Chapter Two

Future oil demand and supply

Oil and gas basics

2.1 Petroleum hydrocarbons, principally crude oil and natural gas, form from the remains of marine organisms and algae which are buried by sediments and subjected to conditions of high temperature and pressure over hundreds of millions of years. Gas forms when the temperature and pressure are higher; oil when they are lower. The oil and gas, being lighter than water, then migrate towards the surface through pores or fissures in the rock. They may reach the surface and be lost; or a recoverable reservoir may form if it accumulates in a layer of rock which is capped by an impermeable layer that prevents it from rising further. A petroleum reservoir may accumulate a variety of gaseous and liquid hydrocarbon compounds, natural carbon dioxide and water at depths varying between some tens of metres to thousands of metres.

2.2 The oil-forming process is still at work, but it is so slow that the current oil and gas resource is effectively non-renewable.

2.3 Simple hydrocarbon molecules are comprised of a chain of carbon atoms with hydrogen atoms attached. The properties of different hydrocarbons depend largely on the length of the carbon chain. Short chain molecules form gases at standard temperature and pressure while longer chains form liquids (and eventually solids), becoming denser and more viscous as the chain lengthens. Crude oil is a blend of up to 300 different hydrocarbons, as well as sulphur, nitrogen and metal compounds, depending on source conditions. Refining separates the different hydrocarbons into groups with properties that are uniform enough to be useful as petroleum products and as feedstocks for petrochemical plants.[1]

2.4 When burnt, hydrocarbon molecules combine with oxygen to form carbon dioxide and water, releasing heat energy. Carbon dioxide released from burning oil, gas and coal is the main cause of human-induced global warming.[2]

Resources, reserves and related terms

2.5 The **resource** is the total amount of oil in the ground, including oil which will never be discovered or, if discovered, will never be produced.[3]

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1 Thus methane CH_4 and ethane C_2H_6 are 'natural gas'; propane C_3H_8 and butane C_4H_{10} may be present in natural gas mixtures and are used to make liquefied petroleum gas; the C5-12 fractions make automotive gasoline; the C14-16 fractions make diesel oil, etc.

2 Other gases also contribute. Methane, the principal component of natural gas, is a powerful greenhouse gas in its own right.

2.6 **Reserves** are quantities of oil in known reservoirs which can be recovered commercially with today's prices and technology. Reserves are divided into:

- **Proved reserves:** quantities which are estimated 'with reasonable certainty' to be recoverable reserves by the definition above; or if probabilistic methods of estimation are used, there is a 90 per cent probability (P90) that the amount recovered will be more than this, and a 10 per cent probability that it will be less. 'In this sense, proved reserves are a conservative estimate of future cumulative production from a field.'[4]
- **Probable and possible reserves**: additional quantities which are estimated to be commercially recoverable reserves with less certainty. Proved plus probable reserves are an 'as likely as not' estimate of future production; proved plus probable plus possible reserves are a more optimistic, less likely estimate. In general, a portion of a field's probable and possible reserves tend to get converted into proved reserves over time as operating history reduces the uncertainty around remaining recoverable reserves.[5]

2.7 Reserves are depleted by production, and enlarged by discovery of new oilfields and by 'reserve growth'.

2.8 **Reserve growth** refers to the commonly observed increase in reported reserves in previously discovered fields over time. This results from 'a combination of several factors, including conservative initial estimates, improvements in exploration and drilling technology, improved production technology, and various political and economic forces'.[6] Future reserve growth is an important element in official estimates

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3 'The entire resource base (Total petroleum initially in place) is generally accepted to be all those quantities of petroleum contained in the subsurface…' Society of Petroleum Engineers, *Glossary of Terms Used*, at www.spe.org/spe/jsp/basic_pf/0,,1104_3306579,00.html
An alternative definition is that resources are reserves plus all the petroleum *that may eventually become available:* 'In practice resource estimates are made only for those accumulations that are seen as potentially economic at some time in the future.' This is a narrower definition of the resource. McCabe P.J., 'Energy Resources - Cornucopia or Empty Barrel' *AAPG Bulletin*, vol. 82 no. 12 November 1998, p. 2115.

4 'Oil reserves': notes to *BP Statistical Review of World Energy 2006,* at http://www.bp.com/sectiongenericarticle.do?categoryId=9011008&contentId=7021601

5 'Oil reserves': notes to *BP Statistical Review of World Energy 2006.*

Society of Petroleum Engineers: *Petroleum Reserves Definitions* at http://www.spe.org/spe/jsp/basic/0,2396,1104_12169_0,00.html
'Probable' and 'possible' are commonly defined as - taking proved and probable reserves together: there is a 50 per cent probability that the true figure is more, and a 50 per cent probability that it is less. Taking proved, probable and possible reserves together: there is a 10 per cent probability that the true figure is more, and a 90 per cent probability that it is less. According to the SPE, 'the effect of possible future improvements in economic conditions and technological development can be expressed by allocating appropriate quantities of reserves to the probable and possible classifications'.

