ASPO 7th annual conference – Barcelona, Spain
October 20th 2008

Forecast of liquids production assuming strong economic constraints

Jean Laherrere & Jean-Luc Wingert

Abstract

The main purpose of our study is to determine the shape of the world "oil production" curve in the event of an economic crisis (above-ground constraints). In the first part of the paper, "oil production" is forecasted, it takes into account "all liquids" sources, including refinery gains and synthetic oils (XTL). Liquids production is forecast under three scenarios corresponding to the following ultimates: mini = 2.7 Tb, most likely = 3 Tb and maxi = 4Tb, assuming only below-ground constraints. These ultimates are estimated from the compilation of technical field databases. The most likely case shows a peak around 2015 at less than 90 Mb/d. In the second part of the paper we consider two economical crisis scenarios, one for what we called a "hard" crisis and the other for a "soft" crisis. We then see what are the consequences of these two scenarios on the oil peak. In the case of the "hard" crisis, the peak would be around 2020 and in the case of a "soft" crisis it would be earlier (2012) but with another point at almost the same level of production in 2027. If these scenarios do not change the big picture of the oil peak, they provide a more precise representation of the "bumpy plateau".

Table of content

Introduction

The impossible separation between "below" and "above" ground constraints

The constraints on oil production can be divided in two categories: above and below ground. Although we do need this distinction for practical reasons, the separation is quite artificial. Oil production is a human activity and if men do not have any will to extract oil, nothing appends. Unfortunately there is a very strong will to extract oil from the ground. The economical activity as it is designed nowadays is boosted by oil. Recent work by economist Robert Ayres shows that energy's contribution to the growth of GPD is much more important than the price paid for it by economical agents. In other words, oil is cheap, even at 150$ per barrel. In 1980 it was higher than today if the price comparison is not made in absolute dollars but estimated with methods taking real inflation into account or in terms of quantity of work time at minimum wage to buy one barrel.
To study the impact of a world economical crisis on oil production, we did make a distinction between, on one side a forecast without constrain, in fact with reasonable constraints, and on the other side the same forecast to which we added the modelisation of an economic crisis. Even if this world economic crisis has been predicted by a few people for quite a long time, we consider this event as unpredicted in our model. In fact, this is quite true for the first of the two types of crisis we considered, the strong and brutal one, that could be caused by the collapse of the world financial system for instance. The second type of economic crisis, softer but longer is more difficult to model, because there is time for a quite strong mentality and behaviour change.
The first part of this paper is an explanation of the forecast with reasonable constraints, without social tensions, without any strong and fast increase of oil prices. This kind of ideal world is titled "below-ground" to be consistent with the organisation of this seminar. The result is a model with a very smooth oil peak around 2015. In the past the term of "bumpy plateau" was used to explain qualitatively that the top of the oil peak is not going to be smooth. In the second part of this paper, called "above-ground" we will design two models of what the bumpy plateau could look like.

Part I : Below-ground

After explaining why it is important to consider "all liquids" forecasts, we will evaluate and discuss the ultimate of the different types of oil taken in account.

"All liquids" oil

There are many definitions of oil. The most relevant definition to be used, as far as peak oil is concerned, is "all liquids", because it is important to know when the oil supply will not be able to satisfy the oil demand that is reported in all liquids (in 2007 84.6 Mb/d for USDOE/EIA and 85.4 Mb/d for IEA). Focussing on restrictive definition of oil leads to pessimistic production forecasts and misleads on the answer to *when oil demand will not be supplied?*

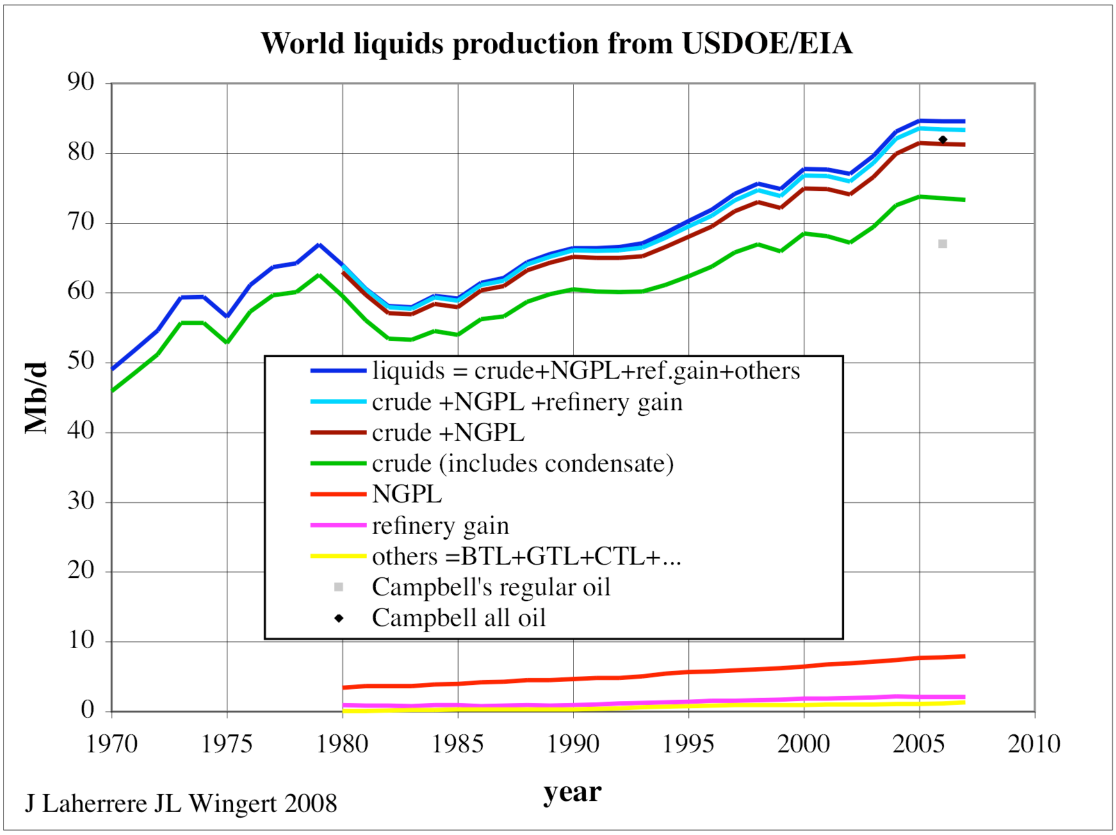
Types of oil taken in account in our "all liquids" definition

Here are the types of oil :

- Crude oil (including condensate in USDOE/EIA report because it is not separated in the US)
- Extra heavy = EH
- Natural Gas Plant Liquids = NGPL
- Refinery gains
- Other liquids being synthetic oils = XTL (CTL, BTL, STL)

The following graph is showing differences in the past production according to the type of “oil”.

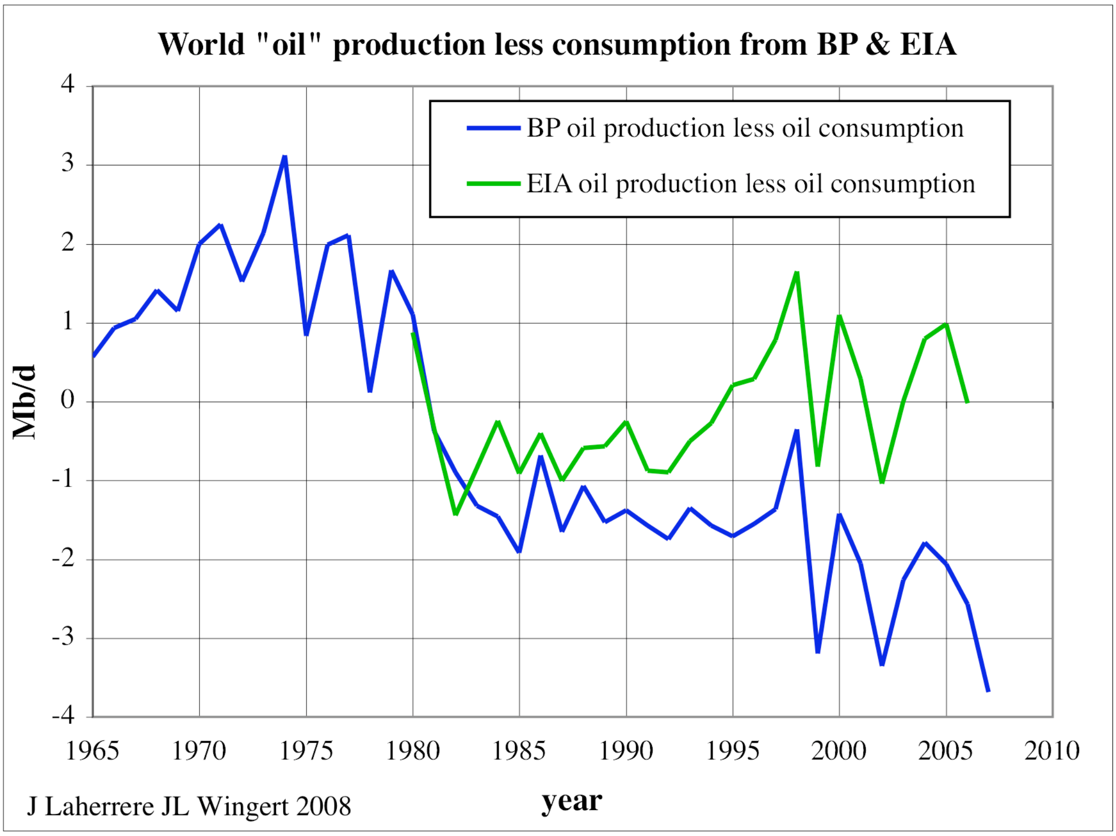
Figure 1: **“oil” production from USDOE/EIA**



On a worldwide basis oil production and oil consumption should be equal, the only possible differences are caused by the storage of oil, but this is fairly insignificant, since the strategic reserves of IEA member countries only cover 3 months of imports and do not change very quickly. Practically, there are differences between world consumption and world production, for two sources (BP and EIA), they are tracked in the following graph.

