The Need for Strong Caveats on Proved Oil Reserves, and on R/P Ratios

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Abstract

Strong caveats are needed when quoting *proved* oil reserves, or R/P ratios, in connection with future oil supply. These caveats are needed for three reasons: the data in the public domain on proved oil reserves by country are extraordinarily poor; their evolution over time has been misleading; and R/P ratios gives no information at all about a region's future rate of oil production. This paper explains these problems, suggests some caveats that might be used, and sets these data problems into the wider context of expected global oil supply.

1. Introduction

When discussing future global oil supply, many people quote countries' proved oil reserves, and also reserves-to-production (R/P) ratios. This should not be done; or if done, only if accompanied by strong caveats. Below we look at the various problems associated with proved oil reserves data, and with the use of R/P ratios.

2. Proved Reserves

The standard definition of proved reserves is well known – for example, BP's *Statistical Review of World Energy* states that they are: "*Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions*."

However, this definition is somewhat misleading. The oil that can be recovered 'with reasonable certainty' is that given by the 'proved-plus-probable' reserves. This is the estimate of the reserves judged to have an equal probability of being greater or less than the actual quantity that can be recovered. Such estimates are often called '2P', to distinguish them from the proved ('1P') estimates.

International oil companies generally have to report proved reserves under US Securities and Exchange Commission (SEC) rules. By contrast, national oil companies, and countries as a whole, can report as 'proved reserves' whatever values they wish.

The data on proved oil reserves by country are widely available – for example, from the US Energy Information Administration (EIA), BP's *Statistical Review*, and the *Oil and Gas Journal* or *World Energy*. The corresponding 2P country (and also field) reserves data are generally held in commercial oil industry databases, such as those of IHS Markit, Wood Mackenzie, Rystad Energy or Globalshift. Access to these 2P data is usually expensive, and the data suppliers place restrictions on what can be published.

The problems with the proved (1P) oil reserves data by country are as follows: being underestimates, being overestimates, and the data not being updated. We discuss these points in turn:

2.1 Underestimates

Because proved reserves exclude the probable reserves, they tend to be (and especially so in the past) *underestimates* of the amount of oil likely to be ultimately extracted. A second factor in this underestimation - often overlooked - is that arithmetic addition of the proved reserves of individual fields in a region underestimates the total proved reserves for the region to the same level of certainty.

US and Canadian proved reserves were notoriously underestimated for many decades, probably in part due to only being allowed to report oil in communication with producing wells, and hence grew many-fold over time. Similar - if significantly less - growth has affected the proved reserves of many other countries.

Today, the proved reserves for most countries are still underestimates when compared to the 2P values. For the UK, for instance, the government-stated proved oil reserves have long been typically about half the size of the stated 2P reserves; and where the latter in turn have typically been only half the size of the 2P reserves estimates as carried by industry databases.

2.2 Overestimates

By contrast, a second and nowadays more critical problem with public-domain proved (1P) oil reserves data by country is that for a number of major countries the proved reserves are almost certainly *overestimates* of the amount oil likely to be extracted. For example, some OPEC countries' proved oil reserves are significantly *larger* than the 2P reserves estimates held by industry; see the table below.

These overestimates resulted mainly from the OPEC 'quota wars' of the 1980s, where a country's production quota was in part dependent on its declared proved reserves. As the table shows, summing current proved oil reserves for the five Middle East OPEC countries of Saudi Arabia, Iran, Iraq, Kuwait and UAE yields some 770 billion barrels (Gb), a value 300 Gb greater than the corresponding industry 2P reserves estimates.[1]

