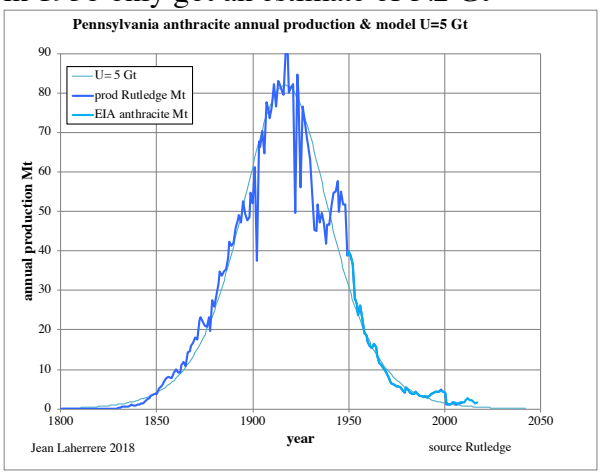
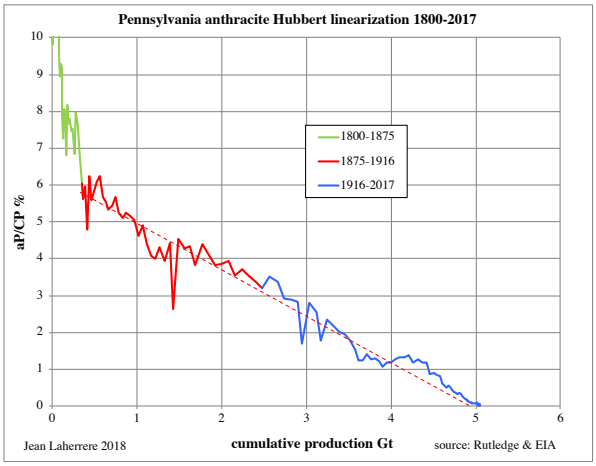
Jean Laherrere 21 May 2018

US, Canada & Mexico oil & gas production, consumption & net import

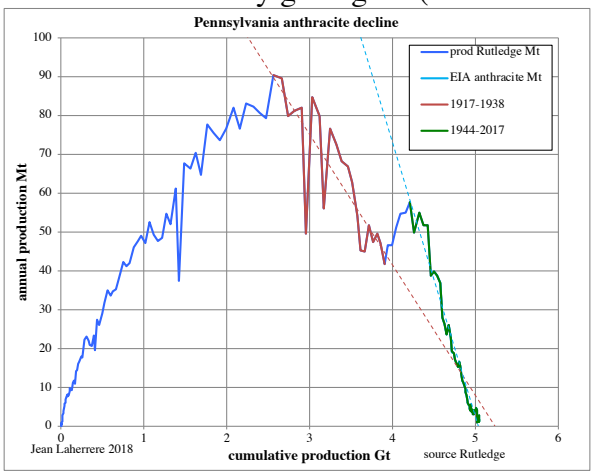
The detail of the forecasts for US and Canada can be found in the two papers:
-Laherrere J.H. 2018 "Forecasts for US oil and gas production" March
https://aspofrance.files.wordpress.com/2018/03/lahall19march.pdf
-Laherrere J.H. 2018 "Forecasts for Canada oil and gas production" May
https://aspofrance.files.wordpress.com/2018/05/canada2018.pdf

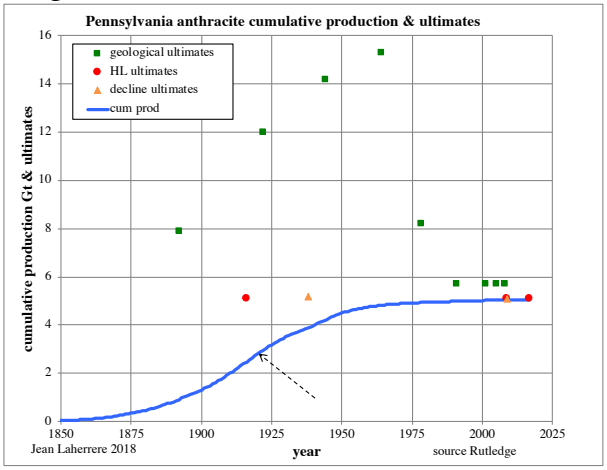
The base of our ultimate estimate is the "Hubbert linearization" (HL, which is the plot of past annual production/cumulative production percentage versus the cumulative production). This approach, originally derived from Hubbert (1982) allows one to get a good value of the EUR (estimated ultimate recovery) (written U in my graphs) even before the peak in production. The best test for the HL is on resources which exploitation is already completed or nearly so. One of the best example is the production of anthracite coal in Pennsylvania (1800-2017), which peaked in 1917. The HL method could have predicted an EUR of 5 Gt, as early as about 1885, well before the peak. 5 Gt is the real value, when the extrapolation of the decline in 1938 only got an estimate of 5.2 Gt



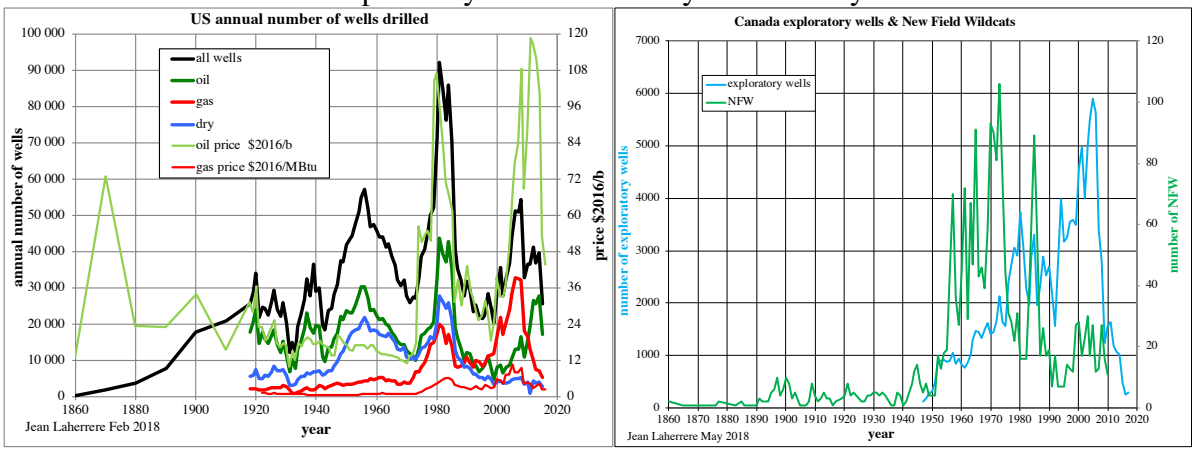


The extrapolation of HL appears to be far more accurate than the extrapolation of the oil production decline curve (which can give an estimate only after the peak) and much better than the estimates by geologists (three times wrong in 1964)

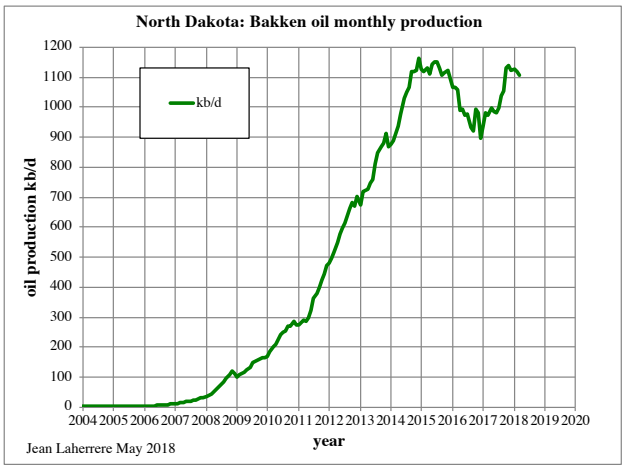




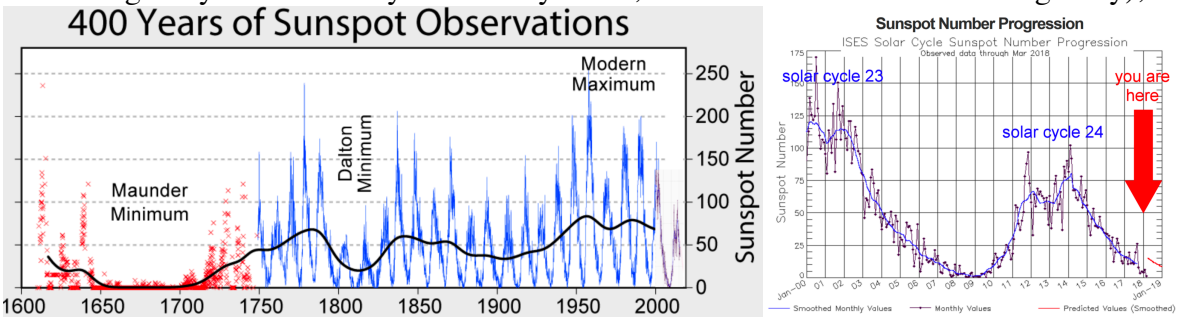
Pennsylvania anthracite production is a single cycle, but many production curves are more complex with several cycles. For example, the annual number of wells drilled in the US shows several cycles of different widths (i.e. length over time), which are almost symmetrical. The down side of each cycle is similar to the previous increase.
It is similar for Canadian exploratory wells: several symmetrical cycles.



The slope of the decline of Bakken production in North Dakota in 2016 is similar to the slope of the increase in 2014.