BP oil production is in 2007 3 Mb/d less than BP oil consumption. All the economists who rely on the growth of BP oil reserves to deny peak oil, should wonder, when finding that oil production is less than oil consumption, why BP reported proved reserves are growing.

Figure 2: “**oil” production minus “oil” consumption in BP and EIA**



If the long term average of EIA statistics varies around zero as it should be, it’s not the case for BP statistics. The main reason is that they do not include synthetic oil in the production but they do in the oil consumption. “*All liquids*” is the relevant data for oil consumption as we explained above. We will work with “*All liquids*” data for the production side also.

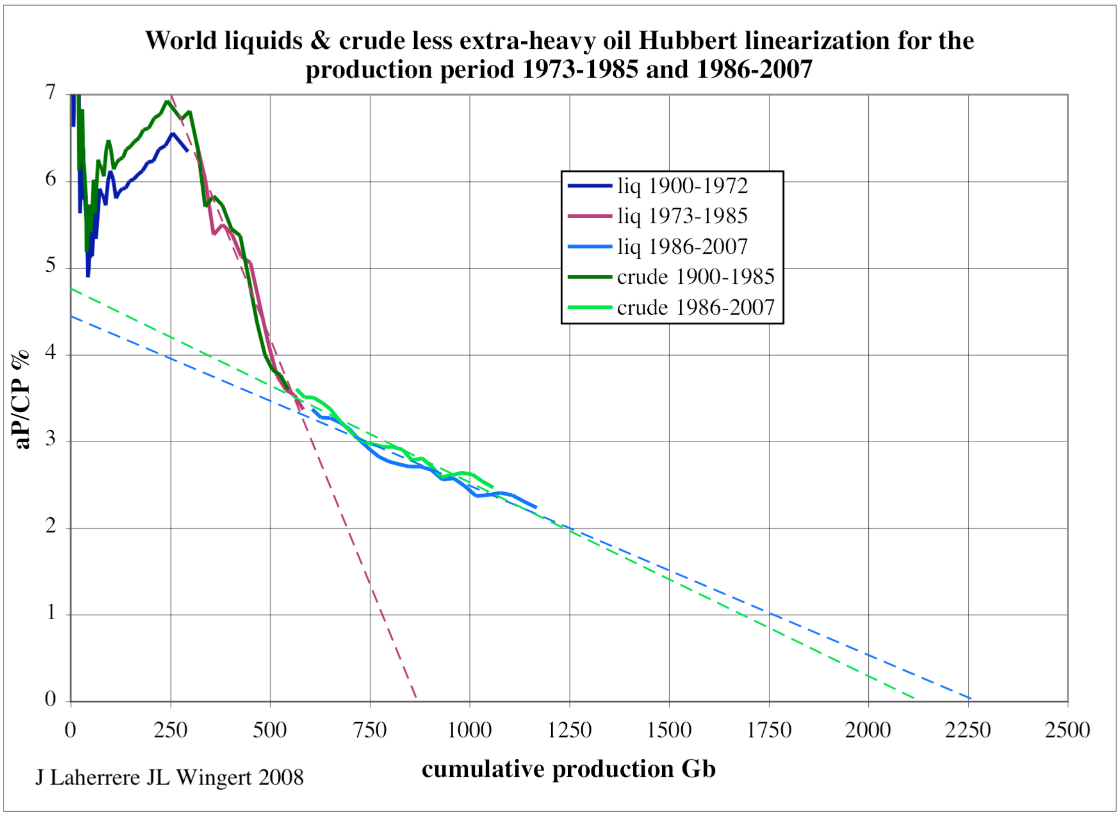
Assessment of ultimates

To forecast the future oil production we need to estimate the ultimate oil reserves, which includes the oil already produced, the oil discovered and oil to be discovered. Some authors use the linearization method which has some weak points, so we will prefer using the creaming curve method.

Hubbert linearization

The risk of this method, that we will only present shortly, is that the plot is not linear, because production does not follow a logistic curve or because production follows several logistic curves. Past production is also disturbed by economic crises or wars. Production follows rarely a perfect logistic pattern which leads to only one linear trend in the so-called Hubbert plot (annual growth versus cumulative production). Some portions are linear, but not all the curve, so it is hard to believe that the last linear portion will be the last one.
World *liquids* or *crude oil less EH* productions display a Hubbert linearization far from being one simple linear trend. There is a roughly linear portion from 1973-1985 (first oil shock to the oil counter shock) and another rough linear portion from 1986 to 2007. The coming depression could change this trend as 1985 did.

Figure 3: World *liquids* and *crude oil less EH* Hubbert linearization for 1973-1985 and 1986-2007



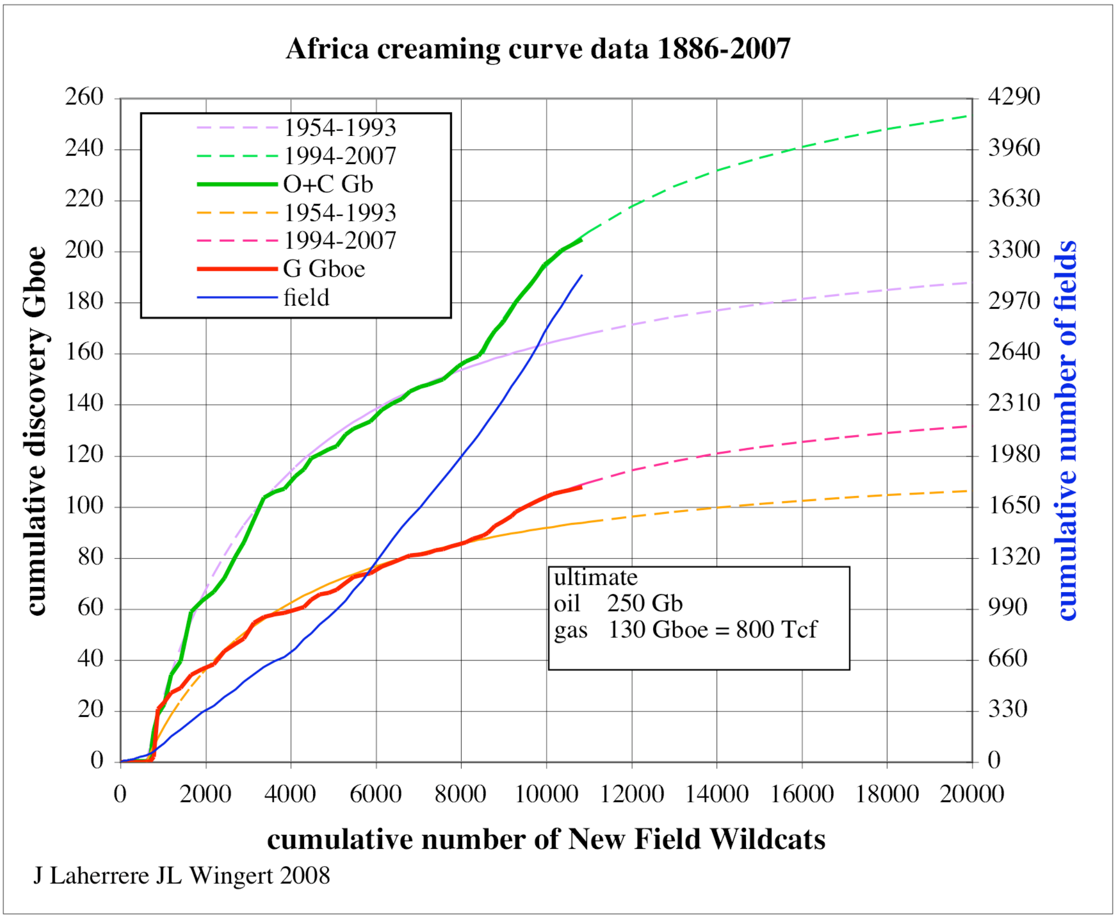
For *crude less EH oil*, the Hubbert linearization (green) for the period 1986-2007 is about 2100 Gb, but the extrapolation of the cumulative discovery fits better with a 2000 Tb, yet the accuracy is not good enough to exclude 2100 Gb. But it is obvious that the linearization for liquids (blue) trending towards 2250 Gb is wrong, because the difference between *liquids* and *crude less EH oil* is much higher than 250 Gb including EH (about 500 Gb), NGL (about 250 Gb) and refinery gains + synthetic oils (= GTL, CTL and BTL) that are difficult to estimate. We believe that the *crude less EH oil* ultimate is about 2 Tb = 2000 Gb and *liquids* ultimate about 3 Tb. The accuracy of such an estimate is less than 10 %, so 100 to 200 Gb can be added (or subtracted) in the future without changing much this rounded estimate

Hubbert linearization of oil production is a poor way to estimate ultimate. It is done by many because it is the only data they have.