Proved (1P)	**UAE**	**Iran**	**Iraq**	**Kuwait**	**Saudi Arabia**	**Venezuela**	**Canada**
1980	30.4	58.3	30.0	67.9	168.0	19.5	39.5
1981	32.2	57.0	32.0	67.7	167.9	19.9	40.2
1982	32.4	56.1	**59.0**	67.2	165.5	24.9	40.3
1983	32.3	55.3	65.0	67.0	168.8	25.9	40.5
1984	32.5	58.9	"	**92.7**	171.7	28.0	40.5
1985	33.0	59.0	"	92.5	171.5	**54.5**	40.9
1986	**97.2**	**92.9**	72.0	94.5	169.7	55.5	41.1
1987	98.1	92.9	**100.0**	"	169.6	58.1	41.2
1988	"	"	"	"	**255.0**	58.5	41.5
1989	"	"	"	97.1	260,0	59.0	41.3
1990	"	92.8	"	97.0	260.3	60.1	40.3
1995	"	93.7	"	96.5	261.5	66.3	**48.4**
2000	97.8	99.5	112.5	"	262.8	76.8	**181.5**
2002	"	**130.7**	115.0	"	"	77.3	180.4
2005	"	137.5	"	101.5	264.2	80.0	180.0
2008	"	137.6	"	"	264.1	**172.3**	176.3
2009	"	137.0	"	"	264.6	**211.2**	175.0
2010	"	**151.2**	"	"	264.5	**296.5**	174.8
2011	"	"	**143.1**	"	265.4	"	174.2
2015	"	157.8	"	"	266.6	300.9	171.5
2016	"	158.4	153.0	"	266.5	"	170.6
2017	"	157.2	148.8	"	266.2	303.2	168.9
Proved-plus-probable (2P)	**42**	**99**	**94**	**48**	**168**	**41**	**106**

Table: Reported Proved ('1P') oil reserves (in Gb) vs. date for selected OPEC countries and Canada; and Comparison to oil industry Proved-plus-probable ('2P') oil reserves as of 2016.

Notes: - Not all years shown. 'Step increases' indicated in bold, red. Gb: Billion barrels.
- For *conventional* oil, 2P reserves are generally added to industry databases when the oil is discovered; for *non-conventional* oils reserves are generally added as the result of identified projects. See additional notes to Figure 1.

Sources: - 1P reserves to 2011 from D. Freedman, from the BP *Stats. Review*; post-2011

directly from BP *Stats. Reviews* at dates shown.
- 2P reserves from Rystad Energy, 2016: http://www.rystadenergy.com/ewsEvents/PressReleases/united-states-now-holds-more-oil-reserves-than-saudi-arabia.

2.3 Static estimates

A final and important factor contributing to the potentially misleading nature of proved oil reserves as reported is that for many years, and for many countries, the data simply do not get updated on an annual basis. For any given year this is usually the case for most countries being reported; and for a number of countries their reported proved oil reserves have remained essentially unchanged for decades; see, for example, the UAE and Kuwait in the table above.

3. Evolution of Proved Oil Reserves

Now we turn to the second key reason why the use of the proved oil reserves has been problematic. Since 1P reserves are typically underestimates, over time they naturally grow towards the more accurate 2P estimates. This growth has led many analysts to the erroneous view that reserves were continually 'being replaced', when in fact reserves were simply being moved from the 2P category into the 1P.

This mistaken belief of reserves being 'continually replaced' remains deeply pervasive. However, if the evolution of global proved reserves is graphed and compared to that of global 2P reserves, the contrast is stark, see Figure 1. While global proved reserves have been on an ever-upward trend, the more accurate 2P oil reserves have fallen steadily since 1980, the date at which global production overtook the rate of discovery.

