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# Long-Term World Oil Supply Scenarios

*The Future Is Neither as Bleak or Rosy as Some Assert*

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Conventionally reservoired crude oil resources comprise all crude oil that is technically producible from reservoirs through a well bore using any primary, secondary, improved, enhanced, or tertiary method. Not included are liquids from mined deposits (tar sands; oil shales) or created liquids (gas-to-liquids; coal oil). Earth's endowment of conventionally reservoired crude oil is a large but finite volume. Production from it may well peak within this century. All or very nearly all of Earth's prolific petroleum basins are believed identified and most are partially to near-fully explored. All or nearly all of the largest oil fields in them have already been discovered and are being produced. Production is indeed clearly past its peak in some of the most prolific basins.

Reflecting increasing consumer demand for petroleum products, world crude oil demand has been growing at an annualized compound rate slightly in excess of 2 percent in recent years. Demand growth is highest in the developing world, particularly in China and India (each with a population in excess of 1 billion) and to a lesser extent in Africa (0.8 billion) and South America (0.35 billion). Where high demand growth exists it is primarily due to rapidly rising consumer demand for transportation via cars and trucks powered with internal combustion engines. For economic and/or political reasons, this high demand growth component did not exist in most of the developing world even a decade ago.

A multitude of analysts consisting of retired petroleum industry professionals hailing from either the geologic or business side of the house, a smattering of physicists, assorted consultants, and less than a handful of economists have predicted at various times over the past two decades, and with increasing frequency, that world crude oil production would peak at times ranging from 8 to 20+ years after their forecast. Dire effects on world oil prices, the welfare of mankind in general, and the United States' economy and lifestyle in particular are typically alleged to implicitly follow the predicted peaks. The times for many of these predicted peaks have already come and gone, or will soon do so.

In April 2000 the United States Geological Survey (USGS) released results of the most thorough and methodologically modern assessment of world crude oil and natural gas resources ever attempted. This 5-year study was undertaken "to provide impartial, scientifically based, societally relevant petroleum resource information essential to the economic and strategic security of the United States." It was conducted by 40 geoscientists (many with industry backgrounds) and was reviewed stage-by-stage by geoscientists employed by many petroleum industry firms including several of the multinational majors.

The above facts prompted the Energy Information Administration (EIA) to take the next logical step by providing the first Federal analysis of long term world oil supply since that published by Dr. M. King Hubbert of the USGS in 1974. The results of EIA's study as presented at the 2000 AAPG meeting and published in July 2000, remain online in slide show format at: http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/index.htm. Since then nothing has happened, nor has any new information become available, that would significantly alter the results. High feedback and sustained requests for "live" presentation indicate widespread cognizance of the analysis among energy policy makers in the Federal government, analysts who focus on energy matters, and senior managers of public and private entities that are major consumers of petroleum products.

## Data and Methodology

EIA's long-term world oil supply analysis was done very much in the spirit of King Hubbert's. However, it had the benefit of a longer exploration and production history and a geologically derived, rather than merely assumed, estimate of the world's conventional technically recoverable crude oil resource base. The methodology developed for the analysis also differed from that used by others, including Hubbert, in several significant ways:

- Although our approach is as "high-level generalized" as those used by the other estimators, it explicitly deals in a quantitative manner with both demand and supply, whereas others' approaches incorporate the demand side of the world crude oil market equation only implicitly.

- Our approach does not assume that the declining production trend after the peak will be a mirror image of the incline prior to the peak. While symmetry appeared to be a reasonable choice at the time Hubbert made his estimates for the United States (which, unlike the world, was not a closed supply-demand system) and later elected (perhaps unfortunately) to apply the same approach at world scale, there is no strong physical or economic rationale that supports a symmetrical outcome for the entire world, particularly in view of the more drawn out time scale of worldwide development.

