World Oil Production Peak - A Supply-Side Perspective

*By Roger W. Bentley and Michael R. Smith**

Introduction

An increasing number of petroleum geologists, particularly those who have worked internationally outside Europe and the United States, are beginning to recognise that the quite dramatic decline in global discovery of new reserves of conventional oil since the mid-1960s will result in oil, and thus energy, supply difficulties in the near to medium term - that is over the next 10 to 20 years.

Assuming a framework of existing demand trends, the analytical requirement is to identify when shortfalls in oil production will most likely occur, and to quantitatively assess by how much a 'business-as-usual' demand forecast will exceed supply. It is a complex challenge since increasing supply tightness pushes up price, which suppresses demand, and encourages more difficult and expensive resources to the market.

The information in this paper is based on two distinct sets of analyses:

a. Work carried out since 1995 by the ‘Oil Group’ at the University of Reading[1] drawing heavily on the work of A. Perrodon, J. H. Laherrère, G. Demaison, and C. J. Campbell. Their analyses have been published in consultancy reports,[2] and in the open literature.[3] The Reading ‘Oil Group’ has checked aspects of these in detail, and additionally carried out its own research.
b. More recent detailed study by Michael R. Smith (an author of this paper) of EnergyFiles Ltd. who has developed a bottom-up model of historic and forecast global oil production constrained by OPEC supply, assuming different future demand levels. The author has long-term field experience as a geologist, oil exploration manager and consultant in a range of locations across the world. His report is published by international energy analysts Douglas-Westwood Ltd.[4]

The data sets supporting the analyses are drawn from a wide variety of sources. A primary source for the Reading Group has been the data set of IHS Energy/Petroconsultants providing information on most oil and gas fields in the world and giving wildcat histories, allowing regional discovery trends to be determined.

M. R. Smith’s work has been derived from public domain production data and from independently determined reserves analyses derived from his experience and personal contacts with oil companies and governments. The various data sets have been subject to considerable comparison, checking and adjustment.

Mainstream Calculation of oil Peaking

Various opinions on the timing of oil peaking have been presented in the literature since the 1970s. Some of these forecasts are given in Table 1, all of which are founded on estimates, at the time, of the world’s original conventional oil endowment (its ultimates reserves, or ‘ultimate’).[5]

Table 1
Forecasts of the Date of Global Conventional Peak Oil Production

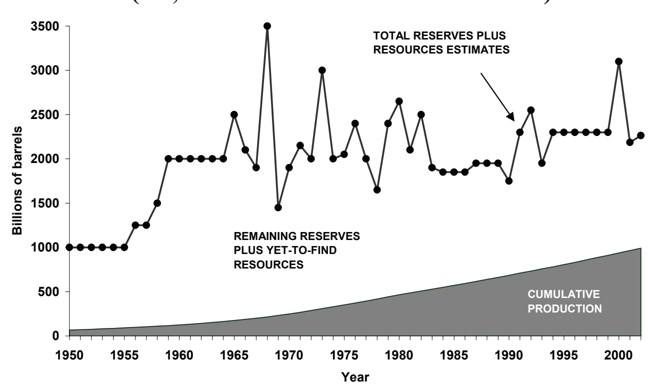
Year	Source	Forecast Date of Conventional Peak	Ultimate (Gb)
1972	ESSO	“oil to become increasingly scarce about the year 2000”	2100
1976	UK Dept. of Energy	“about 2000”	n/a
1977	M.K. Hubbert	1995	2000
1979	Shell	“plateau within the next 25 years”	n/a
1981	World Bank	“plateau around the turn of the century”	1900
1995	Petroconsultants	2005	1800
1997	Ivanhoe	2010	~2000
1997	Edwards	2020	2836
1998	IEA: WEO 1998	2014	2300
1999	USGS (Magoon)	around 2010	~2000
1999	Campbell	around 2010	2000
2000	Bartlett	2004/2019	2000/3000
2000	IEA: WEO 2000	“beyond 2020”	3345
2000	US EIA	2016/2037	3003
2001	Deffeyes	2003-2008	n/a

NB: Gb (billion barrels); Ultimate recoverable oil reserves; Various definitions of conventional oil.

