

This paper was written in association with Charlie Hall in view of a presentation in New Orleans on 21 March at ACS conference “M. King Hubbert: Is He Relevant?”

Forecasts for US oil and gas production

My assumptions for forecasting US oil and natural gas production are several:

1-Reserves estimates of LTO and shale gas, like conventional ones, are based on multiplying estimates of the volume in place (or the volume generated by the source rock) and a recovery factor. Such assessments are completely unreliable because the volume of the accumulation is fuzzy (no water plane) and the recovery factor unknown by lack of historical checks with LTO or shale gas fields produced until abandoned

2-Future production estimated by many (in particular EIA) by assuming a large number (tens of thousands) of future wells multiplied by the optimistic estimated EUR of past wells (in sweet spots) without bothering to check if there is enough room for drilling economical wells is for me very unreliable.

EIA does not bother reporting the cumulative future production of their forecasts up to 2050

EIA publishes the LTO reserves at end 2016 ranked by proved reserves: Bakken is number one but in their AEO forecasts up to 2050 Permian basin is number one

This EIA approach relying on number of wells and well ultimate reminds of the USGS estimate in 1962 of 590 Gb for the US oil ultimate by V.McKelvey (based on Zapp's work

<https://pubs.usgs.gov/bul/1142h/report.pdf>) by multiplying a large number of feet drilled (5 10E9 foot) by the recovery per foot up to 1961 (118 b/ft = 130 Gb discovered for 1.1 Gft drilled = G.Bowden 1982): Hubbert was strongly against such approach, saying that the oil recovery per foot was showing a roughly exponential decline (D.Strahan 2007) and would be lower in the future. Present estimate of the US ultimate is far below Zapp's estimate (590 Gb), but higher than Hubbert's estimate (150-200 Gb for conventional USL48).

It is the same with LTO. The present ultimate recovery per well (EUR) will be lower in the future and the location of future wells will be limited, in particular with lateral length increase.

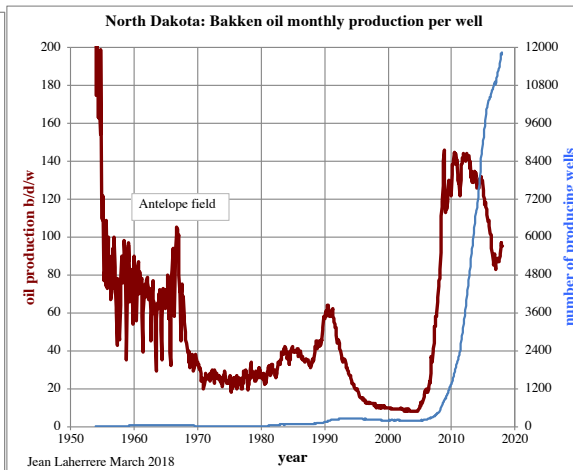
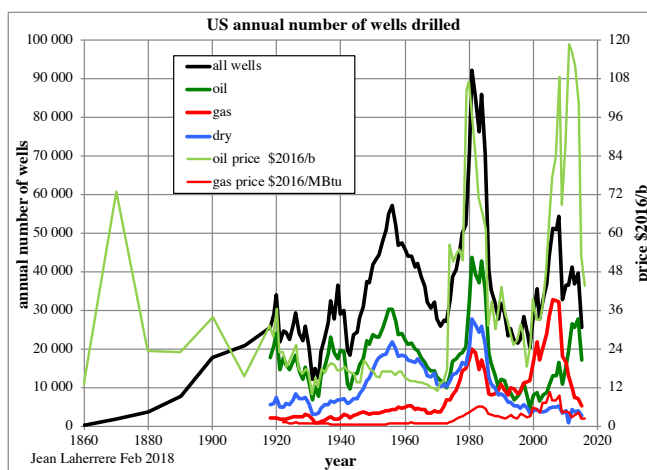
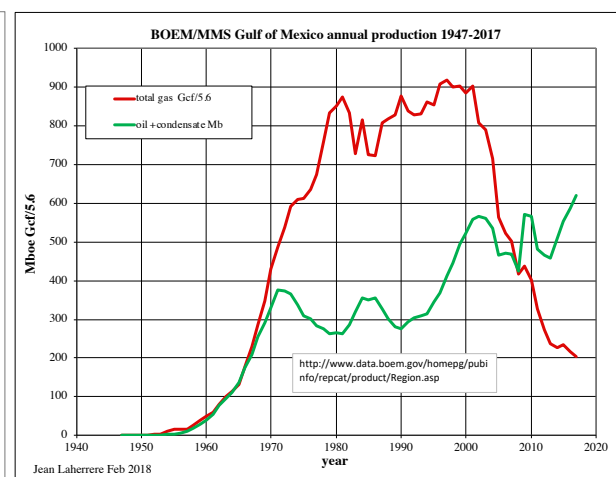
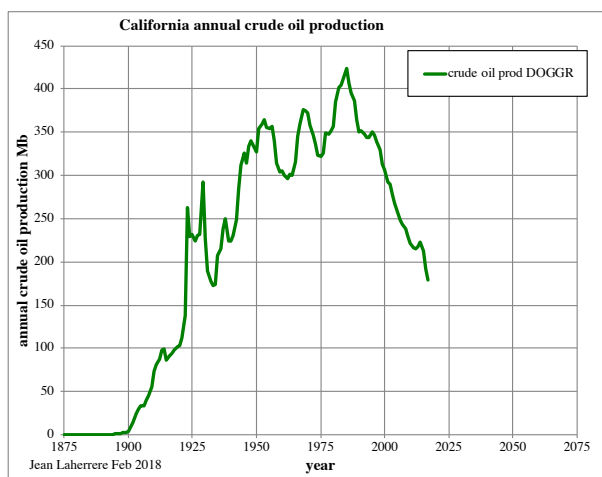
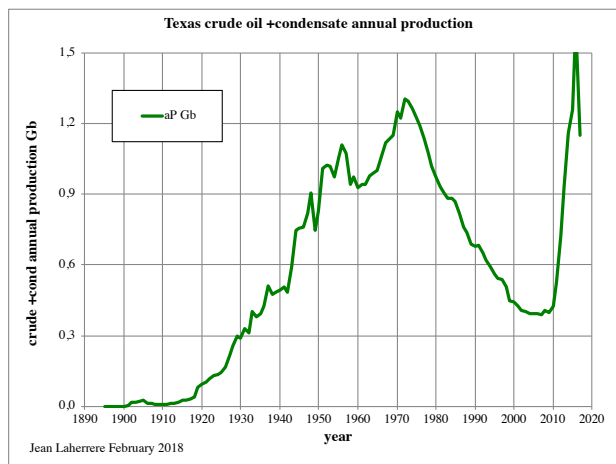
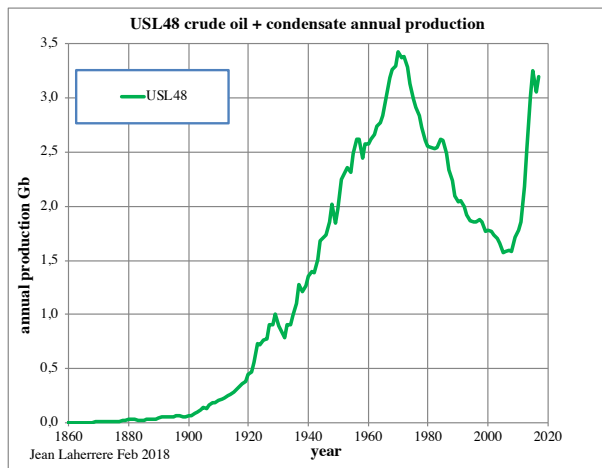
3-I believe it is better to estimate the ultimate production of LTO and shale gas with HL (Hubbert linearization) of past production. But many plots display several declines and the last data with rise

Hubbert Linearization is the plot of the ratio of annual production to cumulative production in percentage (Y axis) versus the cumulative production (Hubbert 1980). Empirically once the field is moderately well developed, this gives one or several relatively straight lines and the last one can be extrapolated to the Y axis, giving the EUR when production will fall to zero (assumed to be the end of the production)

4-Past oil and gas data for the USLower48 displays cycles and most of the cycles display approximately symmetrical rises and declines, so the future cycle is assumed to be also symmetrical.

This symmetry is explained by the fact that, in the USL48, there are thousands of producers acting in random (law of large numbers). Random behavior is described as “Brownian motion”, displaying Gaussian symmetrical curve.

The past crude oil production 1859-2017 of the USL48, Texas, California and Gulf of Mexico displays several cycles and each decline has the same slope as the last increase.



Our main forecasts are based on EIA monthly production data (unfortunately there are several different reports as weekly, monthly).

The following plots show for different plays:

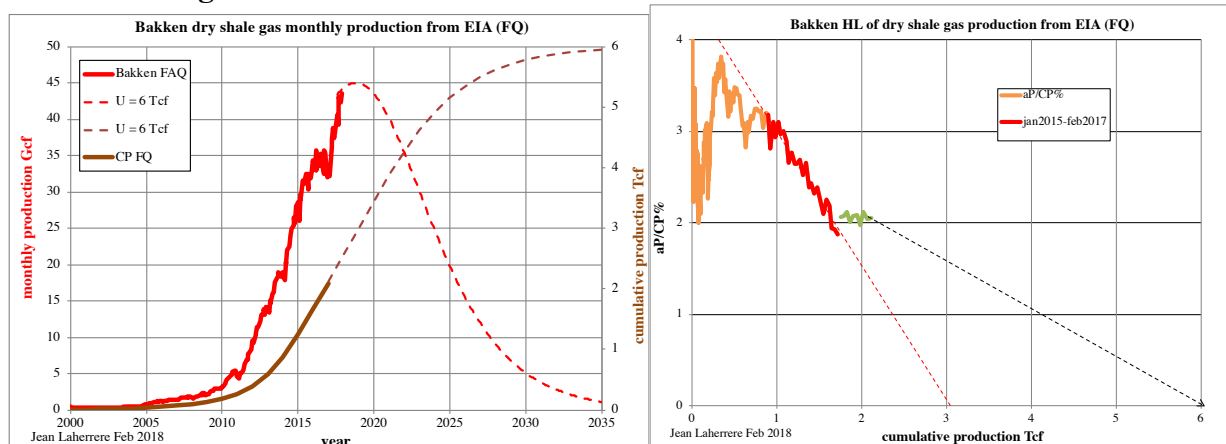
-left: annual & cumulative production as forecast for ultimate from HL

-right: HL (Hubbert linearization) of past production extrapolated to ultimate (U)

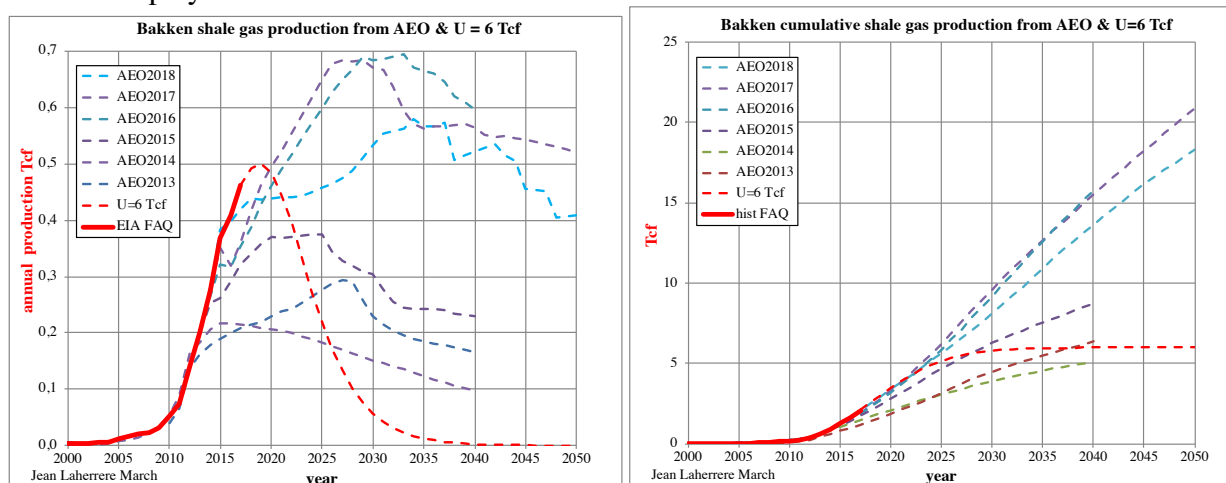
CP = cumulative production, RR = remaining reserves, CP+RR = initial reserves (discoveries)

