Very short world oil & gas production forecasts 1900-2100

The modeling methodology is the same as in my previous analyses, which started 20 years ago, namely the use of a multi-cycle logistic (and its derivatives) curve to extrapolate the future. The ultimate reserves are those extrapolated from the creaming curve. In a creaming curve, the cumulative backdated 2P (proved plus probable) value (assumed to be the mean) of the reserves (which incorporate all past revisions and reserve growths), attributed to the year of discovery is plotted versus the cumulative number of discovered fields (or of the new field wildcats.)
Very few countries (the UK (DECC), Norway (NPD) and the US for Federal US offshore) report production and reserves by field. Therefore, one has to rely on expensive scouting and scout databases, which are not available to the general public. But even then, the scout databases need to be corrected to estimate the actual "2P" reserves.

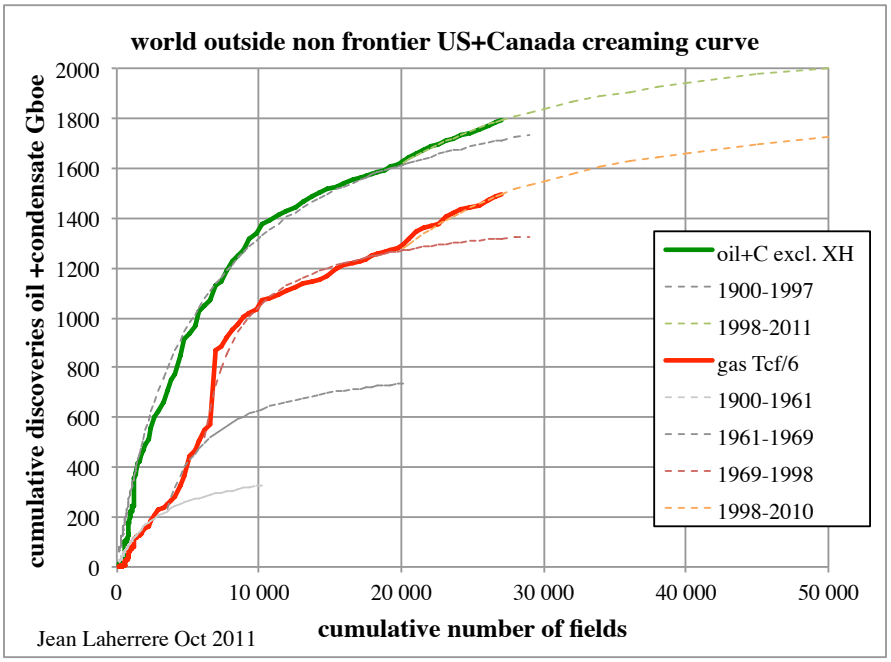

Figure 1: World outside non frontier US & Canada creaming curve for crude less extra-heavy oil

Based on the preceding creaming curve (figure1), the ultimate reserves for the world outside the conventional onshore of US and Canada are ~2000 Gb for crude less XH oil, and ~1700 Gboe for natural gas. This plot of backdated reserves versus the cumulative number of fields cannot be extended to the onshore US and Canada because there are too many fields with unavailable data and different definitions. However, if one adds the backdated 2P discoveries for the US onshore conventional (thanks to US-DOE data) and for Canada (thanks to CAPP backdated data) to the previous data, the cumulative world discovery versus time converges to an oil ultimate of 2200 Gb and a gas ultimate of 2000 Gboe (= 12 Pcf, but this round 12 Pcf in 2012 is now estimated in 2013 at 13 Pcf in figure 15).

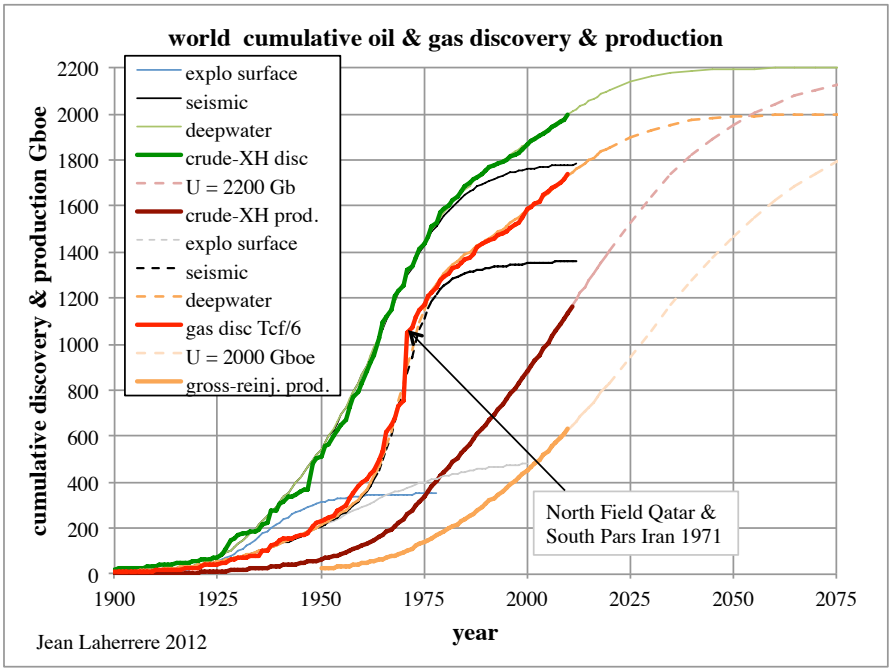

Figure 2: world cumulative oil (crude less extra-heavy) & gas discovery & production

The three cycles, which can be observed on figure 2, are well-known in exploration:

- The first one is the surface exploration based on seeps and on surface anticlines =1900-1945,
- The second one is based on seismic surveys showing buried anticlines =1945-1990,
- The last one is the deep-water and subsalt reservoirs exploration =1990-2011.

Oil production, in particular from OPEC countries, is badly reported because their fight on quotas prevents them to clearly disclose reserves and production data. Sadly, OPEC monthly oil reports rely on secondary sources, often quite different from data directly communicated by OPEC members.

US-DOE/EIA reports the total oil supply as the sum of crude, condensate and NGPL (natural gas plants liquids). The plots display a flattening starting in 2005, followed by a bumpy plateau.
The post-2010 increase is mainly caused by the increase of liquids from US shale gas and of US shale oil.

