Australian Government

Geoscience Australia

# Submission by Geoscience Australia to the Senate Rural and Regional Affairs and Transport Committee Inquiry into Australia's Future Oil Supply and Alternative Transport Fuels

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## Executive Summary

### 1. INTRODUCTION

Geoscience Australia[1], a prescribed agency within the Industry, Tourism and Resources portfolio of the Australian Government, assists the Government and the community it serves to make appropriate and informed decisions about the use of resources, and also the management of the environment and the safety and wellbeing of its citizens. This is done by undertaking geoscientific research and maintaining, developing and allowing, and encouraging access to our fundamental geoscientific data.

Geoscience Australia is directly involved in supporting the petroleum exploration and production industry in the search for future supplies of petroleum. In the 2003 May budget the Australian Government announced funding of $61 million for a major four-year program of data acquisition to assist the petroleum exploration industry in the search for a new oil province. The Government provided funding of $36 million over four years to Geoscience Australia to continue with the supply of pre-competitive data that underpins activities within the petroleum exploration industry, and $25 million over four years to Geoscience Australia to fund the collection of new seismic data and the preservation of existing data.

The qualifications of Geoscience Australia to provide input to this inquiry stem from the following roles:

- Geoscience Australia produces annually a national inventory of Australia's oil and gas resources, including crude oil, condensate, liquefied petroleum gas, natural gas and coalbed methane. This includes assessments of undiscovered petroleum resources and forecasts of production rates. It also estimates resources of shale oil and coal, which may be used in the future to produce liquid and gaseous transport fuels.
- Geoscience Australia, through its geoscientific research activities and new data acquisition, uses this knowledge to provide and enhance assessments of the petroleum prospectivity of sedimentary basins of Australia.
- Geoscience Australia provides technical advice to government on a range of issues in relation to regulation of offshore petroleum resources, exploration, development, and pipelines.
- Public and industry access to petroleum information is also provided by Geoscience Australia through a number of on-line databases and reports, and the annual inventory of Australia's petroleum resources, Oil and Gas Resources of Australia.

This submission provides background information on Australia's oil supply and focuses on the first two terms of reference (ToR) for this inquiry:

[1] Geoscience Australia grew out of the Bureau of Mineral Resources (BMR) and the Division of National Mapping, both of which were founded soon after World War 2. BMR became the Australian Geological Survey Organisation in 1992, several years after the Division of National Mapping had become the Australian Surveying and Land Information Group (AUSLIG). AGSO and AUSLIG merged to become Geoscience Australia in 2001.

a. projections of oil production and demand in Australia and globally and the implications for availability and pricing of transport fuels in Australia.

b. potential of new sources of oil and alternative transport fuels to meet a significant share of Australia's fuel demands, taking into account technological developments and environmental and economic costs.

This submission has benefited from valuable comments and information provided by the Resources Division, Department of Industry, Tourism and Resources, and the Industries Branch, Australian Bureau of Agricultural and Resource Economics.

## 2. SUBMISSION IN RELATION TO SPECIFIC TERMS OF REFERENCE

### 2.1 ToR a: Projections of oil production and demand in Australia and globally and the implications for availability and pricing of transport fuels in Australia

#### 2.1.1 Projections of global oil production

Projections of world oil production vary as there are differing views on reserves and the likely levels of future production from these reserves. In the BP Statistical Review of World Energy (June 2005) world oil production in 2004 was estimated to be 80.26 million barrels per day, and world oil reserves were estimated at 1188.6 billion barrels.

#### 2.1.2 Projections of oil production in Australia

From the start of production at Moonie in 1964, Australia's crude oil production grew dramatically after the discovery of the offshore Gippsland oil fields in the 1960s and has remained at levels around 350 000 barrels per day since then. Recently the most important oil producing area has been the Carnarvon Basin in Western Australia, due to a number of medium to small size discoveries. In addition, as Australian gas production has increased dramatically, associated condensate[2] production has also increased to over 100 000 barrels per day. Twelve Australian sedimentary basins now produce crude oil or condensate.

Projections of future production depend on continued production from discovered reserves, additional production from identified fields due to future upward revisions of reserves in those fields, and discoveries of new fields. As a consequence, there are inherent uncertainties in predicting future production. Estimates of future production are provided at different probability levels by Geoscience Australia. At the median level of probability, current production levels of crude oil plus condensate of approximately 500 000 barrels per day are expected to be maintained until 2009 and decline thereafter. Crude oil production rates are forecast to continue declining while condensate production rates are expected to stabilise or grow.

Identified resources[3] of crude oil plus condensate have been maintained at approximately two billion barrels since 1967, due to a combination of reserves upgrades in discovered fields, and new discoveries of oil fields and condensate in gas fields. Crude oil resources are 1.496 billion barrels, the lowest level since 1967. Remaining commercial crude oil reserves (the part of resources which is currently producing or for which there are firm development commitments) are 0.714 billion barrels.

#### 2.1.3 Projections of oil demand in Australia

Australian demand for petroleum (including crude oil and condensate) is currently over 750 000 barrels per day, and is projected by the Australian Bureau of Agricultural and Resource Economics to increase to:

- over 800 000 barrels per day out to 2009-10,
- over 1 200 000 barrels per day out to 2029-30

This forecast represents a sustained increase of almost 2% annually until 2029-30. On a simplistic analysis out to 2009, the Australian production estimates for crude oil and condensate represent only 63% of the forecast Australian demand for oil. As projections of production rates suggest they will decline after 2009, the shortfall in domestic demand versus domestic supply is anticipated to increase significantly.

[2] Condensate is a light oil-like liquid produced from gas fields. It is originally gaseous at the depth of a gas field.

[3] Identified resources are the total amount of petroleum that can be recovered from specific accumulations that have been identified by drilling. Undiscovered resources are the amount of conventional petroleum that can be recovered from unspecified accumulations that have not been identified by drilling, but may exist within a specific reservoir sequence wherever it lies within a structural or stratigraphic trap.

## 2.2. ToR b: Potential of new sources of oil and alternative transport fuels to meet a significant share of Australia's fuel demands, taking into account technological developments and environmental and economic costs;

Several potential new sources of oil and alternative transport fuels exist. These include: new discoveries of oil and gas/condensate fields; use of natural gas in compressed or liquefied form directly in vehicles; fuel extracted from shale oil deposits; fuels synthesised from natural gas or coal; biologically derived fuels such as ethanol; renewable energy sources such as solar electric vehicles, and various forms of stored energy derived from a number of sources, such as in electric and hydrogen powered vehicles.

### 2.2.1 Potential of new sources of oil to meet demands

Potential new sources of oil may come from:

- reserves growth in fields already discovered,
- enhanced oil recovery in existing fields nearing depletion, and
- yet to be discovered fields in basins which have exploration levels ranging from mature to frontier.

Geoscience Australia's assessments suggest that the potential for:

- Reserves growth could be about 1.064 billion barrels of oil over the period 2003-2050.
    - This is a preliminary assessment, and such reserves growth, if it occurs, is likely to occur towards the end of field life.
- Enhanced oil recovery using carbon dioxide injection could be about 1.131 billion barrels.
    - This is a technical potential assessment and would require access to over 600 MT of carbon dioxide.
- Undiscovered resources from Australian basins currently producing petroleum has a risked mean of 1.729 billion barrels of crude oil and 0.674 billion barrels of condensate.

The potential for discoveries in basins which currently have no petroleum discoveries is undefined. Many of these basins have had little or no exploration, and thus can not be reliably assessed at a volumetric level. The potential of such basins is however routinely assessed by Geoscience Australia in terms of their relative prospectivity[4]. Government initiatives exist to acquire pre-competitive data and encourage exploration in poorly explored regions, which ultimately will lead to volumetric assessments of the potential resource that may be available in the under explored regions.

[4] Prospectivity is a determination of the likelihood that a resource is present in a given area based on the available information. It is developed through: examining data (if possible), examining existing knowledge, application of established conceptual models and ideally the generation of new conceptual models or applying an analogue from a neighbouring basin or some other geologically similar setting. When the level of uncertainty is very high, the prospectivity of an area can and will change with new knowledge and changes in economic and technological factors.

### 2.2.2 Potential of alternative transport fuels to meet demand

In terms of mineral and petroleum resources, black and brown coal are the predominant energy minerals worldwide and in Australia. Processes to convert these to synthetic fuels are available. Similarly natural gas and shale oil which are also widely available can be converted to synthetic fuel. Some of these processes themselves consume considerable amounts of energy to convert or store the energy into a usable form, so the net energy gain from conversion to a convenient and practical form of transport fuel in some cases may be small. Environmental and health effects also need to be considered.

Natural gas can also be used directly in vehicles in compressed or liquefied form, as can liquefied petroleum gas (LPG). While resources of natural gas and LPG are smaller than coal resources, less energy is used in production of these petroleum fuels than in production of synthetic fuels from either coal or gas.

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## 1. INTRODUCTION

Geoscience Australia is a prescribed agency within the Industry, Tourism and Resources portfolio of the Australian Government. Geoscience Australia assists the Government and the community it serves to make appropriate and informed decisions about the use of resources, and also the management of the environment and the safety and wellbeing of its citizens. This is done by undertaking geoscientific research and maintaining, developing and allowing, and encouraging access to our fundamental geoscientific data.

As Australia's national geoscience and spatial information agency, Geoscience Australia undertakes a wide range of activities onshore and in the marine zone. These include:

- provision of pre-competitive data to underpin offshore exploration activities within the petroleum industry
- provision of technical advice to government on a range of issues in relation to regulation of offshore petroleum resources, exploration and development under the *Petroleum (Submerged Lands) Act 1967* and other legislation
- provision of information and data relating to petroleum exploration and development (including resource estimates, prospectivity assessments, seismic surveys and well information) to government, industry, and the public through access to online databases.

In the 2003 May budget the Government provided funding of $36 million over four years to Geoscience Australia to continue with the provision of pre-competitive data to underpin petroleum exploration activities within the oil and gas industry. The programme provides geoscience information to organisations wishing to explore offshore for petroleum and so creates opportunities to potentially increase future Australian oil and gas production. As the existing programme relies on previously acquired data, the Government also decided to fund a programme of new data acquisition. The Government also provided funding of $25 million over four years to fund the collection of new seismic data and the preservation of existing data. The collection of new seismic data by Geoscience Australia in frontier geological provinces adds to the existing collection of industry and government acquired data available for release to organisations wishing to explore for petroleum. The preservation of deteriorating seismic data tapes held by Geoscience Australia, which store valuable geological information, will ensure that the data collections will be available for future use.

The Geoscience Australia annual report on Australia's upstream petroleum industry is *Oil and Gas Resources of Australia* (Petrie and others, 2005), available at the web location http://www.ga.gov.au/oceans/ss_OGRA.jsp

This submission provides background information on Australia's oil supply and outlook and addresses two of the terms of reference (ToR) for this inquiry. It focuses on the first two, drawing on our resources and advice role in the Australian Government:

a. projections of oil production and demand in Australia and globally and the implications for availability and pricing of transport fuels in Australia.

b. potential of new sources of oil and alternative transport fuels to meet a significant share of Australia's fuel demands, taking into account technological developments and environmental and economic costs.

The third and fourth ToRs, dealing with economic and social impacts and conservation, are not addressed here.

## 2. SUBMISSION IN RELATION TO SPECIFIC TERMS OF REFERENCE

### 2.1. ToR (a) projections of oil production and demand in Australia and globally and the implications for availability and pricing of transport fuels in Australia.

#### 2.1.1 Projections of global oil production

Projections of world oil production vary as there are differing views on reserves and the likely levels of future production from these reserves. For example in the BP Statistical Review of World Energy (June 2005) world oil production in 2004 was estimated to be 80.26 million barrels per day, and world oil reserves at end 2004 were estimated at 1188.6 billion barrels. By contrast the International Petroleum Encyclopedia (2005) estimated production in 2004 to be 70.993 million barrels per day, and world proved oil reserves at end 2004 to be 1277.7 billion barrels. The US Energy Information Administration estimated production in 2004 at 72.48 million barrels per day.[5] Careful note needs to be taken as to whether condensate, liquefied petroleum gas, and tar sands are included with crude oil in estimates of production and reserves, and whether figures are preliminary or revised.

#### 2.1.2 Projections of oil production in Australia

Projections of crude oil and condensate production are published annually by Geoscience Australia in its publication *Oil and Gas Resources of Australia* (Petrie and others, 2005).