-Natural gas production

-Shale gas: Bakken

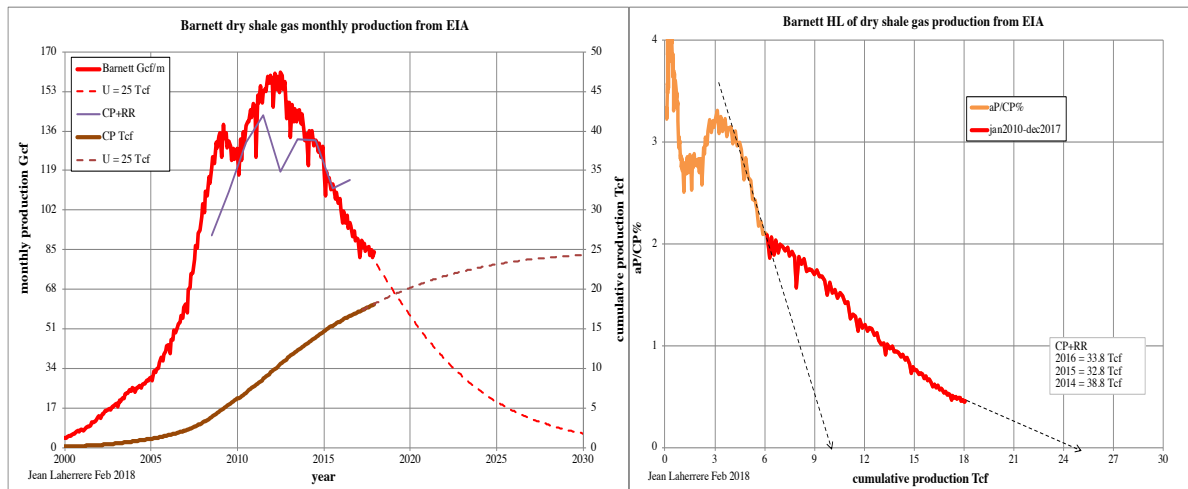


Mason Inman requested the EIA to get more details on the AEO and received the forecasts for each shale play for AEO 2013 to 2018

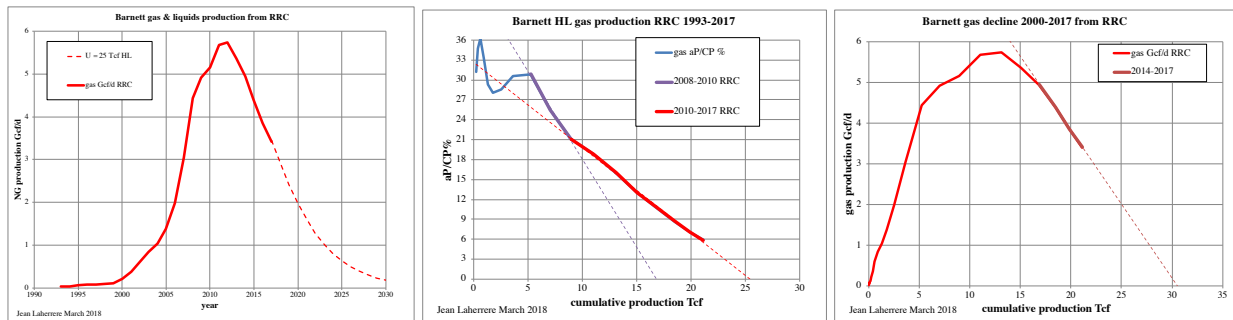


AEO annual production forecasts are chaotic with time!

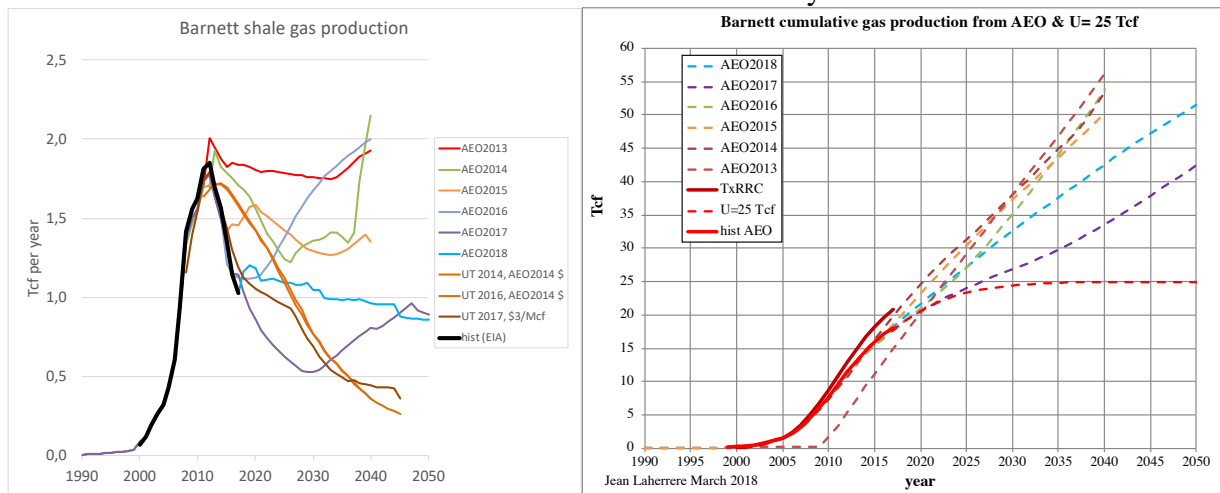
-Shale gas: Barnett



From TxRRC annual data

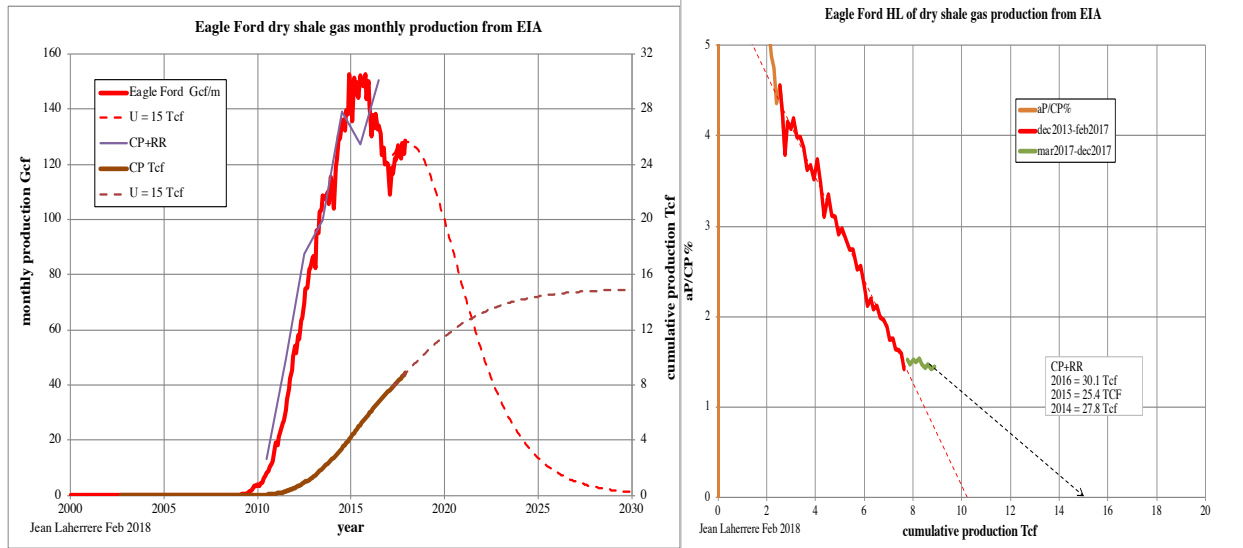


Mason Inman data AEO 2013 to 2018 and also from University of Texas UT

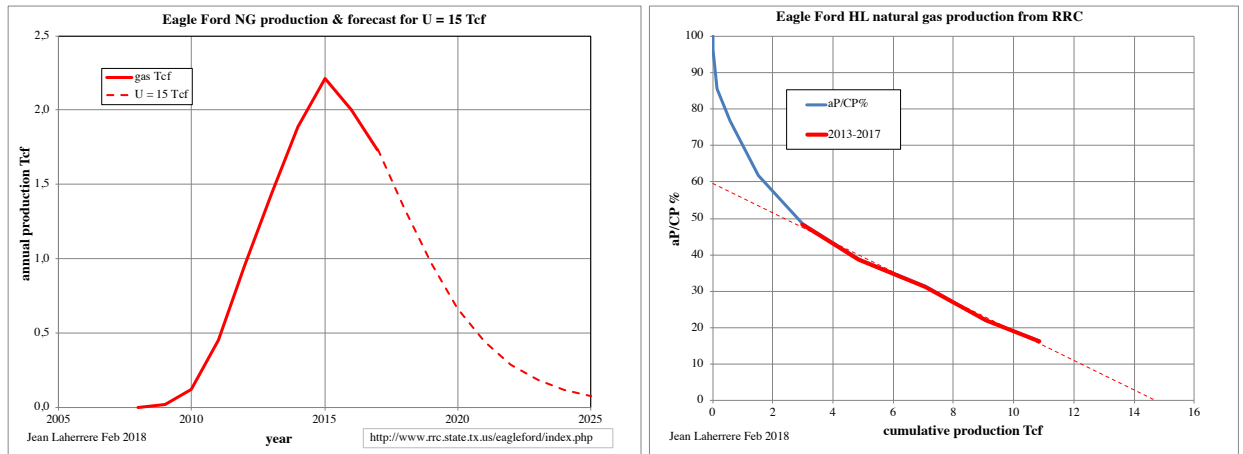


AEO2013 was much higher than AEO2018, missing the decline after the peak of 2012, , UT 2017 (University of Texas) is close to our forecast

