The Shape of World Oil Peaking: Learning From Experience

by
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Abstract

The purpose of this study was to gain insight into the potential time-varying shape of world oil production peaking based on experience in regions where peaking has already occurred. Unencumbered regions and countries were considered. All had significant peak production, and all are almost certainly past their peak. Their experience shows that the onset of peaking can occur quite suddenly – not obvious even a year prior to the event. For the regions and countries considered, peaks were very sharp and some post-peak production declines were relatively steep. The peaking of world conventional oil production may or may not follow previous trends, but these observations do reflect real-world experience and may be of value in planning.

Introduction

World production of conventional oil will reach a maximum -- a peak -- and then decline. The timing is uncertain; some think it could occur within a matter of years, others in a decade or two.[1] Without a major effort to mitigate related oil shortages starting well before the onset of peaking, the economic consequences worldwide will be dire.[2]

The purpose of this study was to gain insight into the potential time-varying shape of world conventional oil peaking based on experience in regions where oil production peaking has already occurred. By conventional oil, we mean oils of higher gravity that make up over 95% of current world production. The likely world oil production profile before, during and after world conventional oil peaking is almost certainly not predictable, because it will be a function of an array of unknowable factors, such as the following:

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[1] Bakhtiari, A.M.S. "World Oil Production Capacity Model Suggests Output Peak by 2006-07." OGJ. April 26, 2004; Simmons, M.R. Twighlight in the Desert. Wiley. 2005: Skrebowski, C. "Oil Field Mega Projects - 2004." Petroleum Review. January 2004; Deffeyes, K.S. Hubbert's Peak-The Impending World Oil Shortage. Princeton University Press. 2003; Goodstein, D. Out of Gas – The End of the Age of Oil. W.W. Norton. 2004; Campbell, C.J. "Industry Urged to Watch for Regular Oil Production Peaks, Depletion Signals." OGJ. July 14, 2003; Drivers of the Energy Scene. World Energy Council. 2003. Laherrere, J. Seminar Center of Energy Conversion. Zurich. May 7, 2003; DOE EIA. "Long Term World Oil Supply." April 18, 2000; Jackson, P. et al. "Triple Witching Hour for Oil Arrives Early in 2004 – But, As Yet, No Real Witches." CERA Alert. April 7, 2004; Davis, G. "Meeting Future Energy Needs." The Bridge. National Academies Press. Summer 2003.

[2] Hirsch, R.L., Bezedk, R., Wendling, R. Peaking of World Oil Production: Impacts, Mitigation, & Risk Management. DOE NETL. February 2005.

1. World economic development prior to peaking;
2. Oil prices a decade or more prior to peaking;
3. The degree to which advanced technology has been applied in the world's largest oil fields;
4. The degree to which large oil fields have been damaged by past mismanagement:
5. Oil supply-demand expectations a decade or more prior to peaking;
6. Concession and contract policies that either encourage or discourage outside investment in regions with large actual or potential oil reserves;
7. Political stability in regions with the largest oil production prior to oil peaking; and
8. The geology of major oil producing regions.

A scenario analysis involving these and other variables might be possible but is likely to be so complex as to be of questionable value.

The Bell-Curve Approximation

Modeling of oil production peaking is often based on a bell-curve[3] approximation of oil production as a function of time. This approach was utilized by M. King Hubbert in 1956 in his forecast of U.S. oil production peaking.[4] Figure 1 shows the 30-year interval near the apex of a bell-curve that was fit to U.S. Lower 48 states conventional oil production by Deffeyes.[5] Production data follow the curve closely from 1910-1960 and from 1980-2003 (not shown here).

The top of bell curve in the figure is relatively broad; the period from 98% of maximum on the upslope to the 98% point on the decline side is approximately 10 years long. If world oil production peaking were to be characterized by such a relatively broad maximum, the task of mitigation would be easier than if the peak were sharp. In addition, a bell curve production profile would provide a degree of forewarning of the approaching peak.

Longer-Term Regional Oil Production

Consider what actually happens in the development of a typical, economically viable oil field. After confirmed discovery, development proceeds, production rises to a maximum -- a peak -- after which it goes into decline. Along the way, oil field operators apply various technologies to increase production beyond what nature would otherwise provide, e.g. water flooding, fracturing, artificial lift, etc.

