Shortened world oil & gas production forecasts 1900-2100

The purpose of this paper is to recall the past production evolution and to update the production forecasts up to 2100 with a detailed breakdown between OPEC and NOPEC (i.e. non-OPEC). It is a shortened version of a more detailed paper written on February 2013 and available on aspofrance.org (documents) site.
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, each "y" value is the cumulative backdated 2P (proved plus probable) value (assumed to be equal to the mean) of the reserves (which incorporate all past revisions and reserve growths), attributed to the year of discovery. The scout reported 2P (declared to be P50 i.e. the cumulative 50% probability or median) is taken in fact as the mean value used to estimate the Net Present Value, which is the base of the decision to develop. Furthermore only arithmetic addition of mean field reserves values corresponds to the mean reserves value of a country.
As shown in my ASPO Brussels paper in 2011, such "backdating" is key for obtaining reliable ultimate reserves estimates). Each "y" value is the amount of mean reserves already discovered and each "x" value is the cumulative number of already discovered fields. Therefore the creaming curve is always positive and growing, starting from the date of the first discovery. Each cycle of discoveries gives birth to a hyperbolic plot with as many hyperbolas as discovery episodes.
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. For instance, OPEC countries artificially increased their reserves in order to obtain larger quotas and therefore produce more, during the period 1985-89 and now oblige scout databases to report their values. Another example is the overestimation for the FSU (Former Soviet Union) countries when using the ABC1 estimates. Gazprom annual reports show that the audit of their reserves put "2P" reserves at 70% or less of ABC1. The cases of continuous–type accumulations described as being unconventional by the USGS, namely the Orinoco extra-heavy belt in Venezuela for which the scout database reports 4 discoveries totaling 215 Gb from 1936 to 1939, or of the Canada tar sands, could also be mentioned.

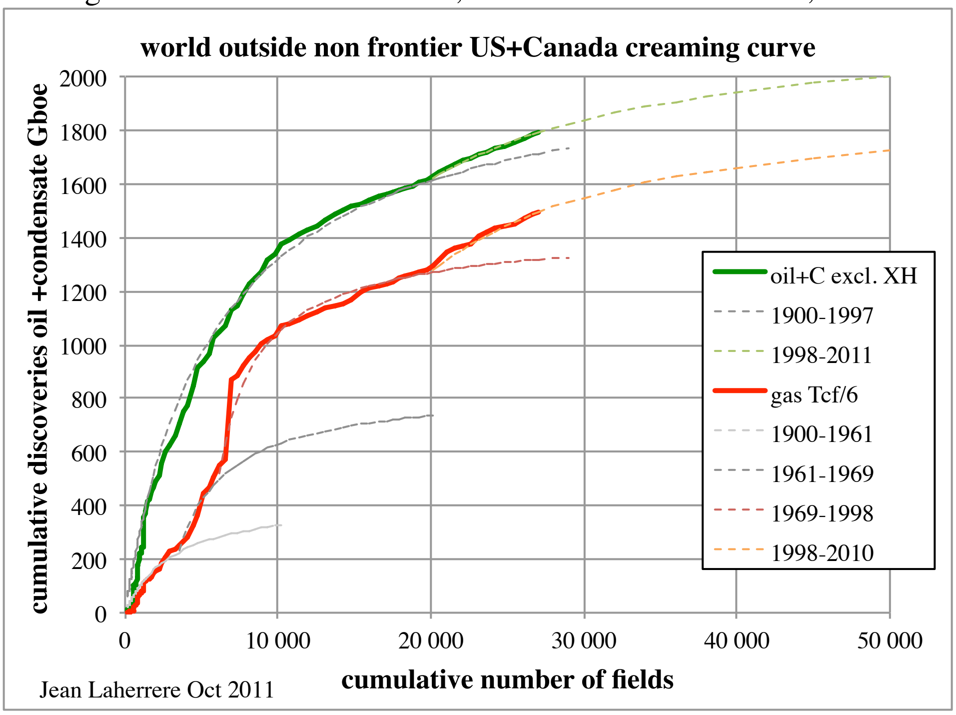

Figure 1: World outside non frontier US & Canada creaming curve for crude less XH oil

The creaming curve for the world outside the onshore US & Canada (excluded because of their to many small fields (or pools) with no available inventory) shows a hyperbolic rise of backdated 2P oil reserves from 1900 to 1997 followed by a new cycle starting then with the deep-water and sub-salt discoveries. At end 2011, there are 1800 Gb 2P crude less extra-heavy (XH) oil reserves, once a ~500 Gb correction is subtracted from the scout databases. The reason of this correction is that the scout databases, which now have OPEC companies as clients, feel obliged to rely on what they officially declare. This leads to a difference between the biased proven sources and the technical 2P data for the world remaining reserves which is large and widening over time. Those relying on these sources ignore that since 1980 there is less oil discovered than oil produced.

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 now estimated at 13 Pcf in figure 22 in 2013). Because the uncertainty of the data, it is useless to try to change estimates by less than 10%: 12 or 13 Tcf is in the same range. This gas modeling misses the next cycle, being the new shale gas. Further in the text the importance of this "new" gas, even though the first production of gas in US in 1821 was shale gas, is discussed.

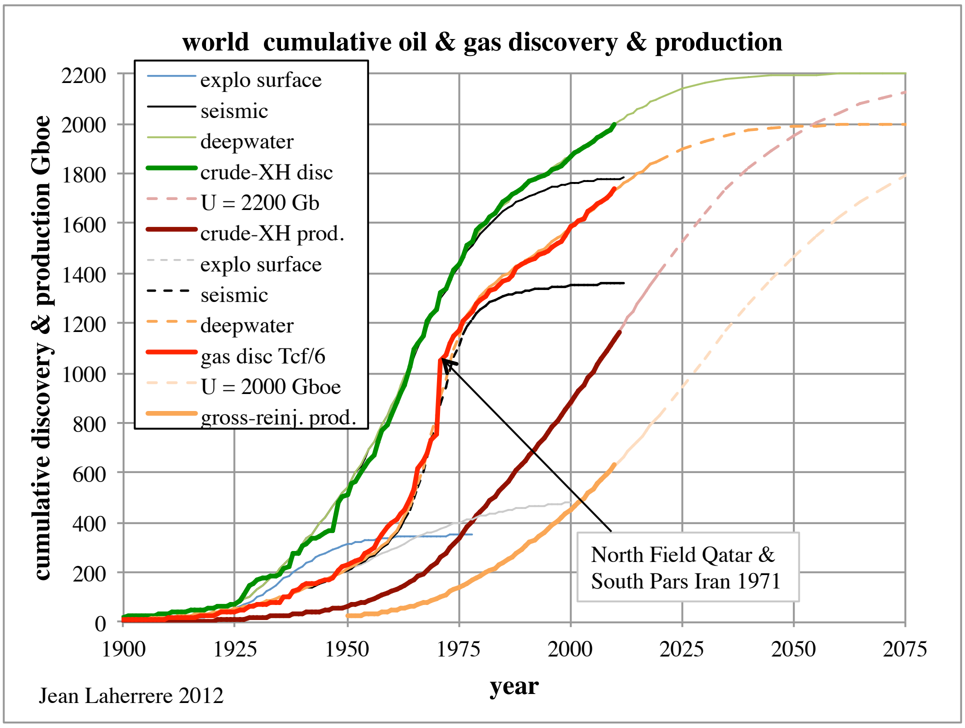

Figure 2: world cumulative oil (crude less extra-heavy) & gas discovery & production

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,
- The second one, after WWII, is based on seismic surveys showing buried anticlines,
- The last one since 1990 is the deep-water and subsalt reservoirs exploration.

Regarding natural gas, there is a jump in reserves in 1971, which correspond to the discovery of the North Dome field located for two thirds in Qatar and one third in Iran. Note that the scout databases report the discovery of the Iranian part of the field, Pars South, only in 1992 to please Iran.

Based on the curve of discoveries, one can extrapolate the cumulative productions. Providing that no new cycle of discoveries happens, the extrapolated values are the ultimate reserves. Geological expertise is needed to foresee if a new cycle is possible. For oil, the only new possible cycle could be shale oil (now called light tight oil). It is only significant in the US, not yet in the rest of the world. There is not enough historical production to reliably estimate world shale oil reserves, but it seems that the amount is much less than the accuracy of the world crude less XH oil reserves. So, the shale oil boom can be hype and it would be wrong to put it as a fourth global cycle. Only time will tell. It may be the same for natural gas and shale gas.

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. On the OPEC May 2013 monthly report, total OPEC crude oil production for 2012 was 31.132 Mb/d based on secondary sources and 32.418 Mb/d (4% more) based on direct communication. For Venezuela, crude oil production was 2.360 Mb/d from secondary sources versus 2.804 Mb/d from official Venezuela value, 19% more than what OPEC apparently believes!

US-DOE/EIA, which added four new countries to their oil supply - Chile, Israel, Estonia and Slovenia - in November 2012, 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 increased US NGL from shale gas and the rise of US shale oil.

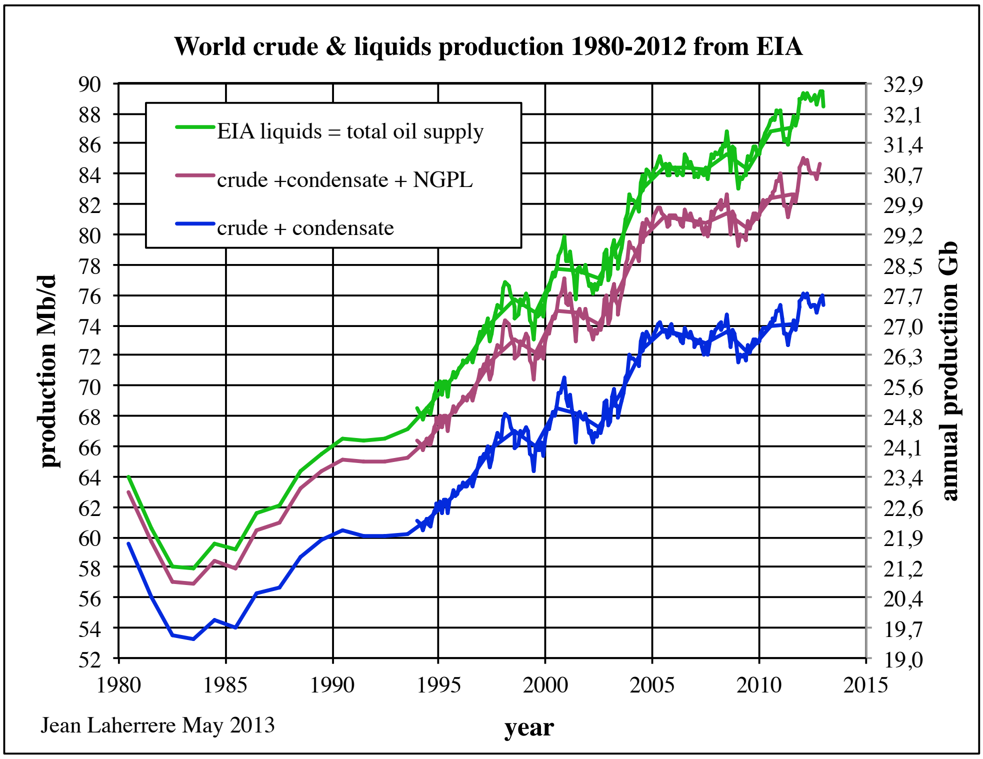

Figure 3: world crude oil (crude, NGL + liquids) production 1980-2012 after the EIA

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.