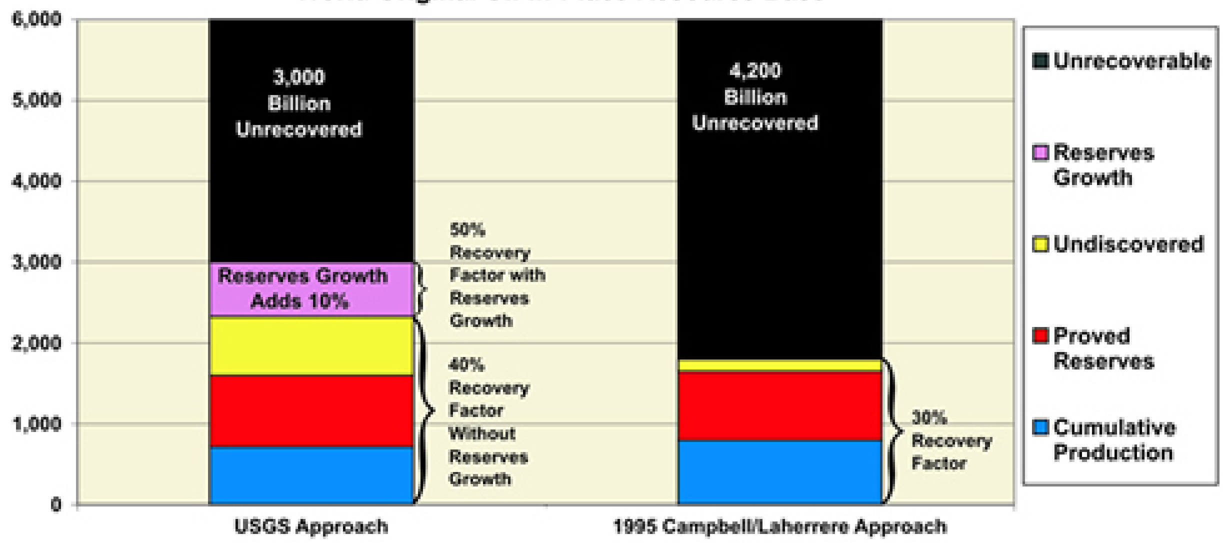
- Pursuant to the prior point, EIA's approach does not assume that a single functional form can accurately model the full production curve. Hubbert's choice of the logistic function to model the full production curve made sense at the time he selected it given the sparse data that were available to him at that time. That is no longer the case. We elected to marry two functional forms, the first of which extends production from history along a constant percentage growth path until the production peak is reached, the second of which declines production post-peak at a constant reserves to production (R/P) ratio (not to be mistaken for a constant decline rate). The estimated time of peak production is therefore determined by the choice of these functional forms, the rate of pre-peak production growth, the post-peak R/P ratio, and the estimated size of the technically recoverable resource base. EIA selected an R/P ratio of 10 as being representative of the post-peak production experience. The United States, a large, prolific, and very mature producing region, has an R/P ratio of about 10 and was used as the model for the world in a mature state.

- In concert with the USGS, our approach assumes that ultimate recovery appreciation (field growth; reserves growth) occurs outside the borders of the United States, albeit not necessarily in every field. For an excellent historical example one need only look at what has happened to projected dates of abandonment in the North Sea over the past three decades. Others who have predicted that the end is imminent either ignore this factor or claim that it does not apply outside the United States.

- In fact, we believe that the USGS estimates are conservative for a variety of reasons, chief among which are that the USGS assessment did not encompass all geologically conceivable small sources of conventionally resevoired crude oil and was limited to the assessment of reserves that would be added within a 30 year time frame because, in part, "... technological changes beyond 30 years are difficult, if not impossible, to conceptualize and quantify." The latter limitation has clear implications for such matters as expectations regarding field discoverability and producibility, not to mention recovery factor improvement.

All else being equal, a larger resource base implies a later date of peak production than does a smaller one. The significant volumetric difference between the conventional crude oil resource base views held by the USGS and EIA and those of most other contemporary long term oil supply estimators is depicted in Figure 1 which compares the former to the 1995-vintage view set forth by Colin Campbell and Jean Laherrère in "The End of Cheap Oil?" (*Scientific American*, March 1998) as applied to a hypothetical *in-place* resource volume.

