Note on Remaining World Oil Resources and Per Capita Production Relations Near the Peak

Web: pages.ca.inter.net/~jhwalsh/wresourcepercapita.html

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Summary

In Figure 1, the parabolic technique for the projection of conventional world oil production over time has been modified to derive the parameters pertaining to a range of peaks chosen from 2010 to 2035. This covers the period when the actual peak output is expected to occur. The individual parabolas so obtained are used to estimate the production at each peak and the quantity of unproduced oil after 2004 consistent with its respective case. The published world oil reserves at the end of 2004 are then subtracted to obtain an estimate of the oil yet to be discovered.

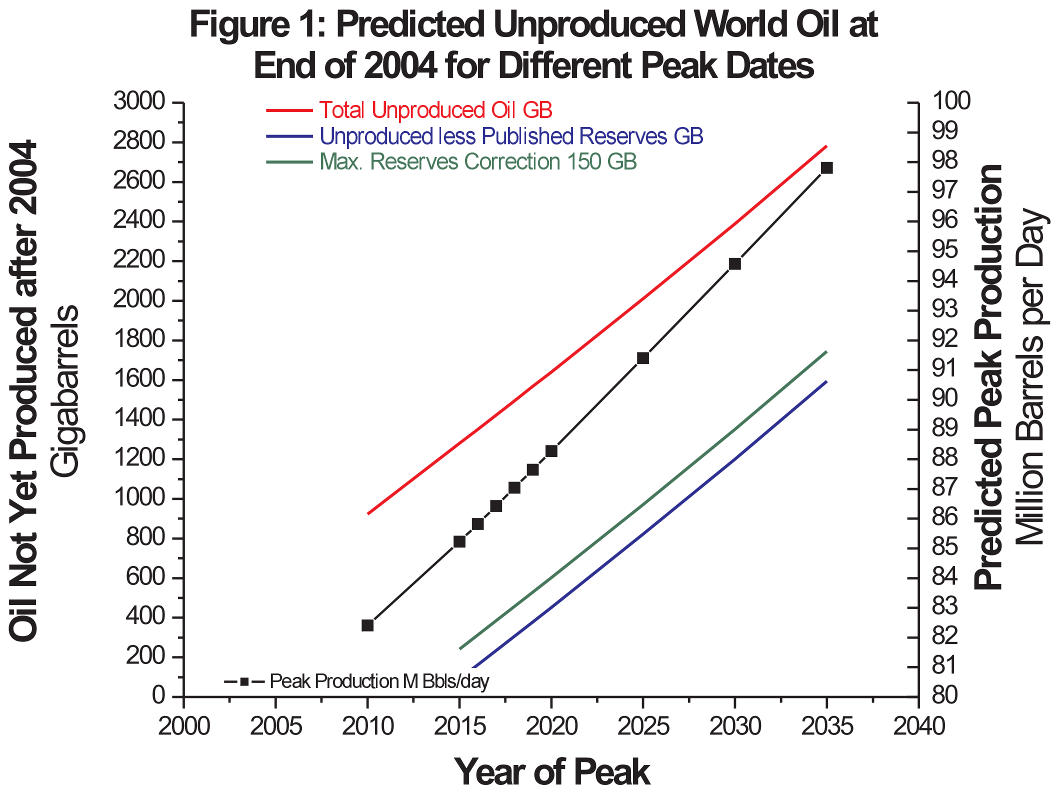
Because of the widely held view that the published reserves may be overstated, a correction line involving 150 gigabarrels (GB) of oil is also plotted to represent a maximum adjustment since the overstatement is most likely in the 50 to 100 GB range. The actual quantity of world undiscovered oil resources is likely to fall between these two lines. The main purpose of such a graph is to test the consistency of the date of the peak with the prediction of both the production at that time and the associated quantity of undiscovered resources. From the figure it appears unlikely the peak could be as early as 2010 or later than 2025.

In Figure 2, historical data for the world per capita production of oil was plotted on a matrix of lines of constant value to illustrate the remarkable constancy of this ratio in recent years. For projections into the future, a single conservative population scenario is employed whose main characteristic is a peak of eight billion people in 2050. The per capita production at a range of peaks of world oil production occurring between 2010 to 2035 was then plotted to show that these values also fall on the same per capita line though there may be a tendency for this ratio to increase in the far out years. A parabolic projection of the decline from the individual peaks was also calculated to illustrate the rapid fall in per capita production to be expected after the respective peaks are reached. The pronounced fall in per capita production results when the decrease in production coincides with a steady (though slowing) increase in population after the peak output; this effect provides an indication of the difficulties to be expected in the economy at that time.

Estimation of the Quantity of World Oil Remaining to be Produced

The parabolic projection technique provides a method of estimating the quantity of oil remaining to be produced for different assumed dates for the peak [1]. Two historical production points along with the assumed date of the peak are required to solve the equations analytically as demonstrated in Appendix 1. The resulting parabola will determine the production at each of the peaks and the quantity of oil remaining to be produced. This latter value is derived by subtracting the integral quantity of oil up to the date of the last historical point (`the basing point') from the total encompassed by the parabola.