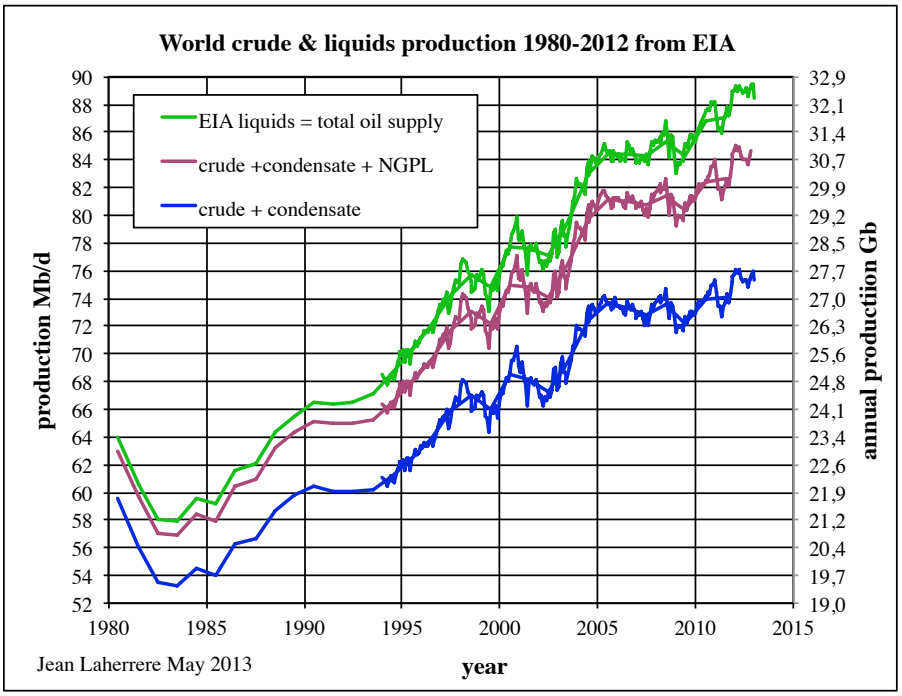

Figure 3: world crude oil (crude, NGL + liquids) production 1980-2012 after the EIA

It is frightening to see the large discrepancy between the values of the so called "oil supply" from different sources and also its evolution with time.

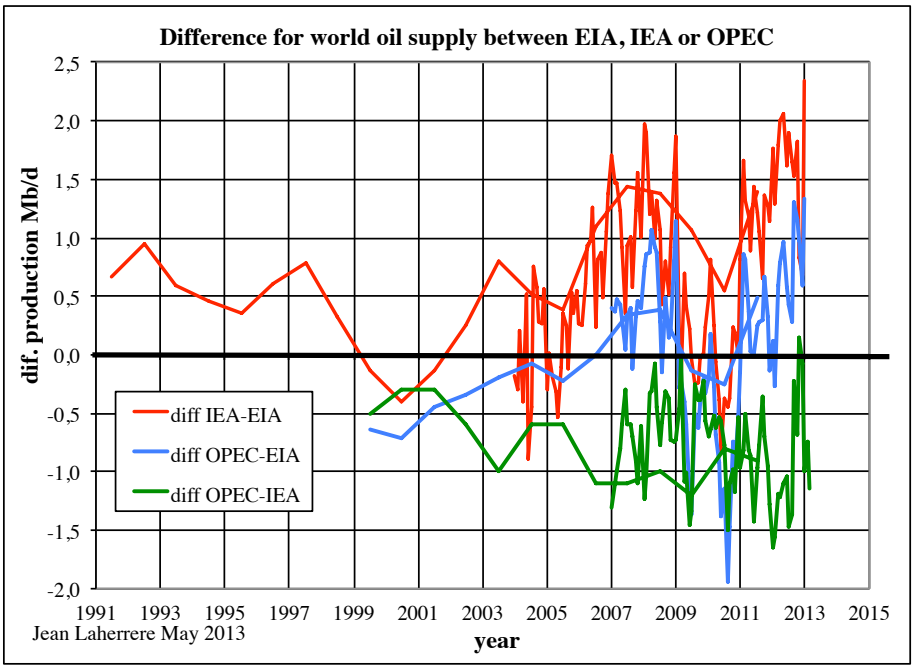

Figure 4: annual & monthly difference from world oil supply between EIA, IEA & OPEC
One can note that big changes occur at the beginning of the year when definition changes occur.

World oil remaining reserves

The published proved reserves data is political (OPEP with no audit) or financial (all majors listed on the US stock market must follow the SEC (Securities and Exchange Commission) rules with an audit). The confidential technical 2P (mean values) is only available from expensive and very large scout databases.

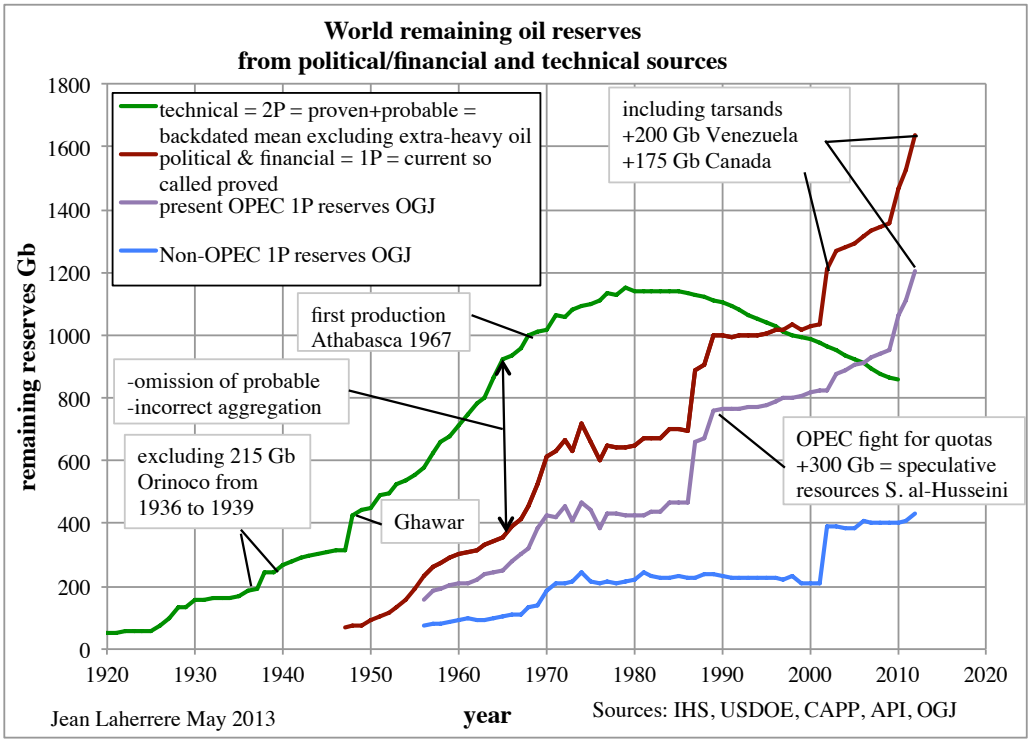

Figure 5: world remaining oil reserves from political/financial and technical sources

There is a huge difference between the political/financial proved reserves in brown, which is increasing since 1947 and the confidential technical 2P reserves in green, which is decreasing since 1980. This graph explains why most economists do not believe in peak oil.

Economists rely only on the proved reserves coming from OGJ, EIA, BP & OPEC data, which is wrong and they have no access on the confidential technical data. Economists ignoring the peak oil does not think wrong, they thing on wrong data!

The paper "The end of cheap oil" published in March 1998 by Campbell & Laherrere in *Scientific American* is confirmed with its graph below. At the time, we expected the green curve to go down and the brown curve to go up, but we did not expect the latter to move so high (+600 Gb) after a long plateau!

