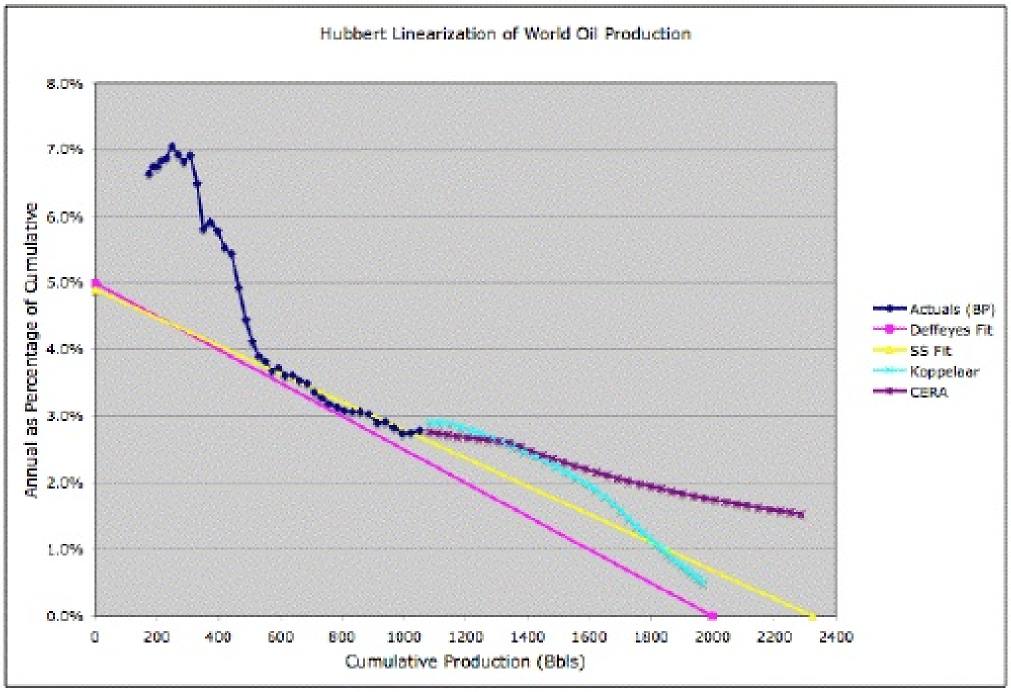
The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Another Way of Looking at CERA

Posted by Stuart Staniford on September 14, 2005 - 8:05pm
Topic: Supply/Production

In this post, I want to investigate how some of the bottom-up projections we've been discussing here look from a top-down perspective. Here's the graph, which I'll explain below the fold. (There's also a bigger version of it down there for your viewing pleasure).



Technorati Tags: peak oil, oil, gas prices

Methodology

The idea behind this kind of graph is as follows. Hubbert's model of total oil production is that it follows a logistic curve. The logistic curve is a famous mathematical model for exponential growth in a finite system. It was originally derived by Pierre Verhulst in 1838 for modeling human population, but has since been widely used in ecology, economics, epidemiology, marketing, and no doubt many other fields. My own connection with the equation is that I rediscovered it in the middle of the night during the spread of the Code Red computer worm, and showed that it predicted the spread of the worm fairly well.

In terms of oil production, the differential equation looks like:

$$dQ/dt = kQ(1-Q)$$

Here, Q is the cumulative production as a proportion of the ultimately recovered resource, t is time, and k is a constant that sets the width of the peak.

The solution $Q(t)$ to this equation is a sigmoid function, and the derivative is the famous Hubbert peak. The idea behind the equation is that early on, the oil industry grows exponentially - the annual increase in production is proportional to the total amount of knowledge of resources, oil field equipment, and skilled personnel, all of which are proportional to the size of the industry. Thus dQ/dt is proportional to Q.

Later, however, the system begins to run into the finiteness of the resource - it gets harder and harder to get the last oil from the bottom of the depressurized fields, two miles down in the ocean, etc, etc. The Hubbert model assumes that all of this complexity just comes down to that annual production gets an extra proportionality term of $(1-Q)$ - the amount still to produce.

