How much oil?

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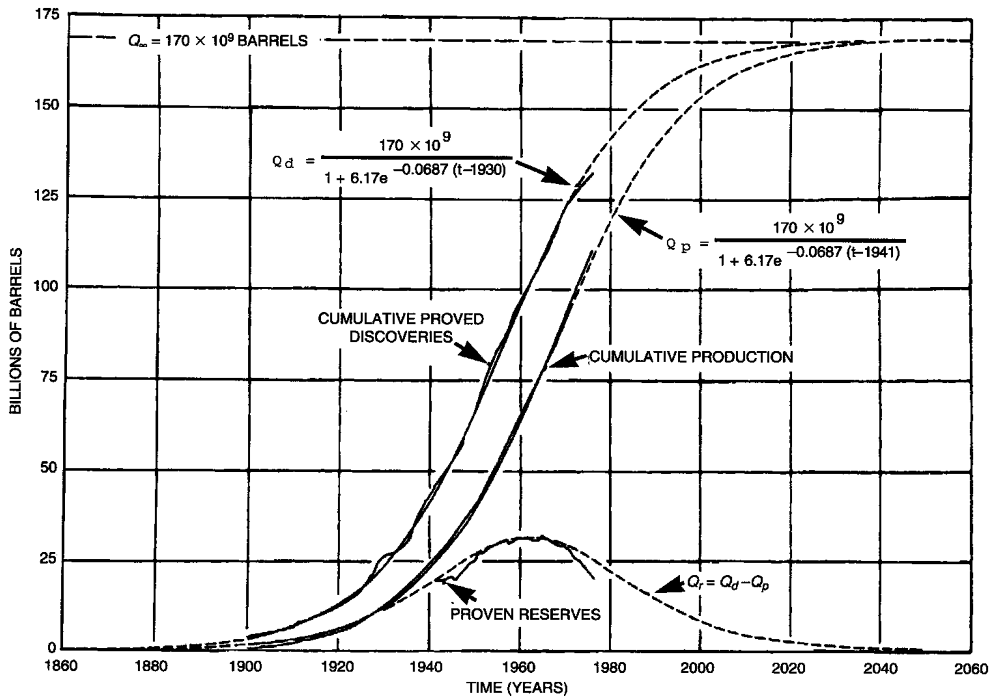
In the 1960s, M. K. Hubbert [1] used a logistic-gaussian model to predict the year of maximum energy production in the lower 48 states, and got is just about right. Recently, Bartlett [2] reanalyzed the data for world oil production. We bring this up to date. The data suggest, based on expert estimates of world oil ultimate production, that the year of maximum world oil production is very near.

1. M. K. Hubbert, *U. S. Energy Resources, a Review as of 1972*, U. S. Senate Committee on Interior and Insular Affairs report, GPO, Washington, D.C
2. A. A. Bartlett, "An analysis of U.S. and world oil production patterns using Hubbert-style curves," *Math. Geol.* **32**, 1 (2000).

In 1968, M. King Hubbert pointed out that for there to be production in a given year, there must have been a discovery of oil in a particular area some time earlier.

The known amount of crude oil (proven reserves) first increases as more discoveries are made, then decreases as these discoveries are used up and we run out of crude oil altogether.

The cumulative production follows a *logistic curve*: starts exponentially, turns over, and rises to the maximum, the limited amount of resource available.