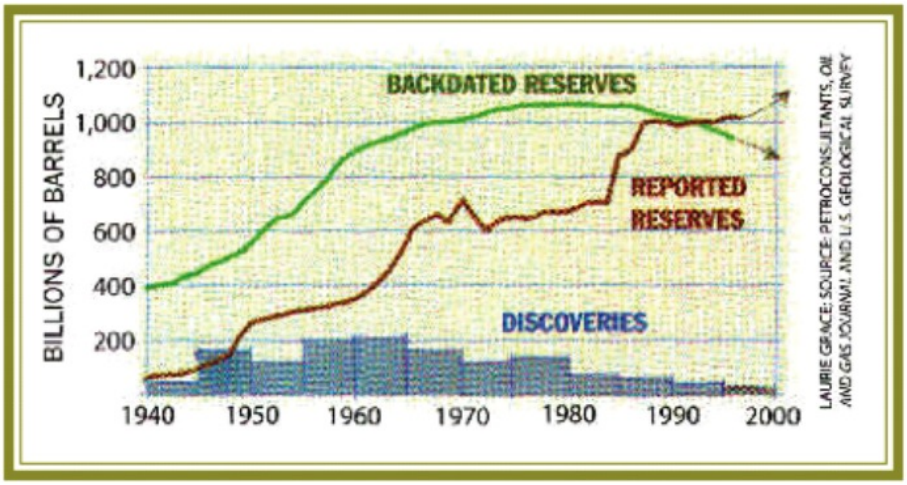

Figure 6: world remaining oil reserves from political/financial and technical sources in Scientific American March 1998 "The end of cheap oil" Campbell & Laherrere

The following graph displays the same data as figure 5, but it is the annual discoveries for 2P and 1P compared to annual production (crude oil + condensate and crude + NGL). Annual production exceeds 2P annual discoveries since 1980, but not 1P annual additions.

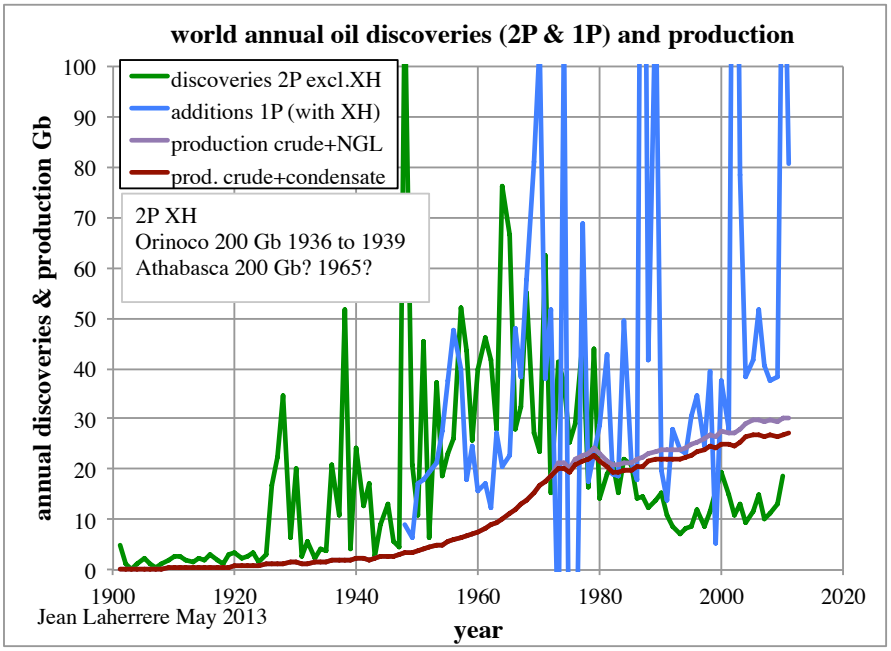

Figure 7: world annual oil discoveries (2P & 1P) and production

The similar graph for natural gas annual discoveries & production shows that 2P discoveries are larger than production up to 2000

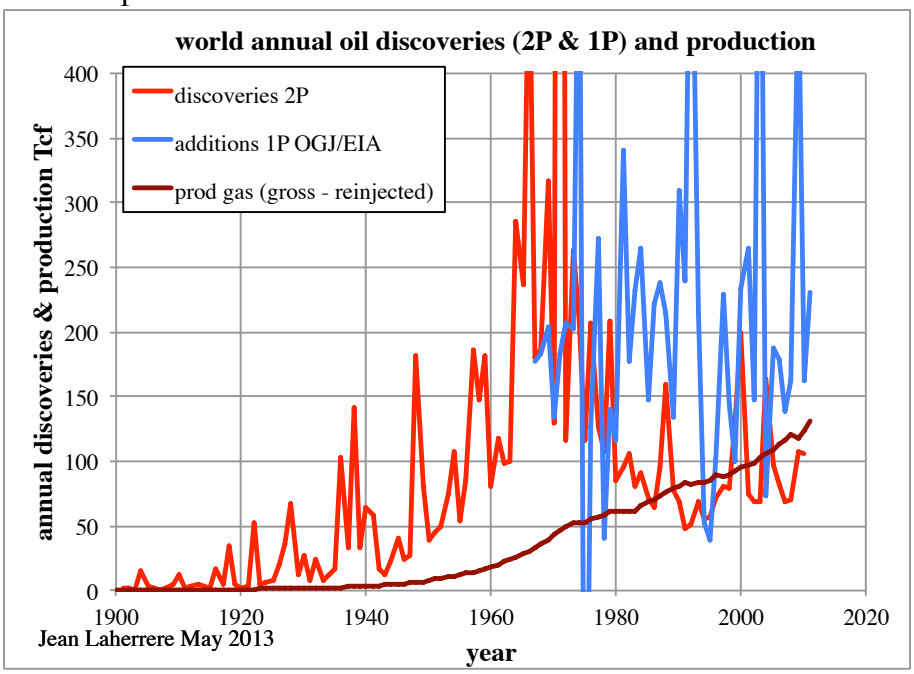

Figure 8: world annual natural gas discoveries (2P & 1P) and production

Economists rely on the EIA 1P additions to believe, even before the shale boom, that there is no problem about reserves, because proved reserves oil and gas additions for oil and gas are twice the production, when in reality 2P oil discoveries are about half the production!

-Estimate of oil & gas ultimate reserves

One can only plot the cumulative (backdated mean) discovery over time, which suggests that the world ultimate for crude less extra-heavy oil can be estimated at 2200 Gb.

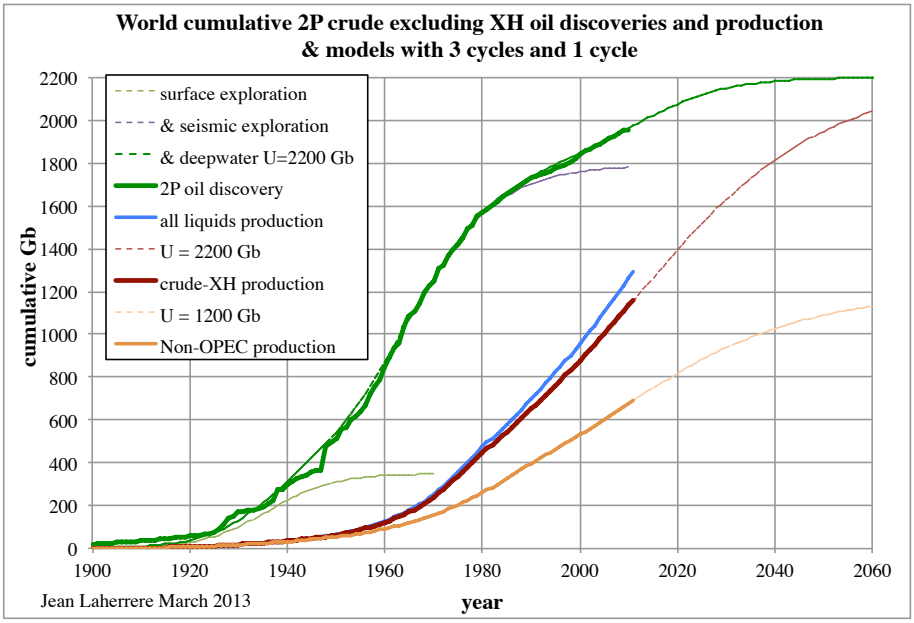

Figure 9: world crude less XH oil cumulative discoveries and cumulative production modeled with an ultimate of 2200 Gb