6 T.R.Klett, D.L. Gautier & T.S. Ahlbrandt, 'An Evaluation of the US Geological Survey World Petroleum Assessment 2000', *AAPG Bulletin*, vol. 89 no. 8 August 2005, p. 1036.

of future oil supply. How valid these estimates are is a major part of the 'peak oil' debate, considered in chapter 3.

2.9 **The ultimately recoverable resource (URR),** according to BP, is an estimate of the total amount of oil that will ever be recovered. This includes production to date, future production from discovered reserves, and future production from not yet discovered fields.[7] According to the International Energy Agency (IEA), 'ultimately recoverable resources include cumulative production to date, identified remaining reserves, undiscovered recoverable resources and estimates of "reserves growth" in existing fields.'[8] This amounts to the same thing if one assumes that all reserves will eventually be produced.[9] An alternative definition of the URR is 'the amount of oil which is thought recoverable given existing technology and economics [including] estimates of undiscovered oil.'[10]

2.10 **Conventional oil** is, in the IEA's definition, 'oil that is produced from underground reservoirs by means of wells'. This leaves as **nonconventional oil** that which 'is produced in other ways or requires additional processing to produce synthetic crude…[including] shale oil, synthetic crude and products derived from oil or tar sands and extra-heavy oil, coal- and biomass-based liquids and the output of natural gas to liquids (GTL) plants.'[11]

2.11 'Conventional' and 'non-conventional oil' are sometimes defined in other ways, and this can be a source of confusion in comparing figures from different sources. For example, by the definition above polar and deepwater oil is conventional; but some include it with non-conventional because of the difficulty of reaching it.[12]

2.12 The natural nonconventional resource is mostly located in Canadian tar sands, Venezuelan heavy oil, and oil shale. The nonconventional resource is very large, though the proportion that is a recoverable reserve is relatively small because of the difficulty of extracting it.[13] There will be greater use of it in future as conventional oil

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7 'Oil reserves': notes to *BP Statistical Review of World Energy 2006,* at http://www.bp.com/sectiongenericarticle.do?categoryId=9009529&contentId=7017933

8 International Energy Agency, *World Energy Outlook 2005*, p. 126.

9 This would be expected given the definition of 'reserves' as 'known *commercially viable* accumulations.'

10 Lynch M.C., *The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers),*n.d..

11 International Energy Agency, *World Energy Outlook 2005*, p. 124.

12 Eg ASPO Ireland, *Submission 10*, p. 2. Definitions are discussed in IEA, *Resources to Reserves - Oil and Gas Technologies for the Energy Markets of the Future*, 2005, p. 26.

13 It is suggested that the nonconventional oil originally in place is up to 7,000 billion barrels, of which economically recoverable reserves are about 600 billion barrels. International Energy Agency, *World Energy Outlook 2004,* p. 95. Hirsch R. & others, *Peaking of World Oil Production: Impacts, Mitigation and Risk Management*, 2005, p. 40. ABARE, *Australian Commodities* June 2006, p. 305.

is depleted. It is sometimes said that this means that what is now non-conventional will become conventional in future. This form of words unfortunately obscures the fact that what is now called conventional is effectively the 'easy oil', and what is now called non-conventional is more difficult and expensive to produce; and that relativity is unlikely to change. Greater exploitation of harder to get oil will become more normal as easier oil is depleted, but it will come at an extra economic cost that economies will have to cope with.

Rate of production and recovery factor

2.13 Oil reserves are stock; production is a flow. The immediate concern in a market is whether the rate of production satisfies demand. Reserves are only of interest for what they imply about future production and resource security.

2.14 As oil is produced the natural reservoir pressure which drives it to the surface through a well bore declines. It becomes gradually harder and eventually impossible to recover what is left. Thus an oil reservoir is not like a tank of water, in which the last drop can be tapped almost as easily as the first. It is more like a tank of waterlogged sand: how fast the water can be tapped depends not only on the size of the tap, but also on how fast the water drains through the sand to reach it. This becomes slower over time. There is still some water in the sand when flow stops.

2.15 **The rate of production** over time from an oilfield will tend to grow as the infrastructure is built up to exploit the reserve, reach a peak, then decline as the reserve is depleted and it becomes progressively harder to produce what is left.[14] The same tends to apply to larger regions or nations: for example, oil production in the US lower 48 states peaked in 1970.[15] Non-OPEC conventional oil production is expected to peak in 2010-2015.[16] Oil production is in decline in 33 of the 48 largest oil producing countries.[17] What this implies for world production is part of the peak oil debate.

