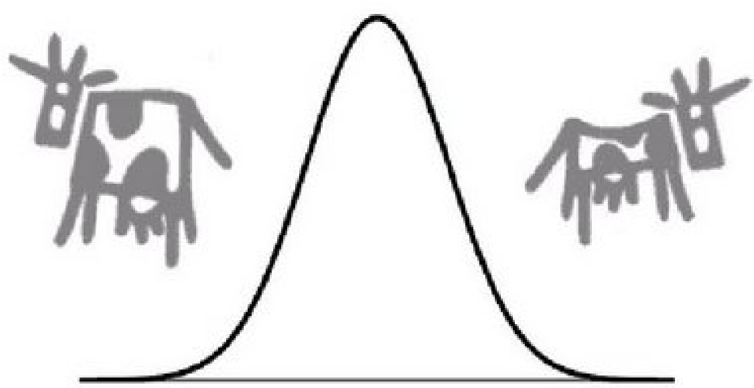
No peak oil yet? The limits of the Hubbert model

Posted by Ugo Bardi on January 17, 2011 - 10:42am



The Hubbert model says that, within a reasonably large region, oil production should follow a bell shaped curve. When the model is applied to worldwide oil production, the maximum level of production is called "peak oil." Fat cows and lean cows are commonly seen as the consequence of being on one or the other side of the curve. Peak oil has been often predicted to occur within the first decade of the 21st century, however, up to now, we are not seeing a well defined peak but, rather, a plateau that has been going on from 2004. This article examines the situation and argues that Hubbert's model, as all models, is valid only in some specific conditions. In particular, we may expect the production plateau to keep going as long as the economy can transfer to oil extraction resources from other industrial sectors.

In 1998, Colin Campbell and Jean Laherrere published an article in "Scientific American" where they predicted that the worldwide peak for oil production ("peak oil") would occur around 2004-2005. They had based their prediction on data on the available oil resources and on Hubbert's model which assumes a near symmetric, bell shaped curve for oil production. Campbell and Laherrere may have been right, at least as long as we look at the production of "conventional" oil. It may at least be argued that production peaked in 2005, although more time will have to pass before the trend can be assessed with certainty.

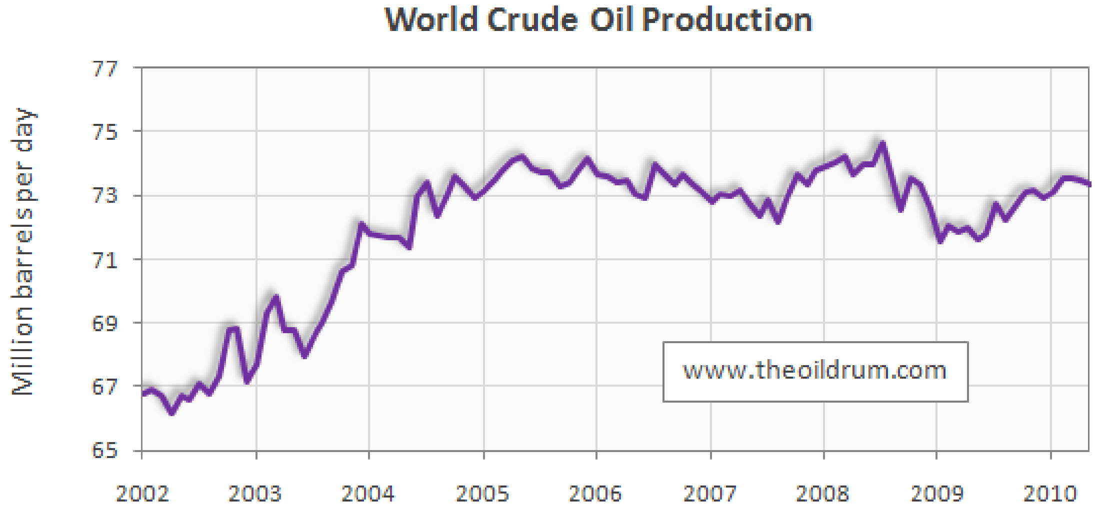


Fig 1. World production of conventional oil. Image from "Oilwatch Monthly"

If we consider production of "all liquids," that is if we include such sources of liquid hydrocarbons as natural gas liquids (NGL), biofuels, tar sands and others, it is hard to detect a peak of any kind. Production has been oscillating around an approximately constant - or perhaps slightly increasing - plateau for at least 5 years by now. The most recent data (for instance from "Early warning") indicate that production may now have exceeded the record observed in 2008.