Crude oil +NGL

The crude oil less XH annual production and also XH and NGPL (natural gas plant liquids) are plotted for the world, OPEC and Non-OPEC,

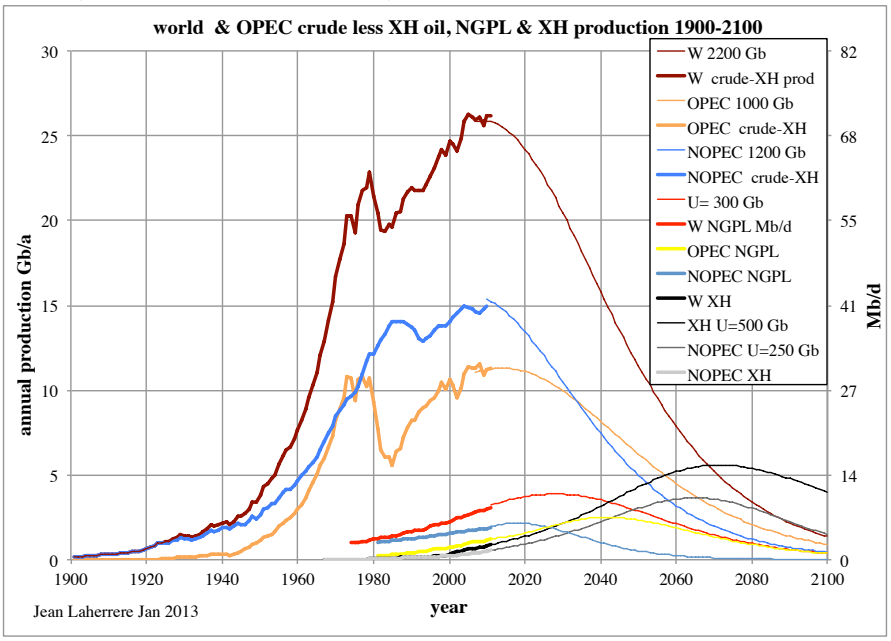

Figure 10: world, NOPEC & OPEC crude less XH, XH & NGPL annual production

OPEC crude less XH oil production will overpass Non-OPEC around 2030. XH production will overpass NGPL after 2040 and crude oil after 2070.

For unconventional oil, despite the sharp increase in the US (mainly light tight oil, new name for shale oil), the rest of the world may face many above ground constraints. So, world ultimate unconventional oil reserves may be lower than the accuracy of the world crude oil and may not change much the long term production. But we could be wrong.

All liquids

The breakdown of all liquids production is given for OPEC and Non-OPEC

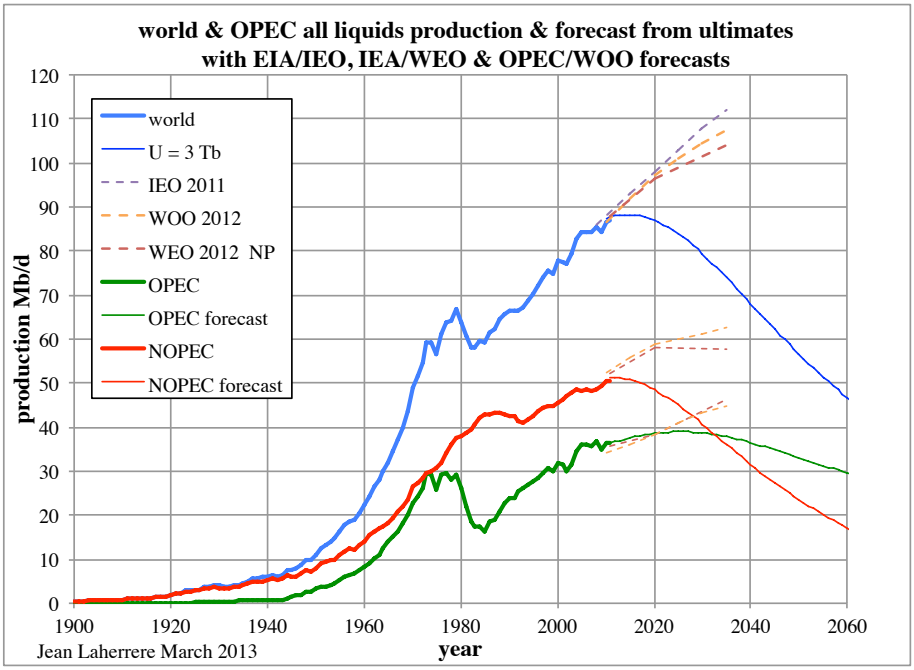

Figure 11: OPEC & Non-OPEC all liquids production & forecast 1900-2060

OPEC all liquids will overpass Non-OPEC around 2030 in our interpretation, when WEO 2012 NP sees it around 2050. Last IEA forecast reports an increase in oil production from 2012 to 2018 of 8% for Non-OPEC (+30% for the US) and of 7% for OPEC, which are doubtful in our opinion.

World and OPEC crude less extra-heavy oil production, petroleum consumption and exports are plotted and extrapolated until 2050. OPEC consumption (thin blue) is extrapolated using the UN population forecast: it will cross OPEC crude oil production (thin green) around 2045.
OPEC export (thin brown) is plateauing and will decline to zero before 2050, unless their consumption due to heavily subsidized is reduced like it was in industrialized countries.

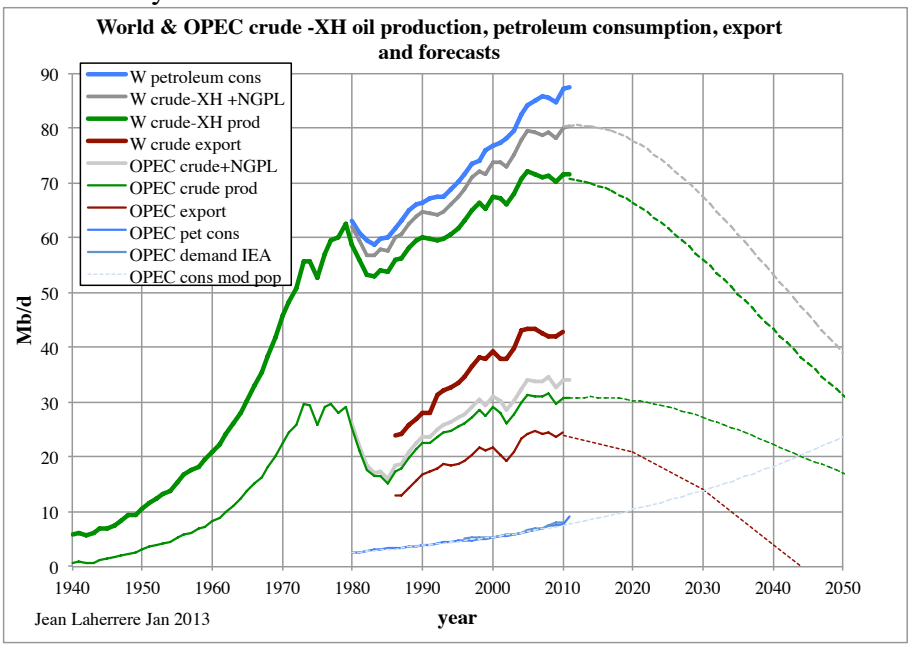

Figure 12: world & OPEC production, consumption & export 1940-2050

When OPEC oil export ceases before 2050, OPEC will cease to act as a producer cartel.