Ultimate with creaming curves

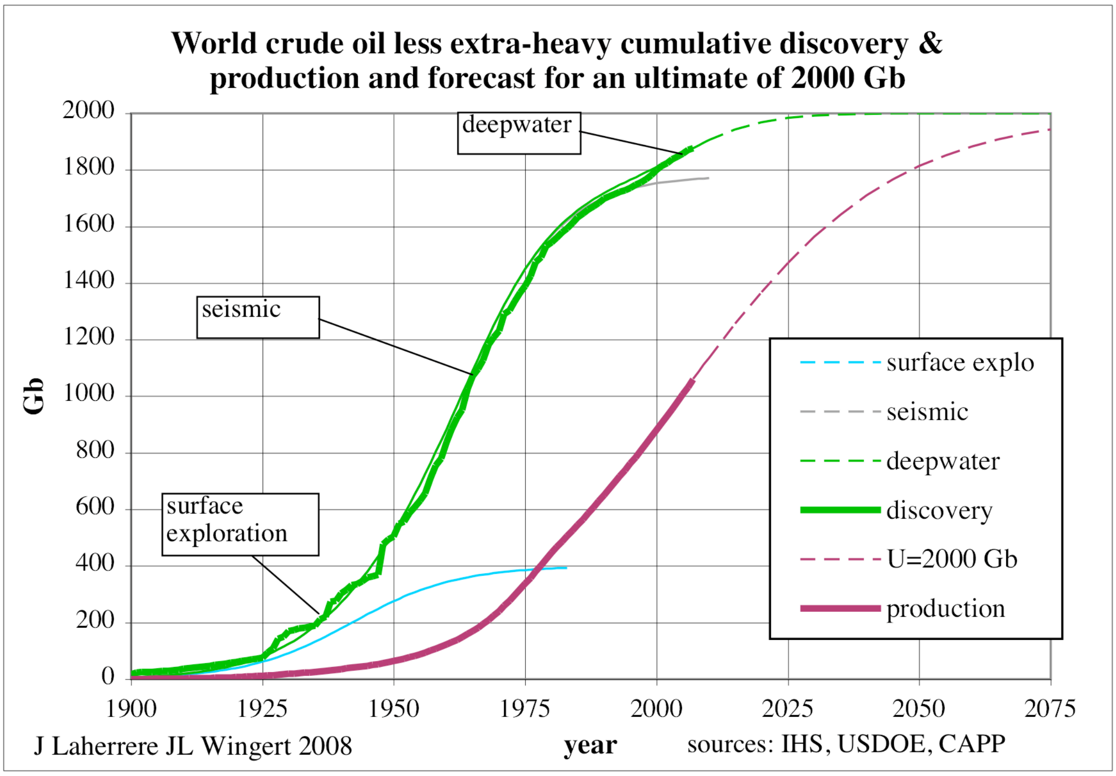
Extrapolation of discovery data (in particular the creaming curve = cumulative discovery versus cumulative number of pure exploration wells = New Field Wildcats) is a much reliable tool, when reserves estimates are close to the mean (expected value) and are backdated. It is also fascinating to find that creaming curves can be easily modelled with several hyperbolas, allowing to get the ultimate assuming that there is no new cycle. Africa displays two cycles, the last one is mainly deepwater. An important third cycle is unlikely.

Figure 4: **Africa oil creaming curve 1886-2007**



Cumulative mean backdated discovery can be also modelled versus time with one or several S curves (logistic curve). The world crude less extra-heavy oil, is modelled with three S curves, the first one corresponding to the surface exploration up to 1945, the second with seismic exploration up to 1995 and the last one being deepwater. If there is no new cycle: most of the petroleum systems have been drilled, even Antarctica with JOIDES and their potential evaluated looking at the possible source-rocks: a few wells are enough for that. The yet to find (YTF) can be deducted from the known cumulative discovery (about 1,9 Tb) and the rounded 2 Tb ultimate. YTF is less than 200 Gb for easy oil, and subsalt deepwater is easily within this volume.
The *crude less EH oil* is the **cheap** (or **easy**) oil and is properly reported.

Figure 5: World *crude less extra-heavy oil* **cumulative** discovery and production with forecast for an ultimate of 2 Tb



Another cycle ?

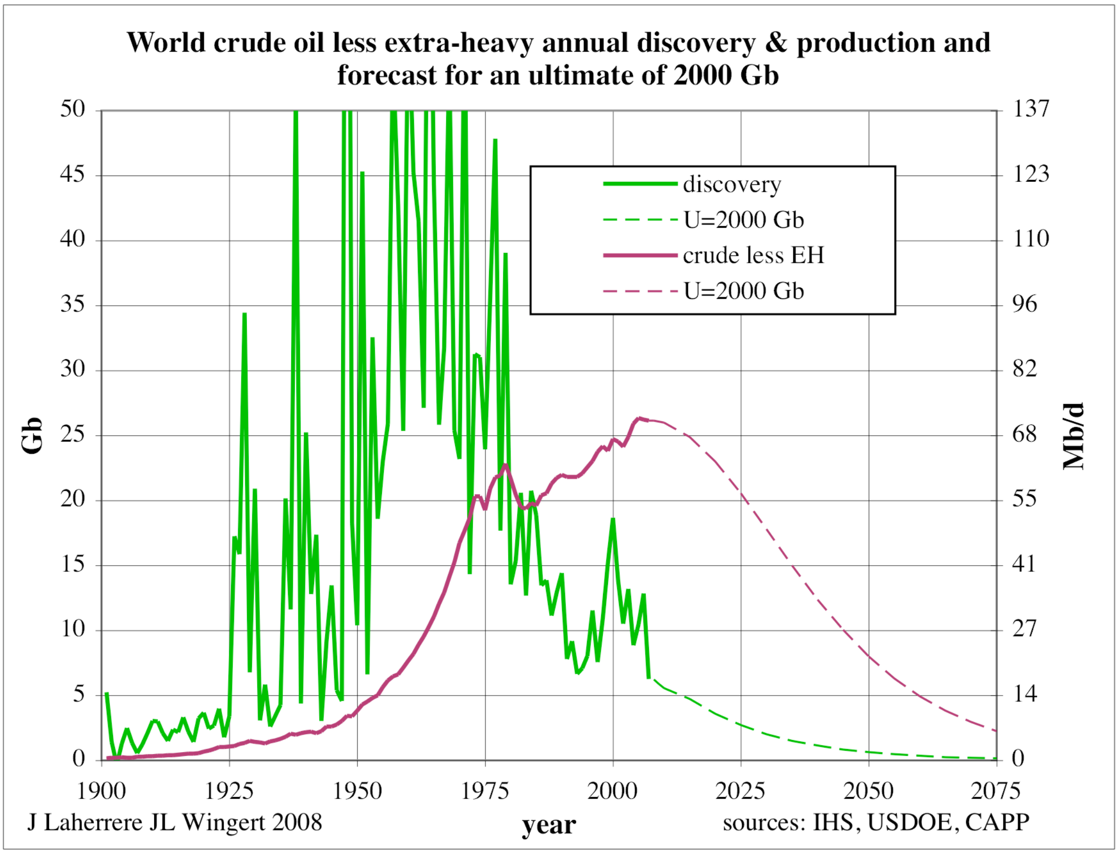
Is there a possibility that a new cycle linked with a new type of oil or new technology could change the ultimate significantly ? Let's make a short assessment of the possibilities.

- Extra heavy? The extra heavy fields where known before 1750 and have not been produced yet for some technical reasons.
- Polar oil? It is already included in the second cycle (seismic).
- Deepwater subsalt reservoirs? The recent discoveries in Brazil were quite a surprise as for the volume, but subsalt reservoirs were already known in Angola (close before Atlantic breakup)…
- Technology? The impact of technology has already been answered many times (Laherrère, 2008). Briefly, technology can help to increase present conventional production but usually decreasing reserves (East Texas, Brent, Yibal, Rabi-Kounga, Canterell).

Annual production forecast of "conventional oil" or "easy oil" only

The annual production forecast with the same ultimate shows that the *crude less EH oil* has peaked in 2006 at 71 Mb/d (discovery has peaked in the 1960s) and the 2 Tb ultimate forecasts a production of 55 Mb/d in 2025.

