

## Oil &amp; gas production forecasts 1900-2100

The goal of this paper is to update the world oil & gas production forecasts up to 2100 starting from 1900 and detailing the breakdown for OPEC and for Non-OPEC (NOPEC), contrary to my previous papers.

The production modeling is the same, using multicycle logistic (and derivatives) curves to extrapolate the past and to fit the ultimate. The ultimate is estimated from extrapolating the past creaming curve (cumulative discovery present 2P reported at discovery year (backdating) versus cumulative number of fields, using also a multi cycles hyperbolic plot.

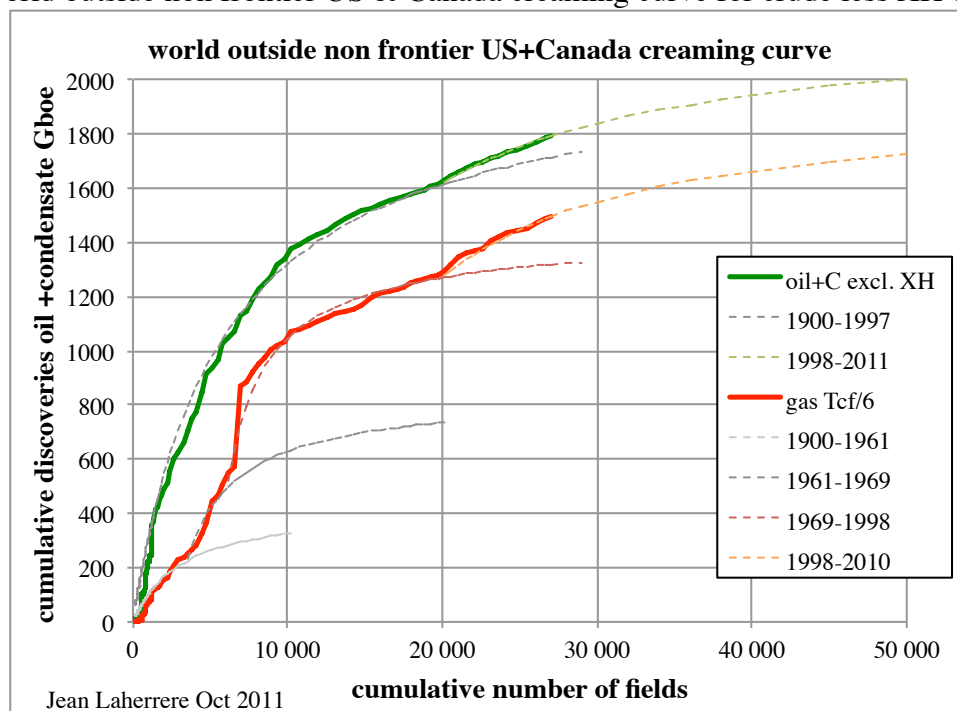
Backdating 2P field data is the key (Laherrere ASPO Brussels 2011) to obtain reliable ultimates.

Field data are found only in scout database, because very few countries (UK (DECC, Norway (NPD) and Federal US offshore (BOEM) report production and reserves by field. The scout databases need to be corrected to 2P because the overestimation of the OPEC countries in their fight between members for quotas during the period 1985-1989 (see figure 10) and the overestimation for former Soviet Union countries using ABC1 estimates (Gazprom annual reports show that the audit of their reserves in ABC1 and 2P, 2P are only 70% or less than ABC1).

Scout database reports four Orinoco extra-heavy oil discoveries totaling 215 Gb from 1936 to 1939. Extra-heavy oil fields, heavier than water has to be treated differently from heavy end light oil fields which are trapped above a horizontal water level, because trapping is completely different as also the exploitation. Extra-heavy oil, close to surface has lost its volatile components; also degraded by bacteria and is usually trapped on surface by asphalt plugs, where there is no water oil contact. It is a continuous –type accumulation as described by USGS being unconventional.

The creaming curve for the world outside the onshore US & Canada (where too many fields of minor sizes with no available inventory) shows for oil a hyperbolic rise from 1900 to 1997 and a new cycle since 1998 (deepwater and subsalt).

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

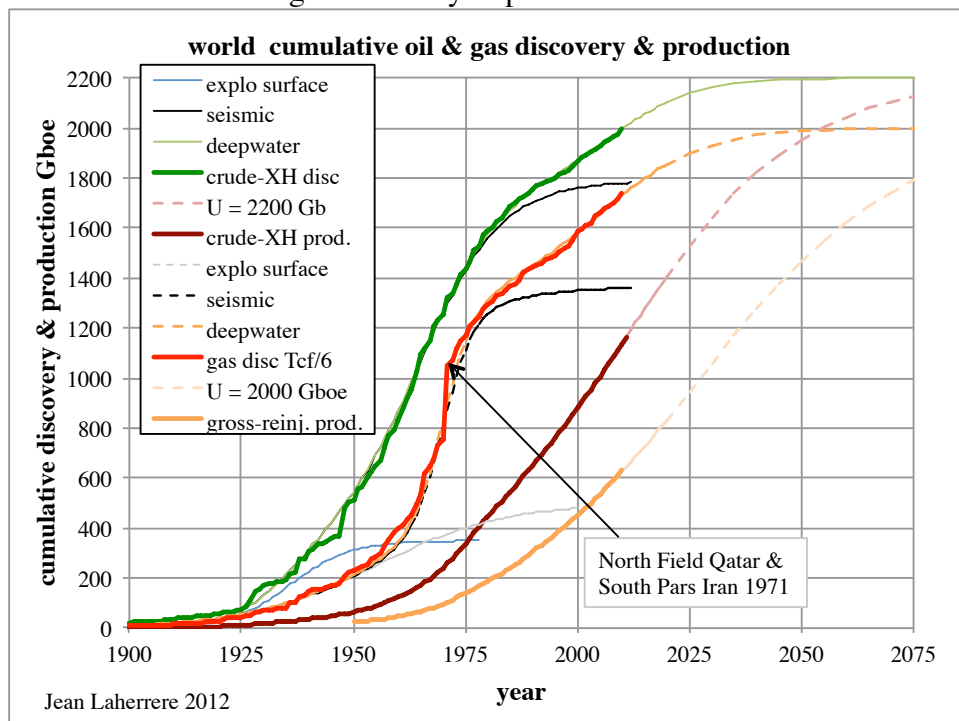


At end 2011 the cumulative 2P discovery is 1800 Gb for crude less XH oil, but it is after a correction of about 500 Gb from the scout databases. This large correction shows that the scout databases (having now as clients OPEC companies) are now spoiled by the political/financial sources. On figure 10 the difference on world remaining reserves from political/financial sources

and technical sources is shown as being drastic and increasing, explaining why economists relying on manipulated data do not see that since 1980 there is less oil discovered than oil produced. The ultimate for the world outside the conventional onshore US and Canada is about 2000 Gb for crude less XH oil and 1700 Gboe for gas. This plot versus cumulative number of fields cannot be extended to onshore US & Canada because the number of fields is very large, the data unavailable and the definition different. Only world cumulative discoveries can be displayed versus time.

Adding the onshore conventional US and Canada backdated 2P discovery (from USDOE and CAPP backdated data) to the previous data, the cumulative world discovery versus time is modeled with a three S curves towards an ultimate of 2200 Gb for oil and 2000 Gboe (12 Pcf) for gas

Figure 2: world cumulative oil & gas discovery & production



The three cycles are the well known cycles on exploration, being first the surface exploration (on seeps and quickly on surface anticline), then after the second war after 1945 from seismic surveys showing buried anticlines and last since 1990 from deepwater and subsalt reservoirs. The cumulative production is plotted and extrapolated towards the ultimates. For natural gas the largest gasfield being the North Dome located two thirds in Qatar and one third in Iran is plotted as found in 1971 when discovered in Qatar (North Field) when scout database report Iranian discovery Pars South only discovered in 1992.

The weak point of the creaming curve is that a new cycle could occur in the future and some geological knowledge is needed to foresee if a new one is possible

The only new cycle could be shale oil (called now tight oil), but it is significant only in the US, but 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.

Shale oil boom can be a hype. A fourth cycle is presently very difficult to be forecasted. Only time will tell.

It is the same for natural gas and shale gas

Oil production data are badly reported, in particular from OPEC countries, because their fight on quotas prevents them for clear disclosures on reserves and production data.

The best proof is given by the OPEC monthly report where OPEC reports oil production based on secondary sources, which differs largely from data based on direct communications (from OPEC members).

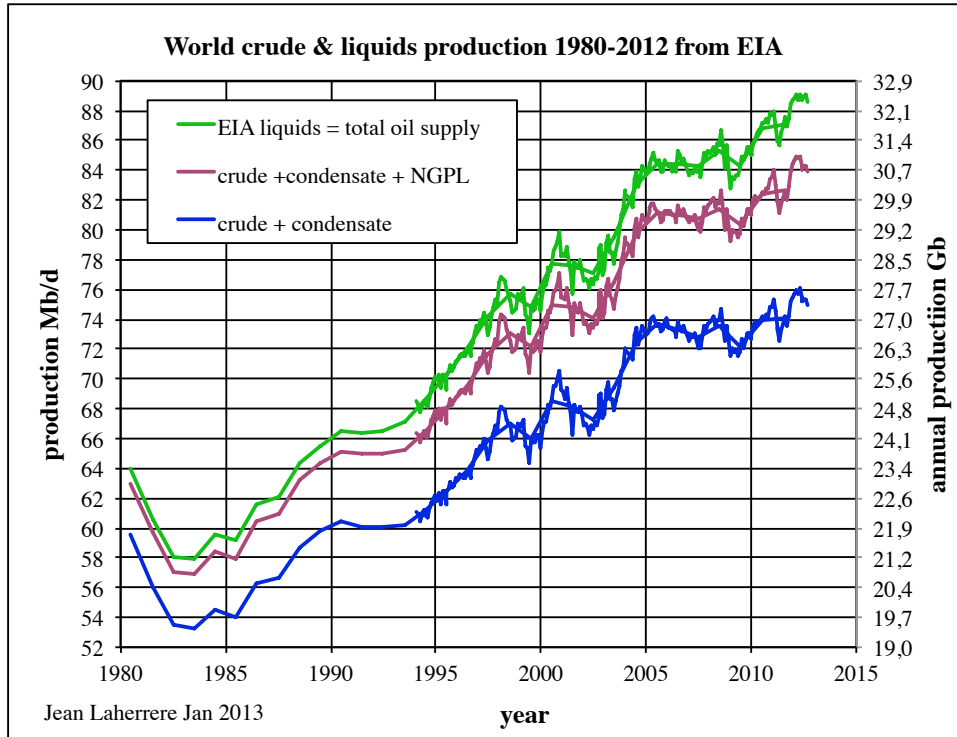
On the OPEC January 2013 monthly report, total OPEC crude oil production for the second quarter was 31.49 Mb/d on secondary sources and 32.76 Mb/d (4 % more) on direct communication.

Venezuela crude oil production was 2.37 Mb/d and 2.82 Mb/d: Venezuela is reporting 19% more than OPEC believes!

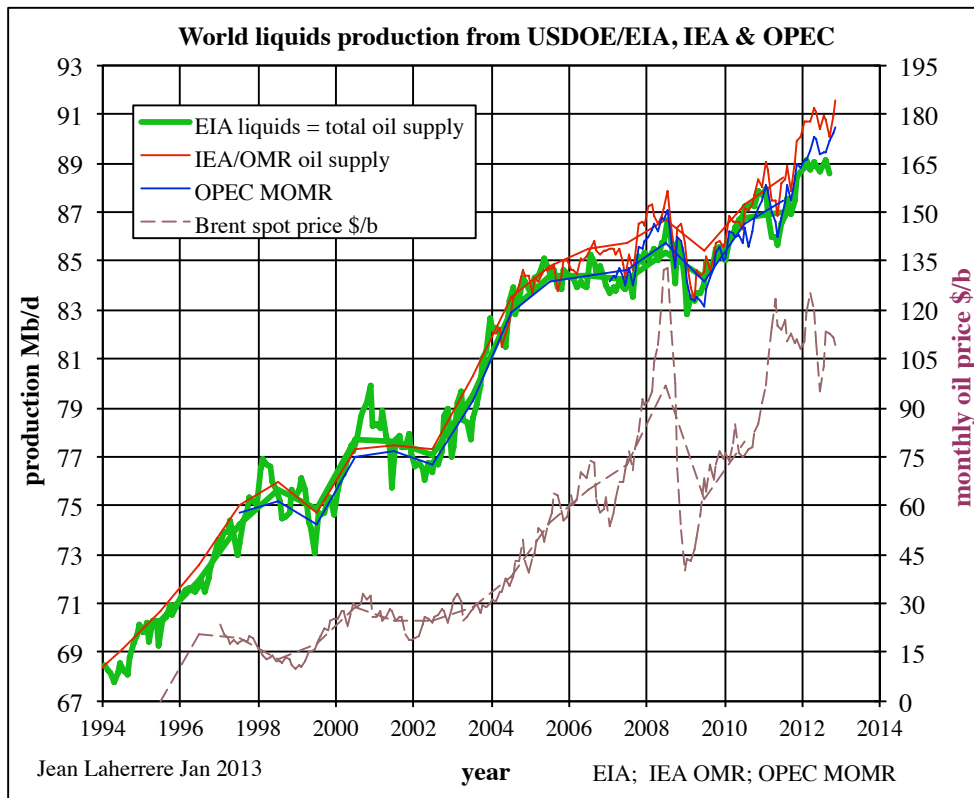
In November 2012 EIA added 4 new countries to their oil supply production: Chile, Israel, Estonia and Slovenia.

USDOE/EIA reports total oil supply, crude and condensate and NGPL = natural gas plants liquids and the plots display a flattening starting in 2005, followed by a bumpy plateau

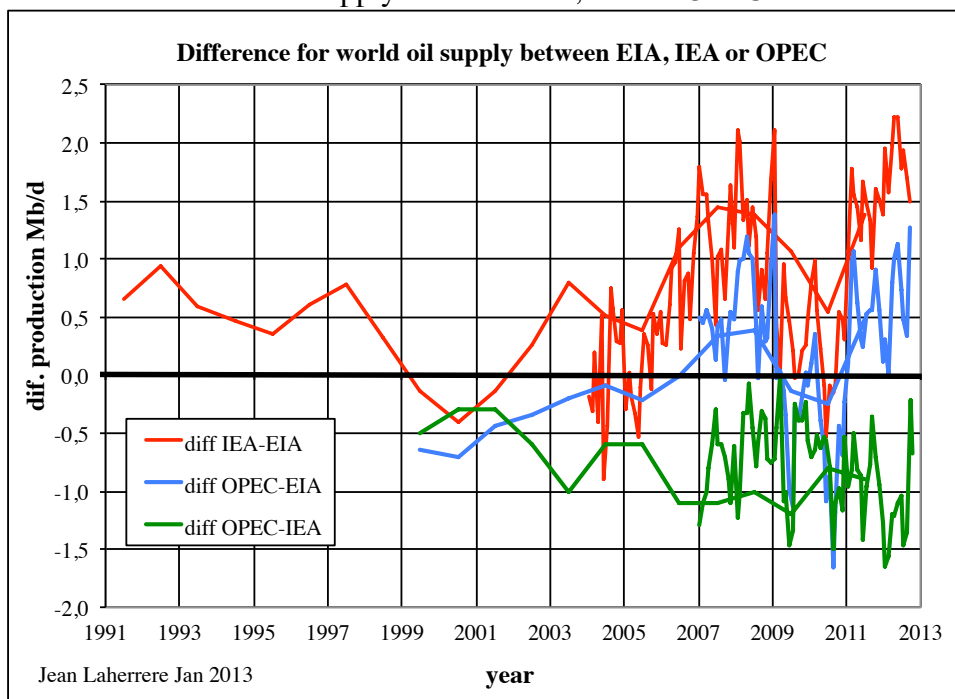
Figure 3: world crude oil, crude +NGL & liquids production 1980-2012 from EIA



The world oil supply is also reported by IEA and OPEC and there is an obvious discrepancy  
 Figure 4: world liquids production from EIA, IEA & OPEC



The discrepancy between the 3 sources is large with a range from -1,5 Mb/d to 2 Mb/d or within 4 Mb/d, which is the range of the bumpy plateau for total oil supply from EIA since 2005. Figure 5: difference from world oil supply between EIA, IEA & OPEC



The difference of the oil supply between EIA and IEA was close to zero (plus or minus 0,5 Mb/d) on the period 1991 to 2001, but since, it is on the increase, due mainly to the difference of definition of NGL by IEA, which classify condensate either in the crude oil or either in the NGL depending the way it is sold.

It is obvious that big change occur at the beginning of the year where definition change occurs.

IEA with OPEC has founded JODI : Joint Organizations Data Initiative which reports oil productions from many countries, but it is incomplete and unreliable (see Oilwatch: reconciliation of JODI and EIA C/C production data <http://www.theoil Drum.com/node/9764#more>)

The big problem is the lack of a world consensus on oil definition

The comparison of the world oil production for 2009 from different sources shows that the values vary drastically

**World oil production in Mb/d**

	definition	2009	2008 corrected	2008 previous yr
OGJ Oil & Gas Journal	oil	70,502 6	72,822 0	72,956 1
WO 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
USDoE/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

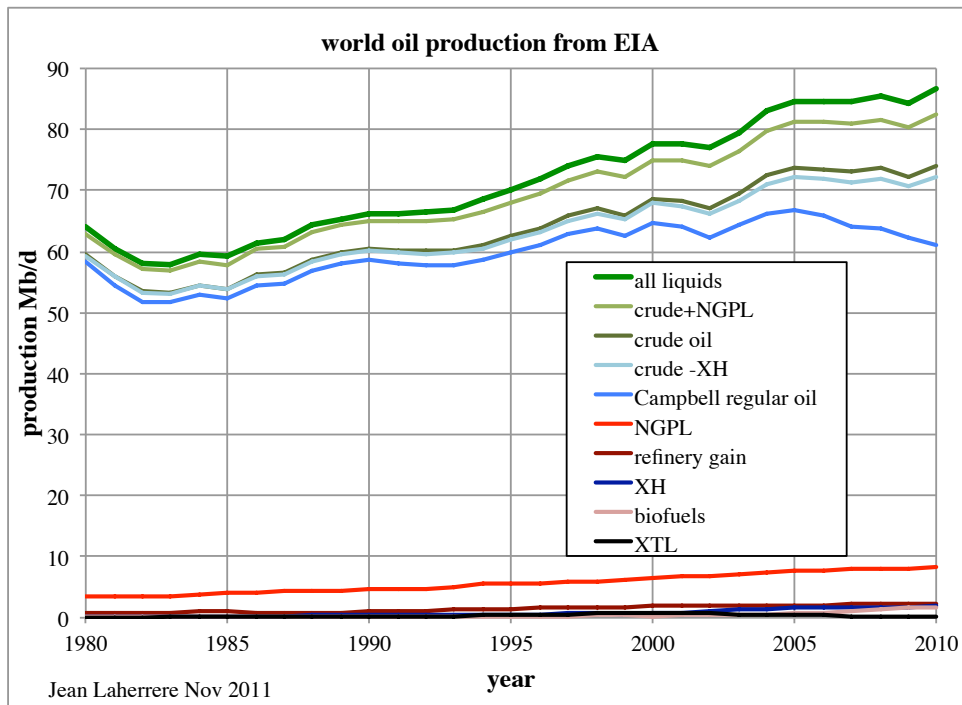
EIA has corrected in its last version its 2009 all liquids value by 1 Mb/d: it is obvious that EIA should report only one decimal in Mb/d and not 8 decimals!

It is amazing to find that BP is reporting (on Excel file) the world oil production with 15 significant digits, the last one corresponding to less than one millionth of a barrel, when every one knows that production is best reported in barrels at best in kb and this stupid number of digits comes from converting cubic metres and tonnes into barrels using a very accurate converter.