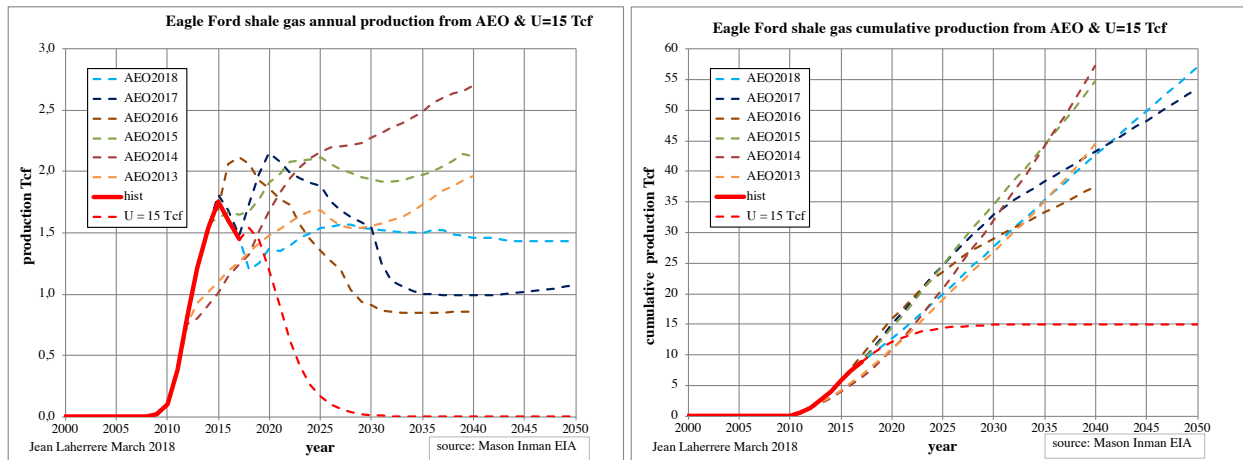
-Shale gas: Eagle Ford



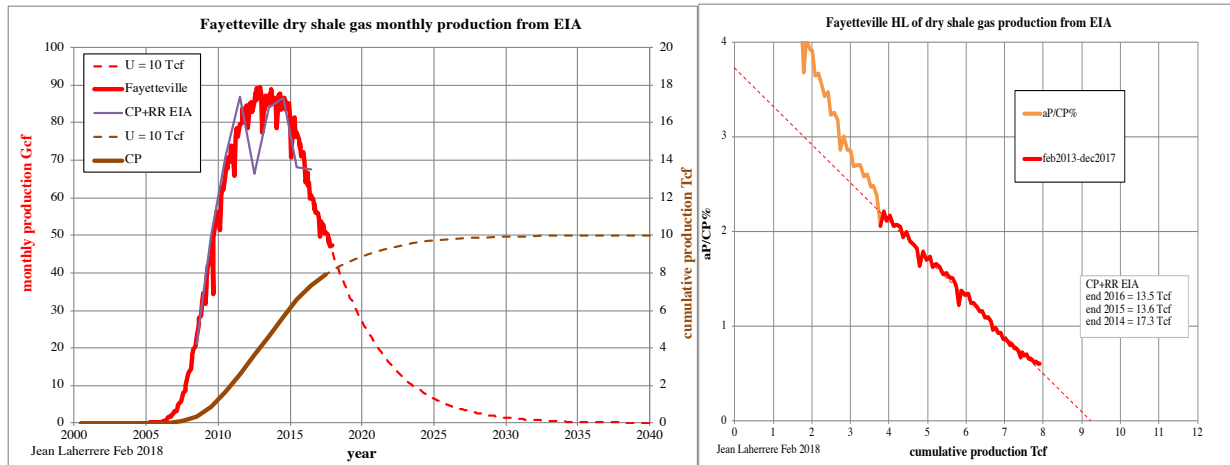
From TxRRC annual data



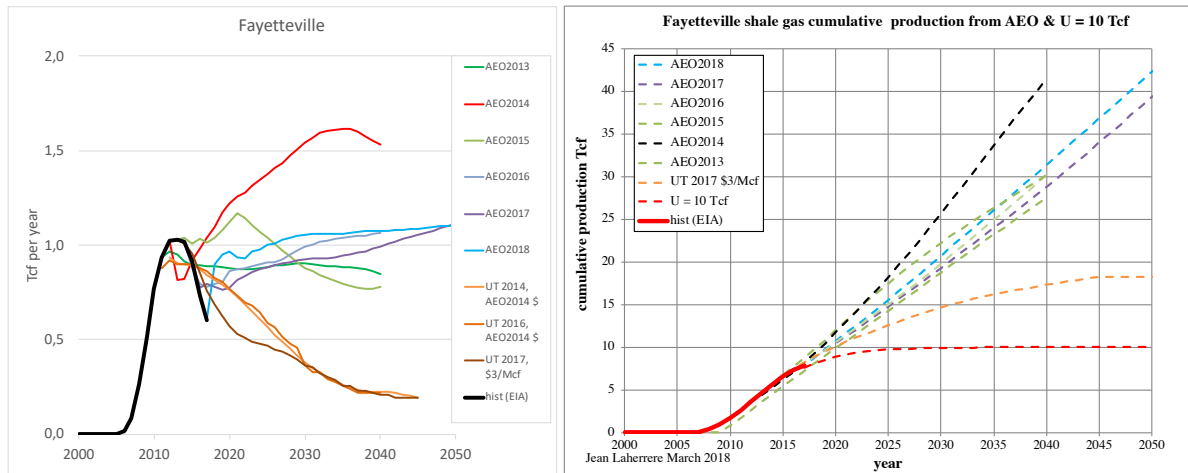
Mason Inman data AEO 2013 to 2018



-Shale gas: Fayetteville

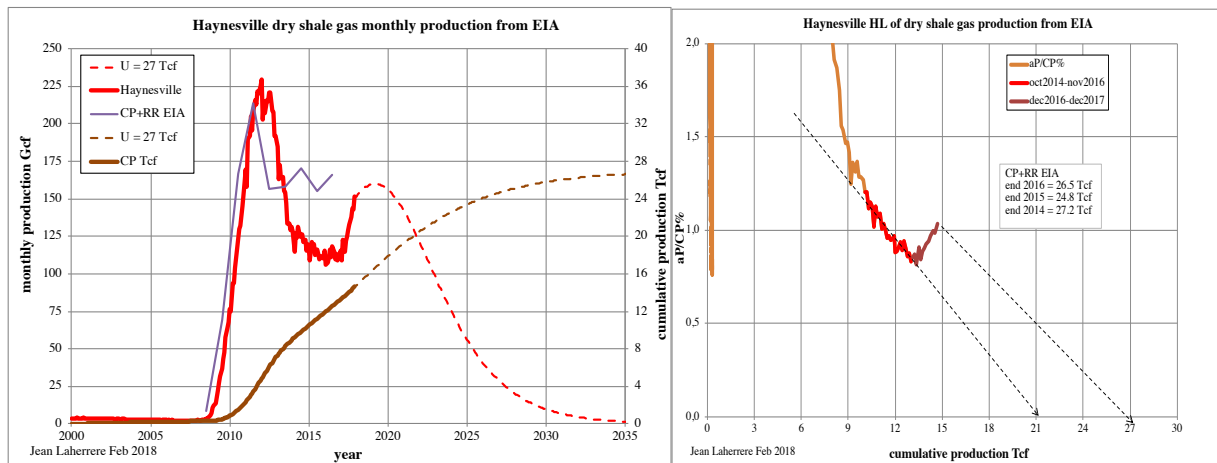


Mason Inman data AEO 2013 to 2018 and UT 2017

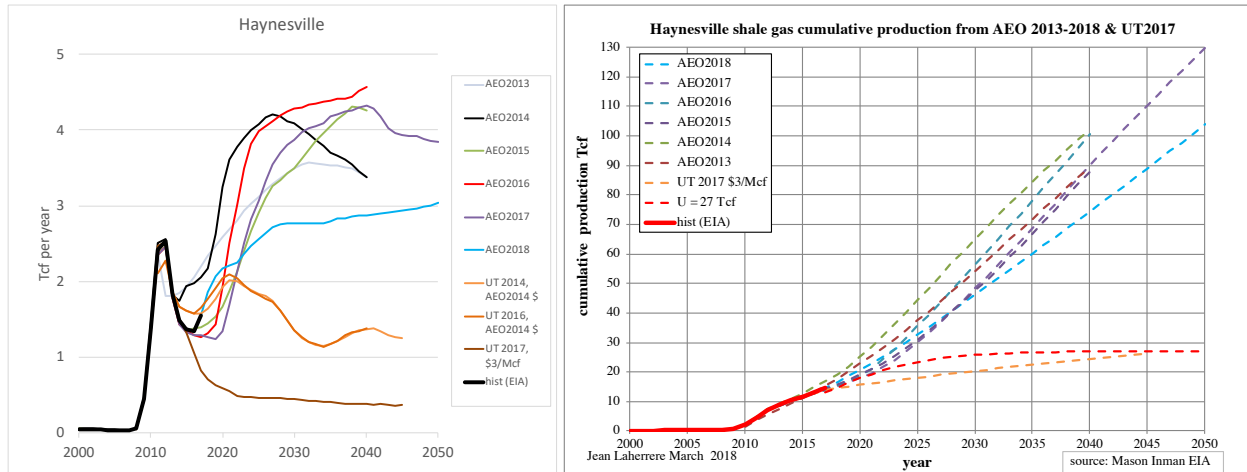


AEO2014 was completely unconnected with reality, when University of Texas UT2017 cumulative production up to 2050 is 18 Tcf against 42 Tcf for AEO2018 or 10 Tcf for my forecast: UT is closer to my estimate than to AEO2018!

-Shale gas: Haynesville

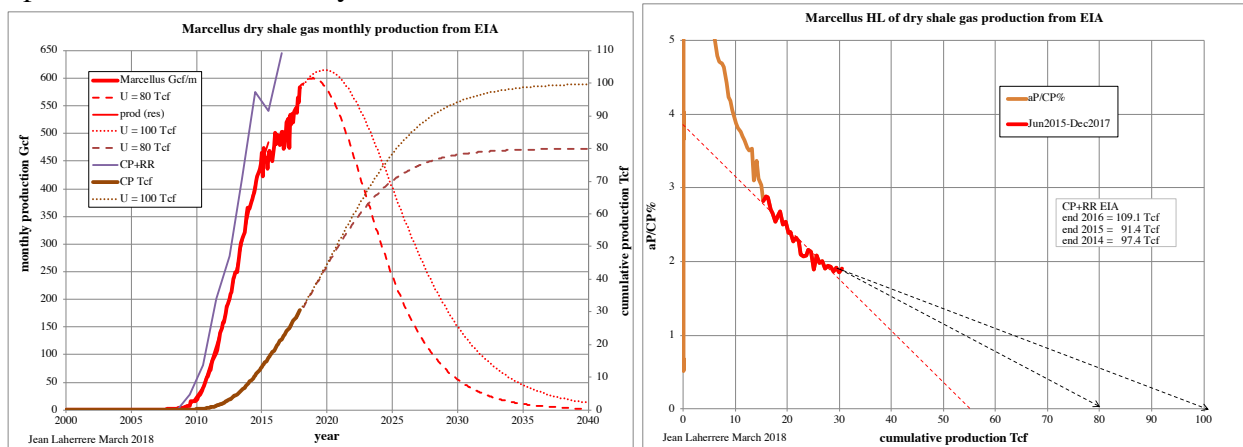


Mason Inman data AEO 2013 to 2018 and UT 2017



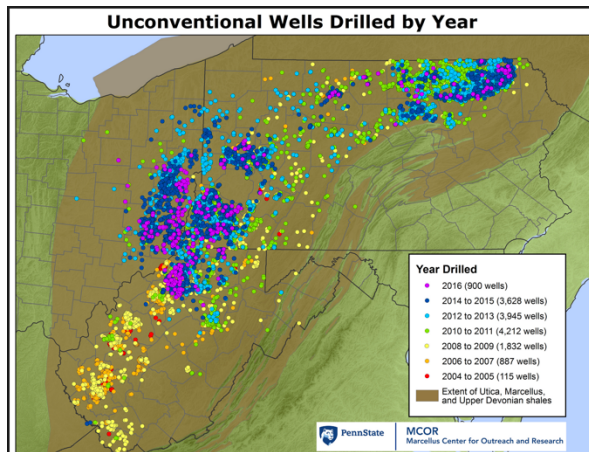
-Shale gas: Marcellus

My estimate for Marcellus gas is within the range 80-100 Tcf, when the cumulative production up to 2050 is forecasted by AEO 2018 to be over 360 Tcf

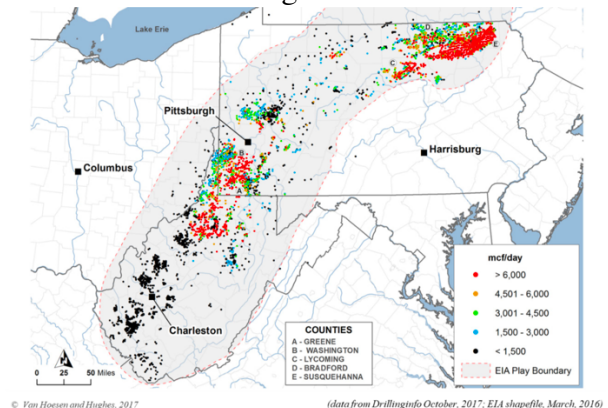


Marcellus basin is huge, but the sweet spots are concentrated in two areas and no drilling in between: its potential is likely to be poor!

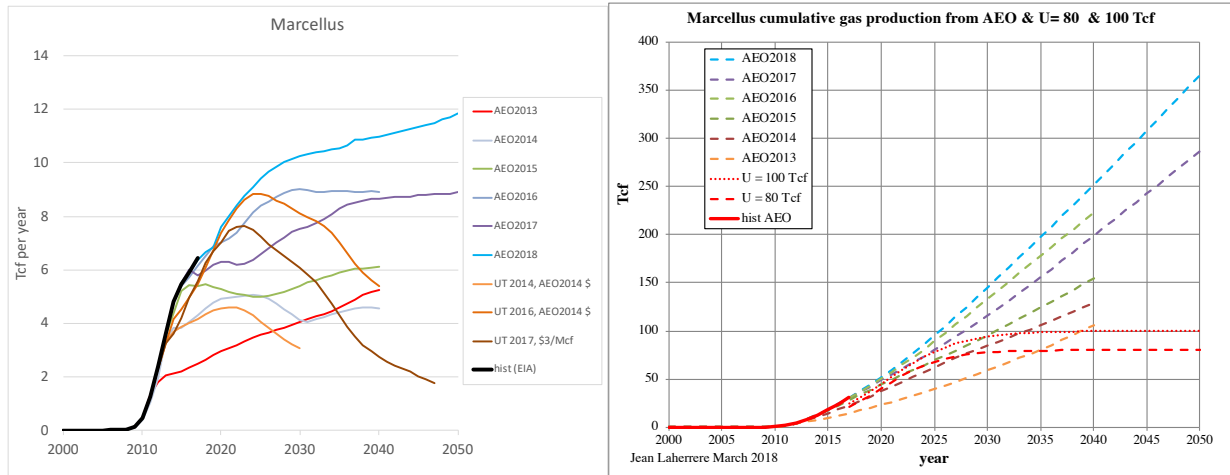
MCOR



David Hughes 2018

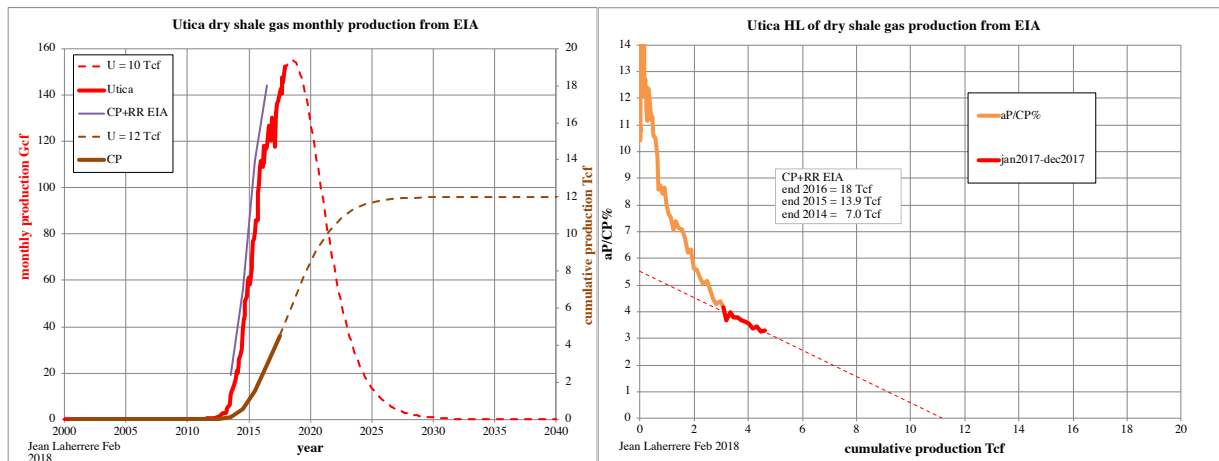


Mason Inman data AEO 2013 to 2018 & UT 2017

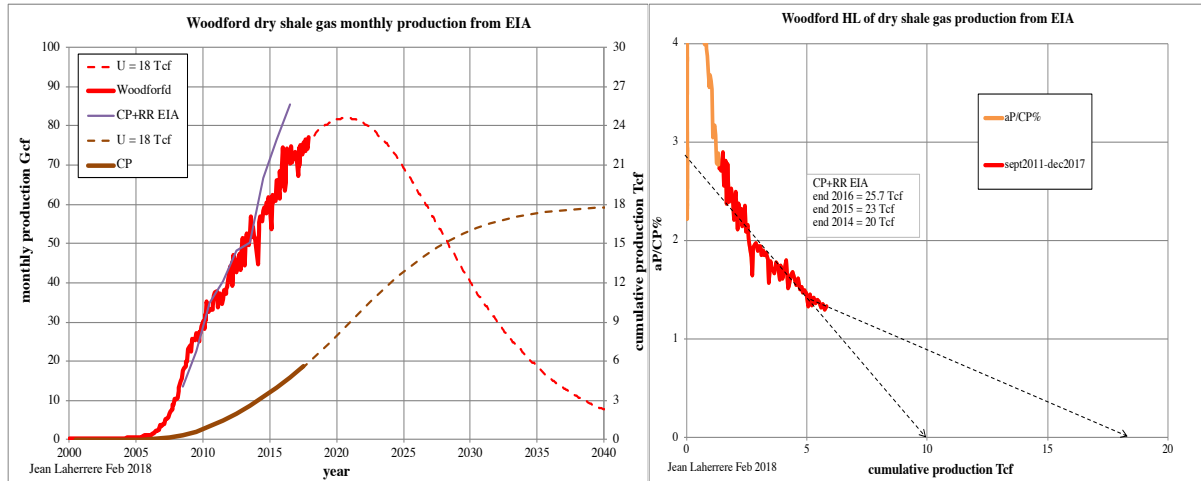


The AEO2018 forecast for Marcellus in 2045 is more than 5 times the UT2017 forecast