Figure 6: World *crude less EH oil* **annual** discovery and production with forecast for 2 Tb

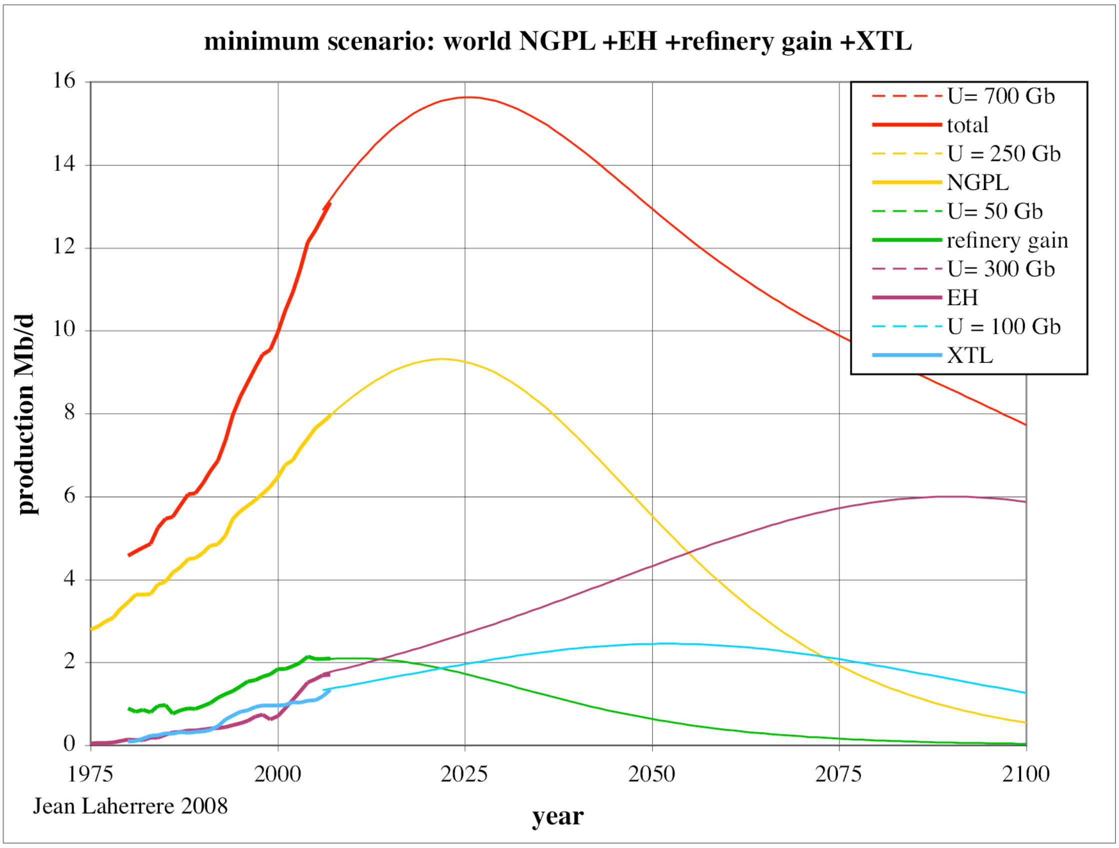


Hypothesis for some types of "non conventional" or "expensive oil"

The gap between *crude less EH oil* and *all liquids* represents EH, NGPL, refinery gains and others = XTL as defined before.

We have estimated a minimum scenario of 0.7 Tb, using the ultimate from natural gas for natural gas liquids (250 Gb) and from crude oil for refinery gain (50 Gb), and taking 300 Gb for EH and 100 Gb for XTL. For unconventional oil, the size of the tank (reserves) does not matter much, it is the size of the tap (above-ground) that matters.

Figure 7: minimum scenario for world NGPL, EH, refinery gain and XTL



"all liquids" forecasts

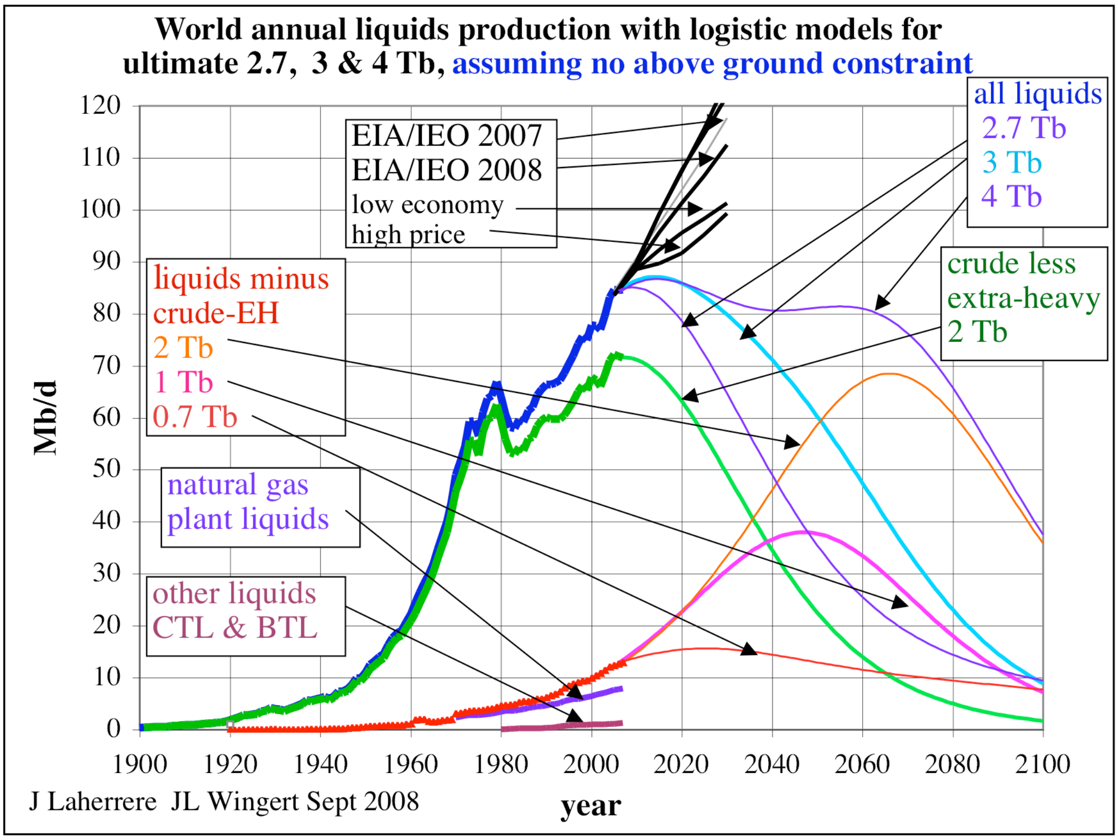
But *liquids* is the aggregation of "*cheap oil*", "*expensive oil*", *NGL*, *refinery gain* and "*synthetic oils*". The difference between the *liquids* and the *crude less EH oil* represents the *expensive liquids* and can be modelled (in red) with an ultimate of 1 Tb (likely) or even 2 Tb (maxi), but the peak is not changed because expensive liquids need time.

All liquids most likely ultimate is estimated at 3 Tb being the sum of :

- crude less extra-heavy 2000 Gb
- extra-heavy 500 Gb
- natural gas liquids and GTL 250 Gb
- synthetic oil (BTL, CTL) & refinery gains 250 Gb

Crude oil less extra-heavy (cheap oil) is modelled in the previous graph with an ultimate of 2 Tb. The rest (being **expensive oil)** is modelled (red curve) with an ultimate of 1 Tb (most likely) with a peak around 2050. The all liquids (2 Tb +1 Tb ultimate) peak is around 2015 and over 90 Mb/d, but this is theoretical assuming no constraint from demand or from investments (above-ground). We consider that the area below the curve which represents the ultimate is reliable but that the curve can vary for sometimes (down or up), yet the change in area will be recovered later. This is why, for the short term, it is better to rely on the study of already planned large oil developments = *megaprojects*. Skrebowski (Petroleum Review 2006) has done it and forecasted an oil peak in 2010 at 94 Mb/d. The Oil Drum megaprojects (crude oil +NGL) has updated the study with a peak around 2010 at 81 Mb/d
Doubling the ultimate of expensive oil (red curve), making the all liquids ultimate at 4 Tb, **will not change the oil peak date**, changing only the slope after the peak.