The authors should know that the accuracy of a sum corresponds to the accuracy of the worst item (for the world to the worst country). The best reporter is OPEC with only three significant digits, but in the case of 2009 world oil supply the last digit changed so only two significant digits is reliable

In fact the all liquids production includes several items and the so called oil production could vary in 2010 from 62 Mb/d (Campbell's regular oil) to 87 Mb/d (all liquids)

Figure 6: world oil production from EIA with different definitions



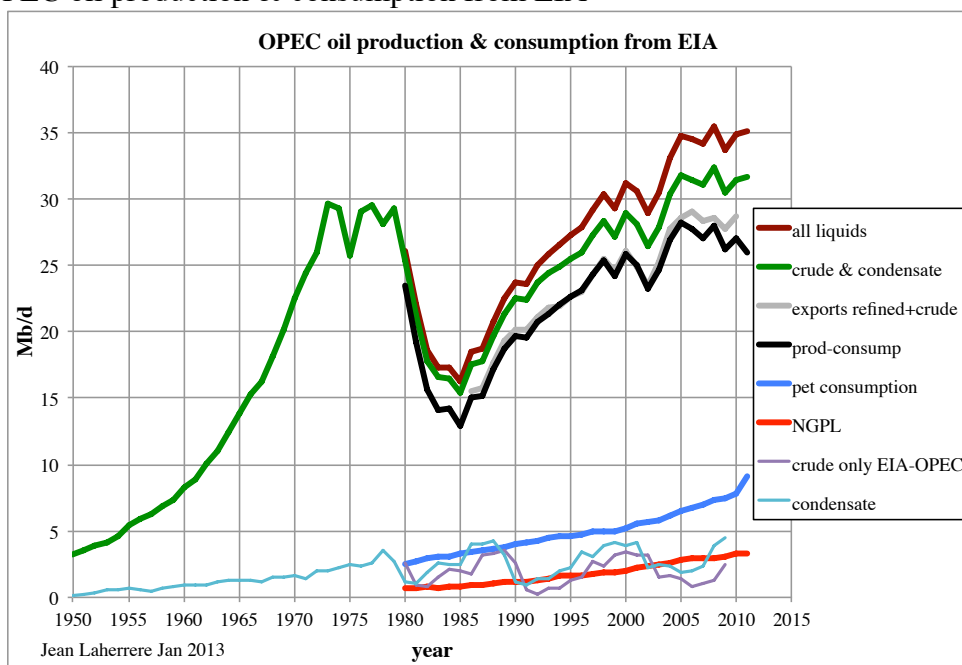
In the US, condensate is measured at wellhead together with crude oil and US data reports crude and condensate on one side and the liquids from natural gas plants on another side  
 But in OPEC countries where quotas apply only on crude oil but not on condensate, condensate is badly reported in OPEC reports.

#### -OPEC oil production

Because the importance of OPEC oil production, the various data from EIA and from OPEC is compared, but again there is a bumpy plateau since 2005 and the variations within the plateau are less than the variations between sources.

OPEC crude oil production is reported by OPEC.com since the beginning in several reports, but the number of members has varied: now Indonesia and Gabon are out, Angola and Ecuador are in. It is necessary to plot the data for the present OPEC members, which are twelve: Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE and Venezuela

Figure 7: OPEC oil production & consumption from EIA

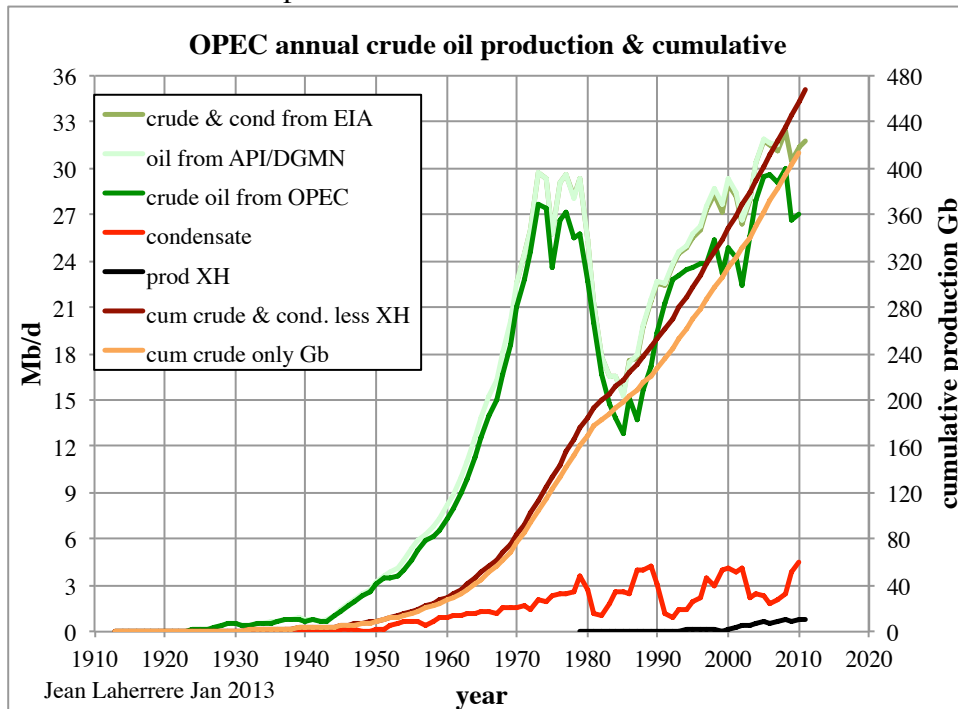


In the above graph there is a large discrepancy (0 to 4 Mb/d) between the crude oil production from EIA and from OPEC, with the plot in purple

OPEC annual crude oil production is plotted together the crude plus condensate with the cumulative production, with also reduced from the extra-heavy oil (Orinoco).

Up to 2011, OPEP has produced 475 Gb of crude oil excluding extra-heavy oil

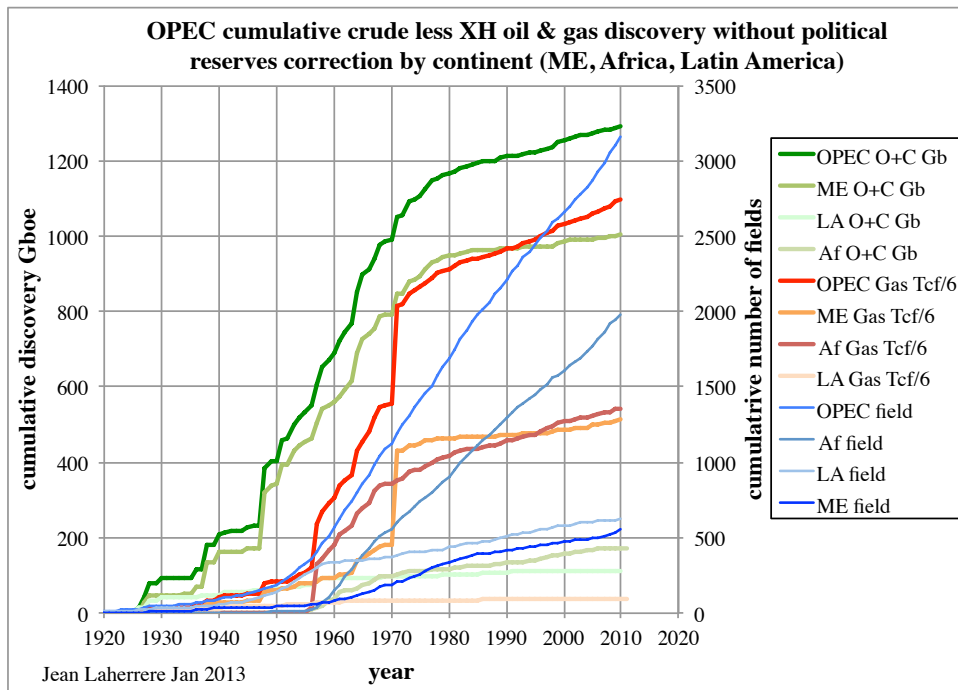
Figure 8: OPEC annual crude oil production & cumulative



The OPEC crude less extra heavy oil 2P (without any corrections outside excluding extra)-heavy of Venezuela) discoveries is plotted with the breakdown by continent. Out of a cumulative total at end 2010 of about 1300 Gb, Middle East covers a large part with 1000 Gb, with 175 Gb for Africa and 115 Mb for Latin America. The total number of fields is 3100.

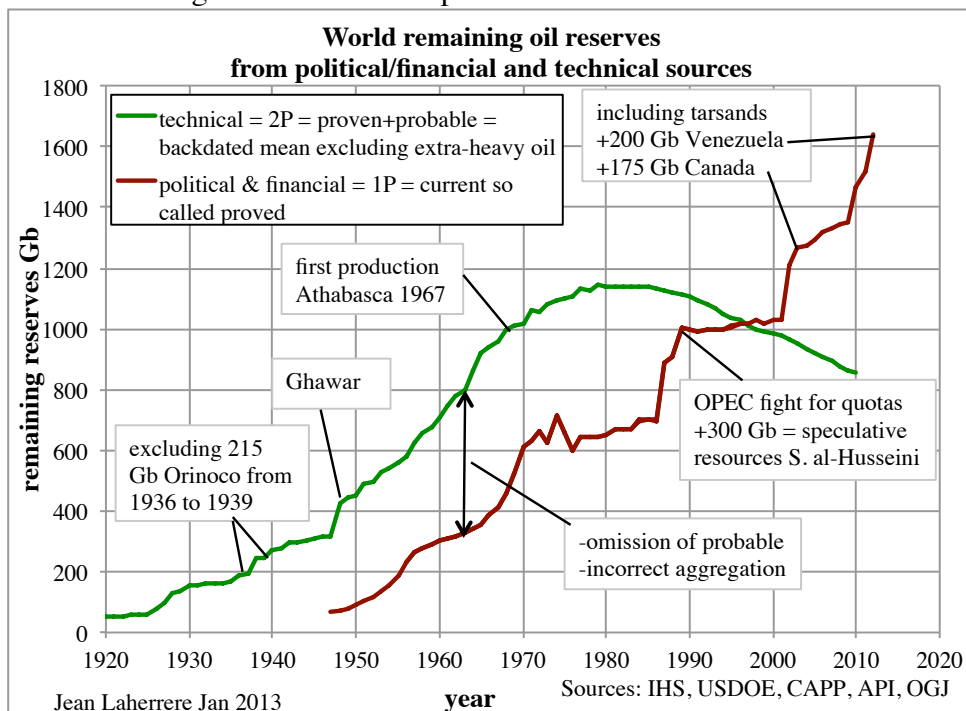
Gas discoveries are also plotted. South Pars is reported by Iran to be in 1992 but it belongs to the largest world gasfield North Dome discovered in Qatar by North Field in 1971.

Figure 9: OPEC cumulative crude less XH oil & gas discovery without political correction by continent



But it is well known that OPEC reserves were manipulated after the oil counter chock during the quotas fight between 1986 to 1989, where 300 Gb of political reserves were added (not involving extra-heavy oil). This fact was confirmed by the former Aramco VP Sadad al-Husseini in 2007 in London. In 2001 the definition of oil was changed and extra-heavy oil reserves were added first for Canada (Athabasca) and then for Venezuela (Orinoco), despite that these extra-heavy oil were reported for a very long time (1936-1939 Orinoco discoveries and Athabasca known since the 18<sup>th</sup> century is produced since 1967).

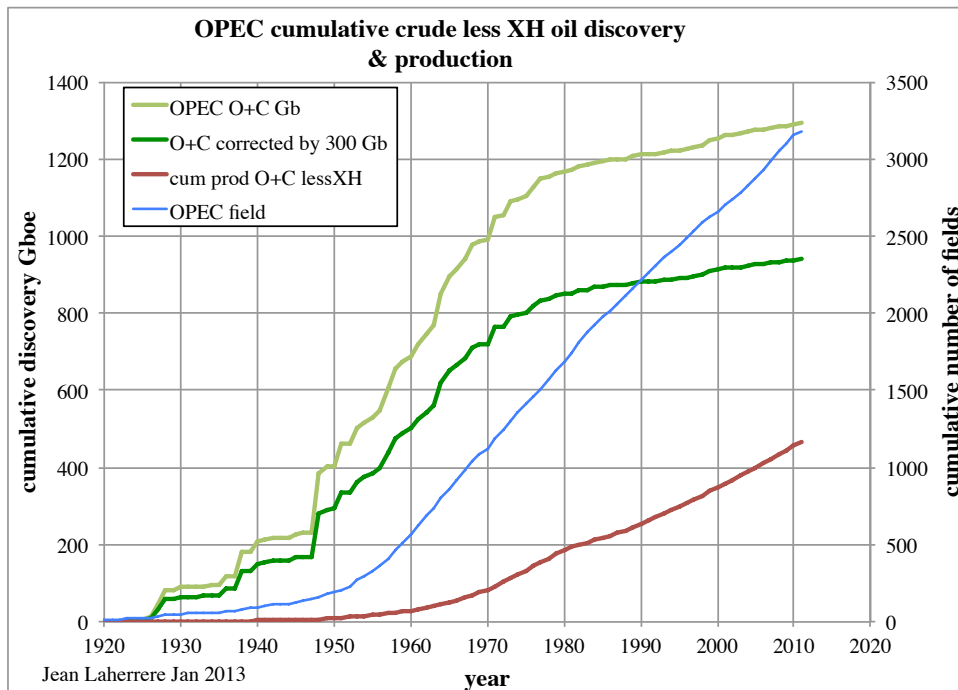
Figure 10: world remaining oil reserves from political/financial and technical sources



A 300 Gb correction is applied to OPEC cumulative crude less XH oil production on a global proportional issue. There is no correction on OPEC natural gas discoveries, because gas is not subject to quotas and they do not try to cheat like for oil

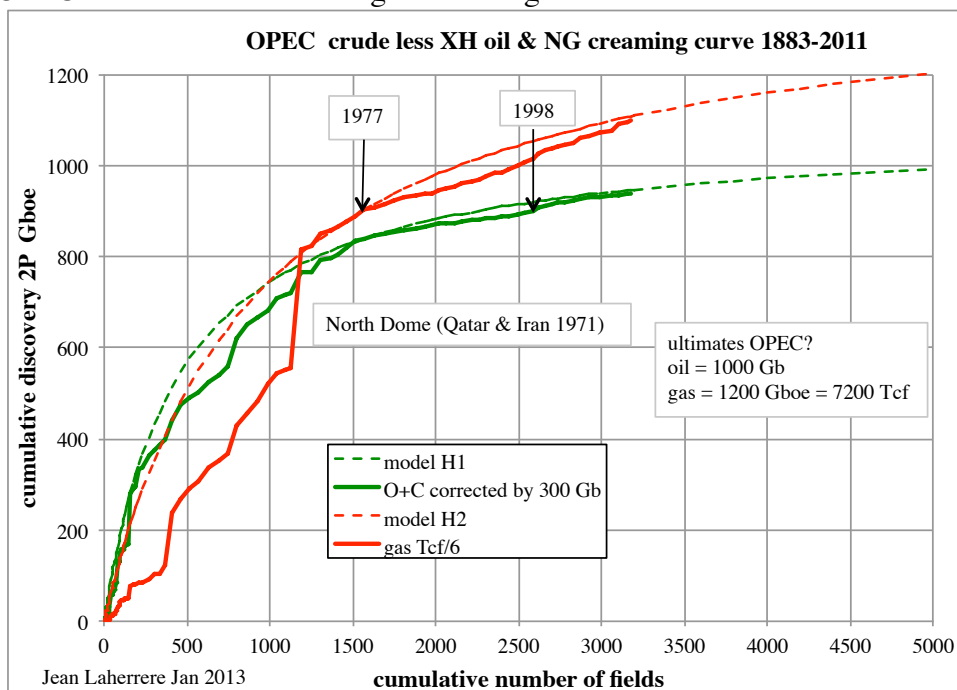
Figure 11: OPEC cumulative crude less XH oil discovery & production





The total corrected is then reduced to 940 Gb and the creaming curve is modeled with one hyperbola

Figure 12: OPEC crude less XH oil and gas creaming curve



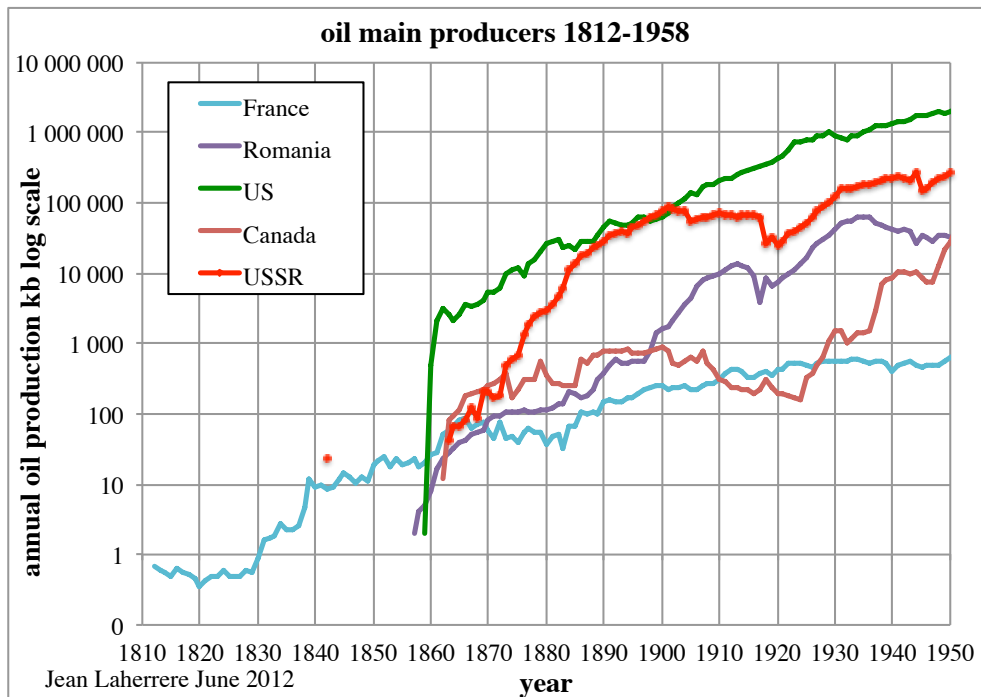
The oil ultimate is then estimated about 1000 Gb and the gas ultimate at 1200 Gboe = 7200 Tcf

The big problem with OPEC producer is that their consumption is increasing sharply by capita and also its population

### -NOPEC oil production

From API report 1857-1958, the US from 1859 to 1973 was the first oil producer in the world, overpassed then by FSU and later by Saudi Arabia. But from published continuous data France was the first oil producer from 1811 to 1859. Baku did produce before but there is no published data

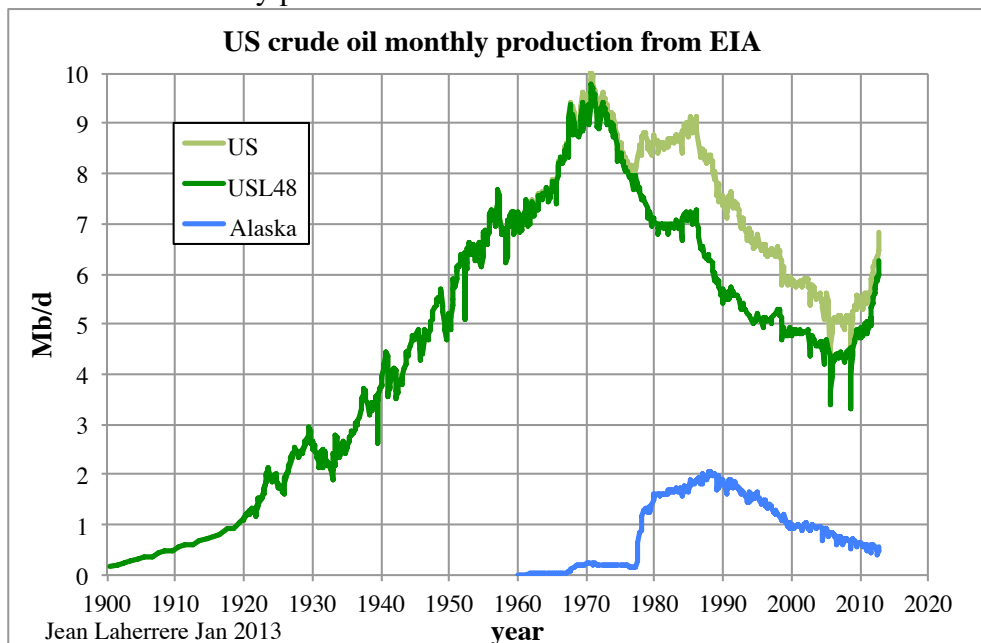
Figure 13: oil main producers 1812-1958 in log scale



-US

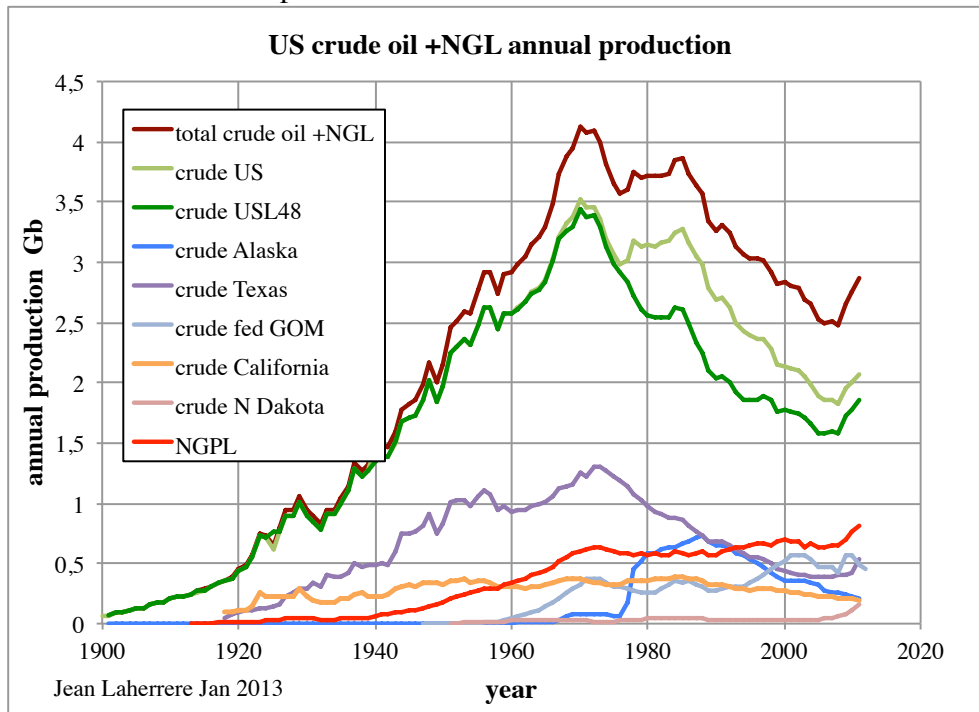
The US are an exception in the world oil production because oil in the ground belongs to the land owner, when, in the rest of the world, oil belongs to the government. It is why in the US there are over 20 000 oil companies and thousands of oil service companies. The US crude oil (including condensate) production excluding Alaska = USL48 displays from 1900 to 2000 a symmetrical curve with a peak in 1970 as forecasted by King Hubbert in 1956. It is fascinating to see that this symmetry in the rise and decline is broken in 1960 (proration) and in 1980 (high oil price), and can be explained by the large number of producers acting in a random activity, except when obliged to act in the same way because proration or high price. Alaska production starting in 1960 (but only significant since 1977) compensated the USL48 decline only up to 1987. Now since 2009 the deepwater and shale oil has changed the trend and some dream to have the increase to continue to suppress the US oil import.