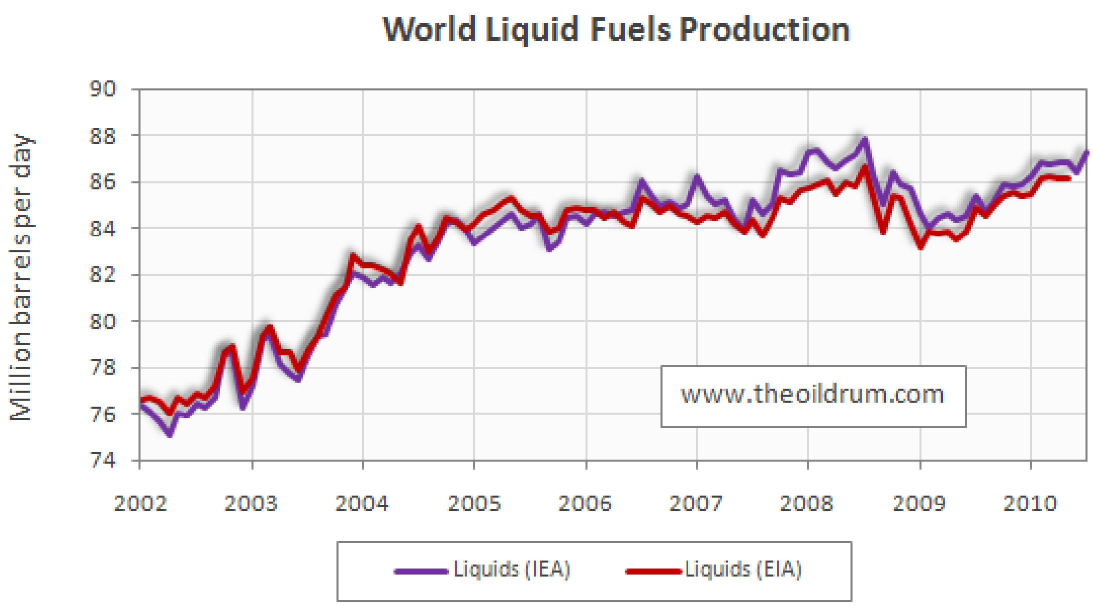


Fig. 2 World production of "all liquids." Image from "Oilwatch Monthly"

A few words of caution before going on. First, it is too early to say that the data are not compatible with the Hubbert model since it may take a few years before the peak is clearly detectable in the curve. Second, the data are relative to the *volume* produced. But a barrel of NGL or of biofuel contains less energy than a barrel of conventional crude oil. So, in terms of energy, production may well be declining even in terms of "all liquids".

Nevertheless, what we are seeing is not what we would expect: we are not seeing a well defined peak, at least for the "all liquids" case. That raises a fundamental question: is the Hubbert model a valid tool for describing the future of oil production worldwide?

We know that the Hubbert model has worked in a number of regional cases, but not in all of them. One of the cases where the model failed is that of natural gas production in the US. Hubbert himself had calculated that it should have peaked around 1973. It did peak when predicted, but it did not significantly decline afterwards. Instead, it oscillated around a plateau and, in recent times, it has exceeded the 1973 peak. A completely different case is that of crude oil in the US, where the post-peak decline is compatible with the Hubbert model. Here is a comparison of the two cases (from [EIA](EIA)). The scale is reported in terms of equivalent energy in Exajoules (EJ) with one cubic foot of gas equal to 1.1x10E+6 J and one barrel of oil equal to 6.1x10E+9 J.