[3] Also known as normal and logistic curves.
[4] Hubbert, M.K. Nuclear Energy and the Fossil Fuels. American Petroleum Institute Drilling and Production Practice, Proc. Spring Meeting, San Antonio. 1956.
[5] Deffeyes, K.S. Beyond Oil: The view From Hubbert's Peak. Hill and Wang. 2005.

Nevertheless, the geology of each oil reservoir will ultimately set an upper limit on the amount of oil that can be practically produced. In addition, the time-varying production profile for an oil field can be strongly influenced by management decisions and political events, which can impact oil field dynamics.

Geographically large regions of oil production typically contain reservoirs of different sizes and types. Regional output is the sum of production of all its producing oil fields, which varies over time. An example of regional oil peaking is the U.S. Lower 48 states, the production profile of which is shown over a 55-year period in Figure 2.[6] This region is of particular interest because it was the world's most prolific conventional oil production regions for much of the twentieth century.

The dashed lines provide a reasonable fit to the data for the 55-year period and show a triangular pattern, not the bell curve described earlier. The approximate slope of both dotted lines is 2%. Accordingly, a 2% decline after peaking is a useful benchmark for judging the decline profiles of other regions. A decline of less that 2% could thus be considered gradual, while a decline of great than 2% could be considered steep.

Some forecasters believe that higher oil prices and new technology will have a dramatic impact on oil production. The Lower 48 experience indicates otherwise. As shown in the Figure 3, oil prices increased dramatically in 1973 and 1979, but those price escalations did not alter the general oil production decline in the Lower 48 region. In addition, the period 1975 - 2000 was characterized by large improvements in oil field technology, including affordable 3D seismic imaging, low-cost directional and horizontal drilling, greatly enhanced geochemical understanding, dramatically improved geological modeling, etc. Nevertheless, the decline in Lower 48 production continued, essentially unabated. This long term, real-world experience provides strong evidence to challenge the thesis that high oil prices and advanced technology can mitigate oil production decline.

No production data set is without numerous complications. In the case of the U.S. Lower 48 states experience, a number of factors beyond price and technology impacted. For example 1) Over the period 1945-1970, the Texas Railroad Commission set allowable production in the state, which represented a significant fraction of total Lower 48 production; 2) After peaking in 1970, low priced oil from the Middle East entered the U.S. market in increasing volumes, almost certainly impacting some domestic oil decision-making; 3) During the period 1970-2000, the U.S. experienced four recessions, etc. It would be extremely difficult, if not impossible to isolate these and other influences in an effort to develop a clear picture of what production might have otherwise been. In fact, every oil-producing region of the world has been and will be influenced by

[6] U.S. Department of Energy, Energy Information Administration, *Long Term World Oil Supply*, April 18, 2000.

complex forces that defy definitive isolation and evaluation.

Understanding the Likely Shape of World Peaking

Not all regional production histories are useful for our purposes because of overriding distortions. To avoid many of the obvious pitfalls, the following selection criteria were adopted:

- A relevant region (often a country) must represent a large, geologically varied province and be clearly past its maximum likely oil production.[7]

- Production at peaking must have been significant, which we took as greater than 1 Million barrels per day (MM bpd) at peak.

- Production data must be available for a number of years before and after peaking.

- The region had to have been generally managed for maximum oil production prior to and after oil peaking. Accordingly, we did not consider regions whose production was constrained by cartel considerations or extraordinary political events.

As part of this analysis, we took note of production one year before and one year after peaking in an effort to identify related short-terms trends.

The regions that fit our criteria were: 1) Texas; 2) North America, which of course included Texas; 3) The United Kingdom; and 4) Norway. Each is certainly or almost certainly years past peak production, so major new discoveries are unlikely to change their peaking profiles. In each case, management, market, and political factors influenced oil production but in ways that we considered second order with respect to our interests in this study. None were subjected to extreme political influences of the types experienced in Russia and Venezuela, for example, and none were part of OPEC.