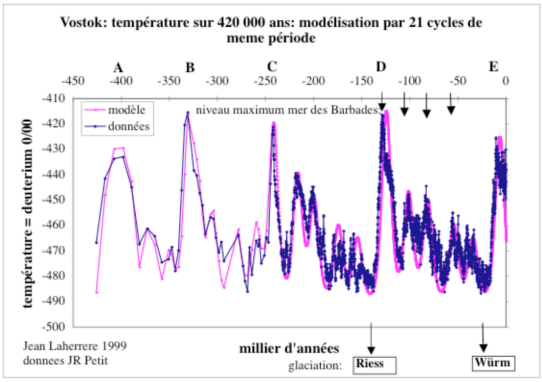


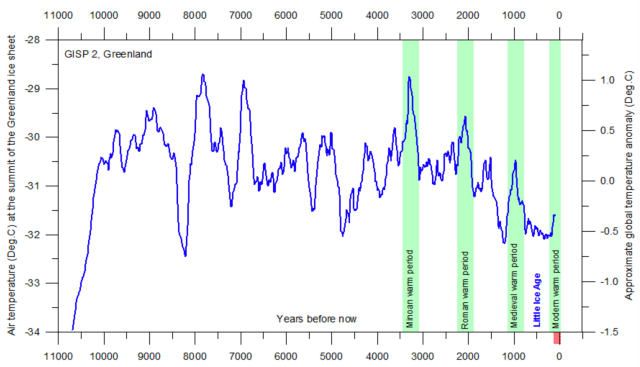
Life on Earth is cycles; life comes from the Sun and most cycles are astronomical: day, year, solar magnetic activity cycle (we are in cycle 24 starting in 2008, ending soon, as we are close to the minimum) of around 11 years (likely due to the influence of Jupiter and Saturn on the center of gravity of the solar system = barycenter, as the Sun is not the center of gravity),



less precise cycles of 65 years, 1000 years and Milankovitch cycles 23 000 years (precession), 41 000 years (tilt) and 100 000 years (eccentricity)) as seen on the cores of Vostok that I modelled in 1999 (see my 2007 paper "Thoughts of a geologist-geophysicist on climate change and energy forecast" FIG Saint Dié - 6 October 2007 http://tinyurl.com/9m23p3)

The last interglacial period, which started 11 000 years ago (the previous one 130 000 years ago was shorter) displayed on GISP2 Greenland core several peaks = warm periods as the medieval, Roman and Minoan ones (see the climate4you graph).

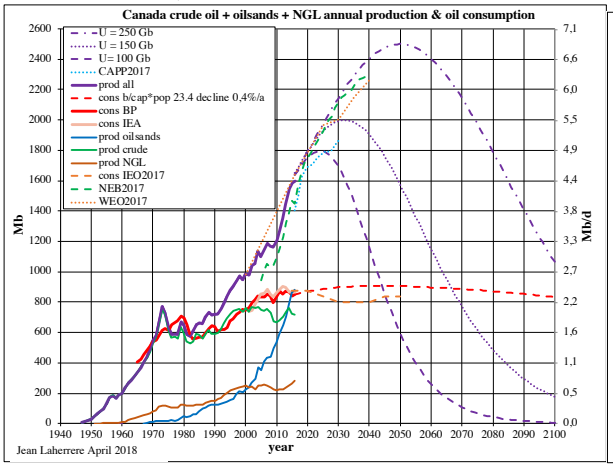


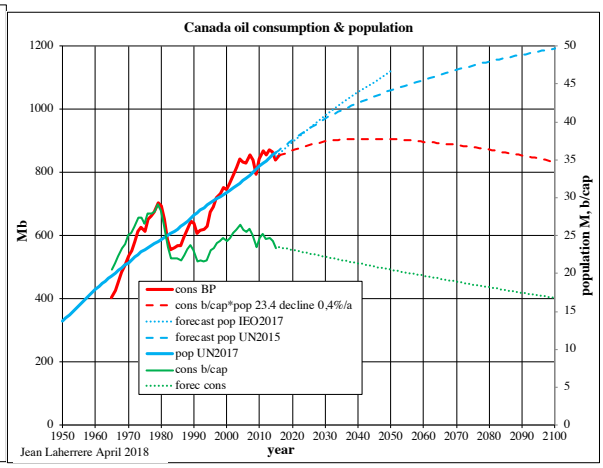


In the Bible, the Pharaoh dreams of seven years of fat cows followed by seven years of thin cows.
Life is cycles and oil production displays several cycles

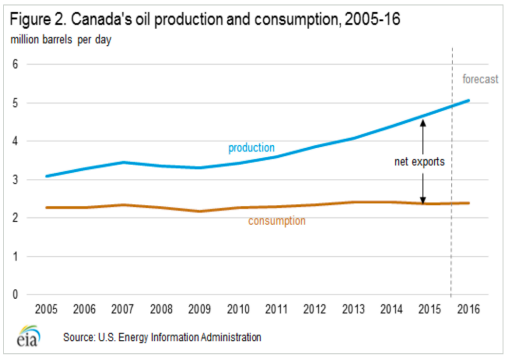
-Canada Oil

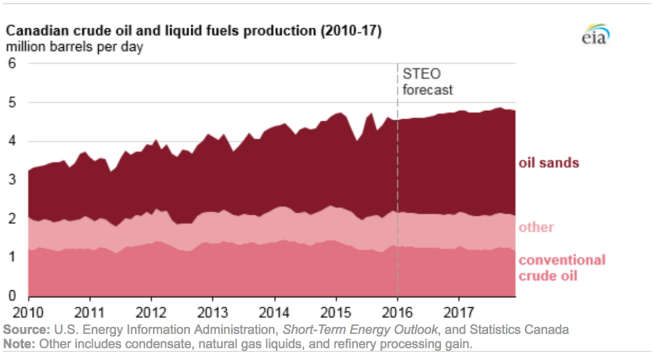
The production of conventional oil in Canada shows an "undulating plateau" since about 2005, but production of extra-heavy oil (bitumen) from "tar sands" has continued to increase, allowing continued exports.
The forecast shows Canada oil consumption surpassing oil production around 2045 for EUR = U =100 Gb, 2065 for U = 150 Gb and after 2100 for U = 250 Gb.





My forecast for oil consumption is based on the UN2015 medium fertility population forecast (EIA population forecast is higher, since it is a linear extrapolation), and a consumption per capita decreasing by 0.4% per year from 2017.





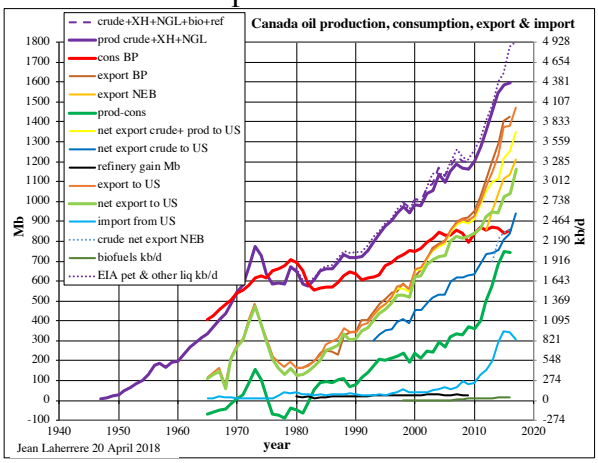
EIA Figure 2 looks too optimistic for 2016 compared to the next EIA graph: EIA presents recent data as measures when they are still estimates.

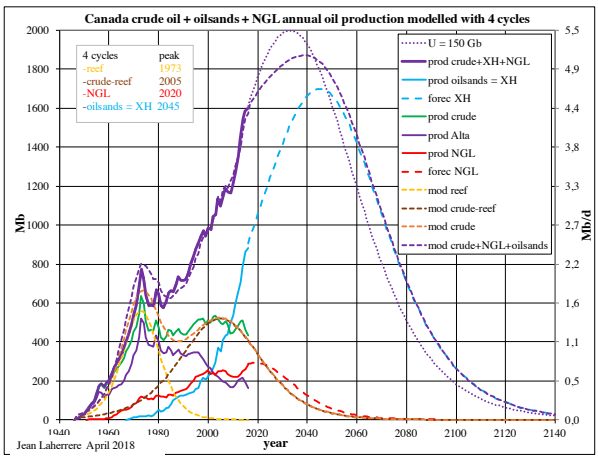
EIA petroleum and other liquids production

https://www.eia.gov/beta/international/data/browser/#/?pa=000001g00006&c=0000001&ct=0&tl_id=79-A&vs=INTL.81-1-CAN-TBPD.A&cy=2000&vo=0&v=H&end=2016

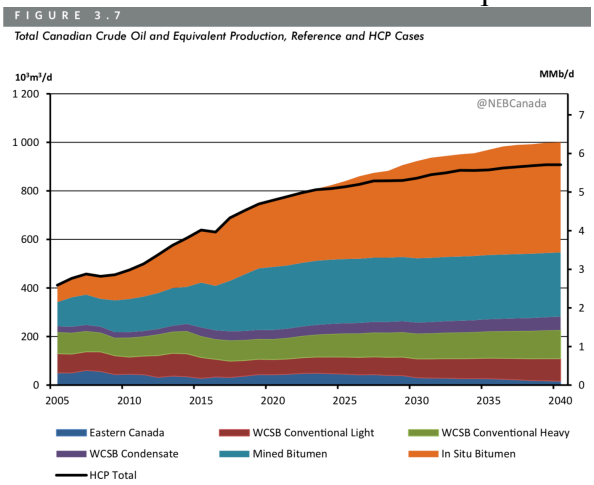
reports for 2016 4.87 Mb/d, when CAPP (Canadian Association of Petroleum Producers) reports on Table 3-7 all liquids production (crude + oilsands + NGL) at 4.38 Mb/d: why is there such difference of about 500 kb/d? It could not be explained by refinery gain (75 kb/d in 2009= last data reported by EIA) or biofuels = 38 kb/d in 2016 (30 bioethanol and 8 biodiesel)

The 1940-2100 all liquids for an EUR of 150 Gb can be modelled with 4 cycles: the first one is the reef play in Alberta with a peak in 1973, the second is crude less reef with a peak in 2005, the third is NGL with a peak in 2020 and the fourth is oilsands = extra heavy = Athabasca with a peak in 2045





The NEB forecast for crude oil and equivalent (all liquids) sees the global peak beyond 2040 .



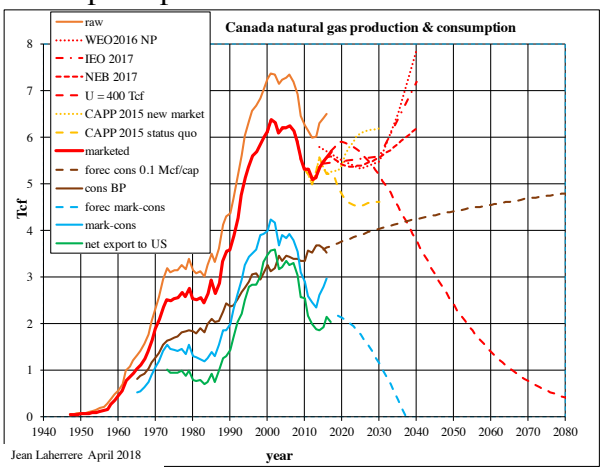
The future of Canadian conventional oil production appears stable for some considerable time. In addition, depending on economics and policy, there may be considerable future production of extra heavy oil. For the immediate future production will be far more dependent upon environmental and other policies than on supply.