<u>The US = exception because of the oil and gas ownership (landowner)</u>

The US is an exception in the world because oil in the ground belongs to the landowner, but in the rest of the world, it belongs to the government. It is why there are over 20 000 oil companies and thousands of oil service companies in the US and one in Saudi Arabia. The US production

excluding Alaska displays a symmetrical curve with a peak in 1970 as forecasted by King Hubbert in 1956.

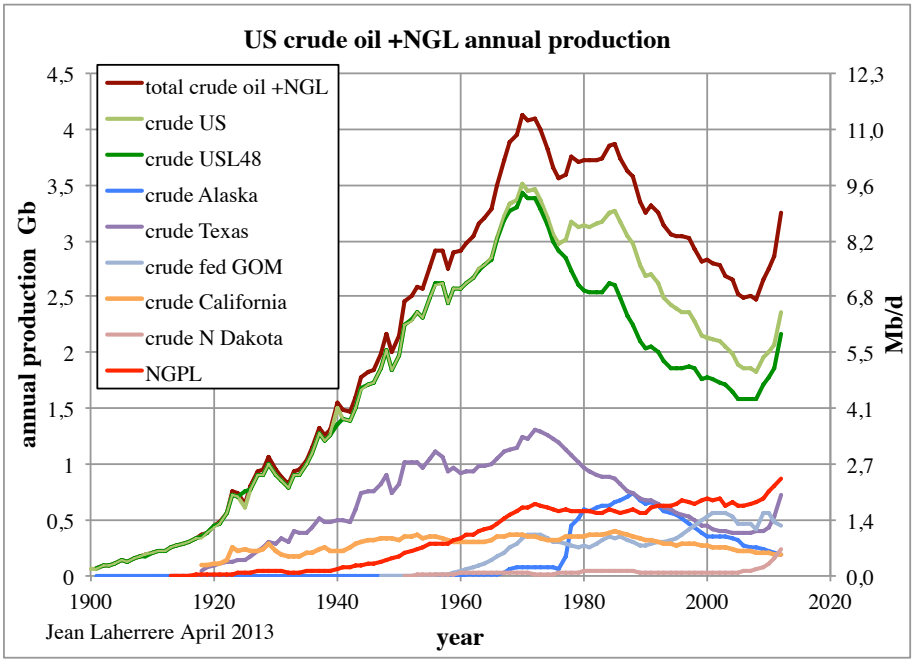

Figure 13: US crude oil & NGL production 1900-2011

The US number of rigs peaked in 1980 when the second oil shock coinciding with the end of price controls triggered a drilling frenzy. Even the worst prospects were drilled, resulting in many dry holes and a sharp decline at the 1986 oil counter shock until the late 1990s.

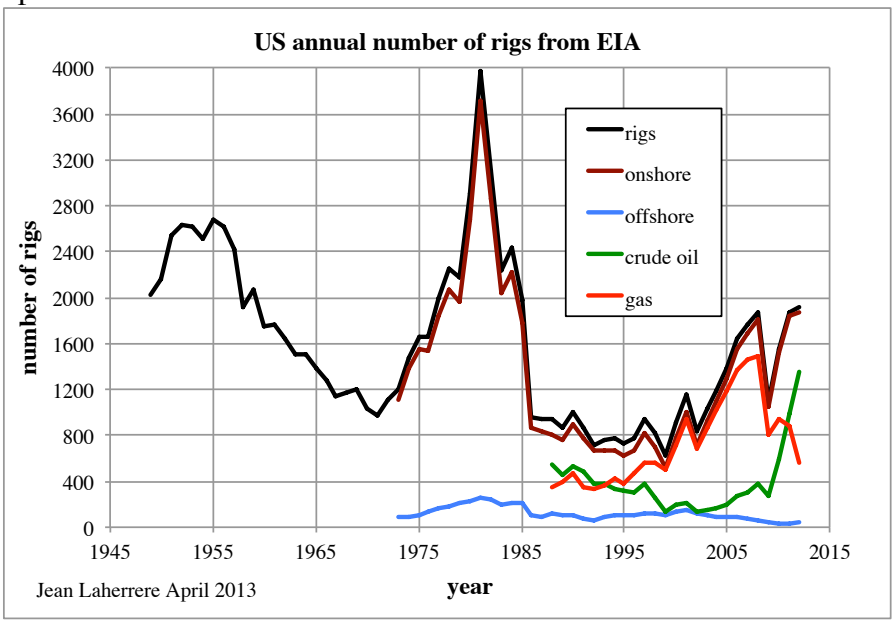

Figure 14: US annual number of rigs 1947-2012

The US drilling activity is cyclic, peaking in 1955, 1980 and probably now. The "baby drill" practice is due to the shale oil boom, itself caused by the high oil price and the easy money flows provided by the eased monetary policy. Today US explorers are complaining about the lack of conventional prospects and, moreover, for unconventional gas, the shale sweet spots seem to decrease.

The US natural gas production, which peaked in 1970 like oil is showing a sharp increase since 2005 because shale gas. In 2011 unconventional (CBM, tight gas and shale gas) gas production (orange) was higher than conventional gas production (red). The ultimate for conventional NG seems to be 1250 Tcf and the unconventional ultimate was estimated at 750 Tcf to obtain the round

total value of 2000 Tcf. USDOE reports shale gas ultimate reserves at 482 Tcf and only 273 Tcf for proved reserves.
This 2000 Tcf (2 Pcf) leads to a peak in 2020 at 22 Tcf and the decline after 2020 of all US NG (green) will be quite sharp. The goal of exporting US liquefied natural gas seems to be based on very optimistic views, as those shown in AEO 2013 where US production is forecasted to be 33 Tcf in 2040 against 10 Tcf in my forecast!
The gross US natural gas monthly production is presently flat since October 2011 after its sharp increase since 2003 with only shale gas production rising.

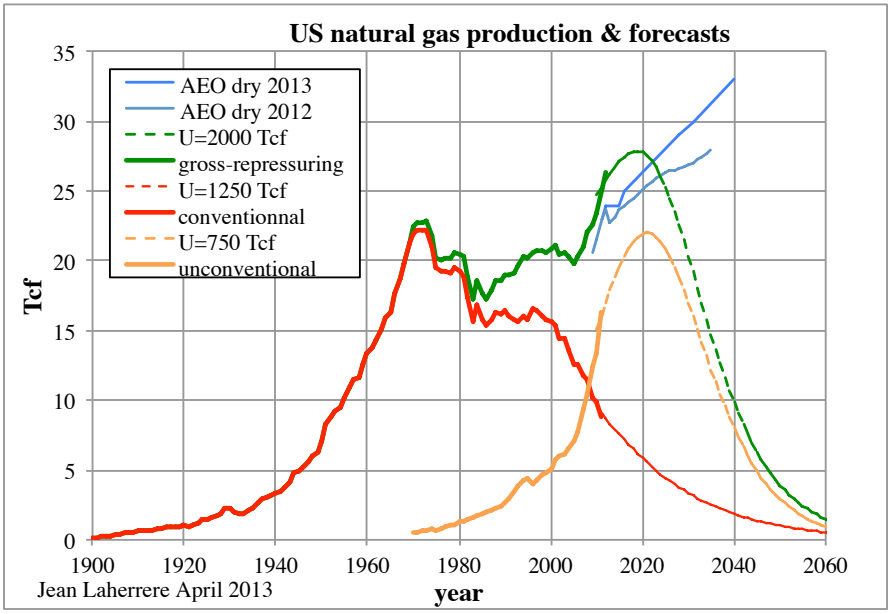

Figure 15: US natural gas production 1900-2060
Some claim that the US can export its shale gas as LNG even though conventional gas (in red) is declining fast and will be quite small in a few years.