***Production to date and sources of production***

There are more than 350 sedimentary basins and sub-basins in Australia (Figure 1), of which 80 lie partly or wholly offshore. Many of these basins are currently perceived to have low to no prospectivity. Approximately 40 to 60 are considered to be sufficiently prospective such that exploration programmes are warranted or underway. Significant levels of exploration are currently occurring in about one quarter of these prospective basins. Commercial oil production began in Australia in February 1964 from the Moonie oil field in the Surat Basin (onshore Queensland). Production rapidly increased after the commencement of production from the Barrow Island oil field (Carnarvon Basin, Western Australia) in 1967 and from the super-giant[6] offshore oil fields Halibut and Kingfish (Gippsland Basin, Victoria) in 1970 and 1971. Continued levels of oil discoveries, of a lower average size, have been complemented by very large gas discoveries which have associated condensate resources. The most significant oil producing area is now the offshore Carnarvon Basin where many medium to small oil fields have been discovered.

Since 1973, Australian fields have maintained crude oil production rates above 350 000 barrels per day (Figure 2). Major increases in gas production rates have resulted in condensate production rates climbing above 100 000 barrels per day since 1996. Total crude oil plus condensate production peaked in 2000 at 732 000 barrels per day (with the Laminaria and Corallina oilfields coming on stream), although there were earlier peaks. Although there are currently 482 producing fields onshore and 71 producing fields offshore, 92% of Australia's crude oil plus condensate production comes from offshore fields.

There are in 2006 a much larger number of producing fields with lower production rates, smaller remaining reserves, and larger amounts of co-produced water than was the case in 1973. The plateau in crude oil plus condensate production, reached between 1985 and the present, has been the result of bringing onstream a large number of additional oil fields and condensate-producing gas fields, including production from additional basins (Figure 2).

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[5] http://www.eia.doe.gov/emeu/

[6] Oilfields are classified by Beddoes (1973) as super-giant if they have initial reserves of over 500 million barrels of oil. Gas fields are classified as super-giant if they have initial reserves of over 3.5 trillion cubic feet of gas. On a heating value basis, 500 million barrels of oil is approximately equivalent to 3.5 trillion cubic feet of gas. There have been two super-giant oil field discoveries (Kingfish and Halibut) in Australia, and 15 super-giant gas field discoveries: (Bayu-Undan, Evans Shoal and Sunrise-Troubadour in the Bonaparte Basin, Scott Reef, Brecknock, Brecknock South and Ichthys in the Browse Basin, Goodwyn, Wheatstone, Gorgon, North Rankin, Io-Jansz, Pluto and Scarborough in the Carnarvon Basin, and Marlin in the Gippsland Basin).

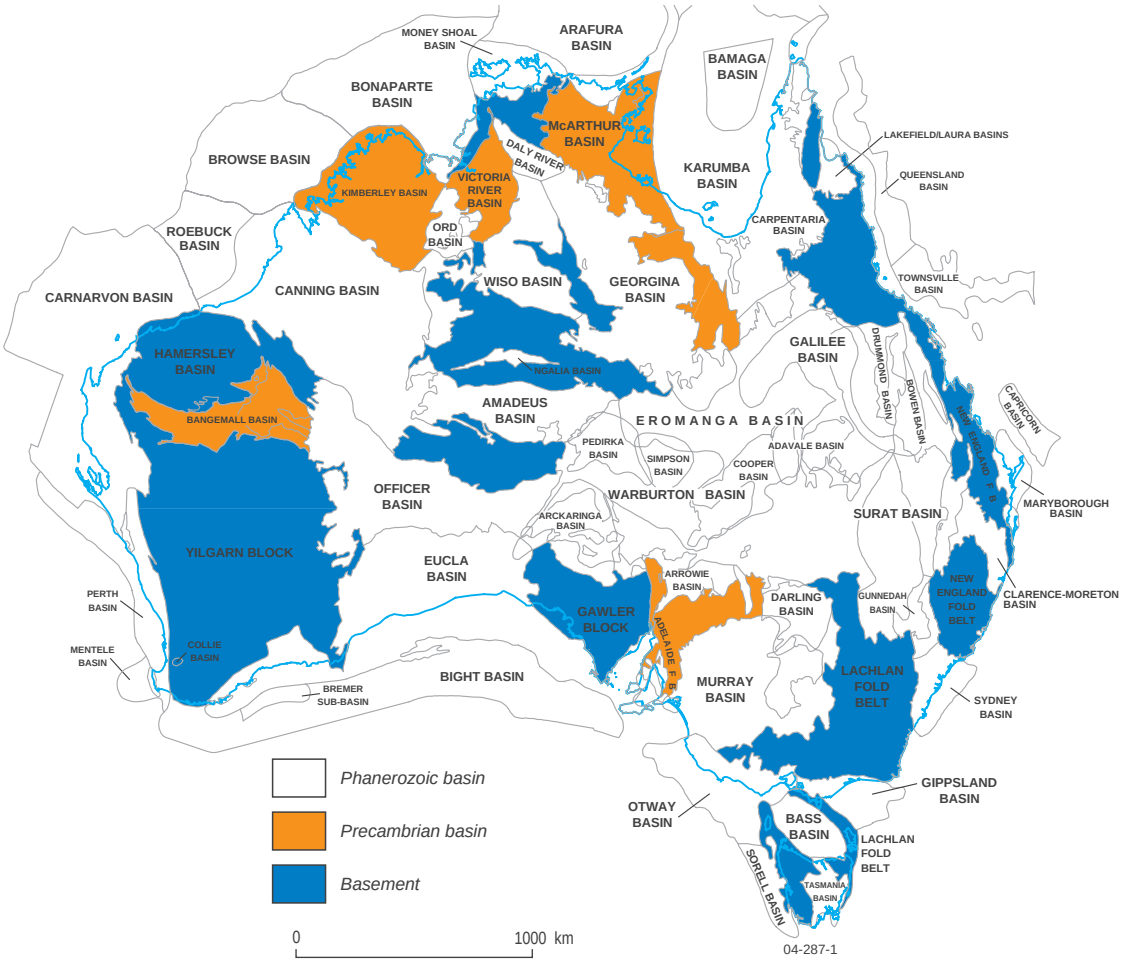


***Figure 1:*** *Australian sedimentary basins.*

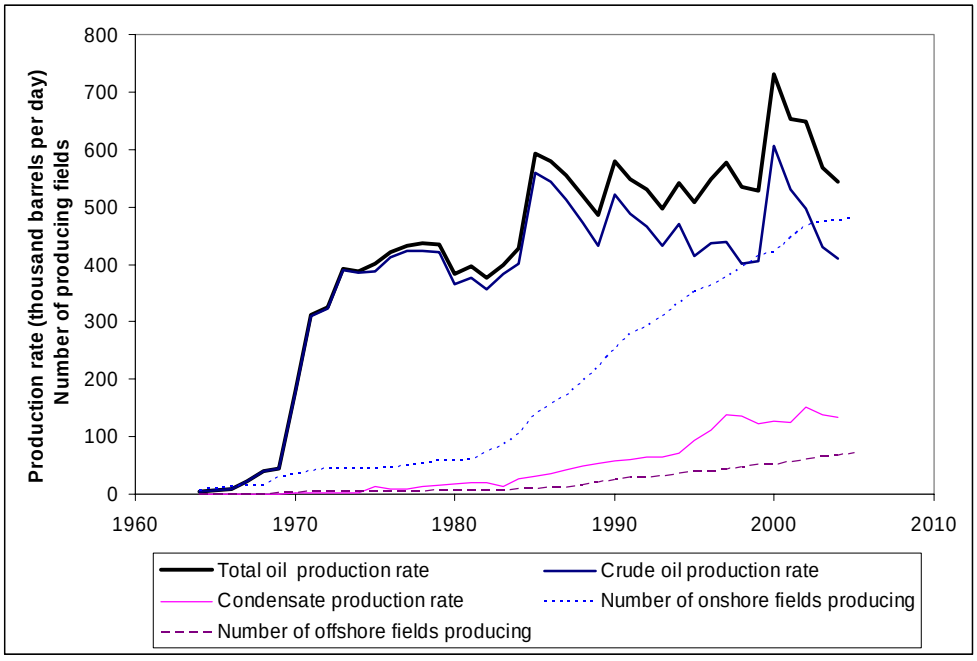


***Figure 2:*** *Historical Australian production rates and number of producing fields.*

Australia currently has commercial production of crude oil or condensate from twelve sedimentary basins, with the date of first production of petroleum shown in Table 1.

**Table 1** First commercial production of crude oil or condensate from Australian sedimentary basins

| Basin | Location of basin | First commercial production | First commercially producing field |
|---|---|---|---|
| Surat | Onshore Queensland and New South Wales | February 1964 | Moonie |
| Carnarvon | Onshore and offshore Western Australia | January 1967 | Barrow Island |
| Gippsland | Offshore and onshore Victoria | March 1969 | Barracouta |
| Bowen | Onshore Queensland | September 1969 | Wallumbillah South |
| Cooper | Onshore Queensland | November 1969 | Moomba |
| Eromanga | Onshore Queensland, South Australia, New South Wales and Northern Territory | November 1969 | Gidgealpa |
| Perth | Onshore and offshore Western Australia | October 1971 | Dongara |
| Amadeus | Onshore Northern Territory and Western Australia | August 1983 | Palm Valley |
| Canning | Onshore Western Australia | September 1983 | Blina |
| Bonaparte | Offshore Northern Territory and Western Australia | September 1983 | Jabiru |
| Otway | Onshore and offshore Victoria and South Australia | April 1986 | North Paaratte |
| Adavale | Onshore Queensland | June 1995 | Gilmore |

As can be seen in Table 1, the commencement of development of Australia's petroleum resources has progressed through different basins over time. Six basins commenced production in the 1960s, one in the 1970s, four in the 1980s and one in the 1990s. The Coonarah gas field in the Gunnedah Basin (onshore New South Wales) commenced gas production in July 2004, but contains negligible condensate. An additional basin which is offshore Victoria and Tasmania (Bass Basin) is planned to commence production from the Yolla field in March 2006.

In addition to the producing oil and gas fields in the above basins, varying levels of oil and/or gas discoveries have also been made in the following basins, but are not currently being commercially produced.

**Significant discoveries:**
Browse Basin (offshore Western Australia and Northern Territory)
**Minor discoveries:**
Clarence-Moreton Basin (onshore and offshore Queensland and New South Wales)
Galilee Basin (onshore Queensland)
Georgina Basin (onshore Northern Territory and Queensland)
Ipswich Basin (onshore and offshore Queensland and New South Wales)
McArthur Basin (onshore Northern Territory)
Sydney Basin (onshore and offshore New South Wales)

It is possible that some of these basins will have commercial production in the future. The Browse Basin is of particular interest as it contains a number of super-giant gas fields with substantial condensate resources, as well as some small oil fields. In the Bowen and Sydney basins coalbed methane is now being commercially produced, and commercial coalbed methane production is expected from the Surat Basin in 2006.

### *Crude oil and condensate production forecast to 2025*

The forecast of production by Geoscience Australia is based on current estimates of production from identified and undiscovered resources. Geoscience Australia estimates are provided at various probability levels to reflect the uncertainty surrounding the development of discovered accumulations (e.g. a production estimate at the 90% probability level (P90) means that there is a 90% chance of production being at least as high as the figure shown).

The figures for production from identified resources incorporate estimates of production from individual developed fields as well as estimates of reserves and timing of development of identified but undeveloped fields. The major factors affecting the accuracy of oil production estimates for identified fields are reserves growth and delays in startup and interruptions to production. The lower probability levels reflect the scope for increases in the reserves estimates on which the forecasts are based.

The accuracy of the production estimates is also dependent on the timing of future gas developments with their associated condensate production. In some cases, the cycling of dry gas allows accelerated and incremental production of condensate. This has occurred for example at the Goodwyn, North Rankin, and Bayu-Undan fields.

Figure 3 and Table 2 show the production of crude oil plus condensate from 1964 to 2004 and forecast production to 2025. The forecast includes production of crude oil and condensate from accumulations that had been discovered by the end of June 2005, plus production of crude oil and condensate from undiscovered accumulations. The forecast includes 10% of production from the Joint Petroleum Development Area (JPDA)[7]. If the P10 probability level forecast is reached, there may be a new Australian peak production rate in 2007. Several medium size oilfields in the Carnarvon basin are expected to commence production in the near term, and condensate production is expected to rise with additional development of some large gas fields.