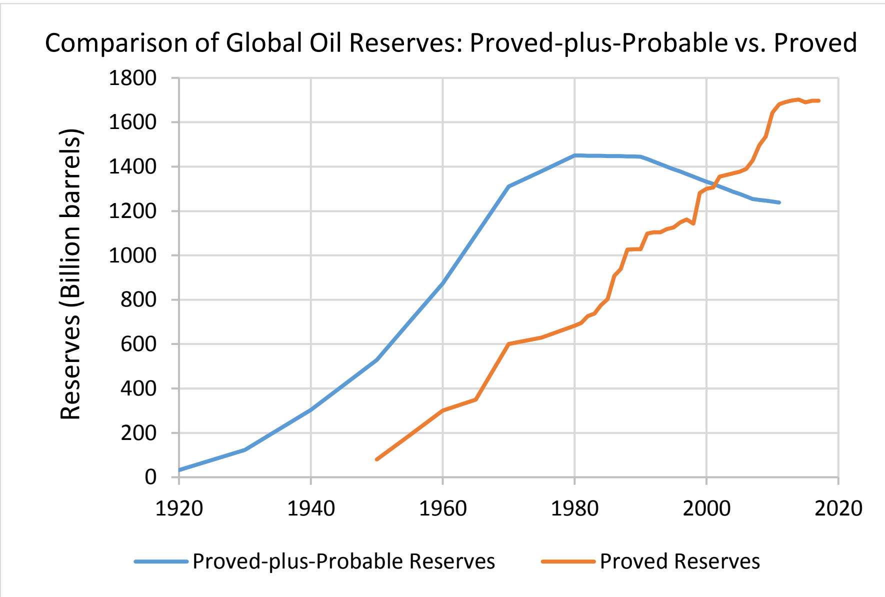


Figure 1. Evolution over time of Global oil reserves: '2P' vs. '1P'
- 1P reserves: 'ever-upward'; 2P reserves: 'peak and then decline'.

Notes: - One would expect global proved (1P) oil reserves to be smaller than global proved-plus-probable (2P) reserves because of excluding probable reserves, and because arithmetic addition of statistically-likely values underestimates the total at the same certainty level. In fact, as shown, global public-domain 1P reserves significantly *exceed* the oil industry's 2P reserves. This is due to inclusion in the 1P reserves of the OPEC probable overstatements (~300 billion barrels, Gb), and of potential oil from Canadian tar sands (~150 Gb) and Venezuelan Orinoco oil (~250 Gb).

- Proved (1P) reserves data are values that were current at the dates shown, whereas the 2P data are *backdated*, i.e. *today's estimates* of 2P reserves at the dates shown.
- For *conventional* oil, 2P reserves are generally added to industry databases when the oil is discovered. For *non-conventional* oils (much of which was discovered long ago) reserves are generally only added to an industry database as the result of *identified projects*, and correspond to the volumes expected to be accessed by these projects.
- The global value for global proved-plus-probable (2P) crude oil reserves, shown here from IHS Markit data as of 2011, of ~1230 Gb, is similar to the Rystad Energy estimate of ~1150 Gb as of 2016 (see http://www.rystadenergy.com/ewsEvents/PressReleases/united-states-now-holds-more-oil-reserves-than-saudi-arabia).

Sources: - Proved reserves to 1980 from J Laherrère, from *Oil & Gas Journal*; post-1980 from BP *Stats. Review*, 2018.
- Proved-plus-probable reserves are IHS Markit data, from Miller and Sorrell, '*The future of oil supply*', Phil. Trans. R. Soc. A 372: 20130179; calculated as cumulative discovery less cumulative production.

3.1 Economics: The impact on reserves volumes of a higher oil price

Before we leave the evolution of proved reserves, we need to look at an important factor that affects the size of reserves, that of economics. This is because if the price of oil goes up, one would expect the size of reserves to increase, both because there will be a greater incentive to find new oil deposits, and because greater extraction from existing deposits is likely to be economic at the higher price.

An example of this has been the recent dramatic growth in the production of a non-conventional oil, that of shale ('light-tight') oil, where oil prices in excess of $100/bbl since 2008 have helped engender a whole new industry for the production of this type of oil. (But see Section 5, below, and Bentley and Bentley, 2015a,b, for the reason why the price of oil was so high).

However for *conventional* oil, it is easy to overstate the effect of an increase in price in yielding increased oil.

The UK provides a good example of this. The UK's first North Sea oil, a small discovery, was found in 1969. This led to the discovery of nearly all the UK's large offshore fields within the next five years, in the period that led up to the start of production in 1975. But as early as 1974, with the main fields discovered and with production not yet underway, it was already possible to estimate the *total amount of oil* that was likely to be recovered from the UK's offshore fields, both from those fields discovered and those expected to find. This volume is called the UK's 'ultimately recoverable resource', its URR. As UK 'Brown Book' data show, in 1974 this was estimated at 4.5 billion tonnes (Gt). In the following years this URR estimate varied somewhat, but on average stayed not too far from 4.5 Gt. And today, nearly 50 years later, this still remains the current estimate of the final quantity of oil that is likely to be extracted, despite the oil price having risen by up to 10-fold in real-terms at times over the period.[2]

The relevance of this to the global proved oil reserves data lies in two recent significant increases in these reserves, that have come from the addition of tar sands oil in Canada, and of Orinoco heavy oil in Venezuela. Both these sources of oil were discovered over a century ago, and have been in production for decades, albeit at relatively low volumes. But with the oil price rising from its 1998 low (of a spot price around $10/bbl, and predicted by some to go to $5/bbl), it has been decided by some (but not all) collators of proved oil reserves to include large volumes first of tar sands oil, and later of Orinoco oil.