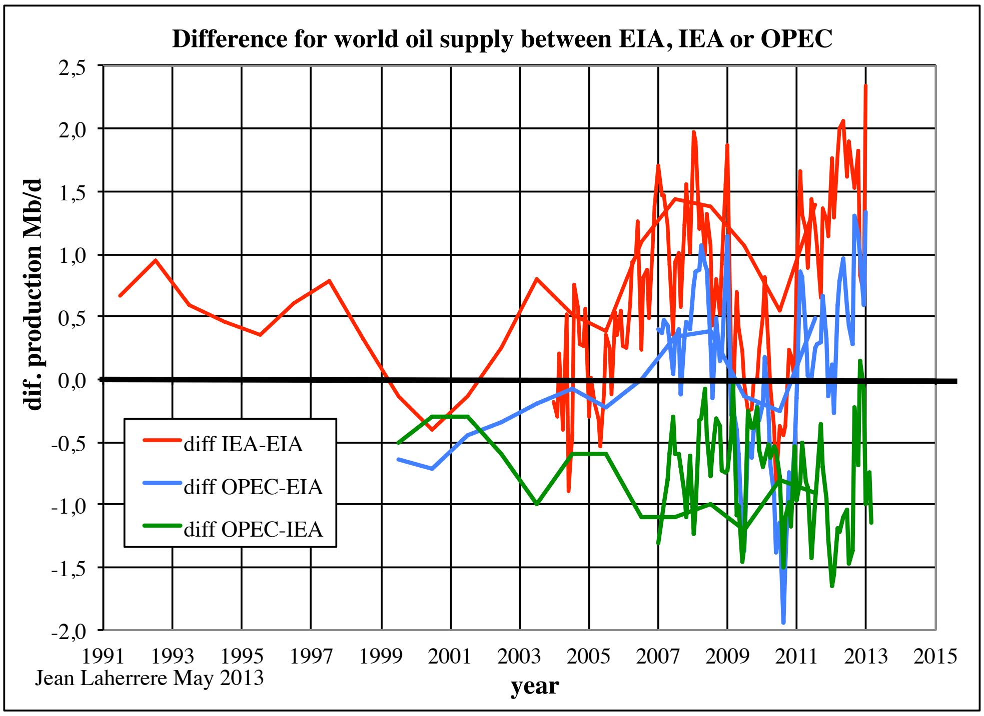

Figure 4: annual & monthly difference from world oil supply between EIA, IEA & OPEC

The discrepancies between the 3 sources are large and range from -1.5 Mb/d to 2 Mb/d since 2005. The difference between EIA and IEA was small (plus or minus 0,5 Mb/d) on the period 1991 to 2001, but since, it is significantly higher, mostly because of the difference of definition of NGL by the IEA, which classify condensate either as crude oil or as NGL depending the way it is sold. One can note that big changes occur at the beginning of the year when definition changes occur.

IEA and OPEC founded JODI (Joint Organizations Data Initiative), which reports oil productions from many countries, but is incomplete and unreliable (see http://www.theoildrum.com/node/9764#more for the reconciliation of JODI and EIA C/C crude and condensates production data). More generally, the biggest problem is the absence of a world consensus on the definition of oil and the comparison of the 2009 world oil production values from different sources shows dramatic differences among them

<u>World "oil" production in Mb/d</u>

	definition	2009	2008 corrected	2008 previous year
Oil & Gas Journal	oil	70,502 6	72,822 0	72,956 1
World Oil magazine	total supply	87,03	87,41	86,12
BP Statistical Review	liquids	79,947 933 766 1567	81,994 709 171 404 2	81,820 404 594 592 9
US DoE/EIA	crude oil	72,300 181 26	73, 647 131 11	73,706 142 5
	all liquids	84,158 559 44	85,459 655 83	84,597 461 4
IEA	oil	85,05	86,56	85,4
OPEC	crude oil	69,025 9	71,901 7	72,028 3
	oil supply	84,2	85,8	86

- Regarding the EIA, in its last version it has corrected all 2009 liquid values by 1 Mb/d, thus showing that one decimal in Mb/d - not 8 decimals – is sufficient!
- Regarding BP, the world oil production in its Excel file is reported with 15 significant digits! The last digit makes less than 10^{-6} barrel. This stupid number of digits comes from the conversion of cubic meters and tonnes into barrels with a very precise converter. The

authors should know that the accuracy of a sum is that of the most inaccurate item - for the world the less certain production.

- Regarding OPEC, it only uses three significant digits, but, unfortunately, they had to change the last one for their 2009 world oil supply, thus proving that only two significant digits are reliable.
- Regarding World Oil magazine: they stopped reporting world reserves in 2009
- Regarding condensates, they are measured at wellhead together with crude oil in the US. This is why the US reports crude + condensate and liquids from natural gas plants separately, whereas in OPEC countries where quotas apply to crude oil but not to condensate, condensates are badly reported.

If it is difficult to get reliable present production data but it is worse for the past and in particular for the beginning of oil production. From continuous published data, France was the world largest oil producer from 1811 to 1859. Then according to the API report 1857-1958, over 1859-1973, the US was the largest oil producer in the world. It was then overpassed by the FSU and later by Saudi Arabia. Baku did produce before but there is no published continuous data.

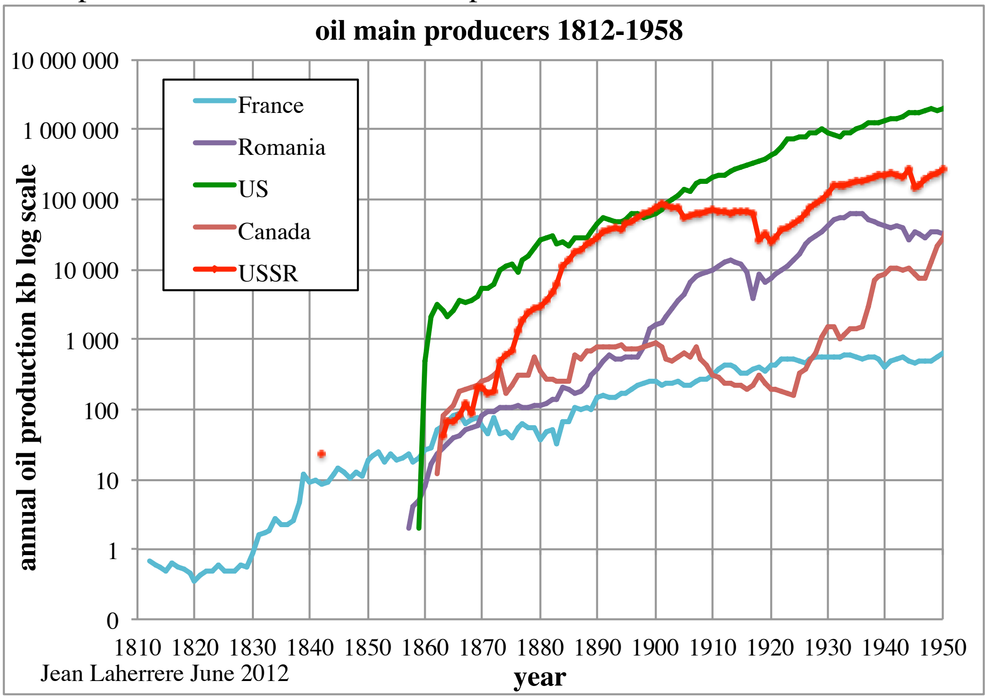

Figure 5: oil main producers 1812-1958 in log scale

The comparison of EIA and OPEC sources for the OPEC oil production shows bumpy plateaus since 2005(I call them plateaus because the variations within a plateau are smaller than the variations between sources). Crude oil production is reported by OPEC since the beginning, but the number of members has varied (Indonesia and Gabon are now out, but Angola and Ecuador are now in). So, for a matter of consistency, it is better to plot the data for the 12 present OPEC members which are: Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE and Venezuela.

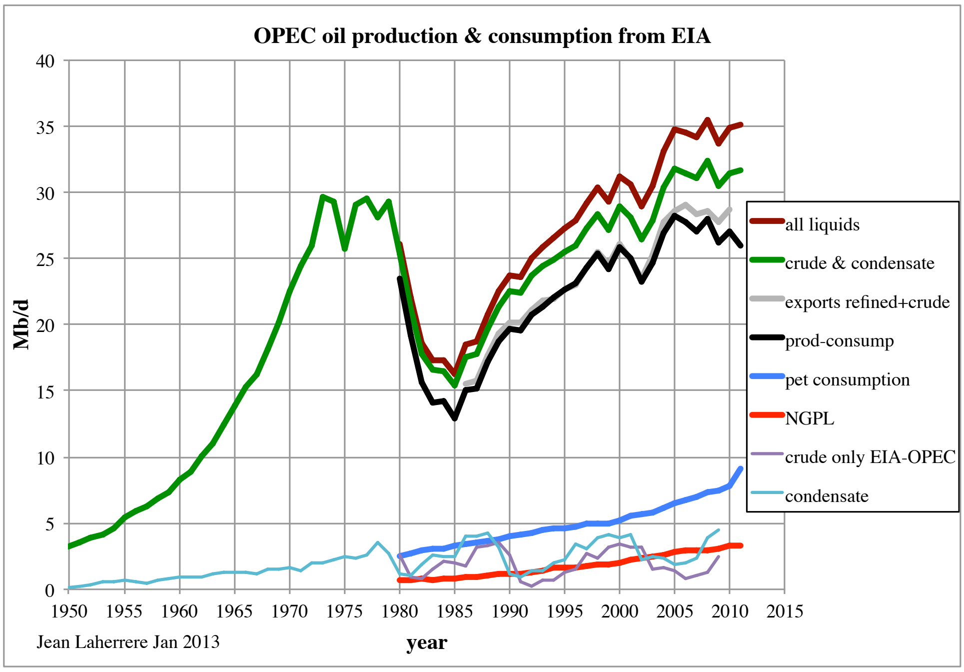

Figure 6: Note the large discrepancy, up to 4 Mb/d between EIA and OPEC crude oil production data

World oil remaining reserves

Here below are a few examples of the way official reserves are manipulated:

- OPEC reserves were inflated after the 1986 oil counter chock, because its members were struggling to increase their productions which had fallen from 30 Mb/d in 1980 to 15 Mb/d in 1985. As quotas were mainly based on reserves, 300 Gb of “political” reserves were added over 1986-1989 without any new discovery or the evidence of extra-heavy (XH) oil. This was confirmed by the former Aramco VP Sadad al-Husseini in 2007 in London at the "Oil and Money" Conference.
- In 2001, the definition of oil was changed with XH oil reserves added, first for Canada (Athabasca tar sands) and then for Venezuela (Orinoco). In reality, XH oil had been identified for a long time with 215 Gb discoveries in 1936-39 in the Orinoco belt, and Athabasca tar sands were known since the 18th century and produced since 1967, but reported separately as bitumen.
- The OGJ plot of Non-OPEC reserves was flat since 1970 but jumped in 2002 thanks to the addition of 200 Gb Athabasca reserves (in production since 1967). It is strange that Non-OPEC "proved" reserves outside Athabasca are since 1970: Has annual production been always replaced by new discoveries? In fact, it only shows that these reserves are purely political.
- In Spain, the OGJ proved reserves have remained the same at 150 Mb from 2006 to 2012, with a cumulative production of 75 Mb during this period! Similarly, Belarus reserves remained at 198 Mb over 1996-2012 with a cumulative production of 211 Mb! The explanation is that when OGJ does not receive any reply from their request of data, they just assume that production was exactly replaced by new discovery, an heroic assumption when it covers 15 years!

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.

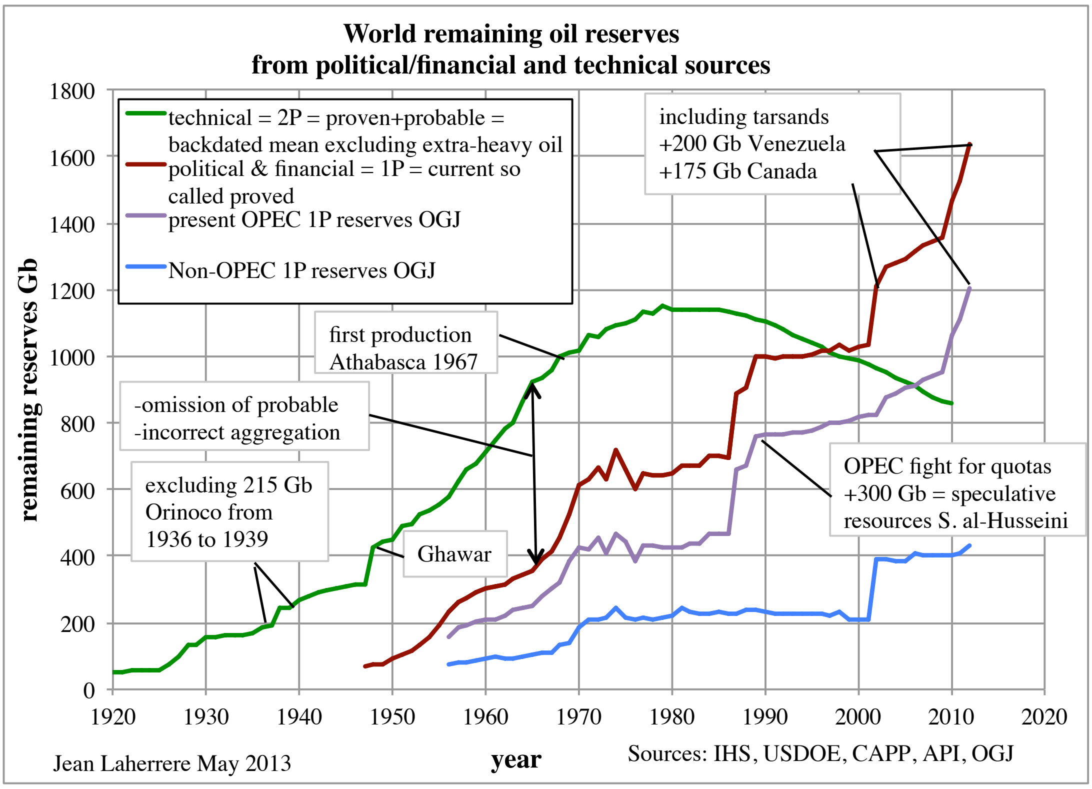

Figure 7: world remaining oil reserves from political/financial and technical sources

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!