[7] On 20 May 2002, the date of Timor-Leste's independence, Australia and Timor-Leste signed the Timor Sea Treaty. This Treaty governs petroleum exploration and development in that part of the Timor Sea subject to overlapping jurisdictional claims. The Treaty came into force on 2 April 2003 and sets the framework for joint administration by Australia and Timor-Leste of petroleum exploration and development in the Timor Sea. The Treaty sets out matters such as fiscal and administrative arrangements and importantly gives certainty to investors in the JPDA created by the Treaty.

Part of the Timor Sea is subject to overlapping territorial claims by Australia and Timor-Leste. This area contains extensive resources of oil and gas and two major petroleum development projects are underway or proposed – the Bayu-Undan field and the Greater Sunrise field. These fields are of major national interest to Australia, and revenue from them will support Timor-Leste's future development. On January 12 2006, the Treaty on Certain Maritime Arrangements in the Timor Sea was signed. The Treaty, together with the 2003 International Unitisation Agreement, establishes a framework for the exploitation of the Greater Sunrise field. It will see the equal sharing of upstream Government revenues flowing from the project. The Treaty builds on the 2002 Timor Sea Treaty in underpinning the income and development of one of Australia's closest neighbours. It also puts on hold the Parties' claims to jurisdiction and maritime boundaries in the Timor Sea for 50 years. See http://www.dfat.gov.au for further information.

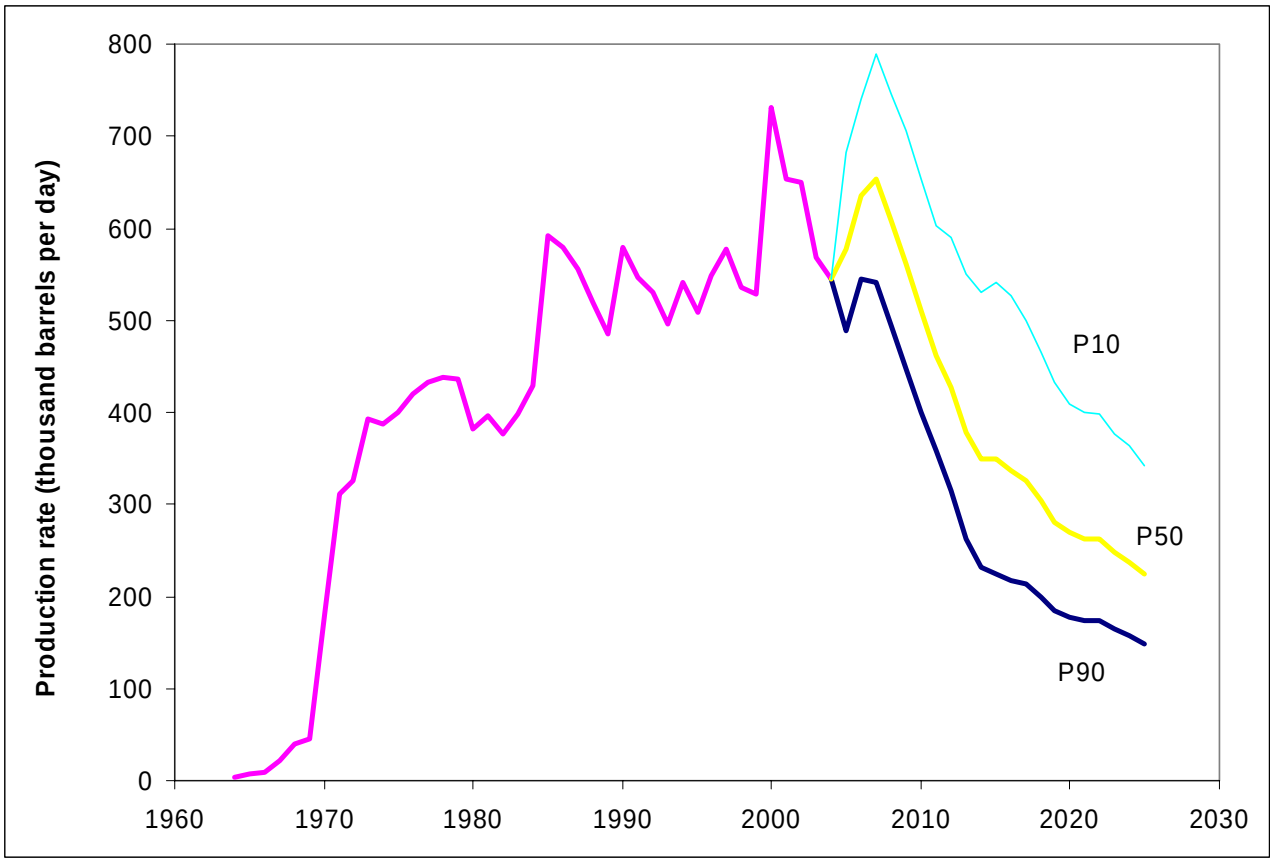


***Figure 3:*** *Historical production and forecast Australian crude oil plus condensate production rate at various probability levels*

**Table 2** Forecast as at July 2005 (thousands of barrels per day) for 2006-2025 of **crude oil and condensate** production from Australia's identified accumulations, and crude oil production from undiscovered accumulations in the Bonaparte, Carnarvon, Eromanga, Cooper, Gippsland, Browse, Bass, offshore Otway and offshore Perth Basins.

| | Identified | | | Undiscovered | | | Both | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | P90 | P50 | P10 | P90 | P50 | P10 | P90 | P50 | P10 |
| 2006 | 542 | 617 | 740 | 0 | 1 | 2 | 544 | 635 | 741 |
| 2007 | 538 | 628 | 785 | 0 | 2 | 7 | 541 | 653 | 790 |
| 2008 | 488 | 589 | 736 | 1 | 3 | 17 | 495 | 608 | 745 |
| 2009 | 437 | 551 | 689 | 1 | 5 | 31 | 447 | 561 | 706 |
| 2010 | 386 | 501 | 627 | 2 | 11 | 47 | 400 | 510 | 654 |
| 2011 | 338 | 448 | 561 | 3 | 20 | 69 | 358 | 461 | 603 |
| 2012 | 287 | 402 | 537 | 6 | 30 | 86 | 315 | 428 | 590 |
| 2013 | 226 | 336 | 486 | 10 | 40 | 105 | 262 | 378 | 550 |
| 2014 | 187 | 295 | 452 | 14 | 50 | 124 | 231 | 349 | 531 |
| 2015 | 174 | 285 | 452 | 19 | 59 | 138 | 225 | 349 | 541 |
| 2016 | 158 | 261 | 423 | 25 | 71 | 153 | 217 | 337 | 526 |
| 2017 | 146 | 239 | 389 | 31 | 79 | 164 | 213 | 325 | 499 |
| 2018 | 129 | 212 | 345 | 35 | 85 | 172 | 199 | 304 | 466 |
| 2019 | 112 | 184 | 300 | 39 | 93 | 182 | 185 | 281 | 433 |
| 2020 | 102 | 167 | 272 | 43 | 98 | 187 | 177 | 269 | 409 |
| 2021 | 95 | 156 | 255 | 46 | 103 | 193 | 173 | 262 | 400 |
| 2022 | 94 | 153 | 250 | 49 | 106 | 195 | 174 | 263 | 398 |
| 2023 | 84 | 137 | 224 | 50 | 110 | 199 | 165 | 248 | 377 |
| 2024 | 77 | 126 | 205 | 52 | 112 | 200 | 157 | 237 | 363 |
| 2025 | 68 | 112 | 182 | 52 | 113 | 200 | 148 | 224 | 342 |

### *Crude oil production forecast to 2025*

Figure 4 and Table 3 show crude oil production from 1964 to 2004 and a forecast of crude oil production to 2025. The forecast is based partly on Geoscience Australia and company estimates of crude oil production from accumulations that had been discovered by the end of June 2005 (identified accumulations), and partly on estimates of crude oil production from undiscovered accumulations. The forecast includes 10% of production from the JPDA.

The forecast steep decline after 2007 is associated with a concomitant increase in water production. There are very few crude oil wells which are water-free in Australia at present. The onset of water production causes a rapid decline in the production rate of petroleum from a well.

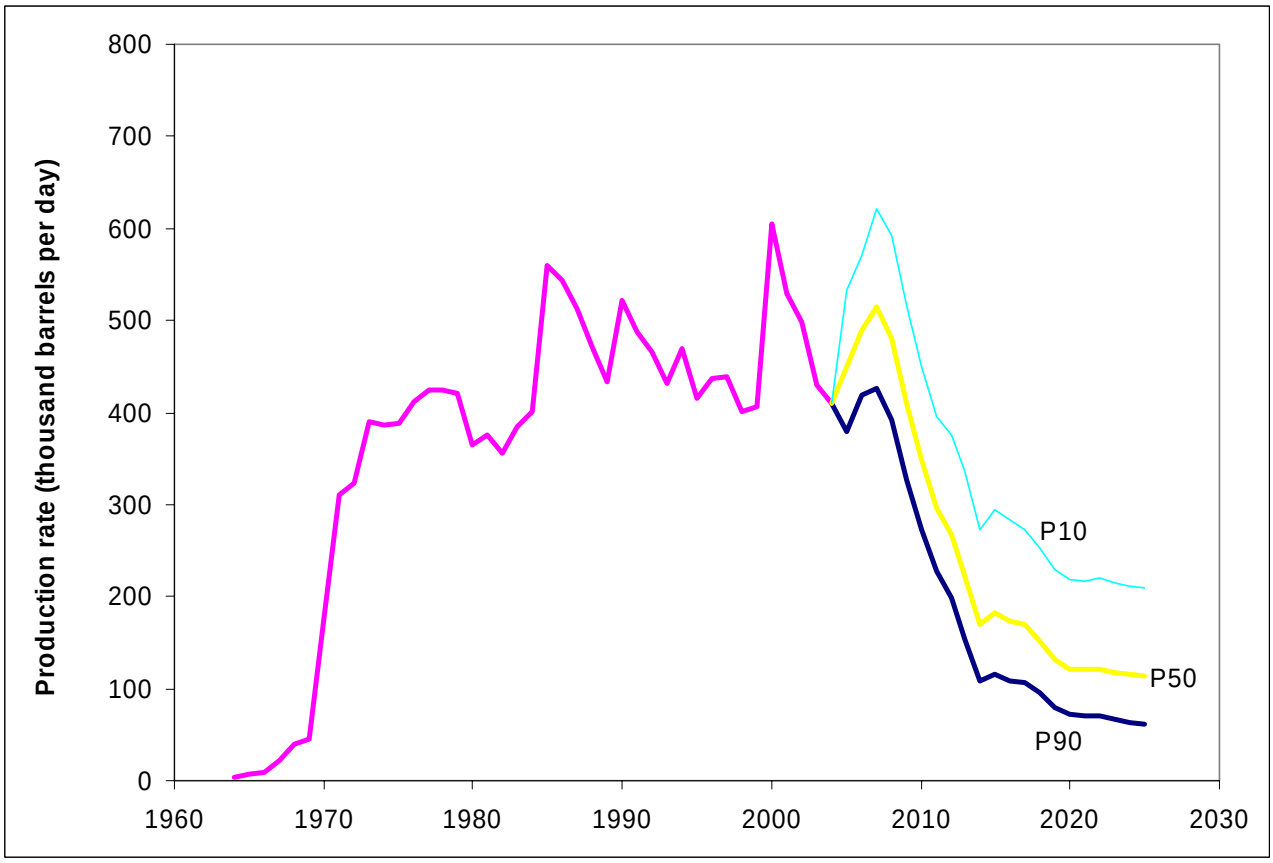


***Figure 4:*** *Historical production and forecast Australian crude oil production rate at various probability levels*

**Table 3** Forecast as at July 2005 (thousands of barrels per day) for 2006-2025 of **crude oil production** from Australia's identified accumulations, and from undiscovered accumulations, in the Bonaparte, Carnarvon, Eromanga, Cooper, Gippsland, Browse, Bass, offshore Otway and offshore Perth Basins.