It remains an open question how much of this oil should properly count as 'proved', where the table shows an oil industry estimate of the 2P oil reserves of these countries.

4. R/P Ratios

Finally, we turn to what is perhaps the most important oil data problem of all. This is that all oil reserves - whether 1P or 2P - give *no indication at all* about the future rate of production in a region. This is because a region can have significant oil reserves (and hence a reassuring R/P ratio) but be well past its *resource-limited* peak in oil production - as is now the case for many countries.

This is because, for conventional oil (and probably for some at least of the non-conventional oils) production in a region typically reaches a peak and then declines when only about half of the total recoverable oil in the region has been produced.

Note that this peak in production often comes as a surprise. This is because, at peak, production in the region has usually been increasing reliably for many years; the region still contains large oil reserves; more oil is still being found; and technology is advancing, allowing more oil to be extracted from existing deposits.

The UK provides a good example of this: With a URR of ~4.5 Gt, its peak would be expected when roughly 2.25 Gt had been produced. This is what occurred for the UK's peak in production in 1999; but though expected by some (based on the 4.5 Gt estimate) the peak came as a surprise to many in government, in the oil industry, and to energy analysts more widely.

5. Future Global Oil Supply

Now we turn to the question of why strong caveats are required on reported proved oil reserves by country, and on R/P ratios.

If the world was in 'business-as-usual' mode, problems with these data might be seen as solely the province of detailed energy statisticians. But instead the world has faced a significant recent change in how it is supplied with oil. In recent years all additional barrels of oil (the 'marginal' barrels) have had to come from the generally more expensive - and often lower EROI, and higher CO_2-emitting - non-conventional oils.

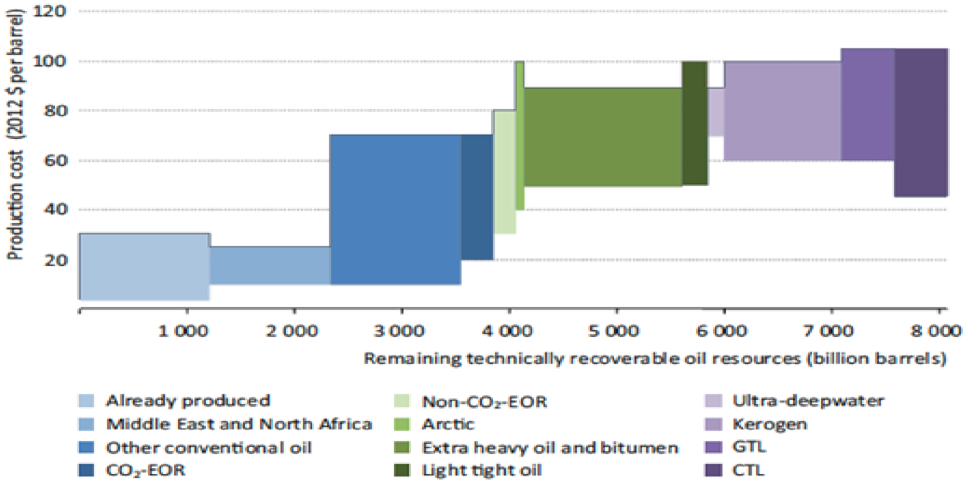
The world needs to be properly aware of this significant change, and where the poor nature of the public-domain proved oil reserves data, and reliance on R/P ratios to underpin expectations of future production, are misleading far too many otherwise knowledgeable and experienced analysts about the true state of global oil supply.

Here we briefly amplify this topic.

5.1 Total oil (and 'other liquids') available

Firstly, as many (but still not all) energy analysts know, the world contains *very large quantities* of technically-recoverable oil, and also of sources of 'other liquids' that can be used in place of oil. Estimates of these quantities are shown in Figure 2.

Figure 13.17 ▷ Supply costs of liquid fuels



Source: *Resources to Reserves* (IEA, 2013).