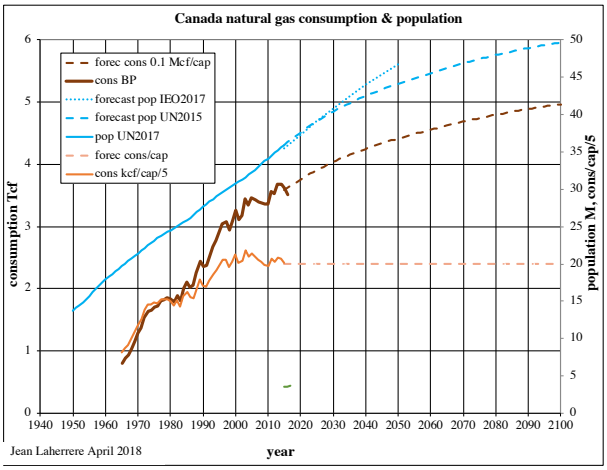
-Canada NG

Canada NG marketed production increased dramatically from 1950 to 2000, peaked in 2001 at 6.4 Tcf, declined to a low of 5.1 Tcf in 2012 and increased to 5.7 Tcf in 2017: it is likely to peak in 2019 at 5.9 Tcf (assuming an EUR of 400 Tcf: see my "Forecasts for Canada oil and gas production"), going down to 3.8 Tcf in 2040 against a forecast of 7.2 Tcf for EIA/IEO 2017, almost double!

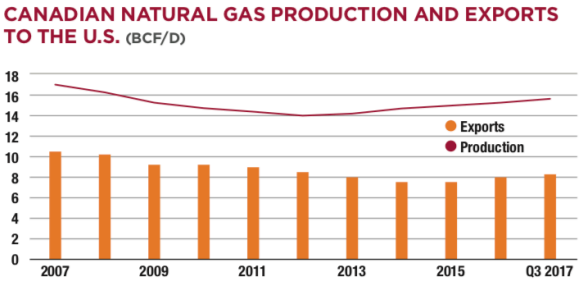
Canada NG consumption forecast will cut production forecast before 2040, leaving no room for net export after 2040. NG consumption per capita is assumed flat from 2000 to 2100 at about 100 kcf/cap.

Net exports peaked in 2002 at 2.2 Tcf.





CAPP https://www.capp.ca/publications-and-statistics/publications/315990 displays only a small part of production and exports.



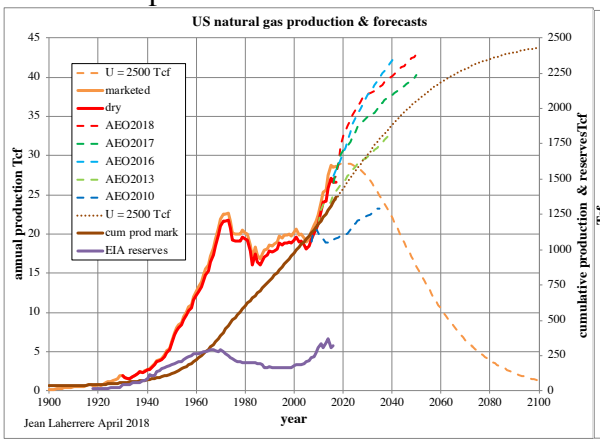
-US NG

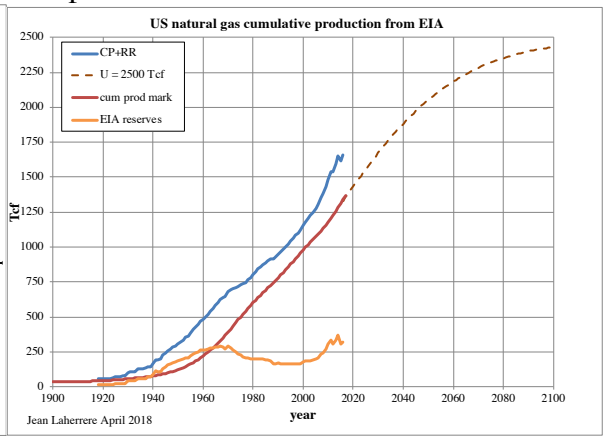
Conventional natural gas production in the United States peaked in 1973 and declined, but then stabilized until 2007, although conventional gas continues to decline through today. But in 2007 unconventional (fracked) gas first replaced and then more than replaced conventional gas so that today total gas production in 2018 is about 50 percent greater than the previous peak in 1973. As a consequence of the availability and low price of gas and the concerns about CO2 release (about twice per unit of energy compared to natural gas) and its apparent relation to climate change, much of the coal-generated electricity for the United States has been replaced with gas. Thus, a continued large availability of gas is critical for the United States, at least if we are not to re-expand coal.

The details of US gas production are given in my paper: "Forecasts for US oil and gas production" (reference above)

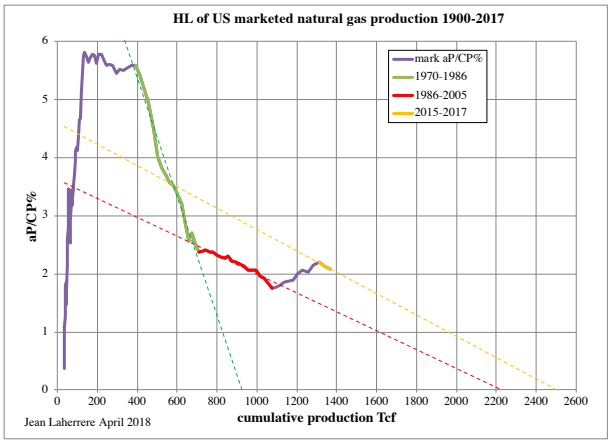
US NG marketed production peaked in 1973 at 22.6 Tcf , down to 16.9 Tcf in 1983 and up to 28.8 Tcf in 2015 (28.6 in 2017) it will stay on a bumpy plateau up to 2022 and decline further using an EUR of 2500 Tcf (much higher than the 1660 Tcf of cumulative production plus remaining proven reserves). There is no historical series to justify any reliable estimate of proven reserves for shale or tight gas.

The HL of past marketed production trends towards 900 Tcf for the period 1970-1986, 2200 Tcf for the period 1986-2005 and 2500 Tcf for the period 2015-2017

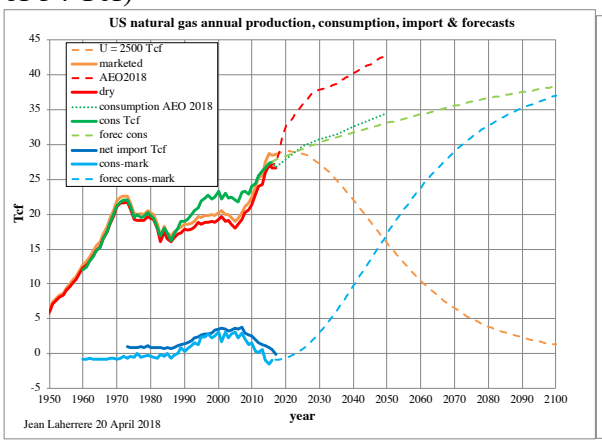


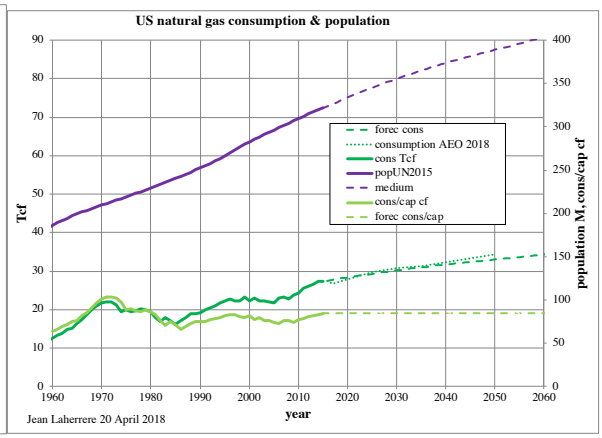


My EUR of 2500 Tcf is higher than the cumulative production + proven reserves at end 2016 which is less than 1700 Tcf

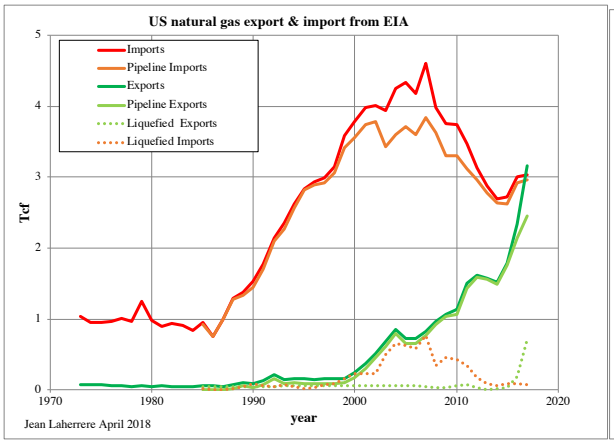


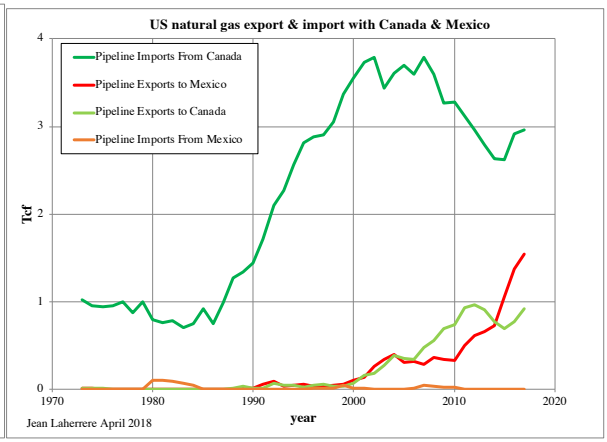
My forecast (EUR = U= 2500 Tcf) for US NG production in 2050 is 15 Tcf against 43 Tcf for AEO2018: a huge difference!
US NG consumption per capita is around 80 cf/cap since 1980 and extrapolation using UN2015 population forecast leads to a NG consumption of 33 Tcf in 2050 (close to AEO2018 of 34 Tcf)