Figure 14: US crude oil monthly production from EIA 1900-2012



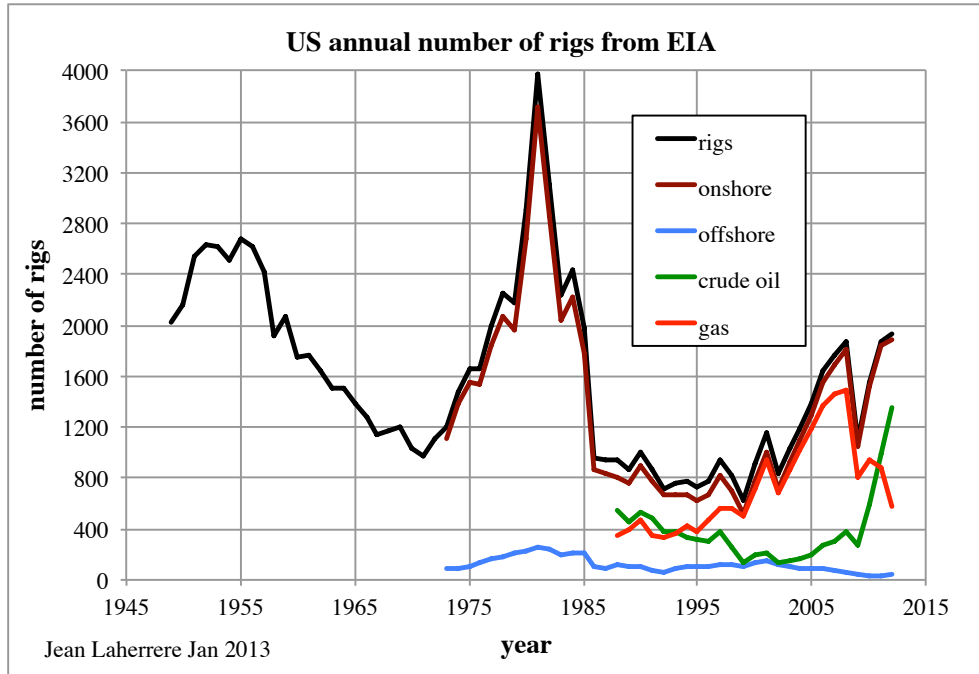
The NGPL production is more than Alaska or Texas production since 1990

Figure 15: US crude oil & NGL production 1900-2011



In 2012 the number of rigs was 1919 in the US, 365 in Canada, 423 in Latin America, 119 in Europe, 96 in Africa, 356 in the Middle East and 241 in Asia Pacific. In the US the number of gas rigs has declined sharply from 2008 at 1491 to 570 in 2012, when the number of oil rigs has increased from 128 in 1999 (10 \$/b) to 1919 in 2012.

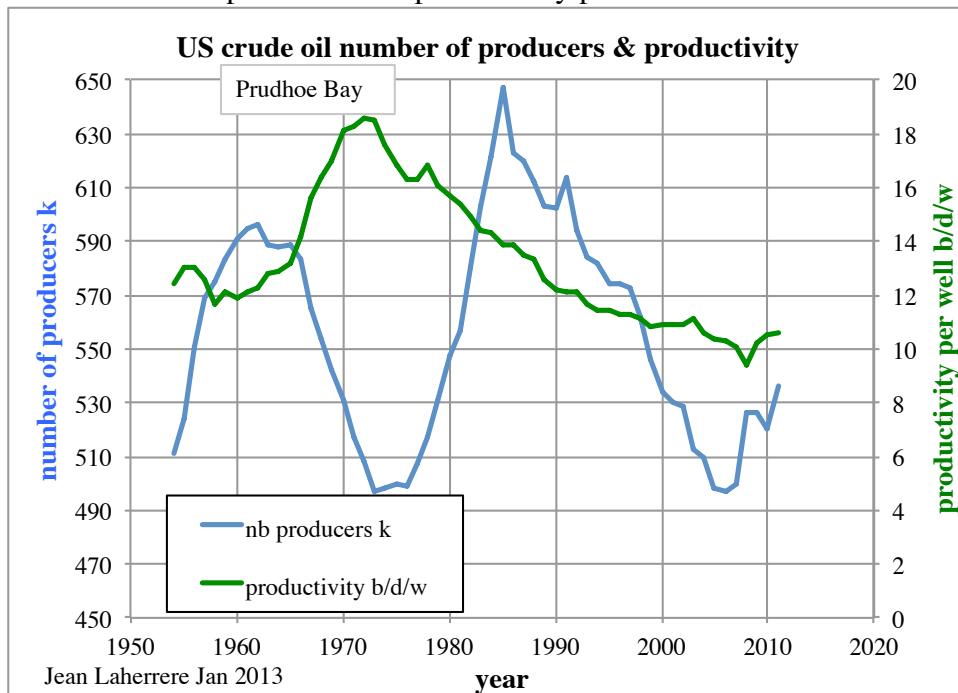
Figure 16: US annual number of rigs 1947-2012



US drilling activity is cyclic: peak in 1955, 1980 and likely now. The drill baby drill practice is due to the shale oil boom, the high price of oil and easy and cheap money to borrow, but US explorers are complaining about the lack of conventional prospects and the shale sweet spots seem to decrease.

The number of oil producing wells has peaked to about 650 000 wells in 1985 (the oil counter shock), it fell to 500 000 in 2005 and has raised to 536 000 in 2011. But the productivity per well has peaked in 1972 at 18.6 b/d/well and has declined since to be 10.6 b/d/w in 2011

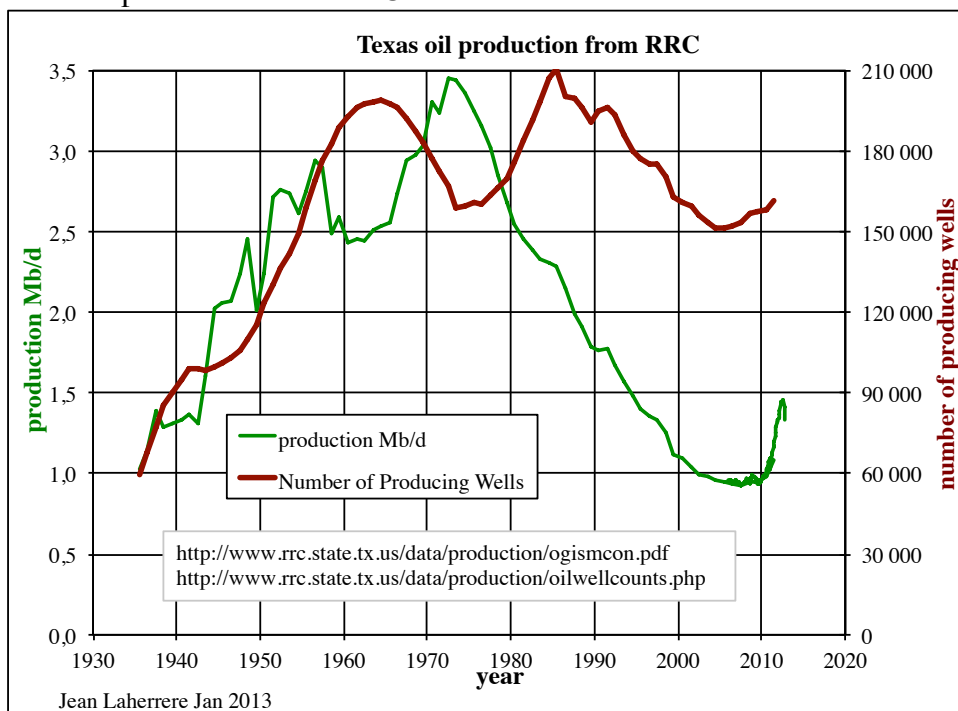
Figure 17: US number of oil producers and productivity per well



-Texas

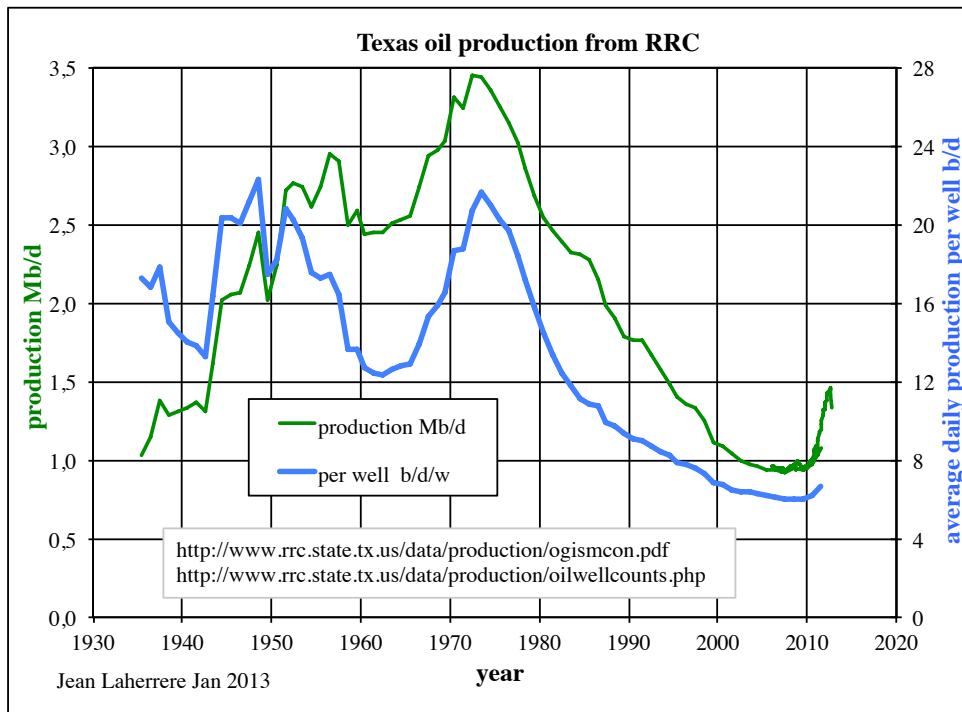
Texas has been the largest oil producer and its production has peaked in 1972 at 3.5 Mb/d to fall below 1 Mb/d in 2010 but thanks to shale oil (Eagle Ford) its production has sharply raised, but it seems to have already peaked. The number of oil producing wells has been oscillating since 1950 between 150 000 wells and 200 000 wells.

Figure 18: Texas oil production from RRC and number of wells



The productivity per well, which was about 20 b/d/w in 1972, is down to about 6 b/d/w in 2011.

Figure 19: Texas oil production from RRC and per well



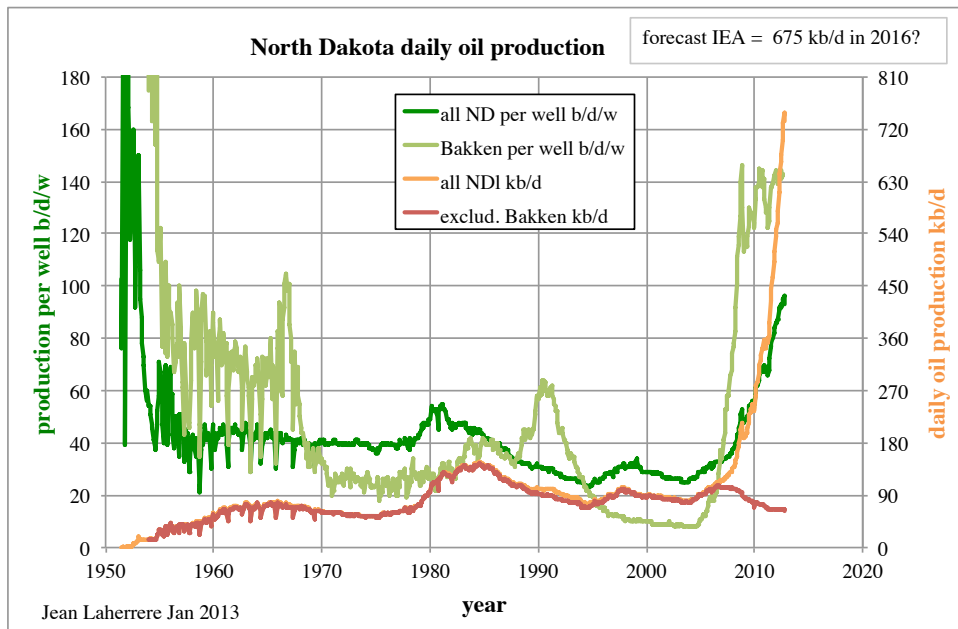
Texas oil production is likely to decline but as long as the oil price is around 100 \$/b and borrowing cheap and easy, oil companies will try to produce oil as fast as they can even if it is not good practice in detriment of the future.

#### -North Dakota

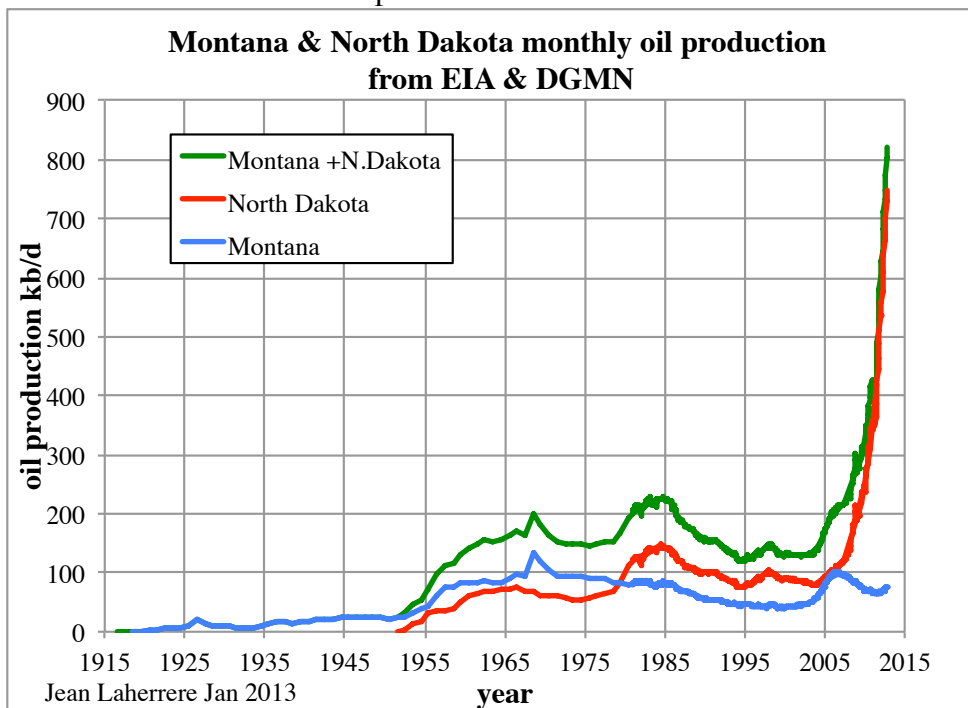
North Dakota oil production is booming thanks to the Bakken shale oil, which in fact is produced from a dolomitic reservoir within the Bakken shales, the trapping is conventional and not a continuous-type accumulation, as obviously shown in Montana with the Elm Coulee field. But thanks to a heavy drilling (over 200 rigs) North Dakota has exceeded Alaska oil production with a production of 750 000 b/d in October 2012 with 7796 wells, but production has declined in November down to 733 000 b/d with 7864 wells. These shale plays are called continuous-type accumulation with oil being present everywhere on the basin. But there are many articles on the use of seismic to find the best place to drill: it means that there are good wells and bad wells. The only difference with conventional field is that a well is not finding oil or finding water, but finding a fair amount of oil making the drilling economical or finding a small amount of oil, which will not reimburse the drilling cost but will pay only for the completion and production, and will save for a while the plugging cost. Also to keep the estimated reserves it is necessary to produce even a small amount. Selling reserves can be more profitable than selling oil.

The “sweet spots” seems to be almost fully drilled! The boom could end (North Dakota unemployment rate is very low and housing costs very high) soon.

Figure 20: North Dakota oil production 1950-2012



The Bakken productivity has reached 140 b/d/well compared to 10 b/d/w in 2005, 60 b/d/w in 1991 and over 180 b/d/w in 1954 at the beginning of Bakken production. Montana was ahead of North Dakota until 1980 and Bakken was produced before with the Elm Coulee stratigraphic trap which peaked in 2006 at 100 000 b/d. Figure 21: Montana & North Dakota oil production from EIA & DGMN



It is likely that North Dakota oil production will decline and the main question is a slow or fast decline.

Shale oil can exist on large areas but their economy varies, only the sweet spot are economical, depending the oil price. The problem is that most shale oil maps display a very large surface, compared to the limited sweet spots. Shale oil is promoted by small companies hoping to make more money from the stock market than from the income of their production. Chesapeake is a good example.

-GOM

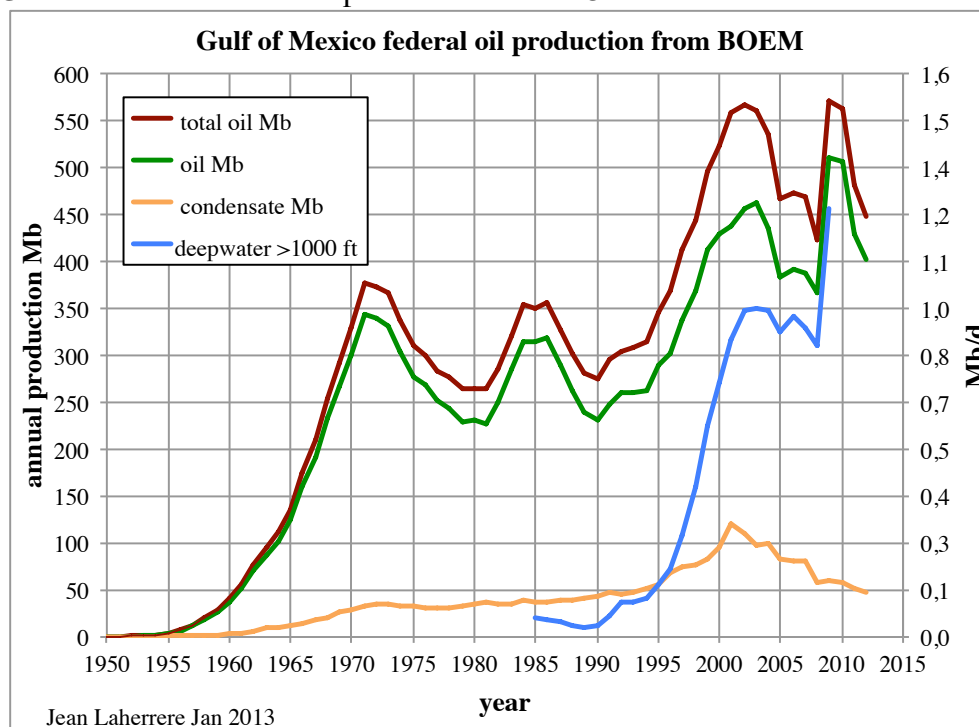
The federal Gulf of Mexico oil production (as seen in figure 15) is slightly exceeding Texas production since 2000. Some of the deepwater discoveries are estimated to be large giants. But their oil production is not long enough to be sure that the estimates will be reached!.