Many countries with large oil production were not useful for this analysis. First are the OPEC countries – Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, and Venezuela. Over the past three decades, OPEC limited member production to less than their maximum productive capacity in an effort to control world oil prices, so their production histories were strongly manipulated from time to time. Oil production in Russia was dominated by

[7] While the cases cited here all appear to be past their likely maximum production, there is still the possibility of a major new discovery altering the picture. For some of the regions and countries cited below, such a trend reversal is essentially impossible. For others that have more recently peaked, a major reversal is unlikely because of extensive exploration with the latest technology, but it is not inconceivable.

significant mismanagement prior to the fall of the Soviet Union. Most recently, political turmoil and transportation constraints have had a major impact on Russian oil production. Venezuela is a member of OPEC and thus limited its oil production over past decades. In addition, recent political turmoil and oil field mismanagement has distorted their production in complex ways.

Data From Regions & Countries Past Peak Production

Figures 4-7 show annualized daily production data for a 10-year period around peak production for the selected regions and countries. Yearly data were considered appropriate for identification of major changes, because monthly data can fluctuate dramatically and obscure longer-term trends. While heavy oil was produced in some of the regions of interest, it was fractionally small enough to be neglected for our purposes.

Table I provides a summary of the data including the fraction of maximum production one year before peaking and one year after for Texas,[8] North America,[9] the United Kingdom,[10] and Norway.[11] In addition, peak production data are shown for three countries that are also past peak production, but whose maximum production was less than I MM bpd – Argentina,[12] Colombia,[13] and Egypt.[14]

Examination of the data leads to the following observations:

1) In all cases, it was not obvious that production was about to peak a year prior to the event.

2) The peaks were sharp, not gently varying bell curves. They were certainly not flat topped, as some forecasters have hoped for.

3) In some cases post-peak production declines were much greater than our 2% benchmark.

4) In three cases pre-peaks were evident.

Table I. Characteristics of oil production in regions & countries that have past

[8] Railroad Commission of Texas. Oil Production and Well Counts (1935-2003). www.state.tx.us
[9] Statistical Review of World Energy 2004. BP. June 15, 2004.
[10] U.S. Department of Energy, Energy Information Administration, *Long Term World Oil Supply*, April 18, 2000.
[11] Statistical Review of World Energy 2004. BP. June 15, 2004.
[12] Ibid.
[13] Ibid.
[14] U.S. Department of Energy, Energy Information Administration, *Long Term World Oil Supply*, April 18, 2000.

their peak oil production. All have relatively sharp peak profiles.

Region or Country	Peak Year & Production (MM bpd)	Special Features	% of Maximum One Year Before Peak	% of Maximum One Year After Peak
Texas	1972 / 3.4	Small pre-peak	96%	99%
North America	1985 / 15.5		99%	97%
U.K.	1999 / 2.9	Pre-peak, sharp decline	97%	87%
Norway	2001 / 3.4	Pre-peak	96%	97%
Argentina	1998 / 0.9	Small post-peak	98%	96%
Colombia	1999 / 0.8	Very sharp peak	90%	75%
Egypt	1996 / 1.0	Small post peak	99%	96%

Summary

In an effort to understand the possible character of the peaking of world conventional oil production, oil peaking in a number of relatively unencumbered regions and countries was considered. All had significant production, and all were certainly or almost certainly past their peak. The data shows that the onset of peaking can occur quite suddenly, peaks can be very sharp, and post-peak production declines can be comparatively steep (3-13%). Thus, if historical patterns are appropriate indicators, the task of planning for and managing world conventional oil peaking will indeed be very challenging.