Figure 8: World *liquids* production for ultimates 2.7, 3 & 4 Tb assuming no above-ground constraint & USDOE IEO 2008

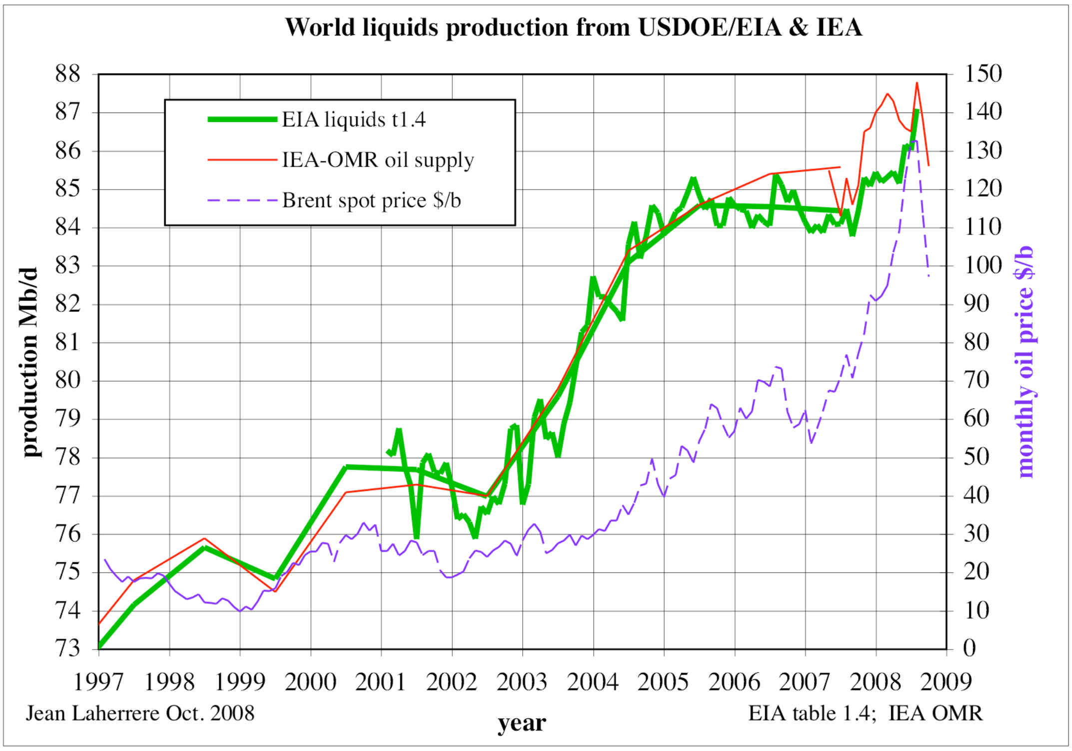


This graph is plotted like the previous one with the assumption that constraints are only from the resources, but that above-ground constraints from demand, investments or politics will not occur, which is unlikely. That is why since 2001 Jean Laherrère forecasts a bumpy liquids plateau with chaotic oil price.
USDOE has changed its 2008 forecast by adding two more scenarios (high & low economy) abnd decreasing its reference. The low economy or high price indicate a large change being about or less than 100 Mb/d.

Has the world production already peaked ?

Some said that oil peak was behind us. Of course if we mention only a part of oil production, let's say very conventional oil, yes we can see a peak, but working "all liquids" shows clearly that the "all liquids peak" has not happened yet.
On the last monthly data from USDOE on liquids, what do we see: a plateau? or just one more step as in 2001?

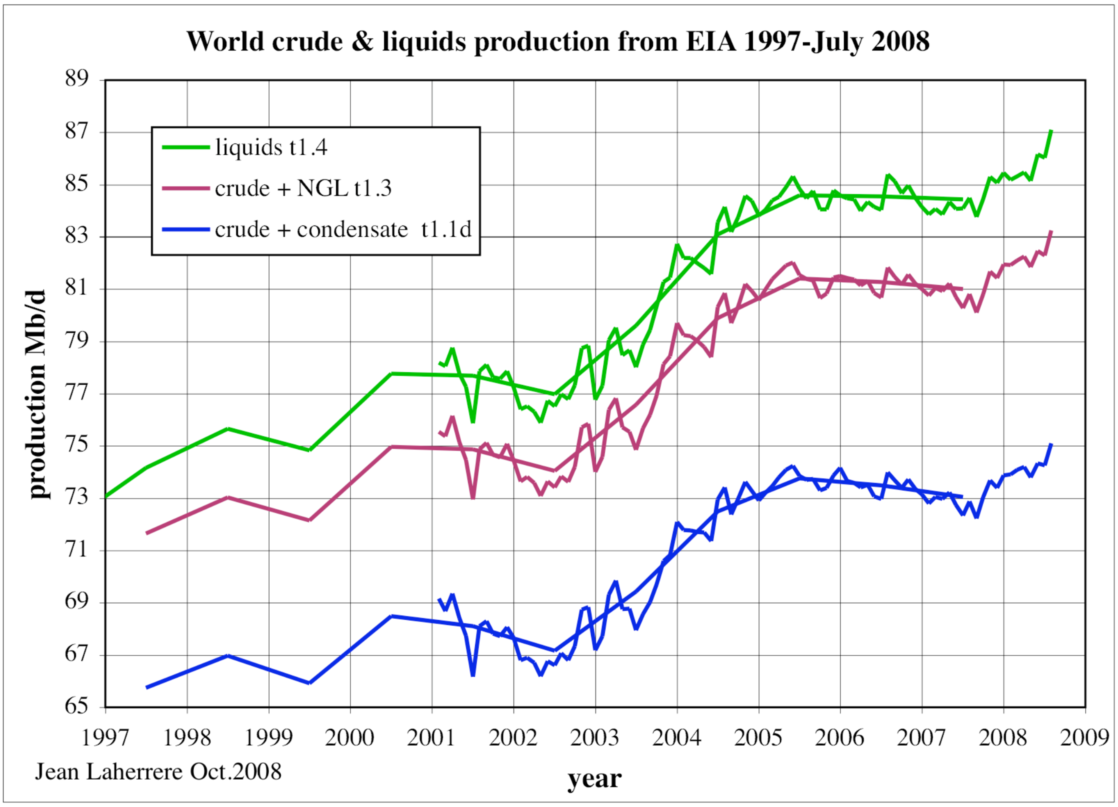
Figure 9: **World liquids production from USDOE & IEA**



The liquids production seems to be entering a bumpy plateau, with one more step, but is July 2008 the peak? (China did fill up it's strategic reserves before the Olympic Games); August's production fell by more than 1 Mb/d and same fall was observed for September (OPEC MR Oct 2008).

But the claim made by some for a 2005 peak for crude oil (which includes condensate in USDOE report) seems to be contradicted by the production of July 2008.

Figure 10: **World crude oil & liquids production 1997-July 2008 from EIA**



Underestimating technical problems ?

Many actors of the oil scene minimise or are not conscious of the technical challenges. The oil industry has made some huge improvements in the last century and a half, and will still do in the future. The age of easy oil is clearly behind us.
Time of development is always considered too optimistically, hoping that everything will be all right. But there is Murphy's law! In Nature it is not possible to make one baby in one month with nine women!
Time is an important factor which is usually underestimated. The Mc Namara law (from NASA experience) said for frontier projects that the ratio between initial proposals and reality is about π (pi = 3,14…) for cost and *e* (Euler number = 2,7…) for time.
Furthermore the modelling on our graph on figure 8 assumes that *below-ground* constraint is only geological, but *above-ground* constraint is political (civil war in Iraq and Nigeria, nationalisation in Russia and Venezuela), financial (investment on supply, depression on demand) could also change the curve, still the area below the curve has to stay the same being equal to the ultimate.
The forecast by USDOE/IEO 2008 (as IEA 2007) is mainly political called Business as Usual (BAU) to please our society of consumption addicted to growth. But EIA is now adding two more scenarios, accepting an economic low.

Part II: Above-ground constraints

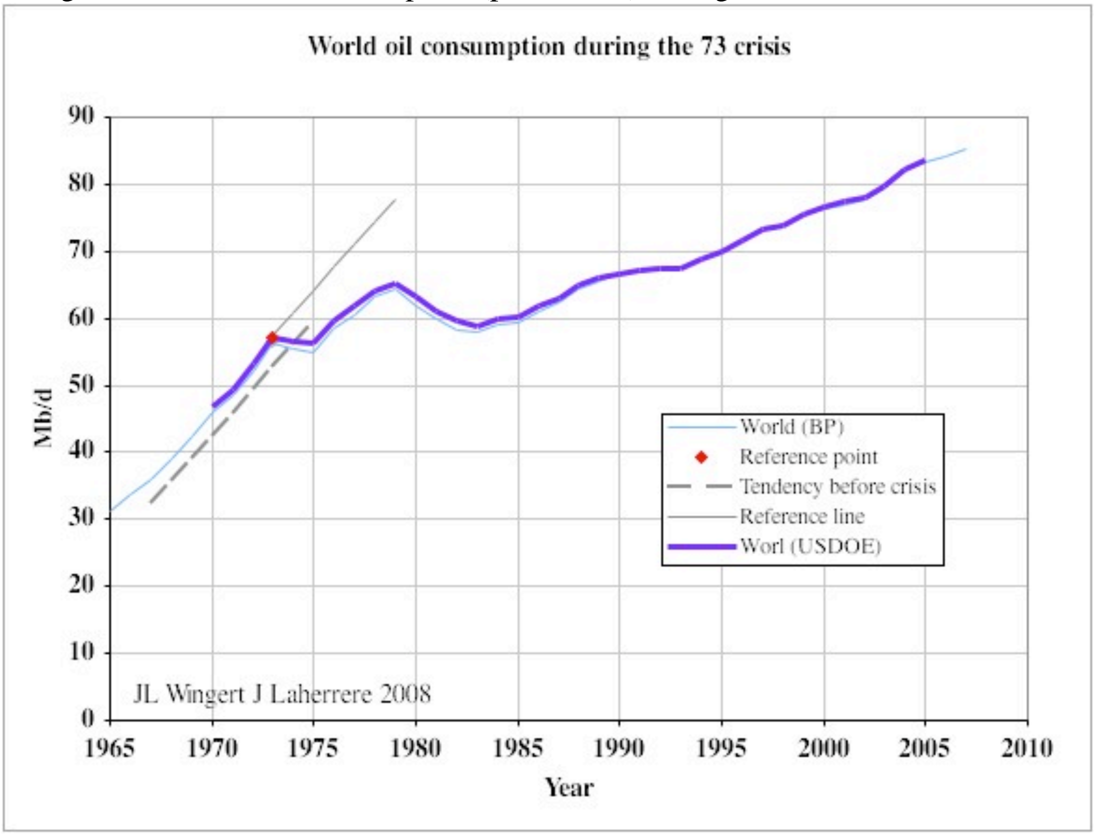
In the first part we modelled 3 peak oil forecasts depending on the amount of oil considered as ultimate reserves, we will now focus on the mean value model (ultimate 3 Tb) and build 2 scenarios to evaluate the effects on oil production of a worldwide economical crisis. The first scenario will consider the case of a brutal and quite short crisis and the other one the case of a progressive and quite long crisis. What is the effect going to be on the peak oil shape and what kind of bumpy plateau will we get? But first let's have a look at the 1970's oil shocks.