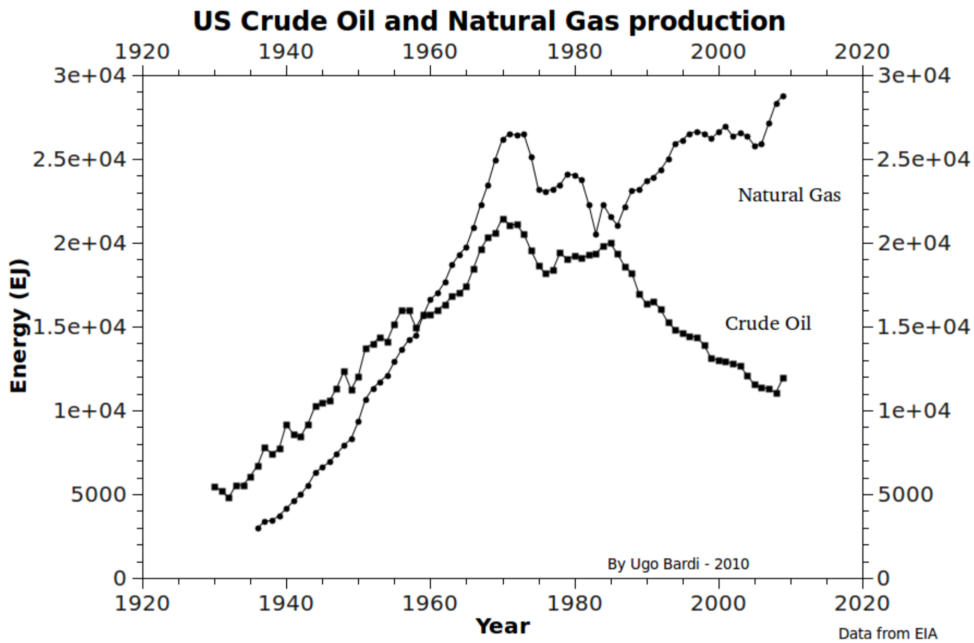


Fig 3. Production of Natural Gas and Crude Oil in the USA

The different behaviour of the two cases is striking, especially considering that we are looking at data coming from the same geographical region, the same economic, political and legal conditions. So, why this difference? We may have a crucial point, here: if world oil production will behave like crude oil in the US, it will soon decline. If, instead, it will behave like natural gas in the US, it might keep going at the present levels for a long time, perhaps decades. Then, the point is to understand what causes the difference. That, in turn, depends on the validity of the assumptions at the basis of Hubbert's model.

An interpretation of the Hubbert model is described in a post of mine that I titled Mind Sized Hubbert ." According to this view, the model is based on the concept of Energy Return for Energy Invested (EROEI). Oil is a form of energy, but extracting oil also requires energy; the EROEI is the ratio of these two energies. The core of the model lies in the assumption that the extractive industry reinvests an approximately constant fraction of the energy it produces into new extraction facilities. In this way, it can grow exponentially, at least for a while. However, the industry tends to extract first the, "easy", high EROEI, resources. With time, it must move to progressively more difficult (lower EROEI) resources. With less energy available for extraction, the growth of production slows down. Eventually, production peaks and then declines. If these considerations are set in mathematical form, the result is the bell shaped curve (see this article in "Energies").

An equivalent way to see this effect is in considering monetary costs. A lower EROEI means higher costs of extraction. As a consequence, profits go down and that reduces the capability of the industry to invest in new resources. Alternatively, the industry may attempt to increase prices in order to keep profits constant. But higher prices reduce demand and, as a consequence, production goes down - it is again the Hubbert curve.

This is a simplified view of the Hubbert model that sees it as an isolated subsection of the whole economy. However, that is an approximation, of course. The economy is more complex than that and the response of demand to price increases depends on a property that economist call "elasticity." Normally, higher prices reduce demand, but a commodity may be so crucially needed that demand remains high even for high prices. In this case, demand is said to be "inelastic." Crude oil and other fossil fuels are so vitally necessary to the economy that the vagaries of oil prices during the past few years have had only a small effect on the production curve. So, oil is a classic case of inelastic demand (within limits, of course).

The consequence of a nearly stable demand coupled with high prices is that the industry can maintain its profits and keep investing in new production facilities, even of high cost resources. In practice, the extractive sector takes energy and resources from other sectors of the economy and uses it to extract low EROEI resources. In this case, you can't expect to see a bell shaped production curve any longer.

These considerations explain the different behaviour of oil and gas in the US. Both are badly needed commodities for the economy and in both cases demand is basically inelastic. But there is a difference. Oil can be imported from overseas by tanker. Gas, instead, needs to be liquefied at low temperatures and that requires special facilities, it also requires special ships for transporting and more - all that is very expensive.

As a result, after the national peak, in 1971, the cheapest route for the US economy to obtain oil was to import it from overseas and, hence, there was no need of an effort to develop high cost resources within the national borders. Oil consumption did not decrease but imports grew gradually and today account for almost twice as much as the national production.

The opposite holds for natural gas, which was very expensive to import. As a consequence, it made sense to invest into developing new domestic resources, even expensive ones. That has been going on from 1973, the peak date for gas in the US. The last round of the process is the recent trend of exploiting the so called "fracture gas". The technology is not new, but it is being used now because all other sources are declining. And if it is used only now, it means that it is more expensive. But the US economy needs gas and - so far - it is willing to invest as much as needed in order to obtain it. As a result, the US domestic production of natural gas remains today almost ten times larger than imports.

