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Is the world running out of oil? A review of the debate

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FOREWORD

The possibility of sustained high world oil prices has fuelled concern over long-term supply. The question is particularly relevant for transport as a major user of oil with few viable alternatives. Internationally, there is a vigorous debate over the ability of this supply to satisfy ever-increasing demand, particularly with the growth in large fast-growth countries such as China and India. The debate can be complicated and, at times, highly emotional. The aim of this Working Paper is to provide an objective summary and analysis of the main issues in the debate.

This study was originally commissioned by former Secretary of the Department of Transport and Regional Services, Ken Matthews (now Chief Executive Officer, National Water Commission). It was researched and written by Lyn Martin with guidance from Phil Potterton. The working paper benefited from comments from ABARE on an earlier draft, from the Department of Industry, Tourism and Resources and from BTRE colleagues, particularly Peter Kain, Quentin Reynolds and Carlo Santangelo. An earlier and shorter version of the paper was presented at the Australasian Transport Research Forum 2004.

Useful background was also provided by a forum on the outlook for oil, hosted by the BTRE in August 2004 where presentations were given by Vivek Tulpulé (then Deputy Executive Director, Australian Bureau of Agricultural and Resource Economics) and Ali Samsam Bakhtiari (Corporate Planning Directorate, National Iranian Oil Company).

Phil Potterton
Executive Director
Bureau of Transport and Regional Economics
February 2005

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AT A GLANCE

- Future oil supplies are vital to transport, with transport accounting for almost half of oil use world-wide and with limited opportunity for substitution to other fuels.
- The dramatic increase in world oil prices during the latter half of 2004 revived speculation that the world is half-way through its oil reserves and oil production is about to `peak'.
- `Depletionists' posit that the pattern of oil production follows that of discovery, and since discoveries of conventional oil peaked in the 1960s, oil production, they argue, has either already peaked or will do so within the next few years to the serious detriment of an unprepared world economy.
- `Antidepletionists' respond that warnings of impending catastrophes have been around for 150 years, always just over the horizon and that proved reserves have a history of increasing faster than consumption.
- The international agencies, the most prominent antidepletionists, maintain that a production peak is unlikely before 2030 and that the remaining resources are sufficient to meet the projected average annual requirements, between now and 2030 70 times over, due mainly to technological advances, improvements in knowledge and changing economics.
- Long-term oil prices, potentially an indicator of scarcity, are forecast by international agencies to decline from the 2004 peak and then to rise gradually to around US$30/barrel in 2030 (in year 2000 US$).
- The depletionists' concerns arise, in part, from the possibility that the signals provided by prices are based on inaccurate reserves data. This suggests that the first stage of a targeted policy response would focus on improvements in reserves reporting, which both sides of the debate recognise as important.
- Efforts are being made at an international level to improve accuracy, consistency and transparency of reserves accounting. Also, in response to major reserves accounting controversies in 2004, regulators in the U.S. and the U.K are turning their attention to a greater use of external auditing.

EXECUTIVE SUMMARY

The world oil market has been subject to significant pressures over the 12 months to October 2004. On the demand side, strong economic growth worldwide, and particularly in China and India, increased the demand for oil. Production disruptions in a number of producer countries and bottlenecks in refining capacity constrained supply. As a result, oil prices spiked dramatically in the second half of 2004—increasing almost 70 per cent in the twelve months to 2004 to a record high in nominal prices of US$55 per barrel in October 2004.

Recent spikes in the price of oil combined with growing insecurities about the long-term stability of the Middle East have refocussed attention on the issue of long-term oil supplies. Two trends are of particular importance: trade in oil will increase with major oil importing countries becoming increasingly dependent on parts of the world that are relatively less stable and transport's use of oil will become increasingly significant as other oil users avail themselves of substitutes.

There are two very distinct schools of thought on the question of whether we are running out of oil. The 'peak theorists'/depletionists argue that half the world's oil supplies have been used and oil production has peaked or is about to peak, signalling a near-term crisis across world economies that will cause massive dislocations. The counter view, held by international energy agencies and other antidepletionists, is that while there are always uncertainties about reserve estimates, it is most likely we have only used around a quarter of world reserves and that the outlook for the next 30 years presents no cause for concern. Oil supplies, they argue, will keep pace with demand, as reflected in the expectation that long-term prices (in year 2000 dollars) are likely to be around $30 per barrel.

The depletionists base their work on the Hubbert curves and draw on M. King Hubbert's prediction of the peaking of U.S. oil production in 1970s as testimony to the validity of their approach. They also focus on *resources* as a physical limit, calling on 'the immutable physical laws of depletion' to support their case and estimating ultimately recoverable resources (URR) at 1.8 trillion barrels.[1] They predict that the downturn in oil production will be sudden and unanticipated, thrusting an unprepared world into economic and social turmoil.[2]

1 Campbell and Laherrère (1995)

2 The possibility of severe supply disruptions through, say, the Al Qaeda taking over Saudi Arabia, is a separate issue and has not been treated in this Working Paper.

The antidepletionists estimate a URR of over 3 trillion barrels and draw attention to the failed predictions of doom throughout history, starting in the early days of the 'oil age'—around 1865.[3] They point to the fact that world oil reserves have grown over the past 50 years faster than cumulative production due to discoveries and enhanced recovery techniques.

A summary of the main points of dispute are presented in Table 1 below.

Table 1 Characteristic differences between depletionists and antidepletionists

Depletionists	***Antidepletionists***
Total endowment and timing of the peak?	
1.8 trillion barrels and will peak within a few years, or sooner	More than 3 trillion barrels and the peak is likely to be around 2030-2040
Is oil reserves growth legitimate?	
Immutable physical laws apply to the process of oil well depletion	Reserve 'grow' in response to technological improvements and higher oil prices
How sudden will the decline be?	
Sudden, sharp downturn in oil production	Gradual and reflected in long term price rises encouraging timely adjustment
Will the market anticipate the decline?	
No—deliberately mislead by the international agencies and US and EU authorities	Markets have very strong incentives to get the prices right
What is the relative role of the market and governments?	
Government should override markets and take early action	Inform the market and assess whether additional incentives are justified
Catchcry	
Recall the fable of 'the boy who cried wolf too often'—the wolf eventually came.	The Stone Age didn't end because we ran out of stones

Much of the debate focuses on when the peak in oil production will occur. The answer to this depends, in part, on how much oil is left and strength of future demand but also, significantly, on how future technologies will impact on both supply and demand—all of which are subject to great uncertainty. The depletionists believe the peak is imminent while the international agencies express confidence that it is still 25-30 years out.

[3] USGS (2000) regard 3 trillion barrels as a conservative estimate given a 95 per cent probability of being an underestimate and reflecting only those parts of the world actually assessed. See http://pubs.usgs.gov/dds/dds-060/ Chapter AR Table 1.

The abruptness of the decline is also an issue, with the depletionists anticipating a sudden decline while the antidepletionists argue it is likely to be gradual, providing time for economies to adjust.

The question arises as to how reliable prices are as indicators of a long-term decline in oil supply. While there have been dramatic price rises in the past, these have generally reflected short-term pressures such as market control by OPEC countries and, more recently, an unanticipated surge in demand coinciding with supply concerns due to unrest in key producing countries—Saudi Arabia, Iraq, Nigeria, Venezuela, and Russia—rather than signal impending depletion of the resource.

From a historic context, the high prices of $55/barrel (for benchmark U.S. crude) in late October were significantly less than the prices during the peak of 1980, when adjusted for inflation. Their impact on economies was also less due to the reduced energy intensity of developed countries. Furthermore, the International Energy Agency (IEA), a major reference point for the antidepletionists, predicts that the high oil prices of late 2004 are unsustainable and that market fundamentals will drive them down over the next two years.

From a longer term policy perspective, if the depletionists' view were endorsed, it should be noted that the 'first-best' policy *mechanisms* are already in place in Australia and other OECD countries. Taxation rates that significantly increase the price of fossil fuel products, thereby discouraging usage, are a hallmark of the developed countries. The concessionary taxation treatment of alternative fuels already provides a stimulus for their production and usage. The cost of oil products is further increased by OPEC's supply constraints. The question that would remain is how much *more* should the price of oil products be increased to accurately reflect what the depletionists regard as oil's scarcity value?

IS THE WORLD RUNNING OUT OF OIL? A REVIEW OF THE DEBATE

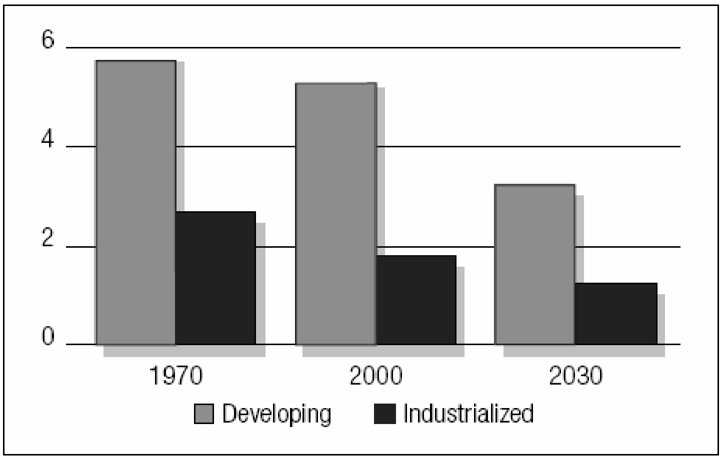
BACKGROUND

The 2004 price spikes

A combination of record demand growth and low spare capacity saw prices reach record highs in 2004. Spare production capacity, normally between 3 million and 5 million barrels a day, dwindled to 1.4 million barrels a day over the recent period. Demand for oil, due in part to China's booming economy, 2004 grew in 2004 at more than double the rate of the previous six years—representing the largest annual gain (in percentage terms) since 1978 (CERA 2004).

High oil prices have an impact on the world economy. However, two factors ameliorated the impact of the 2004 price increases: reduced energy intensity and inflation. In both developing and industrialised countries, energy intensity has declined. In other words, the amount of energy needed to produce a dollar's worth of GDP is significantly less than it was 30 years ago (see Figure 1 below).

Figure 1 Energy use-to-GDP improves
(barrel of oil equivalent per US$1000 GDP)



Source: Exxon Mobil 2004

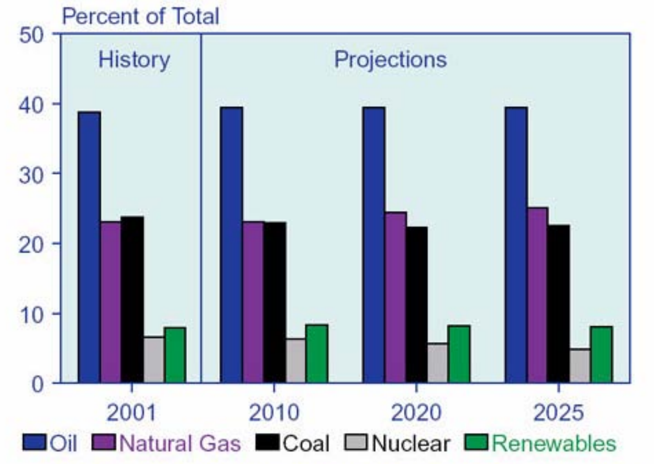
This trend is expected to continue as reliance on heavy industry declines internationally and as energy efficiency improves (IEA 2004b p. 31). In general, developing countries do not follow the same energy path as industrialised countries, often leapfrogging the technologies that were utilised by industrialised countries.

In a sense, inflation has also softened the impact of the recent high oil prices. To match the record high prices of 1980, the oil price would need to reach $80 in 2004 dollar terms. Also, oil prices are denominated in US dollars and part of the price increases since 2002 reflect the depreciation of the US dollar over this period. In Australian dollar terms, the increase has been more moderate (Reserve Bank 2004). While there is clearly a downside to Australia from higher oil prices, there are also some gains in the form of higher prices for our energy exports.