A focus on the 70's oil shocks

When we think of a sudden world economical crisis and its impact on oil consumption, the first oil shock in 1973 comes in mind. We tried to see what has been the impact of this sudden crisis on world oil production (and consumption which is the same data on a worldwide basis). For this purpose we determine the production tendency before the crisis happens and see what is the gap caused by the crisis. We compare real production to what we called the "reference line" which has the same slope as the tendency before crisis but starts at the moment the crisis begins (called reference point here). The gap can be considered as quite relevant when we are close to the crisis and loses meaning progressively. After a few years other events occur and on the long run the structure of the energy system can be modified. In the case of the first oil shock, it is meaningless to try to measure the gap after 1979 for two main reasons. The first one is that the second oil shock happened in 1979 and the other reason is that some measures to reduce oil consumption decided right after 1973 started to have effects, for instance alternative fuels to produce electricity.

Below is a graph of world oil consumption, we clearly see a decrease right after the oil embargo in 1973. The tendency before crisis is quite easy to draw, it's a straight line with a huge increase in the context of the post war boom.

Figure 11: World oil consumption (production) during the 1973-1979 oil crisis



Two years after the crisis, the consumption is 12% lower than it would have been if the tendency had continued.

"Hard" crisis scenario

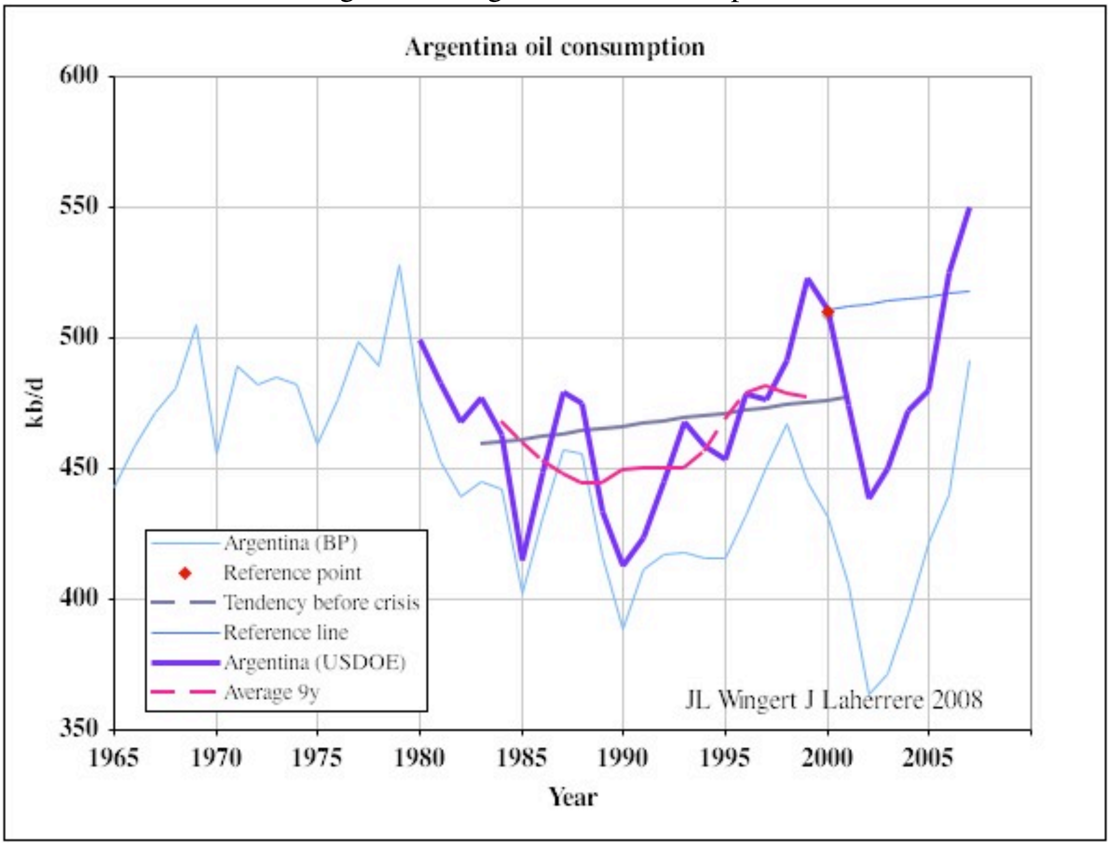
In the first scenario we model a sudden and brutal crisis. The first oil shock is an interesting reference for this scenario, but we needed a more recent crisis, and a crisis that has recovered its initial level of oil consumption. The 2001 financial Argentinean crisis is one of the best examples that can be found. We use the same method as the one described above: we determine the tendency of oil consumption before the crisis and we measure the gap between the real consumption and the theoretical consumption, if the tendency had been followed.

In Argentina, the crisis was both financial and monetary, and in 2001 the financial system collapsed, the effects where tremendous at many levels. December 2001 was a difficult month, with 27 dead in the riots, default on Argentina's debt payment, and two presidents resigned. During the 90's, Argentina had hyperinflation problems and chose to peg it's currency to the dollar. Initially the remedy was efficient and supported by the IMF, but this system also has some strong weaknesses because the monetary policy is set outside the country (in Washington, managing the dollar for its own interests). In case of deficits, Argentina could not print money but had to borrow. This implied to follow a good economic policy, but this country initially had problems, hyperinflation was the worse but not the only one, unemployment, corruption were others. It was already quite difficult to manage Argentina, but when the dollar went upwards the situation became very difficult, especially since exporting to Europe was getting more complicated because the euro was decreasing against the dollar (and the Argentinean peso pegged to it). The risk of investing in this country became greater and, after saying in April 2001 that Argentina had to keep their dollar-peg policy, the IMF finally refused a loan at the beginning of December, leading to the bankrupt of the country. The reason was to make an example that could "stimulate" other countries in keeping their budget management "straight".

The Argentinean crisis did not come in one day and it is quite difficult to set the starting point. We chose the year 2000, the economic situation had been difficult for a few years and the climax of the crisis is in 2001. It would have made sense to choose 1999, the year with the maximum oil production according to the USDOE data. With BP data, it's one year before but the USDOE data seems to be more accurate since it is corrected regularly. On a methodological point of view we cannot choose the date of what we consider the starting point, or let's say "reference point", by looking at oil consumption because it is what we are going to try to determine in our model: the impact of a crisis on oil consumption.
Another difficult point is to spot the tendency before the crisis. We did calculate an average on 9 years to have a smoother graph to work on. The problem with Argentina in our case is that there are regularly economical crisis in this country (1980, 1989, 1995 and 2001). Practically we had to look at the tendency for the 15 years before the 2001 crisis.

As we can see on the following graph, the decrease in oil consumption started one year before the climax of the crisis, we then have to take in account the tendency during the previous decade in Argentina as a reference.