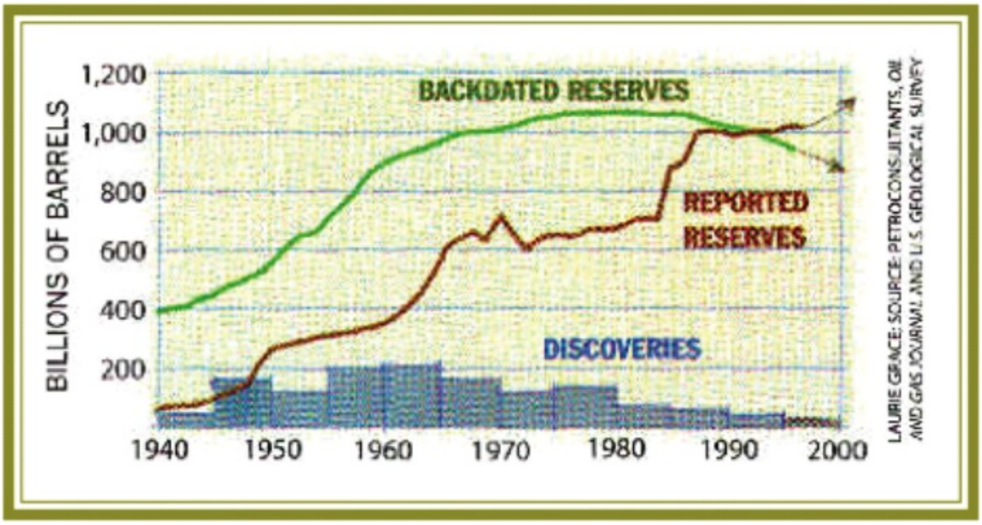

Figure 8: world remaining oil reserves from political/financial and technical sources in Scientific American March 1998 "The end of cheap oil" Campbell & Laherrere

-<u>Estimate of oil & gas ultimate reserves</u>

The creaming curve (cumulative backdated 2P (mean) discoveries versus the cumulative number of fields) is the best way to obtain the ultimate reserves of any producing country. The modeling is usually obtained with several cycles, with, as only unknown, the potential for a new cycle, what only bright geologists could tell, but there is no deepwater in the Persian Gulf!

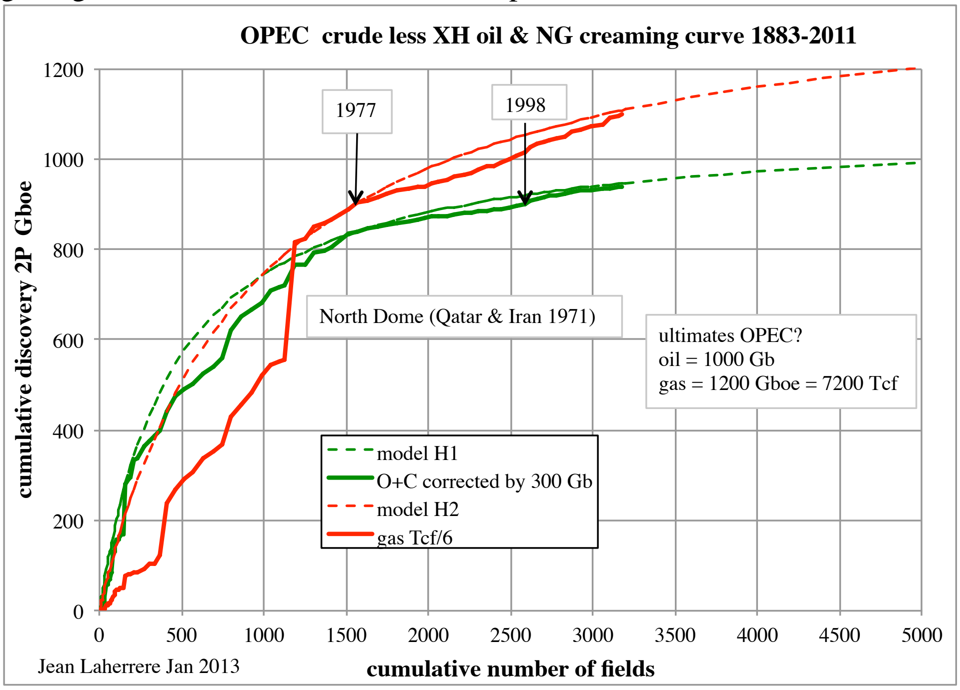

Figure 8: OPEC crude less XH oil and gas creaming curves

A 300 Gb correction is subtracted from the OPEC crude less extra-heavy (XH) oil creaming curve proportionally. So, OPEC oil ultimate reserves are estimated at ~1000 Gb but the large increase over time of their consumption is biting into the oil available for export. For OPEC natural gas, there is no correction, because natural gas is not subject to quotas, there is no attempt to "cheat" like for oil. OPEC gas ultimate reserves are ~1200 Gboe = ~7200 Tcf.

Unfortunately, as there are too many fields in the US, it is not possible to get a world oil creaming curve. 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.

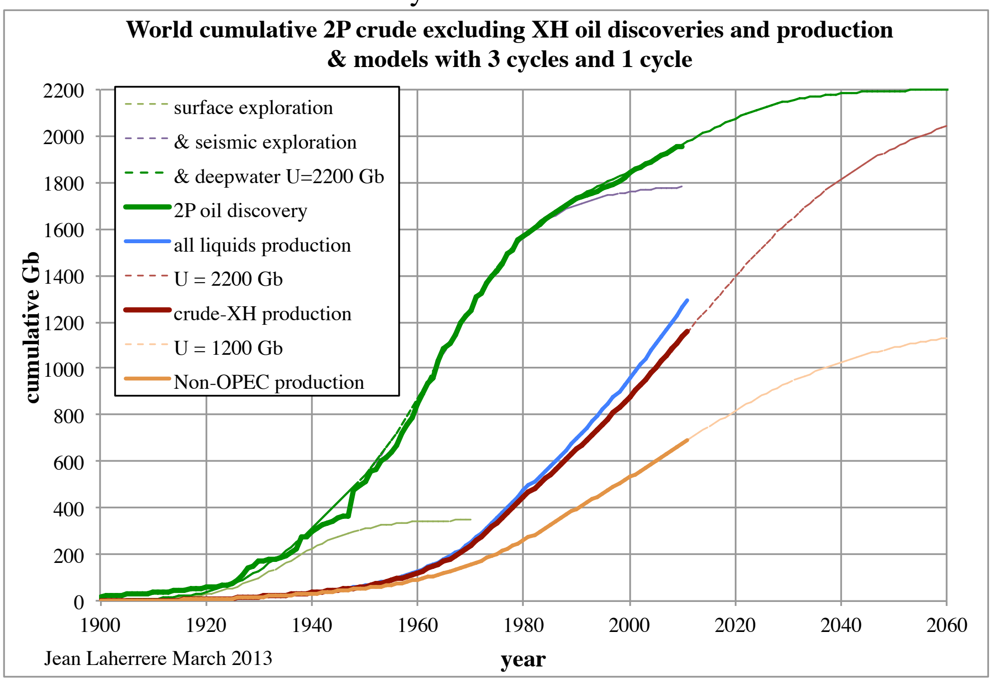

Figure 9: world crude less XH oil cumulative discoveries and cumulative production modeled with an ultimate of 2200 Gb

Because it is hard to get the world backdated mean discovery, some analysts only rely on production data to estimate the ultimate reserves, using the so called Hubbert Linearization method which, unfortunately is not very reliable when there are sudden changes. For instance, the plot of the world crude less XH oil from 1973 to 1985 trends towards ~ 800 Gb but the production from 1985 to 2011 trends towards 2200 Gb, a value consistent with the figure 9 estimate from oil discoveries.

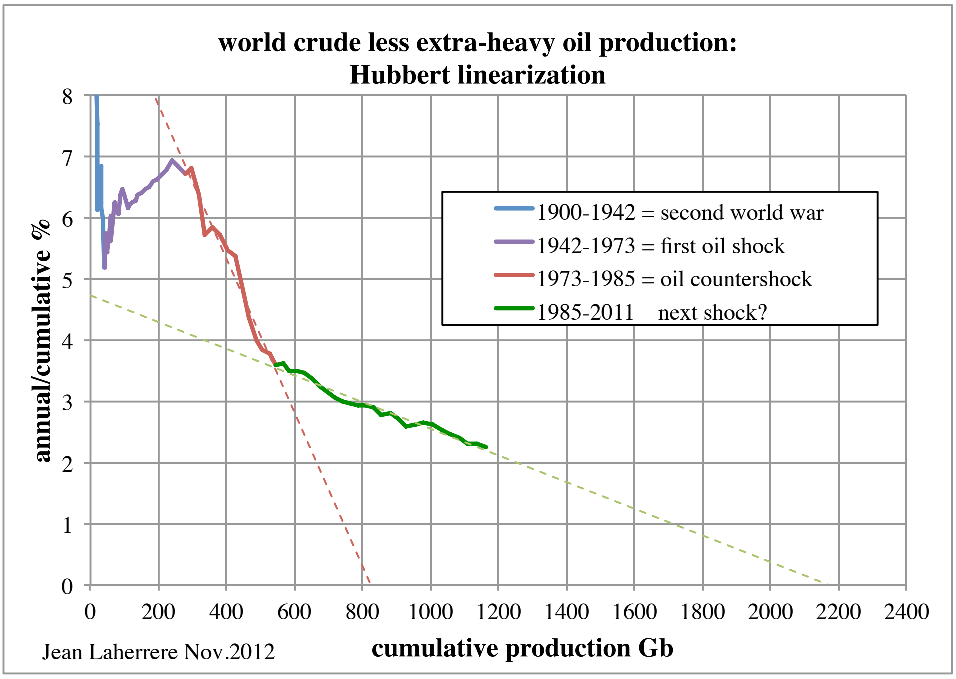

Figure 10: world crude less XH oil Hubbert linearization trending towards 2200 Gb

<u>Crude oil +NGL</u>

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,

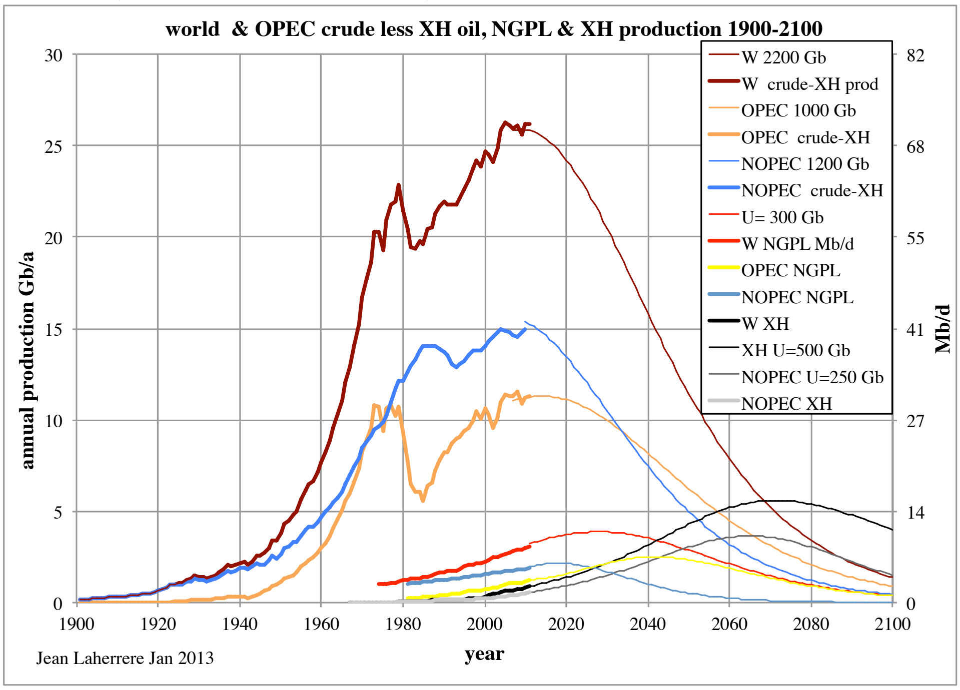

Figure 11: world, NOPEC & OPEC crude less XH, XH & NGPL annual production

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.