The majority of such mainstream calculations are based on the following methodology:

- Conventional oil is differentiated from non-conventional oil.
- Estimates are generated for the world’s original endowment of conventional oil. Such estimates have generally lain in the range 2000 to 3000 billion barrels. There have been perhaps 100 such estimates, with the majority lying fairly close to the 2000 billion barrel level as shown in Figure 1.
- Oil production from a sedimentary basin reaches a

Figure 1
A Succession of Estimates Since 1950 of the World’s Original Endowment of Conventional Oil (i.e., the Total Recoverable Resource)



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

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physical peak, and then declines, when roughly half the original endowment has been produced. The physical explanation for this is straightforward, as falling output from large, early fields cannot be replaced by production from smaller, later fields coming onstream. It is empirically confirmed by the production profiles from depleting basins in the USA and Europe.

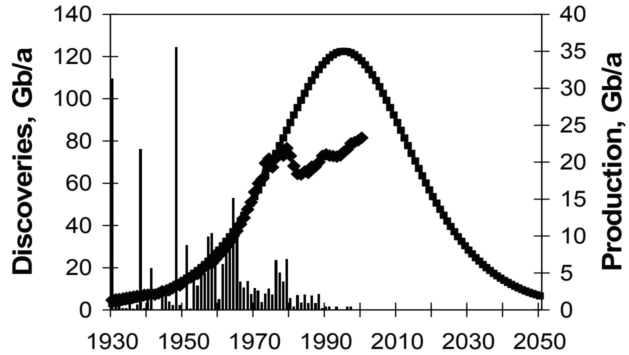
- The majority of estimates of the world conventional oil endowment of about 2000 billion barrels give a global peak in production of conventional oil occurring about 2010.
- The calculations yield a peak date for the production of *conventional* oil only and they may or may not include natural gas liquids (NGLs).
- Forecasts of peak are mostly not demand constrained. They do not account for OPECs efforts to restrict output, which have, for periods, held back demand. And, of course, other energy sources have progressively substituted for oil (especially gas, hydroelectricity and nuclear power for electricity generation), which also holds back demand.

It has also long been known that the world contains large amounts of non-conventional oil - extra-heavy oils, oil (tar) sands and oil shales - that need special extraction and refining techniques to make them useable. In the last decade non-conventional oil extraction and refining costs have fallen as technology has improved and experience has increased.

For prime sites in the Venezuelan Orinoco Belt and the Canadian Athabasca oil (tar) sands, production growth is large, but these oils remain intrinsically more expensive to produce because they require significant energy for extraction. Moreover such oils have higher CO_2 emissions, and are slow to bring onstream. For these reasons, it is estimated that their rate of production growth will be insufficient to offset most of the decline in global production of conventional oil.

The mainstream view is thus summarised by Figure 2, which shows oil discovery history (left-hand scale), a hypothetical mid-point peaking curve and the world's actual production (right-hand scale). The high prices of the two oil shocks in the 1970s curbed demand and delayed the anticipated date of peak.

Figure 2
The Mainstream View of Oil Global Peaking



Source: C.J. Campbell, discovery data (vertical bars, left-hand scale) exclude deepwater & polar oil. Hypothetical production curve corresponds to global original endowment of 1800 bn bbls; diamonds indicate actual production (both right-hand scale).

The Petrocounsultants'/C. J. Campbell Calculations

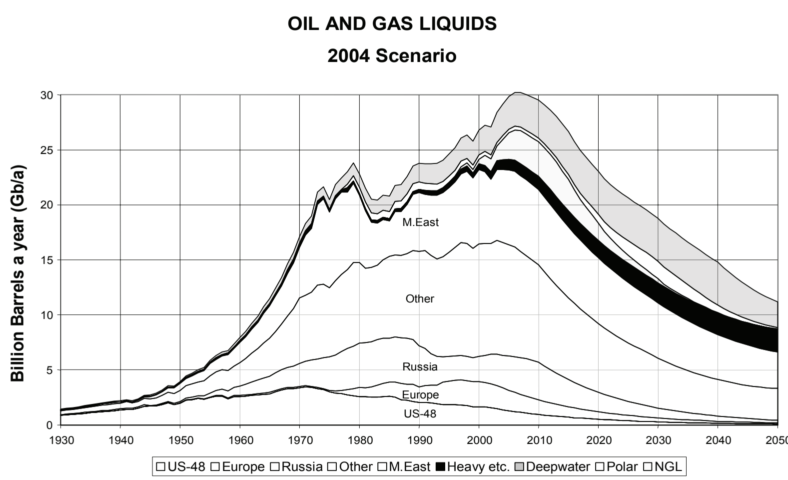
Figure 3 shows a calculation of global oil production based on the 1995 Petroconsultants' report (Campbell & Laherrère), as subsequently modified by Campbell.