**Figure 1. Different Interpretations of a Hypothetical 6,000 Billion Barrel World Original Oil-in-Place Resource Base**



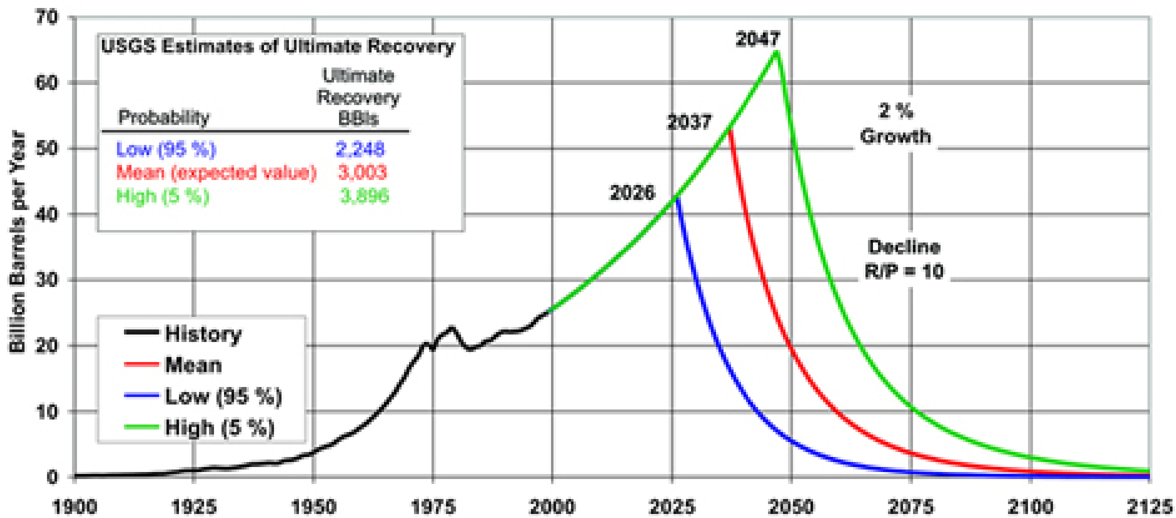

Source: Energy Information Administration

- Last, but by no means least, we elected to explicitly recognize the existence of uncertainty (as did the USGS resource estimation process) by developing an approach which postulates twelve scenarios that *in toto* span a wide range of plausible variation in the inputs. Each scenario has its own unique peak production rate and time of occurrence. Others' approaches do not explicitly recognize uncertainty and typically produce a solitary point estimate.

**Results**

The particular scenario shown in Figure 2 depicts the 2 percent demand growth experience of recent years extended up to the production peak (similar to the 2.2 percent rate applied through 2020 in EIA's 2002 International Energy Outlook) and then the decline path from the peak at a constant R/P ratio of 10. The three divergent curves shown reflect alternative resource base volumes. From left to right they are the sum of the USGS's United States and rest-of-world resource estimates at the 95 percent certain (19 chances in 20 of that much or more), the statistical mean (expected value), and 5 percent certain (1 chance in 20 of that much or more) volumetric levels. Thus, if the USGS mean resource estimate proves to be correct, if 2 percent production growth continues until peak production is reached, and if production then declines at an R/P ratio of 10, world conventional crude oil production would be expected to peak in 2037 at a volume of 53.2 billion barrels per year.

**Figure 2. Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P=10)**




Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

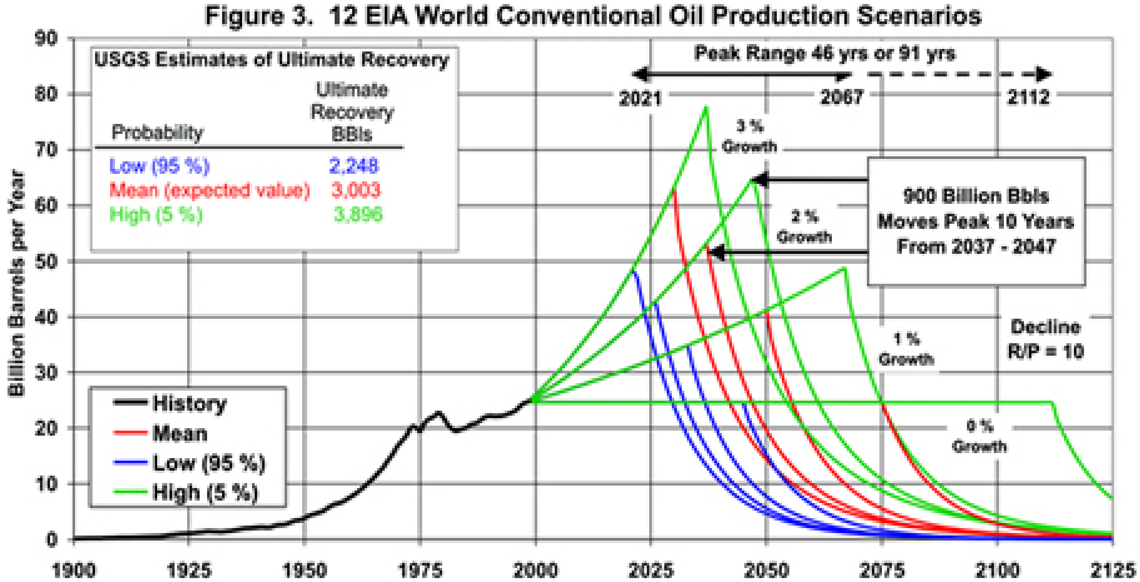
Provided numerically in Table 1 and graphically in Figure 3 are the results of all 12 scenarios, in which the pre-peak production growth rate is varied against the same three USGS fractile estimates of the resource base while post-peak decline remains fixed at R/P=10. Depending on what actually happens to demand, as well as on how fortunate the world eventually proves to be *vis a vis* the volume of its conventional crude oil resource endowment, peak world conventional crude oil production could plausibly occur anywhere between 2021 at a volume of 48.5 billion barrels per year and 2112 at a volume of 24.6 billion barrels per year, though neither of these extremes has a substantial probability of occurrence.