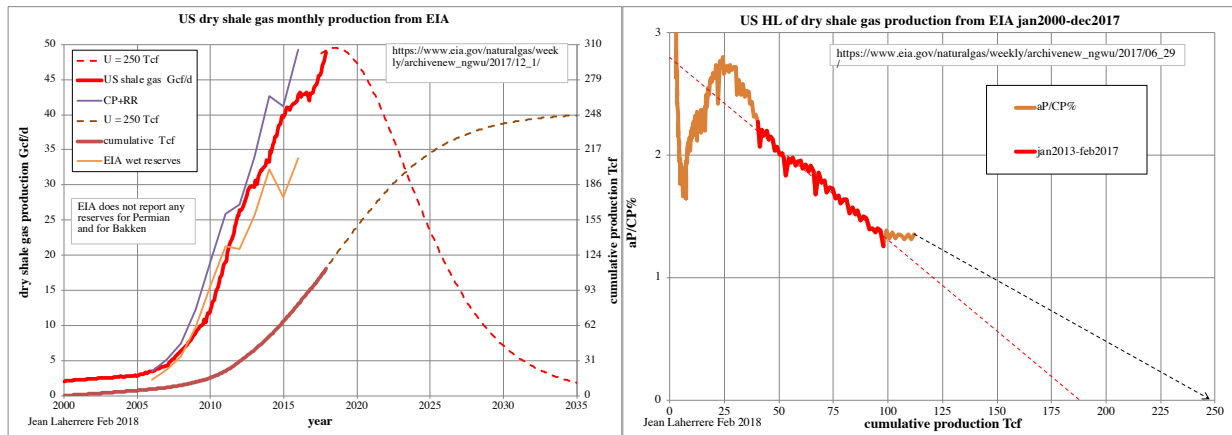
-Shale gas: Utica



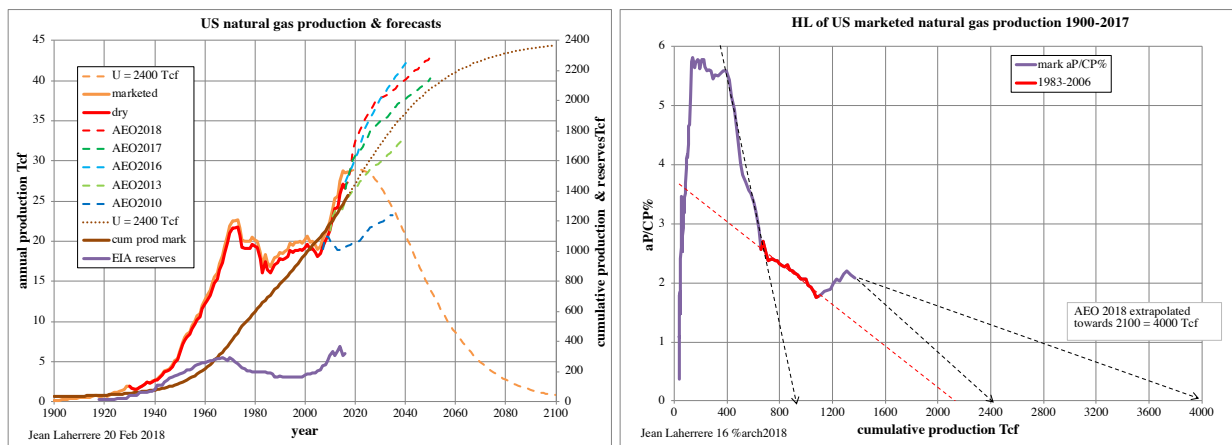
-Shale gas: Woodford



-Shale gas: all US



-Natural gas: US

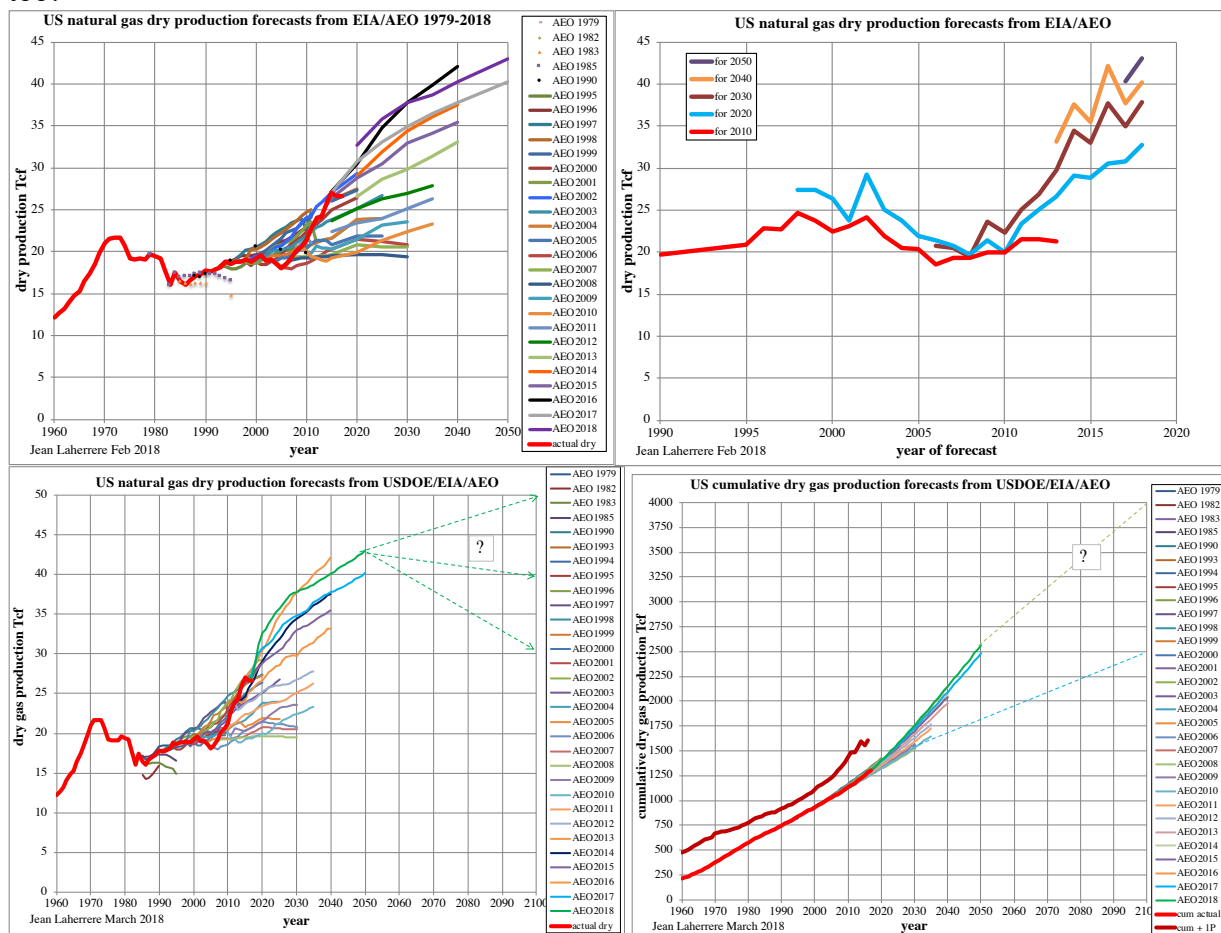


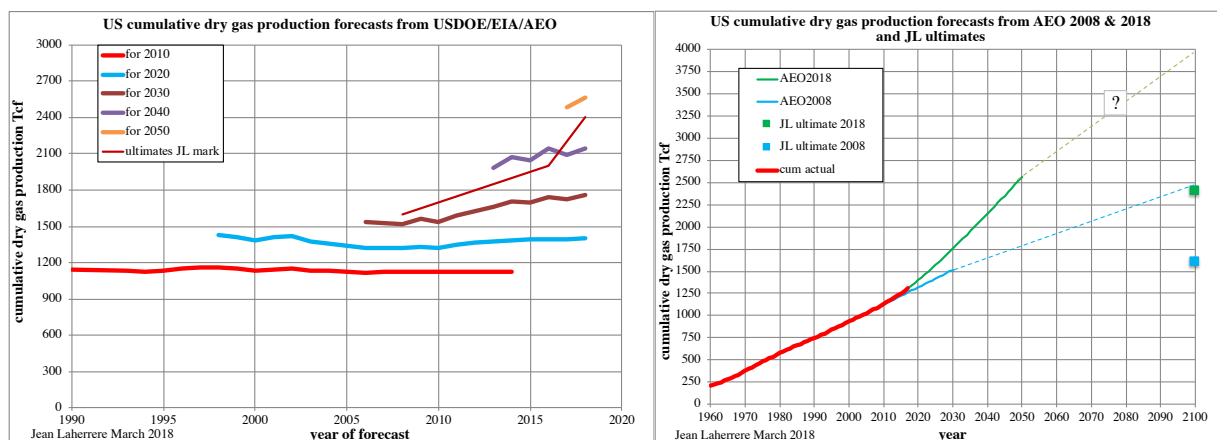
Summary for US shale gas plays

gas play Tcf	ultimate	cum prod 2017	remaining 2017
Barnett	25	18	7
Eagle Ford	15	9	6
Fayetteville	10	8	2
Haynesville	27	15	12
Marcellus	80	31	49
Utica	10	4,5	5,5
Woodford	18	6	12
shale gas	250	110	140
natural gas	2400	1400	1000

-Other forecasts

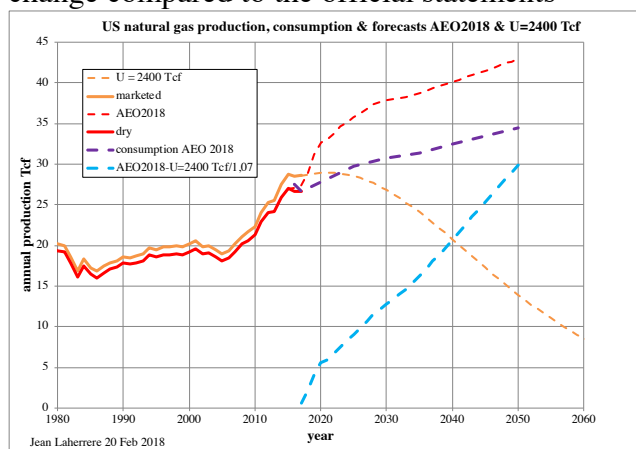
EIA/AEO forecasts from 1979 to 2018 display a huge range of uncertainty or poor practice (often change of the person doing the estimate): it means that the last forecast is likely to be poor too!