Oil and transport

Fossil fuels—coal, oil and natural gas—provide most of the world's primary energy demand and it is anticipated that they will do so for the foreseeable future. Oil will continue to be the single largest fuel in the global primary energy mix, with oil and coal together accounting for over 60 per cent of energy supply, as illustrated by Figure 2 below.

Figure 2 World energy consumption shares by fuel type (2001, 2010, 2020, and 2025)



Sources: **2001:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2004).

Source: EIA International Energy Outlook 2004 http://www.eia.doe.gov/pub/pdf/international/0484(2004).pdf p. 3

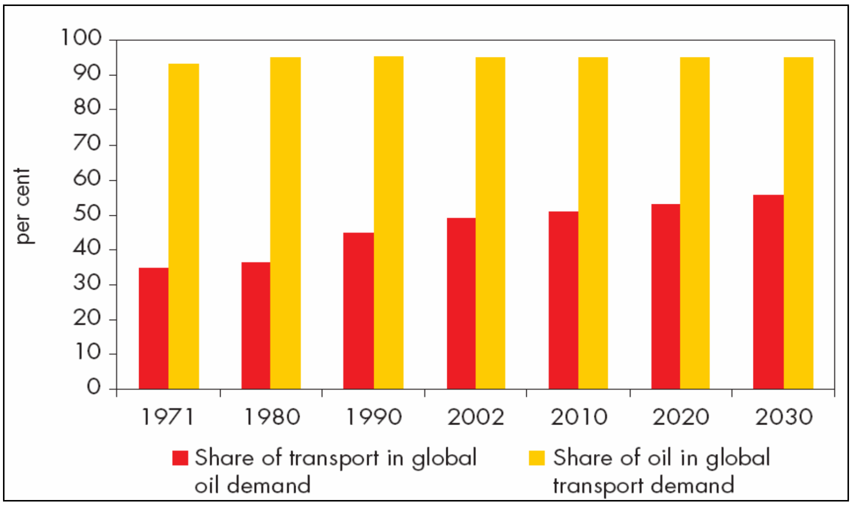
The dominance of oil and coal in total energy consumption reflects the needs of the major energy users—transport and electricity generation. Transport, already a major user of oil and with few viable alternatives, is expected to account for an increasing share of oil demand as the growing abundance of natural gas encourages other users to shift to the cheaper alternative. Figure 3 illustrates the anticipated growth of transport's share in global oil demand (red) and oil's continued role as the 'energy of choice' for the transport sector, accounting for around 90 per cent of transport's energy use.

Internationally, the transport share of oil consumption increased from 33 per cent in 1971 to 47 per cent in 2004 and is expected to increase to 54 per cent by 2030 (IEA 2004b p. 58). In Australia, while transport accounts for 41 per cent of total Australian *final* energy consumption (Energy Task Force 2004 p. 12), it accounts for a significantly higher share (77 per cent) of national oil use (ABARE 2004, table A-1 p. 58). This reflects the fact that in Australia oil is not used extensively in other areas, such as home heating and electricity generation.

In many countries, considerable effort and taxpayers' funds have been committed to reduce transport's 'dependence' on oil. However, alternative energy sources are not expected to become competitive during the standard projection period to 2030.[4]

The share of oil in transport energy demand will remain almost constant over the projection period, at 95 per cent, despite the policies and measures that many countries have adopted to promote the use of alternative fuels such as biofuels and compressed natural gas (IEA 2004b p. 84).

Figure 3 Share of transport in global energy demand and share of oil in transport energy demand (1971-2030)



Source: IEA 2004b fig. 3.2 p. 85

The EIA anticipate that alternative fuels will displace around 2 per cent of light vehicle fuel consumption in 2025 (EIA 2004a). Hence, the future global supply of oil is of significant interest to the transport sector as well as to the wider economy which depends on it.

4 IEA (2004) p. 402 and EIA (2004a) http://www.eia.doe.gov/oiaf/ieo/oil.html

THE PROTAGONISTS

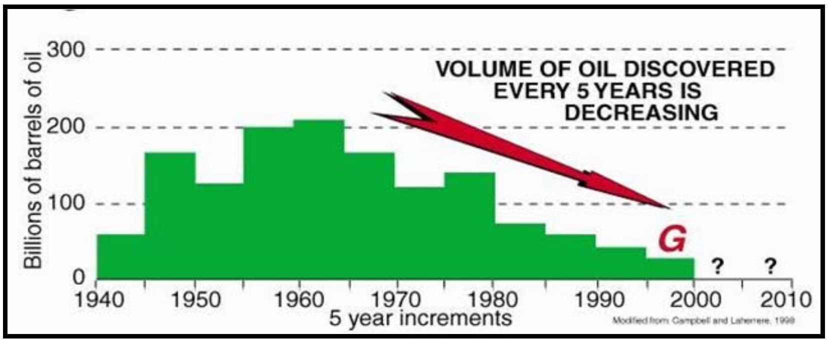
Depletionists/peak oil theorists

'Peak oil' has its foundations in the work by Dr M. King Hubbert and, more recently, by oil industry veterans, C.J. Campbell and J.H. Laherrère.[5] The focus of the depletionists is on the production peak which, it is reasoned, can be predicted from the discovery peak. The depletionists estimate that the rate of discoveries are declining and hence that a dramatic decline in oil production may be just around the corner (see Figure 4 below).

Support for this view comes from a diverse group, many of whom have oil industry experience, such as Kenneth Deffeyes (formerly Shell Oil and Princeton University), Ali Samson Bakhtiari (extensive experience as Senior Expert, Corporate Planning Directorate at Iran's National Oil Company) and Matthew Simmons (leading energy industry financier and a former energy advisor to America's Vice President Dick Cheney). They warn that a sudden decline in oil supplies is imminent and draw support from the 2004 rise in oil prices.

The depletionists reason that if, as they estimate, the ultimately recoverable resource (URR) is around 1.8 trillion barrels, then the world is half-way through its supplies and a sudden downturn in production is to be expected in the near term.

Figure 4 Declining oil discoveries, as illustrated by the depletionists



Source: http://www.oilcrisis.com/magoon/

The repercussions of the anticipated sudden oil depletion are seen as dire:

> …it looks as if an unprecedented crisis is just over the horizon. There will be chaos in the oil industry, in governments, and in national economies. Even if governments and industries were to recognize the problems, it is too late to reverse the trend. Oil production is going to shrink (Deffeyes 2001).

The antidepletionists/international agencies

The mainstream response to concerns of oil depletion is that oil has been running out ever since the beginning of the oil industry 150 years ago and that

5 For more background on Hubbert see http://www.hubbertpeak.com/hubbert/.

reserves have grown, rather than shrunk, over the recent decade. The major international agencies—U.S. Energy Information Agency (EIA, within the Department of Energy), the U.S. Geological Survey (USGS), the International Energy Agency (IEA—composed of the major OECD oil-using nations) and the European Commission—do not share the depletionists concern for the future of world oil supplies. The agencies' (mean) estimates are almost double those of the depletionists, at around 3 trillion barrels (EIA 2004c Table 5 p. 36).

With slight variations, the agencies' forecasts reflect a view that supply growth will, at worse, lag demand growth slightly, avoiding issues of scarcity and very high prices. In the words of the IEA

> …the Earth's energy resources are more than adequate to meet demand until 2030 and well beyond' and 'the world is not running out of oil just yet. Most estimates of proven oil reserves are high enough to meet the cumulative world demand we project over the next three decades' (IEA 2004b p. 29).

In response to the criticism that the world is consuming oil faster than it is discovering it, the antidepletionists suggests a longer time horizon be considered. Over the last 50 years estimates of ultimate oil reserves have risen as fast as or faster than cumulative oil production Deming (2000).

Past Predictions

The antidepletionists point to the many past predictions of the decline of oil production (see Table 2 below), in the same vein as those contained in the Limits to Growth submission to the Club of Rome in 1972, when 'sudden and uncontrollable decline in both population and industrial capacity' were forecast.[6]

Table 2 History of failed oil depletion projections[7]

Year	Prediction	Source
1914	Oil would last a decade	Bureau of Mines (U.S.)
1920	20 billion barrels - total oil remaining in the world	U.S. Geological Survey
1922	US only has energy oil supply to last 20 years.	U.S. Geological Survey
1926	4.5 billion barrels remain	Federal Oil Conservation Board (U.S.)
1932	10 billion barrels of oil remain	Federal Oil Conservation Board (U.S.)
1944	20 billion barrels of oil remain	Petroleum Administrator for War (U.S.)
1950	world oil reserves of 100 billion barrels	American Petroleum Institute
1951	13 years supply of oil left	Interior Department (U.S.)
1977	'could use up all of the proven reserves of oil in the entire world by the end of the next decade'	U.S. President Jimmy Carter

Sources: Fumento, M. 2004 http://www.capitolhillblue.com/artman/publish/article_4525.shtml Energy Time Line at http://www.energyquest.ca.gov/time_machine/1920ce-1930ce.html,

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6 For more detail see www.clubofrome.org/docs/limits.rtf

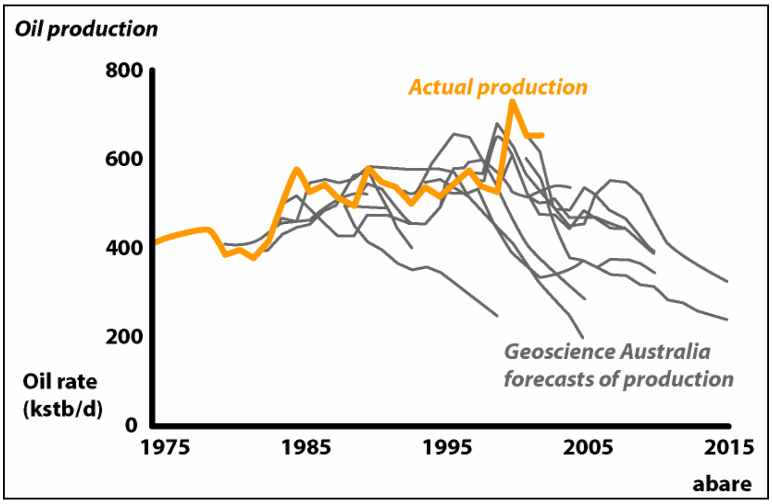
7 A list of oil depletion forecasts for the past 30 years if provided by http://www.oildepletion.org/roger/Key_topics/Past_forecasts/Past_forecasts.htm

http://www.ncpa.org/abo/inthenews/Petroleum.html

Fumento (2004) observed that the earliest claim that the U.S. was running out of oil dates back to 1855—four years before the first well was drilled. In 1920, the U.S. Geological Survey estimated the total amount of oil remaining in the world amounted to only 20 billion barrels.[8]

Australian forecasts reveal the same pattern. Tulpulé (2004) identified 'forecasters' droop' in Geoscience's Australia propensity for consistently pessimistic forecasts of future production of oil—see Figure 5 below.

Figure 5 Forecasts vs. actual production of oil (Australia 1975-2015))



Source: Tulpulé (ABARE) 2004

The Economist (February 2001) noted the series of wildly inaccurate oil price forecasts and comments that 'even Exxon says it has learned one crucial lesson from earlier forecasting mistakes: It greatly underestimated the power of technology. Thanks to advances in exploration and production technology, the amount of oil available has increased enormously'. [9,]

Much of the credibility of the depletionists' model stems from Hubbert's famous prediction in 1956 that U.S. oil production would peak in 1970. However, other applications of the model have proved unsuccessful, such as Hubbert's prediction that world oil production would peak in about 2000.[10] While there was a slight downturn in world production in 2000, as can be seen from Figure 7 and Figure 8, production recovered and the available market forecasts suggest that past production growth will continue.