| | Identified | | | Undiscovered | | | Both | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | P90 | P50 | P10 | P90 | P50 | P10 | P90 | P50 | P10 |
| 2006 | 417 | 475 | 570 | 0 | 1 | 2 | 419 | 489 | 571 |
| 2007 | 423 | 494 | 617 | 0 | 2 | 7 | 426 | 514 | 621 |
| 2008 | 385 | 465 | 581 | 1 | 3 | 17 | 391 | 481 | 592 |
| 2009 | 317 | 400 | 500 | 1 | 5 | 31 | 326 | 410 | 517 |
| 2010 | 259 | 337 | 421 | 2 | 11 | 47 | 273 | 349 | 450 |
| 2011 | 211 | 279 | 350 | 3 | 20 | 69 | 228 | 297 | 395 |
| 2012 | 171 | 239 | 319 | 6 | 30 | 86 | 199 | 267 | 375 |
| 2013 | 122 | 182 | 263 | 10 | 40 | 105 | 153 | 223 | 335 |
| 2014 | 76 | 119 | 183 | 14 | 50 | 124 | 109 | 169 | 273 |
| 2015 | 74 | 121 | 192 | 19 | 59 | 138 | 116 | 183 | 294 |
| 2016 | 62 | 102 | 166 | 25 | 71 | 153 | 109 | 173 | 284 |
| 2017 | 54 | 89 | 145 | 31 | 79 | 164 | 107 | 169 | 273 |
| 2018 | 41 | 67 | 109 | 35 | 85 | 172 | 95 | 151 | 252 |
| 2019 | 26 | 43 | 69 | 39 | 93 | 182 | 80 | 131 | 230 |
| 2020 | 17 | 29 | 47 | 43 | 98 | 187 | 72 | 121 | 219 |
| 2021 | 15 | 25 | 40 | 46 | 103 | 193 | 71 | 121 | 217 |
| 2022 | 13 | 21 | 34 | 49 | 106 | 195 | 71 | 121 | 220 |
| 2023 | 9 | 16 | 25 | 50 | 110 | 199 | 66 | 117 | 215 |
| 2024 | 7 | 12 | 20 | 52 | 112 | 200 | 64 | 115 | 212 |
| 2025 | 6 | 10 | 16 | 52 | 113 | 200 | 62 | 113 | 210 |

***Condensate production forecast to 2025***

Figure 5 and Table 4 show production of condensate from 1964 to 2004 and a forecast of condensate production to 2025. The forecast is based on company and Geoscience Australia estimates of production from accumulations that had been discovered by June 2005 and for which some production planning has been carried out. The forecast includes 10% of production from the JPDA.

In the absence of gas recycling, and because of the association of condensate in gas fields, the ability for Australia to increase its production rate of condensate will be limited by the extent to which future gas markets are developed. The condensate yields from several identified gas fields which may be brought into production in the long term will be lower than the condensate yields from currently producing gas fields. Many of these identified but yet to be produced gas fields are likely to be economically unsuitable for gas recycling as the gas is not sufficiently rich in condensate to justify recycling. Thus condensate production rates are unlikely to be quickly increased in the short term to compensate for a decline in crude oil production rates, as a major increase in demand for the accompanying gas resources will need to have occurred.

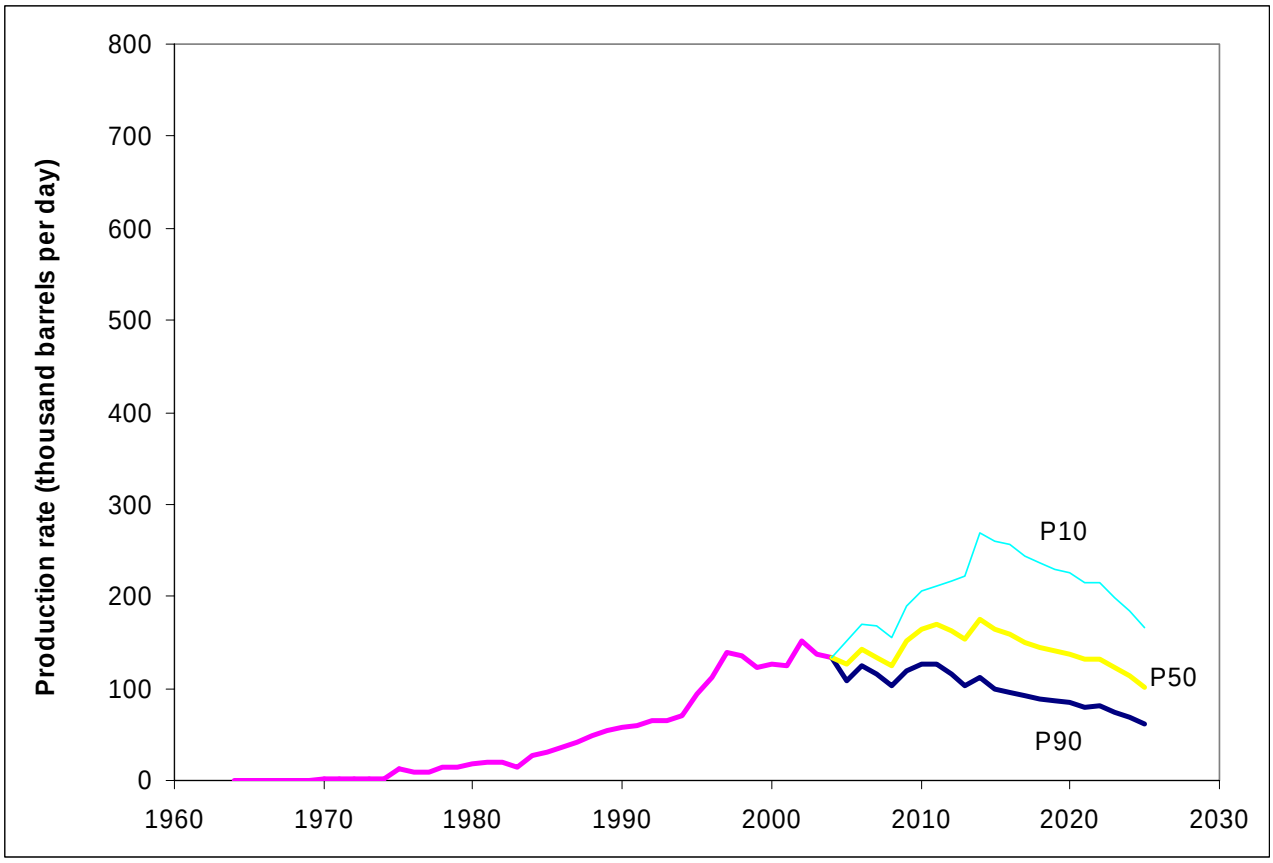


***Figure 5:*** *Historical production and forecast Australian condensate production rate at various probability levels*

**Table 4** Forecast as at July 2005 (thousands of barrels per day) for 2006-2025 of **condensate** production from Australia's identified accumulations.

| | Identified | | |
|---|---|---|---|
| Year | P90 | P50 | P10 |
| 2006 | 125 | 142 | 170 |
| 2007 | 115 | 134 | 168 |
| 2008 | 103 | 124 | 155 |
| 2009 | 120 | 151 | 189 |
| 2010 | 127 | 165 | 206 |
| 2011 | 127 | 169 | 212 |
| 2012 | 116 | 163 | 217 |
| 2013 | 103 | 154 | 222 |
| 2014 | 112 | 176 | 269 |
| 2015 | 100 | 164 | 260 |
| 2016 | 96 | 159 | 257 |
| 2017 | 92 | 150 | 244 |
| 2018 | 88 | 145 | 236 |
| 2019 | 86 | 141 | 230 |
| 2020 | 84 | 138 | 225 |
| 2021 | 80 | 132 | 214 |
| 2022 | 81 | 132 | 215 |
| 2023 | 74 | 122 | 198 |
| 2024 | 69 | 114 | 185 |
| 2025 | 62 | 102 | 166 |

Current estimates of identified Australian petroleum resources appear in Appendix 1.

### 2.1.3 Projections of oil demand in Australia

The following table of consumption of liquid fuels as petroleum products is based on the forecast of consumption of liquid petroleum (other than LPG) in energy units published by the Australian Bureau of Agricultural and Resource Economics as at October 2005 (Donaldson, 2005). The conversion by Geoscience Australia to equivalent oil production rate in barrels per day uses a calorific value of 5883 MJ/barrel (37 MJ/litre).

**Table 4** Forecast as at July 2005 (thousands of barrels per day) for 2005/06-2029/30 of consumption of petroleum products (excluding LPG) in Australia

| | Energy units | Equivalent oil production rate |
|---|---|---|
| | PJ | Thousand barrels per day |
| 2005-06 | 1624.9 | 756.8 |
| 2006-07 | 1646.4 | 766.8 |
| 2007-08 | 1682.0 | 783.4 |
| 2008-09 | 1717.4 | 799.9 |
| 2009-10 | 1754.3 | 817.0 |
| 2010-11 | 1790.0 | 833.7 |
| 2011-12 | 1825.7 | 850.3 |
| 2012-13 | 1862.1 | 867.2 |
| 2013-14 | 1899.7 | 884.8 |
| 2014-15 | 1938.6 | 902.9 |
| 2015-16 | 1978.1 | 921.3 |
| 2016-17 | 2018.1 | 939.9 |
| 2017-18 | 2058.8 | 958.9 |
| 2018-19 | 2100.6 | 978.3 |
| 2019-20 | 2143.5 | 998.3 |
| 2020-21 | 2185.5 | 1017.9 |
| 2021-22 | 2228.2 | 1037.7 |
| 2022-23 | 2271.7 | 1058.0 |
| 2023-24 | 2316.1 | 1078.7 |
| 2024-25 | 2361.6 | 1099.9 |
| 2025-26 | 2408.0 | 1121.5 |
| 2526-27 | 2455.2 | 1143.5 |
| 2027-28 | 2503.3 | 1165.9 |
| 2028-29 | 2552.3 | 1188.7 |
| 2029-30 | 2602.2 | 1212.0 |
| Average annual growth | 1.95% | |

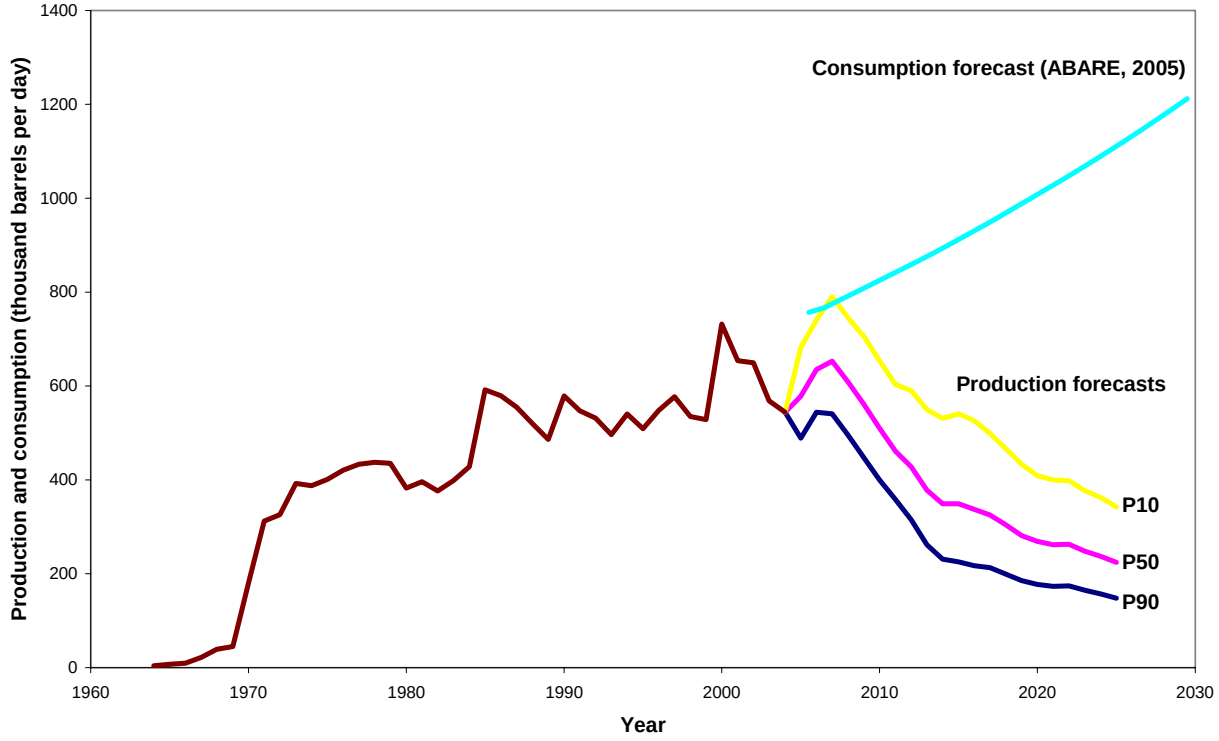


***Figure 6:*** *Forecast Australian consumption of petroleum products (excluding LPG) and forecast of Australian crude oil plus condensate production rate at various probability levels*

Figure 6 shows forecast consumption compared to forecast crude oil plus condensate production for 2005-2030. Australian crude oil plus condensate production has not equalled demand since 1970. As most Australian crude oil lacks heavy components suitable for lubricants, fuel oil and bitumen, crude oil has always been imported into Australia to meet these needs. There have been some recent heavy oil discoveries (Wandoo, Stag, Enfield, Vincent) in the Carnarvon Basin of Western Australia. Overall in terms of energy content Australia is a net exporter of petroleum as the energy content of the significant exports of LNG and LPG exceeds the energy content and value of imported petroleum. For example in 2003/4 the estimated energy content of exported LNG and LPG was 485.3 PJ and the estimated energy content of net imports of oil was 187.3 PJ (Donaldson, 2005).