In this Figure, the production of conventional oil holds close to maximum until around 2010, and then enters decline, driven by the limit of the world's resource of this type of oil. The combined production of deepwater and polar oil also peaks around this date. Production of extra heavy and tar sands oil expands, but is not sufficient to offset declining output of conventional and related oils.

The methodology used to generate this Figure was as follows:

a. Estimation of 'P50' oil reserves, by country. ('P50' reserves are those with a notional 50% probability, i.e., being equally likely to see downward as upward revision with time). The estimates were generated by taking reserves data from the Petroconsultants' database, but adjusting in the light of geological knowledge and on the basis of reasonableness tests. A key test is to plot field production vs. cumulative production. For most fields in decline this plot gives a good check of the field's likely ultimate recoverable reserves. For example, the approach shows that many field reserves in the former Soviet Union are significantly over-reported.
b. Generation of estimates of oil yet-to-find. This analysis was by basin where appropriate, and mostly used a range of statistical approaches, essentially based on discovery data to-date, to estimate the quantities of conventional oil likely be found within a reasonable exploration timeframe (for example, from twice as many wildcats as already drilled in the basin).
c. Addition of cumulative production, P50 reserves, and

Figure 3
Forecast of Oil Production, By Region and By Type.



Source: ASPO Newsletter No. 27, March 2003. (www.isv.uu.se/iwood2002) to yet-to-find, to give an estimate of each country's ultimate (i.e. ultimately recoverable reserves).

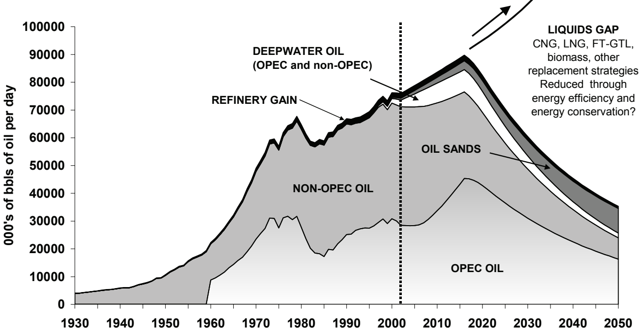
d. Modelling each country's future production. For a country already past peak, this was by declining production at the existing decline rate (fixed percentage of the remaining recoverable resource). If prior to peak, this was by increasing production at an assumed growth rate until cumulative production equals half that country's ultimate, and thereafter declining production at the then-existing decline rate. In the case of the Middle-East swing producers, their production was calculated, subject to their own resource limits, using a number of 'geo-political' scenarios.

Figure 4 shows a calculation of global oil production by M. R. Smith from the 2003 edition of the World Oil Supply Report.[4]

It was concluded that the world's known and estimated yet-to-find reserves and resources cannot satisfy the present level of production of some 74 million barrels per day beyond 2020. Any growth in global economic activity only serves to increase demand and bring forward the peak year. In Figure 4, 1% demand growth brings the year to 2016, when production is expected to peak at around 85 million barrels per day. With 2% growth, peak production of around 90 million barrels per day occurs in 2012.

Non-OPEC decline is expected to begin around 2007 whatever the demand. Even with the Middle Eastern countries producing as much as they can - inevitably requiring major foreign investment - forecasts of demand requirements of anything over 90 to 100 million barrels per day are not achievable.