## Table 1. WORLD OIL PRODUCTION FORECAST

| Probability Estimate | Ultimate Recovery BBbls | Annual Demand Growth, % | Peak Year | Peak Rate, MMBbls/yr | Peak Rate, MMBbls/day |
|---|---|---|---|---|---|
| Low (95%) | 2,248 | 0.0 | 2045 | 24,580 | 67 |
| | 2,248 | 1.0 | 2033 | 34,820 | 95 |
| | 2,248 | 2.0 | 2026 | 42,794 | 117 |
| | 2,248 | 3.0 | 2021 | 48,511 | 133 |
| Mean (expected value) | 3,003 | 0.0 | 2075 | 24,580 | 67 |
| | 3,003 | 1.0 | 2050 | 41,238 | 113 |
| | 3,003 | 2.0 | 2037 | 53,209 | 146 |
| | 3,003 | 3.0 | 2030 | 63,296 | 173 |
| High (5%) | 3,896 | 0.0 | 2112 | 24,580 | 67 |
| | 3,896 | 1.0 | 2067 | 48,838 | 134 |
| | 3,896 | 2.0 | 2047 | 64,862 | 178 |
| | 3,896 | 3.0 | 2037 | 77,846 | 213 |

Source: Energy Information Administration

Figure 3. 12 EIA World Conventional Oil Production Scenarios




Source: Energy Information Administration
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

**Sensitivity to the estimated resource volume**

These results are remarkably insensitive to the assumption of alternative resource base estimates. For example, adding 900 billion barrels -- more oil than had been produced at the time the estimates were made -- to the mean USGS resource estimate in the 2 percent growth case only delays the estimated production peak by 10 years. Similarly, subtraction of 850 billion barrels in the same scenario accelerates the estimated production peak by only 11 years.

It is worth noting that a 1 percent decrease in the pre-peak growth rate has roughly the same effect that adding 900 billion barrels to the estimated resource base does.

**The bottom line**

Will the world ever physically run out of crude oil? No, but only because it will eventually become very expensive in absence of lower-cost alternatives. When will worldwide production of conventionally reservoired crude oil peak? That will in part depend on the rate of demand growth, which is subject to reduction via both technological advancements in petroleum product usage such as hybrid-powered automobiles and the substitution of new energy source technologies such as hydrogen-fed fuel cells where the hydrogen is obtained, for example, from natural gas, other hydrogen-rich organic compounds, or electrolysis of water. It will also depend in part on the rate at which technological advancement, operating in concert with world oil market economics, accelerates large-scale development of unconventional sources of crude such as tar sands and very heavy oils. Production from some of the Canadian tar sands and Venezuelan heavy oil deposits is already economic and growing.

In any event, the world production peak for conventionally reservoired crude is unlikely to be "right around the corner" as so many other estimators have been predicting. Our analysis shows that it will be closer to the middle of the 21st century than to its beginning. Given the long lead times required for significant mass-market penetration of new energy technologies, this result in no way justifies complacency about *both* supply-side and demand-side research and development.

A similar version of this article can also be found in the April 2003 issue of *Offshore* under the title "World conventional oil supply expected to peak in 21st century."