2.16 **The recovery factor** is the percentage of the oil originally in place in a field that can be recovered. The recovery factor varies enormously from one field to another depending on the geological conditions, but averages about 35 per cent world-

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14 As gas flows more easily than oil, a gas field can be produced at a high level for longer, but will then decline much more suddenly when the reserve is exhausted.

15 This phenomenon for an individual oilfield does not *necessarily* imply the same for a larger region. In theory a certain rate of production from a larger region could be maintained indefinitely, **providing** new oilfields of the needed size could be discovered at a constant rate indefinitely. But this is not the case: the rate of discovery of new oil has been declining for many years: see paragraph 3.38. Many nations are past their peak of oil production as noted.

16 International Energy Agency, *World Energy Outlook 2005*, p. 140.

17 Chevron, quoting Worldwatch Institute, *Vital Signs,* 2005, p. 30: http://www.willyoujoinus.com/issues/alternatives/

wide.[18] The recovery factor may be increased by techniques such as injecting water or carbon dioxide to maintain pressure. The cost-effectiveness of these techniques also varies greatly from place to place. A small increase in the average recovery factor through technological advances can create a large increase in reserves.[19] What should be expected in this regard in future is another part of the peak oil debate.

2.17 **The reserves to production ratio** (R/P ratio) is the ratio of proved reserves to production in the year. World wide it is now about 40:1 for oil and 65:1 for gas.[20] This prompts statements such as 'reserves are sufficient to maintain production at present rates for X years.' Such statements are not helpful - firstly, because demand will not be static; secondly, because the R/P ratio says little about the future rate of production. Given the nature of oil depletion as described above, it will not be possible to maintain production at a constant rate until reserves are exhausted, as implied.[21]

Oil and gas in context of total energy use

World energy use and projections

2.18 Energy use tracks economic growth closely. Worldwide, since 1971 each 1 per cent increase in global gross domestic product (GDP) has been accompanied by a 0.6 per cent increase in primary energy consumption. The difference between the 1 per cent and 0.6 per cent reflects the fact that the energy use for each unit of GDP is in long term decline. This is expected to continue as reliance on heavy industry declines and energy efficiency improves.[22]

2.19 In the International Energy Agency's *World Energy Outlook 2005* 'reference scenario' (which assumes no policies to curb energy use or greenhouse gas emissions beyond what governments have committed to already), energy use is expected to increase by 1.6 per cent on average per year to 2030. Oil, gas and coal will retain their dominant position, with about 80 per cent of total energy supply. Renewables will

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18 International Energy Agency, *Resources to Reserves - Oil and Gas Technologies for the Energy Markets of the Future*, 2005, p. 14.

19 For gas, which flows more easily, the recovery factor is naturally higher - about 70% - so future improvements to the recovery factor are less significant. International Energy Agency, *Resources to Reserves - Oil and Gas Technologies for the Energy Markets of the Future*, 2005, p. 14.

20 *BP Statistical Review of World Energy, 2006.*

21 In a period of declining production a constant R/P ratio can be maintained by matching production to reserves correctly as both approach zero. In the USA in the late 20th century the R/P ratio was stable at about 10 over 20 years of mostly declining production. McCabe P.J., 'Energy Resources - Cornucopia or Empty Barrel' *AAPG Bulletin*, vol. 82 no. 12 November 1998, p. 2115.

22 International Energy Agency, *World Energy Outlook 2004,* pp 31 and 41. Primary energy consumption is the sum of end-use energy consumption and energy lost in transmission or conversion processes.

increase significantly in percentage terms, but because they are coming from an extremely small base, they will remain small in absolute terms:

Figure 2.1 – World primary energy demand, IEA Reference Scenario, 2003-2030
million tonnes of oil equivalent

	2003		2030		average annual growth, per cent	total growth in annual demand, per cent
	no.	per cent	no.	per cent		
coal	2,582	24%	3,724	23%	1.4%	44%
oil	3,785	35%	5,546	34%	1.4%	46%
gas	2,244	21%	3,942	24%	2.1%	75%
nuclear	687	6.5%	767	5%	0.4%	12%
hydro	227	2%	368	2%	1.8%	62%
biomass and waste	1,143	11%	1,653	10%	1.4%	45%
other renewable	54	0.5%	272	2%	6.2%	218%
total	10,723	100%	16,271	100%	1.6%	52%

International Energy Agency, *World Energy Outlook 2005,* p.82

2.20 Oil as a proportion of total energy use has declined from 44% in 1971 to the present 35% as users have moved to other energy sources, particularly in response to the 1973 and 1979 oil crises. However it is more difficult to use other fuels for transport, and 95 per cent of transport is fuelled by oil. Thus the trend to prefer other fuels for non-transport purposes means that oil use is becoming increasingly concentrated in transport. The IEA expects that in 2030 transport will use 54 per cent of the world's oil compared to 33 per cent in 1971 and 47 per cent now. In OECD countries, the use of oil for other purposes is expected to decline sharply. However in many developing countries oil products will remain the leading source of modern commercial energy for cooking and heating, especially in rural areas.[23]