<u>All liquids</u>
To obtain the "all liquids curve", built only for the world, it is necessary to add the refinery gains, the BTL (biofuels with a maximum production reduced from 6 Mb/d to 5 Mb/d because the competition between biofuels and food) and other XTL (CTL, GTL, etc.) considered as negligible.

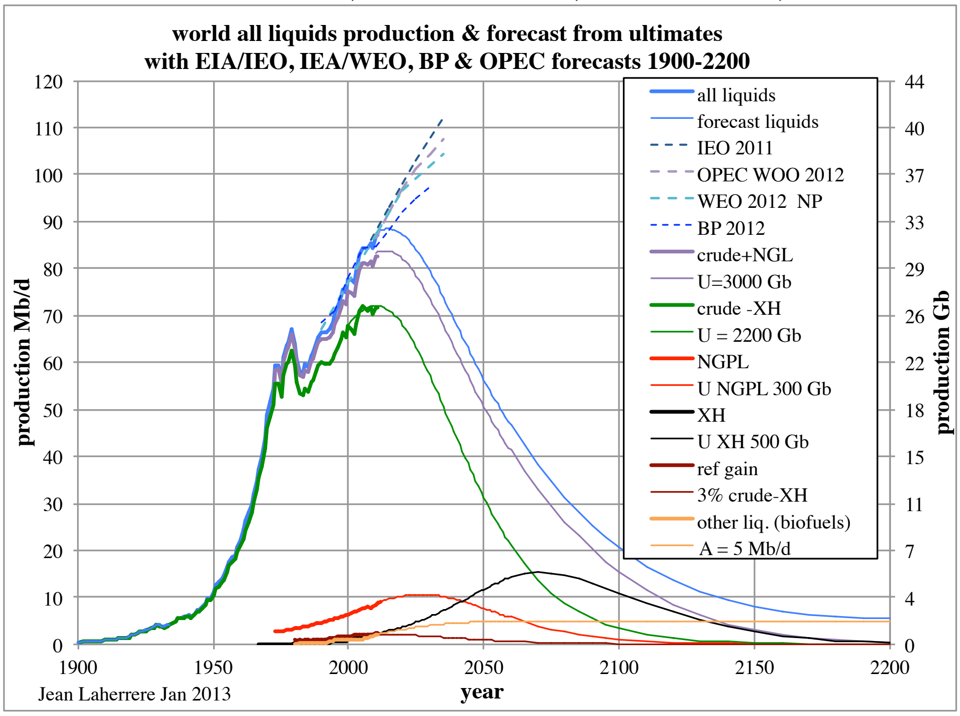

Figure 12: world all liquids production & forecast 1900-2200
Our forecast on "all liquids" supply equal to the "all liquids" demand (for instance, there is biofuel in gasoline when one fills the tank of a car), is compared with those of the IEA (WEO 2012), the EIA (IEO 2011) and BP (BP 2012) which are "Business as usual", always growing up to 2035.

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

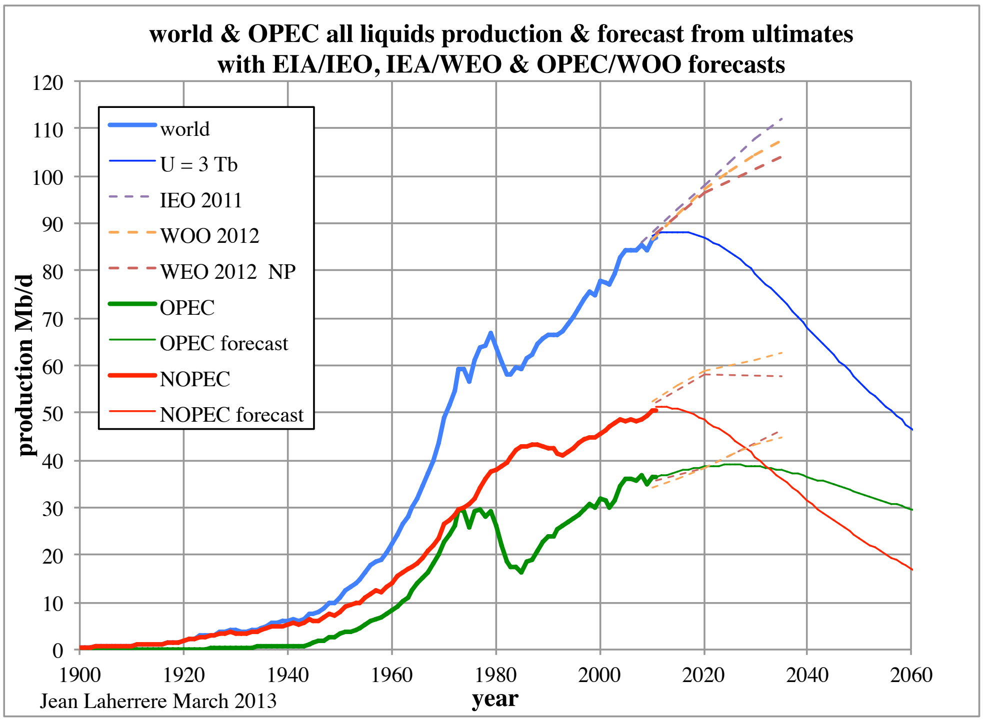

Figure 13: OPEC & Non-OPEC all liquids production & forecast 1900-2060

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

With more and more NGL in the oil production, the figures in weight (Mt) are shrinking versus those in volume (Mb/d). Non-OPEC less FSU (Former Soviet Union) (orange) is at plateau since 1995.

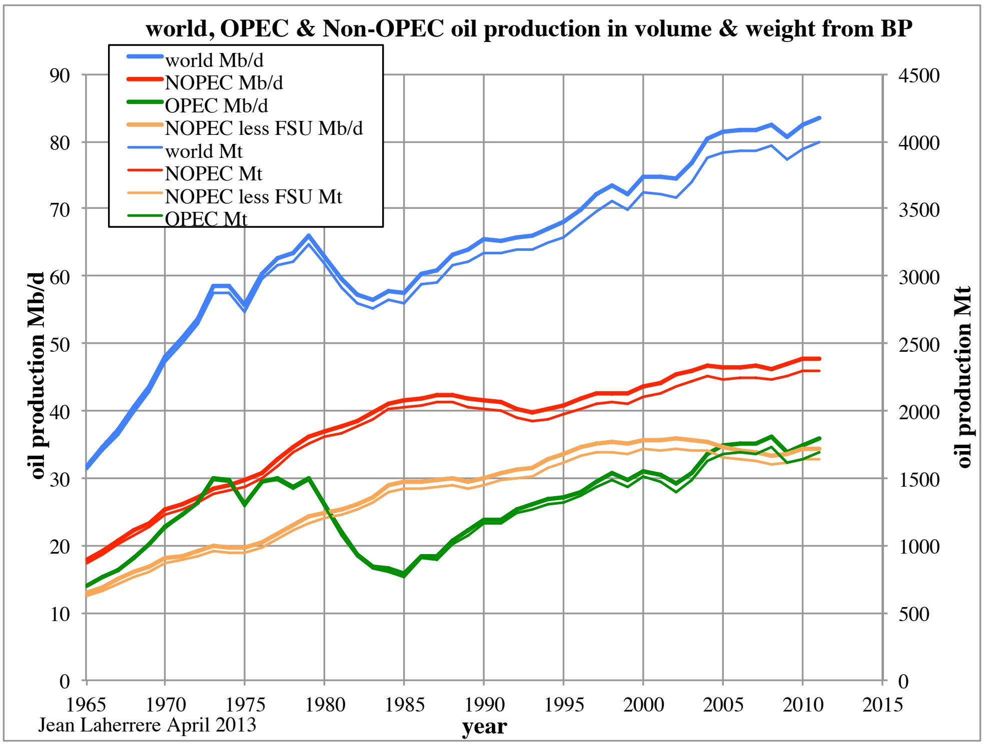

Figure 14: OPEC & Non-OPEC oil production in volume & weight from BP

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 at plateau (like OPEC oil production) and will decline to zero before 2050, unless their large and growing consumption due to heavily subsidized gasoline (Iran gasoline is hundred less expensive than in neighboring Turkey) is reduced like it was in industrialized countries. When OPEC oil export cease before 2050, OPEC will cease to act as a producer cartel

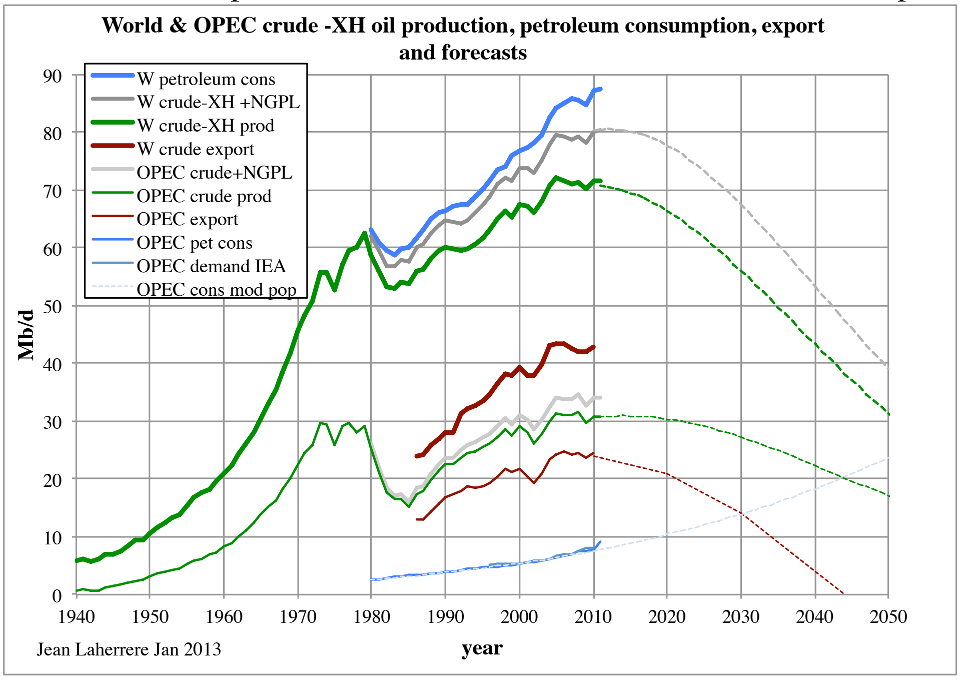

Figure 15: world & OPEC production, consumption & export 1940-2050

<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 (lower 48 states or USL48) displays a symmetrical curve with a peak in 1970 as forecasted by King Hubbert in 1956.

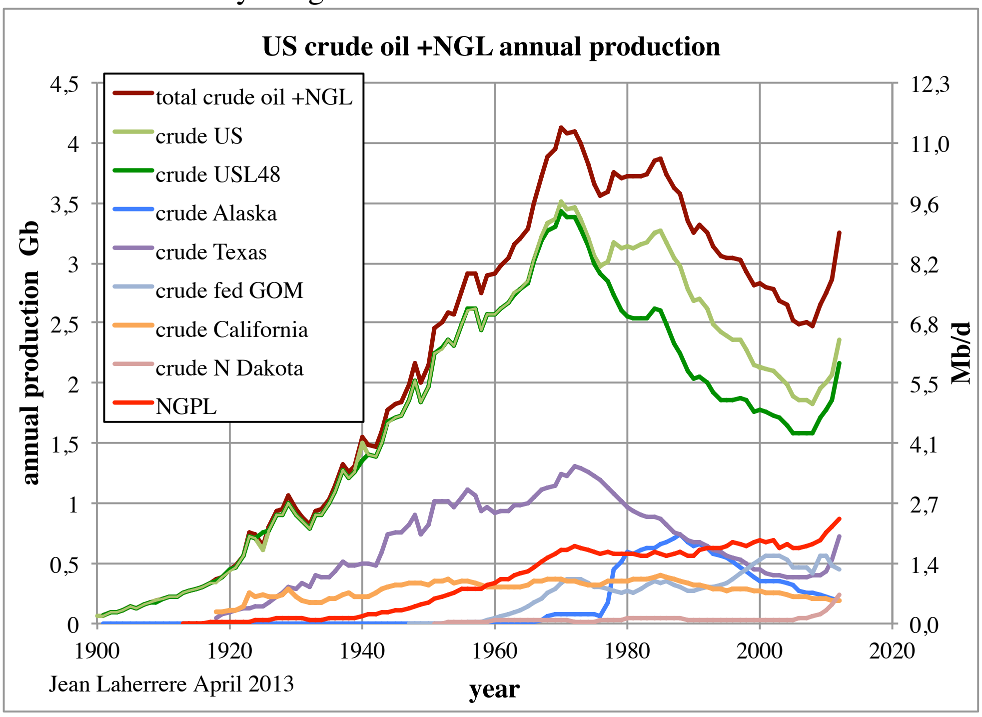

Figure 16: US crude oil & NGL production 1900-2011

It is fascinating to see that this symmetry is only broken in the mid-50s because of the growing cheap OPEC oil imports (stopped in 1959 by the Mandatory Oil Import Program, which led to the creation of OPEC) and in 1980 because of the high oil price. The regularity of the curve is explained by the many producers acting on their own, except when they are all driven by common external factors such as unusual prices or policy decisions. Alaska production began in 1960 but only became significant in 1977 and compensated the L48 decline up to 1987. In detail, one notes that since 1990, NGPL production is larger than Alaska or Texas output. One also notes that, since 2009, deep-water and shale oil has changed the trend, making some people to dream that the increase will continue and eliminate US oil imports.