The last BOEM (part with BSEE of former MMS) 2012-103 report on GOM fields was published in December 2012 lists the 1270 fields estimated at end 2008. The largest fields are:

rank	field name	nickname	disc	water ft	oil reserves	Mboe reserves
1	MC 807	Mars-Ursa	1989	3377	1316,5	1647
2	MC778	Thunder Hors	1999	6080	733,1	848,4
3	EI330		1971	247	429,7	753,3
4	WD030		1949	48	579,9	748,9
5	TS000		1958	13	44,6	674,6
6	GI043		1956	140	381,9	672,7
7	BM002		1949	50	534,5	627,7
8	GC743	Atlantis	1998	6413	558,6	623
9	VR014		1956	26	48,1	596,4
10	MP041		1956	42	267,7	534,9
11	MC776	N.Thunder H	2000	5665	429,9	503,3

The GOM oil production displays a up and down curve with already 4 peaks: 2 at 1 Mb/d and 2 at 1.5 Mb/d. The question is how to extrapolate the present steep decline, which can be explained by the Macondo blow out impact (above ground) or by below ground problem.

Figure 22: Gulf of Mexico federal oil production from BOEM



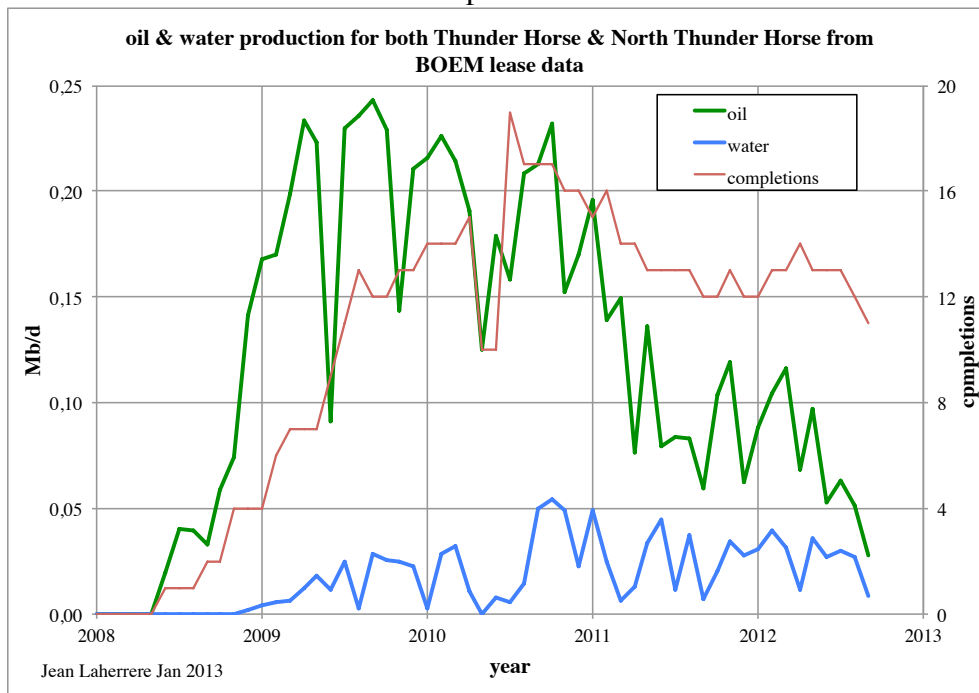
The problem is that after the break down of MMS replaced by BOEM and BESS, which are very slow to deliver compiled data by fields (the last report BOEM 2012-103 published December 2012 is at end 2008, 4 years late!). Data is published on their by wells or by lease site updated every month with few months delay but the compilation by field is unreliable because the result is different from lease or well data and because two fields can be produced from the same platform as it is the case for Thunder Horse, formerly Crazy Horse discovery)

We have plotted the data for the 2 largest deepwater fields.

-Thunder Horse & North = MC 776 & MC 778

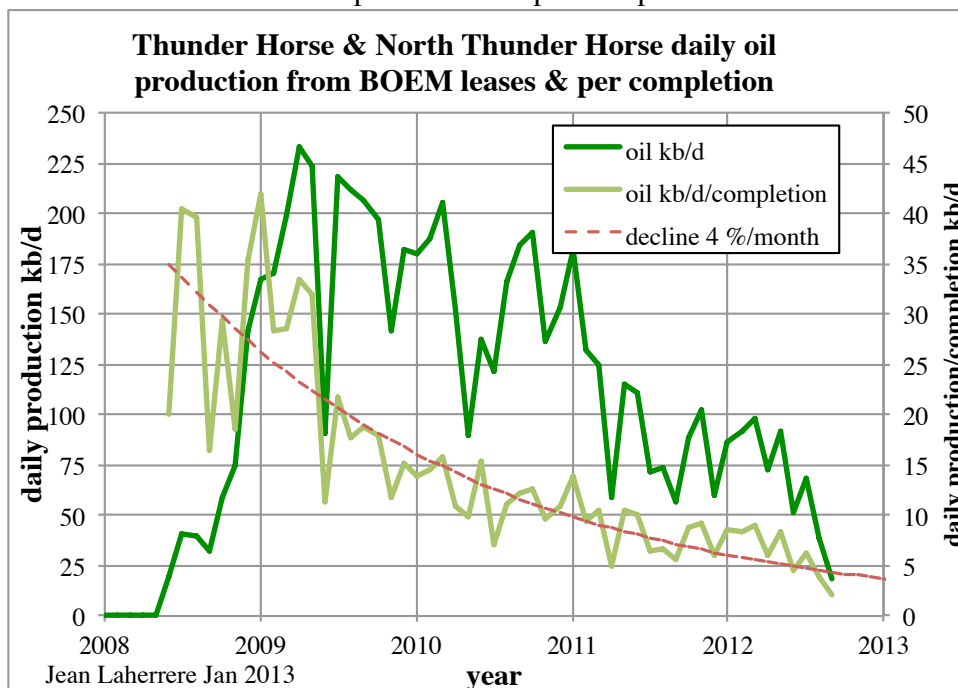
From the BOEM “lease data” the two fields Thunder Horse and North Thunder Horse produced from the same platform display a chaotic production peaking several times to about 230 000 b/d in 2009 and 2010 with a peak of completions at 18 in 2010, but declining sharply to less than 50 000 b/d in August 2012. The water volume stays about the same but the water cut increases

Figure 23: Thunder Horse & North oil & water production



The plot of the oil production per completion (in light green) shows that the production starts around 35 000 b/d and declines with a rate of 4% per month: which is about 50% per year.

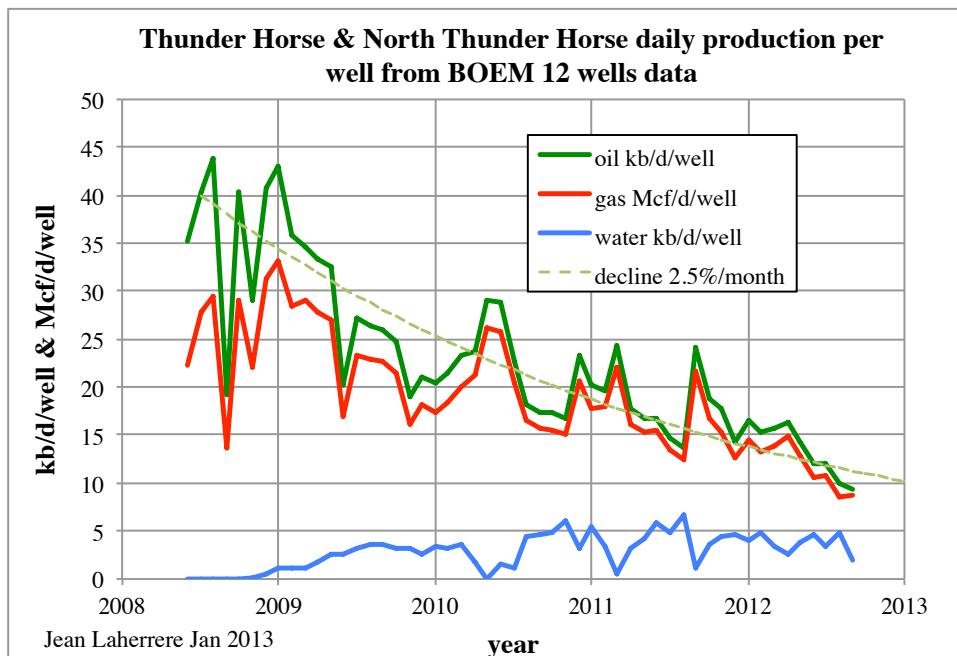
Figure 24: Thunder Horse & North oil production & per completion



From BOEM well data the daily production per well (average of 12 wells) of the 2 fields is plotted for oil, for gas and for water and then the decline for oil start at 40 000 b/d/well and decline by 2.5% per month or 30% per year

Figure 25: Thunder Horse & North oil production per well



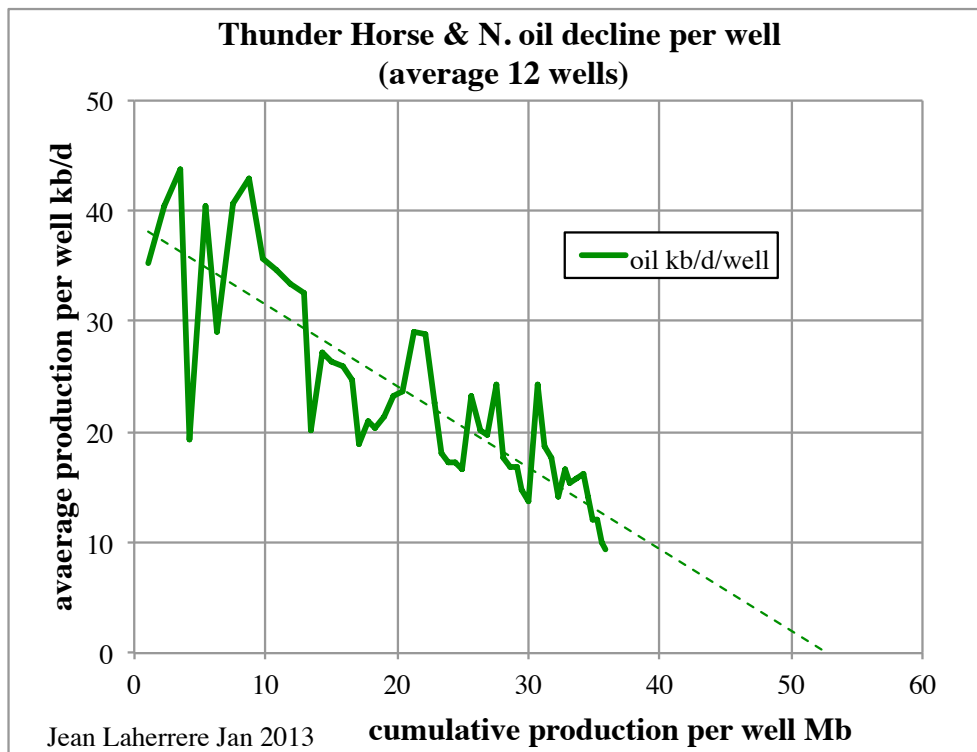


It is confusing to get an annual decline rate of 50% from the lease data per completion and of 30% from the well data per well. However it is huge compared the conventional annual decline which is about 5%. It means that these subsalt deepwater fields have a decline rate similar to the shale plays. However these two fields have been produced only with 12 wells when the planning of the platform was about 28 wells for production and only 5 water injection wells. Drilling was prevented after the Macondo blow out, but it is authorized now. BP is very reluctant to disclose data on the production, but in their third quarter 2012 BP indicates a 5 years plan with the Thunder Horse water injection project, and adds that “*growth will resume in 2014 and to continue for the remainder of the decade*” After 4 years of production, BP needs now water injection to improve Thunder Horse oil production, when it is done usually at the beginning of the development. It means that these fields behave differently from other GOM giant oil fields. It is likely that the reserves estimate will be reduced: it is likely that this problem will occur for others subsalt deepwater fields like those found in Brazil and still in development stage. But we have to wait until 2014 to see if BP forecast is right.

Let's try to estimate the potential of the two fields from past production

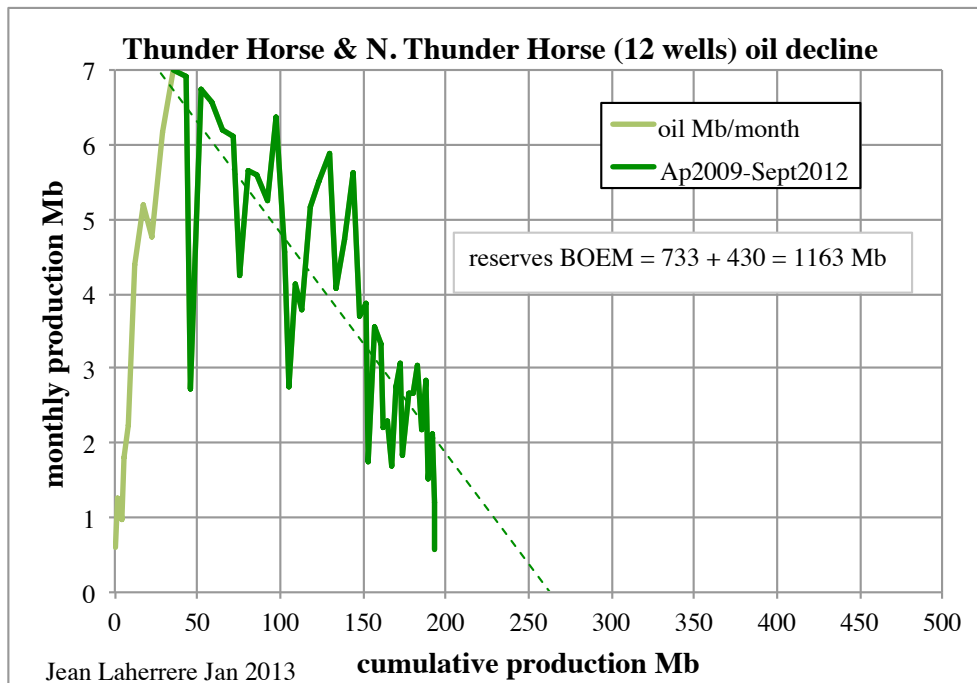
The average production per well versus cumulative production can be extrapolated towards 50 Mb.

Figure 26: Thunder Horse & North oil decline per well



But the oil production from the 12 wells versus cumulative production (presently 190 Mb) can be extrapolated only towards 260 Mb which gives a only 21 Mb per well

Figure 27: Thunder Horse & North oil decline



It is obvious that this kind of simple estimates is not reliable

The oil reserves in Mb were estimated

	BOEM at end 2008	scout 2011
Thunder Horse	733	800
North Thunder Horse	430	400
Total	1163	1200

Let's see another GOM giants field produced by another operator being Shell with Mars-Ursa, but see also my 2011 paper

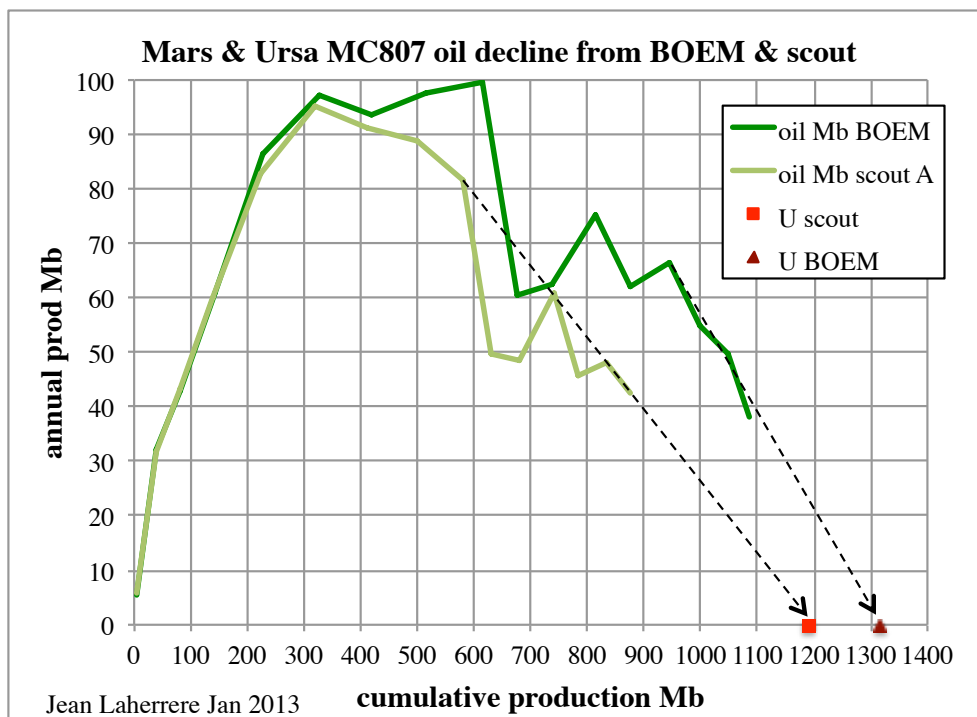
-Laherrère J.H. 2011 » Deepwater GOM: Reserves versus Production» 30 August  
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<http://www.theoil drum.com/node/8366#more>,  
<http://www.theoil drum.com/node/8557#more>,  
<http://www.theoil drum.com/node/8604#more>

-Mars-Ursa MC807

Mars-Ursa is estimated by BOEM being the largest GOM field but it is the addition of two separate fields produced by the same operator Shell.

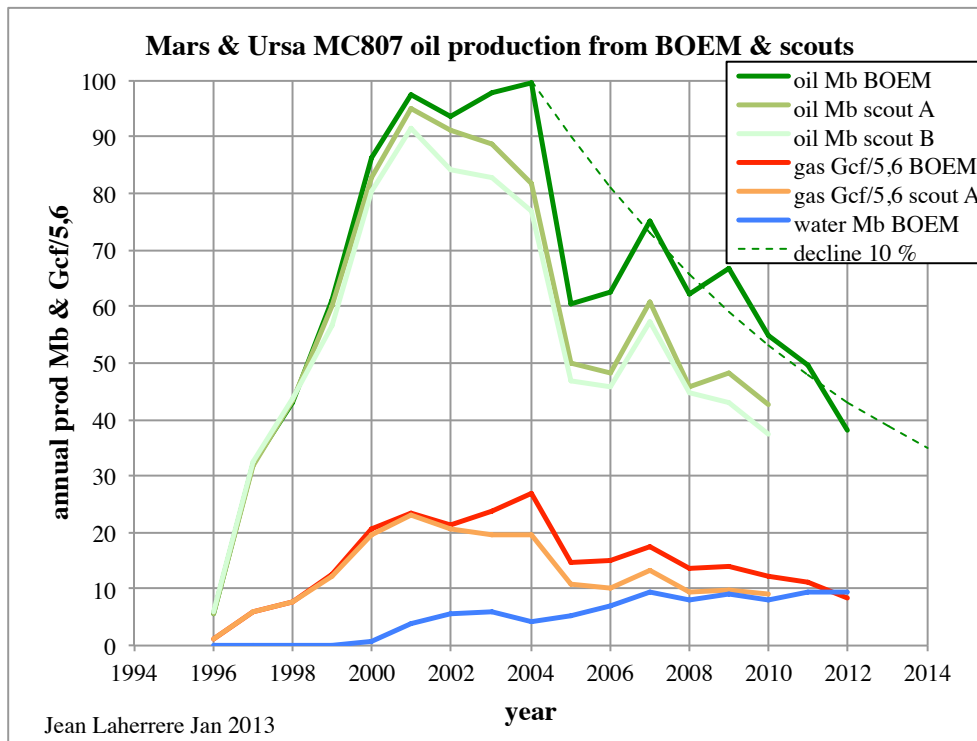
The problem is that production data differs from sources, BOEM data is different from scout data, but both indicates that the ultimate (1.2 or 1.3 Gb could be met)

Figure 28: Mars & Ursa oil decline from BOEM & scout



The oil annual production from two scouts are close, but less than BOEM

Figure 29: Mars & Ursa oil production from BOEM & scouts



The annual decline from BOEM seems to be about 10%, which is larger than onshore decline but it is normal because of the high cost of offshore production to produce offshore fields much faster than onshore fields.