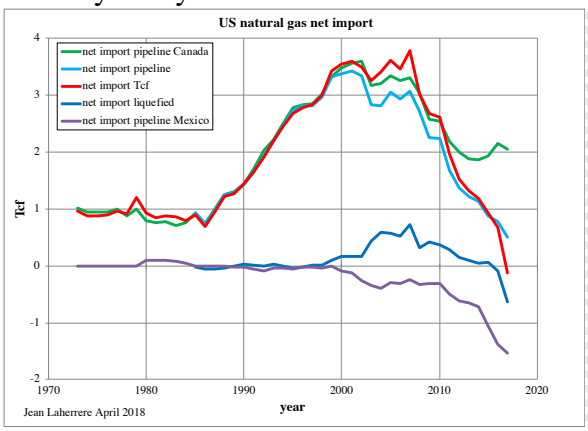


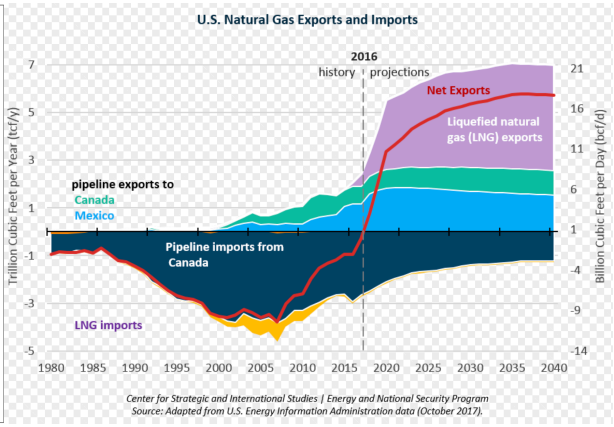
The past net import curve fits with the consumption less marketed production: it peaked around 2000 at 3 Tcf, down to zero in 2016, but it will resume its climb reaching 17 Tcf in 2050, against a negative value of 18 Tcf for AEO2018: it means that for 2050, EIA forecasts NG production higher than consumption by 18 Tcf when I see NG production lower than consumption by 17 Tcf. It is obvious that EIA is too optimistic (both on production and on consumption) and by reaction that I am too pessimistic.
It is likely that reality will be in between and in 2050 NG consumption will be lower than production, meaning positive net imports.
NG imports (mainly pipelines) peaked in 2008 at 4.5 Tcf (mainly from Canada), declining to 3 Tcf in 2016
NG exports, close to zero before 2000, have increased to 3 Tcf in 2016 (mainly to Mexico)
Net NG import was 1 Tcf from 1973 to 1987, peaked at 3,5 Tcf between 2000 and 2007, and down to zero in 2017.





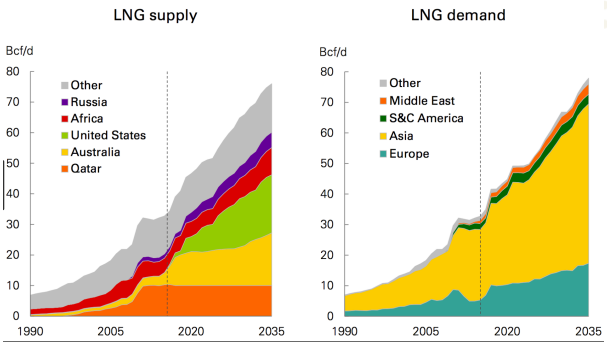
CSIS ("U.S. Natural Gas in the Global Economy" Oct 2017 Sieminski) displays EIA2017 forecasts https://www.eia.gov/todayinenergy/detail.php?id=30052 of US NG exports and imports, contrary to my forecasts.



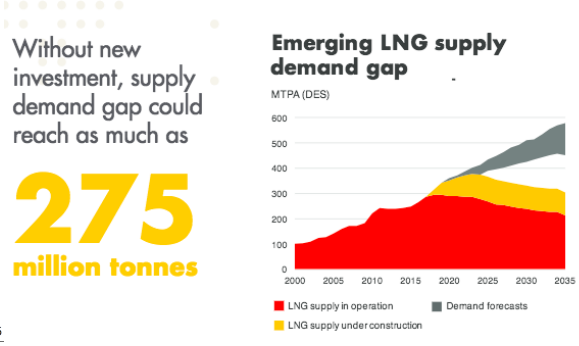


"Global impact of US LNG" by NGW magazine 2017 forecasts US LNG supply at 20 Gcf/a = 7.3 Tcf in 2035 against 4 Tcf for EIA (present capacity of the US LNG is 4 Gcf/a)
Shell outlook 2018 forecasts a large LNG supply gap in 2035

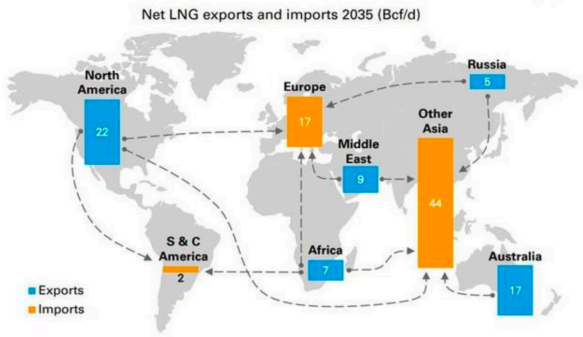
NGW magazine

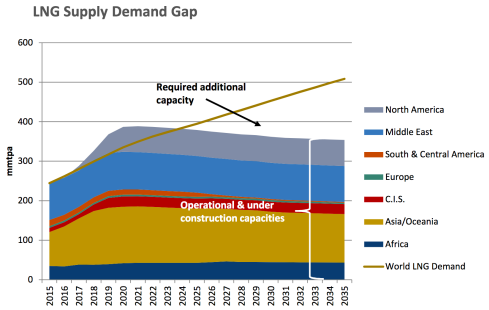


Shell 2018 outlook



In 2035, according to BP 2017, North America LNG exports will be the largest source, higher than Australia exports and Europe LNG imports.
Cedigaz outlook 2017 forecasts for 2035 a large gap in LNG supply demand, and contrary to BP, North America LNG for 2035 is lower than ME or Asia.

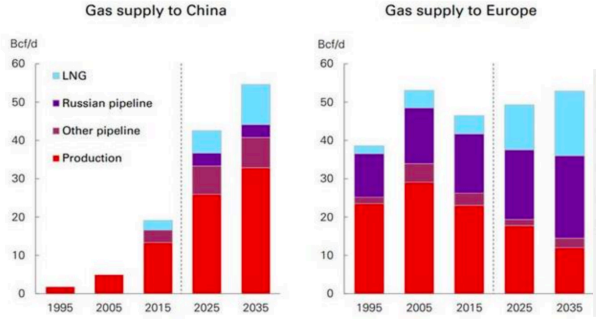


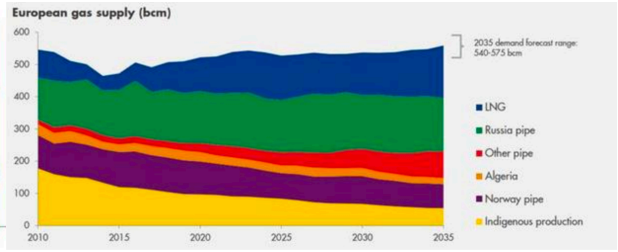


Delays in the second wave of LNG supply bring a risk of tighter markets in the 2020s.

Net LNG Exports and Imports to 2035, Source: BP Energy Outlook 2017, https://www.bp.com /content/dam/bp/pdf/energy-economics/energy-outlook-20...

Using BP outlook 2017, Athanasios Pitatzis displays the share of LNG in Europe increasing in 2035 to 17 Gcf/d = 6.2 Tcf, when Russia pipeline provides 21 Gcf/d = 7.7 Tcf and from Shell outlook 2017 forecasts in 2035 5.6 Tcf of LNG in 2035.

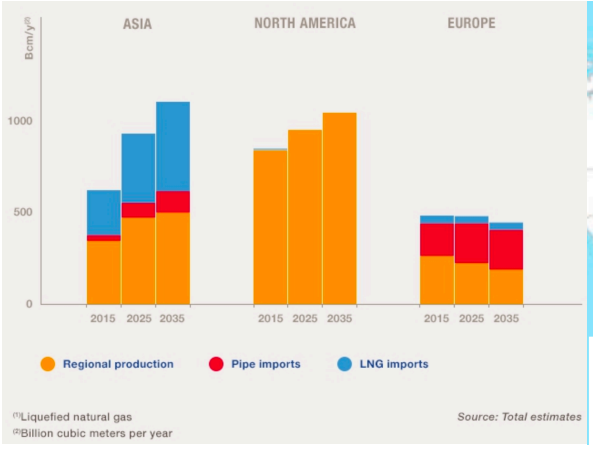


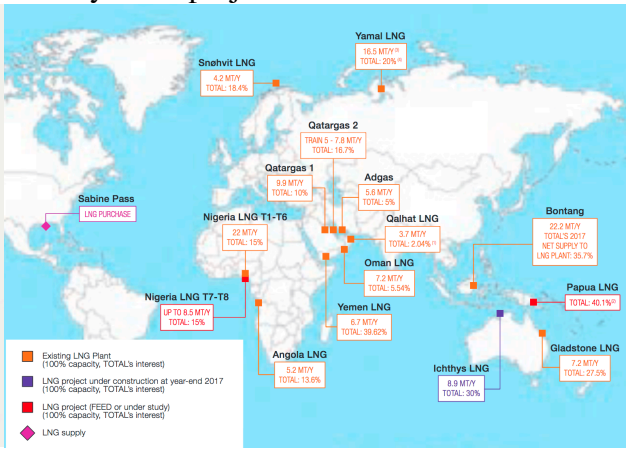


Coverage of natural gas demand for China and Europe by the source of supply since 1995 and with a forecast to 2035, Source: BP Energy Outlook 2017, https://www.bp.com/content /dam/bp/pdf/energy-economics/energy-outlook-20...

The role of LNG in the future European Energy Mix and Planning, Source: Shell, Presentation LNG Outlook 2017, http://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural...

Total https://www.total.com/en/dossiers/lng-total-investing-energy-tomorrow? forecasts as little LNG imports in 2035 as in 2015. Total is involved in many LNG projects in the world as end 2017.