We see in the following figure the behaviour of gas prices in the US. The data are from EIA and are corrected for inflation using the data reported in usinflationcalculator .

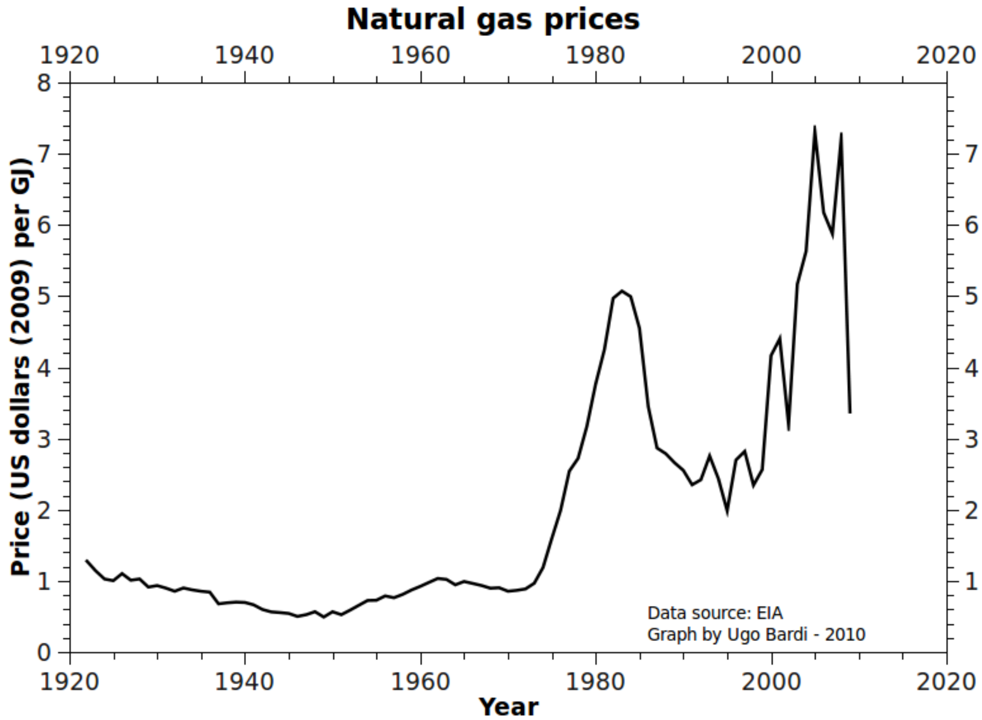


Fig 4. Gas prices in the US

The price increase of natural gas after the 1973 peak may have been sufficient to maintain production at nearly constant levels. Note, however that higher prices were not sufficient for maintaining the rapid rise in production that had been the rule before the 1973 peak. The best that it was possible to do was to keep it approximately stable. Note also that prices have been rising at a rate that might be seen as exponential. If that is what is needed to stimulate production, how long can it last before gas prices become so high that many people can't afford to pay them? Inelastic cannot be forever.

Now, let's see if we can apply these considerations to the case of crude oil worldwide. Oil EROEI has been plummeting in the past decades, as we can see in this well known graph by Cutler Cleveland, reported on The Oil Drum by David Murphy

Fig 5. Crude Oil EROEI in the US.

So, the Hubbert model tells us that progressively lower EROEIs should cause a decline in production. However, we badly need liquid fuels and, since we cannot import fuels from another planet, we can only invest money and energy into extracting it from low EROEI resources. That is what the industry is doing, stimulated by higher prices. Here are, for instance, some recent data about tar sands, from Early Warning . Production of liquids from tar sands is nothing new, but it is starting to play an important role in oil availability.

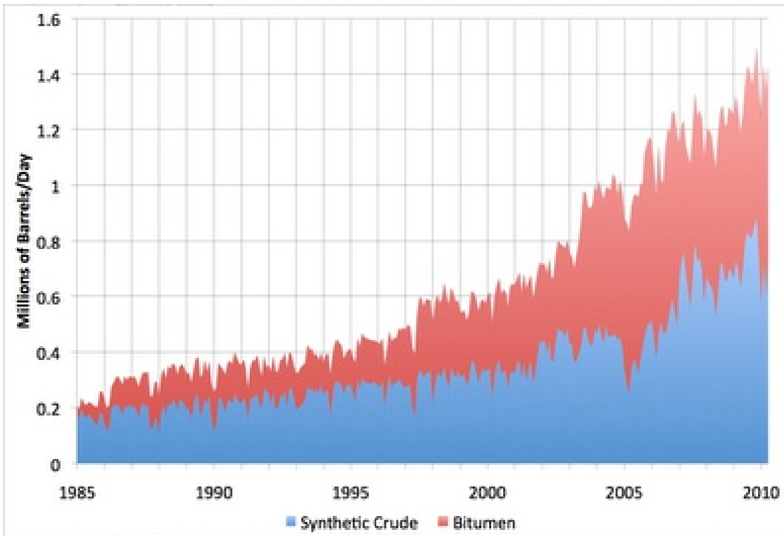


Fig 6. World production of liquid fuels from tar sands.