Oil is not the only resource where physical limits have been confused with economic scarcity, leading to pessimistic projections about declining supply. The famous 1980 bet between economist Julian Simon and Paul Ehrlich (author of *The Population Bom*b) underlined the distinction between finite supply and economic availability (see box below for detail).

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8 By the year 2000, the estimate had grown to 3,000 billion barrels (Deming, D. 2003)

9 http://www.economist.com/displayStory.cfm?Story_id=497454.

10 See Lynch (2003 for more criticisms of Hubbert's model.

Box 1 Julian Simon's bet with Paul Ehrlich

After decades of predicting massive shortages of various natural resources, biologist Paul Ehrlich was challenged by economist Julian Simon to bet on future scarcity of natural resources, as reflected in prices. Simon offered Ehrlich a bet that, despite continued mining and depletion of minerals, prices would fall rather than rise. Ehrlich was free to select a quantity of any five metals worth $1,000 in 1980. Simon bet that the 1990 price of the metals, after adjusting for inflation, would be less than $1,000. If Simon won, it would indicate that, despite declining physical resources, the metals had not become more 'scarce'. The wager was the difference in the price of the basket of metals.

Ehrlich chose copper, chrome, nickel, tin and tungsten. By 1990, all five metals were below their inflation-adjusted price level in 1980. Ehrlich lost the bet and sent Simon a check for $576.07.

http://www.overpopulation.com/faq/People/julian_simon.html

The antidepletionists point out that Ehrlich's error is being repeated by the depletionists today, through their failure to understand that the physical supply is only one factor among a number that determine resource scarcity. The following explanation was advanced for Ehrlich's error. As one commentator noted, 'prices fell for the same Cornucopian reasons they had fallen in previous decades—entrepreneurship and continuing technological improvements'.[11]

The consistent failure of most oil supply predictions has also been attributed to poor modelling practices. One critic observed that: 'the history of oil market forecasting has been a sorry one, all the more so for the inability of many forecasters to perceive—let alone correct—their errors' (Lynch 2002 p. 373). Following a comprehensive study of the oil production forecasts, Lynch demonstrated that most oil supply forecasts have been too pessimistic (with a consistent tendency to predict a peak within a few years, with the peaks then being moved out for the next forecast) and that this is due to serious methodological errors:

- pessimism bias, despite relying on price assumptions that were much too high;
- similar forecasts for every region, ignoring different fiscal systems, drilling levels and/or the maturity of the industry, suggesting omitted variables; and
- misinterpretation of recoverable resources as total resources by using a point estimate instead of a dynamic variable, growing with technology change, infrastructure improvements, etc (Lynch 1998).

[11] Tierney, J, 'Betting the planet', *New York Times Magazine*, Dec 2 1990, quoted in Carnell (2004).

MAIN AREAS OF CONFLICT

Peaking or not peaking?

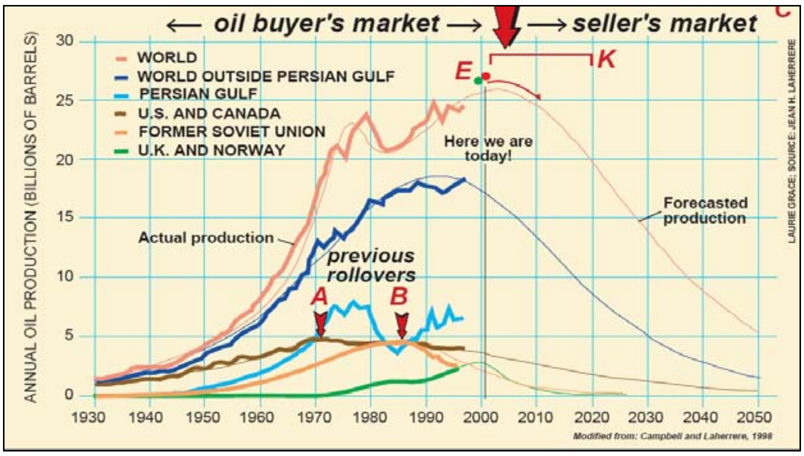
The term 'the big rollover' is commonly used by the depletionists to refer to the peak of production of conventional oil—generally believed to come close to the midpoint of depletion, as illustrated in Figure 6 below.

The significance of the midpoint point/peak derives from the reported strong historical evidence that show that oil production peaks and then starts to decline when half the recoverable resource has been consumed. The depletionists maintain that this is a matter of oil reservoir physics rather than production technology or economics. Depletionists generally predict near-term peaks, although with some variation.[12]

Lindgren (2004), a depletionist, estimated that of the world's 42 top oil-producing nations, production wells in 15 are already in decline, 14 will go into decline within three years, and only wells in six countries (Iraq, Brazil, Saudi Arabia, Colombia, the United Arab Emirates and Kuwait) will pass 2010 without peaking. Of those six, Lindgren suggests that Saudi Arabia is probably the only nation with a substantial level of spare production capacity.

Typical of the depletionists is the alarm raised by Duncan and Youngquist (1999) over the fact that the world is consuming oil at a faster rate than it is producing it, 'any company which is selling its product faster it is being replaced is going out of business. The world is going out of the oil business'. World population growth and high rates of growth from increasingly-industrialised nations (in particular, China and India) are expected to exacerbate the situation.

Figure 6 The 'Big Rollover' in the production of conventional oil



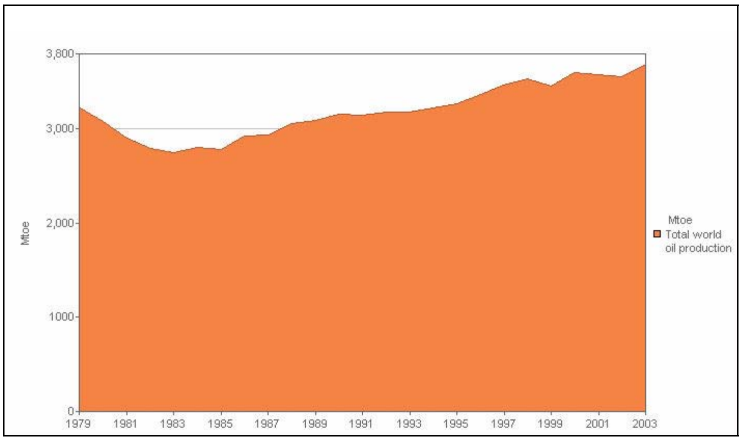
Source: http://www.oilcrisis.com/magoon/ (adapted from Campbell, C. and Laherrère 1998)

The antidepletionists point to the consistent failure of the forecasted peaks to occur, with one remarking that 'the only evidence of a production peak in the

12 See Duncan and Youngquist (1999) for a brief overview of the predictions.

next two decades is a mathematical model which has repeatedly forecast false peak' (Lynch 1999). Figure 7 below illustrates total world production over the past quarter of a century, with some fluctuations but no apparent peak to date.

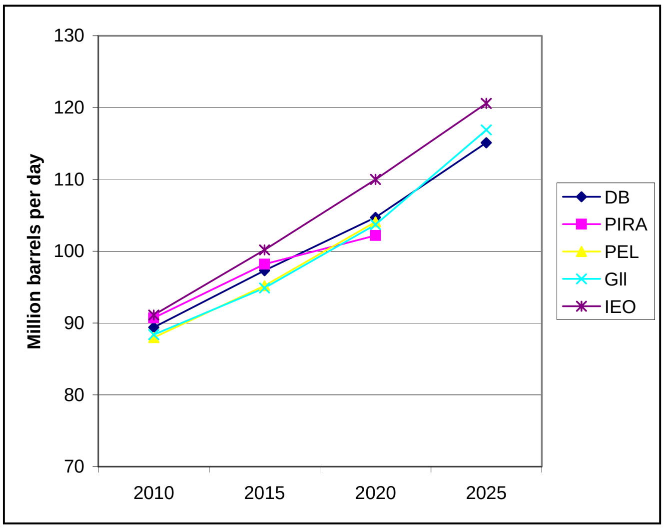
Figure 7 Total world production (1979-2003)



Source : BP Statistical Review of World Energy2004
http://www.bp.com/subsection.do?categoryId=95&contentId=2006480

Major international forecasters do not provide support for a production peak within the next two decades—see Figure 8 below. In general, oil production is expected to increase steadily in response to growing world demand.

Figure 8 Comparison of world oil production forecasts



Source: Derived from EIA 2004c Table 10 http://www.eia.doe.gov/oiaf/ieo/oil_tables.html

Suddenness of the decline

Another important issue is the abruptness of the rollover. The depletionists warn that the decline in production is likely to be quite sudden, leaving the world unprepared to respond to a shortage of oil. Economic chaos and social disorder could result. In Bakhtiari's words: 'there will be no linear change… there will only be sudden explosive change'

Decline of the giant oilfi*e*lds

One reason the depletionists believe that a dramatic decline in oil production is inevitable is the world's dependence on a small number of old, giant oilfields that produce over half the world's daily output. The four largest alone account for 12 per cent of the world's supply (Simmons 2002 p. 13). These fields underpin Middle East oil supplies and for each one there is little verifiable data available to testify to their long-term production capacity. Hence, there are fears that sudden, unexpected declines in these old oilfields—'history has shown that once giant fields peak, the decline can be quite rapid' (Simmons 2002 p. 24).

The antidepletionists acknowledge the significance of the giant oilfields in recognising that 'global supply prospects are far more sensitive to oilfield decline rates than to the rate of growth in oil demand' (Ramsay 2004 p. 3). Much industry attention has focused on Ghawar, the world biggest oil field that alone provides 6 per cent of world production.

Saudi Arabia relies on Ghawar for over half its daily output. The depletionists warn that if Ghawar goes into decline, the world oil production has peaked—'Ghawar underpins Saudi output and Saudi undergirds worldwide production'.[13] To be more explicit, the decline of Ghawar 'would signal the beginning of the end for Saudi Arabia's oil' and should trigger alarm bells all over the petroleum industry and even in the general public (Bakhtiari 2004)

Ghawar is almost 60 years old and depletionists point out that cumulative production through to 2003 is 55 billion barrels—very close to the 1975 estimate of its URR of 60 billion barrels—hence it is already declining after peaking in 1990 (Simmons 2002 p. 20). However, the company responsible for the operation of Ghawar, Saudi Aramco, reports that Ghawar still has 70 billion barrels of remaining reserves of Arabian Light crude and, at the current rate of output, this represents 38 years of production. The lack of transparency of oil well data makes it difficult to confirm this estimate.

In the absence of reliable data, many analysts use the 'water cut' as an indication of the state of health of individual oil fields. As explained by Morton (2004):

> Most new oilfields produce almost pure oil or oil mixed with natural gas—with little water. Over time, however, as the oil is drawn out, operators must replace it with water to keep the oil flowing—until eventually what flows is almost pure water and the field is no longer worth operating.

There are various estimates of Ghawar's water cut, with published reports ranging from 30-55 per cent, and Colin Campbell recently suggesting up to 60 per cent (BBC 2004). The American Association of Petroleum Geologists report that 'Ghawar 'just keeps going gangbusters' with an average production for the last 10 years that has held essentially steady at five million barrels per day. Furthermore, they note that water injection, which was initiated in 1965, has been reduced from 'approximately 35 percent to roughly 30 percent since

[13] http://www.gasandoil.com/goc/news/ntm43590.htm

vertical well drilling was shelved in favor of horizontal wellbores' (AAPG 2005).

The response of the IEA to the future of Ghawar probably sums up the debate most accurately—'the jury is still out' (Ramsay 2004 p. 4).

Terminology and data

Laherrère (2003), a peak theorist, maintains that the lack of consensus on reserve numbers and ambiguous use of basic terms (such as oil, gas, conventional, unconventional, reserves) makes it difficult to compare like with like and represents the major source of disagreement between the two groups.[14]

From resources to reserves

Generally, both depletionists and antidepletionists agree that

- the earth contains a finite amount of oil; and
- the amount of oil is unknown.