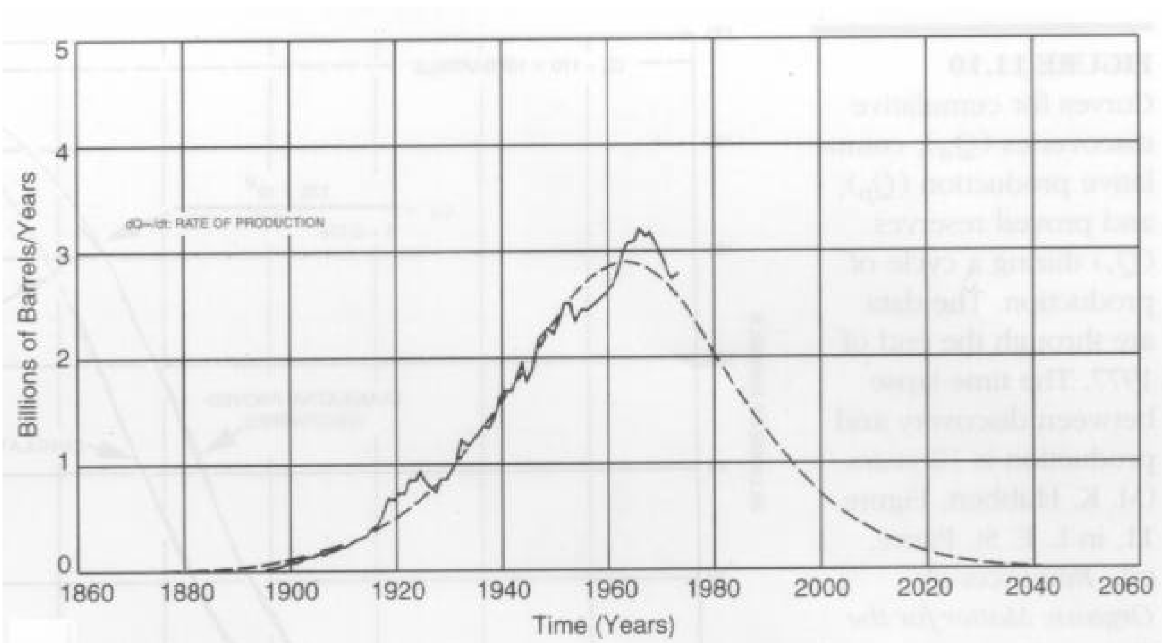


$$D(t) = \frac{170\ \text{Gbbl}}{[1 + 6.17\ e^{-0.0687(t\ -\ 1930)}]}$$

$$C(t) = \frac{170\ \text{Gbbl}}{[1 + 6.17\ e^{-0.0687(t\ -\ 1941)}]}$$

The derivative of this curve is $P(t)$

The total accumulated amount of crude oil produced rises exponentially at first, slows, then gets slowly closer to its final value—the total amount of recoverable crude oil in the crust.



Hubbert predicted in 1968 that maximal oil production in the lower 48 states would occur in 1969.

More realistically than the gaussian, we might expect the actual production curve to be skewed somewhat to the left (the start of exploitation), and to collapse abruptly toward the end of exploitation.

Bartlett has examined the uncertainty in Hubbert's method in some detail and found that the analysis is relatively insensitive to small changes in the parameters (which are basically fixed by the data).

A. A. Bartlett, "An analysis of U.S. and world oil production patterns using Hubbert-style curves," *Math. Geol.* **32**, 1 (2000).

Hubbert assumed a gaussian, curve, described by three parameters:

Q_∞, the total amount produced;

T, the time at which the amount produced is a maximum, and

σ, the standard deviation.

$$P(t) = \frac{Q_\infty}{\sigma(2\pi)^{1/2}} \exp\left[-\frac{(t - T)^2}{2\sigma^2}\right].$$

The total amount produced sets the “normalization,” Q_∞.

In practice, we compare the functional form with the actual data.

The three numbers are varied until the deviation from the data is as small as possible.

We find for US data through 2000:

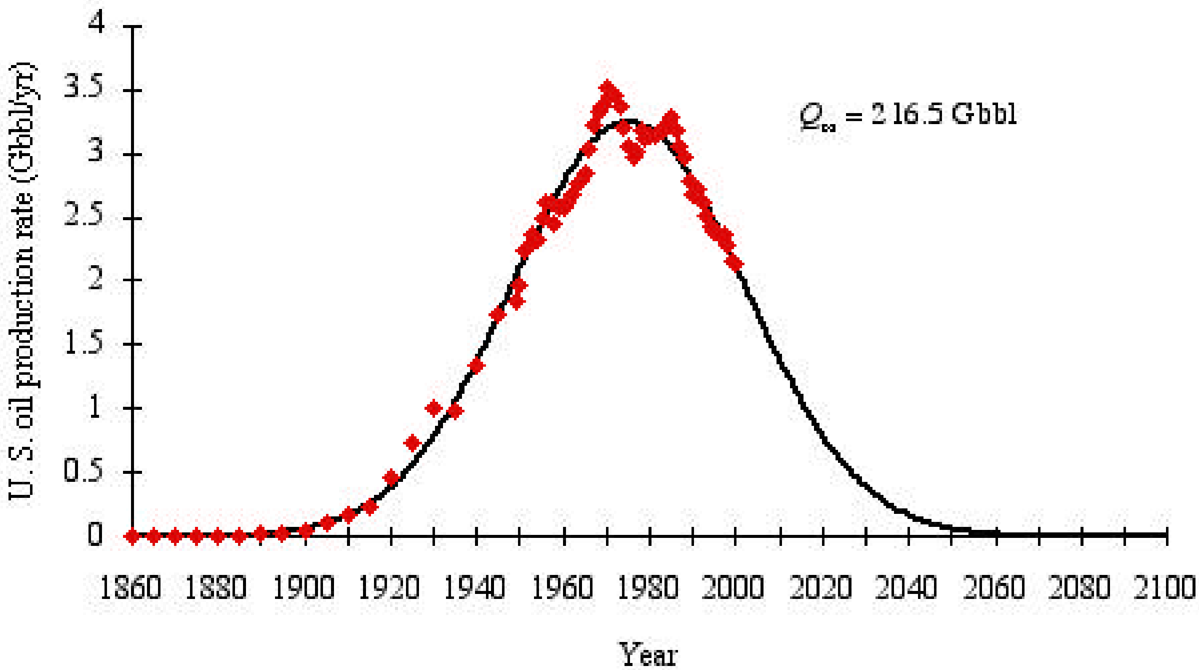
$$Q_\infty = 216.5 \text{ Gbbl}$$

$$T = 1975.3$$

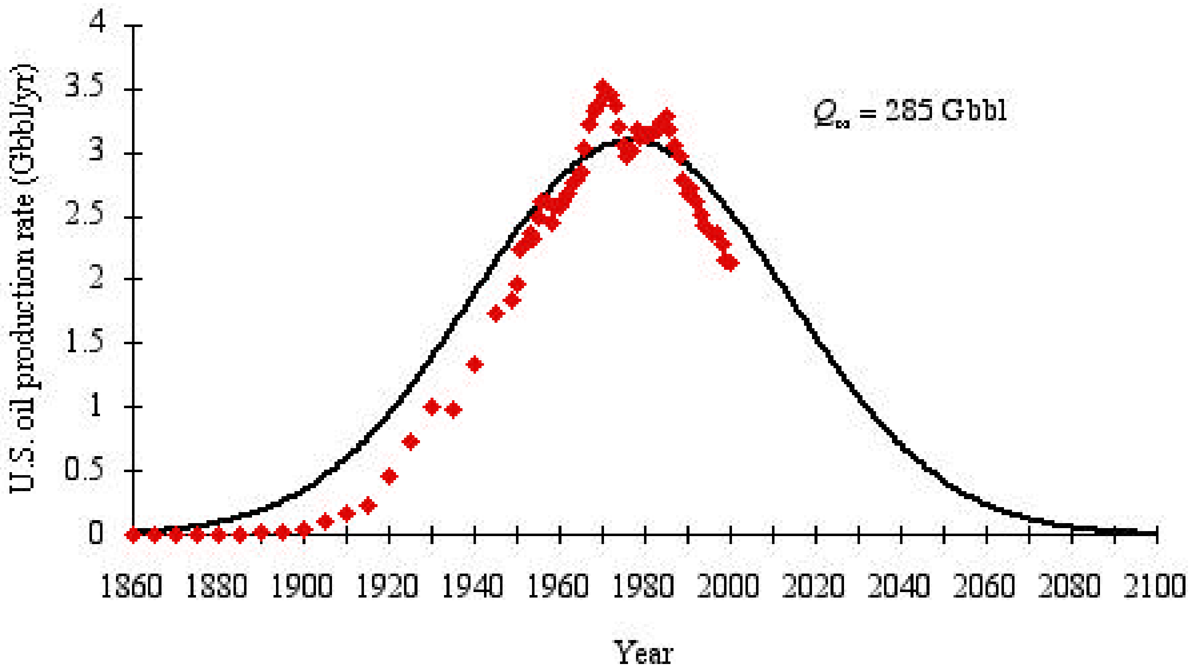
$$\sigma = 26.65 \text{ years}$$

(corresponding to a full width at half height of about 63 years for the normal curve)

The graph shows that Hubbert was just about correct!