Figure 4
World Oil Production 1930 to 2050
Assuming 1% Demand Growth to Peak



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

The methodology, although generally similar to the previous modelling above, used differing estimates of OPEC restrictions in the years to peak to determine four demand growth scenarios (zero, 1%, 2% and 3%). All existing and potential oil producing countries were subjected to a bottom-up analysis of known and 'yet-to-find' oil reserves and resources, including conventional, deepwater, gas substitutes and oil (tar) sands. A production profile was created based on potential productive capacity and depletion history. The data were combined to give views on the limits of global oil production, and alternatives were analysed to assess how energy mix and pricing levels might develop over coming years.

There are ninety-nine countries in the world formerly, actually or forecast to be capable of producing significant oil volumes (above 1000 bbls per day). Of these, forty-nine are already well past their resource-limited oil production peak. They include Germany (peaking in 1968), USA (1970), Romania (1976), Russia (late in the Soviet era), and Indonesia (1991). Eleven countries are just past peak, including Malaysia (1998), UK (1999) and Norway (2002). Twelve countries are at or near peak, including Algeria, Australia, China and Mexico. The remaining twenty-seven will reach peak within 25 years.

Under a 1% demand growth scenario, OPEC's share of oil production will have to substantially increase within five years if demand is to be met. If so, significant capital investments within OPEC countries, particularly Saudi Arabia, Iraq and Iran, will be required to raise gross production by around 2 mm bbls per day every year to offset declines elsewhere.

The Economists' Arguments

It is appropriate in this paper to discuss the views of many of the economists who study world energy resources. The general lack of communication between petroleum geologists and engineers, who study world oil supply, and the energy economists, who tend to focus on demand, has led to a lack of understanding about oil depletion.

At the heart of the controversy is the economists' view that human ingenuity has always kept ahead of resource depletion, and that there is no reason to expect this to change. More specifically, the economists accuse geologists of omitting the effects of price and technology from their models (and hence badly underestimating the future oil resource), and of not understanding the market mechanisms whereby supply and demand equilibrate.

Conversely we argue that the economists are misled by unreliable publicly-announced reserves volumes,[6] ignore evidence for mid-point peaking (and hence are reassured that there is 'at least 40 years of oil remaining') and do not fully understand oil industry conventions on reserves reporting (believing that fields show 'technology gain' when in fact only the reporting has changed).

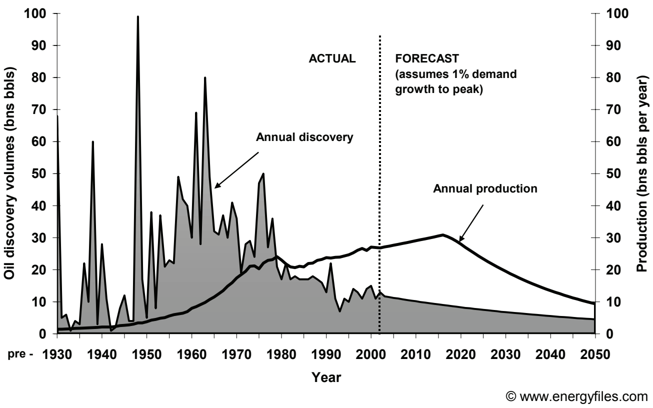
In particular, energy economists see higher price as:

a. Encouraging exploration. High prices do encourage exploration, but the creaming curves of most countries (showing cumulative oil discovery versus cumulative exploration wells) are now almost flat, pointing to a dearth of exploration opportunities. Indeed the 1970s oil shocks only temporarily reversed the decline in discovery rates (as offshore regions began to be exploited), as shown in Figure 5, and led to a decline in exploration well success rates.

b. Bringing in currently uneconomic fields. Although marginal fields do become commercial, their contribution is also marginal. Around 65% of world reserves are contained in a little over 500 giant (greater than 500 million barrel) fields.

c. Raising the recovery factor. Theoretically, there is large scope for increased recovery, however, such techniques have already been used in numerous older fields; are already accounted for in most younger, especially offshore, fields; cannot be applied everywhere; and many of the giant fields are already fully exploited by intense drilling. Most growth in the reserves of existing fields is in their reporting.