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. The increase since 2000 is mainly due to the number of gas rigs with a peak in 2008 because of the high natural gas prices, followed by a collapse in both the natural gas price and the number of gas rigs because of too many wells and too few gas pipelines.

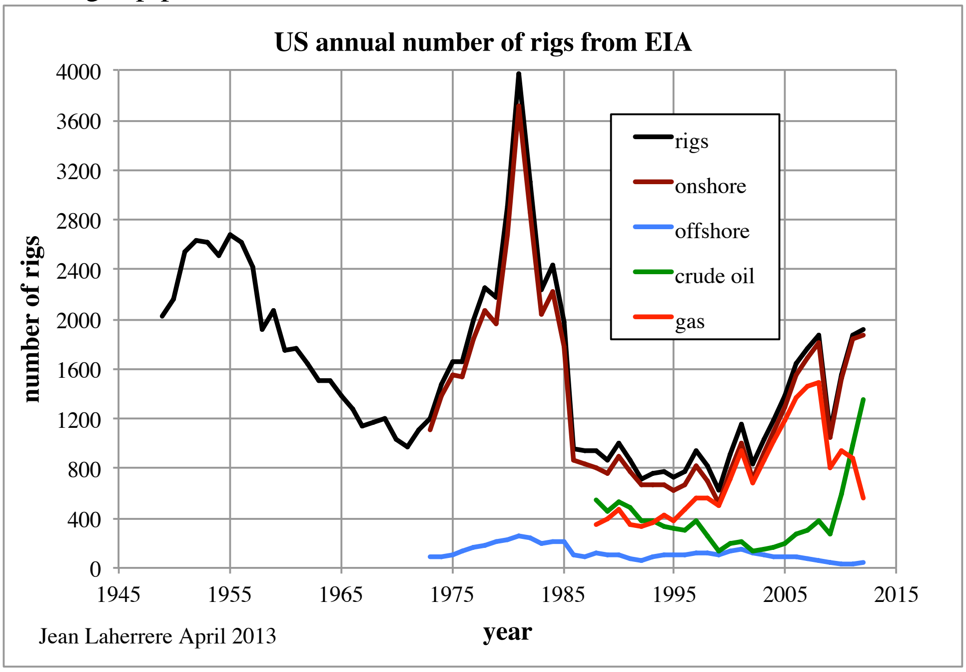

Figure 17: US annual number of rigs 1947-2012

In 2012 there were 1919 rigs in the US, 365 in Canada, 423 in Latin America, 119 in Europe, 96 in Africa, 356 in the Mideast and 241 in the Asia Pacific region. In the US, the number of gas rigs fell from 1491 in 2008 to 570 in 2012, but the number of oil rigs has increased from 128 in 1999 (when oil price was down to 10 $/b) to 1919 in 2012 mostly because of the shale oil boom. 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 (QE). 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, exhibits a sharp increase since 2005 because of the shale gas boom. In 2011 unconventional (CBM, tight gas and shale gas) gas production (orange) was higher than that of conventional gas (red). The amount of ultimate reserves for conventional natural gas seems to be 1250 Tcf and for unconventional gas, it is estimated at 750 Tcf making a round total value of 2000 Tcf (2 Pcf). USDOE reports shale gas ultimate reserves at 482 Tcf and only 273 Tcf for proved reserves
http://www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf

This 2000 Tcf (2 Pcf) leads to a peak in 2020 at 22 Tcf. The decline after 2020 of all US natural gas (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!

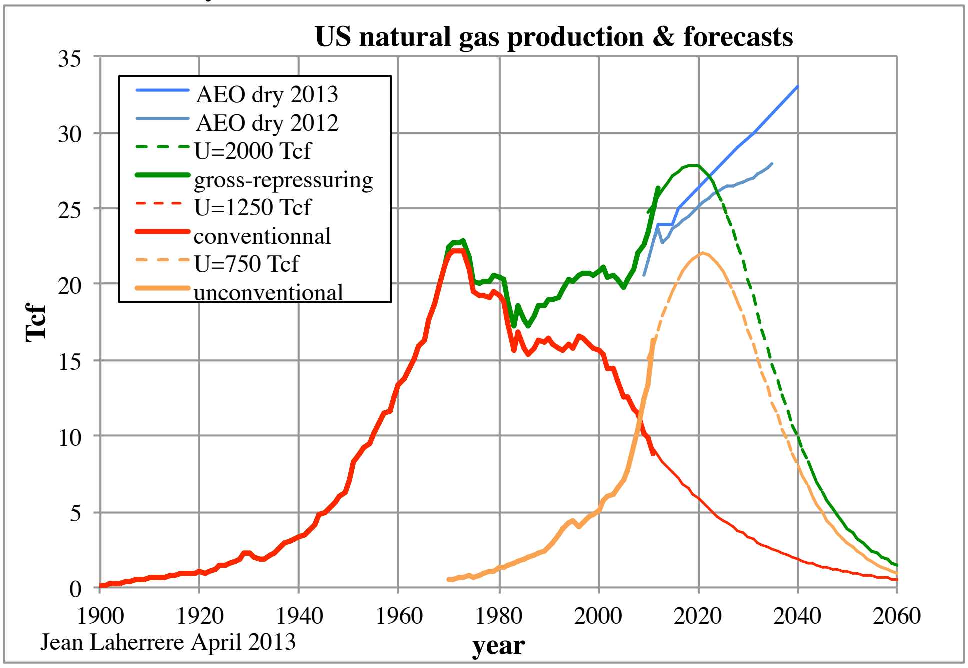

Figure 18: US natural gas production 1900-2060

Some claim that the US can export its shale gas as LNG, and are investing for, even though conventional gas (in red) is declining fast and will be quite small in a few years. The uncertainty on future conventional gas production is low, but it is high on future unconventional gas production.

US gross natural gas monthly production is presently flat since October 2011 after its sharp increase since 2003 when only shale gas production has been rising.
US shale gas production seems to peak in 2012 on Hughes May 2013 Brussels graph: is the peak because lower price or lack of sweet spots? Likely both!

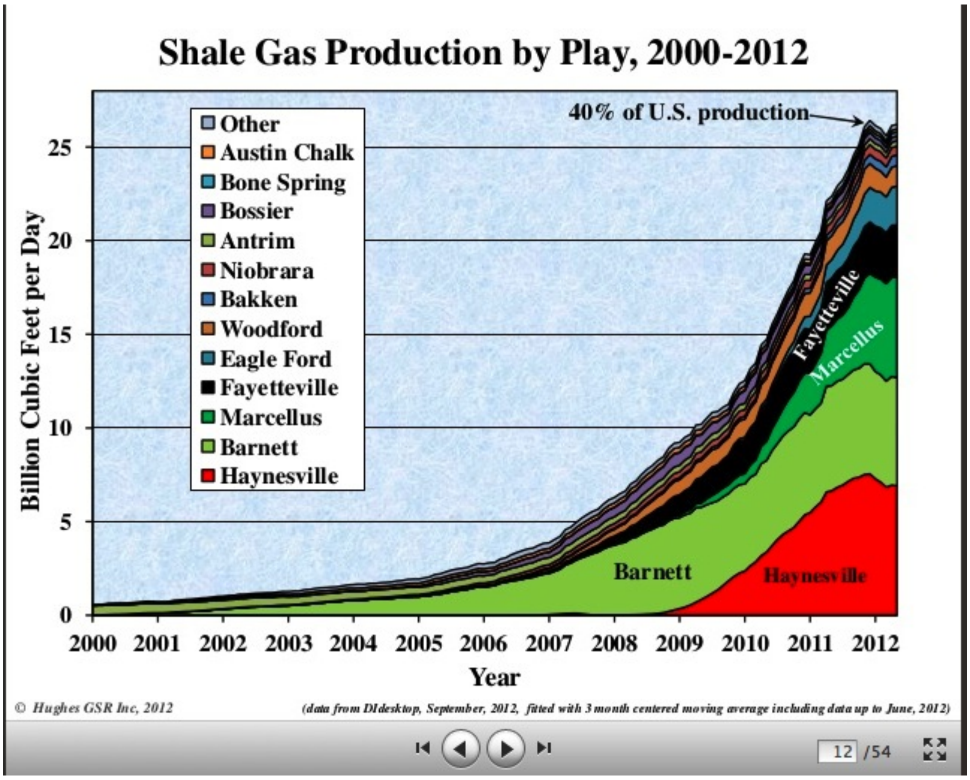

Figure 19: US shale gas production 2000-2012 Hughes 2013

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).

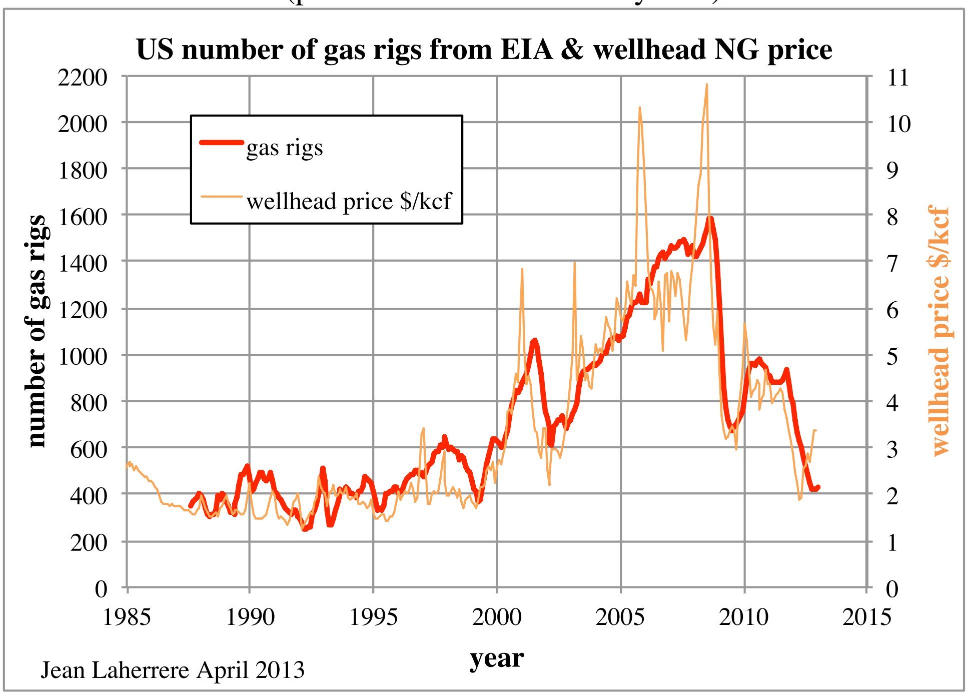

Figure 20: US natural gas price and number of gas rigs from EIA

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 similarly to the US gas flaring and, since 1995, to that 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 lowered coal prices and increased the expectation of LNG exports.