Figure 2. Estimated Global remaining technically recoverable volumes of oil, by category (in Gb) vs. Production cost range, in $2012/bbl.

Notes: - EOR: Enhanced oil recovery; CO2-EOR: EOR using CO_2; GTL: Gas to liquids; CTL: Coal to liquids.

- Conventional oil is shown by the first three blocks at the left, plus 'Arctic' oil.
- The USGS currently estimates the global recoverable quantity of shale ('light-tight') oil to be around 750 Gb; considerably larger than the IEA 2013 estimate of ~250 Gb shown here.

Source: IEA, '*Resources to Reserves*' report, 2013.

As Figure 2 shows, as of 2013 the world had consumed some 1250 billion barrels (Gb) of oil, and had some 7000 Gb or so of technically-recoverable oil and other liquids remaining; where the latter comprise conventional oil; non-conventional oils such as EOR oil, shale ('light-tight') oil, very heavy oil, and oil to be produced from kerogen by pyrolysis; and of other liquids', such as oil produced by the conversion of coal or gas.

In addition, further sources of oil are available from biofuels and - at least potentially, if cheap or surplus energy is available from the renewables or from fusion - from synthetic oil produced from common feedstocks such as carbon and water.

So an *absolute shortage* of technically-recoverable sources of oil is not an issue (and essentially never has been, as the size of most of these sources have been estimated with reasonable precision for well over 50 years, and for some, like coal-to-liquids, for considerably longer).

By contrast to *absolute shortage*, the problem we highlight here is the availability of *conventional* oil, i.e., of the normally-flowing oil extracted from conventional oil reservoirs ('oil fields') that are found in porous, permeable rocks.

5.2 Global production of conventional oil

As Figure 2 indicates, the global production of *conventional* oil is roughly at its 'mid-point', i.e., at the point where about half the expected total recoverable resource has been extracted.

As mentioned above, and has been known for a very long time, once the mid-point in a region's production of its conventional oil is reached, production typically sets into irreversible decline. Forecasts for this coming global constraint to occur around the year 2000 have been made since the 1960s (see, for example, the list in Bentley, 2016); as well as in more recent forecasts, such as that made in 1998 for the 'end of cheap oil' to occur in the period 2000 to 2010 (Campbell and Laherrère, 1998).

The current position on the global production of conventional oil is as follows: By some estimates, and in contrast to Figure 2, for conventional oil the world has a URR of only perhaps ~2500 Gb.[3] With a total of all-oil of ~1400 Gb having been produced to-date, on the 'mid-point' rule the peak of global conventional production is thus to be expected about now. And indeed, as Figure 3 shows, production of this class of oil has been on-plateau since 2004, despite the oil price having been more than double the 2004 price over much of this period.

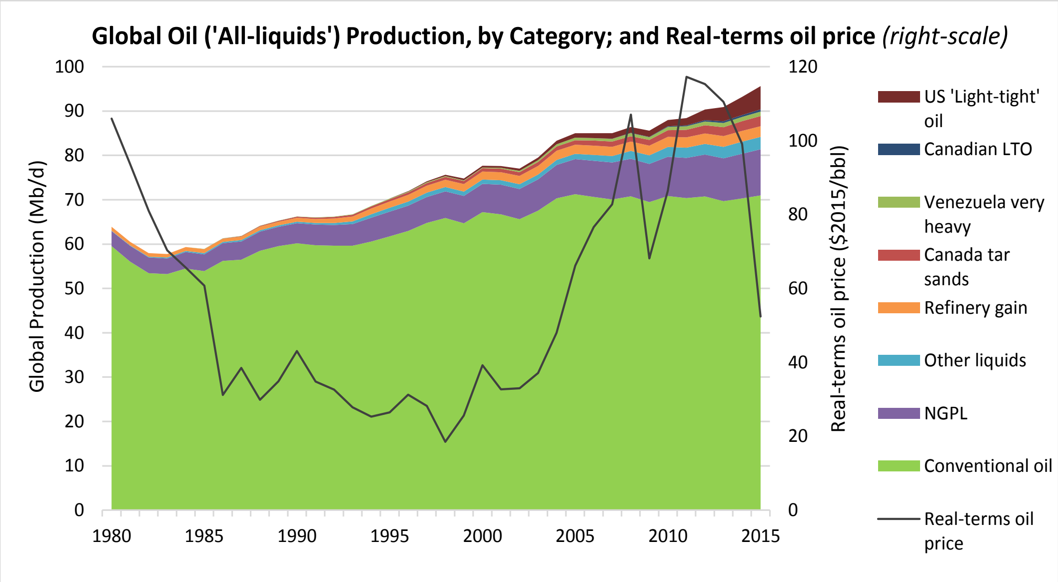


Figure 3. Global production of 'All-liquids', 1980 – 2015.