Now, there's a nice trick which I learned about from Deffeye's book "Beyond Oil", but I don't know if he thought of it or got it from somewhere else. The idea is that if we plot $dQ/dt / Q$ versus Q, the above equation says that it should be a straight line, since

$$dQ/dt / Q = k(1-Q)$$

(excuse the lousy HTML math). So we plot the ratio of annual production to cumulative production to that date, versus cumulative production. In his book, Deffeyes does this on p37 for US oil production. In the beginning, the data are crazy, but after about 1958, they settle down into pretty much a linear regime (with a little noise) that has held good ever since. The nice thing about this method is that you do not need to **input** an estimate for the URR. Instead, you extrapolate the straight line, and it **tells** you the URR. Deffeyes gives a US estimate of 228 billion barrels. Then you can take a point half way, and that fixes the location of your smoothed Hubbert Peak, which Deffeyes reports as 1976 (but noise actually means the year of highest production was 1970). Note that what Deffeyes is looking at is total production including Alaska, not just the lower 48 states as Hubbert was.

It doesn't work quite as well for global statistics, since the world as a whole is less mature in oil production than the US. But there does appear to be a generally similar pattern where the data is crazy until about 1983, and then settles down to a fairly linear pattern till today. This is shown on p43 of "Beyond Oil". Deffeyes fits a line that gives a URR of 2 trillion barrels, and derives his famous estimate of Thanksgiving 2005 for the peak of the smoothed curve.

I wanted to look at various proposals for future oil production in the context of this picture. Now, Deffeyes doesn't cite his data source (which is really annoying). What I did was to take the data from the BP Statistical Review of World Energy 2005, which has oil production numbers from 1965 to 2004. They define oil production to include conventional oil, syncrude from tar sands and oil shale, and gas condensates. They do not include coal-to-liquids (CTL). I think there's only a tiny amount of the latter in South Africa, so presumably it doesn't matter in production to date. But otherwise, the numbers claim to be all-in.

The BP report doesn't have any data for before 1965. To calibrate my graph, I measured off one point from Deffeyes book - he labelled the 1983 dot, and I estimated cumulative production then at 529 billion barrels. Then I used the BP annual numbers to work backwards and forwards in cumulative production, and built my own graph. That's the blue **Actuals (BP)** line in the above graph. You can see the linear regime fairly clearly, as well as the fact that the model isn't that great before 1983.

The Projections

Deffeyes Fit

Having the actuals plotted, the next thing I did was to put Deffeyes' straight line fit into the picture - that's the pink line labelled **Deffeyes**. That's his 2 trillion barrel URR, peak in November 2005 line. As you can see, there's a problem. His line fits **his** data, but it doesn't fit the BP data as well as it might. Since he doesn't cite his data, we don't know exactly why, but in general there do seem to be systematic errors between various oil production times series of at least a few percent, so that's presumably what's going on here. Hopefully the Joint Oil Data Initiative will cause everyone to start telling the same story.

My Fit

To give us a better straight line, I added the yellow curve, which is an eyeball fit to the linear regime (I'm not going to get fussy and do a computer regression when we have systematic problems in the data as large as we seem to have here). The yellow line has a URR of 2.325 trillion barrels, and that gives a smoothed peak in approximately **2007**.

Rembrandt Koppelaar Projection

Next, I took Rembrandt Koppelaar's recent projection, and put that on the picture too (pale blue line). It looks like Rembrandt has been working off yet a different set of data (the IEA statistics) which are a little bit higher than the BP numbers so there's a slight discontinuity between the start of his curve and the end of the BP actuals. But even if you imagine lowering his curve by a little bit, it's still clear how he relates to the Hubbert fit: he's more optimistic in the short term (going up to a peak in 2013), and then towards the end gets more pessimistic as he heads down to a roughly similar URR just over two trillion barrels.