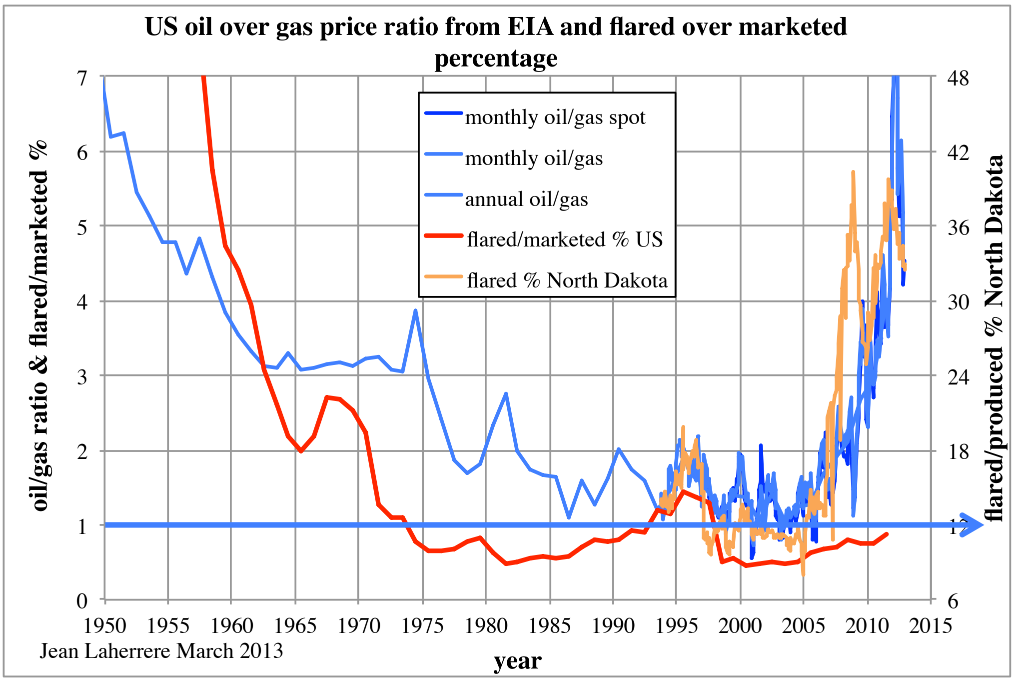

Figure 21: US oil over natural gas price and flared over marketed gas percentage

The tremendous decrease of US natural gas prices since 2009 is a reminder of the collapse of oil price in 1932 (from 1 $/b down to 0.1 $/b) after the discovery of the East Texas oil field because the competition between land owners led to too many wells drilled. The governor of Texas was obliged to issue the martial law and to send Texas guards to close wells in order to return to a more reasonable oil price.

In the same vein, the shale gas boom was driven by promoters like Chesapeake who were trying to produce as fast as possible to pay their debt back and mainly to push up the value of their share on the stock market. This led to a collapse of US wellhead natural gas price from 10 $/kcf in 2008 to 2 $/kcf in 2012, with the number of gas rigs following the price trend.

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In a paper Le Monde Diplomatique March 2013 http://www.collectif-haut-bugey.com/actualite/gaz-de-schiste-la-grande-escroquerie-le-monde-diplomatique-mars-2013 shale gas is described as a big swindle, quoting 11 US papers.

World, Non-OPEC & OPEC natural gas production forecasts

Annual natural gas productions are modeled on the basis of the ultimate reserves including unconventional gas: 13 Pcf for the world, split into 7 Pcf for NOPEC (Non-OPEC) and 6 Pcf for OPEC. The reserves of the largest gasfield is North Dome (Iran/Qatar) are presently estimated to be 1.5 Pcf, but this value could be reduced to 1 Pcf!
The uncertainty of this ultimate is high, because the fuzzy limit between reserves and resources. Furthermore biogas can be produced in higher volume and replaced fossil natural gas.

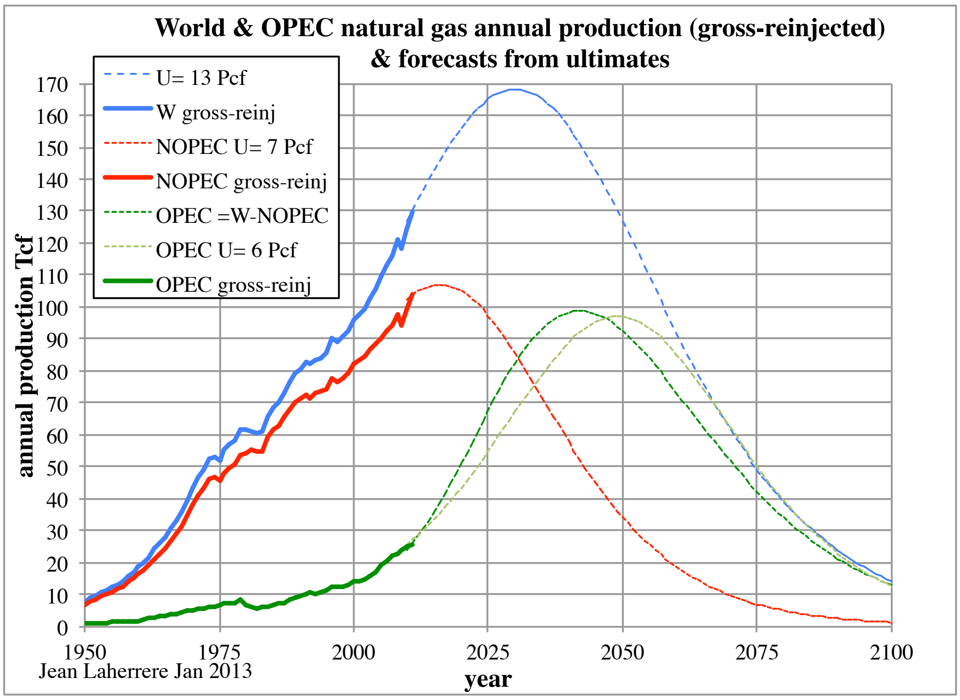

Figure 22: world, NOPEC & OPEC natural gas annual production

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. For OPEC 6 Pcf ultimate reserves, production will peak around 2050 at ~100 Tcf/y. Figure 18 shows the recent surge of US natural gas due to shale gas, which explains why so many are betting on US LNG exports. But US shale gas production has many environmental and economic constraints, and may decline after 2020.
Outside the US, the potential of shale gas is very uncertain because the "Not In My Back Yard" attitude is much stronger when the gas belongs to the state and not to the landowners. Unless mining code are changed, the potential of shale gas is weak with the largest unknown being China. Another problem is that injection of large volume of water at high pressure triggers earthquakes: it occured in several places and it was the same with a geothermal project in Switzerland and also in the US in the 70s with radioactive waters.
Suffice to say that up to now, there is no example of economical shale gas production outside the US. Hence my question: Will the hype on shale gas fall like the hype on biofuels a few years ago?
The problem with unconventional is NOT the size of the resources in the ground nor that of the reserves expected to be ultimately produced BUT the size of the tap which depends on the economy and the energy return over energy invested.
All livestock ruminants emit 115 Mt/y of methane gas (one single cow emits one cubic meter of methane per day), world rice fields emits about 100 Mt/y of methane making 340 Mt/y when combined with livestock and wetlands, against 300 Mt for human activities. Biogas is everywhere, but who is collecting it from cows or rice fields? No one, because it is not economical. For this example as for other cases, people confuses reserves and resources!
Similarly, huge volume of methane are claimed in oceanic hydrates but cannot be produced economically. The Japanese found hydrates in the Nankai offshore in 1999 but the attempt to produce them last March looks like a cow fart, based on the photo of the flare. Dissolved methane in geo-pressured aquifers of the US Gulf Coast was estimated in the 1970s to be over 50 Pcf (more than hydrates!), but the production tests were uneconomical with huge pollution problems because of the brines. No one is talking anymore about producing such dissolved methane!

<u>Liquids from natural gas plants (NGPL)</u>

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.

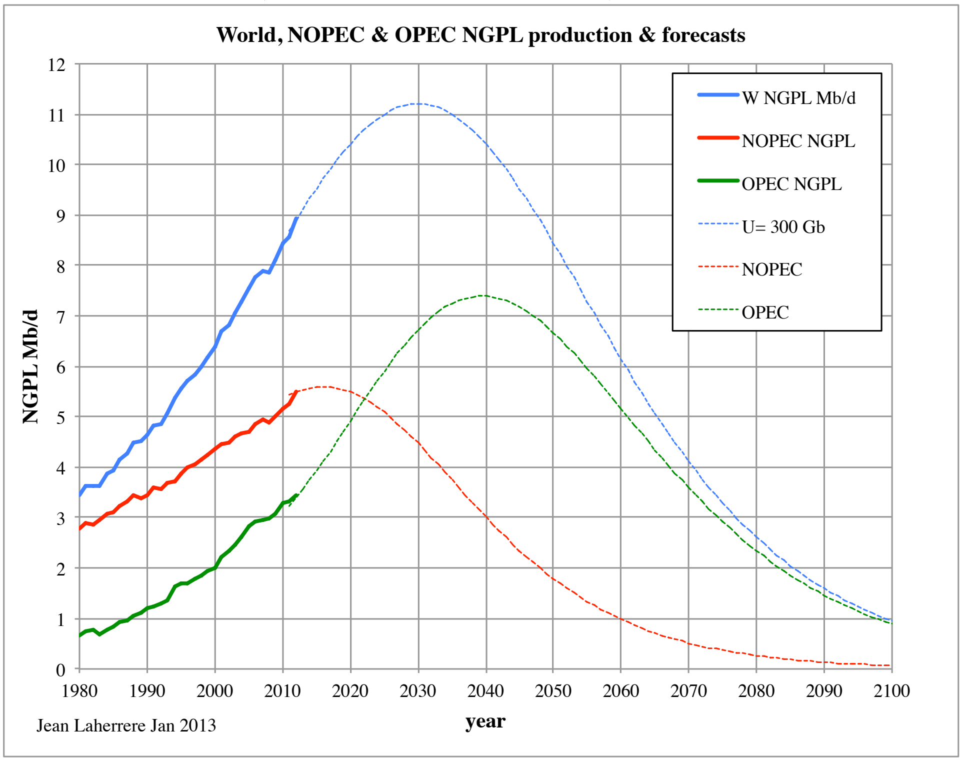

Figure 23: world, NOPEC & OPEC NGPL production & forecasts for 300 Gb ultimate

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.

<u>Oil forecasts from different ASPO authors</u>

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 (*Geologues* n°176 page 68) 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!

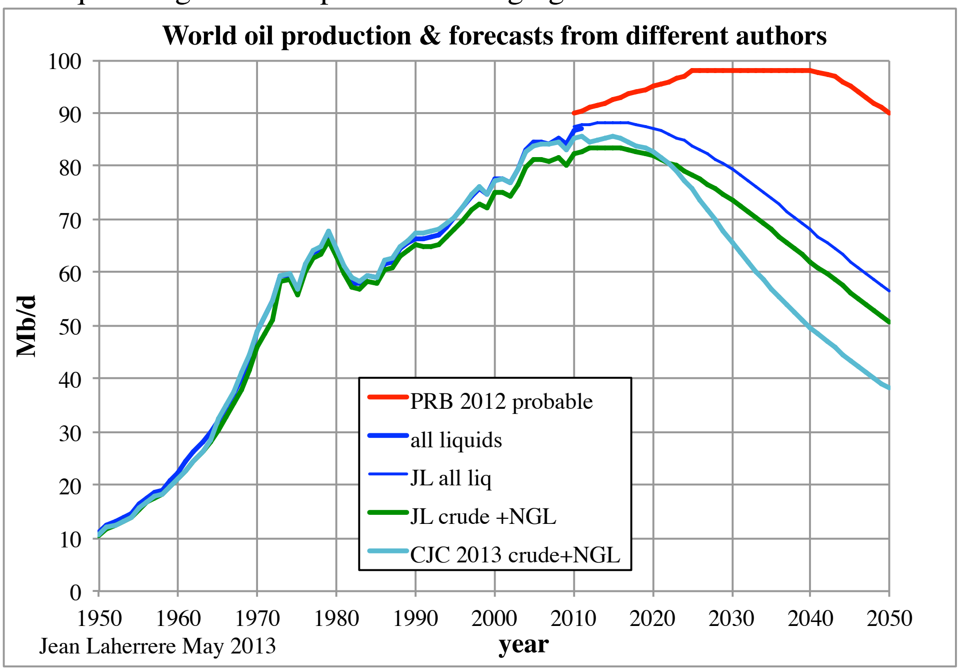

Figure 24: world oil production & forecasts from different ASPO authors

In *Geologues* n°176 page 65 Alain Perrodon & PR Bauquis estimate the oil ultimate at 4300-4600 Gb with the following breakdown: produced = 1200 Gb; proved developed and undeveloped = 1600 Gb (reported page 67 as 1400 Gbep, including XH oil, giving a discrepancy of 800 Gb); EOR = 400 Gb; yet to find = 300 Gb; extra-heavy = 600 Gb; oil from source-rock 200-500 Gb; but where are the natural gas liquids? Are they in oil, when they depend upon the way natural gas is treated in gas plants?
In fact they speak about remaining oil reserves (without indicating for which date), when geologists speak about initial reserves.
This high ultimate of 4600 Gb explains the discrepancy with my forecast based on an ultimate of 3000 for crude +NGL (figure 12 with NGPL = 300 Gb)

One may regret that the detailed inventory made in Geologues n°176 does not mention the bias of political/financial proved current reserves versus the technical backdated 2P as shown in figure 7. It is a denial on the impact of politics and finance on oil reserves.
Economists relying on BP/OPEC or EIA/OGJ proved reserves believe that reserves has been raising since 1950.
For the period 2000-2010 Marc Blaizot *Geologues* n°176 page 47 indicates that 32 Gboe has been discovered per year, against 50 Gboe produced per year: of course he speaks about 2P initial reserves (and not about proved remaining reserves), which is the base of the estimate on ultimate reserves. Blaizot's good graph (except confusing Billion and Giga symbols with Bb and Gb) reports the giant discoveries of the last decade (from IHS 2P reserves), in particular Dhirubai 2.2 Gboe (world's largest gas discovery of 2002) in India (KG-D6 block in Krishna-Godavari basin), but recently the reserves of these gas fields were divided by 3 after an unexpected sharp production decline (peak at 61 Mcf/d in 2010, 15 in May 2013) with Indiapetro asking who is guilty: the operator Reliance or the auditor Gaffney Cline? The bad management of the water (closure of 8 wells out of 18) or the bad estimate? Remember that BP owns 30% purchased 7.2 G$! But in May Reliance has found gas and condensate in new deeper reservoirs (D55).