The published reserves at the basing point may then be subtracted from `the total remaining to be produced' to estimate the `undiscovered resources of oil.' Since the published reserves are widely believed to be overstated in some countries, a downward adjustment of these inflated values can be applied which has the effect of raising the estimate for the undiscovered resources. This overstatement is probably in the range of 50 to 100 gigabarrels (GB) at the present time but no more than 150 GB.



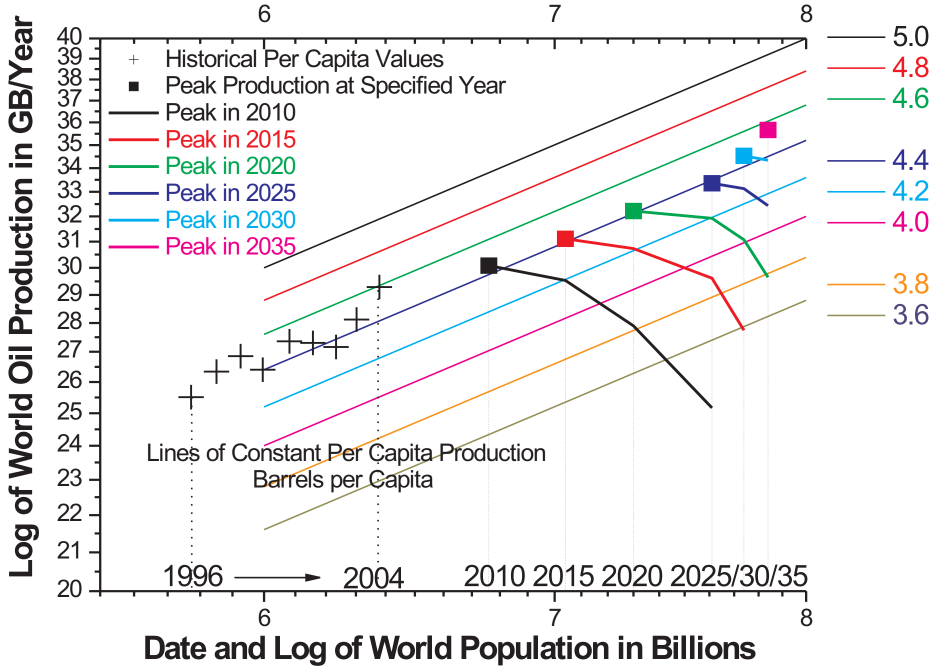
The data in Figure 1 was calculated with peaks chosen from 2010 to 2035 so as to cover the time period widely expected for this event. The parabolic equations were solved for peaks every five years over this range and for every year between 2015 and 2020, the most likely period for the peak to occur in the view of this author. The basing point was the end of 2004, the most recent year for which world data was available from the *BP Statistical Review of World Energy*. The oil remaining to be produced was calculated for each of these cases and then plotted as the top line in Figure 1. The published reserves were deducted from these values and this result appears as the bottom line of the graph. An adjustment line reducing these reserves by 150 GB is also shown. The actual undiscovered resources are expected to lie between these two latter lines. The predicted values for the peak production for the cases assumed are also shown. It is noteworthy that these relationships are essentially linear in the parabolic projection system over the range of interest.

The main application of this technique is to check for self-consistency among the values for the peak date, the peak production, and the predicted remaining undiscovered resources. For example, the prediction of a peak as soon as 2010 requires a negative estimate for the remaining undiscovered resources. Self-consistency considerations would require a much lower figure for the reserves than those published to increase the undiscovered resources to a more probable level. The values calculated for peaks in the 2015-2020 time period indicate undiscovered resources more consistent with geological assessments. In common with other techniques of this kind, the restoration of idle capacity to service, mainly in countries in the Middle East, is a major complication. From now on, this factor will be progressively less important on the world scene.

World Per Capita Oil Production Relations

World per capita oil consumption has been remarkably constant for the last 22 years. Oil consumption averaged 4.49 barrels per capita from 1983 to 2004 with a standard deviation of 0.058 based upon

Figure 2: World Per Capita Oil Production Relations



data provided in the *BP Statistical Review of World Energy* [2]. This value is essentially the same as world oil per capita production when calculated on an annualized basis because changes due to inventory adjustments, etc. are dampened over a full year. Oil only exists a matter of months on the surface on average.

It is almost certain that the peak in world oil production will occur before the peak in world population. The logarithmic plot of world oil production and world population in Figure 2 provides a matrix of straight lines of constant per capita production that may be used to explore this relationship further. Historical points for 1996 to 2004 appear on the left of the graph illustrating the constancy of the per capita production over these recent years. Dates equivalent to the population level are provided along the abscissa.

In this note, a single population scenario is employed for the future whose distinguishing characteristic is a peak of eight billion people in 2050. This is a conservative scenario in that it is more likely to prove too low than too high. If in fact the world population proves higher, then the effects noted on the graph are even more pronounced.