There is less agreement about the significance of the distinction between *reserves* and *resources*. Resources are the finite amount of oil that has been bestowed on the world. Reserves represent the amount of oil that can be recovered *commercially* with *current technology*. This means that reserves can increase without any physical change in resources—simply through a decline in extraction costs or a rise in oil prices.

The URR is an estimate of the total quantity of oil resources that will ever be produced, including the nearly 1 trillion barrels extracted to date. The *remaining* URR includes proven, probable and possible reserves from discovered fields, as well as those that are yet to be discovered (IEA 2004b p. 93). The depletionists estimate a URR of 1.8 trillion barrels compared to around 3 trillion barrels estimated by the antidepletionists (EIA 2004b table 5 p. 36).[15]

The P90 reserve is the amount of oil that can be extracted with a 90 per cent probability, is usually referred to as *proved* reserves. Similarly, the P50 and P10 reserves are labelled *probable* and *possible,* respectively. The sum of proved and probable reserves is commonly taken to mean the best scientific estimate of the size of the field as a whole.[16]

However, U.S. practice differs from that in the rest of the world, being conservative to satisfy bankers and the stock market. The U.S. Securities and Exchange Commission (SEC) rules require 'proved' reserves to be reported while practice elsewhere allows 'proved and probable'. The former Soviet

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[14] Laherrère (2003) also criticised the 'negative camp' for using political (published) data rather than the technical (confidential) data utilised by the affirmative camp.

[15] It is important to recognise the link between the URR estimate and the timing of the production peak—the lower the estimate, the sooner the resource is half depleted, signalled by a production peak.

[16] Campbell http://www.isv.uu.se/UHDSG/articles/OilpeakMineralsEnergy.doc

Union (FSU) definition appears to have an optimism bias being based on the maximum theoretical recovery, free of technological or economic constraints.

The inconsistency and confusion over estimates of world oil reserves arises partly because of the great deal of flexibility within the definitions. As the IEA observed:

> There is no internationally agreed benchmark or legal standard on how much proof is needed to demonstrate the existence of a discovery. Nor are there established rules about the assumptions to be used to determine whether discovered oil can be produced economically (IEA 2004b p. 87).

Reliability of the data

Aleklett and Campbell (2003) criticise the quality of the data on which the antidepletionists base their conclusions, observing that the most widely used public source of information comes from two trade journals (*Oil & Gas Journal* and *World Oil*), the data sets of which differ greatly, despite being compiled in a similar fashion from government and industry sources. The situation is exacerbated by the fact that the International Accounting Standards fail to provide information-disclosure requirements for oil reserves. Hence, these critical sources of industry data do not adjust reported data according to a standardized methodology (IEA 2004b p, 92*)*. Also, methodologies used to measure different categories of reserves vary depending on their purpose, with financial reporting standards being the strictest and leading to the lowest estimates (IEA 2004b p. 89).

The depletionists argue that another widely used source, the BP Statistical Report of World Energy, 'simply reproduces the Oil & Gas Journal material'. The industry database, according to the depletionists, is relatively reliable but too expensive for most analysts to access.

Aleklett and Campbell point out that the task of estimating the size of an oilfield poses no great technological challenge, although with a quantifiable range of uncertainty. However, they contrast this with the *reporting* of the results, which they claim 'are clouded by ambiguous definitions and lax reporting practices', concluding that

> …the atrociously unreliable nature of public data has given much latitude when it comes to interpreting the status of depletion and the impact of economic and political factors on production. This has allowed two conflicting views of the subject to develop (Aleklett and Campbell 2002).

Campbell argues that strategic considerations are involved in data provision—that the industry systematically under-reports the size of discovery (mainly to smooth their assets, thereby presenting a better commercial image) and that governments variously under-report or over-report, or simply fail to update their estimates.[17]

> We might almost call some of them conspiracies of denial and obfuscation. The United States seeks to exaggerate the world's oil endowment to reduce OPEC's

[17] Campbell (2002) http://greatchange.org/ov-campbell,outlook.html

> confidence. It pretends that it does not depend on Middle East oil. It puts out very flawed studies by the U.S. Geological Survey and the Department of Energy. OPEC, for its part, exaggerates its resource base to inhibit non-OPEC investments and moves to energy savings or renewables. It fears losing its oil market on which it utterly depends, with its rapidly rising population. Companies conceal depletion because it sits badly on the investment community (Campbell 2002a).

Simmons (2004b) argued for *13 Points of Light* to improve the reliability of the data:, with historical production accounting for 10 of the 13 points, the remainder being field-by-field proven reserve disclosures which are conspicuous by their absence in current accounting..

The most recent USGS also noted that as set of reporting requirements do not exist worldwide:

> Criteria for the estimation of remaining reserves differ widely from country to country, as do the technical, economic, and political incentives that drive the reserve-growth process. Therefore, patterns of reserve growth for the world as a whole are poorly understood, and the problem of quantitatively estimating world potential reserve growth is formidable.[18]

In 2001, in an effort to improve the quality, reliability and transparency of oil data, the IEA joined with five other international organizations dealing with energy statistics, to launch a Joint Oil Data Initiative (JODI) in 2001. While promising, significant progress is yet to be reported.[19] From a completely different angle, in and in response to major reserves accounting controversies in 2004, regulators in the U.S. and the U.K. turned their attention to the use of external auditing. The Securities and Exchange Commission and Britain's Financial Services Authority are exploring the scope for regulations requiring independent auditing of reserves.

Harmonisation of terminology is fundamental to improving the quality of the reserves data. The United Nations has embarked on a program (Framework Classification for Energy and Mineral Resources) to establish common criteria for evaluating energy resources in different countries, outlined in Box 2 below.

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[18] USGS (2000) http://pubs.usgs.gov/dds/dds-060/ Chapter RG p. 2.

[19] See http://www.iea.org/dbtw-wpd/Textbase/speech/2004/jyg_amsterdam.pdf for an October 2004 update.

Box 2 UN Framework Classification for Energy and Mineral resources

The United Nations Economic Commission for Europe (UNECE) reports that there are currently more than 150 different classifications for energy reserves/resources are in use worldwide and has identified a longstanding need to reconcile this semantic diversity by harmonizing the terminologies applied by the different classifications and to different commodities. To this end, the UNECE is working towards agreement on common criteria for evaluating the different reserves/resources in different countries. The outcome, the United Nations Framework Classification for Energy and Mineral Resources (UNFC), is designed to be a universally applicable instrument for classification of reserves and resources of energy and mineral commodities.

Source: UNECE 2004 p. 2

The International Energy Agency acknowledge that information sources are limited, noting that the most widely-quoted primary sources of global reserves data (*Oil and Gas Journal, World Oil* and the U.S. Geological Survey) are compiled using 'the best available data from national and company sources'. On a positive note they observe that, despite the differences in approaches among these organisations, current estimates of remaining proven reserves of worldwide crude oil and natural gas liquid do not vary greatly (IEA 2004b p. 90).

Reserve Growth and total oil endowment

A major area of dispute between the depletionists and the antidepletionists is the total endowment. The smaller the endowment, the closer the world is to the critical half-way point. The size of total endowment depends, in turn, on the acceptance or rejection of 'reserve growth'.

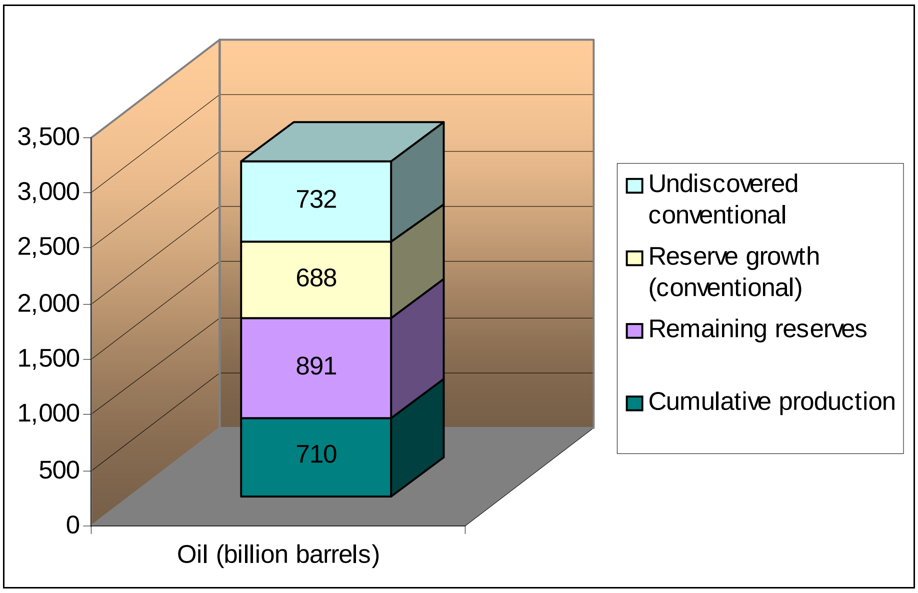
Reserve growth generally refers to increases in known oil volume as a result of technical improvements and corrections of earlier conservative estimates.[20] This relatively new addition to the U.S. Geological Survey (USGS) methodology and represents a significant contribution to reserves, accounting for around one quarter of estimated world endowment of oil.

Additions to reserves come from a combination of reserve growth and new discoveries. Over the last few decades, reserve growth has been responsible for an increasing share of reserve additions—mainly due to improved operational data on known fields or revised cost and price assumptions (IEA 2004b p. 96).

The significance of reserve growth is apparent in the latest USGS assessment of and along with 'undiscovered conventional', account for much of the difference in the estimates of the depletionists and the antidepletionists.

20 Reserve growth is calculated as a product of known petroleum volume and a 30-year growth multiplier, estimated by the USGS assuming that petroleum reserves everywhere in the world will be developed with the same level of technology, economic incentives and efficacy as in the U.S. See Hall *et al* (2003) p. 319.

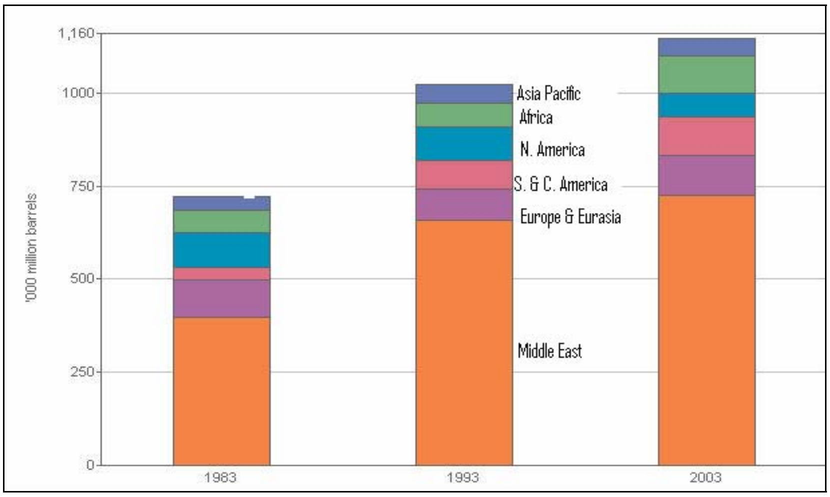
Figure 9 World conventional endowment of oil



Source: USGS 2000 Table. ES-1 http://energy.cr.usgs.gov/WEcont/chaps/ES.pdf

Other agencies have long incorporated reserve growth into their estimates. The BP Statistical Review of World Energy (2004) depict reserves increasing by a third in the 20 years to 2003—see Figure 10 below.