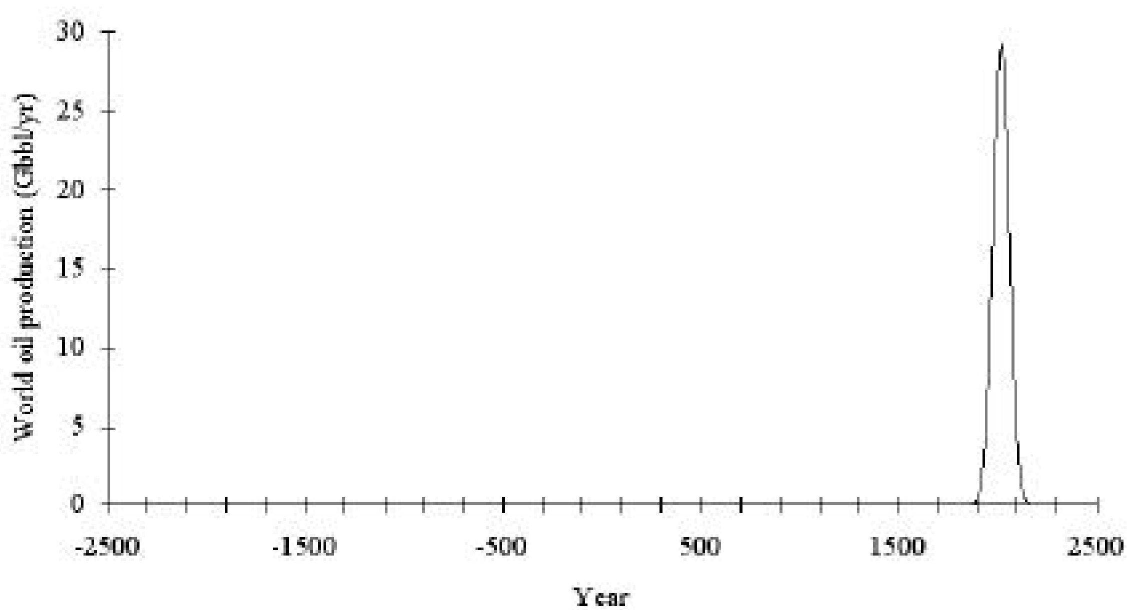


The next curve shows that *there can't be* 30% more oil lurking under the U.S.



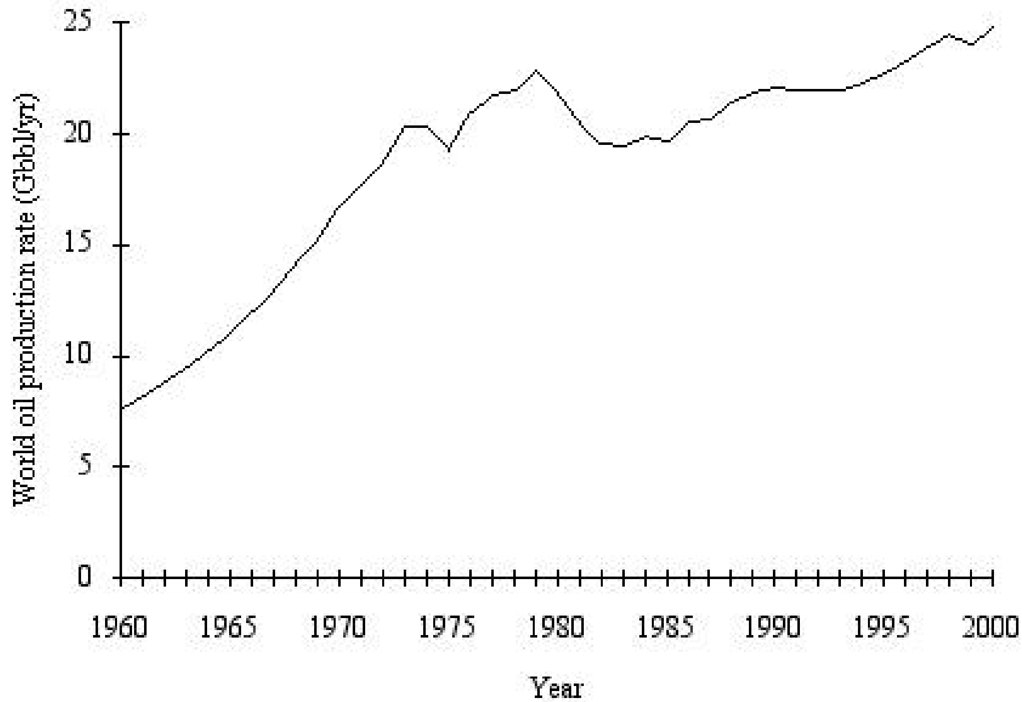
The Hubbert “blip”