There is an amazing fit between the US monthly number of rigs and the wellhead natural gas monthly price from 1987 to 2013 (period of available monthly data).

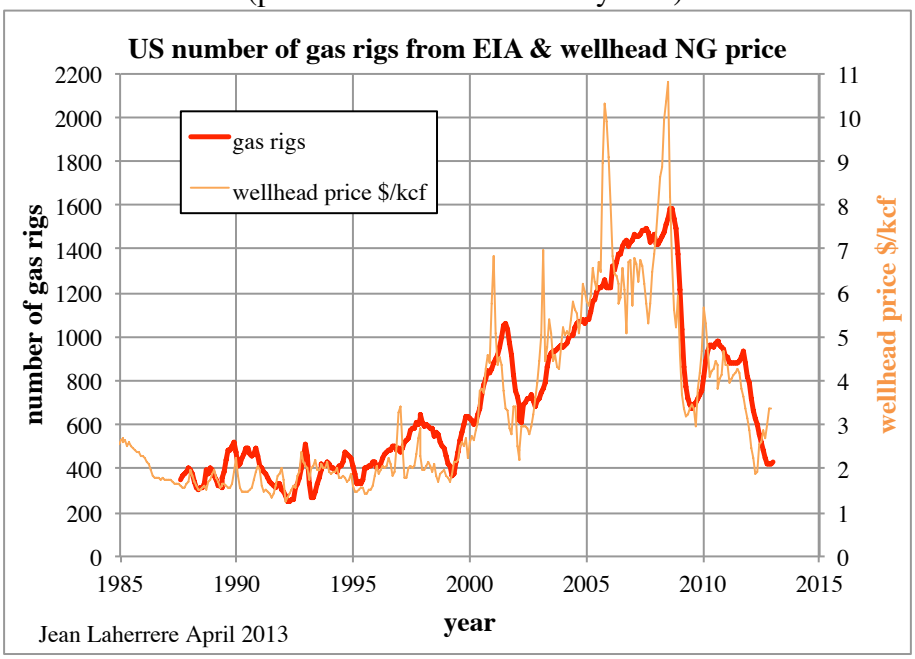

Figure 16: US natural gas price and number of gas rigs from EIA

The US oil over natural gas price ratio has varied widely from 1950 to now starting at 7 (meaning that oil is 7 times more expensive per Mbtu at wellhead than natural gas) down to the 1 (which is

normal) from 2000 to 2005 and up again with a peak at more than 9 in May 2012, and at 4.5 in December 2012. The ratio varies roughly as the percentage of US gas flared (versus marketed production) and, since 1995, as the percentage of gas flared in North Dakota. The lack of gas pipeline creates a glut with low prices and flared gas. This situation of cheap natural gas is unsustainable and has led to lower coal prices and to the expectation of LNG exports.

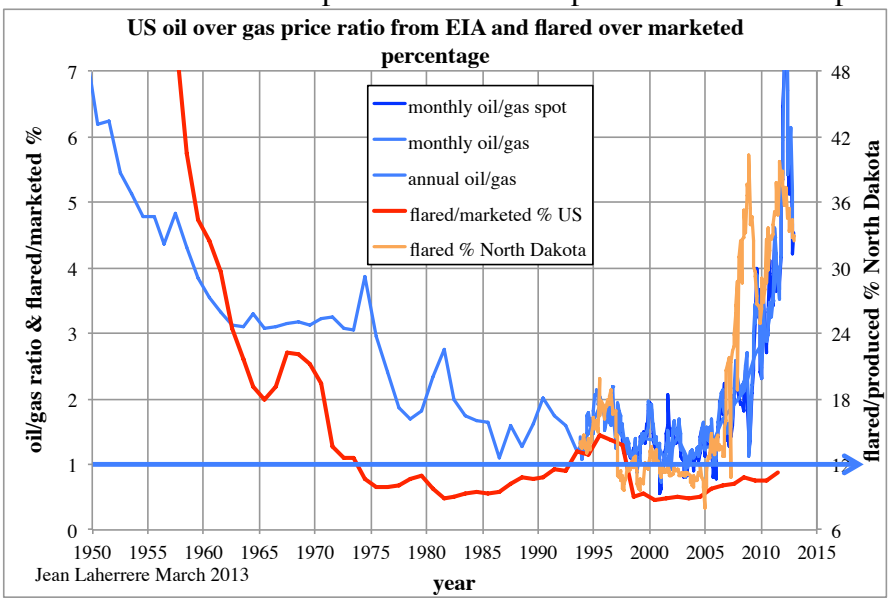

Figure 17: US oil over natural gas price and flared over marketed gas percentage

World, Non-OPEC & OPEC natural gas production forecasts

Annual natural gas productions are modeled on the basis of the ultimate reserves: 13 Pcf for the world, 7 Pcf for NOPEC (Non-OPEC) and 6 Pcf for OPEC.

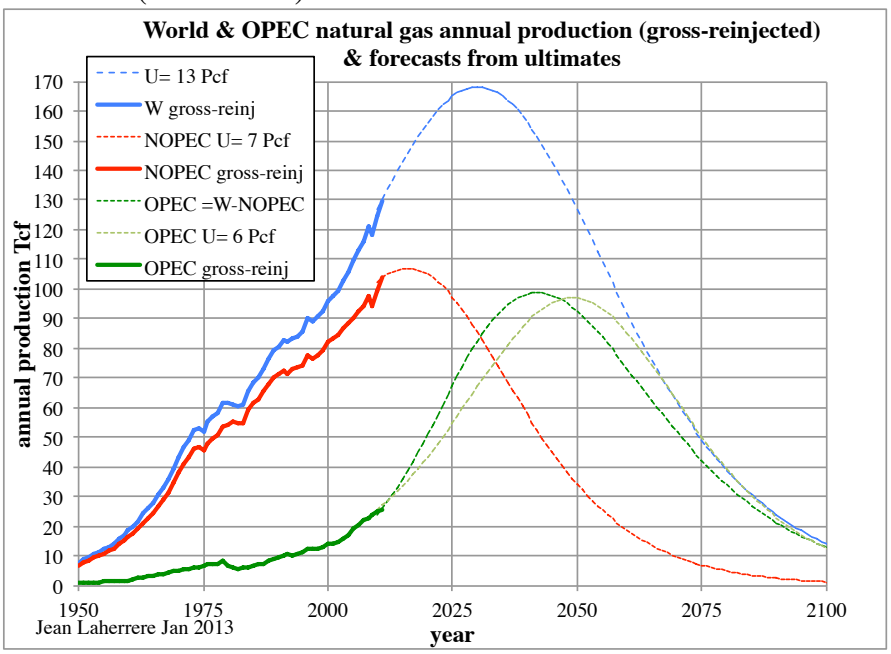

Figure 18: world, NOPEC & OPEC natural gas annual production

If NOPEC has 7 Pcf ultimate reserves, it will peak around 2020 at more than 100 Tcf/y but an intensive drilling program could delay the peak but, unless new reserves become available, it would be at the expense of a sharper decline. OPEC gas production will peak around 2050 at ~100 Tcf/y. Outside the US, the potential of shale gas is very uncertain because the "Not In My Back Yard" effect is much stronger when the gas belongs to the country and not to the landowners. Unless the mining code is changed, the potential of shale gas is weak with the largest unknown being China.