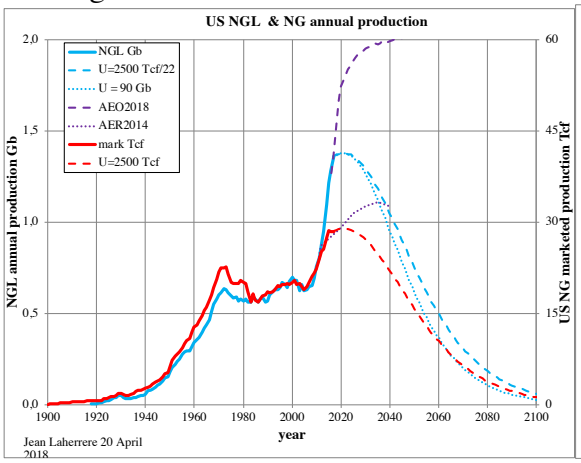
-US oil

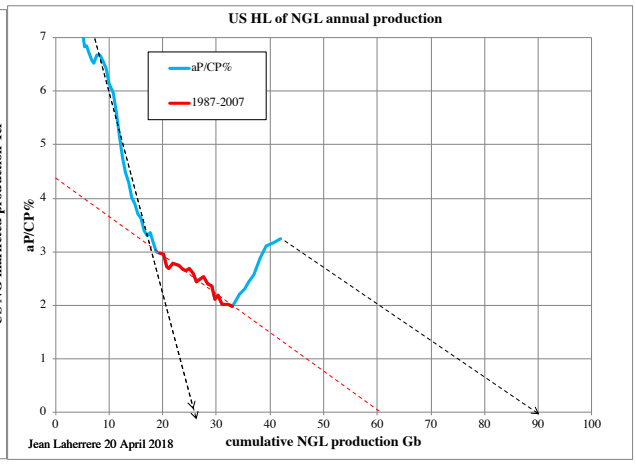
The details of US oil production were studied in my March paper: "Forecasts for US oil and gas production"

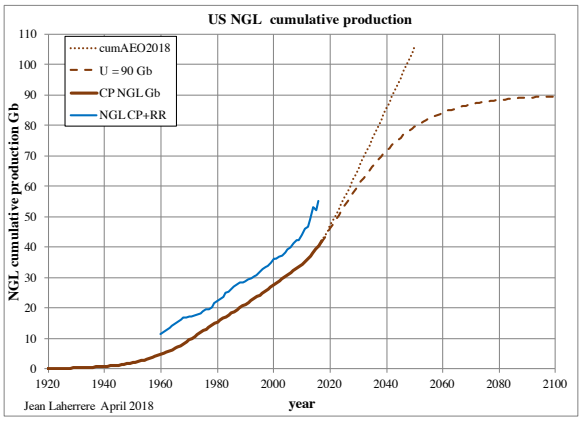
-US NGL (natural gas liquids)

There is a large difference between EIA and IEA data on NGL. Most of US crude production was collected in tanks with lease condensate and later transported by trucks.

EIA reports condensate with crude and the rest of gas liquids in NGLP (NG liquids plants).
IEA reports condensate, either with crude when sold with crude, or with NGL when sold with NGL: as condensate sales vary with time, crude data varies with time. So, only IEA crude + NGL production data is reliable.
NGL production is plotted with marketed NG; the correlation is good from 1920 to 2010.
HL of NG past production trends towards 60 Gb for the period 1987-2007 and is extrapolated towards 90 Gb from the 2017 value.
Cumulative production plus proven reserves at end 2016 is only at 55 Gb, but the cumulative production according to AEO2018 up to 2050 is at 105 Gb, far from the proven reserves data.
NGL production will peak in 2020 assuming an EUR of 90 Gb and will decline to 0.6 Gb/a in 2050 against 2 Gb in AEO 2018.

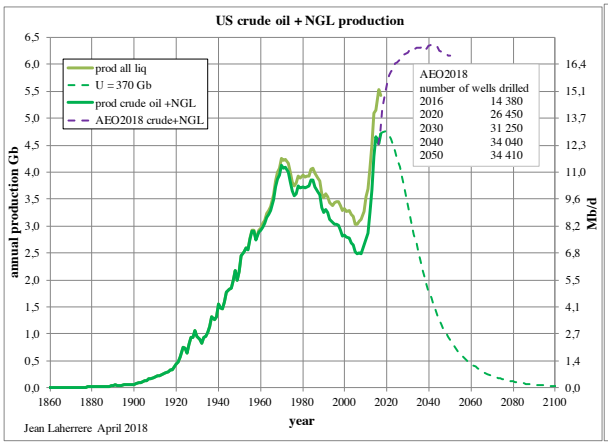


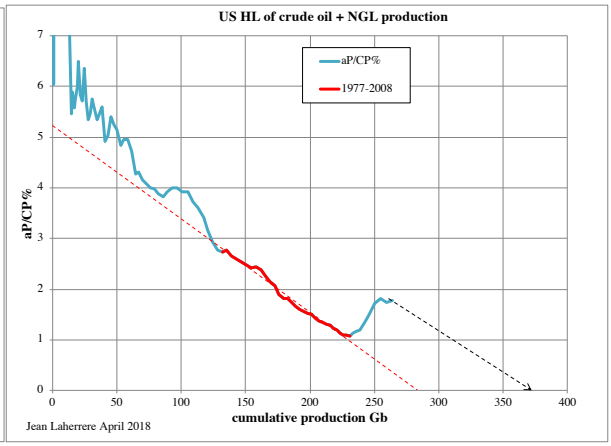




-US crude + NGL

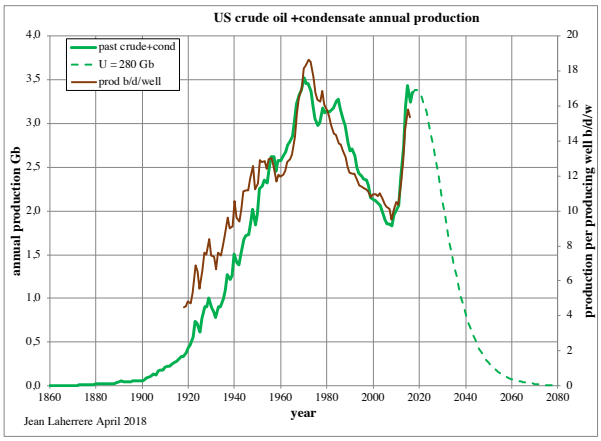
US crude oil + NGL (more reliable production) has peaked in 1970 at 4.1 Gb/a, down to 2.5 Gb/a in 2008 and back up to 4.7 Gb plateauing in 2015-2017.
HL of past production trended towards 280 Gb for the period 1997-2008 and is now extrapolated towards 370 Gb from the 2017 value.

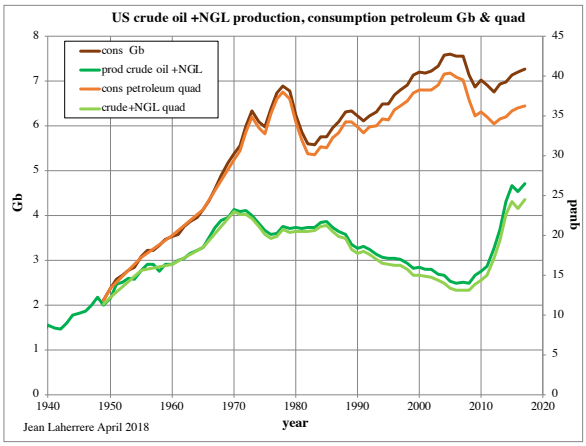




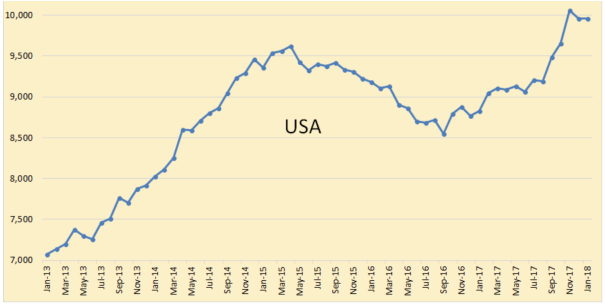
Assuming an EUR of 370 Gb, crude oil + NGL will peak in 2019 and will decline to 0.9 Gb/a in 2050, when AEO2018 forecasts a peak around 2040 at 6.3 Gb/a, but the number of wells drilled annually will increase from 14 380 in 2016 to 34 410 wells in 2050: they did not bother to ask if there is room to drill so many wells. The sweet spots area is already heavily drilled and outside, like Mark Papa (CEO EOG) said: "technology improvements can't cure bad rocks".

The number of oil producing wells was 200 000 in 1918, peaking at 650 000 in 1985, down to 500 000 in 2005 and up to 600 000 in 2014. The production of crude oil + NGL per oil producing well was 5 b/d/w in 1920, up to over 18 in 1973, down to 9.5 in 2008 and 15.8 b/d/w in 2015.





Detail of US crude oil + condensate monthly production, Jan 2013-Jan 2018 (peakbarrel.com) reaching a new peak.



The heat content of the crude oil + NGL production and consumption decreases with time, oil is getting lighter (more condensate) and the crude + NGL production and oil consumption displays a lower value with time in quad.

But EIA reports annual heat contents from source, which look weird with a heat content for crude oil constant at 5800 kBtu/b from 1949 to 2014 (obviously the composition of US crude has changed with time during this long period, but EIA is unable to publish the API of US crude oil production before 2011), then decreasing to 5717 in 2015 and 5722 for the 2016 to 2018 period.
The heat content for NGL is 4500 kBtu/b in 1950, going down to 3700 in 2018. But the computation of heat content using EIA values of production in annual barrels or in quad gives a completely different result, meaning that the published data is not reliable.
EIA does not report production measures, but production estimates from the EIA-914 survey, consulting some operators in some states. EIA-914 was improved in 2015 but there is still a large discrepancy in the short term between EIA and TRRC for Texas. EIA extrapolates revisions. In fact, production data are reliable only two years later. The best proof is that EIA production data changes with time. EIA data depends upon States data and each State has different practices. North Dakota recent data is more reliable than Texas recent data.
EIA values for 2015 https://www.eia.gov/outlooks/aeo/pdf/appg.pdf

Crude oil[1]		
Production	million Btu per barrel	5.719
Imports	million Btu per barrel	6.063
Petroleum products and other liquids		
Consumption[1]	million Btu per barrel	5.148
Motor gasoline[1]	million Btu per barrel	5.057
Jet fuel	million Btu per barrel	5.670
Distillate fuel oil[1]	million Btu per barrel	5.778
Diesel fuel[1]	million Btu per barrel	5.778
Residual fuel oil	million Btu per barrel	6.287
Liquefied petroleum gases and other[1,4]	million Btu per barrel	3.559
Kerosene	million Btu per barrel	5.670
Petrochemical feedstocks[1]	million Btu per barrel	5.441
Unfinished oils[1]	million Btu per barrel	6.111
Imports[1]	million Btu per barrel	5.518
Exports[1]	million Btu per barrel	5.398
Ethanol, including denaturant	million Btu per barrel	3.558
Biodiesel	million Btu per barrel	5.359
Natural gas plant liquids[1]		
Production	million Btu per barrel	3.745