Figure 10 Proved world oil reserves 1983, 1993, 2003

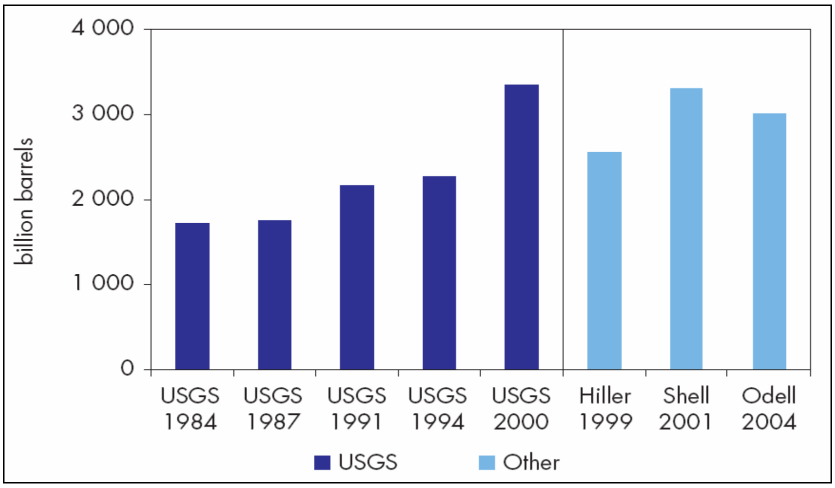


Source: BP Statistical Review of World Energy 2004
http://www.bp.com/subsection.do?categoryId=95&contentId=2006480

Fumento (2004) estimated that proved oil reserves increased 55 per cent in the two decades to 2002, significantly higher than the 13 per cent increase in worldwide consumption of oil. He calculated that if consumption continued to increase at an average rate of 1.4 percent a year, current reserves would last until 2056 'even if not a single new drop is found' Fumento (2004).

The USGS, commonly regarded as 'the most authoritative source of estimates of globally URR of conventional oil' (IEA 2004b p. 93). The USGS estimates of total world resource doubled between 1984 and the most recent study (see Figure 11 below).

Figure 11 Growth in ultimately recoverable oil resources



Source IEA 2004b p. 96

The depletionists reject the proposition that oil reserves 'grow' in response to increases in world oil prices and reductions in exploration and extraction costs. Instead, they maintain that oil reserves are a physical identity and not influenced by economics: 'factors that control oil accumulation in nature and applies immutable physical laws to the process of depletion' (Aleklett and Campbell 2003) Further, they argue that technological improvements cannot find what isn't there—the biggest fields are found and developed first after which increasingly smaller fields are found and brought into production. Eventually the new fields will be small and hard to find. Furthermore, it is argued that technology cannot overcome the fact that a large proportion of the world's oil comes from a small population of giant fields that have an average age of almost 70 years and could not be expected to provided significant amounts of oil for coming decades (Simmons 2002 p. 2).

Alan Greenspan, Chairman of U.S. Federal Reserve, reflecting the views of the antidepletionists, observed in September 2004:

> …despite the paucity of new discoveries of major oil fields, improving technology has significantly increased the ultimate recovery of oil from already existing fields. During the past decade, despite more than 250 billion barrels of oil extracted worldwide, net proved reserves rose well in excess of 100 billion barrels. That is, gross additions to reserves have significantly exceeded the extraction of oil the reserves replaced. Indeed, in fields where, two decades ago, roughly one-third of the oil in place ultimately could be extracted, almost half appears to be recoverable today. …The uptrend in proved reserves is likely to continue at least for awhile (Greenspan 2004)

Reserve growth is expected to continue, with the EIA (2004) projecting a significant increase in world oil supply such that in 2025 it will exceed the 2001 level by 53 per cent.[21]

[21] EIA (2004a) http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2004).pdf

The following areas of dispute, backdating of reserve estimates, OPEC's upward revision, and the resource pyramid are closely related to reserve revisions.

Backdating

The depletionists argue that the failure to assign 'revisions' to the original discovery (backdating) gives the illusion that more is being found than is the case.[22]

The antidepletionists contend that the revisions are properly attributed to the date on which they are announced and that the approach of the depletionists amounts to 'rewriting history'. To quote: 'reserves data from the main public sources are not 'backdated'. In other words, the historical time series of reserves for a given country is not revised in light of new discoveries or increases in recovery rates' (IEA 2004b p. 93).

OPEC Upward Revision

Between 1985 and 1990, total OPEC reserves jumped from 536 billion barrels to 766 billion barrels, resulting in a 30 per cent increase in world oil reserves (IEA 2004b p. 92), as illustrated in Figure 12 below. The depletionists posit that no credence can be placed in the reserves reported by the five Middle East key countries since reported discoveries amounted to no more than 10 Gb and that the estimates are no more than arbitrary revisions aimed at achieving a higher allocation of the OPEC quota. This interpretation finds little argument amongst the antidepletionists: 'This hike in OPEC countries' estimates of their reserves was driven by negotiations at the time over production quotas, and had little to do with the actual discovery of new reserves' (IEA 2004b p. 92).

However, the evidence suggests that this arbitrary upward revision is a symptom of the unreliability of OPEC reserve figures rather than an isolated incident that can be dealt with through an offsetting adjustment. For instance, Kuwait's oil reserve estimates (the world's fourth-largest) did not change over the decade to 2002 even though almost 8 billion barrels of oil was extracted and no new discoveries were made during that period.

On the other side of the coin, reserves for other OPEC countries remained constant despite major deepwater discoveries and development activity. In many of the countries, there has been very little exploration activity, simply because with the huge reserves available, there was little need. Hence, the antidepletionists maintain that, in a number of OPEC countries, the URRs are likely to be understated and hence that it is reasonable to shift these reserves to the 'booked' category.[23]

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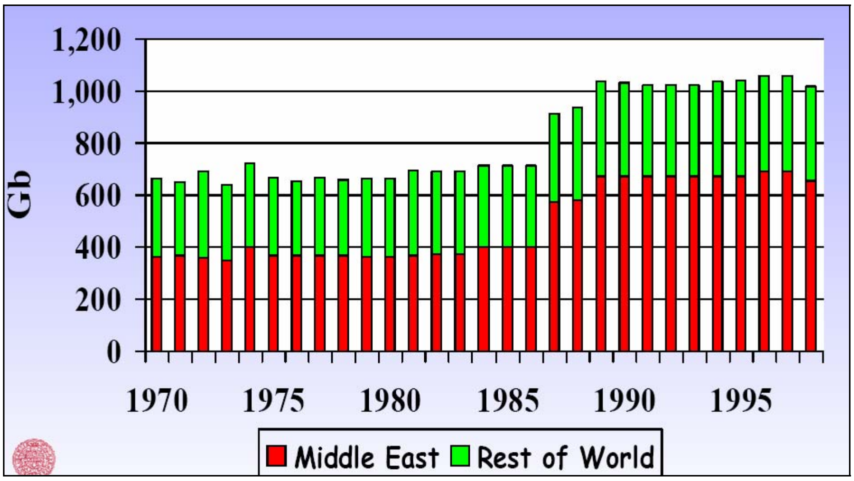
22 Campbell (2002) http://greatchange.org/ov-campbell,outlook.html

23 See Oil and Gas Journal http://ogj.pennnet.com/forum/display_messages.cfm?CategoryID=1&TopicID=685&SiteIDs=OGJ

Figure 12 OPEC's upward revision of reserves



Source: Aleklett 2003 http://www.isv.uu.se/UHDSG/articles/LisbonPDF.pdf

Campbell partly endorses this view, observing that 'the early numbers were too low, having been inherited from the companies before they were expropriated'. However, he goes on to argue that while some of the increase was justified it has to be backdated to the discovery of the fields concerned that had been found up to 50 years before (Campbell 2002).

Resource pyramid

The resource pyramid is a conceptual representation of the 'economic feasibility of an area' of petroleum reserves. It shows a small volume of prime resource at top and, at bottom, larger volumes of low quality resources that are more expensive to extract (Ahlbrandt & McCabe 2002 p. 5). Depletion leads to scarcity, which, in turn leads to higher prices. Consequently, those resources that were once classified as 'nonconventional' because they could not be produced economically at prevailing prices and technology become conventional with higher prices and improved technology.

Prices are an important determinant on estimates of reserves. The EIA notes that:

> Resources are defined as 'nonconventional' when they cannot be produced economically at today's prices and with today's technology. With higher prices, however, the gap between conventional and nonconventional oil resources narrows. Ultimately, a combination of escalating prices and technological enhancements can transform the nonconventional into the conventional. (IEA 2004b p. 37)

The impact of shifting non-conventional resources to convention can be significant. For instance, David Deming, professor of geology and geophysics at the University of Oklahoma, estimated that oil sands worldwide (generally not included in the conventional oil estimates) could provide more than 500 years of oil at current usage rates.[24]

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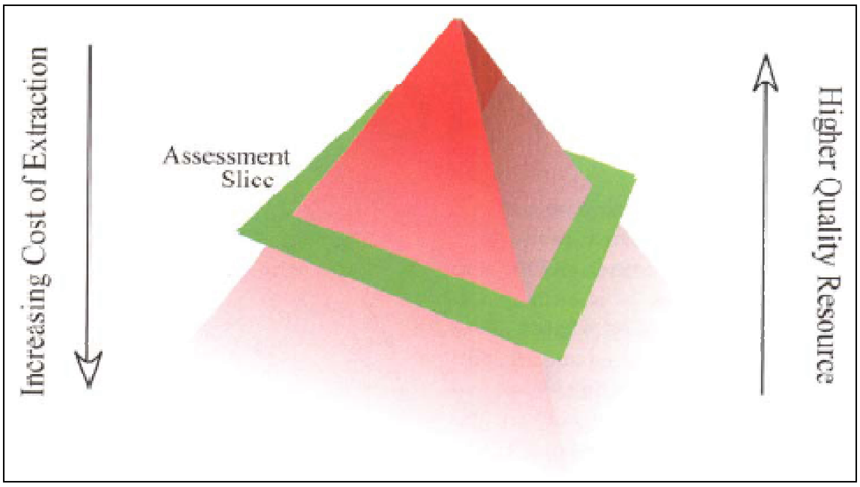
[24] http://www.ncpa.org/abo/inthenews/Petroleum.html.

Figure 13 The resource pyramid



Source: Ahlbrandt. & McCabe. (2002) p. 5

Figure 13 illustrates a geologist's view of the resource pyramid. According to Ahlbrandt and McCabe, 'the upper part of the pyramid is well defined, as these resources are mostly known and are generally considered "conventional". The lower part of the pyramid is less well understood'. It is this lower part where that provides the source of greatest conflict.

Technology's role in the resource pyramid

Technology plays a major role in ensuring future affordable oil supplies, making it possible to draw upon petroleum resources whose extraction was once unviable. There have been significant advances over the past decade in the science and technology of oil exploration and production. Wells can now be drilled up to 30,000 feet deep and long horizontal–reach wells are possible, stretching up to several kilometres. The amount of oil that can be recovered from a single well has been enhanced by a technology that allows multiple horizontal shafts to be branched off from one vertical borehole. The ability to drill offshore in water depths of up to 9,000 feet has opened up the vast petroleum resources of the world's submerged continental margins (Society of Petroleum Engineers 2002).