Figure 12: Argentina oil consumption

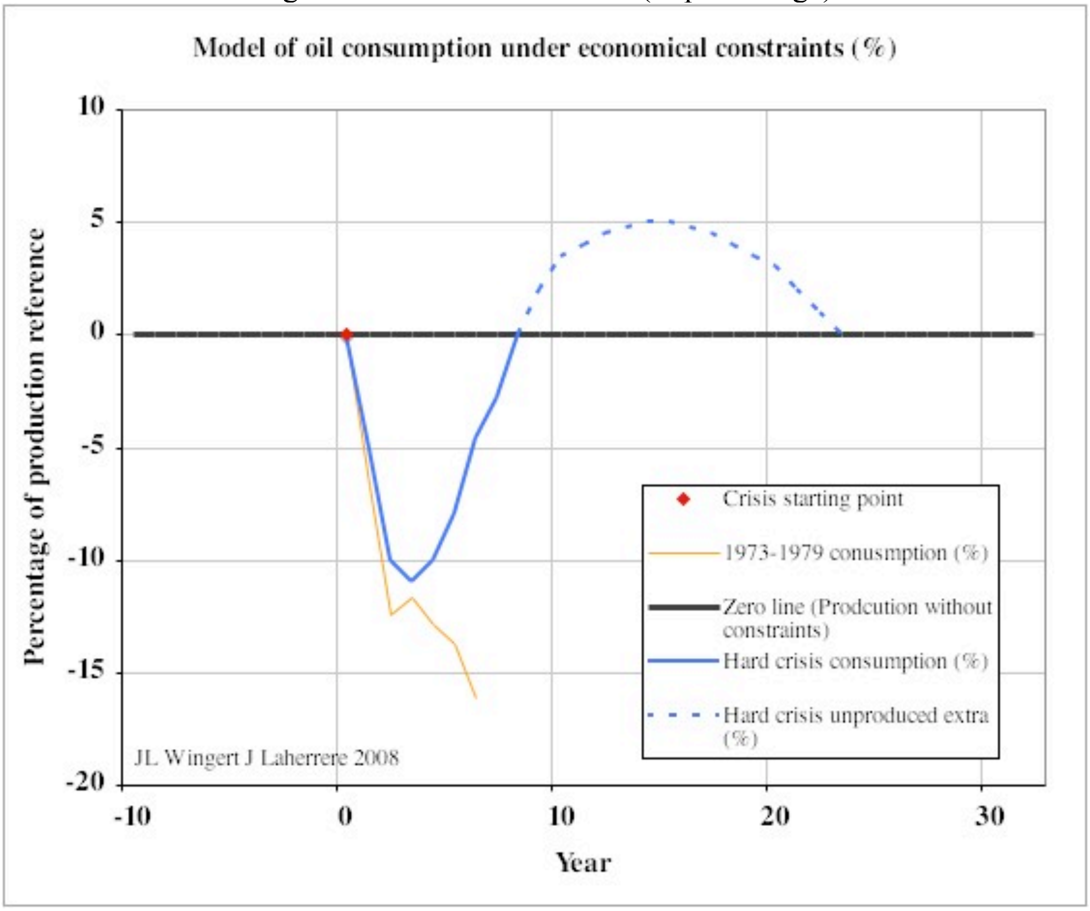


(USDOE data for 2007 is extrapolated)

"Hard" crisis model

We can now design a model using this case and the first oil shock. As we want to apply it on an oil production model without constraints, we decided to make it a "relative model". The idea is to determine what percentage of consumption is subtracted to the consumption without constraints and then to take into account the fact that there is an extra production possible of the same amount of oil that hasn't been produced during the crisis. The graph below shows the model in relative values (%).

Figure 13 : Hard crisis model (in percentage)



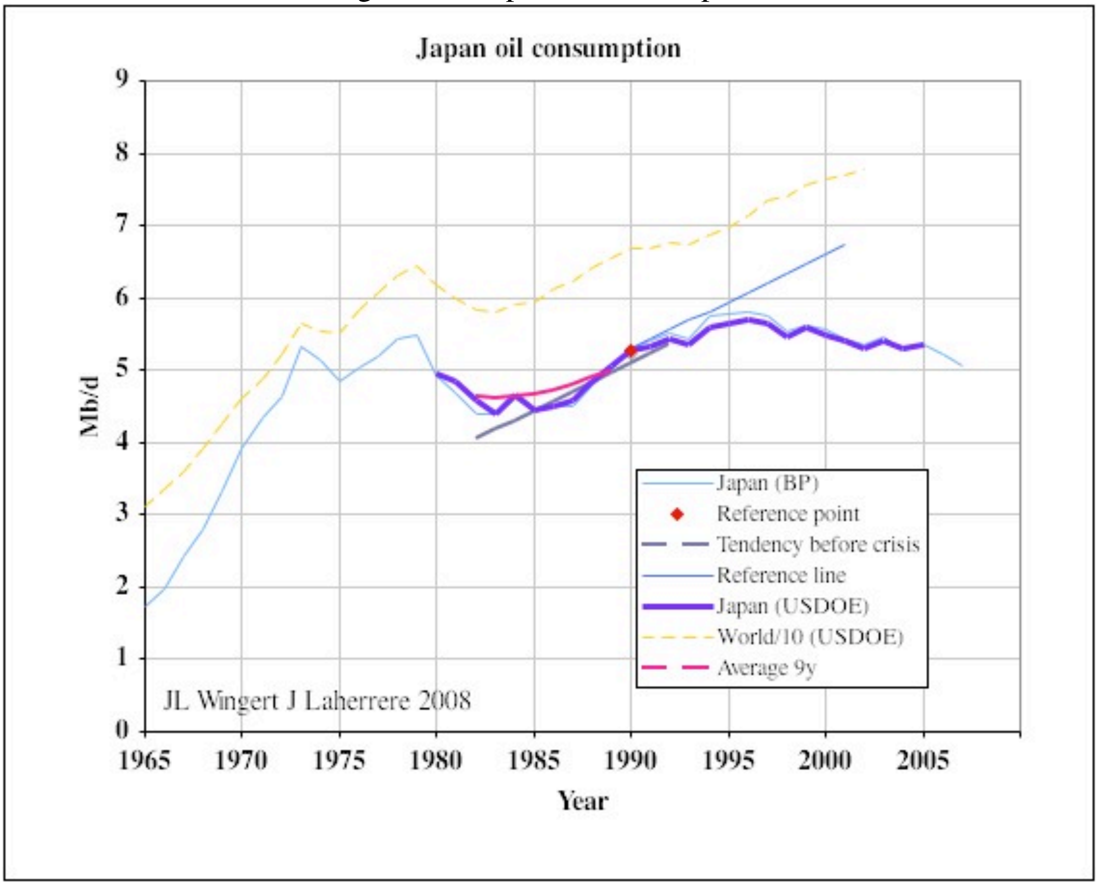
On the model above, there is a brutal decrease in oil consumption, slightly less than the one observed during the 1973 crisis, giving a minimum point of -11% after 3 years. After 8 years, the consumption has reached the zero point again. And there is an extra production capacity during 15 years at a maximum of 5% half way. This episode lasts 23 years in total. The surface of both parts of the crisis is equal by construction. We consider that the shape of the extra production capacity episode is longer and not so deep because the oil industry has time to plan it. The initial crisis is more or less a surprise. Of course this way of designing the model implicitly takes into account the price feedback effect. If consumption drops, prices should also do so and economy can then re-start on the same energy-greedy model. An hypothesis for our two crisis models is that we keep the same socioeconomic development model.

"Soft" crisis scenario

The "soft" crisis scenario would happen, for instance, in the case of a crisis that doesn't leads to a collapse of the financial system, but strong difficulties that last for quite a long time. The model is very difficult to design because it is a long term phenomenon and there can be anticipations of the industry and significant changes in the behaviour of energy consumers. We could imagine that a less energy intensive new socioeconomic development model starts to be invented and applied. In the "hard" crisis scenario, the key part is within the first years, here in what we have called a "soft" crisis scenario the key questions would be, what is the effect of the crisis on oil consumption ? is there a moment when this consumption declines more steadily and by how much? But on a long period of time there is not a single cause to the problems. To design this crisis model we looked at the Japan financial crisis in the 1990's. But we also considered it has a "hard crisis" with a late and not too strong effect.

We used the data of Japan that faced a long crisis period between 1990 and 2002. The date of the beginning of the crisis (reference point) is not easy to determine and could be somewhere between 1989 and 1991, the year 1990 was chosen. In the 1980's the financial sector was deregulated and the 1987 financial crisis didn't stop this movement. The banks where looking for quick growth and invested, with poor internal audit and risk management systems, in real estate and stocks. But the markets finally turned downwards (The Nikkei index decreased by 60% between 1989 and 1992). Political authorities didn't undertake radical actions to clear the banking system and all the 1990 decade was a succession of small crisis and small reflate plans (the commercial real estate market decreased by 84% between 1991 and 2002). Japan only got out of this permanent crisis state in 2004 with the increase of exports towards China and the USA.