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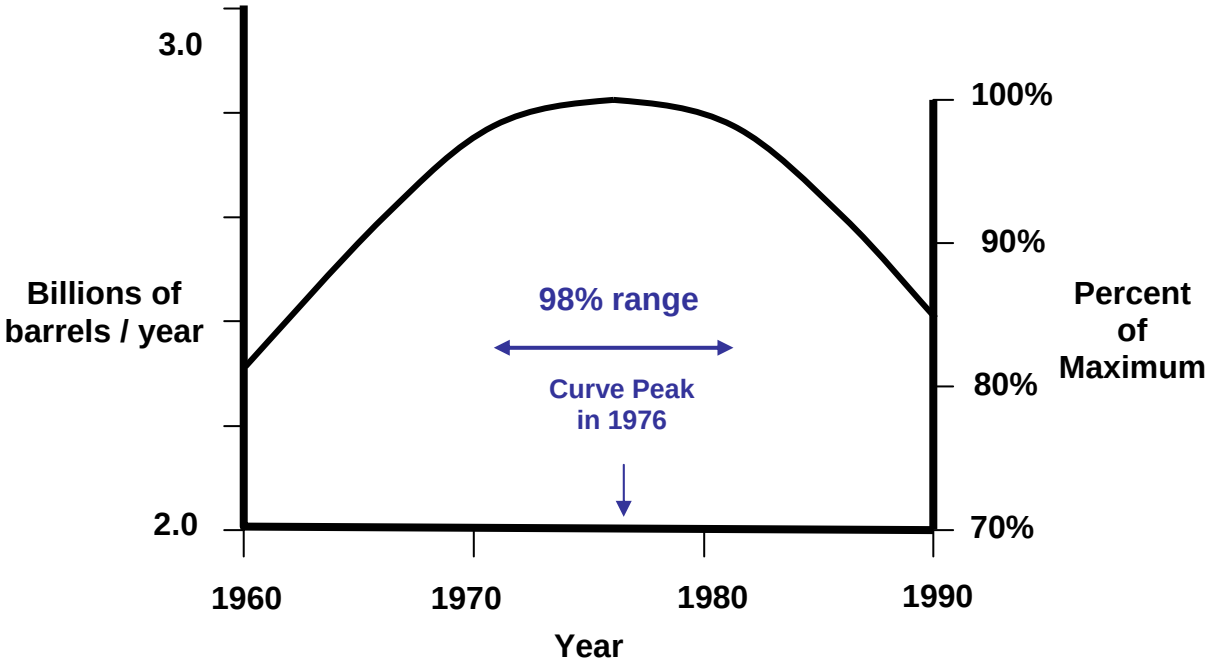

Figure 1. The top of the bell curve that was fit to U.S. Lower 48 states oil production data by Deffeyes. The top of the curve is relatively flat over a 10 year period.