My own estimates for the ultimates of total US NG marketed has increased from 1600 Tcf in 2008 to 2400 Tcf in 2018

In contrast, the official EIA/AEO forecast is for dry gas production, which is about 7% less than marketed gas. Our forecast U=2400 Tcf is for marketed gas. The difference of forecasts between AEO 2108 dry gas and U=2400 Tcf/1.07 is 13 Tcf for 2030, 20 Tcf in 2040 and 30 Tcf in 2050; But AEO2018 NG consumption is well below AEO production by about 7 Tcf, but exceeds my forecast after 2023 and in 2050 20 Tcf is missing. The plot of AEO 2018 US NG consumption shows that US in 2050, instead of exporting 8 Tcf, will be forced to import 20 Tcf: quite a change compared to the official statements

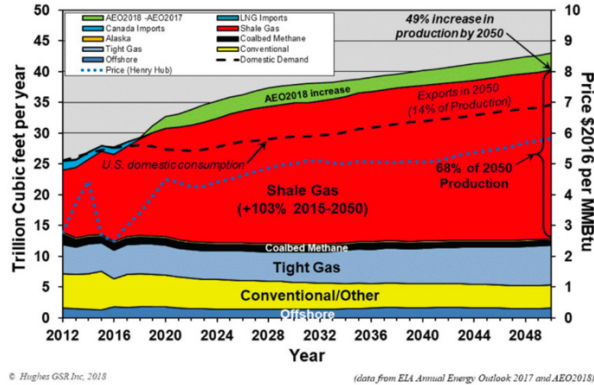


Europe counts on the US shale gas to import LNG, but for that to occur the US must be able to produce more than they consume, which is unlikely

All other analysts beside the US EIA give results that disagree with the EIA estimates, specifically:

David Hughes 2018 displays US NG production 2012-2050 from EIA/AEO 2017 (but not his own forecast) and Art Berman displays US NG monthly production 2000-2017 (production starts at 20 Gcf/d)

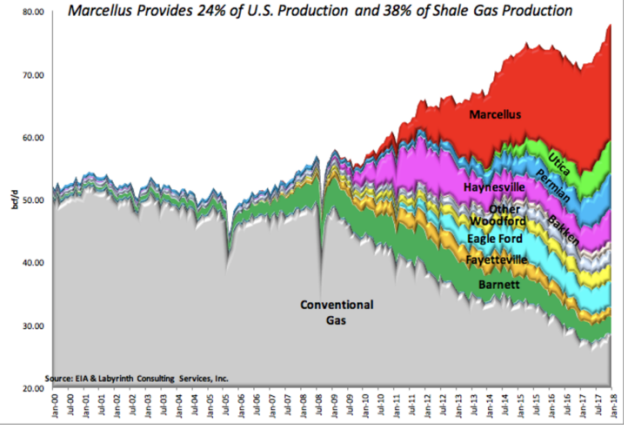
U.S. Natural Gas Supply Projection by Source, 2012-2050, EIA Reference Case AEO2017



© Hughes GSR Inc. 2018

(data from EIA Annual Energy Outlook 2017 and AEO2018)

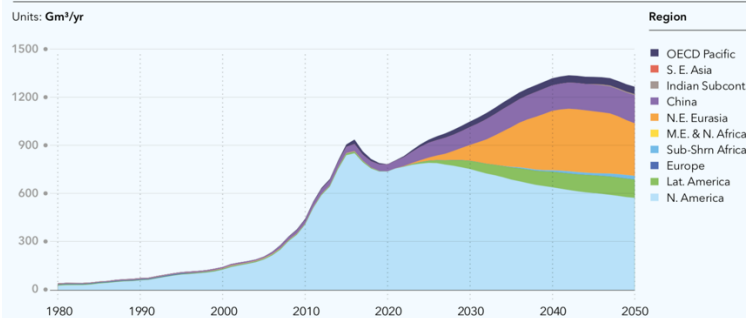
Shale Gas Represents 64% of U.S. Dry Gas Production
Marcellus Provides 24% of U.S. Production and 38% of Shale Gas Production



Source: EIA & Labyrinth Consulting Services, Inc.

DNV GL (Det Norske Veritas Germanischer Lloyd in Norway is assumed to tell the truth!) report “Oil and gas forecast to 2050- Energy Transition outlook 2017” displays a peak of unconventional onshore gas production in 2016 for North America at 880 G.m3 = 31 Tcf

UNCONVENTIONAL ONSHORE GAS PRODUCTION BY REGION (FIG 16)



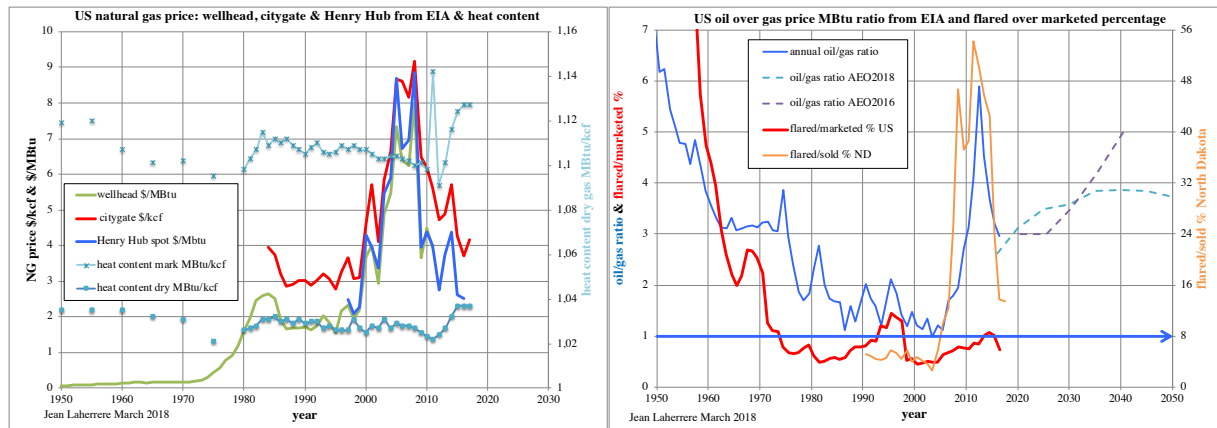
DNV forecasts that North America unconventional onshore gas in 2050 will be 70% of 2016 value (going down), against 160 % (going up) for AEO2018 forecasts for the US unconventional gas (only onshore) as shown in the above graph.

It means that DNV disagrees with the EIA forecasts for US unconventional gas. However DNV adds: unconventional gas will be the primary source for North American LNG exports.

ExxonMobil 2018 outlook forecasts that the North America unconventional gas should be in 2040 150% of its 2016 value, in agreement with AEO 2018

-Gas price, oil/gas price and flaring

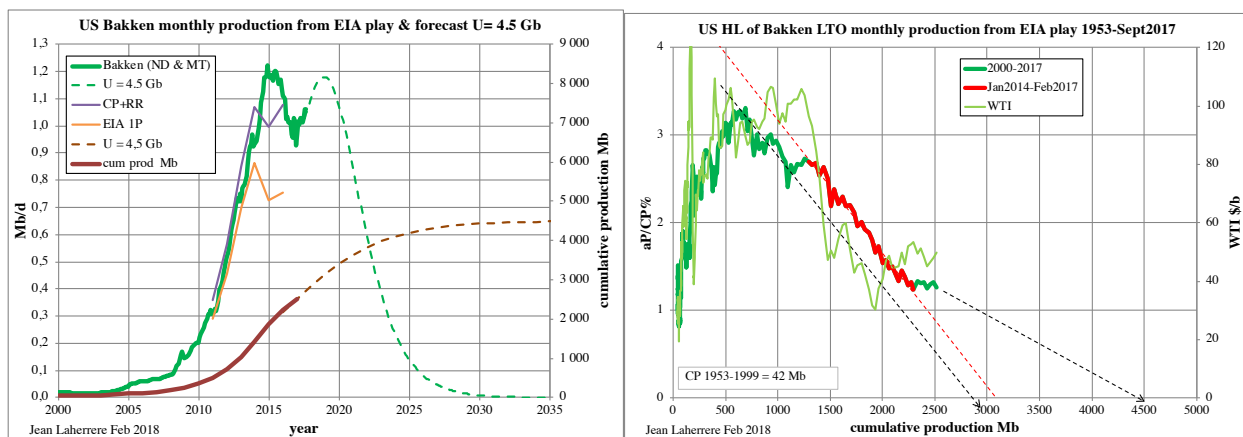
Gas price has sharply peaked in 2005 and 2008 and today back to pre2000 price despite that the heat content has increased.



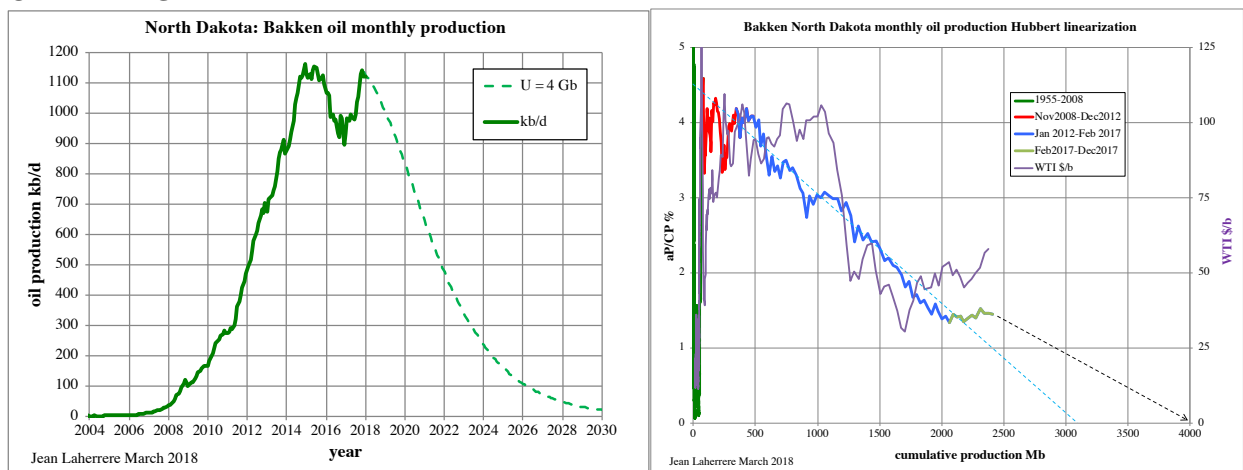
If in Europe some gas contracts are indexed to oil price. The US ratio of oil to gas price per Joule (MBtu) varies largely being over 6 in 1950 decreasing slowly to 1 in 2004, increasing to 6 in 2013 and is presently around 3. EIA forecast that it will increase but stay below 4 in 2050. The problem is that the cost of transporting gas internationally is much higher than transporting oil and when gas is cheap and in excess associated to oil it is flared. The oil over gas price correlates with flared over marketed percentage in the US and since 2004 in North Dakota. I am surprised that the 1950-2005 trend for equality between oil and gas price is not the goal of EIA. I doubt that the future increase of this ratio will occur.

Oil production

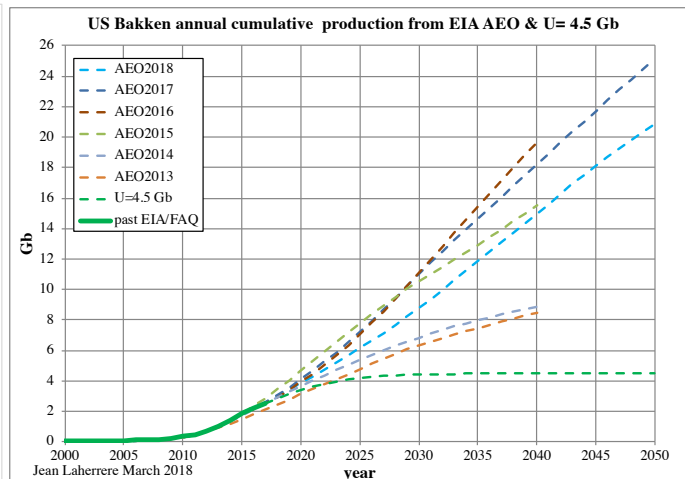
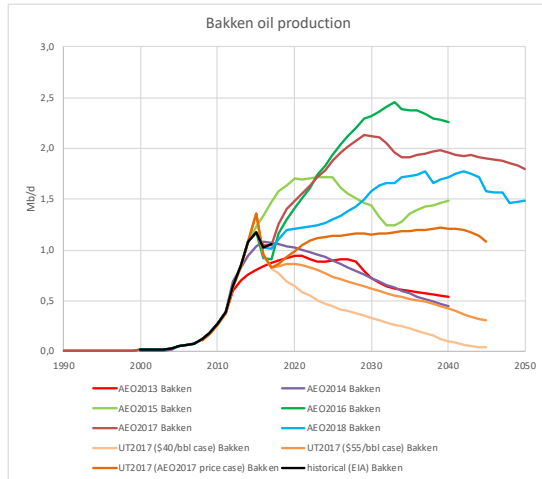
-Tight oil: Bakken North Dakota & Montana



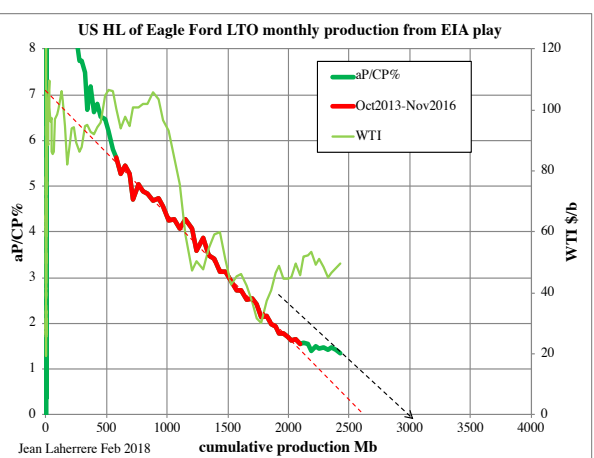
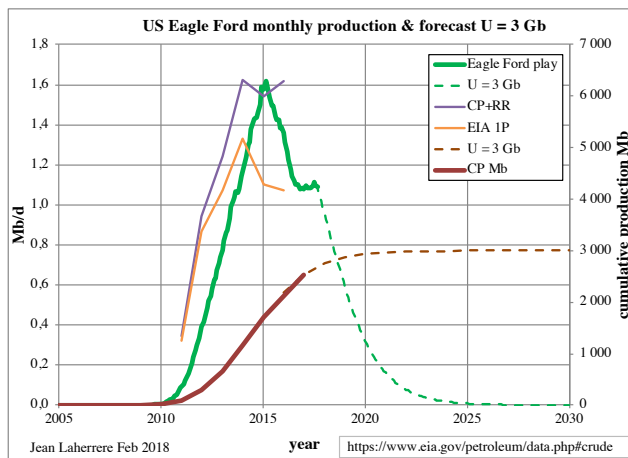
Bakken ND from ND.gov <https://www.dmr.nd.gov/oilgas/stats/historicalbakkenoilstats.pdf>
Ultimate 4 Gb