## 2.2. ToR (b) potential of new sources of oil and alternative transport fuels to meet a significant share of Australia's fuel demands, taking into account technological developments and environmental and economic costs

Several potential new sources of oil and alternative transport fuels for Australia exist in Australia and worldwide. This discussion considers several sources, but focuses on potential for additional Australian petroleum resources and on energy mineral resources where Australia has a substantial fraction of world resources.

Worldwide there are several potential new sources of oil, in both identified and undiscovered conventional oil and gas condensate fields, in heavy oil fields and in tar sands, and in other hydrocarbon bearing minerals, as well as biofuels (such as ethanol) and synthetic fuels produced from gas or coal. In addition, transport fuels may be sourced directly from gas resources as compressed natural gas (CNG), as liquefied natural gas (LNG) and as liquefied petroleum gas (LPG) which already contributes a significant proportion of Australia's transport fuels. There is also potential for converting both fossil fuels and renewable sources of energy into electricity stored in batteries or (via electrolysis) in the form of hydrogen gas for use as a source of energy for use in transport.

The Australian government has introduced several initiatives both to assist the search for additional petroleum and to increase the use of alternative fuels (the Alternative Fuels Conversion Programme and the Energy Grants Credits Scheme -see http://www.greenhouse.gov.au/transport/alternative_fuel.html).

### 2.2.1 Potential of new sources of oil to meet demands

#### *Additional oil reserves in identified fields*

A potential new source of increased oil resources in identified fields is reserves growth (a phenomenon where estimates of reserves in discovered fields tend to increase with time). This is the major factor in oil reserves increases in Australia since 1970, and in the world generally since that date. Geoscience Australia has made some preliminary estimates of potential for reserves growth in identified fields, which were published in *Oil and Gas Resources of Australia 2002* and *2003 (*Petrie and others, 2003 and 2005*)*. The methodology for this assessment is still under development but preliminary estimates of future crude oil reserves growth potential (from fields discovered prior to 2003) of 1.064 billion barrels from 2003 to 2050 were derived. Similarly gas reserves growth of 9 Tcf over the same period was estimated. However, these estimates are subject to major uncertainties and scope for reserves growth is therefore included only at the 10% probability levels in Figures 3 and 4.

Tertiary recovery or enhanced oil recovery has the potential to recover oil not recovered by primary (natural flow) and secondary (water or gas injection) methods. The technical potential for enhanced oil recovery in Australian oilfields using carbon dioxide injection is estimated at about 1.131 billion barrels, but would require access to substantial volumes of carbon dioxide (le Poidevin and Wright, 2005).

#### *Resources of oil and condensate in undiscovered fields*

A second new source of oil could come from undiscovered fields in:

- currently producing basins,
- basins where petroleum has been discovered but not produced, and
- basins in which petroleum has not yet been discovered.

In addition to funding Geoscience Australia for provision of pre-competitive data so as to encourage exploration activity within the petroleum industry, incentives for exploring in remote offshore basins have been introduced recently by the Australian Government (Petrie and others, 2005). In May 2004, as part of the 2004/2005 Budget, the Australian Government announced the introduction of a taxation incentive designed to encourage petroleum exploration in Australia's

remote offshore areas. The Government increased the value of deductible pre-appraisal exploration expenditures incurred in designated offshore frontier areas by 50% for the determination of petroleum resource rent tax (PRRT). This 150% uplift applies to the initial term of the exploration permit awarded over a Designated Frontier Area.

This new incentive to promote exploration of Australia's frontier, offshore areas applies to the annual offshore acreage releases for 2004 through to 2008. Up to 20% of the areas offered each year under the annual offshore Acreage Release Program can be designated as frontier acreage eligible for this new taxation incentive, although Designated Frontier Areas must be at least 100 km from an existing commercialised oil discovery and must not be adjacent to an area designated in the previous year's Acreage Release Program. In the 2004 Acreage Release Program, six frontier offshore areas were eligible for the new 150% uplift on PRRT, and in the 2005 Acreage Release Program, five frontier offshore areas were eligible.

Overall Australia is very lightly explored and few of the basins could be considered mature by international exploration standards (Figure 7).

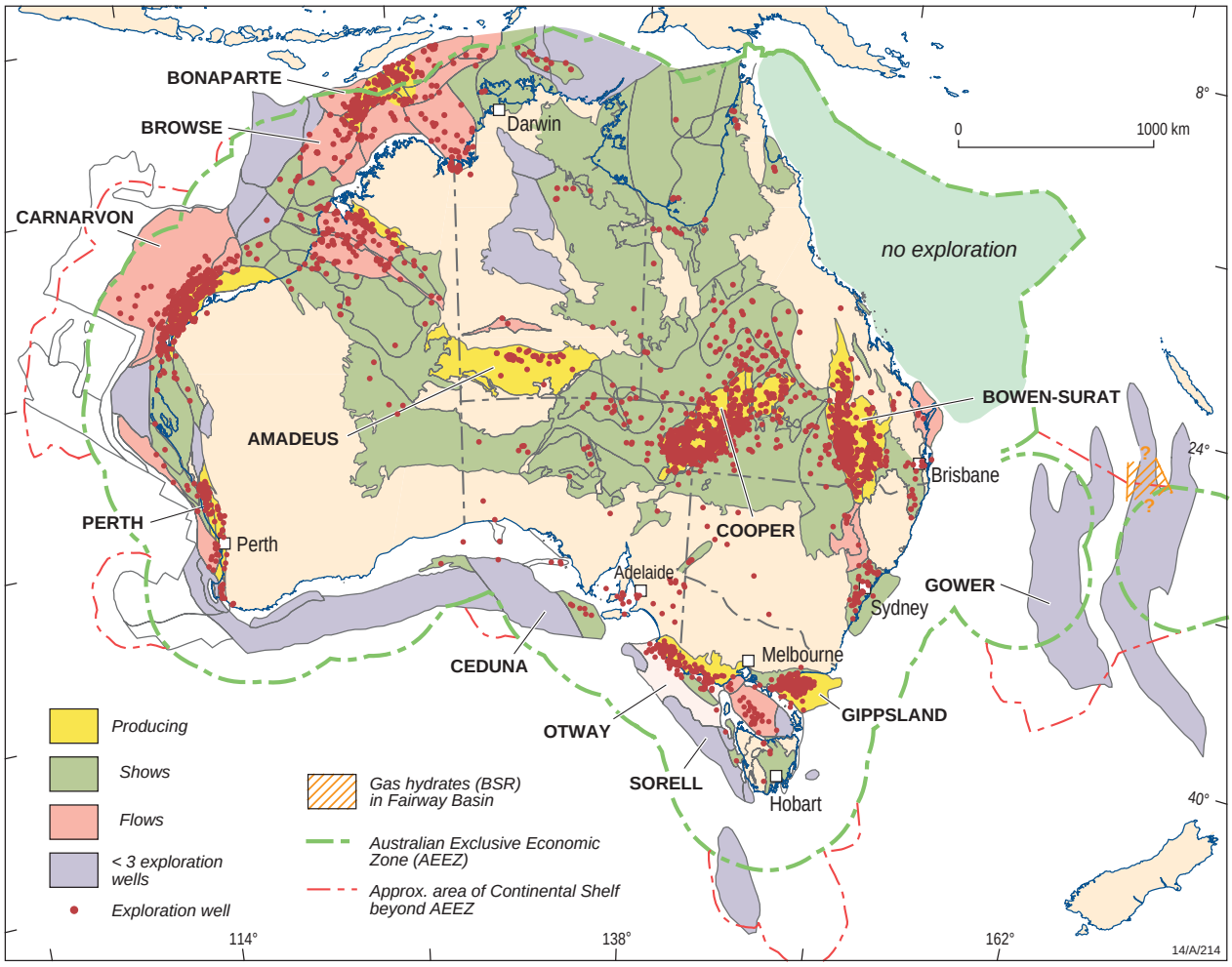


***Figure 7:*** *Map of basins in Australia and the Timor Sea Joint Petroleum Development Area showing well locations, producing basins, basins containing wells with flows and shows and unexplored areas. (Williamson and Foster, 2003)*

Geoscience Australia has conducted assessments of undiscovered potential in some Australian basins[8] (see Oil and Gas Resources of Australia 2003 (Petrie and others, 2005) and earlier editions) and Bureau of Mineral Resources (1988). The following table summarises several assessments of crude oil and condensate resources conducted by Geoscience Australia at different times. Discoveries made after many of these assessments were made will materially affect the value of these assessments.

[8] The methodology used is outlined in Forman and Hinde (1985, 1986, 1990), Forman and others (1987, 1992), Powell (2001) and Barrett and others (2004).

**Table 5** Geoscience Australia assessments of undiscovered crude oil and condensate from a selection of basins with significant discoveries.

| **Oil (million barrels)** | | | |
|---|---|---|---|
| **Basin** | **P90** | **Risked mean** | **P10** |
| Carnarvon | 260 | 535 | 866 |
| Bonaparte | 122 | 359 | 626 |
| Browse | 0 | 46 | 150 |
| Gippsland | 84 | 351 | 712 |
| Perth | 6 | 155 | 409 |
| Otway | 2 | 129 | 329 |
| Eromanga | 44 | 69 | 97 |
| Cooper | | | |

*Note: basin values cannot be arithmetically summed as these distributions have been probabilistically aggregated using a Monte Carlo procedure*

| **Total** | **945** | **1,729** | **2,583** |
|---|---|---|---|

| **Condensate (million barrels)** | | | |
|---|---|---|---|
| **Basin** | **P90** | **Risked mean** | **P10** |
| Carnarvon | 145 | 327 | 549 |
| Bonaparte | 26 | 115 | 246 |
| Browse | 0 | 115 | 321 |
| Gippsland | Included in total liquids | | |
| Perth | 1 | 13 | 36 |
| Otway | 13 | 37 | 67 |
| Cooper/ Eromanga | 12 | 17 | 24 |

*Note: basin values cannot be arithmetically summed as these distributions have been probabilistically aggregated using a Monte Carlo procedure*

| **Total** | **323** | **674** | **1 034** |
|---|---|---|---|

The assessment of undiscovered resources above addresses only a selection of basins in which significant volumes of petroleum have been discovered. The potential of other basins in Australia is much more difficult to estimate, but possibly could be substantial. Geoscience Australia is continuing to conduct assessment of the prospectivity of basins within Australia, both at the frontier and more explored basin level, as well as to make estimates of undiscovered potential in those basins with suitable and sufficient data. As prospectivity is a perception based on best available data, expert opinion, experience and knowledge, it can and will change over time, and requires to be updated with new data, concepts and ideas.

### 2.2.2 Potential of alternative transport fuels to meet demand

Energy resources include petroleum (oil and gas) and mineral energy as well as renewable energy in the form of biomass, hydroelectricity, tidal power, geothermal energy, solar, wind and wave power. Most of the world's mineral energy resources are contained in black and brown coal fields. The energy content of the demonstrated resources of coal fields exceeds the energy content of all discovered oil and gas fields and other forms of mineral energy[9]. Current world saleable coal resources will last about 180 years at current production rates (Geoscience Australia, 2005). Any of

[9] This assumes the energy content of uranium is 0.56 PJ/tonne as assumed by ABARE (Donaldson, 2005) which excludes the energy derived from the use of fast breeder reactors.

these forms of energy can be either used directly as a fuel or used to produce alternative transport fuels.

As with the conventional fuels referred to above, each alternative transport fuel has advantages and disadvantages. Important considerations include adequacy of resources and sustainability of production, full life cycle greenhouse gas emissions, other emissions, OH&S effects, cost and weight of storage, modifications to existing infrastructure and engines. Some of these processes themselves consume considerable amounts of energy to convert or store energy into a usable form, so the net energy gain from conversion to a convenient and practical form of transport fuel may be small. The discussion below focuses on fuels which can be produced from mineral or petroleum resources which are known to be abundant in Australia. Biofuels and electric and compressed air powered vehicles are not discussed below as they are outside the scope of this submission.