Hubbert’s vision of the history of human exploitation of oil compared to a relevant timescale.

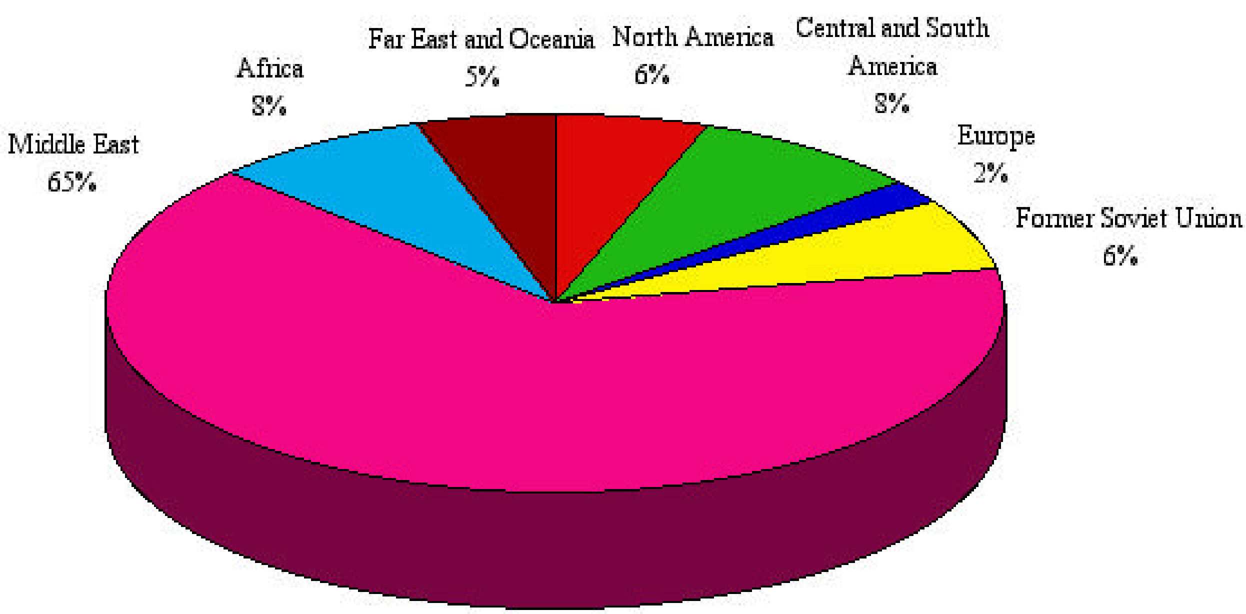


What's happened to world oil:

Short term history, 1960-2000:



Where does world oil come from?



Popular estimates of world oil reserves:

Oil & Gas Journal:
1017 Gbbl

World Oil:
981 Gbbl

BP Amoco:
1046 Gbbl

While this might be assumed to *last* another century, since it took a century to use 900 Gbbl, this is belied by the exponential nature of the curves.

$$900 \text{ Gbbl} + 1000 \text{ Gbbl} \approx 2 \text{ Tbbl}$$

What will happen to world oil production from now on?

We can use the shape of the existing production rate data to see what the ultimate amount of energy might be following Hubbert's idea, applied to the world.