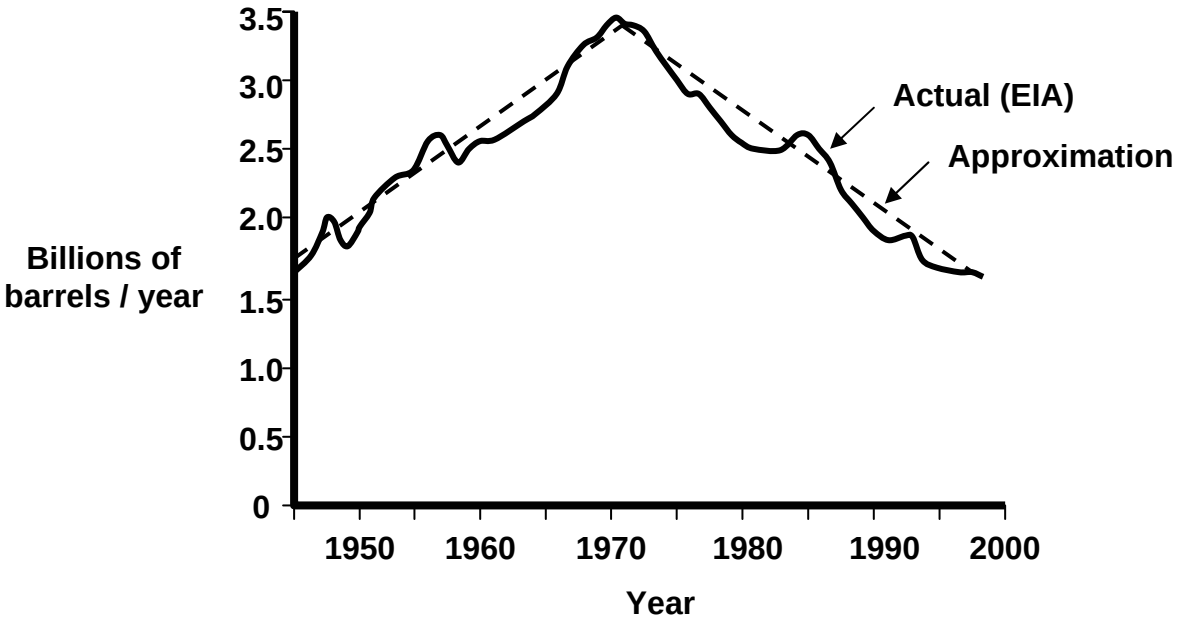

Figure 2. Actual oil production in the U.S. Lower 48 states 1945-2000. During this period, a triangular profile fits the data, as opposed to the bell curve shape shown in the previous figure.

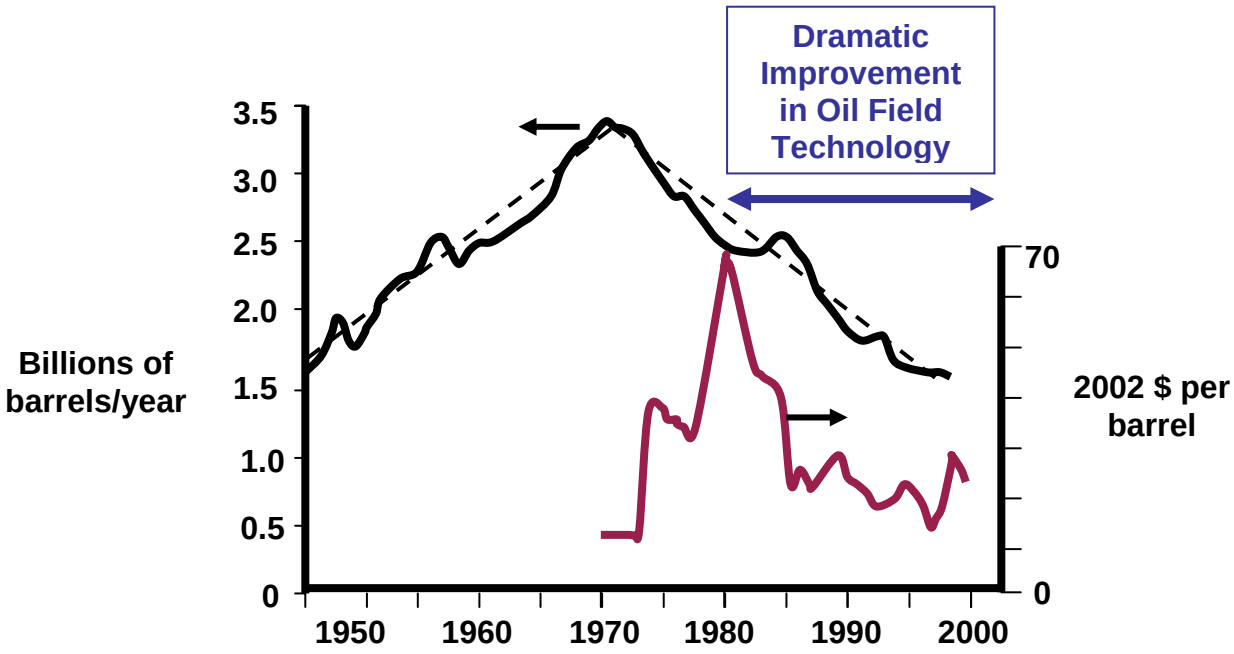

Figure 3. The U.S. Lower 48 states oil production profile and oil prices from 1970 forward. Also indicated is the golden period of oil field exploration and production technology, which started in the late 1970s. Neither oil price nor advanced technology had a major impact on production. Certainly there was no significant reversal of the decline.