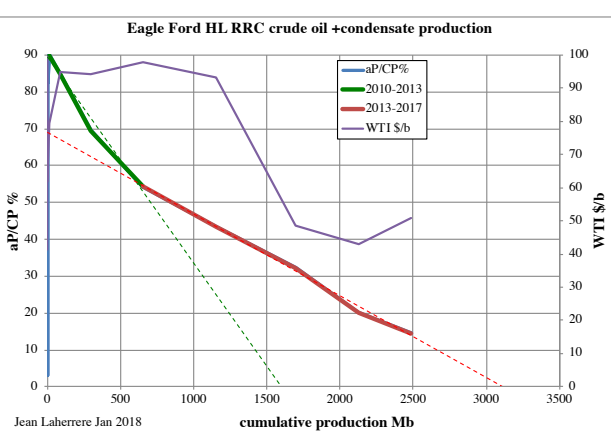
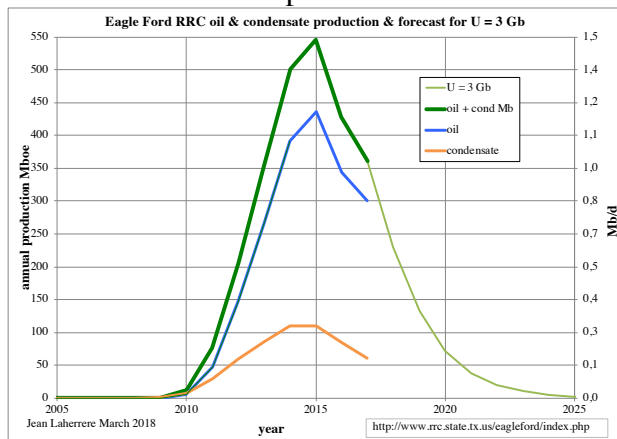
From Mason Inman: AEO 2013 to 2018, and UT2017 forecast



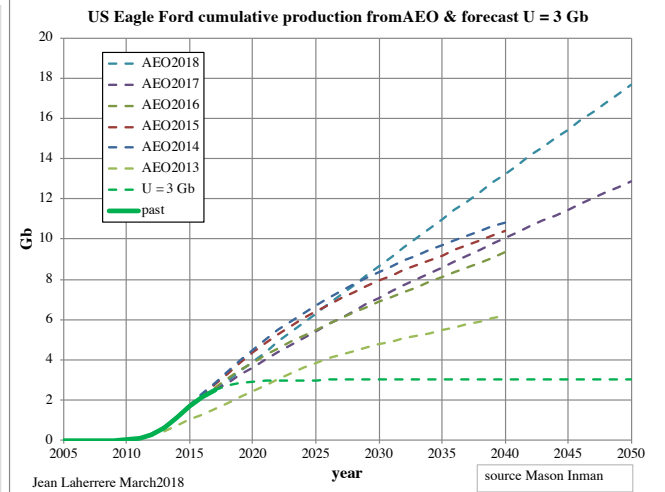
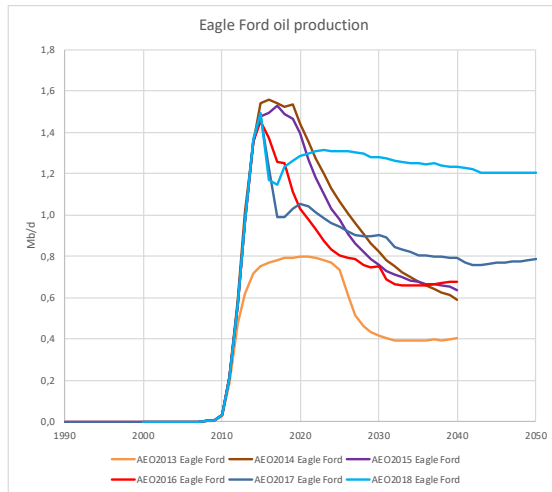
-Tight oil: Eagle Ford



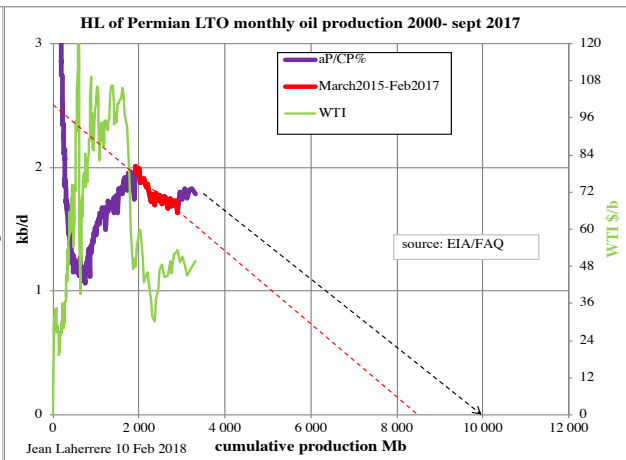
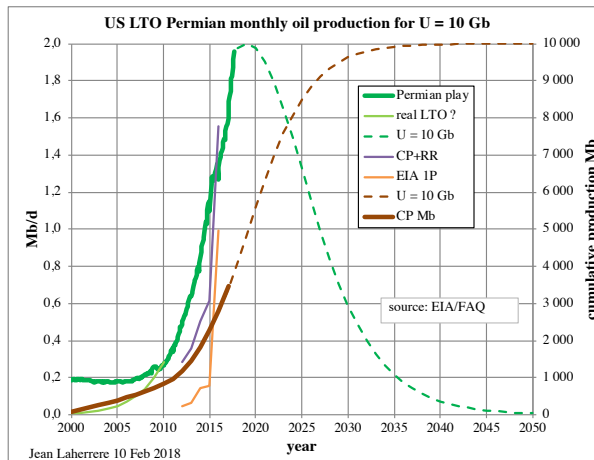
From TxRRC annual production



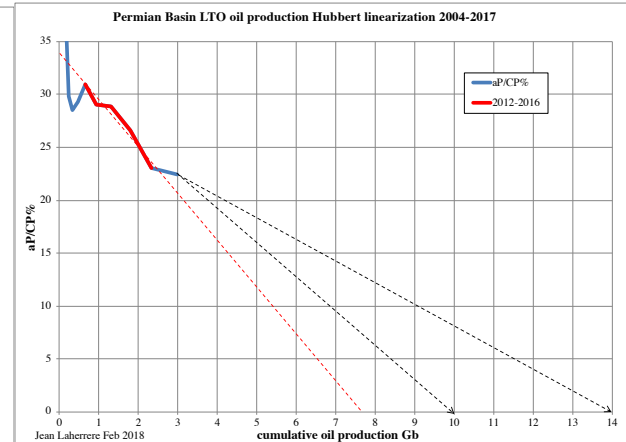
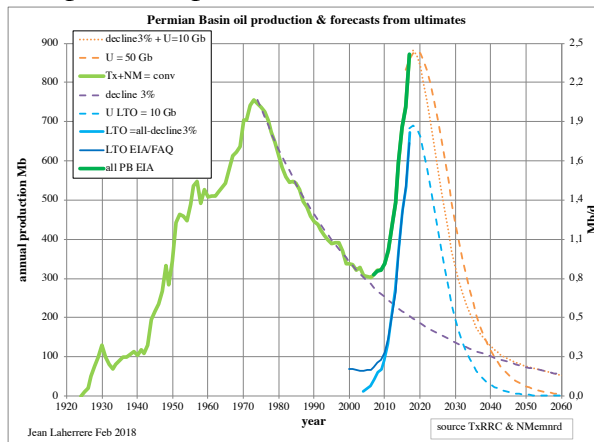
From Mason Inman data: AEO2013 to 2018



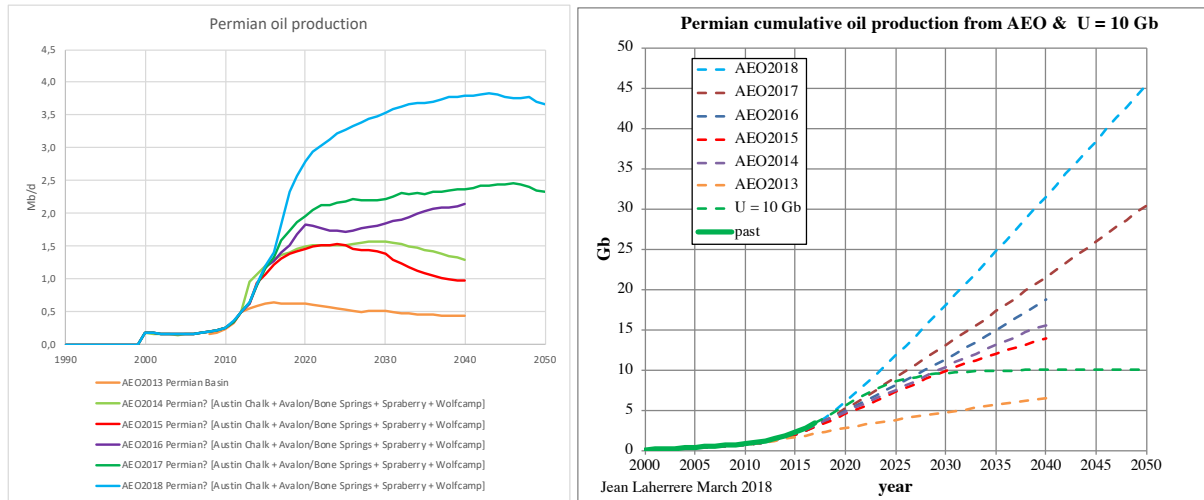
-Tight oil: Permian Basin



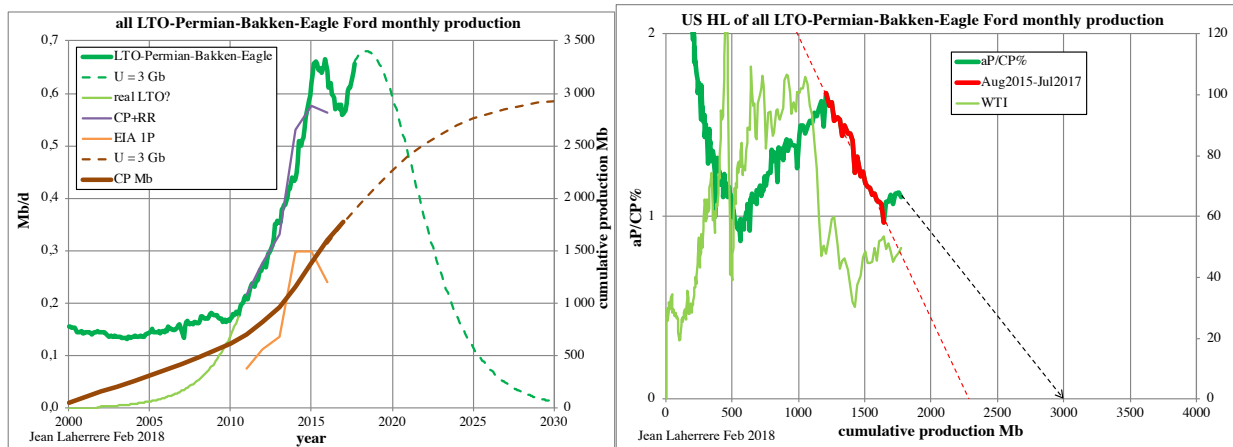
All Permian basin annual production displays a decline since the peak of 1974 which is constant at 3%/a until 2005 before the burst of LTO, this 3% decline is extrapolated down to 2017 and the difference with all oil production is assumed to be the LTO, in agreement with EIA values, except for the period 2005-2010 where the EIA confuses LTO and horizontal wells