2.21 The predictions above derive energy demand from predictions of future population growth, economic growth and energy prices. In the IEA's *World Energy Outlook 2005*, the predicted price trend is for a slight increase in real oil prices from $US36 per barrel in 2004 to $US39 per barrel in 2030 (2004 dollars). This assumes there is no constraint on supply before 2030.[24] (The *World Energy Outlook 2006* appeared at the time of writing. It contains updated, higher price projections. Comments on it are gathered in Chapter 3 - see paragraph 3.121).

23 International Energy Agency, *World Energy Outlook 2004*, pp 58 and 84.

24 International Energy Agency, *World Energy Outlook 2005*, pp 63-4 and 140.

Australian energy use and projections

2.22 In Australia, compared with the world, coal is a bigger proportion of total energy supply (42 per cent of the total); oil and gas are about the same, and renewables are a smaller proportion. Energy consumption is projected to increase by 63 per cent by 2029-30, an average rate of 1.9 per cent per year. The most important driver of this is economic growth. As natural gas becomes more important coal is expected to become relatively less important, though it still increases greatly in absolute terms. Renewables are expected to increase greatly in percentage terms, but because they are starting from an extremely small base, they are still insignificant in absolute terms.[25]

Figure 2.2 – Projection of Australian primary energy consumption by fuel
Petajoules

	2003-4		2029-30		average annual growth, per cent	total growth, per cent
	no.	per cent	no.	per cent		
black coal	1,570	29%	2,248	26%	1.4%	43%
brown coal	679	13%	857	10%	0.9%	26%
oil	1,792	34%	2,981	34%	1.7%	66%
natural gas	1,048	20%	2,136	24%	2.8%	104%
hydro	58	1%	65	1%	0.4%	12%
biomass	183	3%	370	4%	2.8%	102%
other renewables	16	0.3%	71	1%	5.9%	344%
total	5,345	100%	8,728	100%	1.9%	63%

ABARE, *Australian Energy: national and state projections to 2029-2030*, 2005, p. 26
1 petajoule = 23,880 tonnes of oil equivalent. 1 million tonnes of oil equivalent = about 42 petajoules. 1 petajoule = 169,900 barrels oil @ 5883MJ/barrel (Geoscience Australia, submission 127, p. 17.)

2.23 This scenario assumes that crude oil prices fall to below $US30 per barrel by the early 2010s, 'reflecting an assumed easing of geopolitical concerns and an expansion in oil production infrastructure.'[26]

2.24 Worldwide 47 per cent of oil is used for transport; in Australia, 77 per cent. This is because in Australia oil is used much less in other areas such as home heating

25 ABARE, *Australian Energy: national and state projections to 2029-2030*, 2005, p. 23ff.

26 ABARE, *Australian Energy: national and state projections to 2029-2030*, 2005, p. 24.

or electricity generation.[27] Thus for Australia an oil supply problem is to a large extent a transport fuel problem.

World oil production and consumption

2.25 According to BP's *Statistical Review of World Energy*, world oil production in 2005 was 29.5 billion barrels (81 million barrels per day), and proved reserves of oil and natural gas liquids at the end of 2005 were 1,200 billion barrels. Year on year production grew in the OPEC countries and the Former Soviet Union, and declined in the OECD and other non-OPEC countries in total.[28]

2.26 Natural gas production in 2005 was 2,703 billion cubic metres, and proved reserves were 180,000 billion cubic metres.[29]

2.27 On BP's figures proved reserves of oil and natural gas liquids continue to grow: annual additions to reserves through new discoveries and reserve growth are greater than annual production.[30] 62 per cent of reserves are in the Middle East.

2.28 This raises the question: why then have oil prices been high over the last two years?[31] Most analysts answer that demand has grown because of strong economic growth, particularly in China, while supply has lagged because of insufficient investment in new capacity since the period of low prices in the late 1990s. As well, commentators point to the weather in 2005, including hurricanes in the USA which disrupted production; and geopolitical instability, which has caused the market to want 'precautionary inventories'.[32]

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27 Bureau of Transport and Regional Economics, *Is the World Running Out of Oil? A review of the debate.* BTRE working paper 61, 2005.

28 BP, *Statistical Review of World Energy*, 2006, pp 6 and 8. 'Production includes crude oil, shale oil, oil sands and natural gas liquids.' The OPEC countries are Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

29 1 cubic metre = 35.515 cubic feet. 6,000 cubic feet of gas = 1 barrel of oil equivalent (US Geological Survey, *World Petroleum Assessment 2000*, table AR-1). By these figures natural gas production is 16 billion barrels of oil equivalent, and proven natural gas reserves are 1,065 billions barrels of oil equivalent, which is slightly less than proven oil reserves.