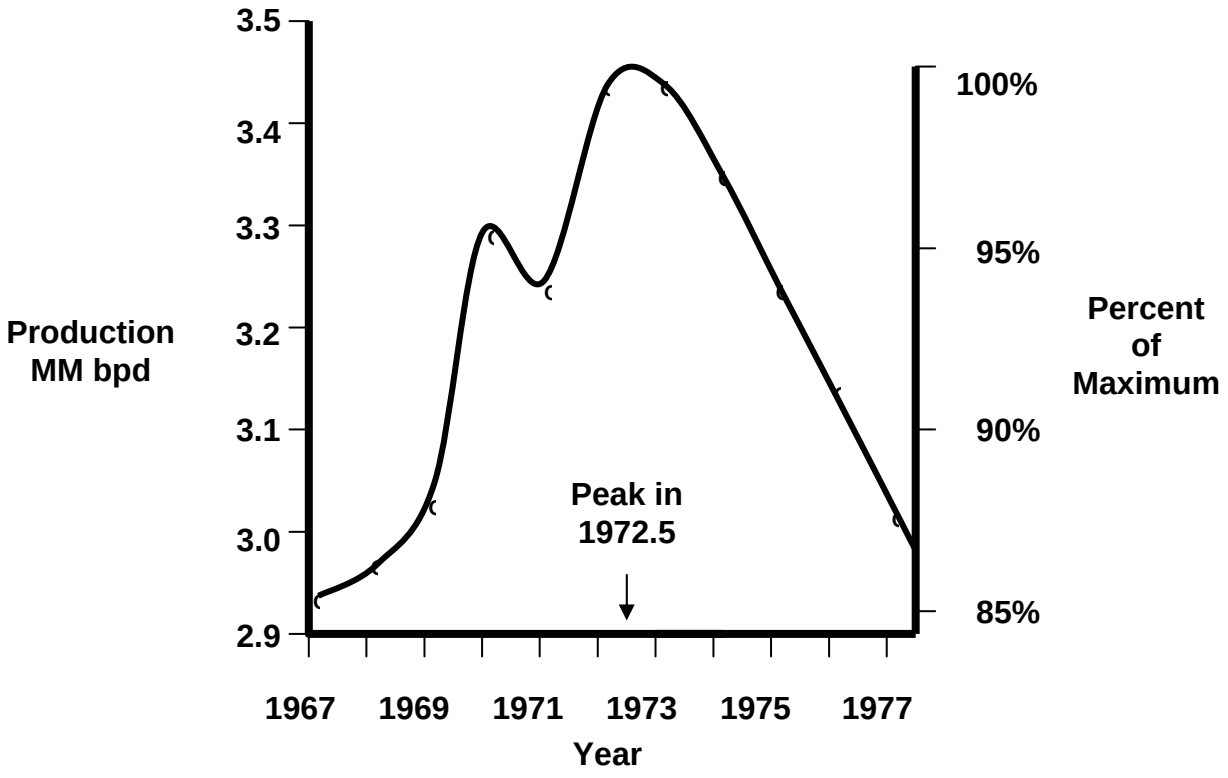

Figure 4. Oil production from the state of Texas near its peak in mid-1972.

