, government consumption, investment and trade. The model therefore produces detailed microeconomic results, such as:

- output by industry;
- employment by industry; and
- industry imports and exports.

*Tasman Global* also produces a full range of macroeconomic results, for each Australian and international region including:

- total economic output – i.e. gross domestic product (GDP), gross state product (GSP) and gross regional product (GRP);
- total employment;



## ACIL Tasman

Economics Policy Strategy

- gross national product (GNP);
- private consumption;
- public consumption;
- investment and savings;
- imports; and
- exports.



## D Bibliography

- ACIL Tasman (2008), *An Assessment of Australia's Liquid Fuels Vulnerability*, Canberra, November.
- Adelman, M., (1995), *The Genie Out of the Bottle: World Oil Since 1970*, Cambridge, Ma: MIT Press.
- Adelman, M. (2004), "The Real Oil Problem", *Regulation*, 27, 1, Spring, pp. 16-21.
- Aguilera, R., Eggert, R., Lagos, C., Tilton, J. (2009), "Depletion and the Future Availability of Petroleum Resources", *Energy Journal*, 30, 1, pp. 141-174.
- Alquist, R., Kilian, L. (2010), "What Do We Learn from the Price of Crude Oil Futures?", *Journal of Applied Econometrics*, 25, 4, June-July, pp. 539-573.
- Australian Bureau of Agricultural Economics (2008), *Australian Energy*, Canberra.
- Australian Bureau of Agricultural Economics (2010), *Australian Energy Projections 2029-30*, Canberra, March.
- Australian Bureau of Agricultural and Resource Economics and Sciences (2011), *Energy in Australia*, Canberra.
- Australian Bureau of Agricultural and Resources Economics and Sciences (2011), *Energy in Australia 2011*, report for Department of Resources, Energy and Tourism, Canberra.
- Australian Institute of Petroleum (2008), *Maintaining Supply Reliability in Australia*, Canberra, April.
- Australian Institute of Petroleum (2009), *Downstream Petroleum*, Canberra.
- Balke, N., Brown, S., Yücel, M. (2010), *Oil Price Shocks and U.S. Economic Activity: An International Perspective*, Discussion Paper, 10-37, Resources for the Future, June.
- Barsky, R., Kilian, L. (2004), "Oil and the Macroeconomy Since the 1970s", *Journal of Economic Perspectives*, 18, 4, Autumn, pp. 115-134.
- Bradley, R., Tanton, T. (2005), *U.S. Petroleum Refining: Let the Market Function*, Institute for Energy Research, Washington DC, 19 December.
- Breunig, R., Gisz, C. (2009), "An Exploration of Australian Petrol Demand: Unobservable Habits, Irreversibility and Some Updated Estimates", *Economic Record*, 85, 268, March, pp. 73-91.
- Brons, M., Nijkamp, P., Pels, E., Rietveld, P. (2008), "A Meta-Analysis of the Price Elasticity of Gasoline Demand: A SUR Approach", *Energy Economics*, 30, 5, September, pp. 2105-2122.
- Brown, S. (2009), "Reassessing Oil Security", *Resources for the Future Policy Commentary Series*, 5 October.
- Brown, S., Huntington, H. (2010), *Reassessing the Oil Security Premium*, Discussion Paper, 10-05, Resources for the Future, February.
- Bureau of Infrastructure Transport and Regional Economics (2008), *How Do Fuel Use and Emissions Respond to Price Changes?*, BITRE Briefing 1, Canberra, June.
- Burmeister, C., Peersman, G., Van Robays, I. (2010), "The Economic consequences of Oil Shocks: Differences Across Countries and Time" in Fry, K., Jones, C., Kent, C. (eds), *Inflation in an Era of Relative Price Shocks*, Canberra: Reserve Bank of Australia, 2010, pp. 91-128.
- Caltex Australia (2006), *Submission to the Senate Economics Legislation Committee Inquiry into the Price of Petrol in Australia*, August.
- Chesnes, M. (2009), "Capacity and Utilisation Choice in the U.S. Refining Industry", Department of Economics, University of Maryland, March; forthcoming in *Journal of Applied Econometrics*.
- Cooper, J. (2003), "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries", *OPEC Review*, March, pp. 1-8.