The following graph displays the same data as figure 7, but it is the annual discoveries for 2P and 1P compared to annual production (crude oil + condensate and crude + NGL)). Annual production exceeds 2P discoveries since 1980, but not 1P additions which are biased and therefore unreliable.

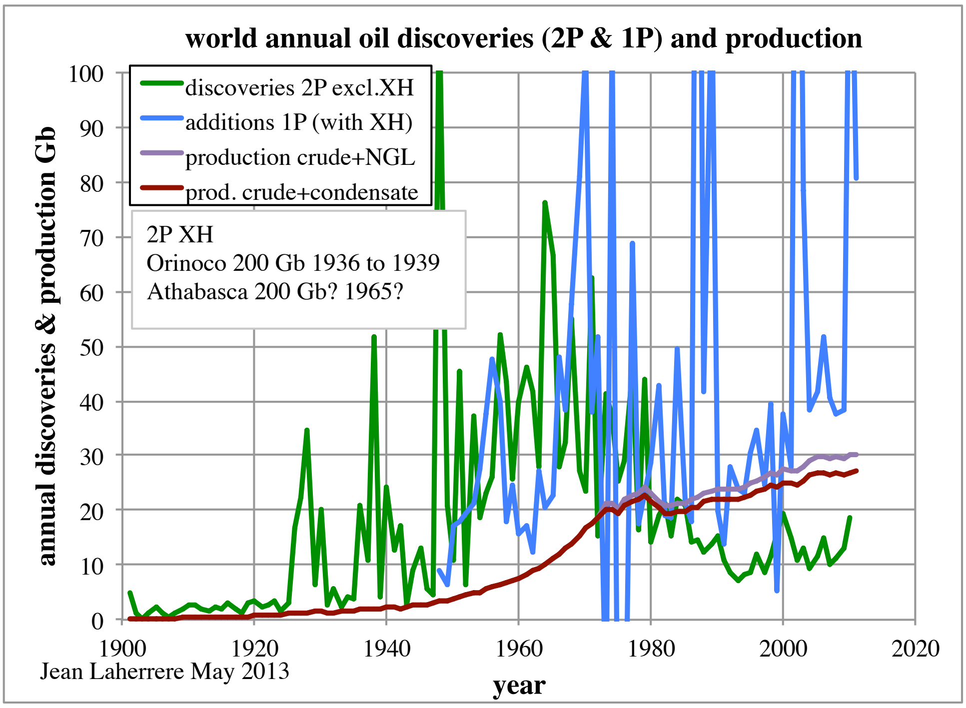

Figure 25: world annual oil discoveries (2P & 1P) and production

The similar graph for natural gas annual discoveries & production shows that 2P discoveries become smaller than production around 2000.

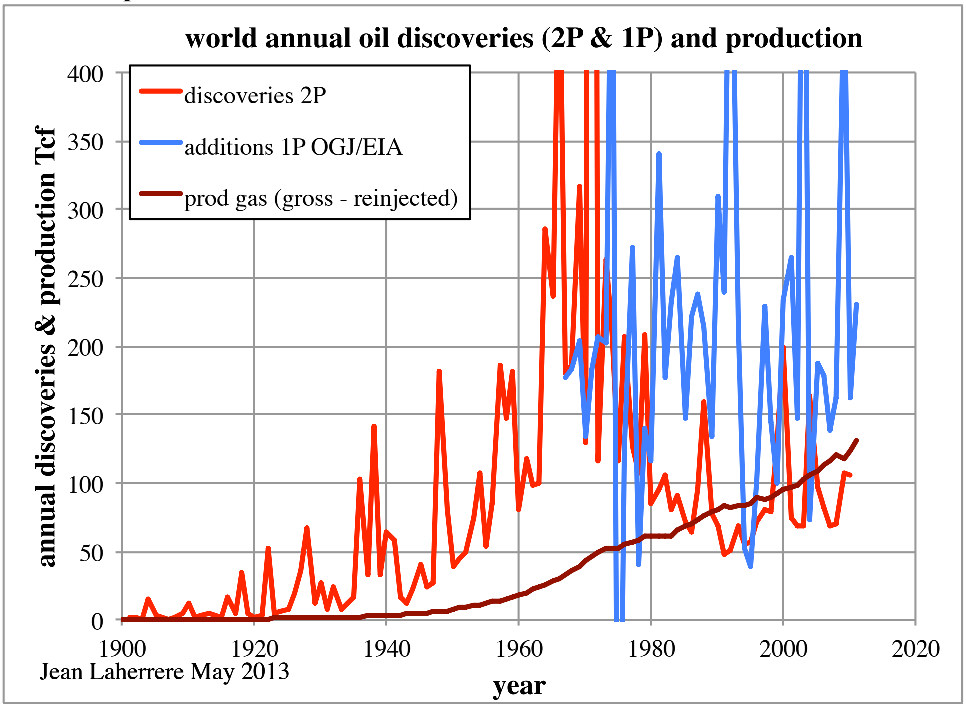

Figure 26: world annual natural gas discoveries (2P & 1P) and production

The cumulative discoveries & production for the period 2000-2010 are as follows

2000-2010	2P discoveries	1P additions	production
oil Gb	163	746	311
gas Gboe	184	449	200
gas Tcf	1105	2695	1198
O & G Gboe	347	1195	511
Gboe/a	32	109	46

Economists rely on the EIA 1P additions to believe, even before the shale boom, that there is no problems of 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!

The same kind of denial exists in *Geologues* n°176 page 93 when explaining the flooding of the Fukushima generators by the tsunami (14 meters wave height - see page 91), but forgetting to say that TEPCO deliberately lowered the plant location by erasing 30 m from the cliff to build their generators, in order to save money on water pumping, in spite of the fact that many tsunamis higher than 10 m were known in the area during the last century. It was a stupid move, as was the decision to switch off all alarms at Chernobyl. Einstein says speaking about "*infinite: best examples Universe and human stupidity, but I am not sure about the first one*"

One may add that these forecasts assume that there are no above ground constraints. The ongoing economic crisis can change this assumption widely.

<u>Walls on oil price and on crude oil production</u>
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.

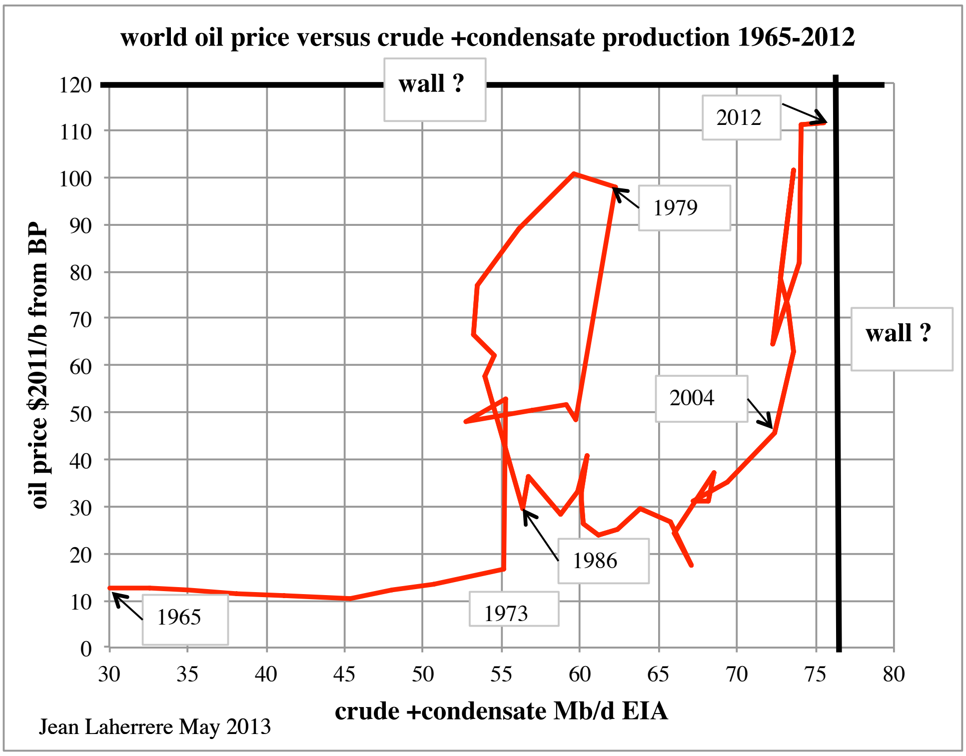

Figure 27: world oil price ($2011/b) versus crude oil production 1965-2012

Energy intensity: GDP/oil production

Economists claim that energy intensity (primary energy consumption divided by GDP in real dollars) has sharply decreased in the past and will continue in the future. The US energy intensity was 24 kBtu/2005$ in 1930 but less than 8 in 2010. The plot shows several linear trends: 1930-1944, 1970-1985, 1985-2011, but it is useless to extrapolate them because it could not go towards zero.

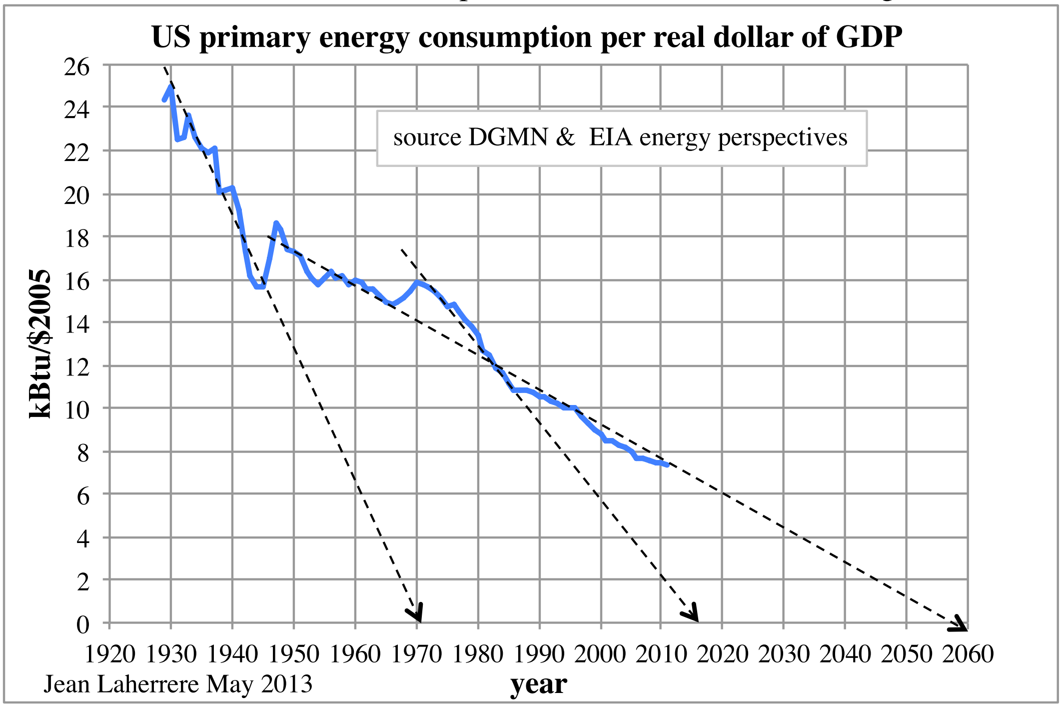

Figure 28: US energy intensity 1929-2011

GPD is a poor indicator, which corresponds to with expenditures and not to wealth: the more wars, catastrophes, drugs, the more GPD grows. Furthermore, as GDP is the growth indicator, allowing to judge the politicians, it is manipulated. In 1998, the hedonic factor was introduced to better account for the productivity brought by IT investments (new computers at same price but with twice memory are valued twice their price). In the same vein, US GDP is 3% inflated after July 2013,

because of the introduction of R&D spending, art, music, film royalties, books, theatre... Is this a gadget to diminish the US ratio debt over GDP?
Similarly, energy intensity which is a ratio of consumption to GDP is also a poor indicator. This being said one has to keep in mind that GDP depends strongly upon energy (Kummel, Ayres estimate its contribution at 50%, the same as the total of labor and capital) and the growth of GDP follows the growth of primary energy consumption as shown for the US.