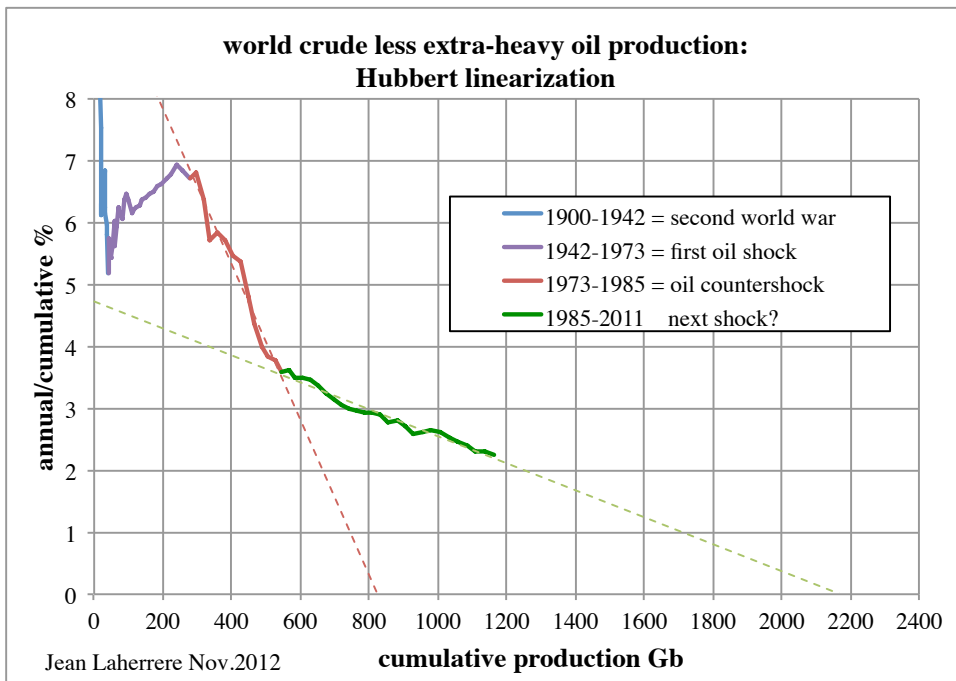
#### -World, NOPEC & OPEC Crude Oil production forecasts

Figure 2 displays the world cumulative crude less XH oil and gas discovery modeled with 3 cycles for an ultimate for crude less XH oil of 2200 Gb and for conventional gas of 2000 Gboe or 12000 Tcf.

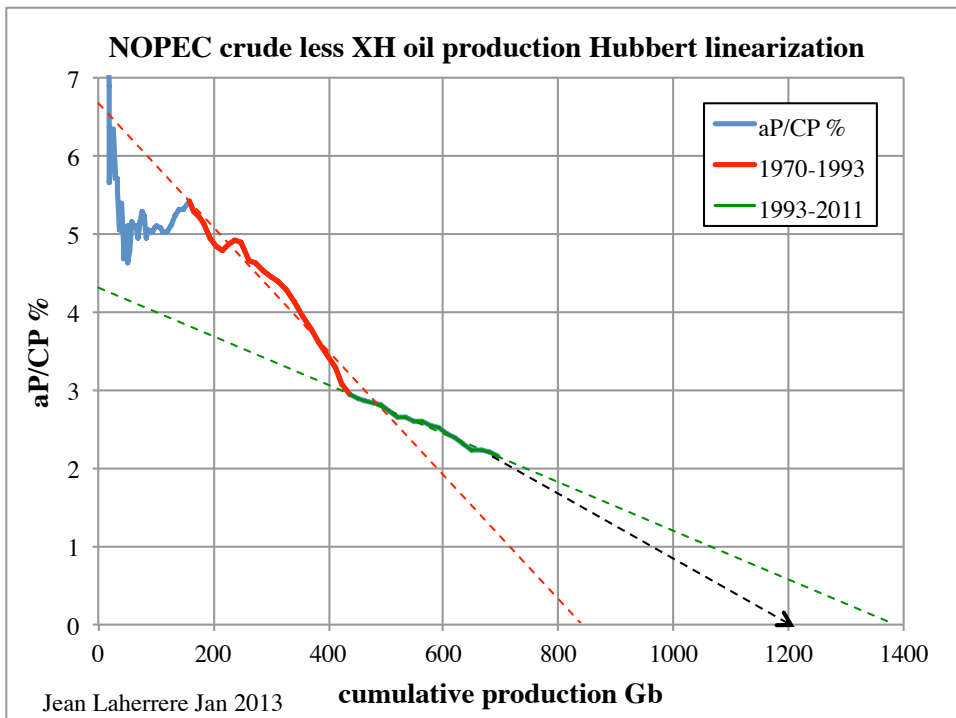
The production data is extrapolated linearly, method which is called Hubbert linearization but which is not too reliable because sudden changes.

For the world crude less XH oil the plot from 1973 to 1985 trends towards about 800 Gb but the production from 1985 to 2011 trends towards 2200 Gb, confirming the estimate from oil discoveries.

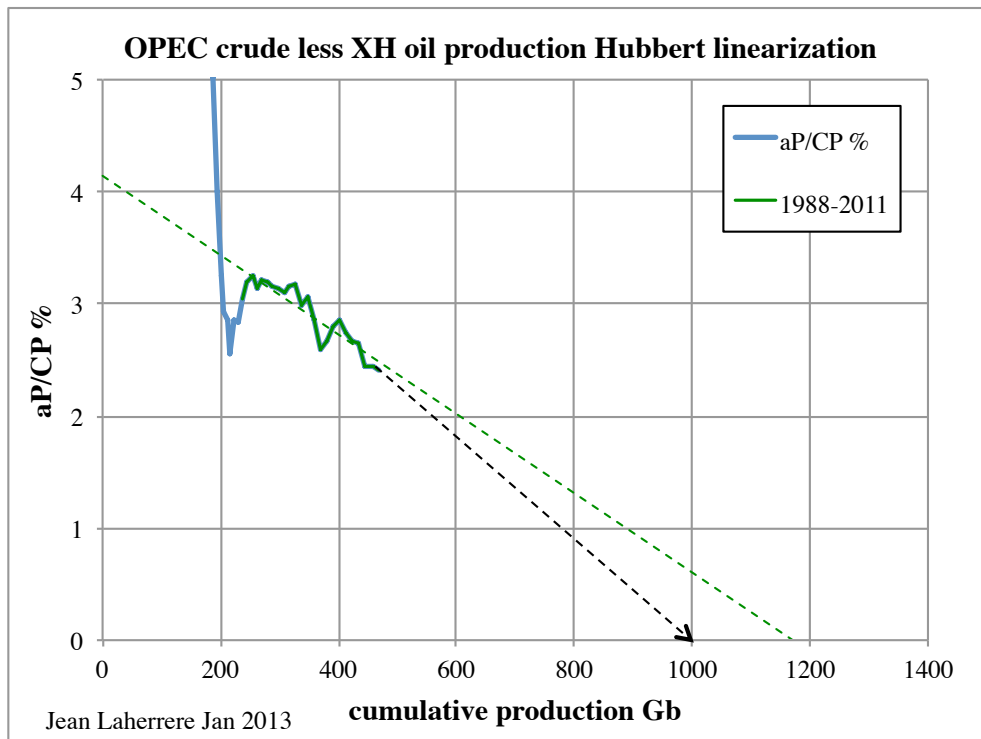
Figure 30: world crude less XH oil Hubbert linearization



For NOPEC the plot 1993-2011 trends towards 1400 Gb  
Figure 31: NOPEC crude less XH oil Hubbert linearization



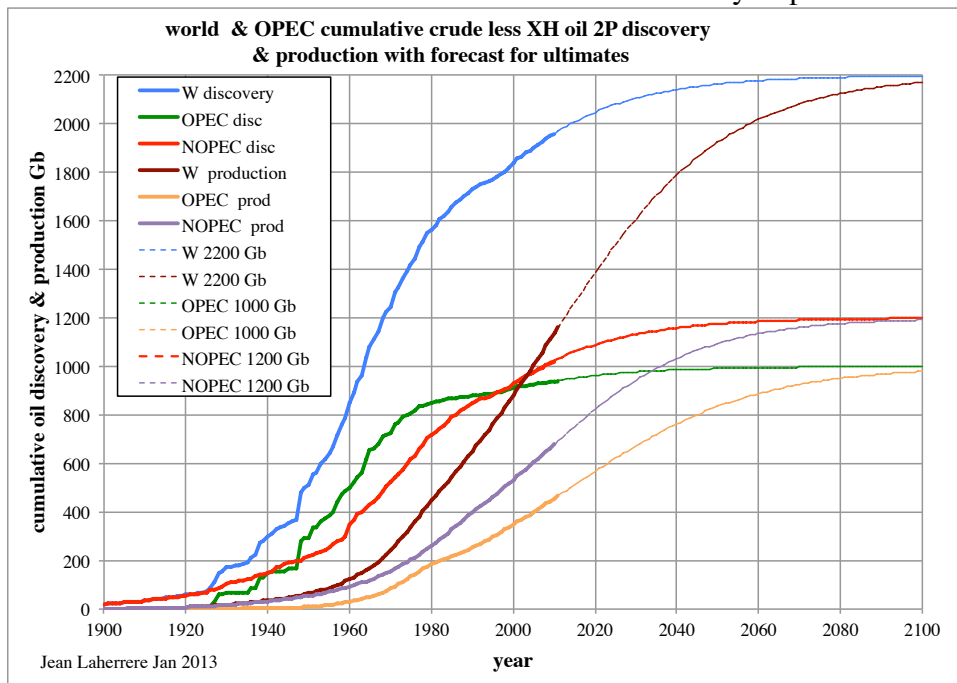
For OPEC the plot 1988-2011 trends towards 1200 Gb  
Figure 32: OPEC crude less XH oil Hubbert linearization



Adding the ultimate estimate for NOPEC and OPEC will give  $1400 + 1200 = 2600$  Gb when for the world it is only 2200 Gb.

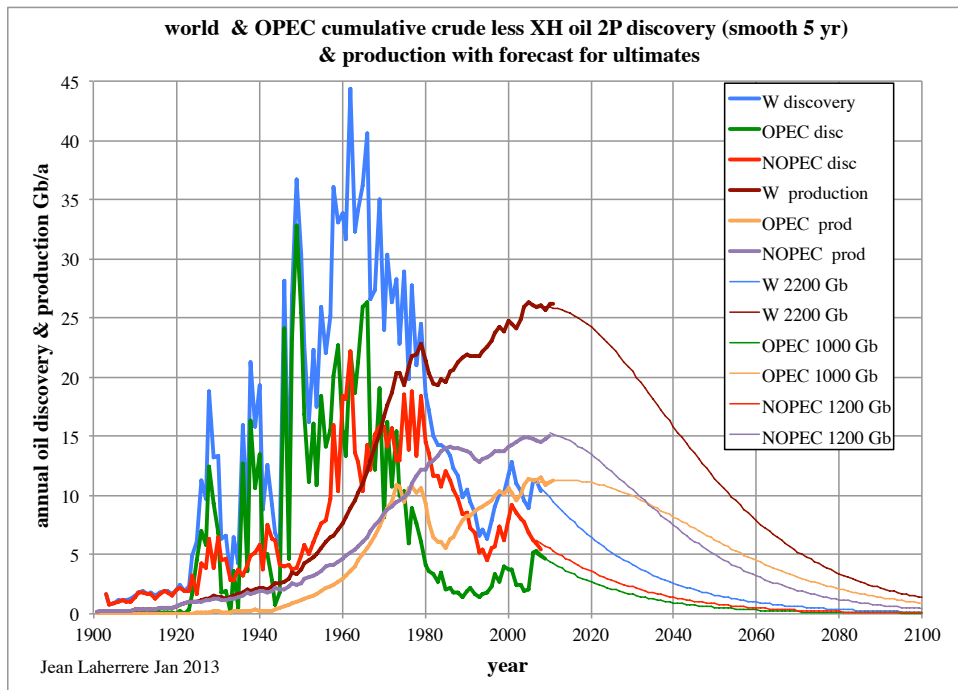
The best fit from cumulative discovery and cumulative production is to take as ultimate 1000 Gb for OPEC, 1200 Gb for NOPEC and 2200 Gb for the world. The plot is given in the next graph

Figure 33: world & OPEC cumulative crude less XH oil 2P discovery & production and forecasts



The annual discovery and production is plotted. The forecasted production shows that the world as NOPEC is presently at peak and that OPEC will start declining only after 2020.

Figure 34: world & OPEC annual crude less XH oil 2P production & production and forecasts

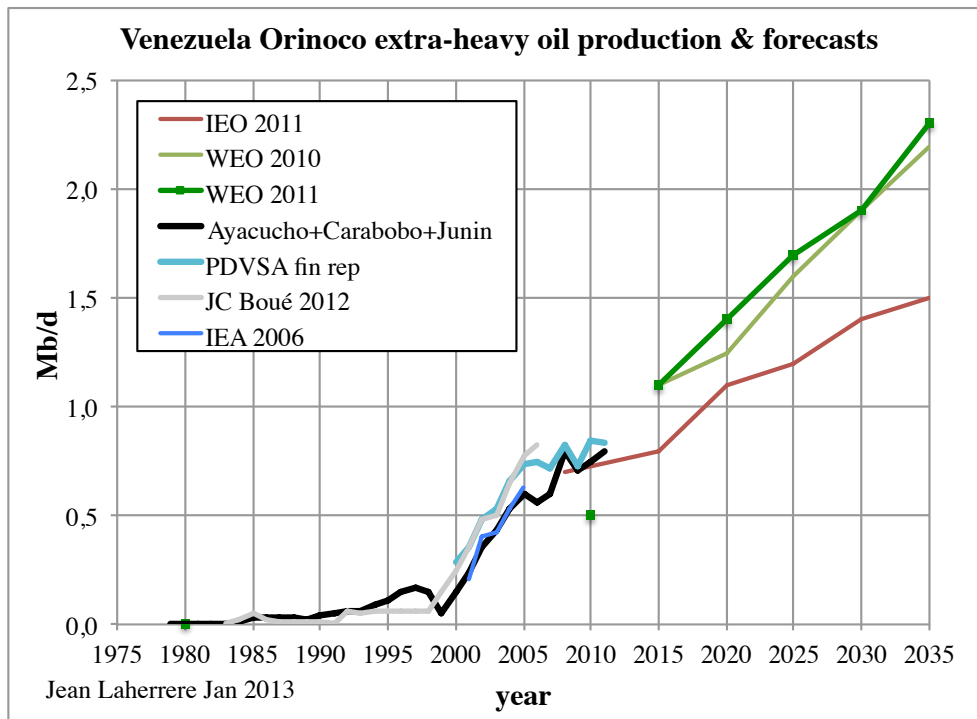


It is now necessary to add the extra-heavy oil which is only produced in Canada and Venezuela. Extra-heavy oil accumulations exist outside Canada and Venezuela, but negligible compared to the first two countries.

**-XH**

In Venezuela extra-heavy oil is concentrated in Orinoco which is divided into four units to fit the former companies operating in the country under PDVSA control. Four discoveries are reported from 1936 to 1939 (Ayacucho, Junin, Carabobo and Boyaca) with a total of 215 Gb reserves. Orinoco production started in 1979 and first was burned as Orimulsion (70% XH & 30% water) stooped in 2007 and later upgraded in plants to be sold as oil. Production data is hard to find and forecasts do not fit well. Orinoco is easy to produce with cold production using horizontal wells drilled in one week. The recovery is less than using steam as in steam assisted gravity drainage SAGD (developed in Canada in the 80s). But Chavez nationalization in 2008 stopped Orinoco growth.

Figure 35: Venezuela Orinoco extra-heavy oil production & forecasts



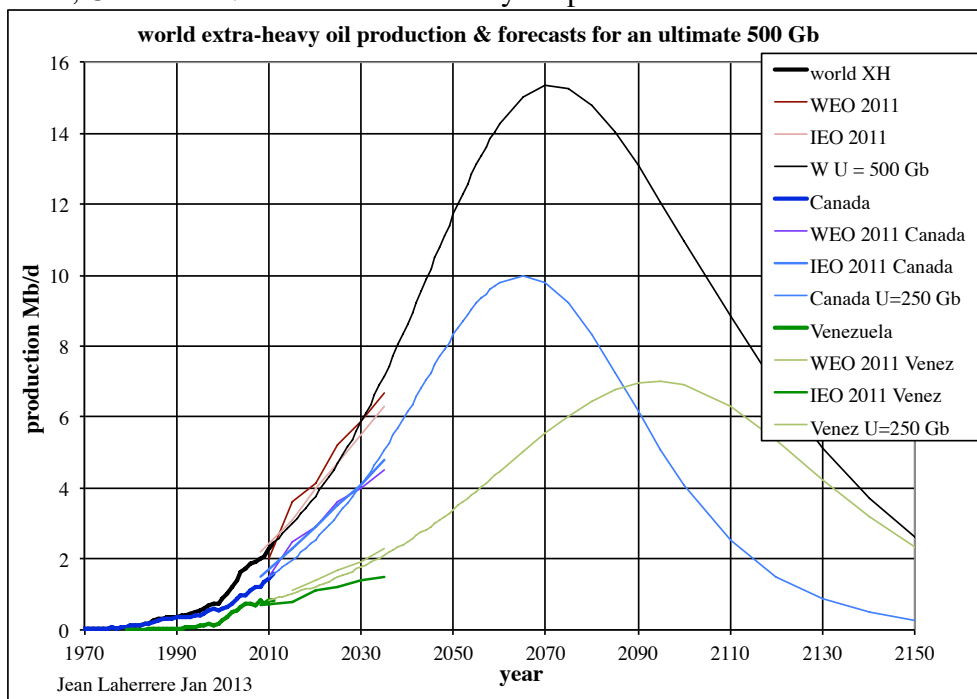
Canadian (mainly Athabasca) extra-heavy oil has the same gravity than Venezuela but is much more viscous because the reservoir is much cooler (5°C against 55°C for Orinoco) and is classified as bitumen having a viscosity above 10 000 cP (mPa.s)

Athabasca (mining or in situ) needs to be heated

The oil in place is huge, but the recovery factor is low. Many estimates have been given but it is better to stay at round figures, like an ultimate of 250 Gb for each: Canada and Venezuela giving a total of 500 Gb. The peak (value and date can vary) but they are fitted to present value and trend. Extra-heavy production needs huge investment, large workforce and very long planning and environmental regulations need to be fulfilled. Obviously above ground constraints can change the forecasted production.

With the estimated ultimates forecast is modeled fitting the past production and forecasts by official agencies for the world (peak 15 Mb/d in 2070), NOPEC (peak in 2060 at 10 Mb/d & OPEC (peak in 2090 at 7 Mb/d)

Figure 36: world, Canada & Venezuela extra-heavy oil production & forecasts





Natural gas liquids (NGL) need to be added

-NGL

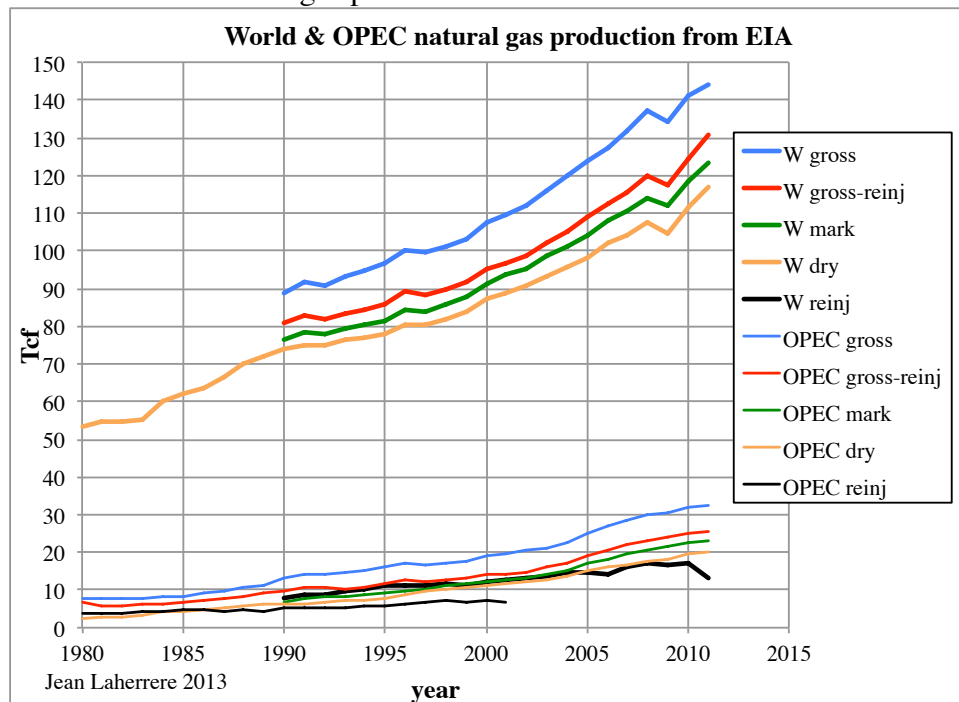
To forecast NGL, it is necessary to see the connection with the NG production and reserves.

-NG production

NG production is often reported as dry production (which is removed from the gas reserves), but before there are losses by venting and flaring and also by liquids extraction. It is necessary to study the different data being gross gas, reinjected gas, vented and flared gas, marketed wet gas and dry gas. Gas reserves must be reduced only by gross less reinjected and not by dry gas.