- Cuddington, J., Jerrett, D. (2008), "Super Cycles in Real Metals Prices?", *IMF Staff Papers*, 55, 4, December, pp. 541-565.
- Cuddington, J., Ludema, R., Jayasuria, S. (2007), "Prebisch-Singer Redux" in Lederman, D., Maloney, W. (eds), *Natural Resources Neither Curse Nor Destiny*, Washington: World Bank/ Stanford University Press, 2007, pp. 103-140.
- Dahl, C. (2011), "Measuring Global Gasoline and Diesel Price and Income Elasticities", *Energy Policy*, advance access.
- Dargay, J., Gately, D., Huntington, H. (2007), *Price and Income Responsiveness of World Demand by Product*, Energy Modelling Forum, Stanford University, December.
- Department of Resources Energy and Tourism (2011), *Australian Petroleum Statistics*, Canberra:Commonwealth of Australia.
- Dvir, E, Rogoff, K. (2010), *The Three Epochs of Oil*, Economics Department, Harvard University, August.Energy Information Administration (2010), *Aftermath of Katrina*. US Department of Energy.
- Energy Information Administration (2011). *World Energy Outlook*. US Department of Energy.
- Espey, M. (1998), "Gasoline Demand Revisited: An International Meta-Analysis of Elasticities", *Energy Economics*, 20, pp. 273-295.
- Frankel, J. (2010), "Real Energy Security: Drill, Baby, Drill – But Not Know", *Resources for the Future Policy Commentary Series*, 3 November.
- Frankel, J., Rose, A (2010), "Determinants of Agricultural and Mineral Commodity Prices" in Fry, K., Jones, C., Kent, C. (eds), *Inflation in an Era of Relative Price Shocks*, Canberra: Reserve Bank of Australia, 2010, pp. 9-51.
- Fyfe, D. (2011). *Oil Market Report*, International Energy Agency, March.
- Gordon, R. (2009), "Hicks, Hayek, Hotelling, Hubbert, and Hysteria or Energy, Exhaustion, Environmentalism, and Etatism in the 21<sup>st</sup> Century", *Energy Journal*, 30, 2, pp. 1-16.
- Graham, D., Glaister, S. (2002), "The Demand for Automobile Fuel: A Survey of Elasticities", *Journal of Transport Economics and Policy*, 36, 1, January, pp. 1-26.
- Hamilton, J. (2009a), "Understanding Crude Oil Prices", *Energy Journal*, 30, 2, pp. 179-206.
- Hamilton, J. (2009b), "Causes and Consequences of the Oil Shock of 2007-08", *Brookings Papers on Economic Activity*, Issue 1, Spring, pp. 215-261.
- Holland, S. (2008), "Modelling Peak Oil", *Energy Journal*, 29, 2, pp. 61-79.
- Hughes, J., Knittel, C., Sperling, D. (2008), "Evidence of a Shift in the Short-Run Price elasticity of Gasoline Demand", *Energy Journal*, 29, 1, pp. 113-134.
- Humphreys, D. (2009), "Comment: Unravelling the Causes of the Mineral Price Boom", *Resources Policy*, 34, 3, September, pp. 103-104.
- Humphreys, D. (2010), "The Great Metals Boom: A Retrospective", *Resources Policy*, 35, 1, March, pp. 1-13.
- Hymel, K., Small, K., Van Dender, K. (2010), "Induced Demand and Rebound Effects in Road Transport", *Transportation Research Part B*, 44, 10, December, pp. 1220-1241.
- International Energy Agency (2010), *World Energy Outlook 2010*, Paris: OECD/IEA.
- International Energy Agency (2008), *IEA Response System for Oil Supply Emergencies*, Paris: OECD/IEA, December.
- International Energy Agency (2009), *Medium-Term Oil Market Report*, Paris: OECD/IEA, June.