Cera Projection

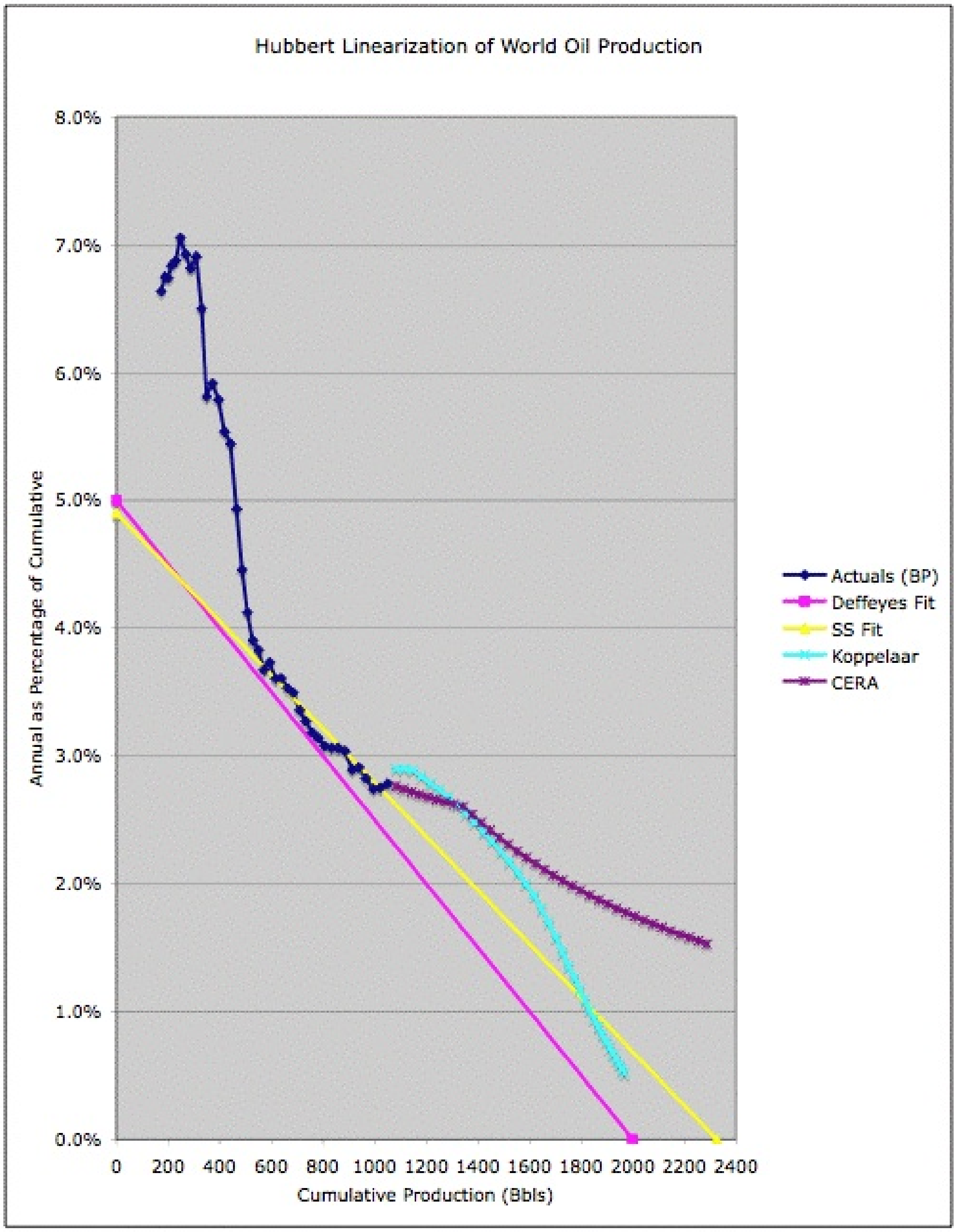
Finally, I put CERA on there. I don't really have precise information on their scenario, but they report in the press release, that capacity can go up by 16 billion barrels by 2010, or maybe a bit longer if there's delay and disruption, and that the peak will be in the "third or fourth decade" of this century and be a bumpy plateau that lasts "several decades". So I built a scenario that goes up from current production at 2% a year till it gets to 96 mbpd (16mbpd over BP's 2004 number). They reach that in 2013, and I assume they are then flat until 2040. That's the purple **CERA** line in the picture. If CERA wants to give me more precise numbers about their scenario, I'm happy to replot their curve. As I have it at present, they are headed off to a URR of 4 trillion barrels or somewhere thereabouts.

Summary

The difference between Deffeyes' line and mine is a data problem. Koppelaar is basically assuming that we can pull in a bunch of production early, and then, later on, will drop faster later than the Hubbert model predicts. I think the only remotely possible interpretation of CERA's line is that we will be making very large scale use of oil shale, tar sands, etc - with the eventual URR from those reserves being comparable to what we get from conventional oil.

But I think what they are also effectively assuming is that those reserves can be ramped up as fast as conventional oil ramps down. That, I think, is a very problematic assumption, given that those alternatives have EROEI on the front side of their peak an order of magnitude poorer than EROEI on the front side of the conventional oil peak, and heaven knows what it's like on the back side of their peak. I don't see how the curve today can possibly extrapolate in the way they suggest. Not to mention the lousy climate (and us poor suckers that have to live in it). But those are subjects for another day.

Finally, here's the big version of the graph:


Hubbert Linearization of World Oil Production
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Annual as Percentage of Cumulative
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Cumulative Production (Bbls)
Actuals (BP)
Deffeyes Fit
SS Fit
Koppelaar
CERA