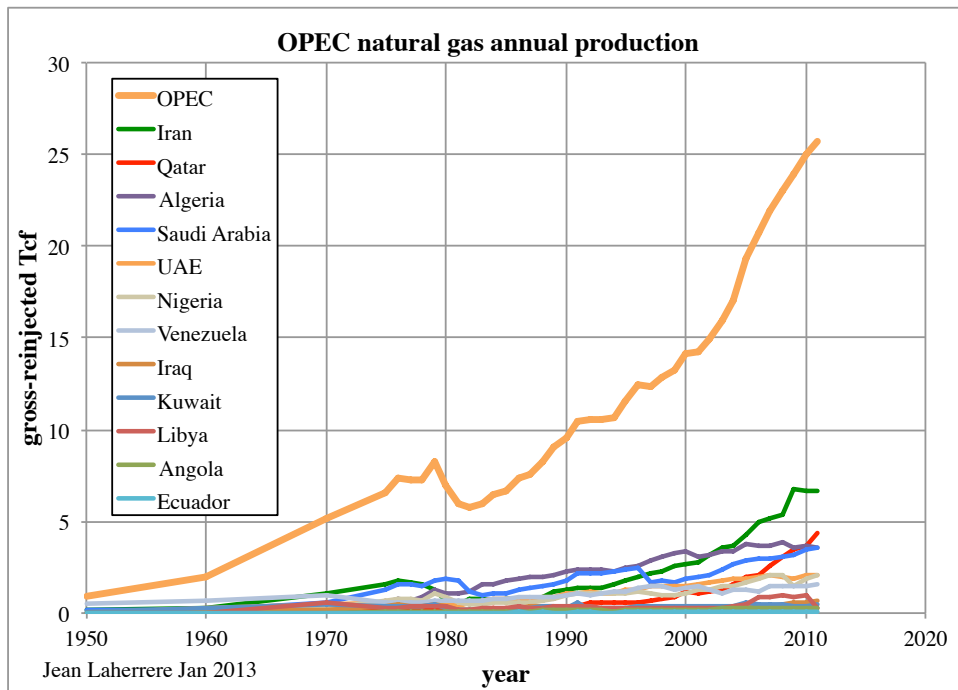
It is difficult to obtain historical production data. EIA reports only detailed data since 1990 and the next graph shows that there are significant differences following the definitions.

Figure 37: world & OPEC natural gas production from EIA 1980-2011

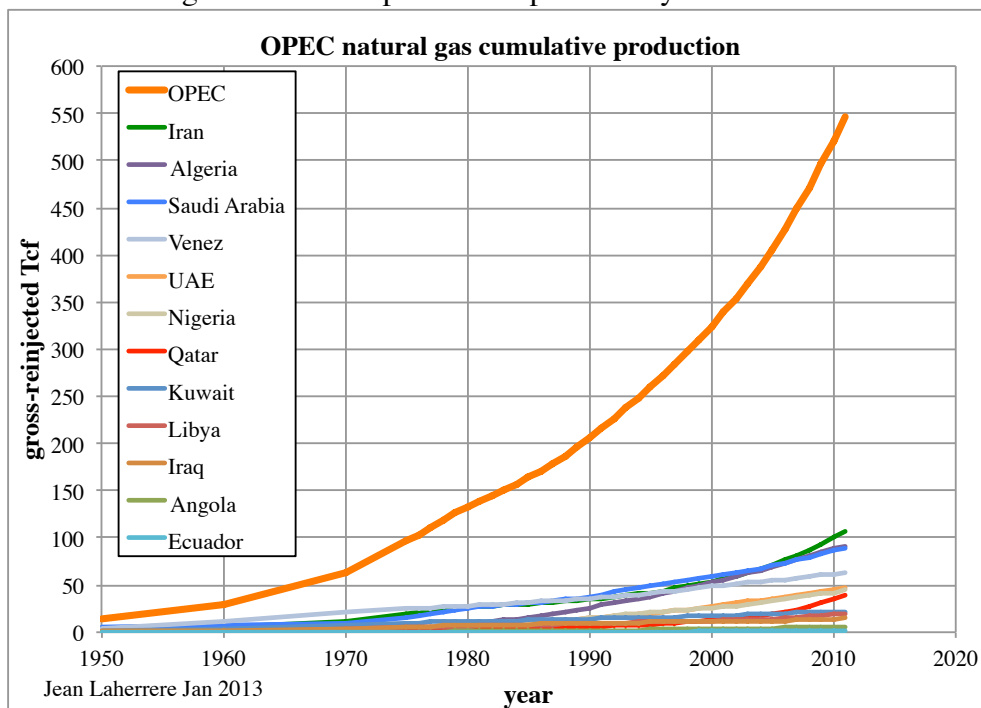


The data for gross less reinjected from Cedigaz and EIA displays OPEC production since 1950 with the detail by OPEC countries. Today Iran is the first producer, followed by Qatar Algeria and Saudi Arabia.

Figure 38: OPEC natural gas production per country 1950-2011



OPEC cumulative gross less reinjected gas production is 550 Tcf at end 2011  
 Figure 39: OPEC natural gas cumulative production per country 1950-2011

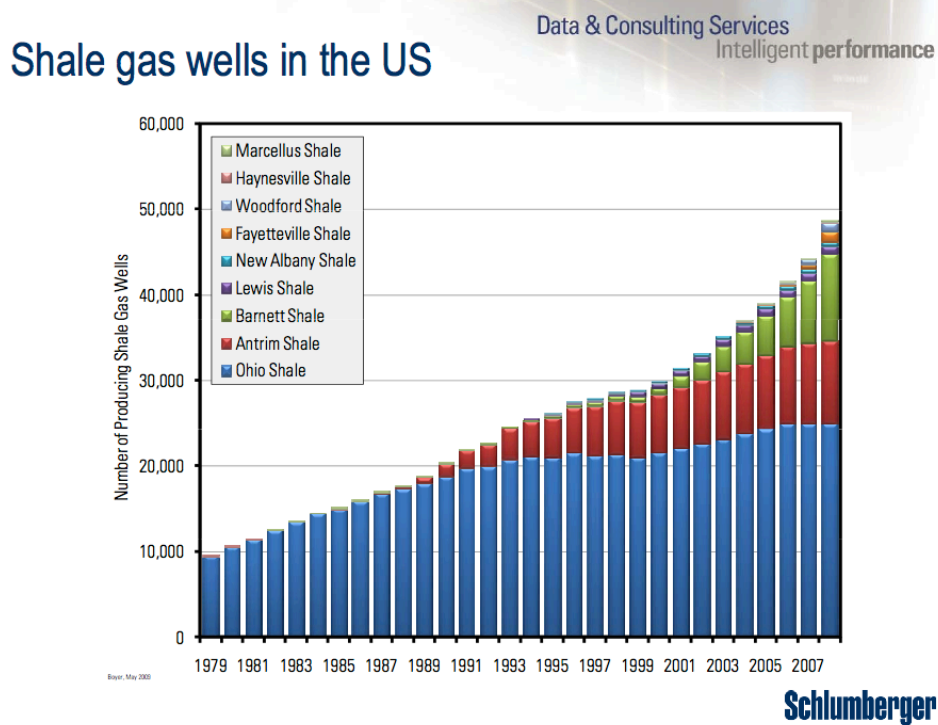


-US unconventional gas production

On figure 2 the world cumulative gas discovery & production is modeled towards an ultimate of 2000 Gboe or 12 000 Tcf = 12 Pcf, but the accuracy of this estimate is weak, because the fuzzy boundary for gas between resources (in the ground) and reserves (what will be the cumulative production at the end of production). The recent arrival in the medias of the shale gas has disturbed the minds of many believing that this new arrival is due to new technology starting in 1990. Shale gas is prevented as a new discovery, but in fact the first US natural gas production started in 1821 in Fredonia from Devonian shale in the New York State (for lighting) and the Big Sandy field (Kentucky & W Virginia) produced from the Devonian shale (called Ohio shale) since 1914 (? or

before EIA 2003 report states 1881) and in 2009 it is listed in the top 50 fields by USDOE/EIA as the 20 rank with a cumulative production of 2.5 Tcf from more than 10 000 wells (average 0,25 Gcf/well). In the 60s this shale gas production was improved by using explosives (nitroglycerine with up to 2t per well on 200 m). The present USDOE/EIA is completely forgetting this old shale gas. But Schlumberger reports that the US number of shale wells in 2007 were about 50 000 wells with half being in the Ohio shale (most in the Big Sandy) ignored by USDOE.

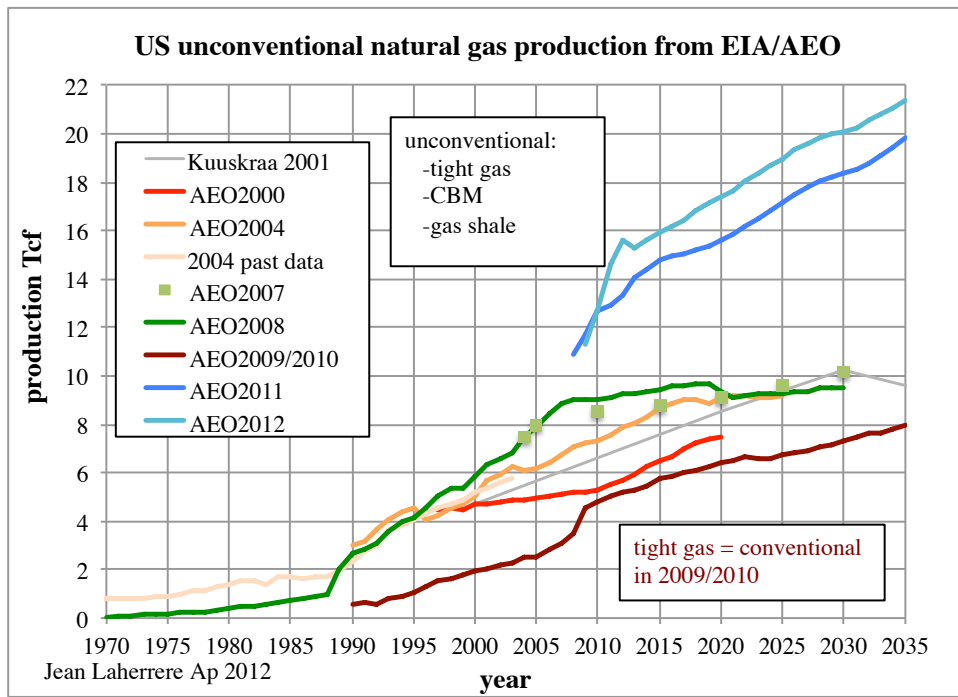
Figure 40: US shale gas from Schlumberger 1979-2008



b2

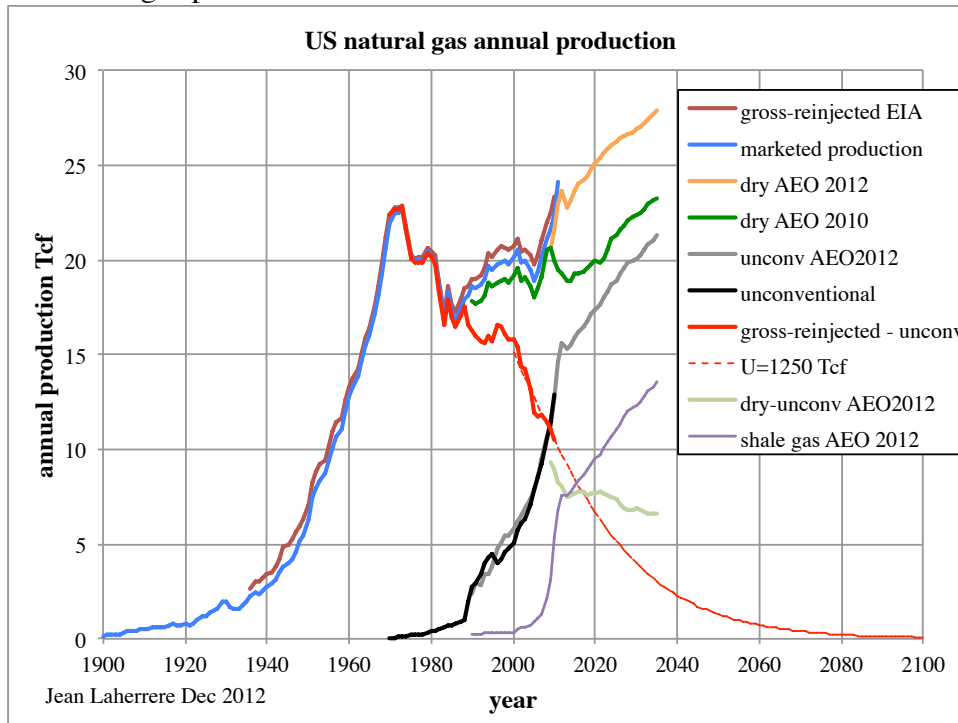
The US is the only producer of shale gas and is the main producer of other unconventional gas (coal bed methane = CBM and tight gas) but USDOE does not report properly unconventional gas. Even in the 2009 report tight gas was considered as conventional. It is a pity to find that it is not possible to obtain a reliable historical on US unconventional gas and the forecasts in the Annual Energy Outlook (AEO) vary without giving a continuous display.

Figure 41: US unconventional gas production from EIA



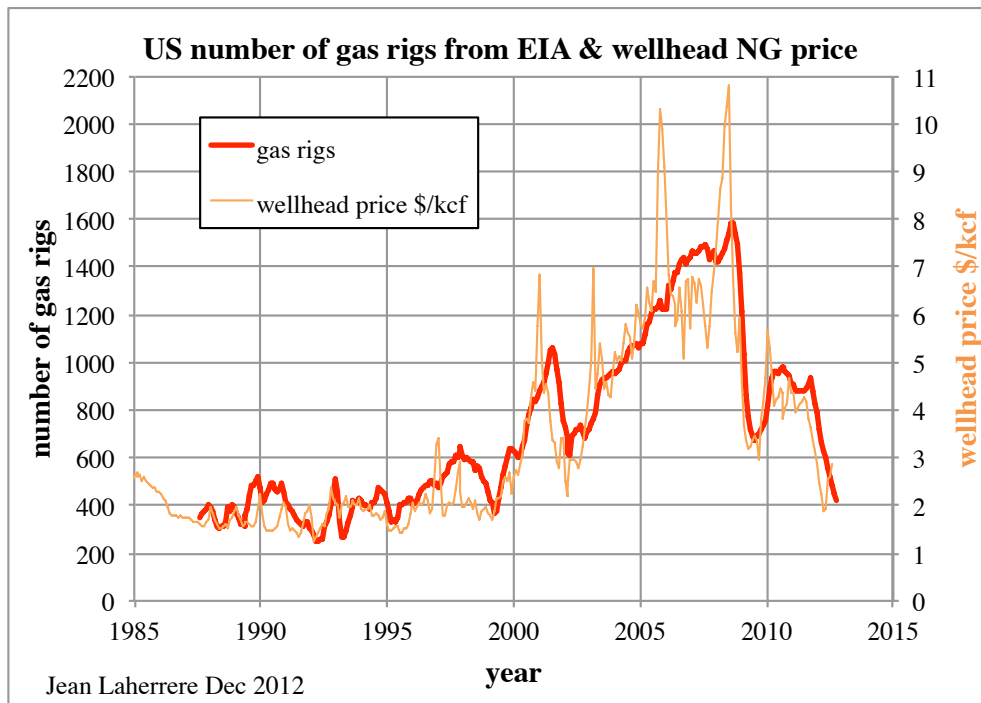
But the importance of US unconventional gas is considerable for its future, some claiming that the US can export its shale gas as liquefied. But it is obvious that the US conventional gas (in red) is declining fast and will be quite small in 2050/8

Figure 42: US natural gas production 1900-2035



The shale gas boom driven by promoters like Chesapeake fighting to produce the most to pay their debt has led to a drastic fall in the US wellhead gas price (from 10 \$/kcf in 2008 down to 2 \$/kcf in 2012), which correlates perfectly since 1987 with the number of gas rigs

Figure 43: US natural gas price and number of gas rigs from EIA



Chesapeake which has sold US gas interests to majors (Exxon, Statoil, Total, CNOOC) for 24 G\$ has still 12 G\$ of long-term debt. Standard and Poor's quotes Chesapeake as BB. The chairman McClendon was obliged to leave the chair. The head of Exxon Mobil Tillerson who bought XTO for 41 G\$ stated "we are all losing our shirts today, we're making no money. It's all in red"

The US gas price is presently 5 times less than the oil price in \$/Mbtu when it was about equal few w years ago. It appears abnormal to have such discrepancy, which is due to the lack of gas pipeline in the shale gas booming areas. In North Dakota about one third of the produced gas is flared. But the US oil over gas ratio was also very high (over 6 times) in 1950 where 12% of the US gas was flared or vented. This flared percentage went down to less than 1% in 1975 but up in 1996 as the oil/gas ratio and again in 2011. The percentage of flared gas in North Dakota displays a very good correlation with the oil/gas ratio

It appears that the present low gas price is due to the lack of gas pipeline, but this lack will be remedied only if this shale gas production is a long-term prospect

Figure 44: US oil over gas ratio and flared over marketed percentage

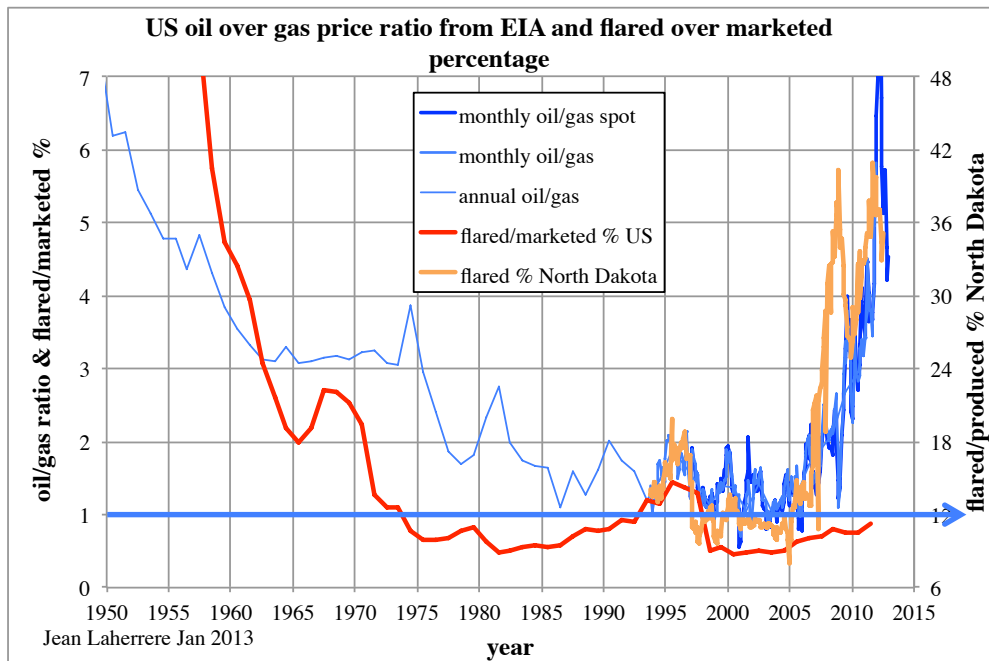
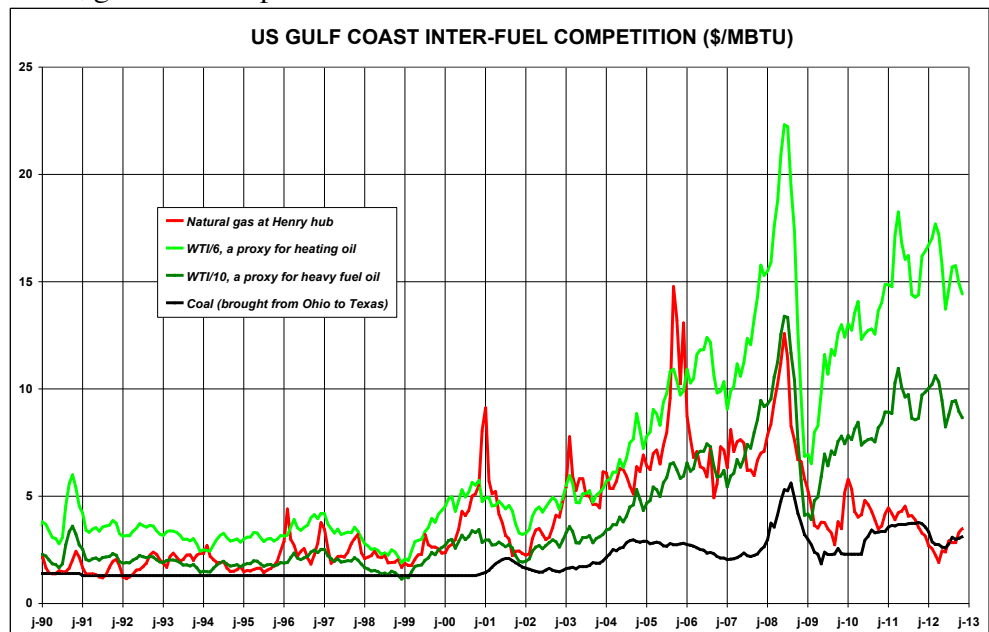


Figure 45: US oil, gas and coal price from JM Bourdair



All medias claim that shale gas has changed the world. Coal price is down. In fact shale gas boom which is claimed to be due to the technical breakthrough from horizontal drilling and hydraulic fracturation (they exist since about 50 years) is due to high gas price of 2008 and also the change in SEC rules to report undeveloped proven reserves in 2010: before rules were very conservative proven reserves should be only around producing wells, now rules are very optimistic allowing undeveloped reserves from a model (kept confidential) away from wells. Majors, lacking new conventional discoveries, were eager to add certified unconventional reserves and bought reserves from promoters like Chesapeake or XTO.