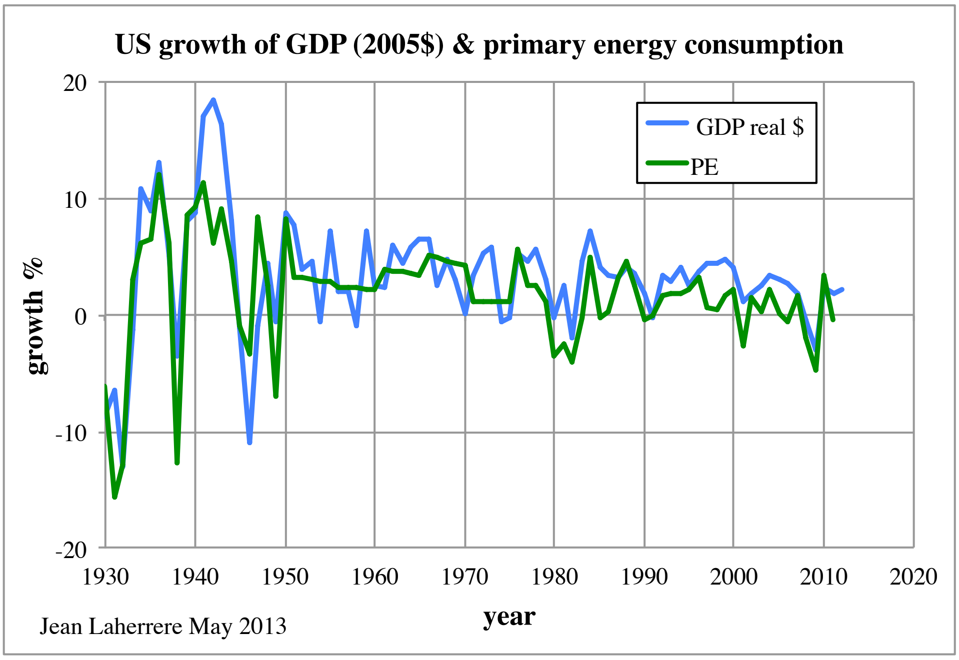

Figure 29: US energy intensity 1929-2011

EROEI

Many economists claim that if oil price increases, some uneconomical resources will be changed into reserves, but they forget that, if gold can be extracted in mines at 4000 m when its price is high, coal deeper than 1800 m or offshore are no more "reserves" because the energy invested to produce them is higher than the returned energy: it is the EROEI concept (energy return on energy invested) promoted by Charlie Hall (and his students like Cleveland.) This is an important reminder that, in addition to cost versus price, there is also the limit of energy balance. This limit can apply for shale plays. However, the problem of EROEI is the difficulty to measure the invested energy in energy units and not in monetary units. For more than 10 years The EROEI for corn methanol was estimated by several university studies as being below 1 (around 0.7) when the US-DOA puts it above 1 (around 1.3).

-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 (see for instance Thierry Bros paper at APGEF-AMIGAZ 27 March 2013). They confuse proved reserves, which are supposed to represent the expected production with present technology and economic conditions 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.
Prudhoe Bay was discovered in 1968 and in 1970 initial oil reserves were estimated by OGJ (from geologists) in the 10-15 Gb range, when the oil price was about 3 $/b. Presently Prudhoe Bay has produced about 12 Gb and its ultimate is about 14 Gb, which is well within the range of 1970 when

oil price was 30 times lower. Oil price does not change much the ultimate of conventional oil fields, when correctly estimated (therefore not based on the SEC rules, which are purely financial!)

The best proof of the quality of our estimate on remaining 2P reserves on figure 7 in 2013 with an oil price of 100 $/b is that the values are nearly the same as in figure 8 of 1998 when the oil price was of 10 $/b. Anecdotally, Elsevier published in 2003 an Encyclopedia of Energy with an article I wrote: "Oil and Natural Gas Resource Assessment: Production Growth Cycle Models". Elsevier asked me to update this paper where the 2003 estimate for the world conventional oil was 2000 Gb!

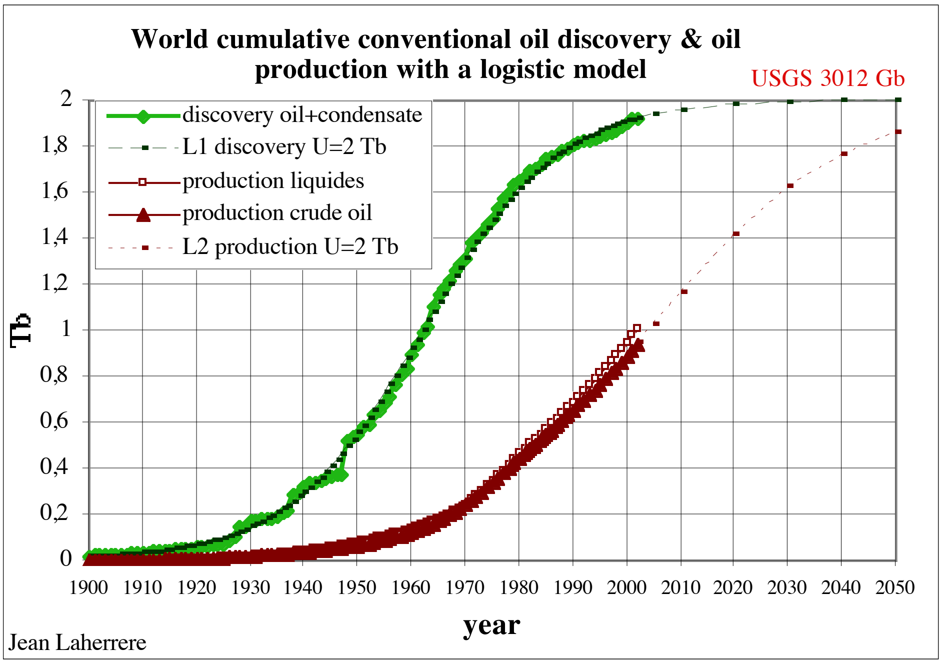

Figure 30: world cumulative conventional oil discovery & production from Laherrere 2003 figure 10

In 2003, where the oil price was around 25 $/b, the uncertainty on world oil reserves was such that only one digit was used to estimate the world conventional oil ultimate which was chosen as 2000 Gb or 2 Tb., using only one cycle to model both discovery and production

In 2013, with an oil price around 100 $/b, on figure 9 for the world crude less extra-heavy oil (there is no consensus on the definition of conventional) our ultimate reserves are now 2200 Gb, thanks to the addition of a new cycle for deepwater and subsalt. Our guess on the inaccuracy of 2P reserves is about 20 % and any change by less than 10% is useless.

For the unconventional oil (using third recovery as steam, hydraulic fracturation) 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 12 where the peak of extra-heavy oil is 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 dolomitic 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 Arabo-Iranian Petroleum System (most of the Middle East covering 600 000 km^2), 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. The average Bakken production per well is 132 b/d/w on March 2013 with 5457 wells, it was 145 b/d/w in June 2010 with 1663 wells, but in February 1954 the first Bakken well had a peak of 274 b/d/w. North Dakota production may very likely peak in 2013 because the number of rigs peaked in June 2012 with 200 rigs (176 rigs in April 2013).

In 1998 we (Colin Campbell and myself) wrote in Scientific American an article "The end of cheap oil" when oil price was at 13 $/b. Our article was on the Censored 1999: *The News That Didn't Make the News, the Year's Top 25* http://www.projectcensored.org/top-stories/articles/21-global-oil-reserves-alarmingly-over-estimated/ 21. *Global Oil Reserves Alarmingly Over-Estimated*
Source: SCIENTIFIC AMERICAN, Title; "The End of Cheap Oil," Date: March 1998, Authors: ***Colin J. Campbell and Jean H. Laherrere, two independent oil-industry consultants, predict that global production of conventional oil will start to decline within the next 10 years,*** *and be unable to keep up with demand. Their analysis contradicts oil-industry reports which suggest we have another 50 years worth of cheap oil to sustain us. As the independent report points out, economic and political motives cause oil-producing companies and countries to publish the inflated figure, and this affects all of us.*
The IEA WEO 2010 stated (page 125) that the world conventional crude oil production peaked in 2006 at 70 Mb/d, fell to 67,9 Mb/d in 2009, then 69,3 Mb/d in 2010 WEO 2011 and 68,5 Mb/d in 2011 WEO 2012, thus confirming our 1998 forecast of a conventional crude oil production peak before 2008. But the problem is that there is no consensus on production data nor on the definition of conventional oil, and the uncertainty is about the same as the variations of the plateau on the last 8 years..
Our 1998 forecast of the end of cheap oil is also confirmed by the present oil price.
The best proof for present forecasts to be reliable is when past forecasts have been confirmed.
It seems clear that most of peak oil deniers have poor forecast like CERA
http://petrole.blog.lemonde.fr/2011/09/26/peak-oil-laherrere-responds-to-yergin/

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)

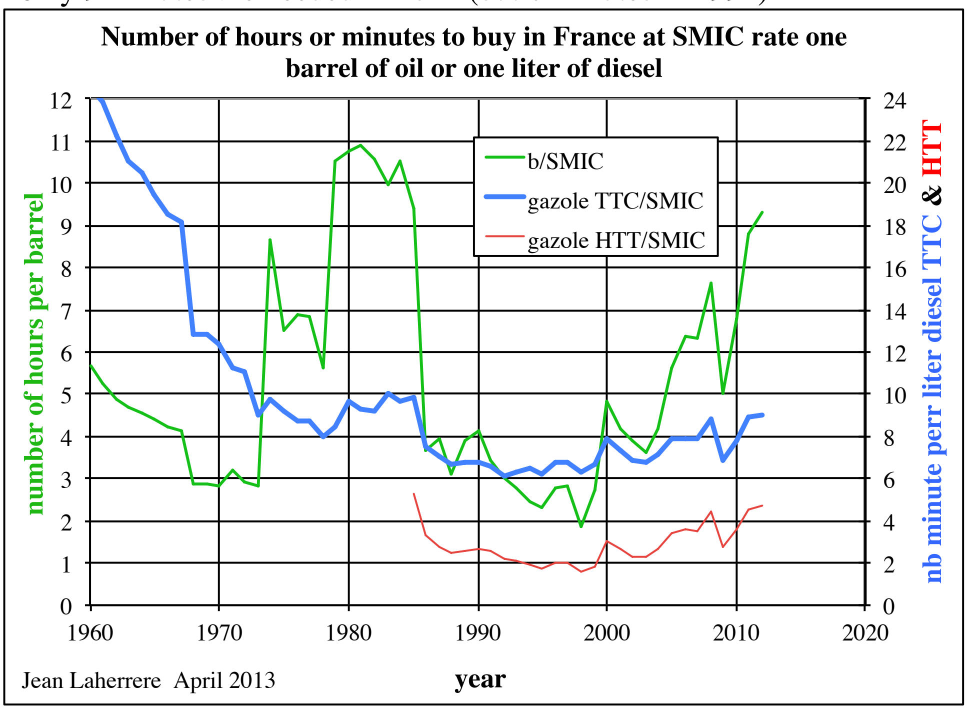

Figure 31: number of hours or minutes to buy one barrel of oil or one liter of diesel fuel with SMIC wage

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 large increase of world population since 1850 is due to medical progresses and abundant cheap energy. Now, we have entered a new era with the end of cheap energy. We need to drastically save energy but many do not want to change their way of life, counting on a continuous growth on energy, and/or dreaming that renewables can replace fossil fuels.

It is a must to get the true data showing that oil and natural gas will soon peak. 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.

In France the national debate on energy is axed on renewables and the energy ministry did not reply to ASPO France letter sent last year in order to be involved in the debate. The French energy ministry wants to ignore the peak oil, but it is likely that the peak oil will not ignore the French energy.

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 very short version from this paper is available on Aspofrance.org site