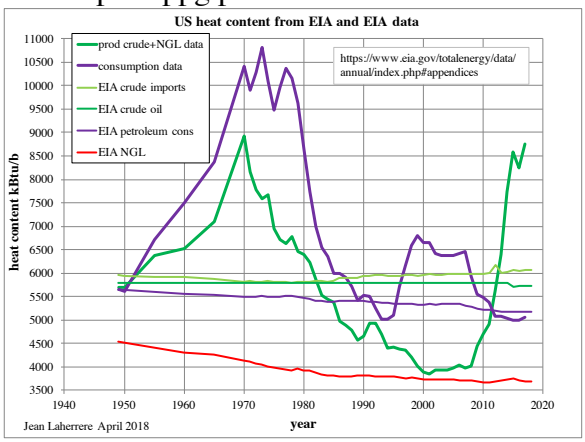
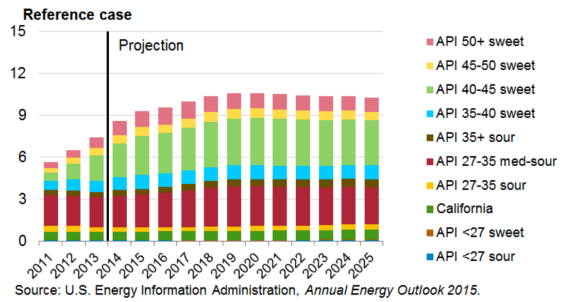


Figure 1. U.S. crude oil production by crude type, Reference case



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015.*

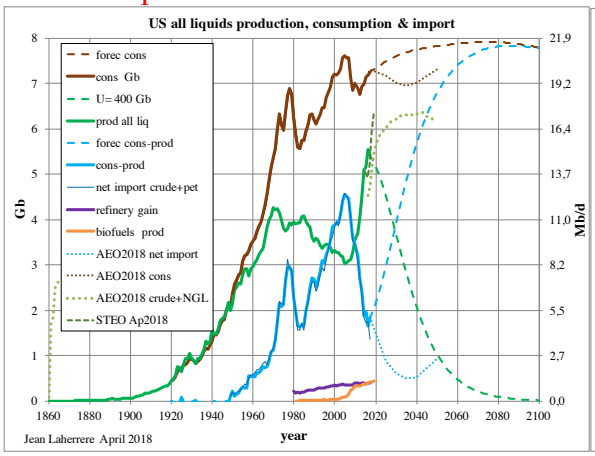
Table 3. State Lags and Methods Used to Estimate Oil Production, March 2015 Sorted by Decreasing Volume

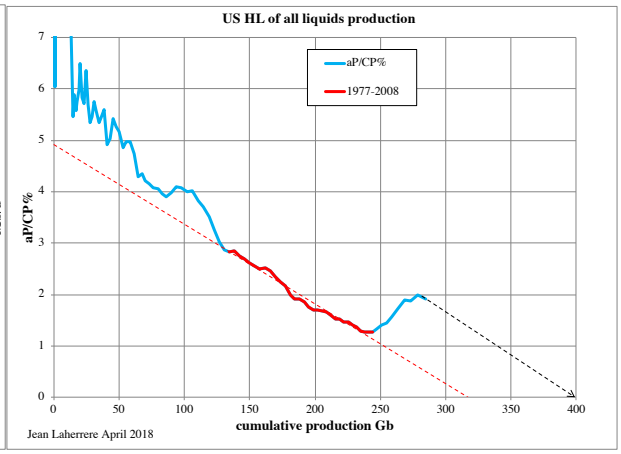
		Number of months methodology was used					
State	Total lag time (months)	Average lagged ratio estimate (months)	Alternative estimate* or expert judgment (months)	LVS data (months)	DI data (months)	March 2015 production (Mbopd)
TX	24		3		21	3674.60
GOM	4	1		3		1407.17
ND	0					1190.58
CA	3		3			552.00
AK	0					510.94
NM	5	5				412.62
OK	45	14	4		27	371.11
CO	2	2				303.96
WY	1		1			238.69
LA	1		1			176.60
KS	2	2				137.70
UT	3	3				121.94
MT	4	4				90.81
OH	3	2	1			70.07
MS	4	4				66.09
FP	3	3				44.31

-US all liquids

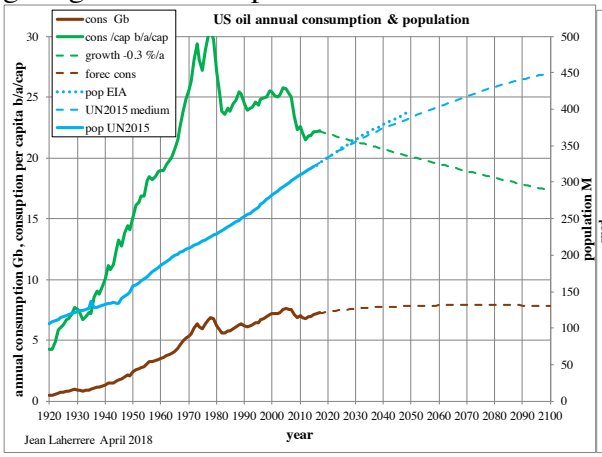
US all liquids (green color curve, including crude oil, NGL, XTL (X (gas, coal, shale or biomass To Liquids), refinery gain) peaked in 1970 at 4.2 Gb, down to 3 Gb in 2005 and will likely peak again in 2016 with an EUR of 400 Gb, if there's no new cycle in future.
The HL of past production trended towards 310 Gb for the 1978-2008 period and the last two 2016-2017 data sets is extrapolated towards 400 Gb with the same slope as the last 1978-2008 period.
Using an EUR of 400 Gb, the future production in 2040 will be 2 Gb/a, when AEO2018 forecasts 6.3 Gb: the difference is huge (4.3 Gb) compared to the forecasted consumption.

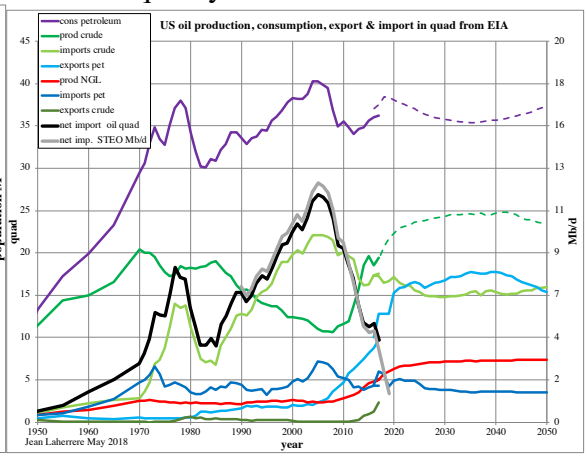
The difference (in blue), oil consumption less oil production, has peaked in 2006 at 4.5 Gb/a and is in 2017 at 1.8 Gb/a. It is surprising to find for the 1950-2016 period a perfect match with EIA net imports (thin blue); but future consumption less production (= net import) will rise in 2040 to 5.6 Gb/a in my forecast, but for AEO2018 it will continue to decline to 0.5 Gb/a.
It is obvious that EIA is too optimistic and that I am too pessimistic in order to show a different view justified by data and well quantified explanations, contrary to EIA, refusing to give EUR. It is likely that the mid-point for 2040 will be an increase of net import: the US will not export oil in 2040.





US oil consumption per capita has peaked in 1978 (oil shock) at over 30 b/a/cap, again in 2004 at 25.8 b/a/cap, a sharp decline to 21.4 in 2012 and a slight increase to 22.2 in 2017. Using the medium UN2015 forecast and assuming a decrease of 0.3 %/a of the oil consumption, the 2040 forecast for oil consumption is 7.7 Gb/a, but 7 Gb in AEO2018, less than in AEO2017, which is an optimistic forecast when considering US population increase. EIA provides oil production, consumption, export and import from 1950 to 2050 in quad, giving a better comparison between sources of different quality .





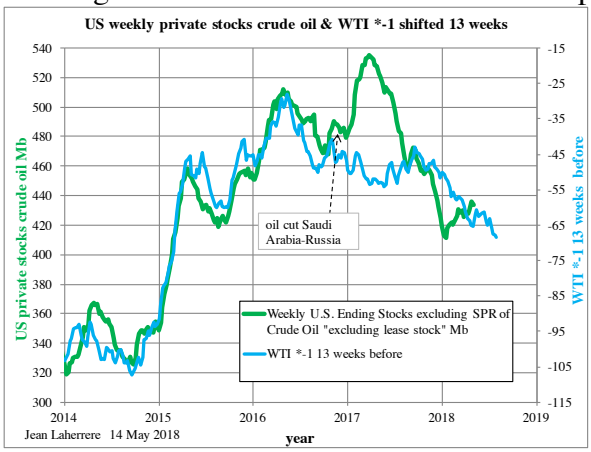
EIA STEO reports the net import of crude oil and petroleum products from 1990 to 2019 in Mb/d, displaying a peak in 2006 at 12.5 Mb/d and a sharp decline trending towards 0 in 2021.

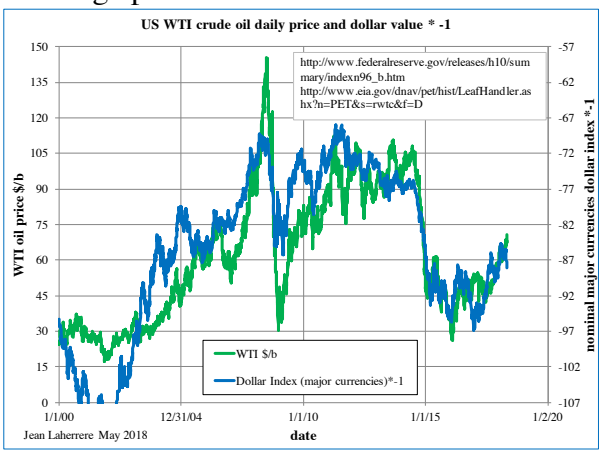
-US crude oil private stocks, WTI and dollar value

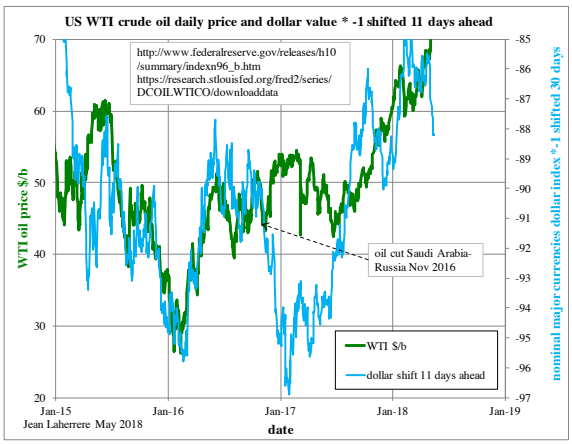
For many the oil price depends upon US stocks, when the display of US weekly crude oil private stocks (green in the following graph) correlates well with the WTI value (blue) of 3 months before, from 2014 to November 2016, at the start of the Saudi Arabia/Russia production cut. But the correlation resumes in October 2017 to now.