Note: Global production of conventional oil has been on-plateau since 2005 despite an on-average high oil price, where the oil price averaged >$80/bbl for most of 2007 to 2014, and >$100/bbl for a considerable part of this period.

Sources: Data from US EIA (crude-plus-condensate, NGPLs, other liquids, and refinery gain); other categories from Laherrère et al. '*Oil Forecasting – Data Sources and Data Problems, Part-1*', The Oil Age (2) 3; 2016. Real-terms oil price: BP *Stats. Review*.

5.3 Forecasting future global oil production

Given the problems identified above with the public-domain proved oil reserves, and with the use of R/P ratios, we now turn to the question of how should global oil supply be forecast?

The answer is to use a detailed forecast model that combines oil industry 2P reserves data with realistic field decline rates and with estimates of the yet-to-find, and with scope for higher oil prices to bring on additional oil. In 2008 the International Energy Agency (IEA) significantly improved its oil forecast model and now incorporates these factors.[4] Since that date, it has forecast global oil supply as getting increasingly difficult in the years ahead, leading to an ever-upward real-terms price of oil; see Figure 4.

The primary driver for the IEA's forecast trend in oil price is that no significant increases are expected in the global production of conventional oil, a consequence of falling discovery of this class of oil over the last 50 years. Thus, as mentioned earlier, all future extra barrels of oil must come from the generally more expensive non-conventional oils, including NGLs, tar sands and Orinoco oil, shale oil, kerogen and biofuels.

Note that some forecasters, for example DNV-GL, the World Energy Council, Carbon Tracker and Citi bank, see a peak in the global production of oil in the near or medium term, driven by falling *demand* for oil (partly or wholly resulting from technological and societal changes required to meet climate change goals); and where these organisations see this 'demand-driven' peak as occurring before any peak in global oil production driven by constraints on supply.

The IEA, however, is not persuaded of this view, maintaining - in the absence of a significant shift in CO_2 policies - that electrification and increased vehicle efficiency will not yield an overall decline in global demand for oil, at least out to their forecast horizon of 2040. This is because the IEA forecasts that while light vehicles may indeed see 'peak oil demand', increased demand from trucks, shipping, aviation and petrochemicals will more than offset this fall.

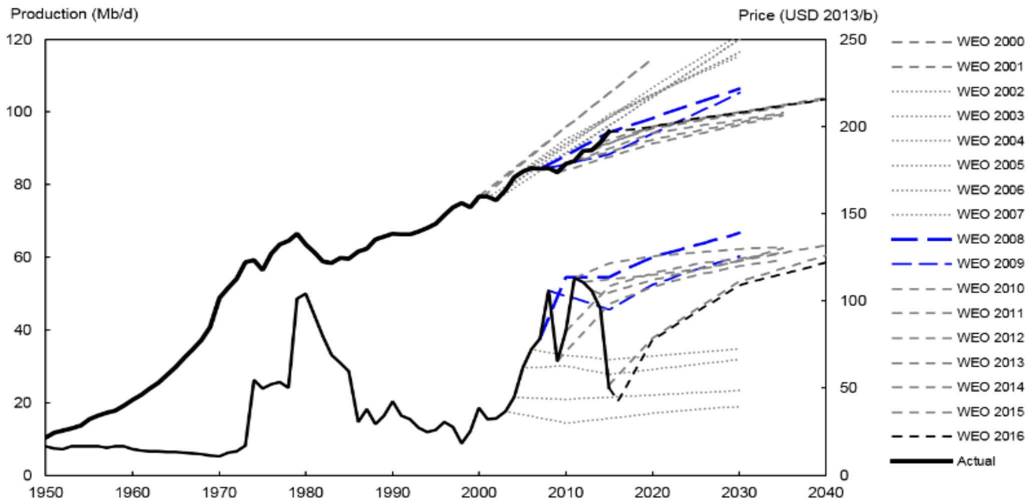


Figure 4. Historical World oil production and price from 1950 to 2015, and Projections for world oil supply and oil prices from central scenarios of IEA *World Energy Outlooks*, 2000 - 2016.
Source: Wachtmeister, H., *et al.* (2018).