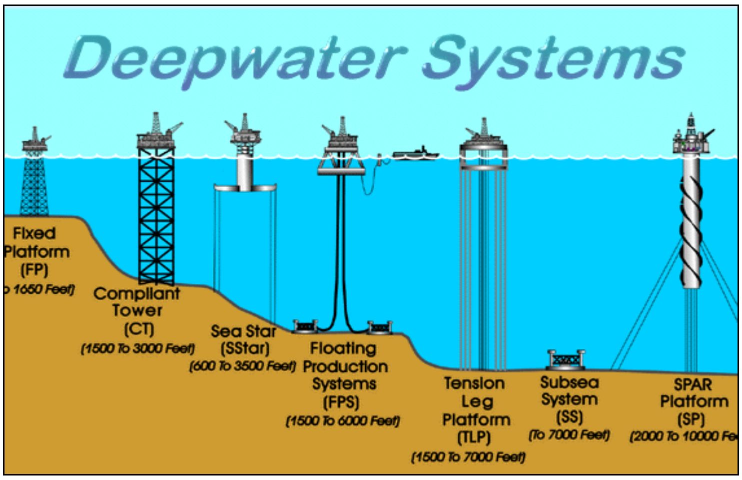
IHS Energy, a leading provider of oil and gas information, reporting in October 2004 that oil had reached a new peak in production during 2003 and that their analysis indicated that 'the global resource base for hydrocarbons is still healthy and will be aided by a growth in exploration investment that is now underway'. In explaining the contribution of technology they went on to note that:

> Deepwater played an increasingly dominant role in the past decade — with a record 70% of all discoveries in 2003 being made in water depths of over 200m and 65% of all discoveries occurring in water depths greater than 1,000m. Significant investments in deepwater exploration and production technologies by major international operators over the decade fuelled growth in reserves and production which were inaccessible and uneconomic at the beginning of the period (HIS Energy 2004).

The world also contains major sources of unconventional oil resources that have not yet been tapped. For example, tar sands found in Canada and South America contain 600 billion barrels of oil, enough to supply the U.S. with 84 years of oil at the current consumption rate. The amount of oil that can be extracted worldwide from oil shales has been estimated as up to 14,000 billion barrels—enough to supply the world for 500 years (Deming 2003).

The EIA estimates that 'enhanced supplies' made possible through technological gains will provide 25 per cent of oil production in 2025. Incremental technology improvements are illustrated in Figure 14 below.

Figure 14 Incremental technology improvements



Source: EIA 2004c

Professor Peter Odell (author of *Oil & Gas: Crises and Controversies 1961-2000*), proposed that higher exploitation and extraction costs will be offset by technologically-derived savings, and hence there will be little or no pressure of demand on supply for at least the next 20 years. There is no reason, in his view, why oil prices should rise much in real terms over this period, nor any reason why the world will need to resort to the higher-cost oil reserves (Odell 2000 and 2003).

The dispute echoes that which surrounds reserve growth. The depletionists counter that the technology is not new, and while it allows cheaper and faster production it does not add to the reserves themselves in conventional fields' (Laherrère 2003). Campbell (2002) accuses the adherents of the 'resource pyramid' philosophy as failing to grasp the polarity of oil which is normally either there in profitable abundance or not there at all. He elaborates, 'that the oil-water contact in a reservoir is abrupt giving virtually no possibility of tapping lower concentrations and that the heavy oil and bitumen deposits, which could be considered as the lower part of the pyramid, are present in large quantities only in western Canada and eastern Venezuela.'

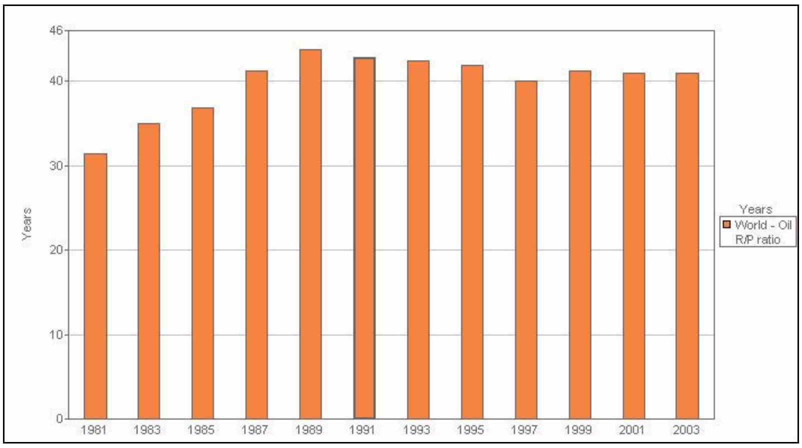
Campbell (2002a) also points out that through enhancing the knowledge of the resource, the technology has *reduced* (rather than enhanced) the perceived potential, because it shows a dearth of large prospects.

However, improvements in technology have increased the exploration success rate—from 20 per cent in the late 1940s to over 40 per cent in recent years—as well as reduced the cost of drilling wells (IEA 2004b p. 99). For instance, oil in the Troll field in Norway was once considered 'uncommercial'. The use of advanced technology increased the recovery rate to 70 per cent and reserves fivefold between 1990 and 2002 (IEA 2004b p. 100). Hence, it would appear that there is validity in both sides of the debate on this point. While clearly, oil that *isn't* there can't be extracted, more of the oil that *is* there can now be extracted economically.

Reserves to production ratio

The reserves to production (R/P) ratio is widely used as a measure of the adequacy of oil reserves. The R/P ratio (reserves divided by annual production) indicates the number of years that remaining reserves would last if production were to continue at current levels and is estimated to be around 40 years (see Figure 15 below).[25] Possibly as significant is the fact that the R/P ratios for coal and natural gas, substitutes for oil in many markets, are estimated at 200 years and 70 years, respectively.[26]

Figure 15 World oil reserves to production ratio (1981-2003)



Source: BP Statistical Review of World Energy 2004
http://www.bp.com/subsection.do?categoryId=95&contentId=2006480

However, the depletionists dismiss the use of this figure, countering that the R/P is meaningless because the important question is not how long will the reserves last, but whether production can be maintained at the current level.[27]

25 For more detail see http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/T/Table_of_proved_oil_reserves_at_end_2002.pdf

26 BP (2004) http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/publications/energy_reviews/STAGING/local_assets/downloads/spreadsheets/statistical_review_of_world_energy_full_report_workbook_2004.xls

27 http://www.oilcrisis.com/laherrere/supply.htm

They question the value of a measure whose relevance depends on production (consumption) remaining constant.

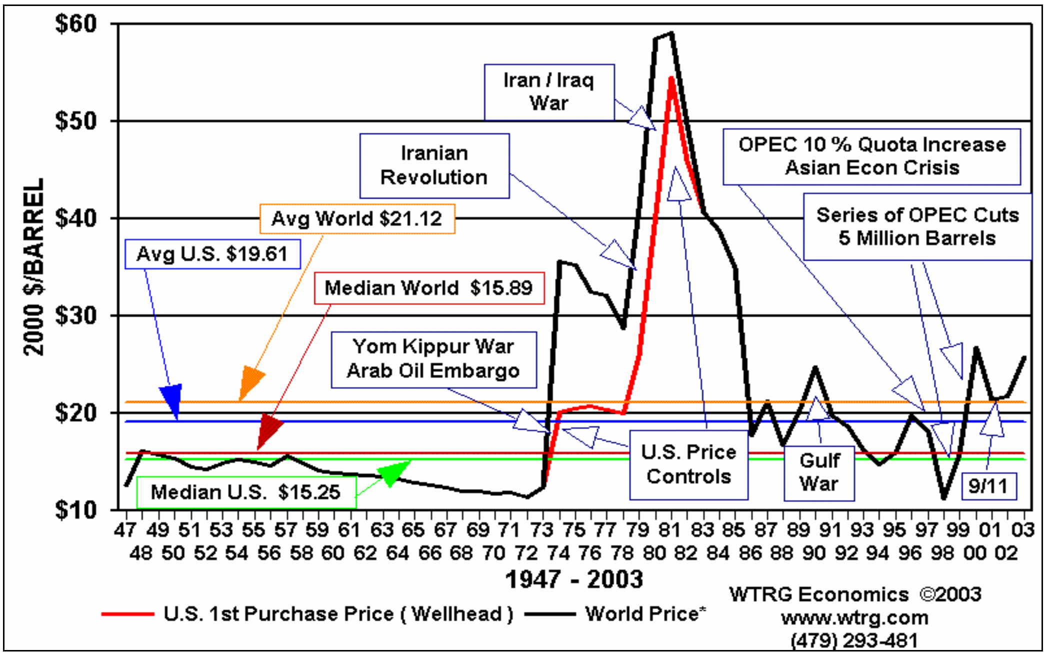
The antidepletionists recognise the shortcomings of a simple R/P ratio, but note that while oil production is likely to increase over time, reserve revisions are also likely to be upward. The IEA suggests that a better guide to the ability of reserves to meet future demand would be the ratio of remaining URRs to the *expected* average production level over the projection period. Furthermore, that this ratio is much *higher* than the R/P ratio: 'Globally, remaining resources are sufficient to meet the projected average annual production, between now and 2030, 70 times over, based on USGS estimates and this *Outlook's* projections' (IEA 2004b p. 95).

Role of prices

A crucial difference between the two schools of thought is the role prices play in signalling rapidly depleting oil supplies. Prices, if given a chance, will provide a quantitative summary of factors that impact on demand and supply—now and in the future. The antidepletionists value three measures to indicate the extent of the oil resource base: prices, proved reserves and URR, with long-term price trends being generally regarded as a more accurate indicator. In general, depletionists dismiss market prices as reliable harbingers of a collapse in oil supplies, arguing that the production decline will be too dramatic for the market to anticipate, particularly given the short-sightedness of the market and lack of reliable industry data.

What does a review of price trends over the past 60 years tell us about the role of prices? Oil prices have fluctuated widely, but generally in response to short-term factors, rather than long-term concerns about supply availability. As can be seen from the inflation-adjusted prices depicted in Figure 16, the volatility is due to many factors, none of which include concerns over estimates of world oil reserves.

Figure 16 Crude oil prices 1947-2003 (US$ 2000 per barrel)



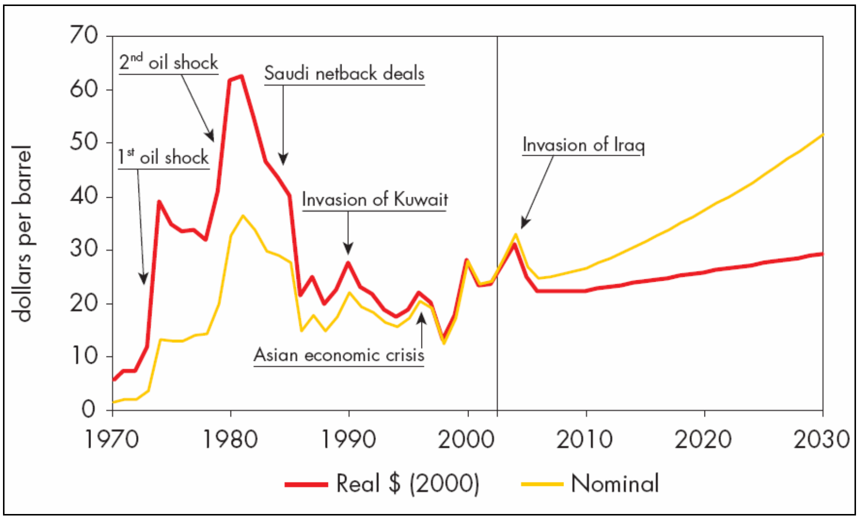
Source: Energy Economics Newsletter http://www.wtrg.com/prices.htm

The 12 months to October 2004 saw world prices rise around 70 per cent, reaching historical highs (in nominal terms) of US$55 a barrel. However, unsettling as the dramatic price rises were, none of the professional market analysts suggested that they signalled a long-term decline in world oil reserves. Rather, they were attributed to a variety of factors including unanticipated growth in demand from China and a series of relatively minor supply disruptions coupled with the 'geopolitical risk premium' from the instability in Iraq and the Middle East..

The question exercising the minds of the analysts is whether October 2004 was a market aberration or a sign of future price trends. The IEA's World Energy Outlook (October 2004) concluded that 'prices reached in mid-2004 are unsustainable and market fundamentals will drive them down the next two years (IEA 2004b p. 47).[28]. Consistent with this view, the IEA anticipates prices (in US$2000 a barrel) to decline to $22 by 2006, climbing again to $29 by 2030, as illustrated by Figure 17 below.

[28] However, the IEA (2004 p. 47) also warn that 'a continuing surge in demand and underinvestment in production capacity combined with a large and sustained supply disruption could still result in a new price hike.