Figure 14 : Japan oil consumption

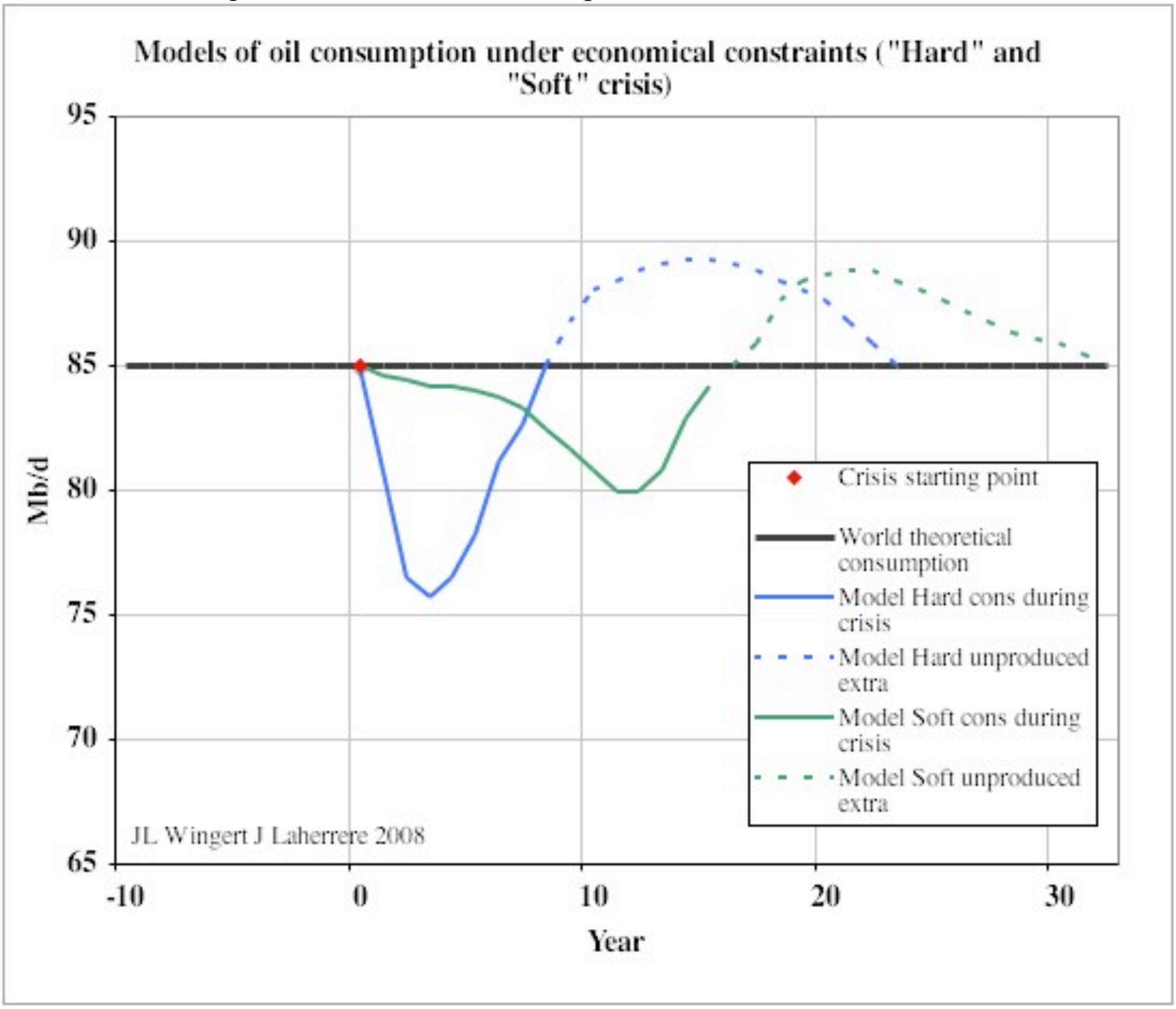


Before the crisis, oil consumption was increasing more or less on the same trend as the world, in yellow on the graph. We compared the decrease both with the tendency before the crisis and world consumption in the 1990 decade. At this time there were no energy efficiency programs in place as we have now. During the first years there is almost no significant gap with the tendency. In our soft crisis model we considered that there was no collapse in consumption but a delayed decrease before an increase afterwards (due to our method). This model is inspired from the Japanese crisis but, unlike the hard crisis model with Argentina, is quite far from the Japanese case which still has a decreasing consumption. The whole sequence is very long, from the decrease to the post-crisis extra production there are 32 years to return to zero.

Two crisis models

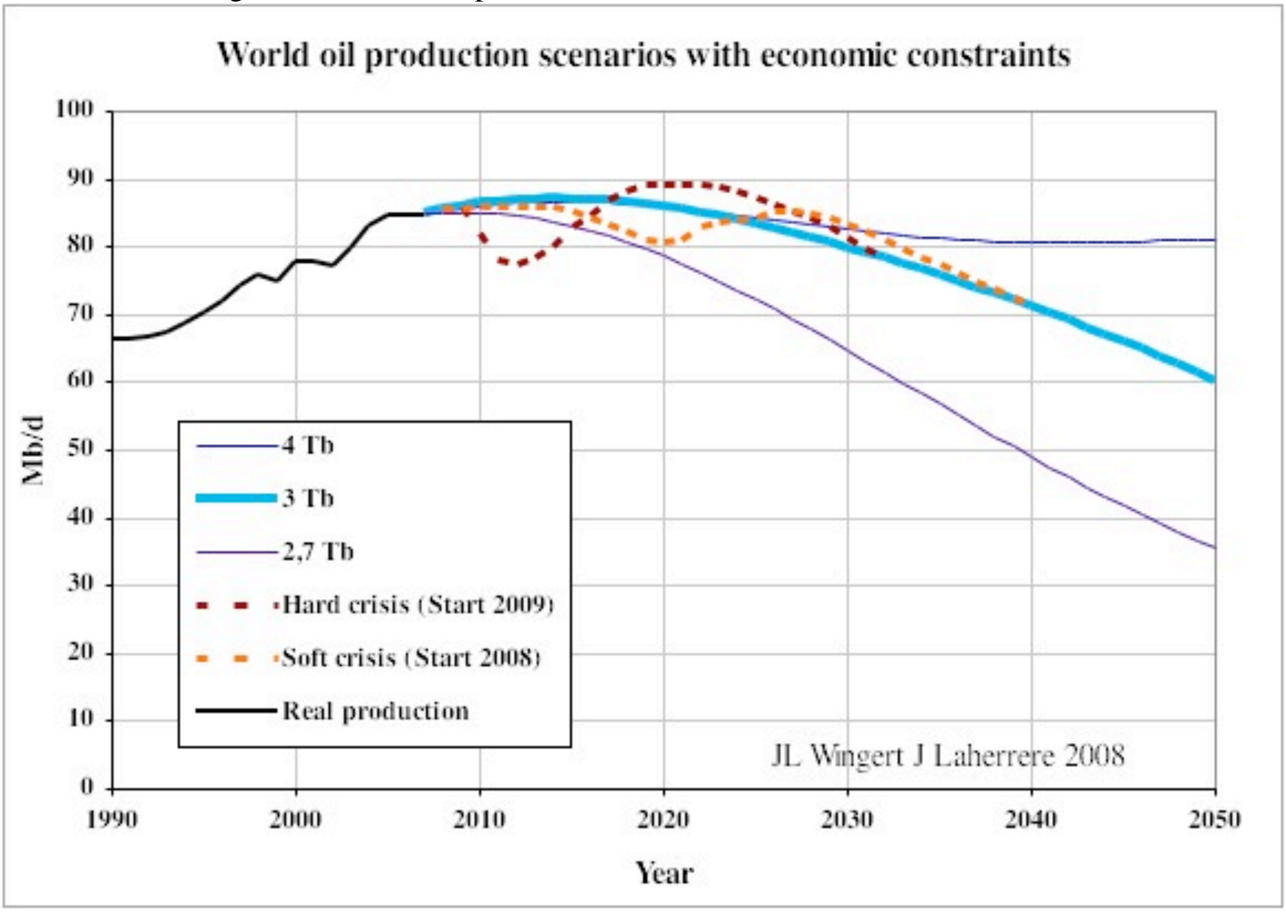
The two models we designed are both showed on the next graph applied to a theoretical production as they are meant to be used, here a flat production of 85 Mb/d. The "hard crisis" model is 23 years long altogether and the sharp minimum is -11% after 3 years only. The "soft crisis" model is 32 years long has a flat minimum of -6% after 11 and 12 years.

Figure 15: models of oil consumption under economic constraints



We apply the two models to the production forecast without constraints as showed at the end of the « below the ground » section. The reference scenario is the most likely (3 Tb, peak oil in 2015) and we now take into account the strong economical constraints. With the hard crisis scenario there is a shift of the peak oil date, which would then be in 2020. The soft crisis scenario is interesting because the peak oil date would be advanced to 2012, but there is a second peak with a similar production in 2027. What is important to see is that there are periods of time during which the tension on oil production will be released. The hard crisis scenario is the most easily readable on this point, more or less the 5 or 6 years that follow 2009 would see few tensions on production capacities. Is it long enough to forget the necessary efforts on energy efficiency? The soft crisis scenario is a real trap because the first oil peak around 2012 would happen without tensions on production until around 2025 with our model. This gives plenty of time to put energy efficiency out of the agenda. It could potentially be good news for fast developing countries like China to continue their development on the same trend if they manage not to suffer too much of the economic crisis.

Figure 16: World oil production scenarios with economic constraints



Conclusion

Since 2001 we in ASPO France have claimed that future oil production will be a bumpy plateau with chaotic oil price, but we did not plot any curve, only saying that the smooth peak model (below-ground constraint only) with the estimated ultimate could be disturbed by above-ground constraints. The strong financial crisis the world is now facing will of course have some impact on the world economical situation and oil consumption. Is the financial system going to collapse or not and how quickly is it going to recover? We do not try to answer these questions but imagined two crisis models. Reality will probably be none of the two but we can see that with these simple scenarios, the possible oil peak dates vary below 90 Mb/d from 2012 to 2027 with the same ultimate of 3 Tb. The tensions on oil production will be realised for some years, the risk would be to forget the necessary efforts that have to be made to increase our energy efficiency.