***Compressed natural gas (CNG) and liquefied natural gas (LNG)***

Australia has resources of natural gas that are significant on a world scale. Unlike crude oil and petrol, natural gas has to be reduced in volume before it can be conveniently used by consumers as a transport fuel. This can be done by compression or liquefaction. There is some additional energy input required to achieve this, but no further refining processes are required. Compressed natural gas has been widely used as a transport fuel worldwide. Compressed natural gas vehicles are commonly used in buses in major cities around the world, and compressed natural gas vehicles were widely used in New Zealand in the post 1980 period. At its peak there were 110 000 CNG vehicles in operation in New Zealand (Kojima, 2001). Argentina leads the world in CNG with 1.46 million vehicles (International Association for Natural Gas Vehicles, 2005).

Small liquefied natural gas (LNG) plants are producing LNG for use in vehicles in Australia. Plants are located in Melbourne and Kwinana (Gasnet, 2004).

***Liquefied petroleum gas (LPG)***

As shown in the reserves tables in the Appendix, Australia has substantial resources of LPG (propane and butane), derived primarily from gas fields. Although the calorific value of LPG is lower than that of crude oil, resources on an energy equivalent basis are comparable to crude oil resources. LPG is already used widely as a transport fuel in Australia. Production is not energy intensive compared to the production of synthetic fuels from coal or gas (Beer and others, 2001).

***Production of fuel from oil shale***

Oil shale is organic-rich shale that yields substantial quantities of oil (shale oil) by heating and distillation (Geoscience Australia, 2005). One tonne of oil shale may produce over 200 litres of oil. The 2001 survey of energy resources by the World Energy Council reported that Jordan, Australia and Morocco have the largest deposits of 'proved oil shale in place'. The same survey also reported that production of oil from shale for 1999 was recorded in Brazil at 239 ML (4.1 thousand barrels per day) and Estonia at 185 ML (3.2 thousand barrels per day).

Australian oil shale deposits of commercial interest are predominantly in a series of narrow and deep extensional-basins near Gladstone and Mackay in central Queensland. These are thick Palaeogene lacustrine (lake-formed) deposits that are relatively easy to mine. They contrast with generally harder carbonate bearing oil shales (marls) found elsewhere in the world that are more difficult to mine and process. Australia has 4.6 GL (29 million barrels) of shale oil economic demonstrated resources [10](EDR) (Geoscience Australia, 2005). This could increase significantly if the research and development demonstration-scale processing of shale oil conducted at the Stuart deposit near Gladstone from 2000 to 2004 were to lead to a commercial plant. The Stuart facility is now on care-and-maintenance in an operable condition to allow for any further testing if required while design efforts continue on the next phase of development. It is estimated that these studies will take 12–18 months, after which a decision to proceed with front-end engineering design of the preferred project configuration will be made.

[10] Economic demonstrated resources are resources judged to be economically extractable and for which the quantity and quality are computed partly from specific measurements and partly from extrapolation for a reasonable distance on geological evidence

Paramarginal and submarginal[11] demonstrated resources are 202.1 GL (1.3 billion barrels) and 3719 GL (23.4 billion barrels) respectively. The demonstration plant at Stuart produced over 1.5 million barrels of oil, and production in 2003 averaged 1.7 thousand barrels per day (the rate per stream day was over 3 thousand barrels per day).

### *Production of transport fuels from tar sands*

These petroleum deposits are very extensive internationally, with resources potentially comparable to those of conventional petroleum, and already contribute significantly to production and reserves in Venezuela and Canada. They are not significant in the Australian context.

Tar sand projects are capital and energy intensive. World production rates are expected to grow significantly in the near future.

### *Synthetic fuels produced from black or brown coal*

Australia has very significant black and brown coal resources (Geoscience Australia 2005). The resource life of accessible economic demonstrated resources (EDR) of black coal (40.3 Gt) is greater than 100 years at current rates of production. The resource life of accessible EDR of brown coal of 30.0 Gt is close to 450 years. Australia has 5% of the world's recoverable black coal EDR and ranks sixth behind USA (20%), China (13%), India (12%) and South Africa (7%). It produced about 7% of the world's black coal in 2004 and ranked fourth after China (37%), USA (22%) and India (8%). Australia has about 24% of the world's brown coal EDR and is ranked number one in this category. Australia produces about 8% of the world's brown coal and is the fifth largest producer after Germany (22%), Russia (10%), USA (9%) and Greece (8%).

There is potential to convert black or brown coal to diesel fuel using a number of different processes. Conversion of Latrobe Valley brown coal to diesel has been proposed using the Fischer-Tropsch gas-to-liquids technology. Between 1985 and 1990 the Brown Coal Liquefaction (Victoria) Pty Ltd pilot plant trial (50 tonne/day) of the liquefaction of Victorian brown coals was carried out by a consortium of Japanese companies. A two-stage hydrogenation process was used.

### *Synthetic fuels produced from gas*

There are substantial Australian resources of natural gas which are not currently being produced due to isolation, low condensate yield and/or high carbon dioxide content. Natural gas consists predominantly of methane. These resources may be suitable for conversion of methane (by catalytic reaction with water, oxygen and carbon dioxide) to methanol. The methanol can be sold as a fuel or as a petrochemical feedstock, or further processed to produce dimethylether, which can be further reacted to produce olefins and eventually petrol. The New Zealand Methanex plant operates in this way. Alternatively, the syngas process converts methane to hydrogen and carbon monoxide, which are then reacted to form heavy hydrocarbons such as petrol, diesel or waxes.

A number of projects have been proposed to produce methanol from Australian gas fields, particularly those offshore from Western Australia and the Northern Territory. Many of these projects have now been deferred or cancelled.

[11] Paramarginal: That part of subeconomic resources which, at the time of determination, almost satisfies the criteria for economic. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria which define economic. Included are resources which would be producible given postulated changes in economic or technologic factors.
Submarginal: That part of subeconomic resources that would require a substantially higher commodity price or some major cost-reducing advance in technology, to render them economic.

### *Hydrogen*

Hydrogen can be produced from steam reforming of natural gas (Beer, 2005). HCNG (hydrogen blended with compressed natural gas) is considered a transition fuel to a hydrogen economy (USDOE, 2005). Any source of energy, including renewable energy, can be used to produce electricity which can then produce hydrogen from water by electrolysis for use in hydrogen powered vehicles.

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# Appendix 1: Remaining reserves of oil in Australia

### *World Ranking*

Australia's endowment of petroleum is modest by world standards. Australia's relative reserves and production position is shown in Figure 8. Australian gas reserves and production in Australia are more significant in a world context than are Australian oil reserves and production.

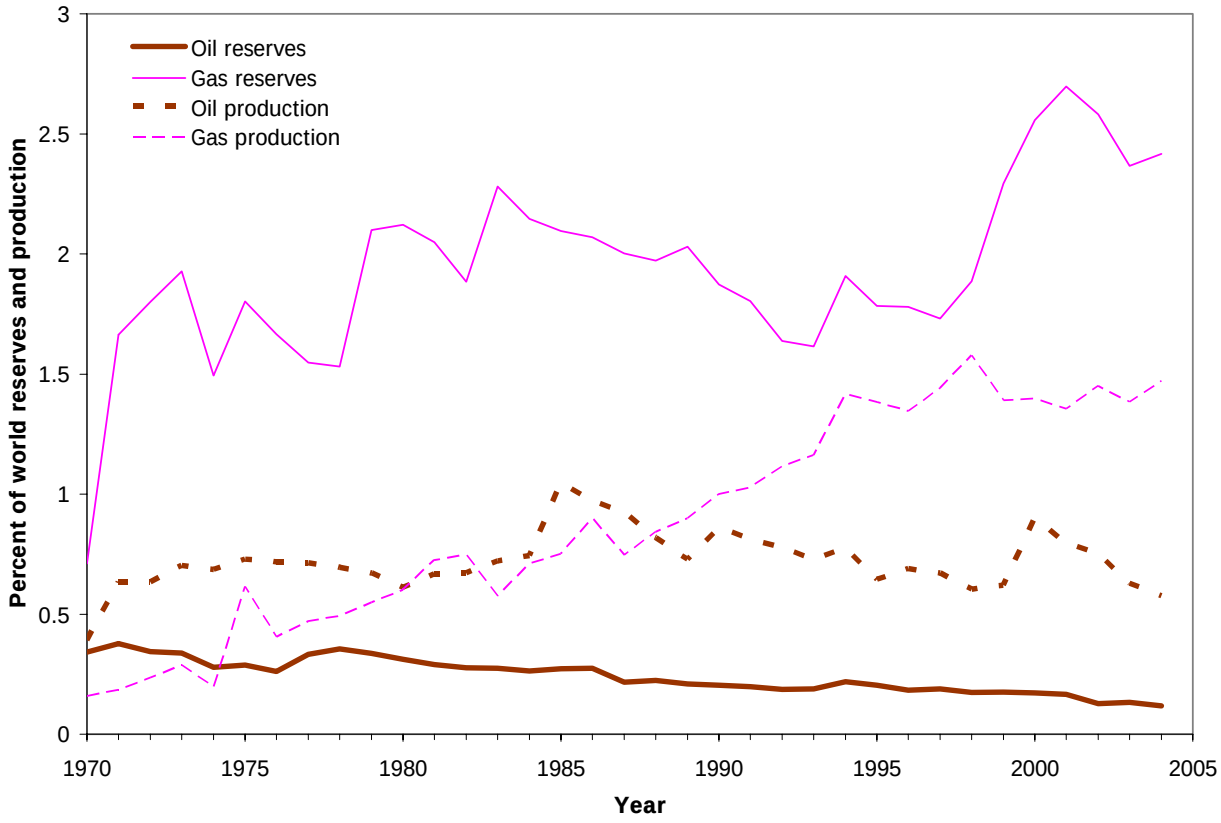


***Figure 8:*** *Australian petroleum production and reserves relative to world production and reserves*

### *Identified Resources*

Australia's identified petroleum resources are compiled from Geoscience Australia's in-house data and data provided by companies and State and Northern Territory mines departments. Information on individual accumulations is provided in the Geoscience Australia series Australian Petroleum Accumulations. The reserves estimates at 1 January 2005 are presented in Table 6, and are categorised by basin. The corresponding estimates according to the McKelvey reporting system are listed in Table 7. Bonaparte Basin estimates include the total reserves in the JPDA (Joint Petroleum Development Area) with Timor-Leste.