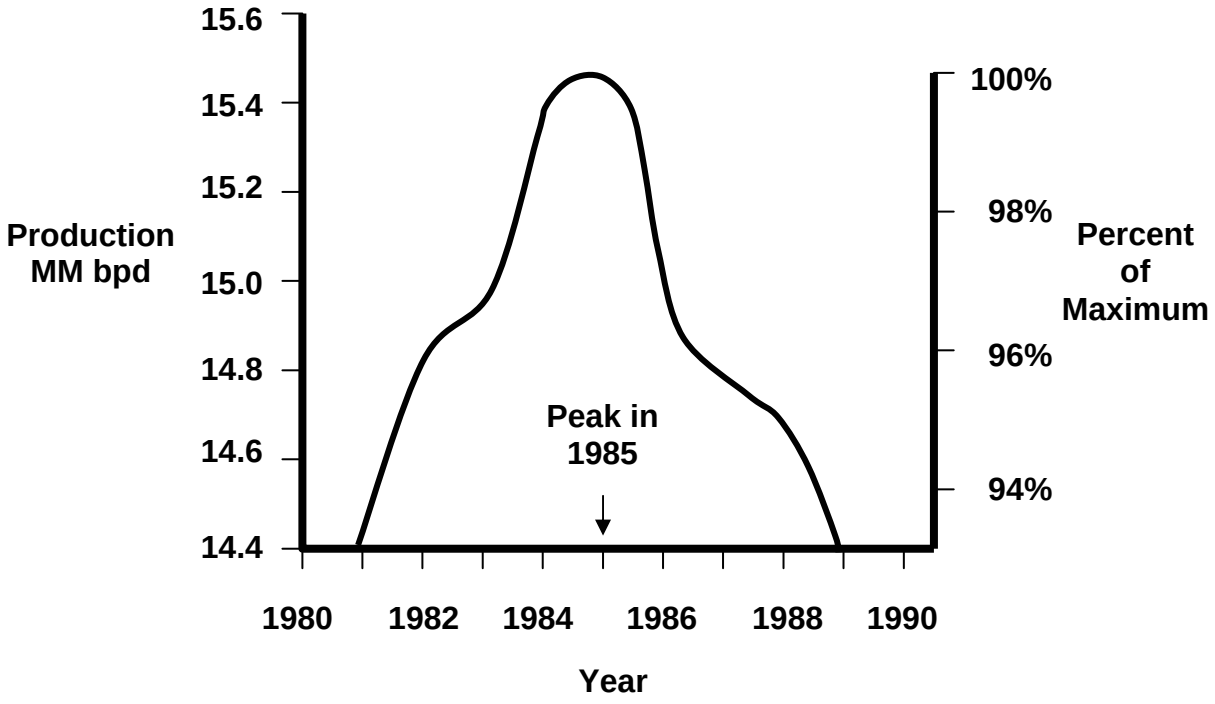

Figure 5. Oil production in North America near its peak in 1985.