30 Year on year change in reserves is found by subtracting production and adding new discoveries and reserve growth. On BP's figures world oil reserves were 770 billion barrels in 1985, 1,027 billion barrels in 1995, 1,194 billion barrels in 2004 and 1,200 billion barrels in 2005.

31 The price of West Texas Intermediate crude oil rose steadily (with some fluctuations) from about $US35 per barrel in early 2004 to $US78 in July 2006. It then declined to $US63 in September 2006 and $US59 in early November. ABARE, *Australian Commodities*, vol. 13 no. 3, September 2006, p. 499. S. Kinsella (ABARE), personal communication, November 2006.

32 For example, P. Davies (BP), *Quantifying Energy - BP Statistical Review of World Energy 2006,* speech 14 June 2006. International Energy Agency, *World Energy Outlook 2005*, p. 5.

2.29 In this view there is no fundamental geological constraint on the supply of oil, and prices may be expected to fall again in the medium term as higher prices stimulate exploration and investment, and supply catches up with demand. ABARE predicts that oil prices ‘could remain relatively high for a number of years, but should fall towards the end of the decade ‘in response to higher global oil production and a substantial increase in oil stocks by that time.’[33] Contrary views by peak oil proponents are considered in chapter 3.

Projections of world oil production and consumption

2.30 The International Energy Agency (IEA), in its *World Energy Outlook 2005*, predicts that in a 'reference scenario' world demand for oil will grow from 82 million barrels per day in 2004 to 92 million barrels per day in 2010 and 115 million barrels per day in 2030 - an average growth rate of 1.3 per cent per year over the period. The growth rate will be above average in the developing countries, and below average in OECD countries.

2.31 The *World Energy Outlook 2005* argues that resources are adequate to meet the demand, but 'reserves will need to be "proved up" in order to avoid a peak in production before the end of the projection period [2030].'[34] It comments that 'the exact cost of finding and exploiting those resources over the coming decades is uncertain, but will certainly be substantial…financing the required investments in non-OECD countries is one of the biggest challenges posed by our energy-supply projections.'[35] It makes no significant comment on the future after 2030.[36]

2.32 The *World Energy Outlook 2005* assumes that most of the increased demand for oil to 2030 will be supplied by a large increase in OPEC production, particularly in

33 ABARE, *Australian Commodities,* June 2006, p. 303ff.

34 In the market of economics textbooks, supply is the amount brought to market, and demand is the amount sold. Demand in this sense cannot exceed supply. In the future oil supply debate, discussion of whether supply will be adequate to meet demand implicitly means 'demand as it would be if supply was unconstrained'.

35 International Energy Agency, *World Energy Outlook 2005*, pp 45, 83 and 140. The reference scenario assumes no policies to curb energy demand or greenhouse gas emissions beyond what governments have committed to already: p. 59.

36 In the *World Energy Outlook 2005* a brief relevant comment on the longer term future is: 'Using a more optimistic assumption of 3,200 billion barrels [of ultimately recoverable oil] pushes the production peak out to around 2035…non-conventional sources, including tar sands in Canada, extra-heavy oil in Venezuela and gas-to-liquids output, fill the growing gap between conventional oil production and global oil demand.' p. 140.

A 2003 IEA report considered energy scenarios to 2050. The scenarios describe different responses to environmental concerns. All scenarios assume that 'there are sufficient fossil energy resources to meet demand in the next 50 years; whether they will actually be extracted depends on the pace and direction of technological change and on the level of environmental concern.' International Energy Agency, *Energy to 2050 - scenarios for a sustainable future*, 2003.

the Middle East, 'because their resources are greater and their production costs lower' (peak oil concerns about whether this will be possible are considered in chapter 3).[37] OPEC production is expected to increase from 39 per cent to 50 per cent of world production.

Figure 2.3 – World oil production and demand projections, IEA Reference Scenario

million barrels per day. Includes natural gas liquids and condensates

	2004	2010	2030	average annual growth, per cent	total growth 2004 - 2030, per cent
Oil production					
OPEC[38]	32.3	36.9	57.2	2.2%	77%
of which OPEC Middle East	*22.8*	*26.6*	*44.0*	*2.6%*	*93%*
OECD[39]	20.2	19.2	13.5	-1.5%	-32%
transition economies[40]	11.4	14.5	16.4	1.4%	44%
other countries	15.2	17.7	16.3	0.3%	7%
non-conventional oil[41]	2.2	3.1	10.2	6.1%	364%
total	**82.1**	**92.5**	**115.4**	**1.3%**	**41%**
Oil demand					
OECD	47.6	50.5	55.1	0.6%	16%
transition economies	4.4	4.9	6.2	1.3%	41%
other countries	27.0	33.9	50.9	2.5%	86%
international marine bunkers	3.1	3.1	3.3	0.3%	6%
total	**82.1**	**92.5**	**115.4**	**1.3%**	**41%**
OPEC production as percentage of world demand	*39%*	*40%*	*50%*		
OPEC Middle East production as percentage of world demand	*28%*	*29%*	*38%*		
International Energy Agency, *World Energy Outlook 2005,* pp 83, 90, and 124.					