**Table 6** Petroleum reserves estimates by basin as at 1 January 2005

| **Category** | **Crude oil** | | **Condensate** | | **LPG** | | **Sales gas** | |
|---|---|---|---|---|---|---|---|---|
| Basin | GL | million | GL | million | GL | million | Bcm | Tcf |
| | | barrels | | barrels | | barrels | | |
| **Category 1** | | | | | | | | |
| Adavale | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.01 |
| Amadeus | 0.54 | 3.40 | 0.39 | 2.45 | 0.25 | 1.59 | 5.44 | 0.19 |
| Bonaparte | 8.89 | 55.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 |
| Bowen | 0.03 | 0.19 | 0.07 | 0.45 | 0.08 | 0.48 | 1.70 | 0.06 |
| Canning | 0.02 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Carnarvon | 65.02 | 408.96 | 82.28 | 517.53 | 85.09 | 535.22 | 589.65 | 20.82 |
| Cooper | 1.05 | 6.60 | 2.62 | 16.47 | 4.54 | 28.57 | 34.53 | 1.22 |
| Eromanga | 5.20 | 32.68 | 0.02 | 0.10 | 0.00 | 0.00 | 0.26 | 0.01 |
| Gippsland | 31.00 | 194.98 | 15.40 | 96.86 | 27.10 | 170.45 | 119.60 | 4.22 |
| Otway | 0.00 | 0.00 | 0.02 | 0.12 | 0.00 | 0.00 | 1.04 | 0.04 |
| Perth | 1.80 | 11.29 | 0.00 | 0.01 | 0.00 | 0.00 | 1.09 | 0.04 |
| Surat | 0.04 | 0.24 | 0.01 | 0.09 | 0.02 | 0.11 | 0.93 | 0.03 |
| TOTAL | 113.58 | 714.37 | 100.81 | 634.07 | 117.08 | 736.43 | 754.66 | 26.65 |
| PREVIOUS TOTAL | 127.47 | 801.78 | 101.23 | 636.73 | 120.73 | 759.34 | 782.08 | 27.62 |
| **Category 2** | | | | | | | | |
| Amadeus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.56 | 0.02 |
| Bass | 2.11 | 13.28 | 6.88 | 43.26 | 9.31 | 58.55 | 14.78 | 0.52 |
| Bonaparte | 12.51 | 78.70 | 95.33 | 599.61 | 60.81 | 382.46 | 665.70 | 23.51 |
| Bowen | 0.00 | 0.00 | 0.01 | 0.03 | 0.01 | 0.07 | 4.35 | 0.15 |
| Browse | 2.16 | 13.59 | 86.40 | 543.44 | 69.67 | 438.19 | 732.98 | 25.89 |
| Canning | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.01 |
| Carnarvon | 89.48 | 562.81 | 95.78 | 602.45 | 33.05 | 207.90 | 1823.00 | 64.38 |
| Cooper | 0.06 | 0.40 | 0.78 | 4.88 | 0.86 | 5.39 | 9.74 | 0.34 |
| Eromanga | 0.35 | 2.21 | 0.05 | 0.30 | 0.06 | 0.40 | 0.51 | 0.02 |
| Gippsland | 14.67 | 92.27 | 4.62 | 29.03 | 0.40 | 2.52 | 58.03 | 2.05 |
| Gunnedah | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.01 |
| Otway | 0.00 | 0.00 | 2.56 | 16.08 | 0.00 | 0.00 | 47.97 | 1.69 |
| Perth | 2.86 | 17.99 | 0.30 | 1.89 | 0.00 | 0.00 | 22.78 | 0.80 |
| Surat | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL | 124.21 | 781.25 | 292.69 | 1840.97 | 174.17 | 1095.48 | 3380.90 | 119.40 |
| PREVIOUS TOTAL | 137.81 | 866.79 | 283.31 | 1781.93 | 189.21 | 1190.11 | 3303.38 | 116.66 |
| GRAND TOTAL | 237.78 | 1495.62 | 393.50 | 2475.04 | 291.25 | 1831.91 | 4135.56 | 146.05 |
| PREVIOUS TOTAL | 265.28 | 1668.57 | 384.54 | 2418.66 | 309.94 | 1949.45 | 4085.46 | 144.28 |

**NOTES**

Category 1 comprises current reserves of those fields which have been declared commercial. It includes both proved and probable reserves.

Category 2 comprises estimates of recoverable reserves which have not yet been declared commercially viable; they may be either geologically proved or are awaiting further appraisal.

For McKelvey resource classification see Table 7.

"Previous" totals refer to revised estimates of remaining reserves for the previous year.

**Table 7** McKelvey classification estimates by basin as at 1 January 2005

| **Category** | **Crude oil** | | **Condensate** | | **LPG** | | **Sales gas** | |
|---|---|---|---|---|---|---|---|---|
| Basin | GL | million barrels | GL | million barrels | GL | million barrels | Bcm | Tcf |
| **Economic Demonstrated Resources** | | | | | | | | |
| Adavale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amadeus | 1 | 3 | 0 | 2 | 0 | 2 | 5 | 0 |
| Bass | 1 | 7 | 2 | 14 | 2 | 12 | 8 | 0 |
| Bonaparte | 11 | 69 | 84 | 530 | 61 | 382 | 308 | 11 |
| Bowen | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Canning | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Carnarvon | 102 | 642 | 168 | 1058 | 118 | 743 | 2018 | 71 |
| Cooper | 1 | 7 | 3 | 16 | 5 | 29 | 35 | 1 |
| Eromanga | 5 | 31 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gippsland | 35 | 218 | 16 | 101 | 27 | 171 | 144 | 5 |
| Otway | 0 | 0 | 2 | 15 | 0 | 0 | 37 | 1 |
| Perth | 2 | 11 | 0 | 0 | 0 | 0 | 1 | 0 |
| Surat | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| TOTAL | 157 | 988 | 276 | 1738 | 213 | 1339 | 2560 | 90 |
| PREVIOUS TOTAL | 187 | 1175 | 271 | 1707 | 232 | 1457 | 2584 | 91 |
| **Subeconomic Demonstrated Resources** | | | | | | | | |
| Amadeus | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Bass | 1 | 6 | 5 | 30 | 7 | 47 | 7 | 0 |
| Bonaparte | 10 | 66 | 11 | 70 | 0 | 0 | 358 | 13 |
| Bowen | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| Browse | 2 | 14 | 86 | 543 | 70 | 438 | 733 | 26 |
| Canning | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Carnarvon | 52 | 330 | 10 | 62 | 0 | 0 | 395 | 14 |
| Cooper | 0 | 0 | 1 | 5 | 1 | 5 | 10 | 0 |
| Eromanga | 1 | 4 | 0 | 0 | 0 | 0 | 1 | 0 |
| Gippsland | 11 | 70 | 4 | 25 | 0 | 2 | 33 | 1 |
| Gunnedah | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Otway | 0 | 0 | 0 | 1 | 0 | 0 | 12 | 0 |
| Perth | 3 | 18 | 0 | 2 | 0 | 0 | 23 | 1 |
| Surat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 81 | 507 | 117 | 737 | 78 | 492 | 1576 | 56 |
| PREVIOUS TOTAL | 79 | 494 | 113 | 712 | 78 | 493 | 1502 | 53 |
| GRAND TOTAL | 238 | 1496 | 394 | 2475 | 291 | 1832 | 4136 | 146 |
| PREVIOUS TOTAL | 265 | 1669 | 385 | 2419 | 310 | 1949 | 4085 | 144 |

**NOTES**

Economic Demonstrated Resources are resources judged to be economically extractable and for which the quantity and quality are computed partly from specific measurements, and partly from extrapolation for a reasonable distance on geological evidence.

Subeconomic Demonstrated Resources are similar to Economic Demonstrated Resources in terms of certainty of occurrence and, although considered to be potentially economic in the foreseeable future, these resources are judged to be subeconomic at present.

For traditional petroleum industry classification see Table 6.

"Previous" totals refers to revised estimates of resources for the previous year.

### *Trends in initial and remaining identified crude oil and condensate resources*

Initial and remaining identified resources of crude oil and condensate together with production, for the period 1964–2004 are shown in Figure 9. The upper curve shows estimates at each time of the total identified initial resources (i.e. the resources before production commenced) of crude oil and condensate respectively. The lower curves show the remaining resources (initial resources minus cumulative production to that date). Remaining crude oil resources are continuing to show signs of a decline after having remained approximately unchanged since 1967. Reductions in resources due to production have historically almost been compensated for by reserves growth in previously discovered fields and by new discoveries. In the last 10 years, this replacement rate has not been sustained. Condensate resources continue to grow as more super-giant gas fields are discovered and appraised, but to date there has been relatively little development and production of these resources, essentially making the condensate resources unavailable at this time.

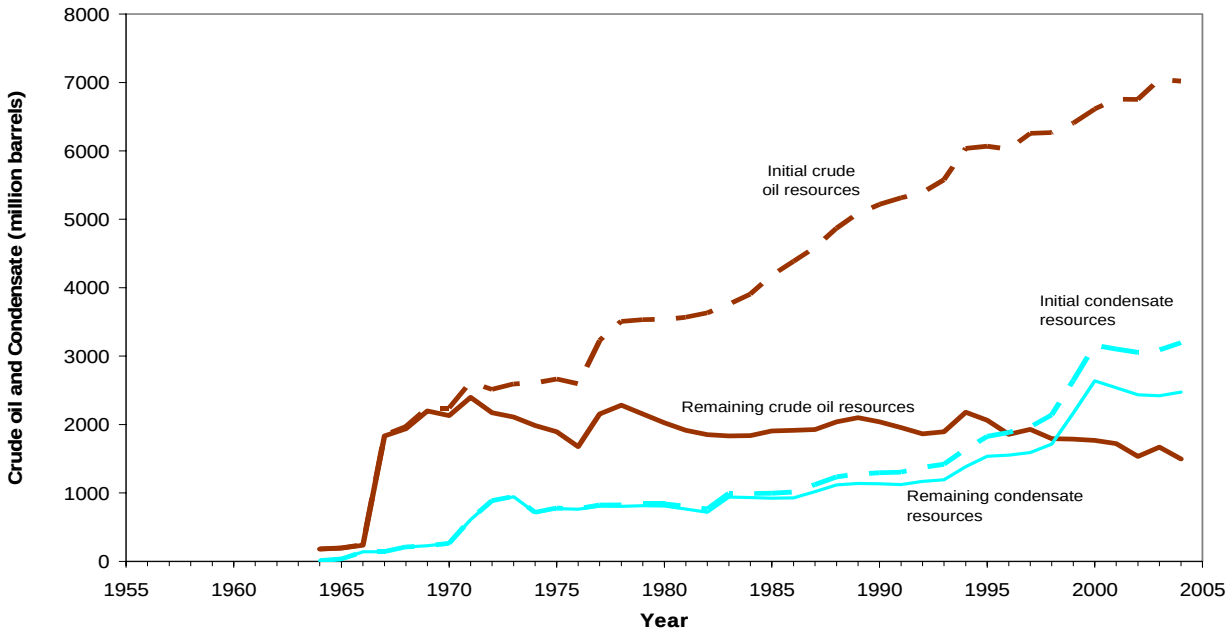


***Figure 9:*** *Initial and remaining identified crude oil and condensate resources*

### *Trends in initial and remaining identified crude oil plus condensate resources*

The situation for crude oil plus condensate resources is shown in Figure 10. Resources continue to grow as a result of the condensate associated with gas discoveries. As many of these fields are yet to be developed, it means that it is uncertain as to the precise timing when condensate production from them would occur.

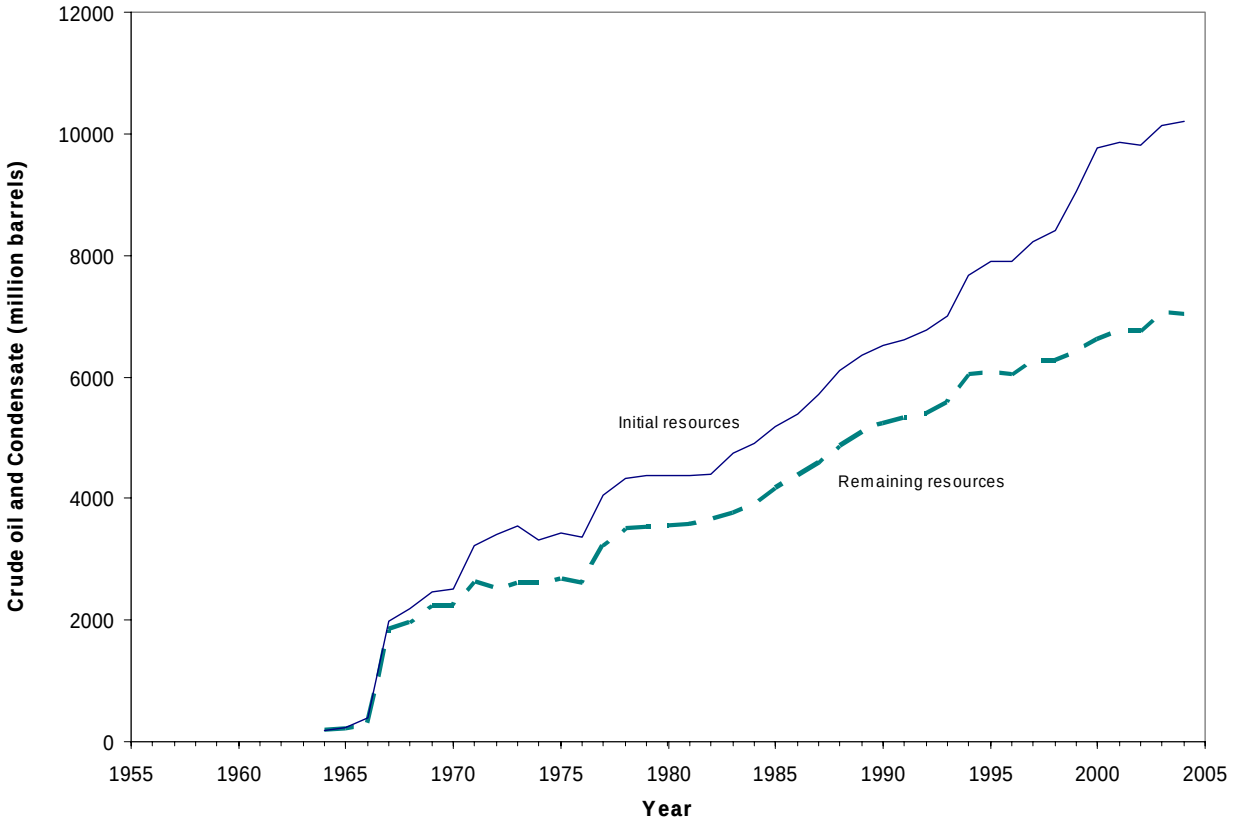


***Figure 10:*** *Initial and remaining identified crude oil plus condensate resources*

### *Life of resources*

The ratio of economic demonstrated resources to production indicates how many years of production the current estimate of resources would support, assuming present production rates could be maintained (Petrie and others, 2005). Figure 11 shows this data for crude oil for the period since EDR figures were first compiled in 1982. This has decreased significantly since 1995 from a plateau of around 10 years to a current level of 6.6 years.[12] The corresponding ratio for natural gas is 65 years.