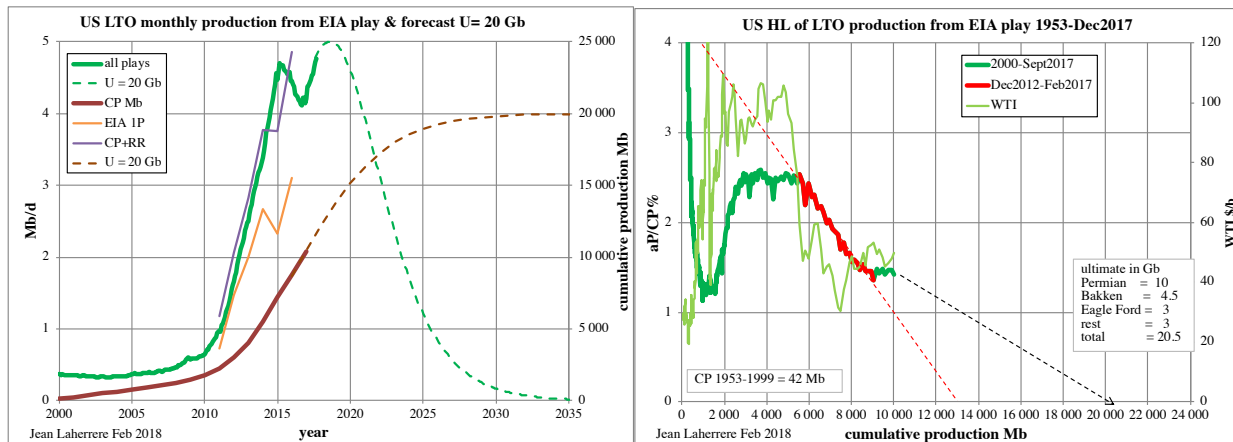
From Mason Inman data: AEO 2013 to 2018



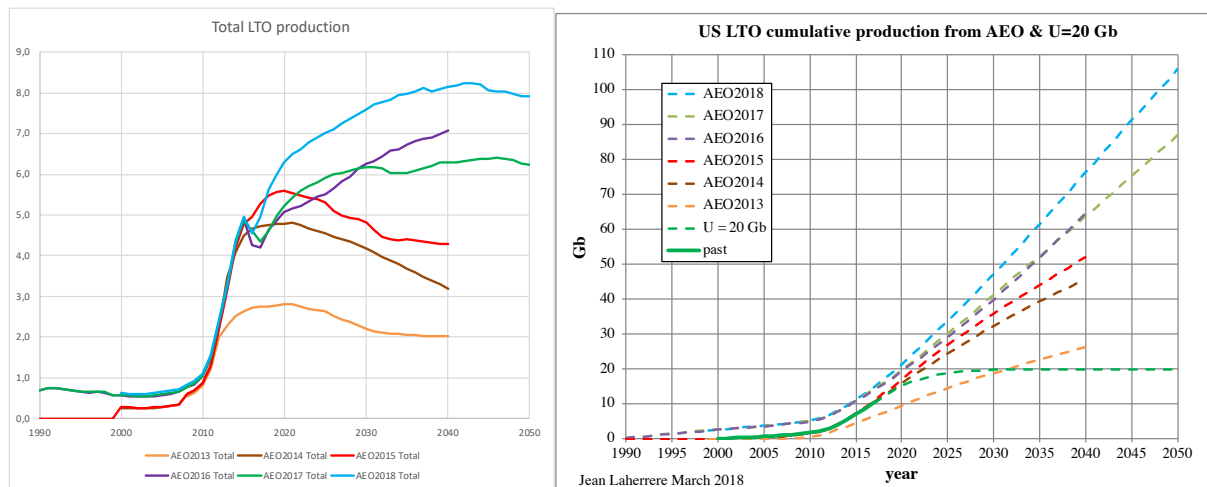
-Tight oil: all less Permian, Bakken & Eagle Ford



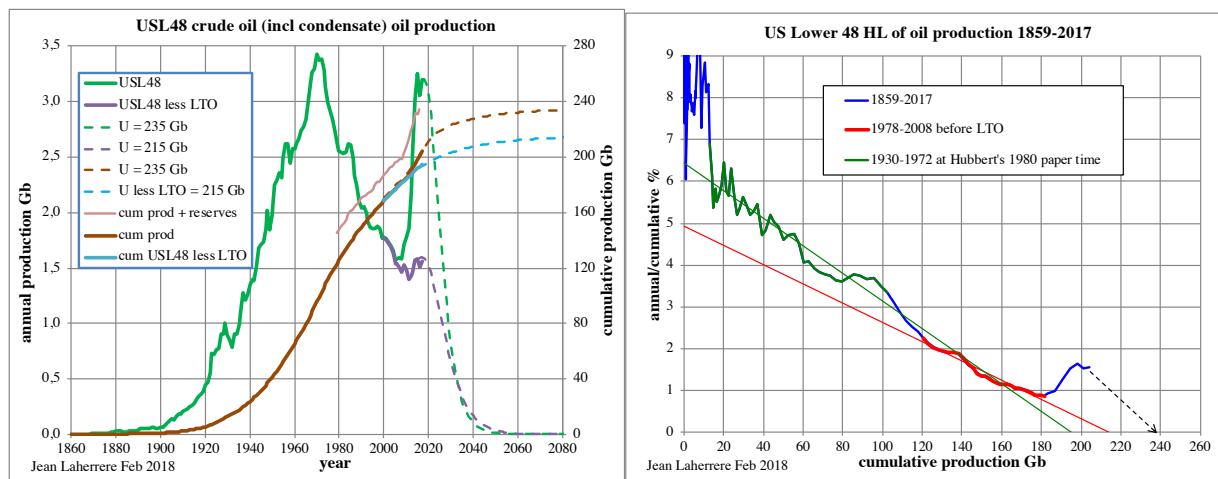
- Tight oil: all US



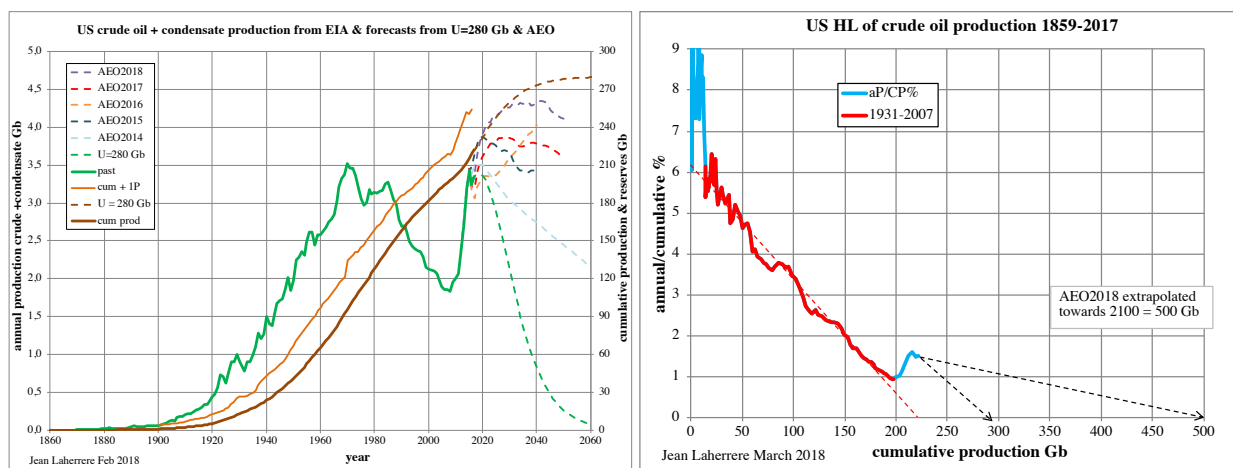
From Mason Inman data: AEO 2013 to 2018



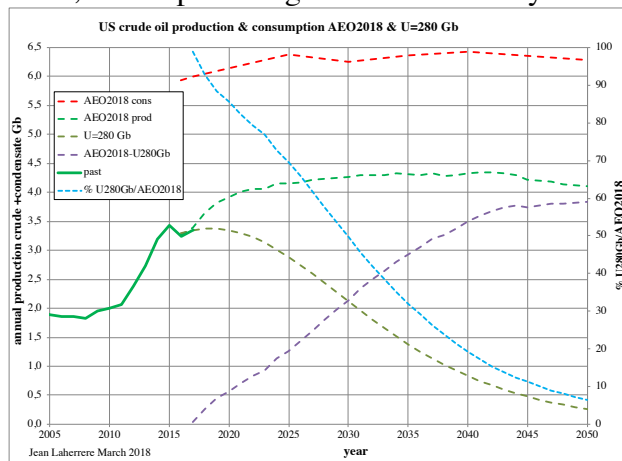
-Crude oil: USL48 without Alaska



-Crude oil: US



The difference between AEO 2018 and my forecast for U = 280 Gb is over 2 Gb in 2030 and 3.8 Gb in 2050. AEO 2018 crude oil consumption is forecasted flat around 6.2 Gb/a from 2016 to 2050; But in percentage of AEO 2018 my forecast is 50% in 2030 but only 6.5 % in 2050



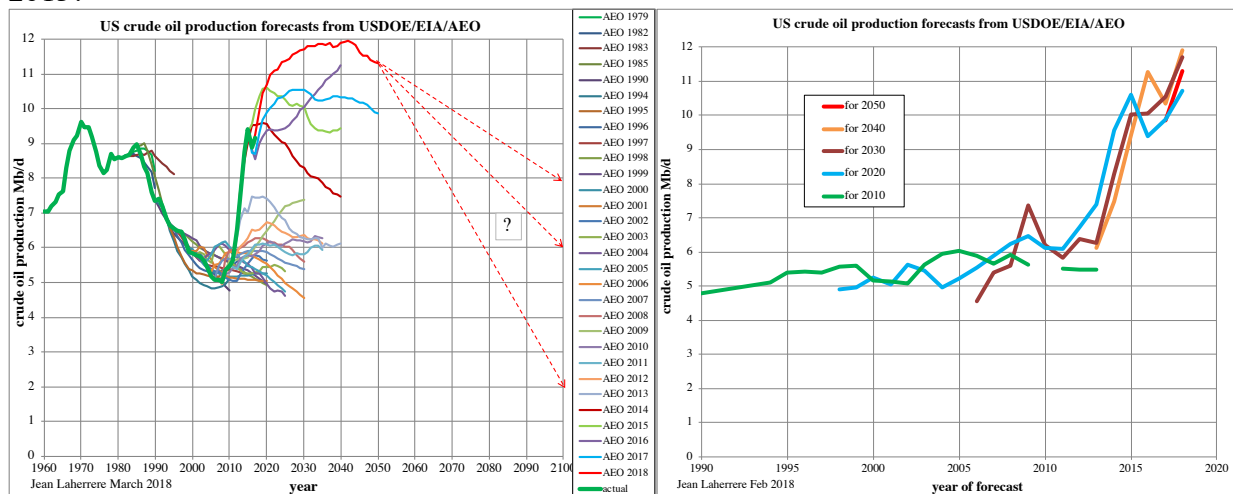
Summary for the oil plays

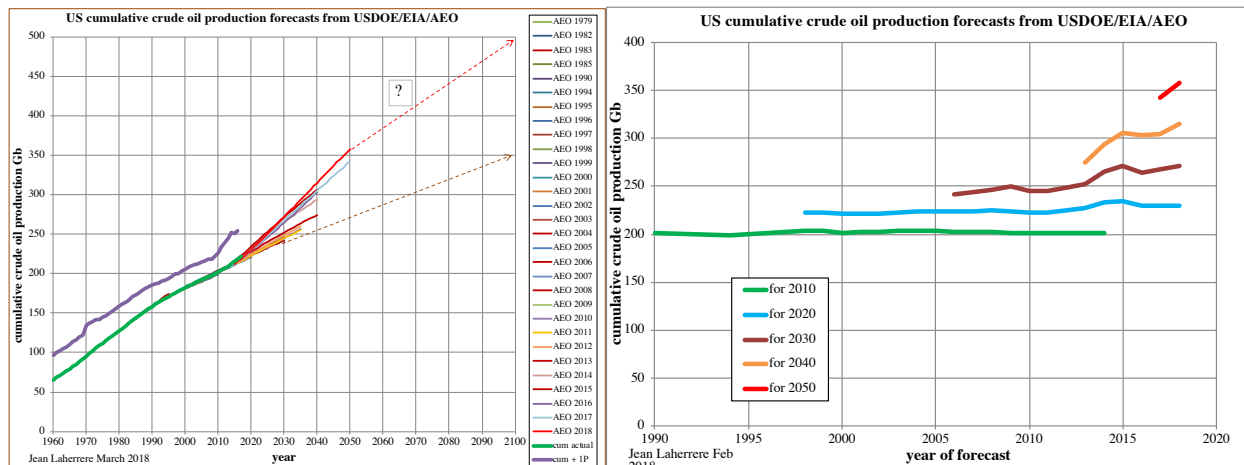
oil play Gb	ultimate	cum prod 2017	remaining 2017
Bakken	4,5	2,5	2,0
Eagle Ford	3	2,5	0,5
Permian	10	3,5	6,5
LTO	20	10,4	9,6
USL48	235	204	31
US	280	222	58

-EIA/AEO forecasts evolution

EIA/AEO forecasts from 1979 to 2018 display a huge and chaotic range of uncertainty: it means that the last forecast is likely to be poor too!

For example AEO 2011 forecasted 6 Mb/d for the US in 2020 when over 9 Mb/d was reached in 2015!





Rystad (a Norwegian data seller) has published a paper on world reserves in 2016.

Laherrere J.H. 2016 « World, US, Saudi Arabia, Russia & UK oil production & reserves -Comments on Rystad 2016 world reserves » August http://aspoFrance.org/files/reservesUS_SA_%20Ru_UK-JL2016.pdf
<https://aspoFrance.org/2016/08/11/world-us-saudi-arabia-russia-uk-oil-production-reserves-august-2016-jean-laherrere/>

Bowden reported in 1982 the US crude oil resources (ultimate?) showing an evolution with time: ultimates less than 200 Gb from 1940 to 1956 (Hubbert in 1956 was using 150 & 200 Gb for USL48), between 150 and 600 Gb (with Zapp's estimate in 1962 = 590 Gb from unrealistic recovery per feet drilled) from 1956 to 1974 and between 200 and 280 Gb from 1974 to 1980: the range was wild and it is still!