Figure 5
World Oil Discovery Volumes 1930 to 2050



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

d. Giving adequate warning. Not only can production costs fall as supplies are drawn down, but also OPEC production restrictions have meant that higher cost reserves are being depleted faster than lower cost reserves. As cheaper Middle East oil becomes more important in the supply mix, prices could decrease. In fact price signals in the USA before the 1970s oil shocks were small, and ignored.

e. Correcting imbalances in the market, by curbing demand and bringing on new types of supply. Of course new types of energy will attempt to alleviate oil supply shortfalls, but the key questions are: at what cost, and at what rate?

Oil price will certainly have effects both on global demand, and on supply, but it is also a driver that will lead to severe disruption to economic growth. It should not be used as an excuse to dismiss the oil depletion problem.

Gas

This paper does not consider gas resources or supply. However the decline in the discovery of conventional gas since the late 1960s, allied to growth in gas demand and continued replacement of oil by gas in electricity generation, will also lead to gas supply difficulties in the medium-term. See, e.g., www.oildepletion.org for a model of global 'all-hydrocarbons' production.

Conclusions

Global conventional oil production will reach a resource-limited peak, and subsequently decline, between 2011 and 2020, with the actual year depending on the rate of demand increase. The global non-OPEC resource-limited conventional oil peak will occur probably within 5 years, triggering price increases that will dampen demand.

The resource base of non-conventional oil and oil substitutes, especially oil (tar) sands in Canada and Venezuela, will be tapped to an increasing degree, but energy-cost, investment and pollution constraints are likely to keep production increases significantly below the corresponding conventional oil shortfall. The global production of all-oil will, therefore, also decline.

Acknowledgements

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Notes and References

[1] The 'Oil Group' at the University of Reading, UK, consists of Professors M. L. Coleman and B. W. Sellwood of the Postgraduate Research Institute for Sedimentology; Dr. J. D. Burton, Mr. R. H. Booth, Dr. R. Mayer and Professor P. D. Dunn of the Dept. of Engineering; Dr. G. R. Whitfield, and R.W. Bentley of the Dept. of Cybernetics. Publications include: R.W. Bentley. *Global Oil and Gas Depletion: An Overview*. Energy Policy, Vol. 30, No. 3, February 2002, pp 189-205. Elsevier, 2002; and R.W. Bentley, R.H. Booth, J.D. Burton, M.L. Coleman, B.W. Sellwood, G.R. Whitfield. *Perspectives on the Future of Oil*. Energy Exploration and Exploitation, Vol. 18, Nos. 2 & 3, pp 147-206, Multi-Science, 2000.

[2] See:

- *Undiscovered Petroleum Potential*. J. H. Laherrère, A. Perrodon and G. DeMaison. Petroconsultants S.A., Geneva, 1994.
- *The World's Supply of Oil, 1930 – 2050*. C. J. Campbell and J. H. Laherrère. Petroconsultants S.A., Geneva, 1995.
- *The World's Gas Potential*. J. H. Laherrère, A. Perrodon and C. J. Campbell. Petroconsultants S.A., Geneva, August 1996
- *The World's Non-Conventional Oil and Gas*. A. Perrodon, J. H. Laherrère and C. J. Campbell. The Petroleum Economist Ltd., London, March 1998.

[3] E.g.: C.J. Campbell and J.H. Laherrère. *The End of Cheap Oil*. Scientific American, March 1998, pp 60-65.

[4] *The World Oil Supply Report 2003-2050* 2nd Edn., author Michael R. Smith (e-mail: glow@lineone.net, Web: www.energyfiles.com), published by Douglas-Westwood Ltd.

[5] For a more detailed table and commentary see: R.W. Bentley. *Oil Forecasts, Past and Present*. Proc. Int'l Workshop on Oil Depletion 2002, Uppsala University. (www.isv.uu.se/iwood2002).

[6] Public-domain proved oil reserves data are very misleading. The data are generally either very conservative (e.g., the U.K.), or conservative (many countries); although some countries (such as the FSU) are over-reported. The data can change suddenly (e.g., OPEC 'quota wars', or Mexico). But, worst of all, the data are simply not updated for the majority of countries.