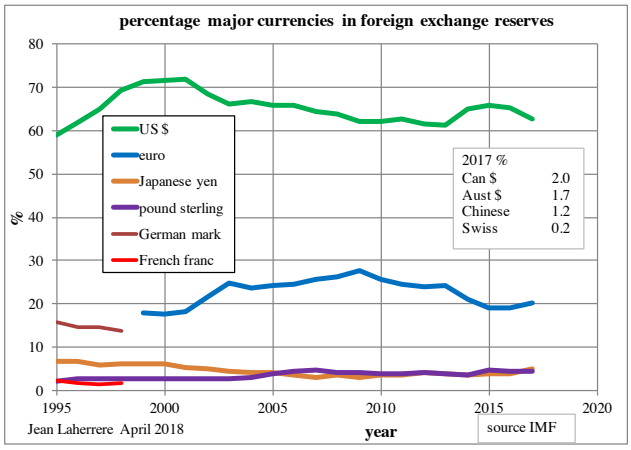
If US stocks depend upon the WTI, the WTI depends upon the dollar value since 2004. The US rule the world oil industry, the crude oil (in particular the WTI) is mainly given in dollar by barrel, defined as 42 US gallons, despite that in Europe oil production is reported in cubic meter or in tonne.
Why 42 gallons: The Weekly Register, an Oil City newspaper of late August 1866: « *We, all producers of crude petroleum on Oil creek, mutually agree and bind ourselves that from this date we will sell no crude by the barrel or package, but by the gallon only. An allowance of two gallons will be made on the gauge of each and every 40 gallons in favor of the buyer.* »
It already showed the lack of accuracy in measuring oil. This 5% bonus was to compensate for bad measures, losses or as a discount (as 13 by dozen).
The Petroleum Producers Association finally adopted in 1872 the 42-gallon oil barrel, which was adopted by the Census Bureau in 1880 and in 1882 by the U.S. Geological Survey, U.S. Bureau of Mines and other agencies until today.
But the 42 US gallons barrel is not a US official unit (official liquid barrel in the US, and in particular in Texas, is defined as 31.5 US gallons) and EIA is forced in official documents to add after barrel (42 US gallons). The funny side is that there is not a single old wooden 42 gallons barrel left in the US museums! There is no official symbol to write barrel, and several symbols can be found b, bl, bbl (used by many but no one knows why two b: several explanations, plural or blue barrel (color of the crude barrel = bbl to be different from the refined barrel =red barrel = rbl, or color of the Standard Oil of California).

There is a good correlation between the WTI (green) and the negative value of the Dollar since 2004. The Saudi-Russia production cut disturbs the correlation for six months, as in detail the best present correlation since mid 2015 is with WTI shifted 11 days ahead.
The US dollar represents since 1995 over 60% when plotting the major currencies in foreign exchange reserves from IMF. The US dollar percentage peaked in 2000 and in 2015.







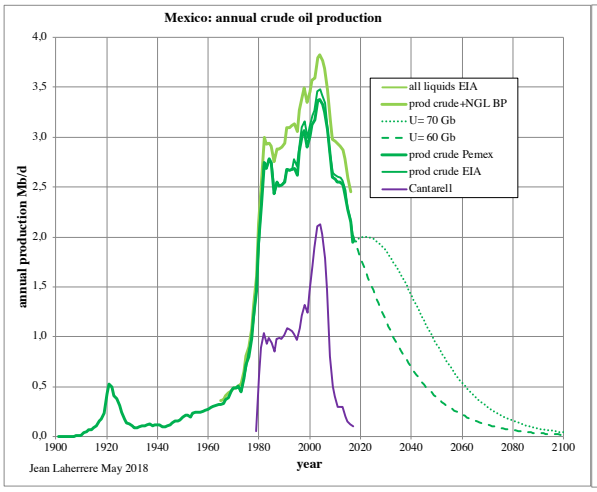


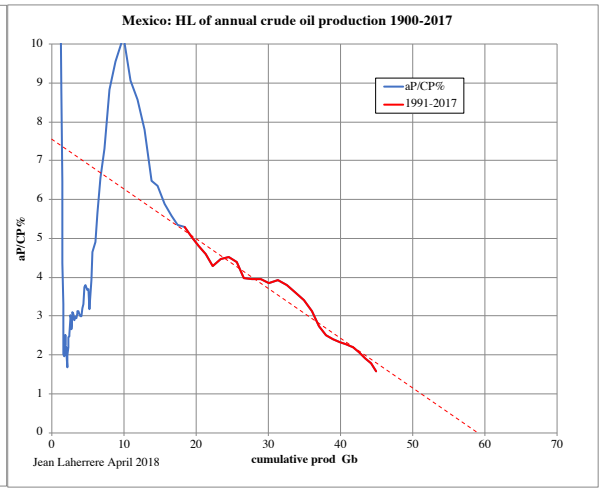
-Mexico oil

-Crude oil

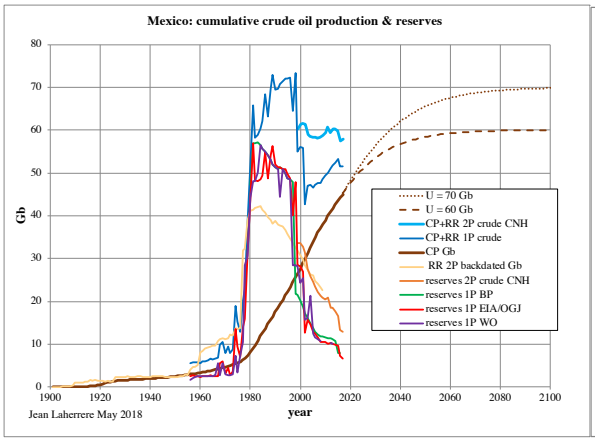
Mexico crude oil production peaked in 1921, again in 1982, and again in 2005, but is presently in steep decline, which will continue, assuming an EUR of 60 Gb as shown by the extrapolation of HL of past production for the 1991-2017 period.

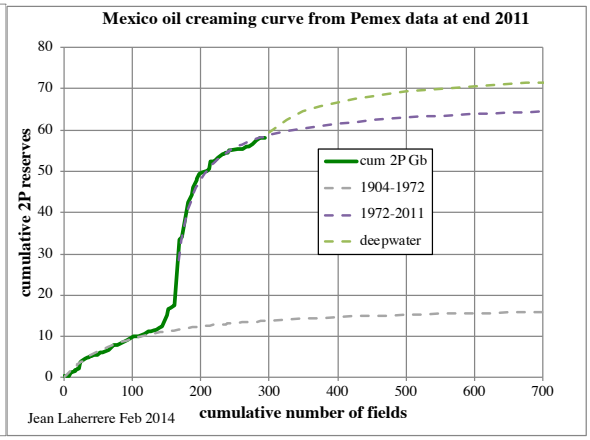
The oil production from Cantarell field is shown in purple, displaying a steep increase due to nitrogen injection and then a sharp decrease.



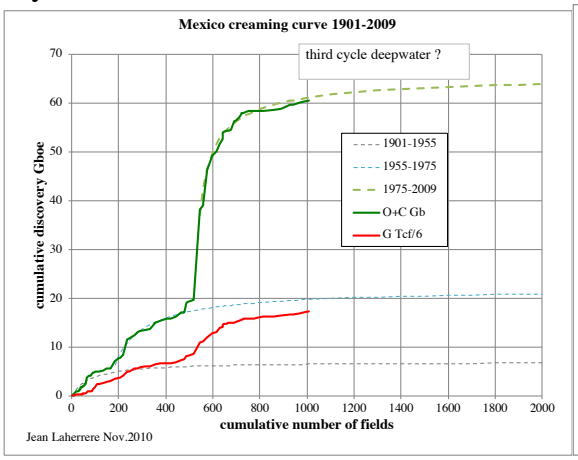


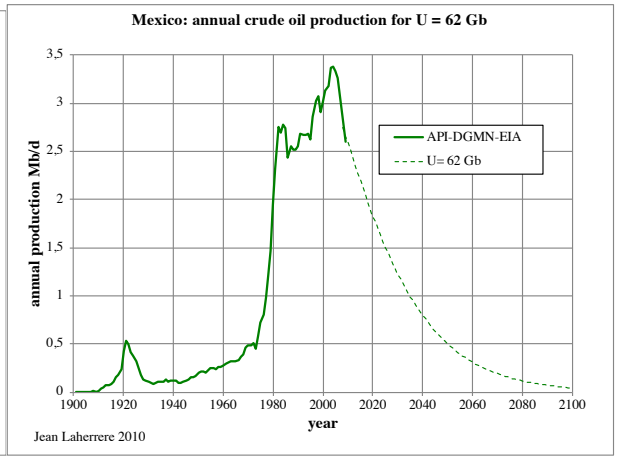
But the cumulative 2P discoveries up to 2011 from Pemex data is 58 Gb and the creaming curve displays three cycles and the last one is deepwater with a large unexplored area adjacent to large discoveries in the US. It appears that the EUR is rather 70 Gb or more. The production of future large deepwater discoveries could lead to a new small peak in the 2020s.