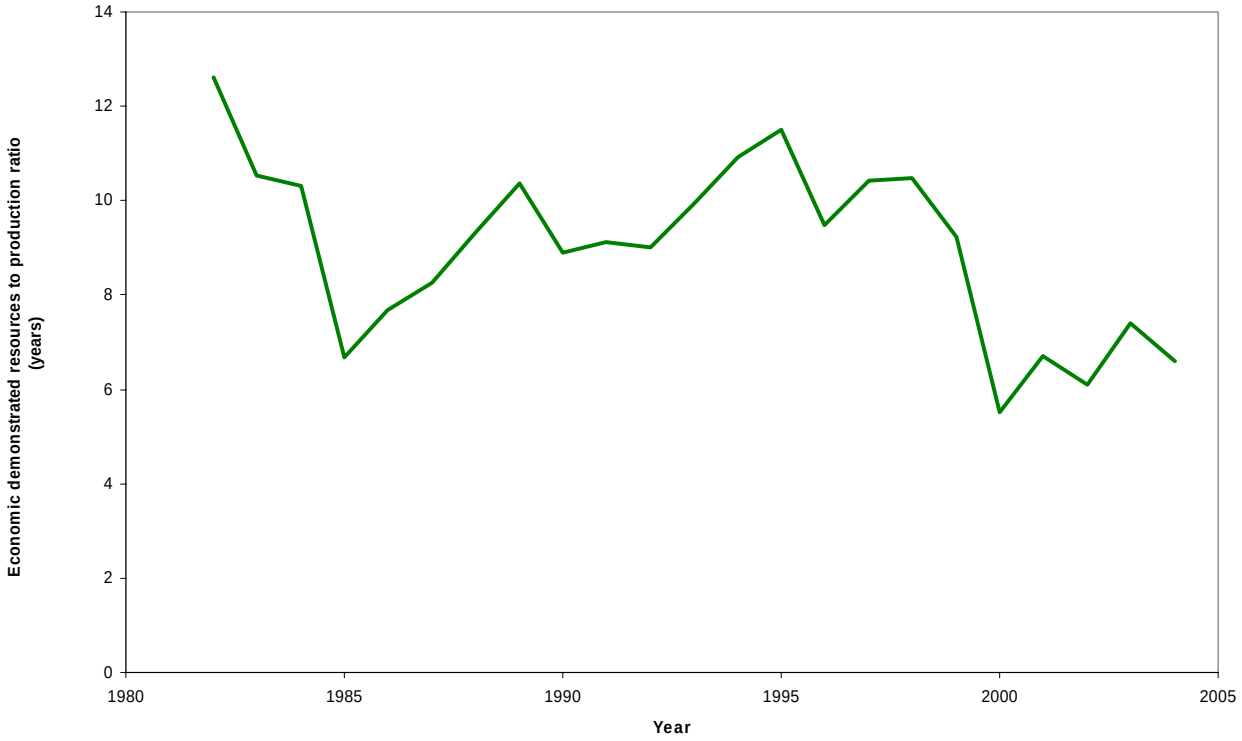


***Figure 11:*** *Economic demonstrated resources to production ratio for Australian crude oil*

Current liquid fuel demand is over 750 thousand barrels per day. Only a limited number of Australian fields have been able to sustain high rates of production in order to meet this demand. Historically, only eight oil fields have sustained an annual rate of over 50 thousand barrels per day and only three have maintained that rate for a decade. All these fields are now in decline. Another 20 fields have sustained rates of over 10 thousand barrels per day but, as their reserves are typically smaller, they can only manage this for a few years. New discoveries might help to maintain production rates for a time, but as later discoveries in a basin typically contain much smaller resources, they can not sustain high rates of production for more than a few years. The impact is that the number of fields required to maintain a given rate of production increases with time, and if the demand rate increases over the same time interval, then the shortfall in demand versus supply will grow.

This concept is illustrated in terms of crude oil replacement rate in Figure 12, which depicts the number of crude oil discoveries and their effect on net crude oil inventory changes for each year.

[12] A buffer of remaining reserves of approximately 10 years has been documented previously across a range of countries and petroleum provinces (McCabe, 1998). The proved reserves to production ratio for world oil is estimated by BP to be 40.5 years (BP, 2005).

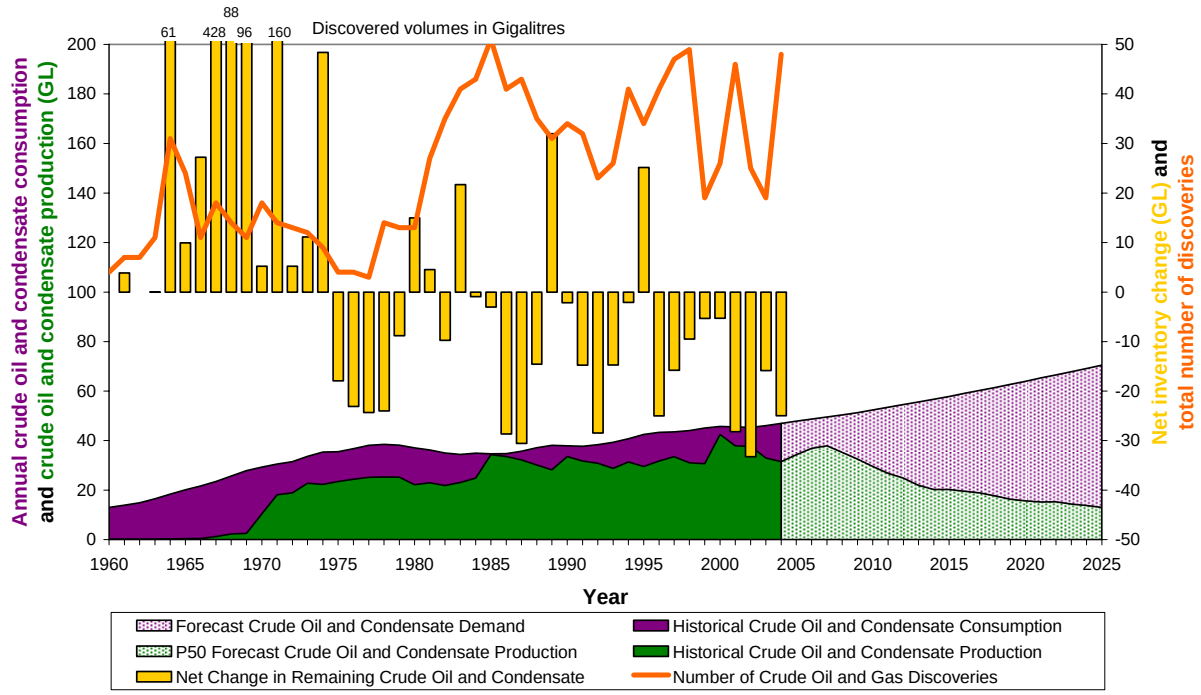


***Figure 12:*** *Crude oil and condensate discoveries, inventory and production and demand*

In spite of a large number of crude oil and condensate bearing gas discoveries, both onshore and offshore, only five years have seen significant net additions to inventory since the discovery of the Gippsland Basin oil fields three decades ago. Trends suggest the disparity between domestic production and demand will, in the absence of substantial new discoveries, widen markedly in the medium term.

Condensate from gas fields can replace crude oil supply to a degree. However condensate is produced under two sets of circumstances:

- As liquids recovered during conventional gas production
- By producing and reinjecting some or all of the produced gas to recover incremental and/or accelerated liquids (gas cycling)

Thus condensate recovery during conventional gas production will be based on the actual gas production rate, which will depend upon the contracted gas supply rate for the market, and therefore is inflexible as a source of liquid fuel. The economics of condensate from gas recycling projects depends on the liquids yield of the gas, the condensate-gas ratio or CGR. These are shown for Australian gas fields with more than 1 trillion cubic feet of reserves in Figure 13.

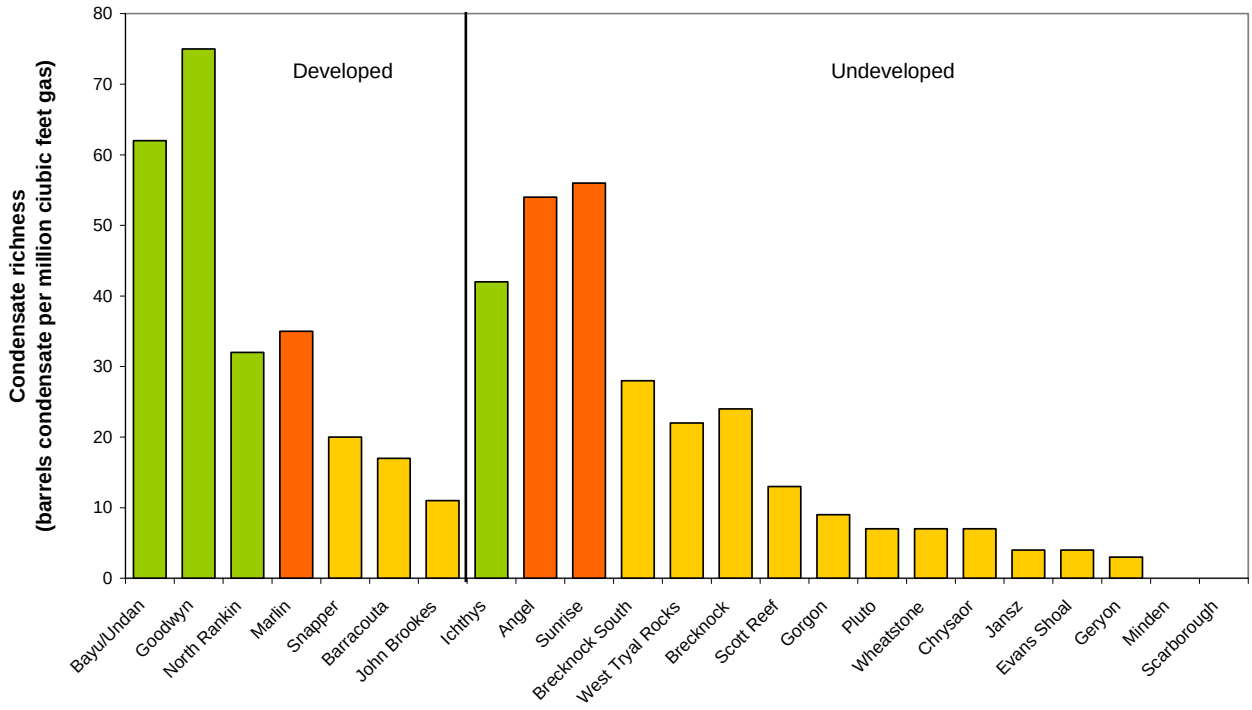


***Figure 13:*** *Condensate yield and potential for gas recycling*

In Figure 13, the bars in

- green indicate fields that have been recycled or have been proposed for recycling,
- orange indicate fields that have a condensate yield for which recycling could be seriously considered,
- yellow indicate fields that not sufficiently rich in condensate or are otherwise unsuitable for recycling.

Some 65% of Australia's gas reserves in fields containing more than 1 trillion cubic feet of gas are not suitable for recycling. The trend in recent discoveries is for fields to have low condensate yields.

In summary:

- Australia's supply rate of crude oil from current discoveries is declining.
- Condensate can provide a useful increment to crude oil production but is not an adequate substitute, as it can depend on gas supply rates.
- To sustain Australia's domestic crude oil supply will require the discovery of a major new oil province.