- Kesicki, F. (2010), "The Third Oil Price Surge – What's Different This Time?", *Energy Policy*, 38, 3, March, pp. 1596-1606.
- Kilian, L. (2008a), "A Comparison of the Effects of Exogenous Oil Supply Shocks on Output and Inflation in the G7 Countries", *Journal of the European Economic Association*, 6, 1, March, pp. 78-121.
- Kilian, L. (2008b), "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy", *Review of Economics and Statistics*, 90, 2, May, pp. 216-224.
- Kilian, L. (2008c), "The Economic Effects of Energy Price Shocks", *Journal of Economic Literature*, 46, 4, December, pp. 871-909.
- Kilian, L. (2009a), "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market", *American Economic Review*, 99, 3, June, pp. 1053-1069.
- Kilian, L. (2009b), "Causes and Consequences of the Oil Shock of 2007-08: Comment", *Brookings Papers on Economic Activity*, Spring, pp. 267-283.
- Kilian, L. (2010a), "Oil Price Shocks, Monetary Policy and Stagflation" in Fry, R., Jones, C., Kent, C. (eds), *Inflation in the Era of Relative Price Shocks*, Canberra: Reserve Bank of Australia, pp. 60-84.
- Kilian, L. (2010b), "Explaining Fluctuations in Gasoline Prices: A Joint Model of the global Crude Oil Market and the U.S. Retail Gasoline Market", *Energy Journal*, 31, 2, pp. 87-112.
- Kilian, L. (2010c), "A Primer on Oil Price Shocks Past and Present", *Resources for the Future Policy Commentary Series*, 21 May.
- Kilian, L., Murphy, D. (2010), *The Role of Inventories and Speculative Trading in the Global Market for Crude Oil*, University of Michigan, 10 May.
- Maugeri, L. (2009), "Understanding Oil Price Behaviour through an Analysis of a Crisis", *Review of Environmental Economics and Policy*, 3, 2, Summer, pp. 147-166.
- Newbery, D., Stiglitz, J. (1981), *The Theory of Commodity Price Stabilisation: A Study in the Economics of Risk*, Oxford: Oxford University Press.
- Nordhaus, W. (2007), "Who's Afraid of a Big Bad Oil Shock?", *Brookings Papers on Economic Activity*, Issue 2, Autumn, pp. 219-238.
- Organisation of Petroleum Exporting Countries (2010), *World Oil Outlook 2010*, Vienna.
- Radetzki, M. (2006), "The anatomy of Three Commodity Booms", *Resources Policy*, 31, 1, March, pp. 56-64.
- Radetzki, M. (2008), *A Handbook of Primary Commodities in the Global Economy*, Cambridge: Cambridge University Press.
- Radetzki, M. (2010), "Peak Oil and Other Threatening Peaks – Chimera without Substance", *Energy Policy*, 38, 11, November, pp. 6566-6569.
- Radetzki, M., Eggert, R., Lagos, G., Lima, M., Tilton, J. (2008), "The Boom in Mineral Markets: How Long Might it Last", *Resources Policy*, 33, 3, September, pp. 125-128.
- Roberts, I., Rush, A. (2010), *Sources of Chinese Demand for Resource Commodities*, Research Discussion Paper 2010-08, Reserve Bank of Australia, November.
- Roberts, M. (2009), "Duration and Characteristics of Metal Price Cycles", *Resources Policy*, 34, 3, September, pp. 87-102.
- Smith, J. (2009a), "World Oil: Markets or Mayhem", *Journal of Economic Perspectives*, 23, 3, Summer, pp. 145-164.
- Smith, J. (2009b), "The 2008 Oil Price Shock: Markets or Mayhem", *Resources for the Future Policy Commentary Series*, 6 November.



Stiglitz, J. (2006), *Making Globalisation Work*, New York: Norton.

United States Congressional Research Service, the Library of Congress (2005), *The Macroeconomic Effects of Hurricane Katrina*, Washington DC, 13 September.

United States Energy Information Administration (2005), *Hurricane Katrina's Impact on the U.S. Oil Market Special Report*, 31 August.

Zhang, L. (2011), "Asian Refining Industry – New Paradigm", *Hydrocarbon Asia*, January-March, pp. 6-13.

## Melbourne (Head Office)

Level 4, 114 William Street  
Melbourne VIC 3000

Telephone (+61 3) 9604 4400

Facsimile (+61 3) 9604 4455

Email [melbourne@aciltasman.com.au](mailto:melbourne@aciltasman.com.au)

## Brisbane

Level 15, 127 Creek Street

Brisbane QLD 4000

GPO Box 32

Brisbane QLD 4001

Telephone (+61 7) 3009 8700

Facsimile (+61 7) 3009 8799

Email [brisbane@aciltasman.com.au](mailto:brisbane@aciltasman.com.au)

## Canberra

Level 1, 33 Ainslie Place

Canberra City ACT 2600

GPO Box 1322

Canberra ACT 2601

Telephone (+61 2) 6103 8200

Facsimile (+61 2) 6103 8233

Email [canberra@aciltasman.com.au](mailto:canberra@aciltasman.com.au)

## Perth

Centa Building C2, 118 Railway Street

West Perth WA 6005

Telephone (+61 8) 9449 9600

Facsimile (+61 8) 9322 3955

Email [perth@aciltasman.com.au](mailto:perth@aciltasman.com.au)

## Sydney

PO Box 1554

Double Bay NSW 1360

Telephone (+61 2) 9389 7842

Facsimile (+61 2) 8080 8142

Email [sydney@aciltasman.com.au](mailto:sydney@aciltasman.com.au)



**ACIL Tasman**

Economics Policy Strategy

**ACIL Tasman Pty Ltd**

[www.aciltasman.com.au](http://www.aciltasman.com.au)