6. Suggested Caveats

Given the problems identified in Sections 2 to 4 above, and the need for a more widespread understanding of the likely coming constraints on global supply as explained in Section 5, in this section we suggest caveats on by-country proved oil reserves, and on R/P ratios, that data providers might wish to use.

First, however, we need to recognise that recently some (but not all) of the public-domain sources that report proved oil reserves by country have been making their caveats on these data more explicit; the evolution of the US EIA's caveats being a good example of this. (However, as far as we know, no organisation so far is offering caveats on the use of R/P ratios.)

Given the data problems outlined above, that many analysts still quote these data, and that some analysts - basing their analysis on proved oil reserves and R/P ratios - are not aware of the coming likely constraints to global oil supply, it is clear that still stronger caveats are required.

To this end, for the proved oil reserves data by country (and globally), a caveat along the lines of one of the following is suggested:

- 'Proved oil reserves data should be treated with caution.'
- 'Proved oil reserves data for individual countries should be treated with considerable caution.'

- ‘Proved oil reserves data for individual countries are often underestimates of the most-likely (‘proved-plus-probable’) reserves; in some circumstance may be significant overestimates; and frequently are not updated on an annual basis.’

For R/P ratios, one of the following caveats is suggested:

- ‘Note that R/P ratios give no indication of future production rates.’
- ‘Note that the R/P ratio of a region often gives little indication about future production rate as the region may already be close to, or past, its resource-limited production peak.’
- ‘Note that the R/P ratio for a region gives a very poor indication of future production from the region, and should be used with considerable caution. Firstly, a region will typically have more (although sometimes less) oil in likely reserves than indicated by the ‘proved’ reserves; it will likely also have additional oil to be discovered in future; and also better technology and a higher price is likely to increase volumes of oil that are economically producible. But by contrast, the region may be close to, or already past, its *resource-limited* maximum in production, driven by the size and production profiles of its existing reservoirs.’

7. Conclusions

Public-domain proved (‘1P’) oil reserves by country, and also for the world as a whole, are quoted widely, but in general should not be used.

Where it is necessary to use these data, for example, due to lack of access to oil industry proved-plus-probable (‘2P’) reserves, then the proved reserves should be accompanied by a strong caveat. This is because the data are very poor, being significantly variously underestimates, or overestimates, of the more-likely 2P reserves; and with annual changes to the data frequently not being reported. Moreover, the evolution over time of by-country (and global) proved oil reserves data has misled many analysts about the reality of ‘reserves replacement’.

In addition, also often quoted, are R/P ratios by country. Again, these should not be used, as they can give a very misleading impression of the future supply of oil from a country. This is because the country might be well past its *resource-limited* peak in production of - at least - conventional oil; as is the case for example for the US, Indonesia, the UK and Norway, or else be close to its peak production of this class of oil, as is expected for example for Russia and Nigeria. Suggested wording for such caveats is given in Section 6 of this paper.

These data problems would be less significant were it not for the near-term constraints on global oil production of oil which are likely to result from the coming peak in the global production of *conventional* oil, as identified (since 2008) by the IEA, and by a number of other forecasters.

Overall, this paper seeks to raise awareness of the coming likely constraints to global oil supply, and to suggest that analysts avoid the use of poor data (proved oil reserves), and a poor methodology (R/P ratios), which obscure these constraints, so that their impact on society can be better anticipated.

Acknowledgements

This paper was kindly reviewed by Colin Campbell (ex-FINA, and other companies), Richard Miller (ex-BP), Jean Laherrère (ex-Total), Michael Smith (Globalshift Ltd.) and Henrik Wachtmeister (Uppsala University). The viewpoint, and errors that remain, are those of the author.