37 International Energy Agency, *World Energy Outlook 2005*, p. 46.

38 OPEC: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela.

39 OECD: 23 European countries plus USA, Canada, Mexico, Australia, New Zealand, Korea and Japan.

40 Transition economies: 23 nations of eastern Europe and former Soviet Union.

41 Conventional oil: produced from underground reservoirs by wells. Non-conventional oil includes shale oil, synthetic crude and products derived from oil or tar sands and extra-heavy oil, coal- and biomass-based liquids and the output of natural gas to liquids (GTL) plants.

2.33 The *World Energy Outlook 2005* assumes a crude oil price of about $US35 per barrel in 2010, increasing to $US39 by 2030 (2004 dollars). It notes that 'the near term outlook for oil prices remains unusually uncertain'; and 'the assumed slowly rising trend in real prices after 2010 reflects an expected increase in marginal production costs outside OPEC, an increase in the market share of a small number of major producing countries, and lower spare capacity.' Most of the new production capacity needed to satisfy the predicted demand is expected to come from OPEC countries, particularly in the Middle East. The slowly rising price trend is not intended to mean a stable market: 'indeed, oil prices may become more volatile in future'.[42]

2.34 The IEA's *World Energy Outlook 2006* was released at the time of writing with updated, higher price projections. Comment on it is at paragraphs 3.121–3.124.

Official estimates of the ultimately recoverable resource of conventional oil

2.35 The core document used to support the assumption that oil supply will not be constrained before 2030 appears to be the US Geological Survey's *World Petroleum Assessment 2000* (USGS 2000). This estimated that the world's total conventional oil and natural gas liquids produced to 1995, or with potential to be added to reserves from 1995 to 2025, is about 3,345 billion barrels.[43] This is the mean estimate.[44] Future additions to reserves are composed of future discoveries and future 'reserve growth' in already discovered fields as explained above (paragraph 2.8):

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42 International Energy Agency, *World Energy Outlook 2005*, pp 63-5.

43 US Geological Survey: *World Petroleum Assessment 2000*, table AR-1, p. ES-1. New work for USGS 2000 considered the world except the United States. Figures for the United States were imported from previous work to give world totals.

Note that 'with potential to be added to reserves by 2025' is not an estimate of the *ultimately* recoverable resource (URR). A corresponding estimate of the URR, since it would include post-2025 additions, would be higher. USGS 2000 disavowed any attempt to estimate the URR (p. IN-5). However this proviso is commonly overlooked, and its figures are quoted as though they are an estimate of the URR - including by the International Energy Agency (for example, *World Energy Outlook 2005*, p. 126).

44 USGS 2000 estimates relating to future events are the output of a mathematical procedure whose inputs were the authors' expert opinions on many detailed matters, such as the likely number of undiscovered fields in a region, the likely size of undiscovered fields, etc. The mean estimate is derived from a probability distribution and is slightly greater than the P50 (50 per cent probable) estimate.

Figure 2.4 – USGS 2000 estimate of conventional petroleum with potential to be added to reserves 1995 to 2025. Mean estimate billion barrels (for gas, billion barrels of oil equivalent @ 6,000 cubic feet = 1boe)				
	oil	natural gas liquids	oil and NGLs	gas
World except United States				
undiscovered conventional	649	207	856	778
reserve growth (conventional)	612	42	654	551
remaining reserves	859	68	927	770
cumulative production	539	7	546	150
total	2,659	324	2,983	2,249
United States				
undiscovered conventional	83	with oil	83	88
reserve growth (conventional)	76	with oil	76	59
remaining reserves	32	with oil	32	29
cumulative production	171	with oil	171	142
total	362	with oil	362	318
Total				
undiscovered conventional	732	207	**939**	866
reserve growth (conventional)	688	42	**730**	610
remaining reserves	891	68	**959**	799
cumulative production	710	7	**717**	292
total	**3,021**	**324**	**3,345**	**2567**

source: US Geological Survey, *World Petroleum Assessment 2000*, table AR-1.
Note: reserve and cumulative production figures date from 1995. Proved reserves of oil at the end of 2005 were 1,200 billion barrels. Cumulative production of oil and natural gas liquids to 2005 was 1,048 billion barrels. *BP Statistical Review of World Energy*, 2006. IEA, *World Energy Outlook 2005*, p. 126.