Figure 17 Average IEA crude oil import price (1970-2030)



Source: IEA 2004b p. 48

The IEA noted that while they have generally overestimated prices (IEA 2004 p. 522), on average, their oil price assumptions contained in the *World Energy Outlook* (*WEO*) have been within 19 per cent of the recorded level. However, since 1999, their price assumptions have tended to be on the low side due to the ongoing global tensions and the 'appearance of sustained OPEC cohesion' (IEA 2004b p. 523).

Forecasting is not an exact science. Hence, a wide divergence between the long-term price assumptions of well-regarded analysts is not surprising. Table 3 below illustrates the range of oil price projections among different forecasting agencies—from $15.10 to $33.40 for 2020 (in US$2000). The IEA attributes part of the difference to technical factors, such as different types or baskets of crude oil. The higher price forecasts (IEA, EIA, EC and IEEJ) reflect the view that production will increase to meet rising demand but there will be a gradual increase in marginal production costs, leading to higher prices. In contrast, OPEC anticipates prices to stabilise in real terms, while the Centre for Global Energy Studies (CGES) foresees oil prices weakening over the projection period (IEA 2004b p. 529).

Table 3 Comparisons of long term oil price assumptions 2010-2030 (US$2000 per barrel)

Source	***2010***	***2020***	***2030***
IEA	22	26	29
EIA	23.3	25.1	
EC*	27.7	33.4	40.3
OPEC	19.3	19.3	
IEEJ	24.0	27.0	
CGES	20.5	15.1	

*Based on the average euro-dollar exchange rate for 2003 of 0.88, IEA International Energy Agency, EIA Energy Information Agency (US Dept of Energy), EC European Commission, OPEC Organization of Petroleum Exporting Countries, IEEJ Institute of Energy Economics (Japan),CGES Centre for Global Energy Studies.

Source: IEA 2004b p. 530

The supply and demand assumptions underlying these price forecasts are critical. If demand is higher than expected (or supply lower) then prices will be higher. The EIA forecasts an increase in world oil demand by just over 50 per cent between 2002 and 2025—an average annual growth in demand of 1.9 per cent per year (EIA 2004c p. 2). Similarly, the reference case for the IEA projections has energy demand growing by almost 60 per cent between 2002 and 2030—a projected annual demand growth of 1.7 per cent.

OPEC producers are expected to be the major suppliers of increased production requirements, with production expanding 80 per cent over this period.[29] Offshore resources are anticipated to be competitive, especially in the Caspian Basin, Latin America, and deepwater West Africa. More oil will become available from Russia and the Caspian region.[30] However, a former senior OPEC insider warned in late October 2004 that the EIA estimates of future global supplies are too high. Sadad Al-Husseini, recently retired as Head of Exploration at Saudi Aramco, the Saudi Arabia national oil company, also suggested that a price move below $50 a barrel was unlikely any time soon (Halligan 2004).

Saudi Arabia plays a key role in future oil provision, currently accounting for one third of OPEC supply and around 11 per cent of world supply. Saudi Aramco expresses confidence that it can meet the increased demand for oil:

> …we stand upon a firm foundation of 260 billion barrels of crude. Those reserves are spread across 85 fields and 320 different reservoirs, and represent a conservative accounting of our total reserve base, given our cautious assumptions about ultimate recovery rates. We are also working hard to identify new reserves through additional discoveries, enhanced recovery techniques…for many years we have been able to make healthy additions to our reserves, or at the very least to replace our production, meaning that despite our prolific output, we have not had to draw down our total reserves.… Depending on market demand, we can now produce 10 million barrels of oil daily, and easily sustain that production level for the next five decades…we have developed a range of long-term crude development scenarios that would raise our production capacity to 12 or even 15 million barrels a day.[31]

This conclusion is echoed by an international oil forecasting authority: 'by the end of 2005, the kingdom [Saudi Arabia] could reach a sustainable capacity of about 11.5 mbpd and a surge capacity closer to 12 mbpd' (CGES 2004 p. 17).

OPEC would appear to have a strong incentive to keep oil prices within its desired band, since high oil prices are not conducive to long-term economic

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[29] For the IEA and other institutional forecasters the assumption is made that the Persian Gulf OPEC producers can expand capacity at a cost that is a relatively small percentage of projected gross revenues (EIA 2004c p. 37).

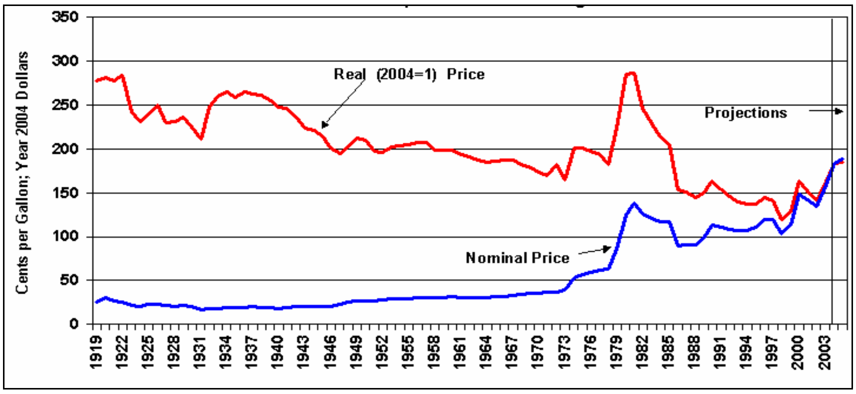
[30] http://library.iea.org/textbase/weo/pubs/weo2002/WEO2002_1sum.pdf p. 29

[31] President and Chief Executive Officer, Saudi Aramco, May 26 2004 http://www.saudiaramco.com/bvsm/JSP/content/articleDetail.jsp?BV_SessionID=@@@@2037427485.1086154008@@@@&BV_EngineID=ccckadclilmklkicefeceefdfnkdfih.0&datetime=06%2F02%2F04+08%3A26%3A48&SA.channelID=-11748&SA.programID=19469&SA.contentOID=1073763419

stability and they also provide incentives to seek alternative energy sources. The BBC supports this interpretation of OPEC's assumed responsibility for price stability, noting that 'the west is gradually waking up to the fact that in recent years OPEC has been trying to ensure market stability through its price range mechanism.'[32]

In addition to understanding the impact of oil prices on supply and demand, it is critical that real, rather than nominal, prices be considered. As can be seen from Figure 18, the real price of petrol in the U.S. is still relatively low by historic standards, exceeding only the even lower prices of the 1990s.[33]

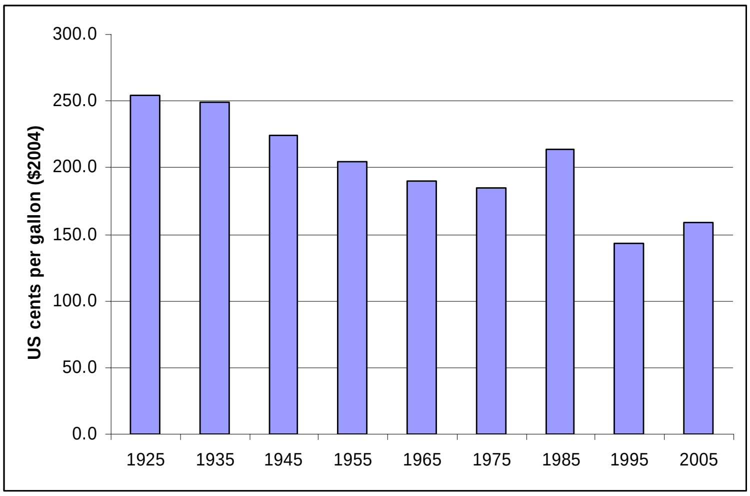
Figure 18 Real US gasoline pump price: annual average 1919-2005



Source EIA *Short-Term Energy Outlook October 2004*
http://www.eia.doe.gov/emeu/steo/pub/fsheets/RealMogasPrices.html

The point can be seen more clearly from the inflation-adjusted average price over the past half decade (historic prices plus one year of projected prices) compared to the previous decades in Figure 19 below.

Figure 19 Real U.S. gasoline pump price decade averages 1919-2005



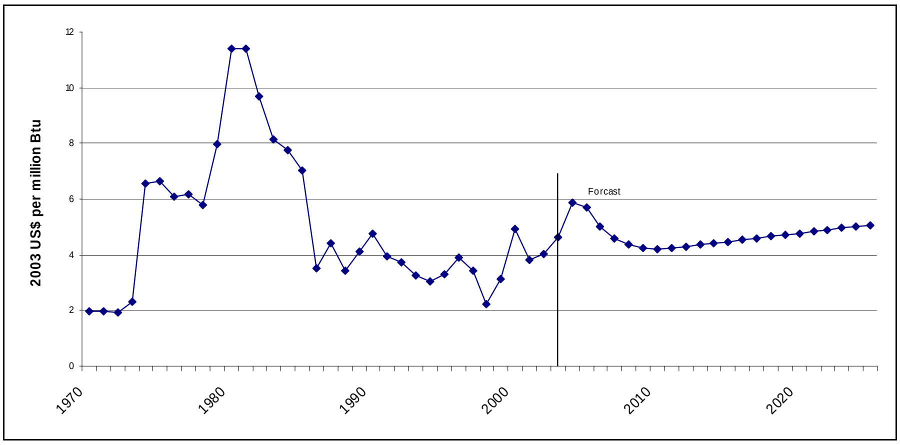
Source Source Calculated from US DOE Short-Term Energy Outlook October 2004
http://www.eia.doe.gov/emeu/steo/pub/contents.html

32 See http://news.bbc.co.uk/1/hi/business/3768971.stm

33 Since this was for illustrative purposes, the more readily-available US data is used.

Hence, even with the dramatic increase in world oil prices, pump prices in the U.S. are still low by historic standards. Australian motorists 'benefit' from higher fuel excises that serve to buffer domestic pump prices from fluctuations in world oil prices. However, the EIA anticipates gradual increases in energy prices, in real terms.

Figure 20 World oil prices, 1970-2025 (2003 US$ per million BTU)



Data source: EIA 2004e

IMPLICATIONS

From a longer term policy perspective, the main issue is not so much one of the physical quantities of oil remaining, nor of the dynamic measure of oil supplies resulting from the overlay of economic factors, but of the efficient operation of the oil market and the factors that may inhibit that operation. Is oil being depleted at an optimal rate, taking into account future estimates of supply and demand, exploration and extraction costs and technological improvements? If not, why not and what can governments do, if anything, to correct the problem?

The sub-text in the depletionists' argument is that oil is being depleted too fast and that governments should divert more taxpayer funds into alternatives to oil and into measures aimed at reducing 'oil dependency' in general. Such intervention may take a variety of forms but generally translates into subsidies that would not normally be warranted and restrictions on oil use. As Campbell (2002a) noted of the transition away from oil dependence 'priorities [may] shift to self-sufficiency and sustainability. It may end up a better world, freed from the widespread gross excesses of today'.

However, a basic rule of government intervention is to treat market failure at its source. If, as is implied, the absence of reliable data is the source of the problem, then options for treating the problem directly (say through government action to ensure the provision of reliable data) should be explored initially. Some progress has been made in the U.S. in requiring independent auditing—a major step towards more accurate data. Also, the key 'swing' producer, Saudi Arabia, has agreed to improve the access to information regarding its reserves.

Since data is not costless, it would be unrealistic to aim to remove all uncertainty regarding future oil supplies. However, improving the reliability of market intelligence would be the first logical step for government intervention if inaccurate market signals were identified as the source of market failure.