The individual parabolas derived for the different peaks assumed to occur every five years from 2010 to 2035 are used to project world oil production at their respective peaks and into the decline period for some years thereafter. The production data starting from each peak in turn was converted to per capita terms employing the population scenario and the results plotted in Figure 2. The dates corresponding for each of the peaks calculated are also provided along the abscissa. The details of this calculation appear in Appendix 2.

Up to each peak, the world per capita production appears constant and in line with the historical points although there may be a tendency for this ratio to increase at the later peaks. In sharp contrast, the per capita production falls rapidly after the respective peaks are passed.

This effect may be explained in the following way: before the peak, the rise in production and the rise in population tend to off-set each other in the per capita calculation whereas, after the peak, these two factors work against each other. A fall in world per capita oil production is therefore strong evidence the peak has passed. The rapid change in this parameter after the peak is an indication of the major effect this event will have upon the world's economy.

References

[1] J.H. Walsh, *Procedure for the Parabolic Projection of Geological Assessments of Conventional Oil and Gas Resources with Examples*, Revised January 2004. Web: pages.ca.inter.net/~jhwalsh/wpara1.html

[2] J.H. Walsh, *World Per Capita Oil Consumption*, Updated yearly. Web: pages.ca.inter.net/~jhwalsh/woilcap.html

Appendix 1

The parabolic equation is calculated according the scheme outline in detail in Reference [1].

The time on the abscissa of the parabola for the `basing point' (so-called because it marks the boundary between the past and the future) is designated $t_2$ and normally corresponds to the most recent year for which world statistical information is available (in this note 2004). The `reference point' required for the calculation is normally a historical point t_1 selected ten years previously. Any past year could be chosen but it is important that it be far enough in the past to smooth effects from year-to-year fluctuations yet not so far as to be affected by the disruptive period of the first oil crises. A ten-year period appears adequate and corresponds to the production of about 275 GB of oil between 1994 and 2004 (300 GB at the present level of production).

The peak dates are selected at five-year intervals from 2010 to 2030 so as to encompass the probable timing of the actual expected peak. It is then possible to derive the parameters of the parabola analytically that passes through the production points at t_1 and t_2 and the assumed peak date.

From Reference [1] the parabolic production equation is:

$$p = 6Q/T^2 \,.\, t\,(1 - t/T)$$

where p is the yearly production expressed in GB, t is the time in years from the origin for the parabola (not the date), Q is the area of the parabola, and T is the time in years between the origin and the return of the parabola to the abscissa.

The ratio is then taken of the published production at t_2 (2004) to that at t_1 (1994) giving a definite numerical value.

$$p_2/p_1 = t_2\,(1 - t_2/T) \,/\, t_1/(1-t_1/T)$$ = known ratio of production in 2004/1994.

Both t_2 and T are then expressed in terms of t_1. If ten years was chosen between the reference and the basing point dates, then $t_2 = t_1 + 10$. If t_1 occurs in 1994 and because in this example the peak of a symmetrical parabola is assumed in 2010, it is possible to write:

$$T/2 - t_1 = 2010 - 1994 = 16; \text{ thus } T = 2 \,.\, (t_1 + 16)$$

It is then possible to substitute for t_2 and T in the production ratio equation that may then be solved for t_1 with the aid of the quadratic formula. The other quantities required for the production equation (T, Q, t_2) may then be determined. The production at the peak P is obtained from the fundamental parabolic area equation of $Q = 2/3\ T.P$

This calculation is repeated for each of the assumed years for the peak between 2010 and 2035. A different parabolic equation is thus obtained applying to each.

The oil to be produced is given by the area under the curve of the parabola between t_2 in 2004 and T when the parabola returns to the abscissa. It is computed by deducting the area from the start at t = 0 to t_2 from the total area Q using the following integral area relationship:

Partial area q_2 (from $t = 0$ to $t = t_2$) $= 3Q\,r_2^2 - 2Qr_2^3$ where $r_2 = t_2/T$.

After deducting q from Q, the undiscovered oil is determined by the subtraction of the published reserves. This figure is also augmented by an arbitrary 150 GB which is chosen to represent the maximum overstatement of the published reserves. The actual undiscovered oil resources are thought to lie between the two values.

Appendix 2

A population scenario is assumed that starts at 2004 and peaks at eight billion in 2050

The world per capita production, c, is determined from the world production, p, and the world population, N, by:

$$c = p/N \text{ and after rearranging, } \log p = \log N + \log c.$$

For a given value of c, there is a straight-line relationship between log p and log N with a slope of + 1. A matrix of straight lines is then drawn over the per capita range of interest (3.6 to 5.0 barrels per capita). The historical points are plotted as the production and population for those past years.

The parameters for the parabolas starting at each of the respective peaks are calculated as in Appendix 1.

The predicted production, p, is derived from the production equation using the same notation as before:

$$p = 6Q/T^2 . \, t \, (1- t/T)$$

The values of N for the various future dates are determined from the assumed population scenario. The values for p and N are then plotted for each of the parabolic cases derived for the peaks assumed at five-year intervals.

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