2.36 USGS 2000 published 5 per cent probable and 95 per cent probable estimates only for the world except the United States:

Figure 2.5 – USGS 2000 estimate of conventional petroleum with potential to be added to reserves 1995 to 2025. billion barrels (for gas, billion barrels of oil equivalent @ 6,000 cubic feet = 1boe)		
	undiscovered conventional	reserve growth (conventional)
Oil		
P95 estimate	334	192
mean estimate	649	612
P5 estimate	1,107	1,031

Natural gas liquids		
P95 estimate	95	13
mean estimate	207	42
P5 estimate	378	71
Oil and NGLs		
P95 estimate	429	205
mean estimate	856	654
P5 estimate	1,485	1,102
Gas		
P95 estimate	383	175
mean estimate	778	551
P5 estimate	1,362	924
Source: US Geological Survey, *World Petroleum Assessment 2000*, table AR-1.		

2.37 The USGS 2000 mean estimate of future reserve additions is much higher than previous estimates. Most of the increase in USGS 2000 resulted from including an estimate of future reserve growth, which the USGS had not done previously.[45] For example, the USGS 2000 mean estimate of future oil reserve additions (not including natural gas liquids) outside the USA is 1,261 billion barrels (649+612 in figure 2.4 above). The corresponding figure from the USGS's previous survey in 1994 was 539 billion barrels.[46]

2.38 The IEA's *World Energy Outlook 2005* gives an updated estimate of the ultimately recoverable resource, based on USGS 2000:

Figure 2.6 – Estimate of ultimately recoverable oil and natural gas liquids. IEA 2005. Mean estimate. Billion barrels				USGS 2000 mean estimate, conventional oil/ NGLs/ total
	Middle East/ North Africa	rest of world	total	total
future discoveries	313	570	883	732/ 207/ 939[1]
future reserve growth in existing fields	109	199	308[3]	688/ 42/ 730[1]
reserves	784	322	1,106	891/ 68/ 959[2]
cumulative production	334	714	1,048	710/ 7/ 717[2]
total: ultimately recoverable resource	**1,541**	**1,804**	**3,345**	**3,021/ 324/ 3,345**
source: International Energy Agency, *World Energy Outlook 2005*, p. 126. The figures				

45 US Geological Survey: *World Petroleum Assessment 2000*, p. ES-3 & figure ES-2.

46 US Geological Survey: *World Petroleum Assessment 2000*, figure ES-2.

appear to be for conventional oil, although the accompanying text is not explicit.
US Geological Survey, *World Petroleum Assessment 2000*, table AR-1.

1. USGS 2000 figures were estimates of amounts with potential to be added to reserves from 1995 to 2025: p. IN-2.
2. USGS 2000 figures for reserves and cumulative production date from 1995.
3. The IEA figure for reserve growth is said to be based on 'IEA analysis based on USGS'. The accompanying text does not explain the large difference from the USGS 2000 estimate of reserve growth.

2.39 On these figures, about a third of the ultimately recoverable resource of conventional oil has already been produced. 'Peak oil' arguments about the reliability of these figures are considered in chapter 3.

2.40 It should be noted that USGS 2000 was a geologists' estimate of possible future additions to reserves. It was not concerned with whether the resource will be brought to market in a timely way to meet demand.

Oil production and consumption in Australia and projections

2.41 Commercial crude oil production in Australia started at Moonie in 1964, and grew dramatically after the discovery of the offshore Gippsland oilfields in the 1960s. It has mostly been between 400,000 and 500,000 barrels per day since then. As gas production on the North West Shelf has increased, production of associated condensate has also increased, to around 150,000 barrels per day. Over the last decade production of crude oil and condensate has mostly been between 500,000 and 600,000 barrels per day.[47]

2.42 The rate of new discoveries has declined significantly since the discovery of the supergiant Gippsland fields in the late 1960s. More recent smaller discoveries have slowed but not reversed the overall decline in reserves as oil is produced.[48] Geoscience Australia (GA) predicts that Australian production of crude oil plus condensate will hold at current levels of about 550,000 barrels per day until about 2009 then decline to about 224,000 barrels per day by 2025 (mid-range estimate).[49]

2.43 Australia's demand for petroleum (including crude oil and condensate) is over 750,000 barrels per day, and is projected to rise to over 800,000 barrels per day by 2009-10, and over 1,200,000 barrels per day by 2029-30 – an increase of almost 2 per cent per year over the period.[50]

47 Geoscience Australia, *Submission 127*, pp 13-16. Condensate is a light oil-like liquid produced from gas fields. 1 barrel = 158.987 litres.

48 Dr C. Foster, Geoscience Australia, *Proof Committee Hansard,* 12 May 2005, p. 4.

49 Geoscience Australia, *Submission 127*, p. 13.

50 Geoscience Australia, *Submission 127*, based on ABARE, *Australian Energy - National and State Projections to 2029-30*, 2005, p. 63.