Something similar is happening with biofuels, which have been growing rapidly (data from Koppelaar's OilWatch Monthly)

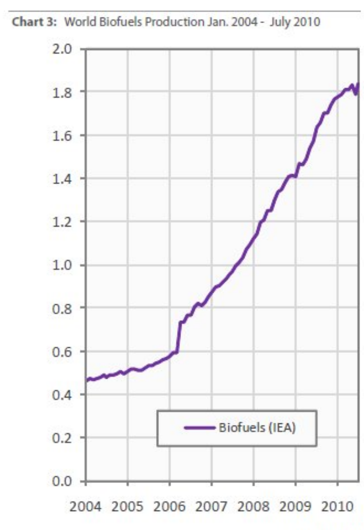


Fig 7. World production of biofuels (the vertical scale is in million barrels per day)

Note also that even the US domestic production of crude oil seems to be deviating from the Hubbert curve in recent times; it is - again - an effect of rising prices that have spurred new investments in extraction facilities.

So, the world's economy is diverting resources in various forms to oil extraction in order to keep the vital supply of liquid fuels to the world. But that comes at a cost. Energy and resources needed to keep on producing from low EROEI sources must come from somewhere: some other sector of the world's economy must do without them. In other words, the net total energy available to the economy does not increase and may actually go down.

Biofuels are an interesting example of this phenomenon. The EROEI of a biofuel such as corn ethanol is low, around the value of one or little more. But you can use energy from coal to make ethanol from corn and, doing so, you are effectively transforming coal into a liquid fuel. But coal used in this way is not available to the economy for other purposes - the net energy available to society does not increase. This kind of phenomenon occurs also for other resources and the reduced availability of energy is a possible explanation for the world's economic troubles of recent times.

So, what is it going to happen in the future? We are moving, here, towards a completely uncharted territory. It has never happened in modern history that a crucial non-renewable commodity has been exploited to the "peaking point" worldwide, as it is happening now for fossil fuels. Surely, the mechanisms of the economy will try to maintain the production levels of a commodity which is indispensable for our society: liquid fuels. For this purpose, resources will continue to be removed from other sectors of the economy, from coal for instance, and used for boosting production of liquid fuels. That will go on as long as possible - but not forever: the economy is not infinitely large and the resources available are finite. We cannot say exactly when but, at some point, the production of liquid fuels will have to start declining. We cannot say with certainty which shape the decline will take, but some models such as those of The Limits to Growth that take into account the whole economy indicate that decline might be abrupt.

If you expect a model - any model - to be able to predict the future you are going to be sorely disappointed. The Hubbert model is no exception, but many models can tell you enough about the future that you may prepare for it. It doesn't matter if models are approximate and in some cases don't even work; it is the way one uses them that makes the difference. A feather falling in air does not mean that Newton's law of gravitation is wrong. It only shows that you must use the model understanding its limits. The same is true for Hubbert's model: the case of natural gas in the US doesn't mean that the model is wrong. It only shows that you must understand its limits. If you do, the Hubbert model can tell us a lot about what is happening and about the reasons for the troubles we are having. And that should tell us something about where we are heading to; there is still some time, not much, to get prepared.

References

A good historical account of the career and of the work of Marion King Hubbert can be found at this page by Ron Swenson

The March 1998 paper on Scientific American by Colin Campbell and Jean Laherrere can be found at this link on "dieoff.org"

The paper by Ugo Bardi and Alessandro Lavacchi that describes the "mind sized" interpretation of Hubbert's model can be downloaded at this link at mdpi

About the EROEI of biofuels, there is a classic paper by Patzek and Pimentel. It has been contested many times, but the basic idea that corn based ethanol has a very low EROEI seems to remain valid.

A discussion of the concept of elasticity in economics can be found in this paper by Ron Cooke.

About the evolution of the ratio of net and gross energy available to society, see this document by Charles Hall

A description of the relation between "peak oil" and "The Limits to Growth" studies can be found in this post by Ugo Bardi