424 PACIFIC SOCIOLOGICAL REVIEW / OCTOBER 1982

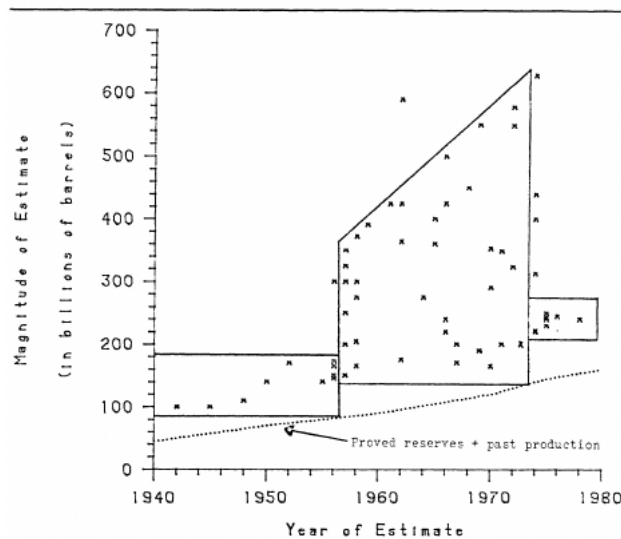
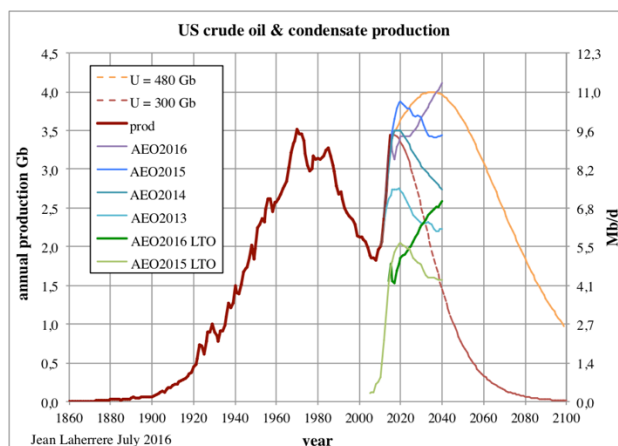


Figure 1: Historical Periods in the Estimation of U.S. Crude Oil Resources

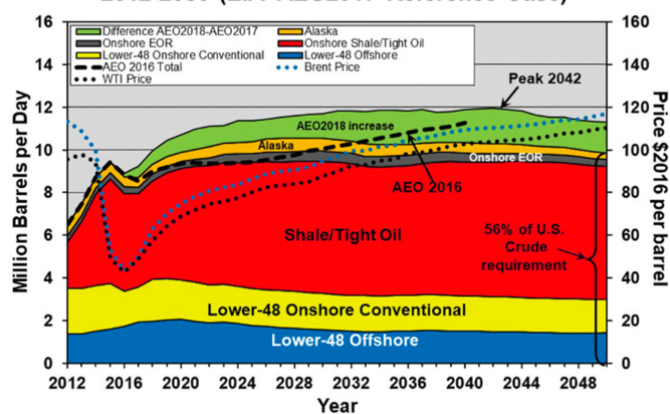
The future US crude oil (+condensate) production is modeled with the likely ultimate of 300 Gb and the unlikely Rystad 480 Gb and the EIA/AEO forecasts from 2013 to 2016. It appears that Rystad ultimate of 480 Gb is related to AEO 2016 forecast of more than 11 Mb/d in 2040. There is a wild change in LTO forecasts between AEO 2015 and AEO 2016



-Other forecasts

David Hughes 2018 displays US crude oil production from AEO2018 peaking in 2042, because of steady tight oil but not his own forecast.

U.S. Crude Oil Price and Production by Source and Region 2012-2050 (EIA AEO2017 Reference Case)



As for unconventional gas, DNV forecasts unconventional onshore oil production for North America, but if for gas Canada production is small compared with the US, it is not the same for oil. CAPP forecasts the oilsands to increase by 1 Mb/d from 2015 to 2030 for Canada, when AEO2018 forecasts an increase of 2 Mb/d for the US, when DNV forecasts an increase of 4 Mb/d for North America: it means that DNV is more optimistic than EIA

UNCONVENTIONAL ONSHORE OIL PRODUCTION BY REGION (FIG 9)

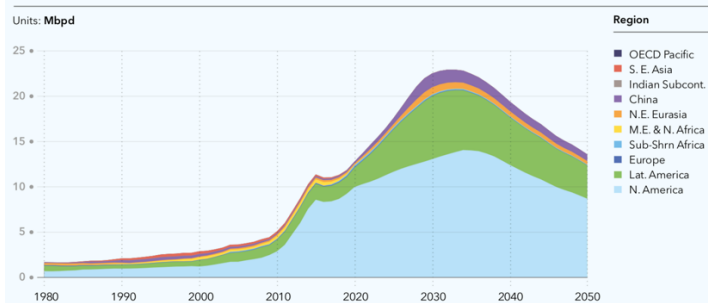
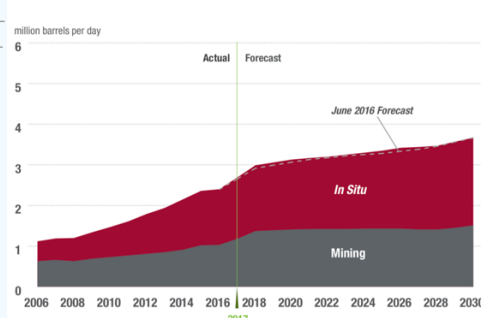


FIGURE 2.5 WESTERN CANADA OIL SANDS PRODUCTION



ExxonMobil Outlook 2018 forecasts that tight oil in 2040 will be 3 times the value of 2016

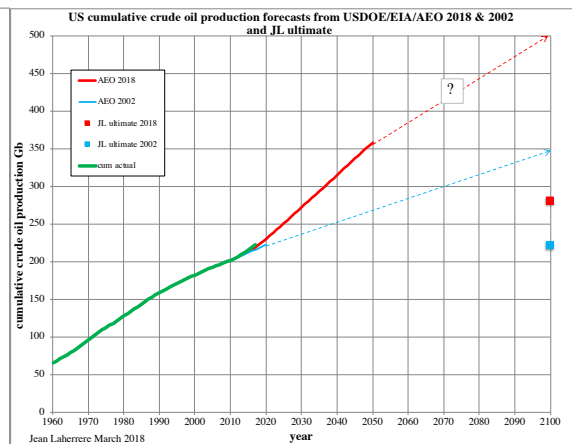
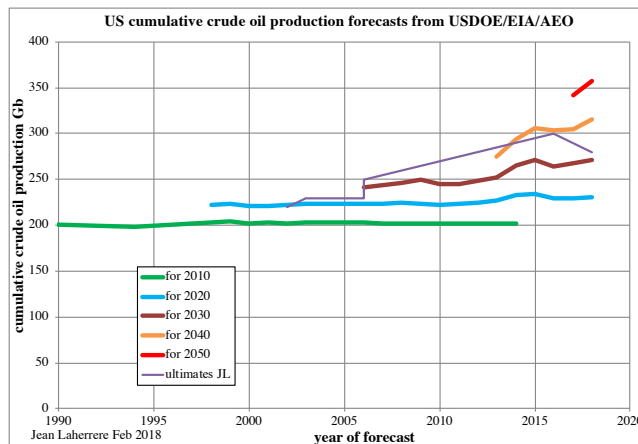
-My forecasts

If the performance of the EIA is not good in forecasting US crude oil production, what about my forecasting?

My modeling of the future is based on the estimate of the ultimates

My estimate of the US crude oil ultimate has changed from 220 to 300 Gb between 2002 and 2018, when the extrapolation of AEO 2002 cumulative production to 2100 (assumed close to ultimate) is 350 Gb and AEO2018 500 Gb. My change is less than EIA

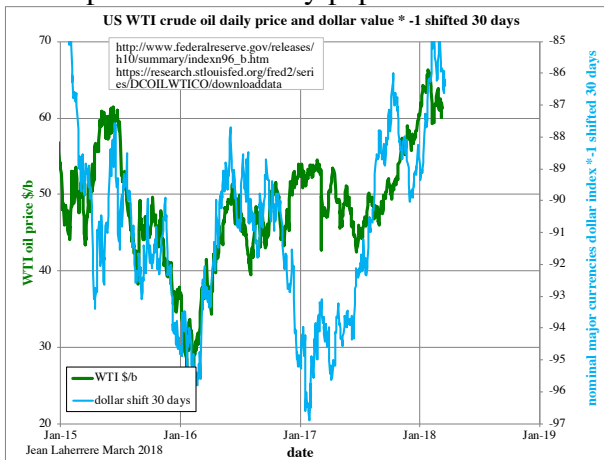
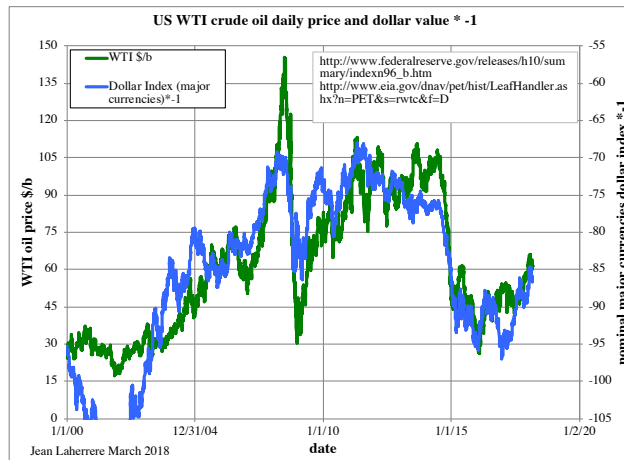
US all			USL48		
site	year forecast	ultimate Gb	site	year forecast	ultimate Gb
Uppsala	2002	220	Enc Energy	2003	200
Enc Energy	2003	230	ENSMP	2004	200
Lisbon	2005	230	MIT	2014	225
Beijing	2006	230		2018	235
Luxembourg	2006	250			
comRystad	2016	300			
	2018	280			



-Oil price and dollar value

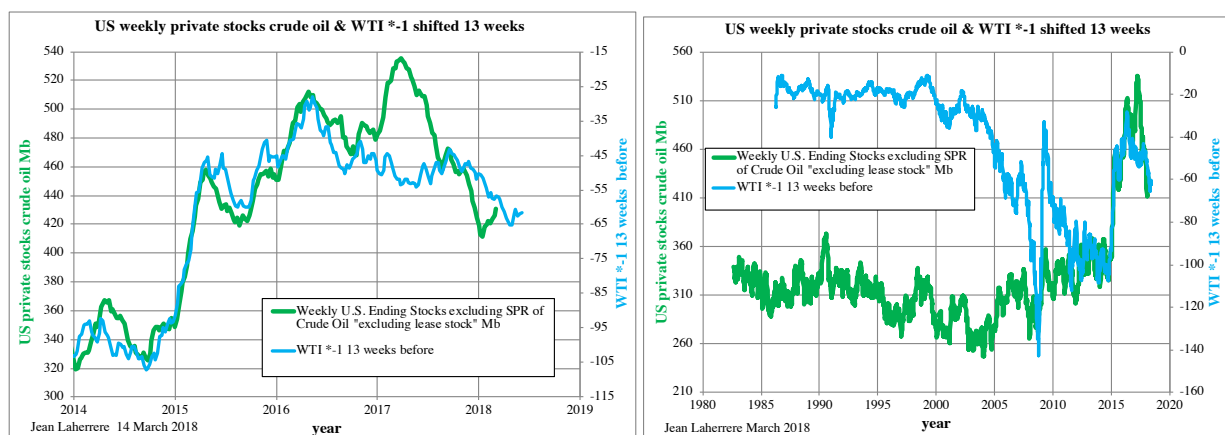
Oil price influences the US oil production, it is then important to know how the oil price changes.

The best correlation for the WTI is the dollar value as I presented in many papers



-US private crude oil stocks and WTI 3 months before

Some believe that the oil price follows the private stocks of crude oil, but since 2014 it appears that the stocks follows the WTI 13 weeks before, except few months in 2017 after the OPEC Russia deal for reducing production



Conclusions

The USDOE/EIA believes that the US oil and gas production will be higher in 2050 (and in every year in between) than in 2017, based on the growth of shale plays coming from the drilling of a huge number of wells. They do so without bothering to check if there is enough room in the sweet spots to do so or if the yield in the non sweet spots is enough to generate that much oil ; we believe the contrary, based on the estimate of the ultimate of shale plays from the Hubbert linearization of past production and on the assumption that in the USL48 many cycles of past production and drilling were symmetrical that the shale plays will also display symmetrical future production curves.

AEO2018 forecasts US production in 2040 for oil at 12 Mb/d, my forecast is 4 times less at 3 Mb/d, for gas at 40 Tcf, my forecast is half at 20 Tcf. It is not a small difference, but a huge one. I can be wrong, but EIA has to prove that their future drilling is possible economically and geologically, but up to now I cannot find any view from EIA on this problem.

The EIA has also to estimate the ultimate of each play, but, in order to do so, they have to reject the stupid rule of the SEC (to please the bankers) forbidding the reporting of 2P (proved + probable) reserves. The EIA has to recognize the fact reported by the SPE/PRMS that the aggregation of proved (1P) reserves is incorrect, only the addition of 2P is correct. (Laherrère J.H. 2008 «Advice from an old geologist-geophysicist on how to understand Nature» presentation Statoil Oslo 14 August http://aspo-france.viabloga.com/files/JL_Statoil08_long.pdf)

USDOE/EIA should report the 2P US reserves like the USDO/BOEM for the reserves of the Gulf of Mexico. Reporting 2P and backdating discovery allows to estimate ultimate using creaming curve.

EIA once reported as an open file backdated established reserves with USDOE/EIA-0534 1990 "US oil and gas reserves by year of field discovery» Aug: it was supposed to be the first of a series, but in fact later it was censured and never updated. It is time to restart such good practice. Exxon and Total 10 years ago were reporting proved and non-proved reserves (2P), but today they report only 1P to follow the SEC rule. Today only Gazprom is reporting 1P and 2P, as also their queer ABC1.

All scouting agencies report the confidential 2P reserves used internally by the operators to decide the development of their fields.