2.44 In Australia 77 per cent of oil is used for transport, and 97 per cent of transport is fuelled by oil. Transport accounts for 14 per cent of Australia's greenhouse gas emissions.[51]

2.45 On Geoscience Australia's figures, it appears that over the next 20 years Australia's net self-sufficiency in oil and petroleum products will decline from 84 per cent to 20 per cent (using a mid-range estimate of future production), or from 98 per cent to 31 per cent (using an optimistic estimate of future production):[52]

Figure 2.7 – Forecast Australian production of crude oil and condensate. Forecast Australian consumption of petroleum products excluding LPG

Thousand barrels per day

	production			consumption[1]	production as percentage of consumption		
	P90	P50	P10		P90	P50	P10
2006	544	635	741	756.8	72%	84%	98%
2010	400	510	654	817.0	49%	62%	80%
2015	225	349	541	902.9	25%	39%	60%
2020	177	269	409	998.3	18%	27%	41%
2025	148	224	342	1099.9	13%	20%	31%

P90: 90 per cent probability that the true figure will be at least this much (most cautious estimate). P50: 50 per cent probability that the true figure will be at least this much. P10: 10 per cent probability that the true figure will be at least this much (most optimistic estimate). See text for qualifications.

1. 2006 figure is that shown in the source as '2005-06' etc.

Geoscience Australia, *Submission 127*, p. 13ff.

2.46 The production forecasts listed above include production expected from already identified fields, and production expected from not yet discovered resources in known petroleum provinces. They include future reserve growth only in the P10 estimate. The figures do not include enhanced oil recovery in fields nearing depletion, but GA estimates that under certain conditions this could add up to 155,000 barrels

51 Bureau of Transport and Regional Economics, *Is the World Running Out of Oil? A review of the debate.* BTRE working paper 61, 2005. Australian Government, *Securing Australia's Energy Future*, Dept of the Prime Minister and Cabinet, 2004, pp 82 and 137.

52 *net* self-sufficiency: the concept of self-sufficiency is somewhat artificial in any case, as Australia both imports and exports crude oil. This is because Australian crude oil is relatively light, and cannot provide the full range of petroleum products. Australian production of crude oil, condensate and LPG is about 95% of Australian consumption of liquid petroleum products; however over half of Australian production is exported, and over half of Australian refinery inputs is imported. ABARE, *Australian Commodities*, vol. 13 no. 13, September 2006, pp 507-8. Australian Institute of Petroleum, *Crude Oil Pricing*, at www.aip.com.au/pricing/crude.htm

per day. The figures do not include future discoveries in provinces which have not been explored or have no discoveries to date, as these cannot be estimated.[53]

2.47 ABARE expects that Australia's crude oil and condensate production will remain steady at over 1,000 petajoules per year (about 466,000 barrels per day[54]) to 2029-30. This would means Australia's net self-sufficiency in petroleum products falls to about 50 per cent by 2029-30. This is rather more than Geoscience Australia's estimate.[55] This is because ABARE, unlike GA, makes an estimate of prospective production from resources that have not yet been discovered in basins that have not yet been fully explored, based on the resource estimates of USGS 2000. This includes modelling economic variables which are not within GA's brief.[56]

2.48 In either case Australia’s oil self-sufficiency is predicted to decline significantly. The predicted demand growth is a much more important cause that the exact level of future Australian production.

2.49 The Australian Petroleum Production and Exploration Association (APPEA) noted that Australia has historically been a net exporter of oil, gas and petroleum products; however this situation has turned around in the last two years because of rising prices and a fall in domestic crude oil production. In 2005 imports exceeded exports by $4.7 billion. APPEA suggested that by 2015 this figure could be in the range of $12 billion to $25 billion, depending on assumptions about Australian production and price.[57]

2.50 How serious the effects of this reversal are will depend in part on the long term price of oil.[58] That will reflect the long term supply-demand balance. That brings into play peak oil concerns about future oil supply, which are considered in the next chapter.

53 Geoscience Australia, *Additional information,* 13 September 2006.

54 At 5883MJ per barrel: Geoscience Australia, *Submission 12*, p. 17.

55 ABARE, *Australian Energy - national and state projections to 2029-30*, report 05.9, October 2005, pp 38 and 45. ABARE, *Submission 166*, p. 2.

56 ABARE, *Additional information,* 27 November 2006.

57 Australian Petroleum Production and Exploration Association, *Submission 176*, p. 8.

58 Treasury pointed out that as Australia is a net energy exporter, there may be compensation for a rising oil price if the price of substitutes which Australia exports also rises. Dr S. Kennedy, Department of the Treasury, *Committee Hansard*, 18 August 2006, p. 22.