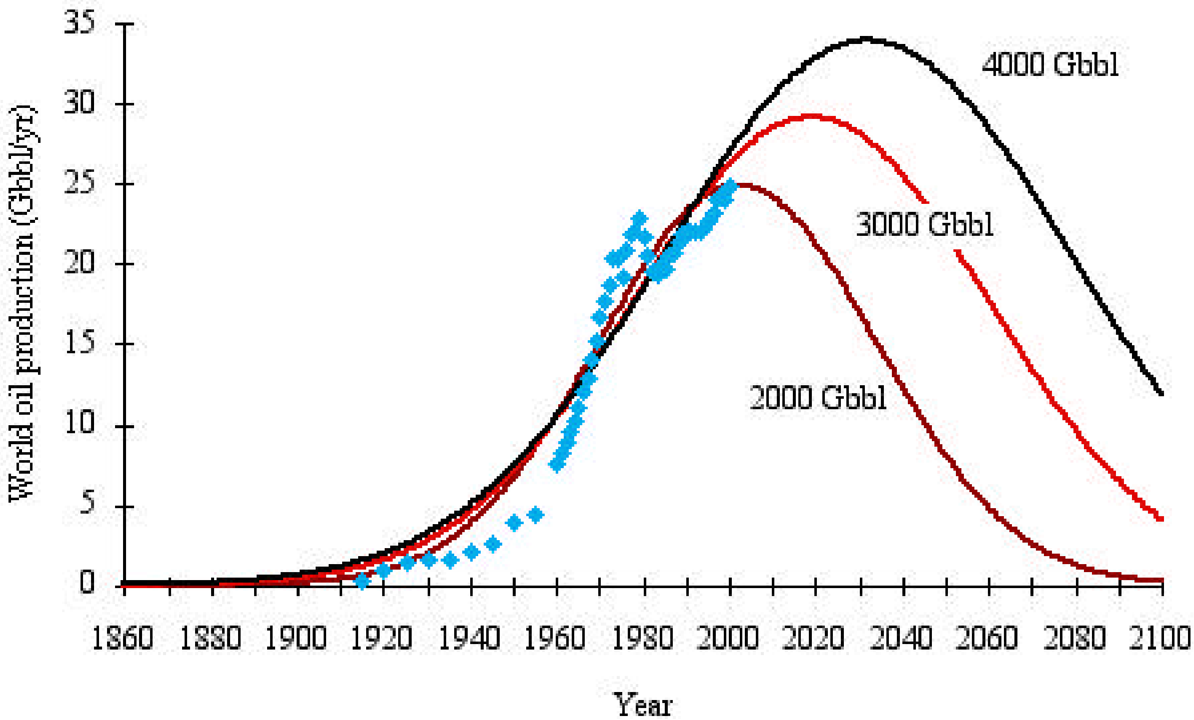
We have assumed that Q_∞ is one of three possibilities:

2000 Gbbl (2 *trillion* barrels of oil—the choice of expert opinion),

3000 Gbbl, 50% more, and

4000 Gbbl, 100% more.

Result



Q_∞ = 2 Tbbl, 3 Tbbl, 4 Tbbl

T = 2002, 2019, 2032

σ = 32 yr, 41 yr, 47 yr

Oil “runs out” in 2040, 2060, or 2100.

(Oil is left, but the price will certainly have risen substantially at lower production rates. Resources are not produced at increasing rates immediately prior to exhaustion. And 2100 is very close, see the Hubbert blip, which assumes 4 Tbbl in ultimate production.)

Note that, even though the second and third estimates are 50% and 100% greater than the original, the date of maximum production is not 50% or 100% farther in the future. Bartlett was the first to point out that

"for every new billion barrels of oil added to the estimate of the world's [estimated ultimate recovery], the date of the world peak production is delayed by approximately 5.5 days!"

(emphasis in original)

Think about this:

We have pumped out 900 billion barrels so far in a century of exploitation.

A billion barrels is a lot of oil.

That extra amount would only delay the day we run out by
5.5 days.

The fits suggest

2002

as the year of maximum production *if* reserves plus produced is 2 Tbbl!

What do experts (independent of Hubbert's analysis) say?

"Pessimists"—

Colin Campbell and Jean Laherrère: Maximum in or before

2010

"Optimists"—

Maximum *before*

2020

Campbell and Laherrère say

"global discovery peaked in the early 1960s and has been falling steadily ever since."

Free marketeers say that the markets will produce the oil when the price rises. Campbell and Laherrère note that when crude oil prices hit highs in the 1980s,

"explorers ... scoured the world for new fields. They found few."

When is the age of oil going to be over?

SOON