Regardless of which side of the argument policymakers find more convincing, any policy response would require sound data. If it were to be collected as a prelude to direct government intervention then arguably a case could be made to take the step of better informing the market (treating the problem at its source) before embarking on the next stage of overriding market preferences.[34]

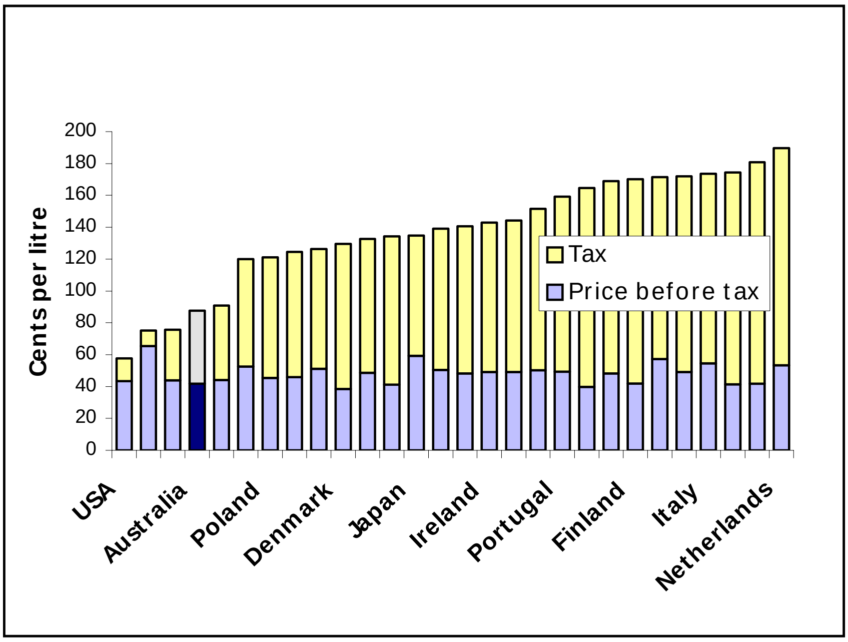
If, after ensuring more accurate market intelligence, governments considered that the markets lacked a long-term perspective and were undervaluing oil, then the most direct and efficient way of correcting this would be to increase the cost of oil and oil products.

For budgetary reasons, most developed countries have already gone a long way to increasing the fuel prices above the market price. Within the OECD, average fuel excise rates are significantly greater than 100 per cent. (see Figure 21 below).[35] Fuel prices are further artificially increased by the supply constraints introduced by the OPEC semi-cartel. The higher prices achieved through a combination of restricted supply and taxation result in a slower extraction rate than otherwise. The question facing the depletionists is how much higher such prices should be to meet their expectations. Simmons, who maintains that oil is far too cheap at the moment, suggests instead a figure of around $182 a barrel.

34 Those that believe the market has overestimated oil reserves have the opportunity to 'buy long', with the anticipation of significant profits when the market becomes better informed and the price of oil jumps as they anticipate.

35 The fact that excise is not paid on the production of intermediate products, as in Australia, does not negate this point.

Figure 21 Petrol prices and taxes in OECD countries (Dec quarter 2003)



Source – IEA 2003 Energy Prices and Taxes 2003

On the other hand, many countries encourage higher-than-otherwise fuel use through widespread subsidies. In Thailand, Malaysia, China and India fuel prices (of one type or another) are kept below market rates through either direct subsidies or tax breaks. The Indonesian government is currently facing a fuel subsidy bill that is almost as much as Indonesia's total budget for development. India is spending US$1.4 billion this year to subsidise kerosene and LPG alone. In Malaysia, fuel subsidies and forgone taxes account for roughly half this year's budget deficit of 20 billion ringgit ($5.3 billion).[36]

A related question is that of resource security. Welfare economists would argue that a soundly operating market is more likely to deal effectively with the timely and efficient allocation of scarce oil reserves than government planners who, in the words of one U.S. Congressional witness 'simply do not have a very good track record when it comes to the centralized allocation of resources'.[37]

Seltzer also noted that supply shortages are often not the main problem:

> Often ignored, however, is that the price spikes experienced in 1973, 1979, and 1990 were not caused primarily by international oil shortages…Rationing, punishing taxation, trade restrictions, and political embargoes—not dramatic supply cutbacks by producing nations—are what caused the price increases of those years.

Australia is in a different position to many countries of the world in that it both wins and loses from rising world oil prices: benefiting from the resultant rise in the value of energy exports but losing through higher domestic energy prices and lower world growth than otherwise. The net impact would depend on

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36 The Economist, *Pump priming: dear oil and subsidised petrol are hurting Asia's economies*, September 30 2004, http://www.economist.com/displaystory.cfm?story_id=3247096

37 See http://www.cato.org/testimony/ct4-16-5.html for full testimony.

many factors, including the value of the Australian dollar. However, the chances of a net loss are likely to increase if governments were to embark on a program of subsidising non-viable energy sources and thereby producing negative returns for the taxpayer.[38]

Emergency oil supplies, while related to the current discussion, are a separate issue. For an explanation of Australia's approach to managing an oil emergency see Taylor (2004). The Liquid Fuel Emergency Act was recently reviewed, with reference to the multiple objectives of economic efficiency, equity and administrative simplicity (ACIL Tasman 2004).

CONCLUDING REMARKS

On 9 January 2004, when Shell announced that it had significantly overstated its reserves, its market capitalisation immediately fell by almost £3 billion.[39]

However, the greater impact was probably on the doubt thrown on international reserve estimates. As one commentator put it, 'if Shell doesn't know how much oil it has got then it is likely that the world doesn't know how much oil it has got.' Confidence in the world oil market was further undermined by the record high prices (nominal) reached in October 2004.

Cheap oil has been a key ingredient to the last 150 years of unprecedented prosperity. However, the uncertainty engendered by major reserve revisions and dramatic increase in oil prices over 12 months to October 2004 reawakened fears concerning long-term oil supplies. These fears have been fuelled by warnings from experienced industry experts of an imminent and sudden decline in oil production as the world reaches the half-way point of its oil reserves.

In contrast, international energy agencies and other oil experts argue that the concerns are the result of interpreting short-term factors as long-term market fundamentals. Prices exceeded US$55 a barrel in October 2004, in response to a combination of strong and unanticipated demand growth, scarce production capacity, concerns about continuity of supplies in the event of output disruptions in key countries and jittery speculator activity. None of these factors touch on the key elements of the debate between the depletionists and the international institutions—the estimate of ultimate recoverable resources, the role of prices, and the appropriate role for the government.

Part of the difference in the URR estimates can be attributed to the use of different recovery factors and the inclusion of reserve growth by the international agencies when formulating their estimates. Hence, these differences stem more from differing economic and technological assumptions than from disagreements about geology. Both sides of the debate recognise that resource assessments are never 'correct' in an absolute sense, but evolve

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38 Robinson (2004) discusses the pitfalls of governments targeting favoured energy activities.

39 See Financial Services Authority (US) for details of penalties imposed http://www.fsa.gov.uk/pubs/press/2004/074.html

through time as knowledge, technology, and economics change[40]. There is agreement that: 'nobody knows how much oil exists under the earth's surface or how much it will be possible to produce in the future. All numbers are, at best, informed estimates'.[41]

There is less agreement on the role of prices. The antidepletionists generally view prices as having two important roles—to signal changes in scarcity/abundance and to encourage the market to adapt to these changes. Future price expectations quantify the net effect of a mass of information including the current state of existing reserves and of the investment needed at the margin to install an additional unit of capacity.

In contrast, the depletionists express serious doubts over the reliability of oil prices to signal increasing scarcity and in the role of economics, in general, in determining oil reserves and influencing usage. Currently, the institutional long-term price projections are not consistent with the depletionists' view that oil is soon to become ever more scarce and expensive. The price spikes of October 2004 combined with the higher long-term price forecasts floated by some of the financial institutions are regarded as more accurate by the depletionists.[42]

In essence, depletionists maintain that oil prices will rise dramatically after the 'low hanging fruit' has been exhausted and hence governments should embark on preparatory action. The antidepletionists do not deny the existence of diminishing returns, as the industry moves from larger to smaller deposits and from better to poorer quality oil. However, they point to the fact that, to date, this has been offset by improved knowledge and advances in science and technology generally.

A major point of agreement between the two schools of thought is the need to improve the quality, reliability and transparency of oil reserve data. Some steps have been taken over recent years in this regard, although major benefits are yet to be realised. The Joint Oil Data Initiative, the UN Framework Classification for Energy and Mineral Resources and moves by regulators in the U.S. and the U.K. to incorporate external auditing procedures should all serve to improve reserves reporting and strengthen confidence in oil forecasts.

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40 As articulated by the USGS http://energy.cr.usgs.gov/WEcont/chaps/AR.pdf AR-2

41 See http://www.bp.com/genericarticle.do?categoryId=108&contentId=2004232

42 For instance, 'Brent oil for delivery in 2005 jumped above $40 a barrel for the first time, in what some observers say is a crucial shift in long-market expectations' (Times Online August 23 2004).

ACRONYMS AND ABBREVIATIONS

P1	proved reserves > 90 % certainty
P2	probable reserves > 50 % certainty
P3	possible reserves > 10 % certainty
Bl	Barrel
EIA	Energy Information Agency (within the U.S. Department of Energy and producers of the International Energy Outlook (IEO)
Gb	Gigabarrel, or billion barrels
Gt	Billion of tons
Gtoe	Billion of tons oil equivalent
IEA	International Energy Agency
Mt	Million tons
Mtoe	Million ton oil equivalent
NCEP	National Commission on Energy Policy (U.S.)
OPEC	Organisation of Petroleum Exporting Countries
USGS	U.S. Geological Survey

Conventional Oil

There is no universal agreement on how to define it. Campbell defines it to exclude oil from coal and "shale" and bitumen and extra-heavy oil

Energy intensity

The amount of energy needed to produce a dollar's worth of GDP. The decline in energy intensity is forecast to continue as 'energy efficiency improves and the global economy relies less on heavy industry' (IEA 2004b p. 31).

Grown Conventional Petroleum Endowment

Sum of the known petroleum volume (cumulative production plus remaining reserves), the mean of the undiscovered volume, and additions to reserves by reserve growth

Grown Petroleum Volume

Known petroleum volume adjusted upward to account for future reserve growth. For the USGS2000 assessment, 30 years of reserve growth is considered. See also 'Reserve Growth'.

Known Petroleum Volume

Sum of cumulative production and remaining reserves as reported in the databases used in the USGS2000 assessment. Also called estimated total recoverable volume or *ultimate recoverable reserves*

Proved reserves

The estimated quantities of crude oil, natural gas, and natural gas liquids which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from know reservoirs under existing economic and operating conditions, i.e. prices and costs as of the date the estimate is made.

Remaining Petroleum Reserves

Volume of petroleum in discovered fields that have not yet been produced. For this assessment, remaining reserves were calculated by subtracting cumulative production from known volumes.

Reserves Oil that can recovered commercially with current technology

Reserve Growth

Increases in known petroleum volume that commonly occur as oil and gas fields are developed as a result of technical improvements and corrections of earlier conservative estimates. This relatively new addition to the USGS methodology is based on experience in the U.S. and a few other well documented regions (Hall *et al* 2002). See also 'Grown Petroleum Volume'.

Undiscovered Recoverable Reserves

Those economic resources of crude oil yet discovered, but that are estimated to exist in favourable geologic settings.

URR (ultimate recoverable resource)

The total quantity of oil that will ever be produced, including the nearly 1 trillion barrels extracted to date

USGS Assessed Petroleum Volumes

The quantities of oil, gas, and natural gas liquids that have the potential to be added to reserves within some future time frame. For this assessment, the time frame is 30 years. The USGS assessed petroleum volumes includes those from undiscovered fields, whose sizes are greater than or equal to the stated minimum field or pool sizes, and from the reserve growth of fields already discovered.

Sources: EIA Energy Glossary http://www.eia.doe.gov/glossary/glossary_main_page.htm and Financial Services Authority 24 August 2004 http://www.fsa.gov.uk/pubs/final/shell_24aug04.pdf

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