Notes

1. Colin Campbell suggests, based on oil industry data, that for some Middle East OPEC countries the proved (1P) oil reserves they report may be the country's *original* 2P reserves, i.e., the 2P reserves before production started; see page 6 of '*Campbell's Atlas of Oil and Gas Depletion*', Second Edition, Springer, 2013. This approach might be seen as defensible, as it matches the basis on which oil and gas fields which cross national boundaries are allocated, and would explain why these estimates do not change year on year.
2. Jean Laherrère notes (slightly re-wording): 'Proved reserves for a given year are estimated for the oil price of that year; if the oil price increases then so will the proved reserves. [By contrast] major oil companies decide the development of a field after an estimate of the field's net present value. This typically uses a Monte Carlo approach, and generates a mean (= 2P) value of the reserves that takes into account anticipated changes in the oil price.'
3. The estimate of the global ultimately recoverable resource (URR) of conventional oil, excluding enhanced oil recovery (EOR), indicated in Figure 2 of ~3600 Gb almost certainly reflects a USGS estimate. Some analysts have pointed out that such a value can only be attained well into the future, given the total volume of conventional oil discovered to-date (of between 2000 Gb and 2400 Gb, depending on assumptions), the current and projected rates of discovery of this class of oil (of less than 10 Gb/yr.), and the relatively modest global average increases in field recovery rate when EOR is excluded.
4. For more detail on this change of modelling at the IEA in 2008 see Chapter 29 of Auzanneau, M., *Oil, Power and War,* Chelsea Green, 2018.

Further Sources

(To access '*The Oil Age*', go to: www.theoilage.org)

- For data on when oil production in specific *regions* has declined, or will decline, based on analysis of 2P data, go to: www.globalshift.co.uk, then select 'Numbers', and then 'Reserves & Peaks'. For this information for *individual countries*, contact Globalshift Ltd. directly, or another commercial oil data supplier.
- For data on URR estimates, see:
  Bentley, R.W. (2015, 2016). *A Review of some Estimates for the Global Ultimately Recoverable Resource ('URR') of Conventional Oil, as an Explanation for the Differences between Oil Forecasts. Part-1*, The Oil Age, (1) 3, 63-90; *Part-2*, The Oil Age, (1) 4, 55-77; *Part-3*, The Oil Age, (2) 1, 57- 81.
- For detailed analysis of all oil data, and of the data providers, see:
  Laherrère, J.H., Miller, R., Campbell, C.J., Wang, J. and Bentley, R.W. (2016, 2017). *Oil Forecasting: Data Sources and Data Problems. Part 1*, The Oil Age, (2) 3, 23-124; *Part 2*, The Oil Age, (2) 4, 1-88; *Part 3*, The Oil Age, (3) 1, 1-135.

References

Bentley, R.W. (2016). *Introduction to Peak Oil*. Lecture Notes in Energy Vol. 34. Springer.
Bentley, R.W. and Bentley Y. (2015a). *Explaining the Price of Oil, 1861 to 1970: The need to use reliable data on oil discovery and to account for 'mid-point' peak*. The Oil Age, vol. 1, no. 2, pp 57 – 83.

Bentley, R.W. and Bentley Y. (2015b). *Explaining the Price of Oil, 1971 to 2014: The need to use reliable data on oil discovery and to account for 'mid-point' peak*. Energy Policy, Special issue on 'The Enigma of Economic Growth', Vol. 86, pp 880-890.

Bentley, R.W., Mannan, S.A., and Wheeler, S.J. (2007). *Assessing the date of the global oil peak: The need to use 2P reserves*. Energy Policy, vol. 35, pp 6364–6382, Elsevier.

Campbell, C.J. & Laherrère, J.H. (1998). *The End of Cheap Oil,* Scientific American, March.

Sorrell, S., Speirs, J., Bentley, R., Brandt, A., Miller, R. (2009). *Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production*. Technology and Policy Assessment report: UK Energy Research Centre, August 2009. ISBN 1-903144-0-35. (Go to: www.ukerc.ac.uk & search 'TPA reports'.)

Wachtmeister, H., Henke, P. & Höök, M. (2018). '*Oil projections in retrospect: Revisions, accuracy and current uncertainty*'. Applied Energy, No. 220 (2018) 138-153.

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