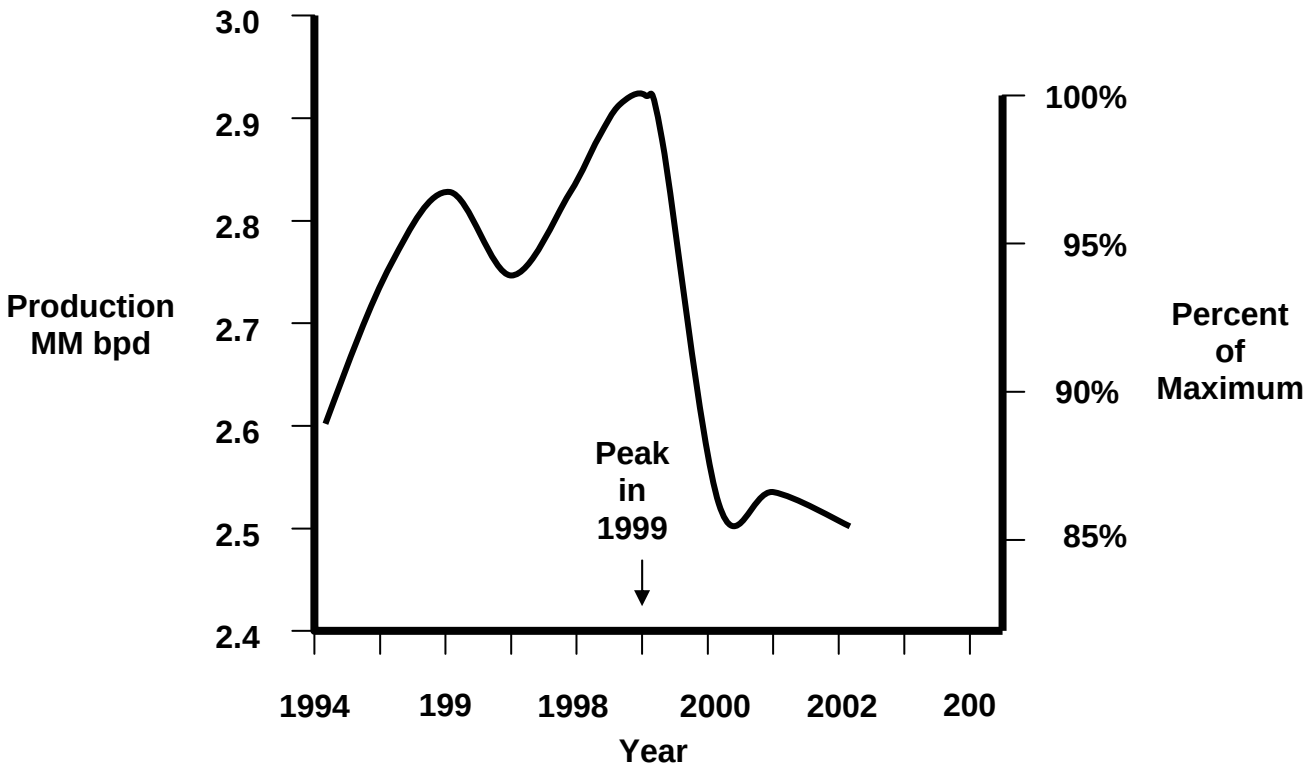

Figure 6. Oil production in the United Kingdom near its peak in 1999.

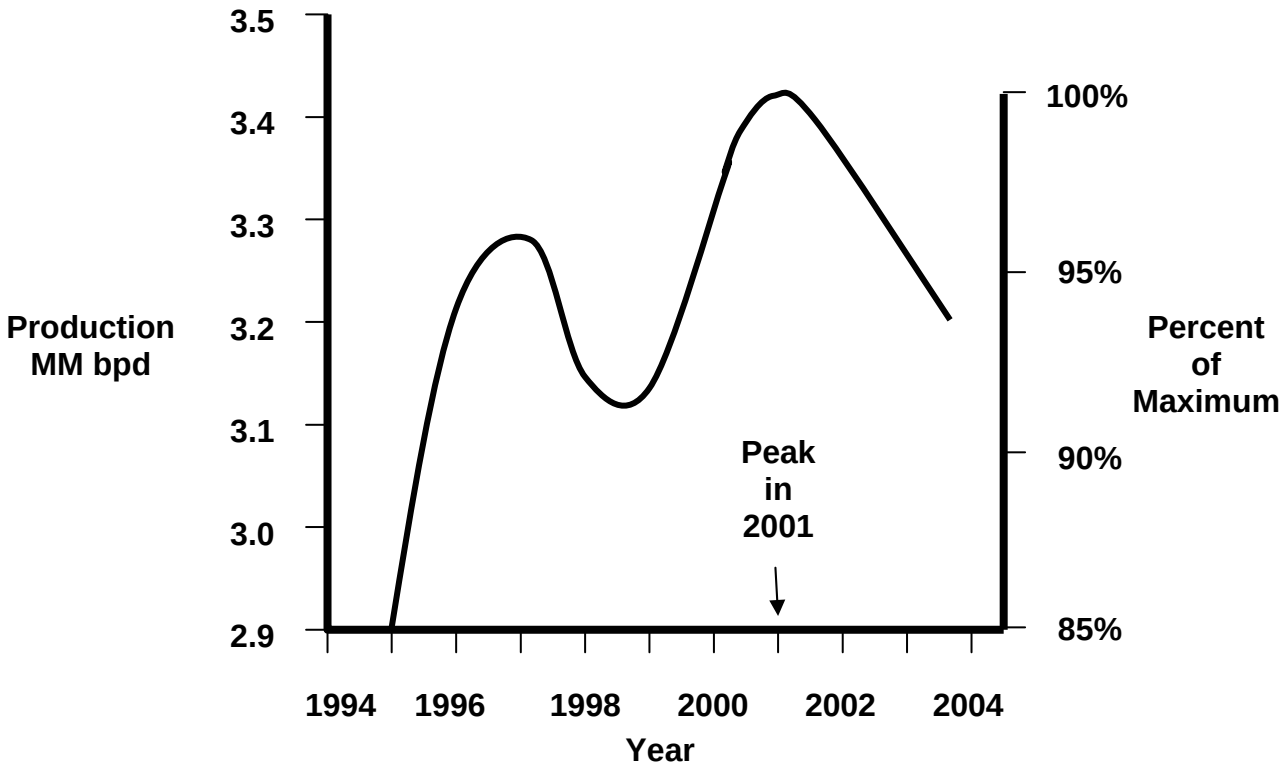

Figure 7. Oil production in Norway near its peak in 2001.