There is a rush to find shale gas reserves outside the US, but the recent attempts in Poland, UK, China, Argentina, lack any concrete & reliable result. But there is methane in many places on earth and in space (marsh gases, cows, Titan) the problem is to produce it economically and without local opposition. The big problem of shale gas outside the US is that the legislation should be changed in order that the landowners and the local authorities receive a certain percentage of the

production, which is not presently the case: it will take a while to change the laws and to reduce the NIMBY opposition.

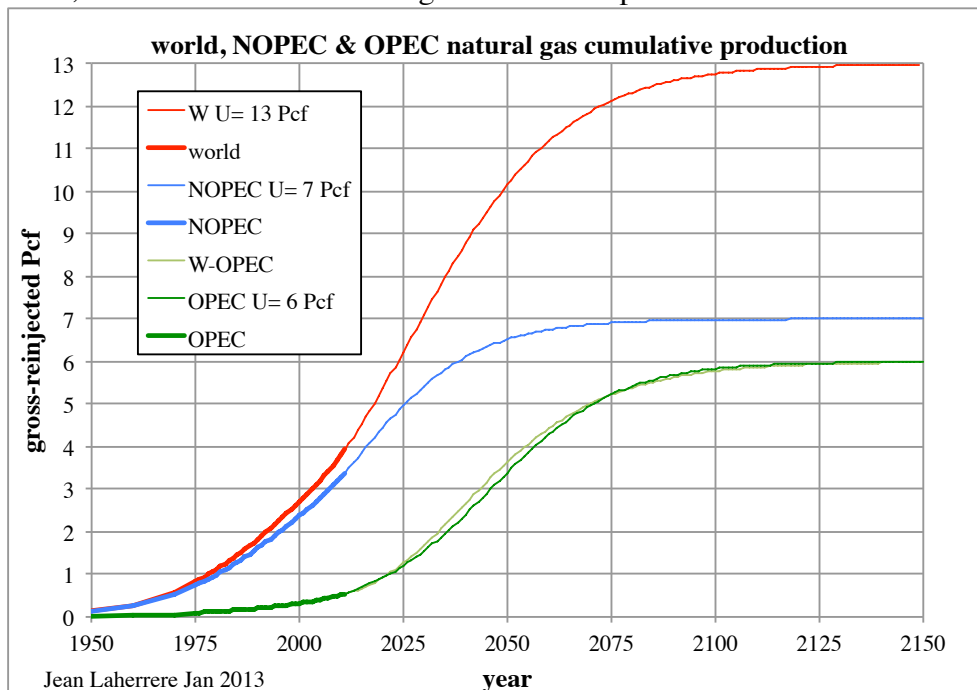
But some of these shale gas resources will be produced, the question is to estimate how much are (= reserves).

Shale gas ultimate could be about 500 to 1000 Tcf, but there is some indications that the largest gas field North Dome (Qatar/Iran) which is estimated at 1500 Tcf could be only 1000 Tcf.

The uncertainty on ultimates is large: about 20% and any increase in ultimate has to be 5%.

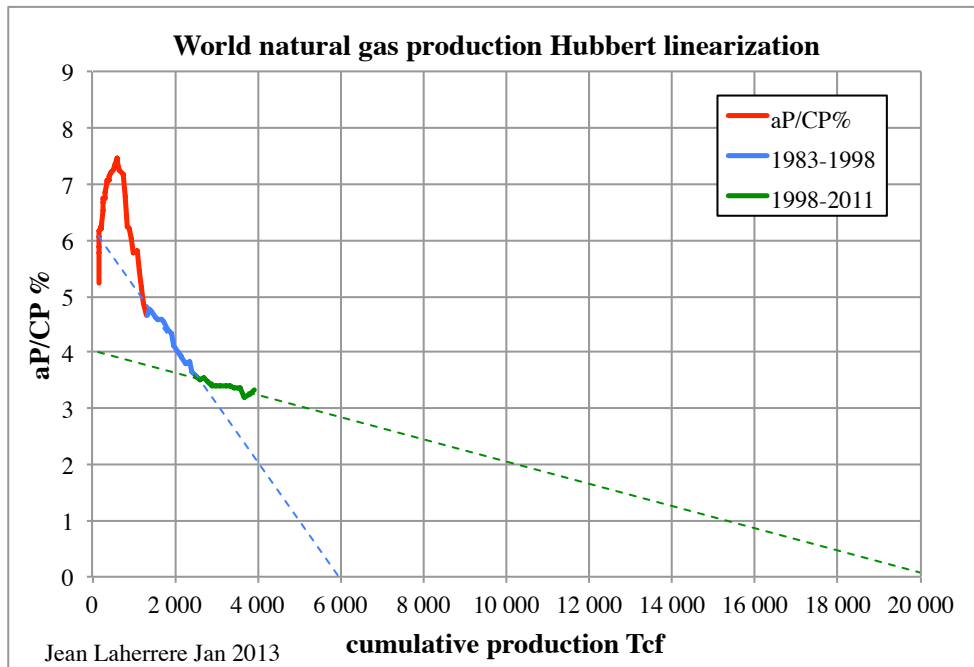
In order to take into account this shale gas, the world NG ultimate is then taken as 13 Pcf (120 Pcf in previous study) with a breakdown of 7 Pcf for NOPEC and 6 Pcf for OPEC as shown in the next graph

Figure 46: world, NOPEC & OPEC natural gas cumulative production 1950-2150



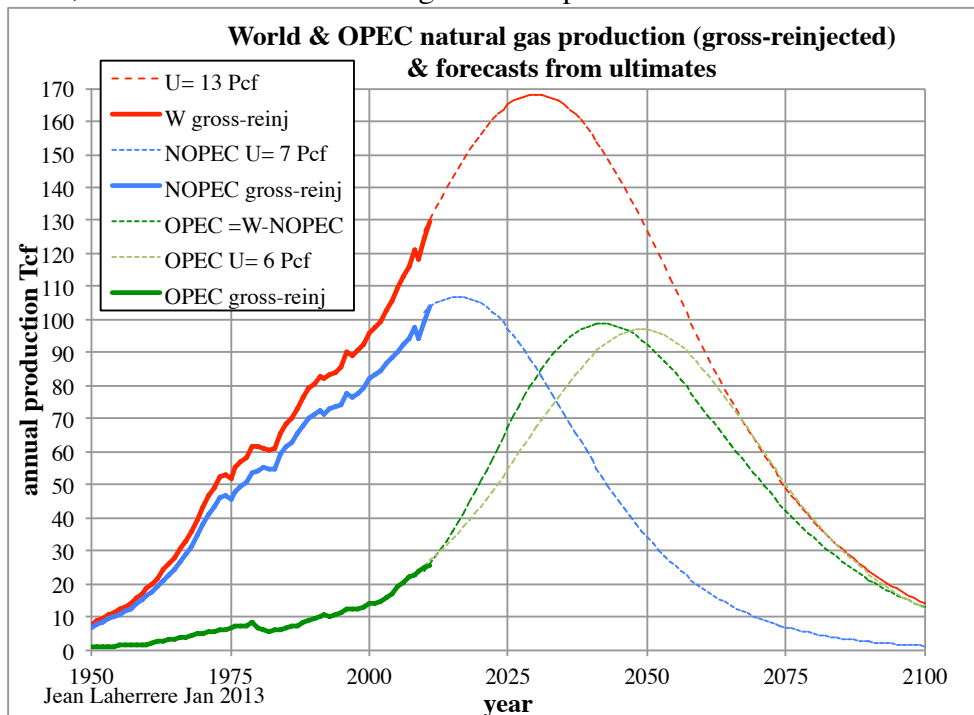
The world past production Hubbert linearization (cumulative production at end 2011 = 4 Pcf) shows a chaotic plot, which can be extrapolated to any value between 6 and 20 Pcf. The 13 Pcf estimate seems realistic.

Figure 47: world natural gas production Hubbert linearization 1900-2011



The annual production is modeled for the world (13 Pcf), NOPEC (7 Pcf) and OPEC (with an ultimate of 6 Pcf or the difference of forecast world less NOPEC)

Figure 48: world, NOPEC & OPEC natural gas annual production



The result is despite the recent sharp increase of NOPEC production our hypothesis of an ultimate of 7 Pcf leads that NOPEC will peak before 2020. Of course a “drill baby, drill” program could delay the peak but the following decline will be sharper.

OPEC gas production will peak around 2040-2050 at a level close to NOPEC peak.

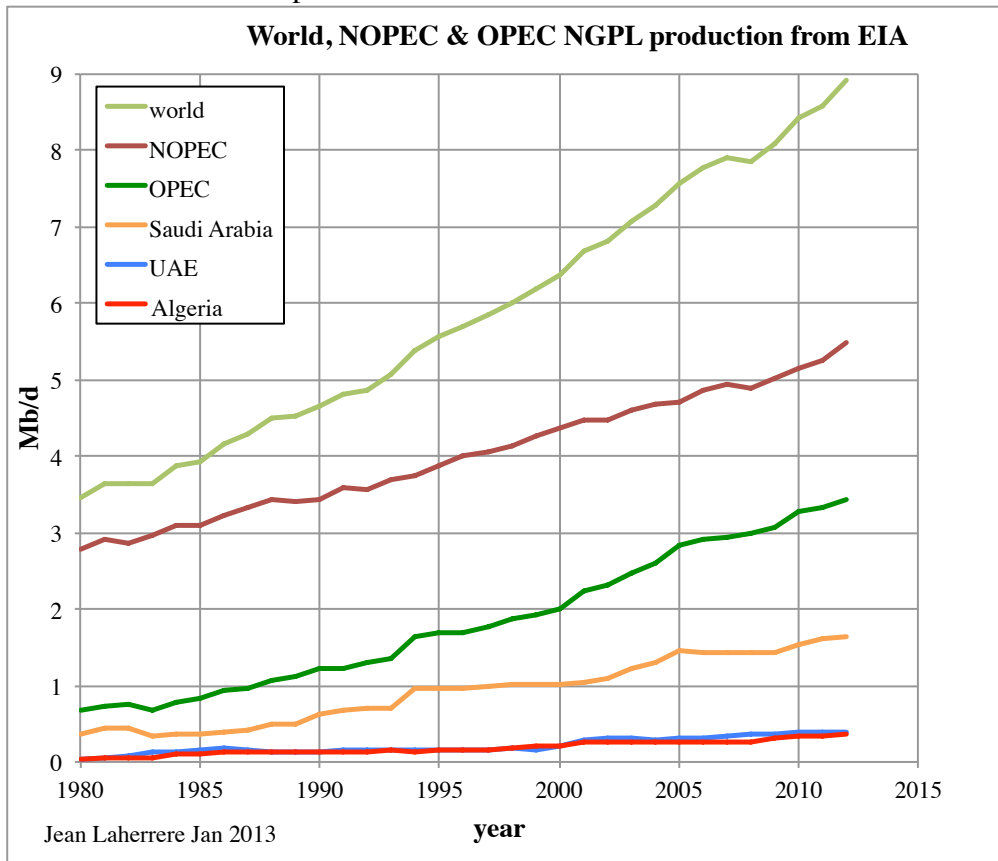
#### -NGPL

The big discrepancy found on WEO 2008 of 2 Mb/d on world NGL between IEA oil supply and EIA oil supply is that EIA includes condensate in the crude data because in the US condensate at wellhead is measured with crude, when IEA includes condensate either with crude or within NGL following the way it is sold. It is likely that IEA is wrong on NG data and it is surprising that no one has found the real cause. Uppsala Group stated in 2009 that the reason is that EIA reports NGL in



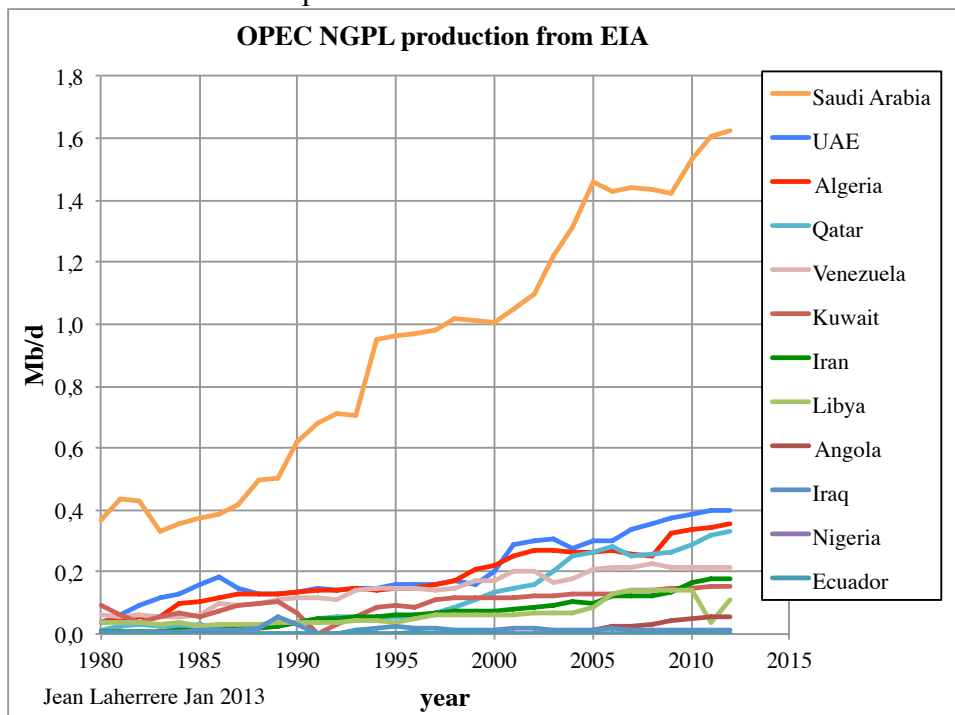
barrel oil equivalent boe, it is why the data is less. But it is wrong EIA reports on their site NGPL in real barrels and furthermore they reports for each country the heat content of NGPL. For 2012 the world NGPL production is 8.9 Mb/d when OPEC NGPL production is 3.4 Mb/d and NOPEC 5.5 Mb/d

Figure 49: world & OPEC NGPL production from EIA

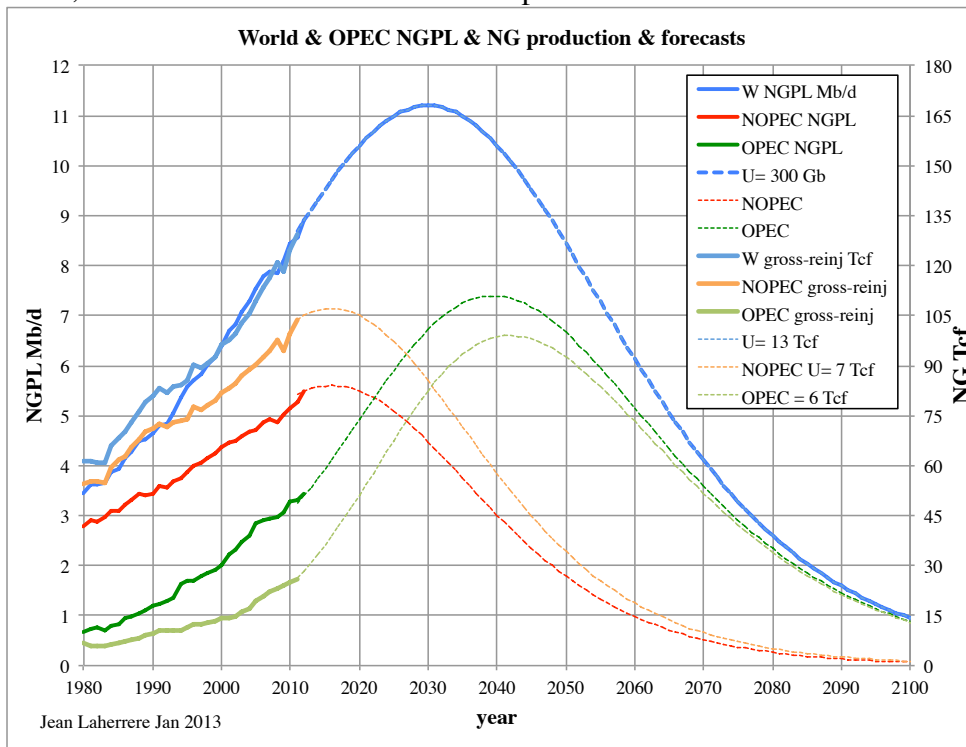


In OPEC by far Saudi Arabia is the largest producer with 1.6 Mb/d in 2012

Figure 50: OPEC countries NGPL production from EIA



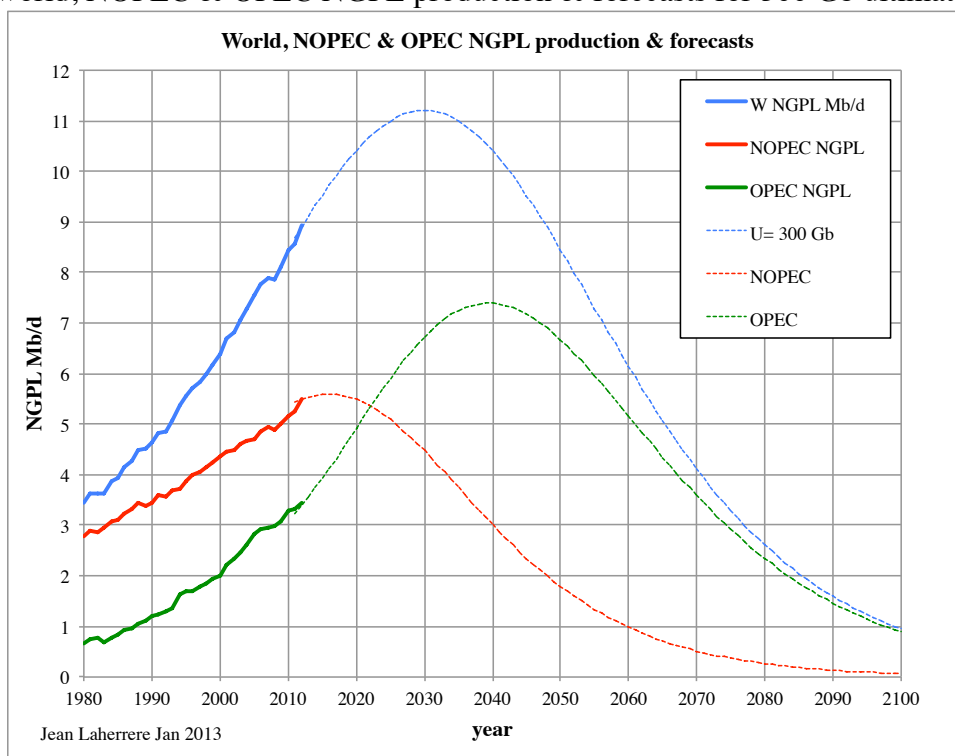
NPGL production in Mb/d is plotted together with NG production in Tcf/a with forecasts. NGPL forecasts are estimated being similar with NG forecasts with a world ultimate of 300 Gb. Figure 51: world, NOPEC & OPEC NGPL and NG production & forecasts



Same graph only for NGPL

NGPL peak will be for the world (blue) in 2030 at over 11 Mb/d; for NOPEC (red) before 2020 at 5.5 Mb/d and for OPEC (green) in 2040 at 7.7 Mb/d.