Suffice to say that up to now, there is no example of economical shale gas production outside the US. Will the hype on shale gas fall like the hype on biofuels few years ago.

Liquids from natural gas plants (NGPL)

They make 9 Mb/d in 2012, but with a 36% lower heat content than oil. In 2012, heat content is 5.8 MBtu/b for oil and 3.7 MBtu/b (versus 3,9 MBtu/b in 1980) for US NGPL

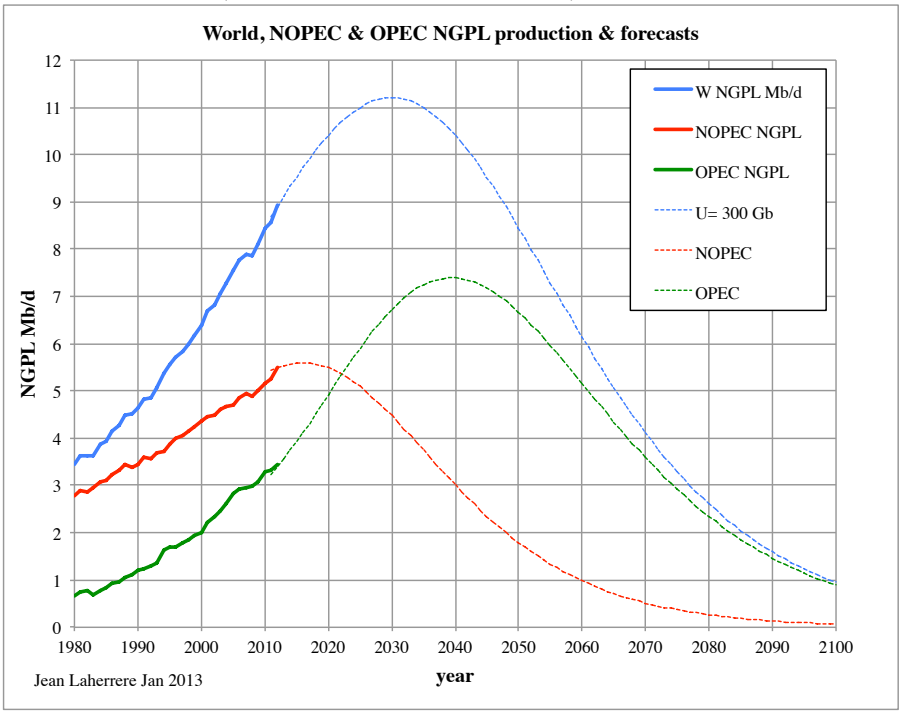

Figure 19: world, NOPEC & OPEC NGPL production & forecasts for 300 Gb ultimate

World NGPL (blue) may peak in 2030 at over 11 Mb/d whereas it will be before 2020 for NOPEC (red) at 5.5 Mb/d and in 2040 for OPEC (green) at 7.5 Mb/d.

Oil forecasts from different ASPO authors

For a long time, Colin Campbell has published (in an Atlas) oil and gas forecasts up to 2030, recently up to 2050. His forecast crude oil +natural gas liquids (NGL) is compared to mine and to PR Bauquis and to past all liquids data. The 2010 data uncertainty is 3 Mb/d (figure 4) between sources, as the discrepancy between the three authors, despite all three being among the founders of ASPO. For 2020 the forecast discrepancy rises to 10 Mb/d and for 2040 it becomes quite large with oil production ranging from 50 to 100 Mb/d!

The uncertainty is high on past oil production and much higher on future oil production

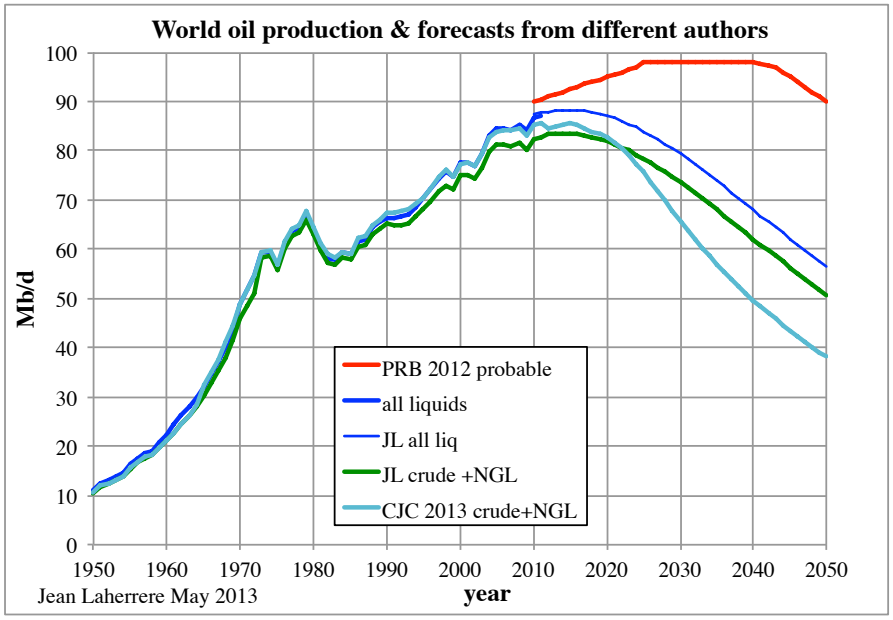

Figure 20: world oil production & forecasts from different ASPO authors

Walls on oil price and on crude oil production

The plot of oil price in $2011 versus crude oil + condensate production based on BP data seems to have two "walls": one at 120 $/b for the price and another one at 76 Mb/d for the production. However, official inflation figures and BP data are questionable. So, where should these two "walls" be put exactly? In fact extra-heavy oil should be excluded.