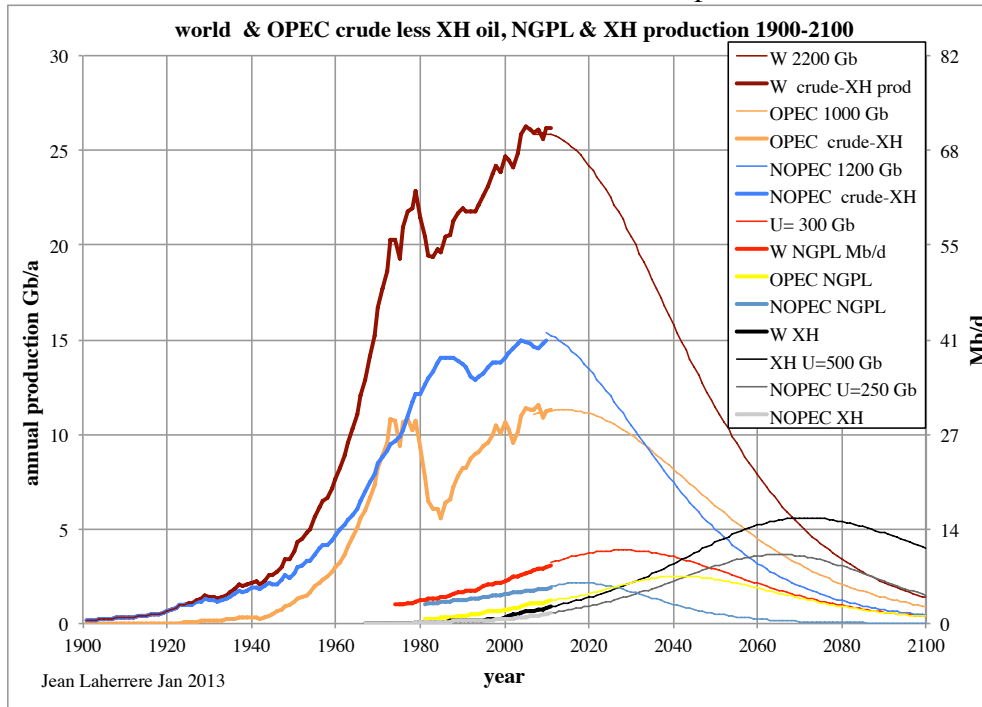
Figure 52: world, NOPEC & OPEC NGPL production & forecasts for 300 Gb ultimate



-crude oil +NGL

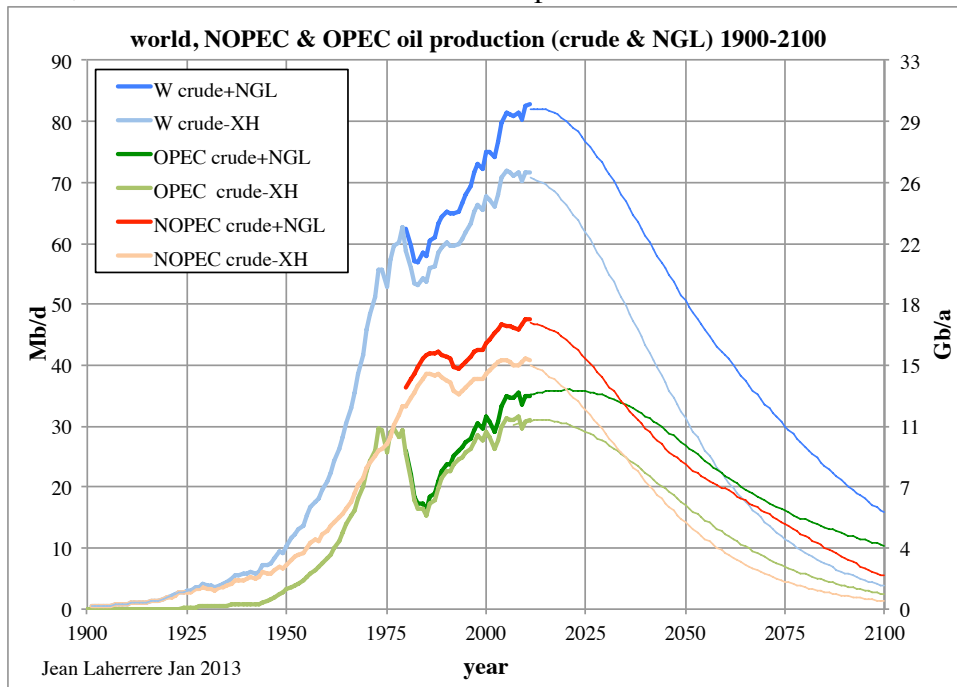
Adding the previous graphs of crude less XH oil with XH oil and NGPL leads to crude oil +NGL  
 The crude oil less XH production (already in figure 34 with discovery) is plotted again with XH and NGPL

Figure 53: world, NOPEC & OPEC crude less EH, XH & NGPL production



The crude oil + NGL will peak for the world before 2020 at 82 Mb/d, for NOPEC now at 47 Mb/d and for OPEC in 2020 at 36 Mb/d

Figure 54: world, NOPEC & OPEC crude oil +NGL production

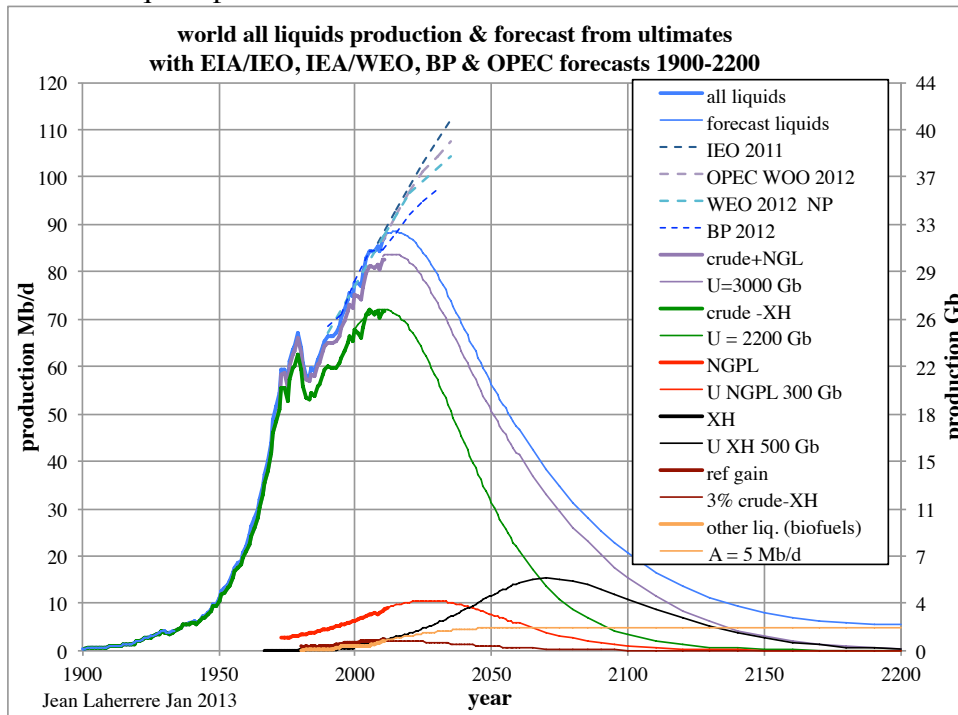


To obtain the all liquids it is necessary to add the refinery gains, the biofuels and the XTL: it is done only for the world. The maximum production for biofuels has been reduced from 6 Mb/d to 5 Mb/d because the competition between biofuels and food.

The forecasts on oil supply which is assumed to include all liquids in order to satisfy the oil demand which includes all liquids (there is biofuel in gasoline when filling the tank of a car) are compared

with our forecast and those of WEO 2012, IEO 2011 and BP 2012 which are business as usual always growing up to 2035

Figure 55: world all liquids production & forecast 1900-2200



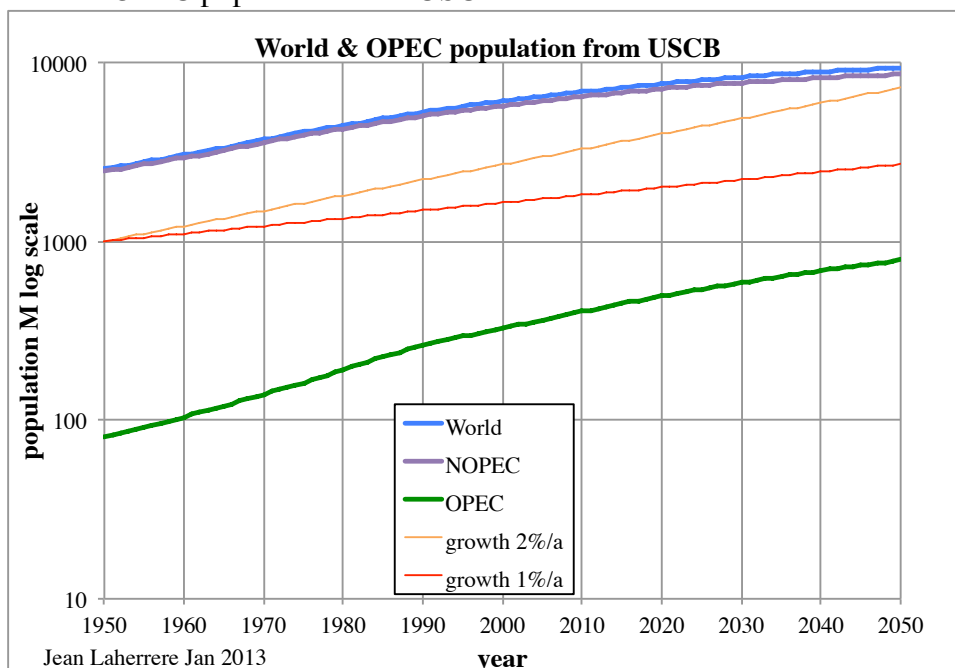
To complete the study it is necessary to forecast the consumption per capita from the population forecasts.

-forecasts on population and consumption per capita

UN population forecasts (2003 and 2010) are based on fertility rate, which is assumed to trend for every country towards the replacement rate of 2.1 child per woman; it is political wishful thinking. The USCB forecasts are used reporting population from 1950 to 2050 using a log scale to compare growth. With log scale world and NOPEC are very close

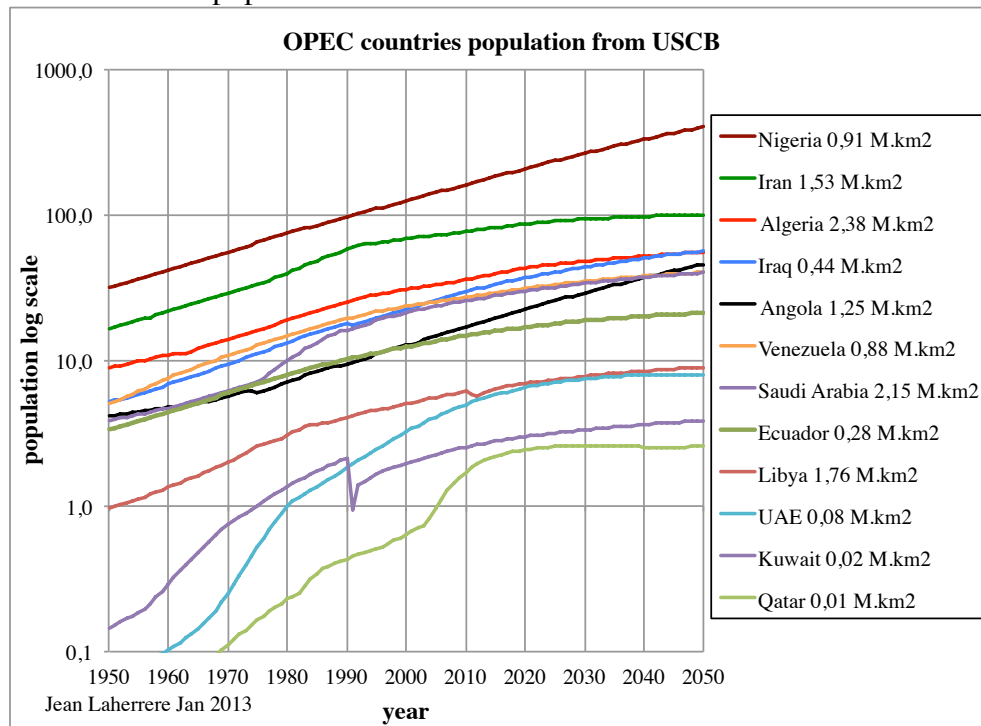
The growth of the population is compared with a growth of 1% and 2%: OPEC future growth is about 2% when NOPEC growth is less than 1%

Figure 56: world & OPEC population from USCB



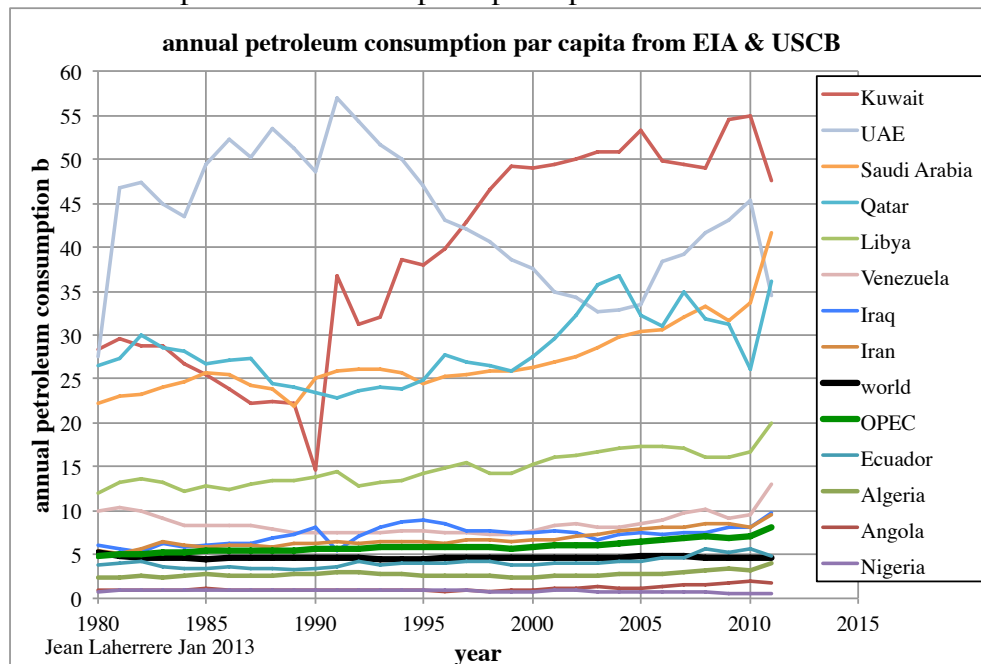
OPEC members population is compared. Surface of the country is indicated.  
 The largest OPEC member production is Nigeria and the smallest is Qatar. The fastest growth is Nigeria and Angola

Figure 57: OPEC countries population from USCB



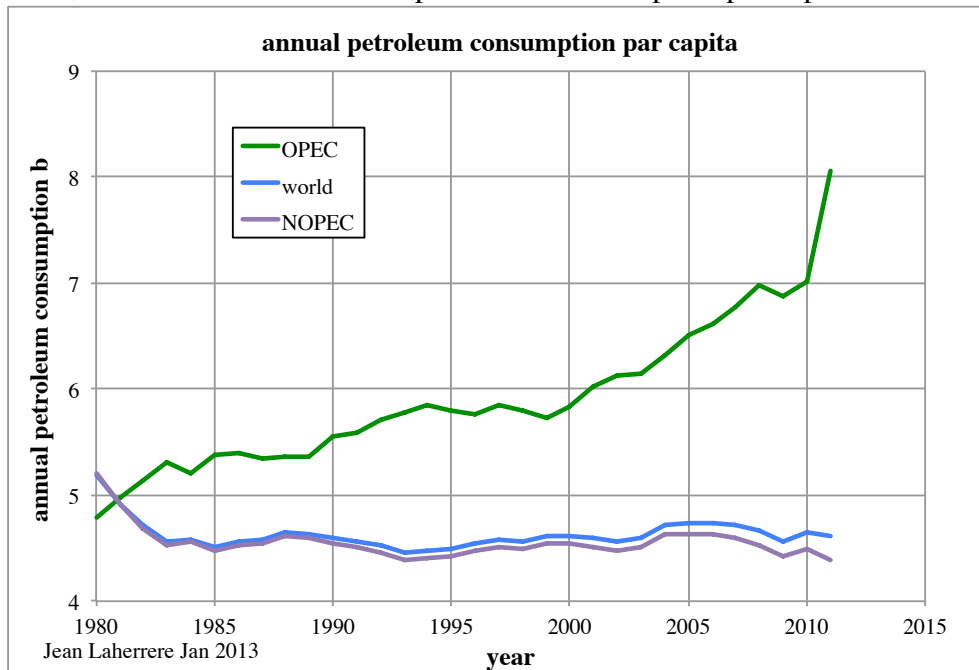
OPEC annual petroleum consumption (IEA data) is plotted per capita (USCB data).  
 Kuwait consumes about 50 barrels per capita per year, compared to 5 b for the world and 0.5 b for Nigeria: the range is huge!

Figure 58: OPEC annual petroleum consumption per capita from EIA & USCB



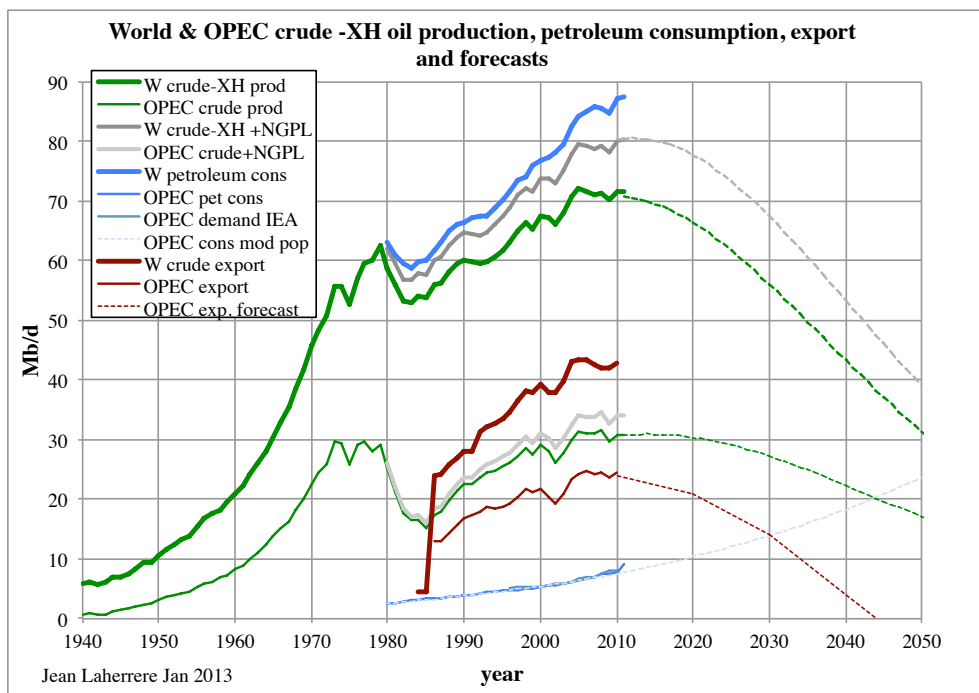
The annual petroleum consumption per capita was about 5 b in 1980 both for NOPEC and OPEC.  
 In 2011 it is 4.5 for NOPEC (decrease) but 8 b for OPEC. OPEC members are wasting oil and their population is growing twice more than NOPEC. The future is obvious: less oil for export.

Figure 59: world, NOPEC & OPEC annual petroleum consumption per capita



For the period 1940-2050 world petroleum consumption, crude less XH production and export are plotted for the world and for OPEC. The OPEC consumption (in light blue) is modeled using population forecast and it will cross the OPEC oil production around 2045, meaning that the OPEC export will decline down to zero in 2045

Figure 60: world & OPEC crude less XH oil production, petroleum consumption, export & forecasts



If OPEC will continue to grow in population and consumption as plotted, the OPEC export, which is at 24 Gb in 2010, will decline soon and will go down to zero about 2045.

## -Conclusions

Production oil & gas data are unreliable and the UN should put as a priority to oblige every country to publish true and complete data on energy, in particular on fossils fuels which are the gift of humanity, because soon the world will suffer energy constraints.

The large increase of world population since 1850 is due to the progress in medicine and abundant cheap energy. We have entered the end of cheap energy and we need to save energy. But many do not want to change their way of life, count on a constant growth on energy, dreaming the renewable can replace fossil fuels.

It is a must to get the true data to show that fossil fuels will soon peak.

The present study is based on ultimate estimated mainly from 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 follows their example, such study would be much more reliable. It is a shame that it is not understood in New York at the United Nations or in Brussels for the European Union.

With the poor present data it seems that world oil production will peak before 2020, Non-OPEC soon and OPEC around 2020.

OPEC oil export will cease before 2050.

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.

But I do not know any study showing as much as this paper.

I am sorry for the broken English and for being too long.

A shorter paper should be written after discussions within Clarmix or outside.

I will be glad to receive any comment and to discuss it.

jean.laherrere@alsatis.net