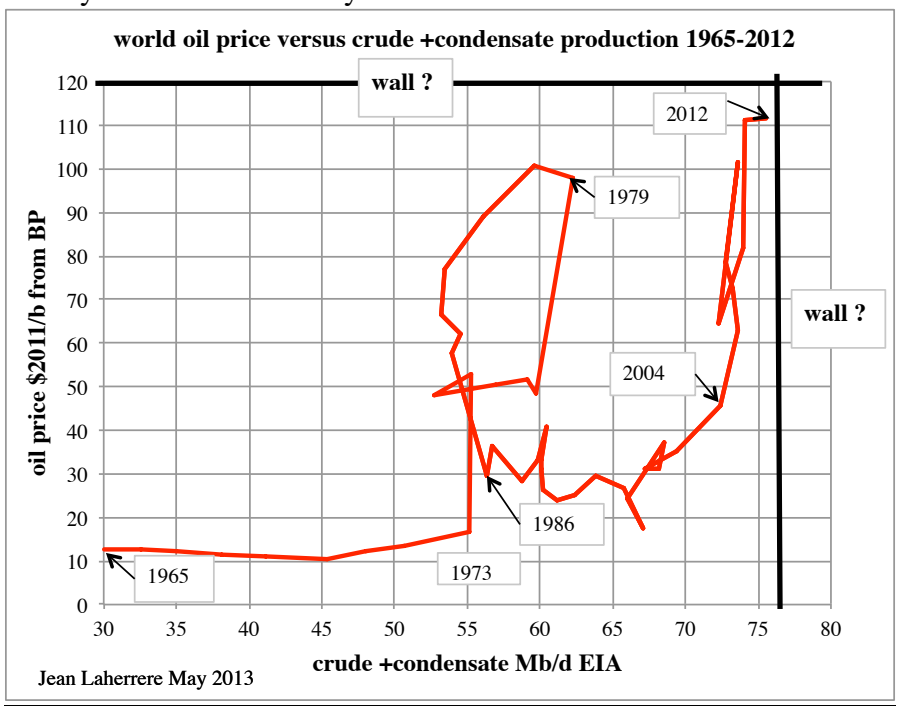

Figure 21: world oil price ($2011/b) versus crude oil production 1965-2012

-Deniers on peak oil

Peak oil deniers claim that peak oil is a unscientific theory, ignoring that peak oil has actually happened in several countries like France, UK, Norway... and that there are more producing countries on decline than on increase!

Peak oil deniers claim that our estimate on world ultimate does not take into account the economy, in particular the oil price. They confuse proved reserves, which are supposed to represent the expected production with present technology and economy (with the oil price at end-year) with the

2P mean reserves, which are used to compute the Net Present Value from a forecast on oil price for the life of the production.
The best proof of the quality of our estimate on remaining 2P reserves on figure 5 in 2013 with an oil price of 100 $/b is that the values are nearly the same as in figure 6 of 1998 when the oil price was of 10 $/b.
For unconventional oil (using tertiary recovery such as steam, fracking) the problem is not the size of the "tank" but the size of the "tap" and oil price is very important as it is shown in figure 10 where the peak of extra-heavy oil is put around 2070.
Shale oil, which is now called light tight oil (because the production in the Bakken is not from a shale reservoir, but a sandy dolomite reservoir between two shale formations) has huge resources when estimating the amount of hydrocarbons generated by the source-rocks within the oil kitchen. In the (Laherrere, Perrodon, Demaison) 1994 report "Undiscovered petroleum potential" the efficiency factor (percentage ultimate reserves versus HC generated from source-rocks in the kitchen) was estimated as being very low: 1.4 % in the Arab-Iranian Petroleum System (most of the Middle East), 1% in the North Sea, 0.8 % in the Saharan Triassic, 0.6% in the Niger Delta, 0.4 % in Gippsland, 0.3 % in Kutei & Putamayo, 0.03 % in the Paris Basin. Most of the generated is either lost, or diffused in the sediments or still within the source-rocks within the fractures. Huge volumes of HC still exist in source-rocks, but the recovery factor should be quite low: a few % at best!
In Montana, Bakken production is mainly from the stratigraphic field being Elm Coulee which is in decline since 2008 and in North Dakota, Bakken production has increased sharply from 50 000 b/d in 2008 to 715 000 b/d in March 2013 but it may be close to peak by lack of more sweet spots to drill. North Dakota production may very likely peak in 2013 because the number of rigs has peaked in June 2012 with 200 rigs (176 rigs in April 2013).

Increase in fuels: price of oil or one liter of diesel in France compared to the minimum wage
For many Frenchmen, diesel fuel (80% of the French cars consumption) is today very expensive, but they forget that in 1960 25 minutes of work at SMIC rate were necessary to buy one liter of diesel, when only 9 minutes are needed in 2012 (but 6 minutes in 1991)

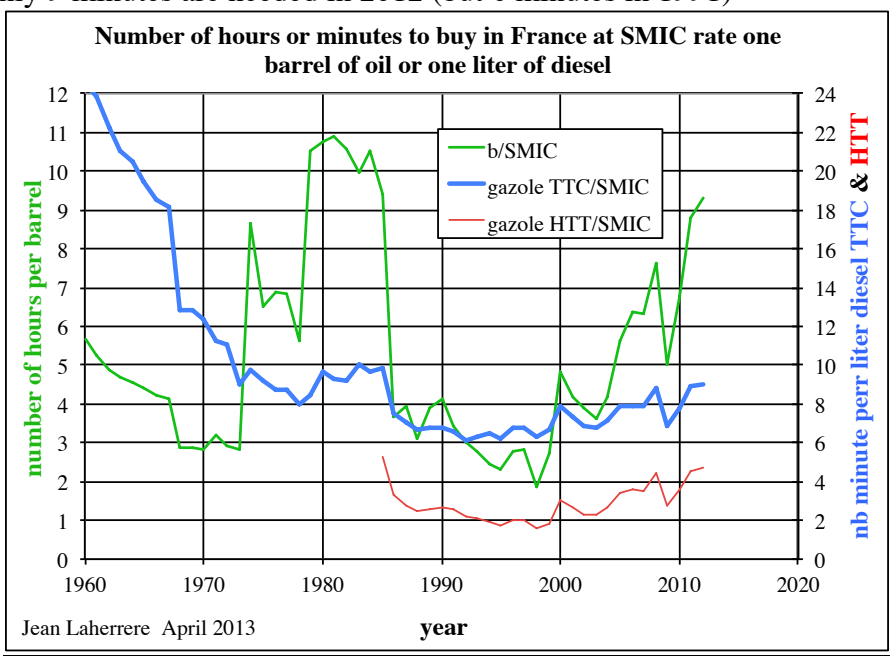

Figure 22: number of hours or minutes to buy one barrel of oil or one liter of diesel fuel with SMIC wage

The display for the number of hour to buy one barrel of oil with the SMIC wage is quite different because the French taxes. In 1960 6 hours were needed, in 1980 11 hours and in 2012 over 9 hours.

Conclusions

Oil & gas production data are unreliable and the UN should oblige every country to publish true, updated and complete data on energy, in particular on fossils fuels which are a gift for humanity, alas sadly soon to be reduced because of energy supply constraints. The SEC rules should be changed in order to report mean (2P) reserves instead of proved reserves.

The present study is based on ultimate reserves mostly estimated from the extrapolation of discovery data coming from scout databases. Only three countries report reliable field data: UK, Norway and the Federal US. If most other countries were to follow their example, such study would be much more reliable. It is a shame that the need of reliable data is not understood in New York at the United Nations or in Brussels at the European Commission.

With the poor data available today, it seems that world oil (all liquids) production will peak before 2020, Non-OPEC quite soon and OPEC around 2020.

OPEC oil exports will cease before 2050.

The present subsidies on gasoline price in Venezuela and Iran (one hundred less expensive than in Turkey) are unsustainable and lead to high consumption in detriment to export.

OPEC production will overpass Non-OPEC production around 2025 for NGPL and around 2030 for natural gas, for crude less XH oil and for all liquids.

The dream of the US becoming independent seems to be based on resources, but not on reserves.

Of course the present study is based on questionable assumptions and unreliable data, but anyone can look at the graphs and make his own interpretation or can challenge the data. Again alas, I do not know any free study showing as much as this paper.

PS: -thanks to Jean-Marie Bourdaire for his comments and for correcting my Broken English
-a longer paper was written in February and can be found on aspofrance.org site
-a shortened paper was written in May and can be found on aspofrance.org site