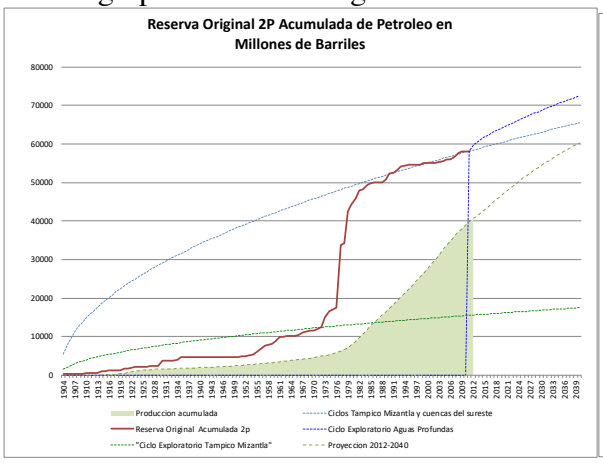


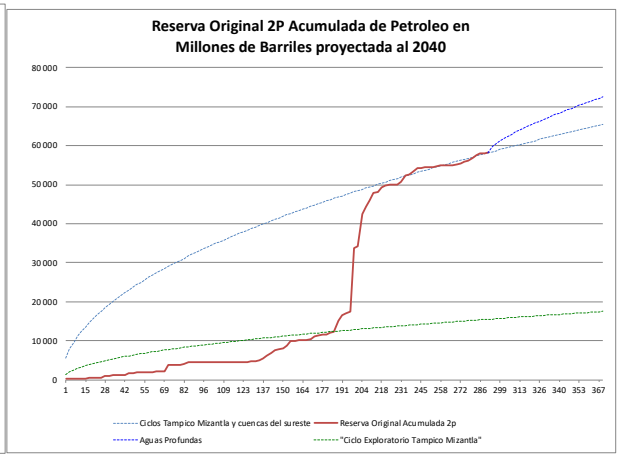
My 2010 forecast was for an EUR of 62 Gb





Pemex graphs: the creaming curve from 2P reserves trends towards an EUR above 70 Gb.



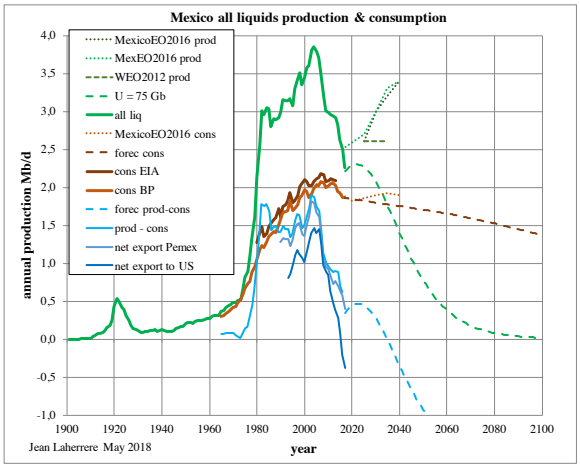


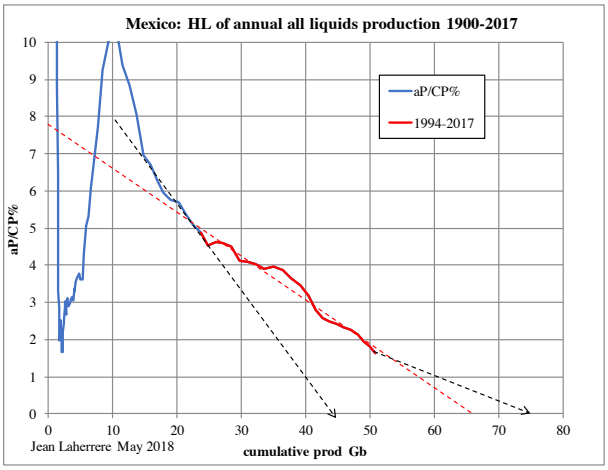
-Mexico all liquids

The HL of past all liquids trends towards 65 Gb, 5 Gb more than for crude oil. But with the potential of deepwater it is likely that the real ultimate is rather 75 Gb. A small peak is likely in 2022, but the all liquids production will be 1.5 Mb/d in 2040 compared to the IEA/WEO2016 forecast at 3.4 Mb/d.

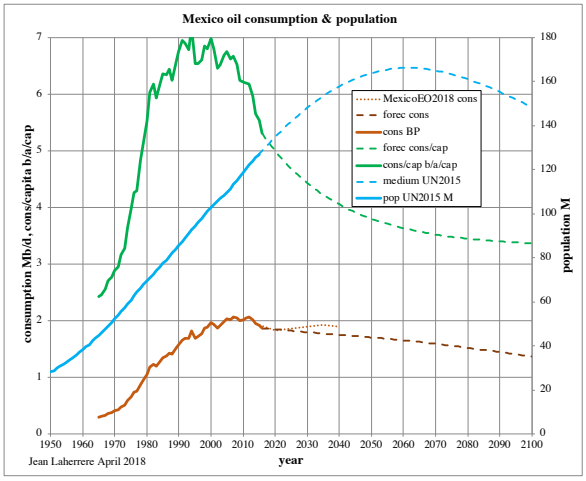
The potential of LTO in Mexico is not large. US Eagle Ford LTO does not extend much into Mexico. Pemex has tried to produce the poor tight oil reservoir (turbidites) of Chicontepec since 1952 (SENER = 42 Gb oil resources, Schlumberger 2003 = 12 Gb oil reserves discovery in 1926). 1952-2002 cumulative production with 951 wells =111 Mb.

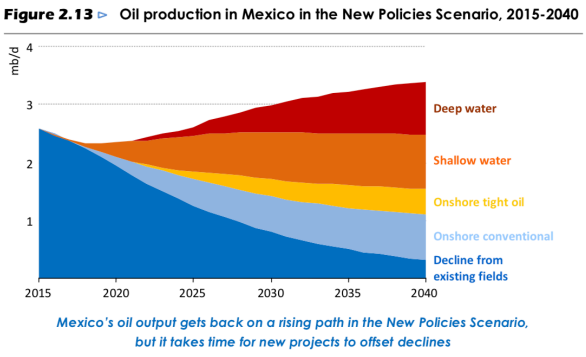
Pemex planned 13 500 wells from 2008 to 2020, to reach a production of 1Mb/d and signed a service contract with Schlumberger. After a few years this contract was a failure, with a peak production of 0.1 Mb/d in 2013. In 2017 Renaissance oil corp. drilled 10 wells on Chicontepec: the absence of Majors shows that this play is a poor one.
Mexico oil consumption has plateaued in 2000-2013 and is starting to decline. Oil consumption per capita is declining since 2007 from 6.7 b/a/cap to 5.3 in 2016 and we assume that the decline will continue to flatten at 3.4 in 2100 with a global oil consumption of 1.4 Mb/d.





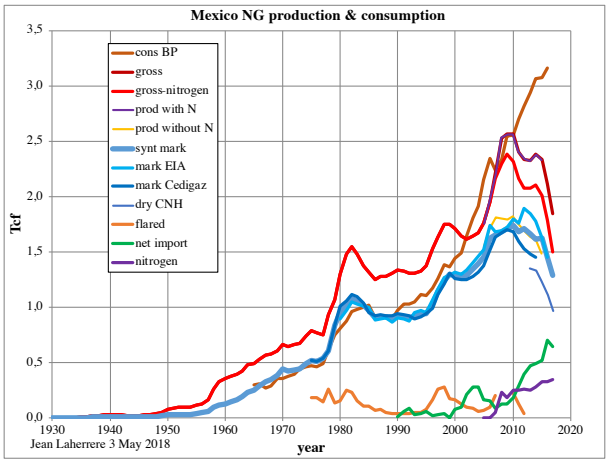
IEA/MexicoEO2016

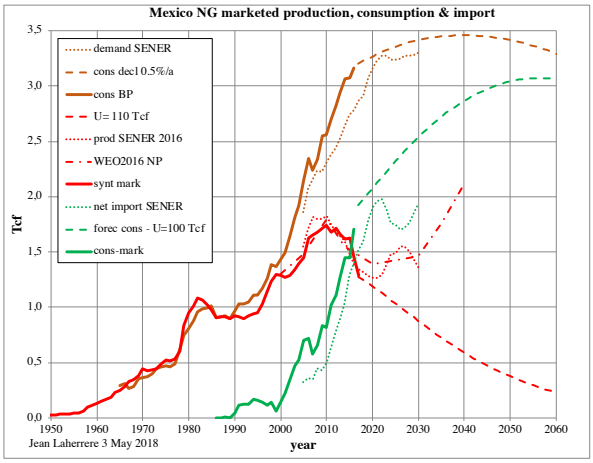




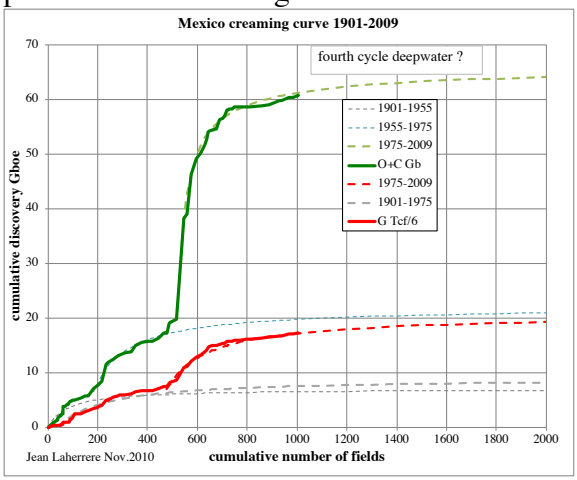
-Mexico NG

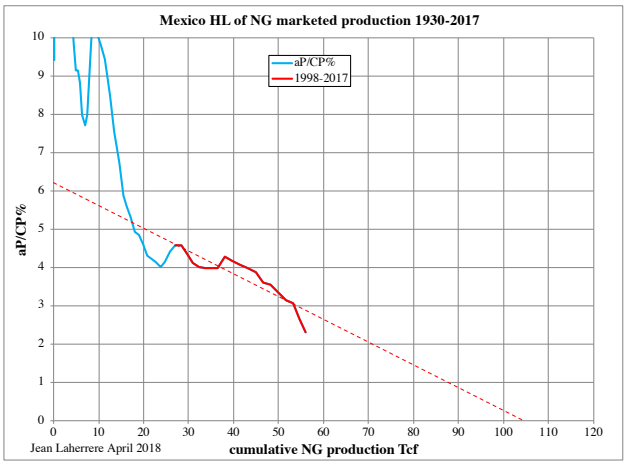
Since 2007 NG production includes a significant percentage of nitrogen (N), used to increase the production of oil in Cantarell field. Since 1977 there is no reinjection of NG, meaning that the marketed should be gross (excluding N) less flared and vented.
As NG reserves do not include nitrogen, it is necessary to deal with NG production excluding nitrogen, but most data lack a clear definition. SENER and Pemex do not report marketed or dry historical production. But as US and Canada NG production data is marketed, EIA & CEDIGAZ marketed gas production are used to get a historical marketed data since 1930.



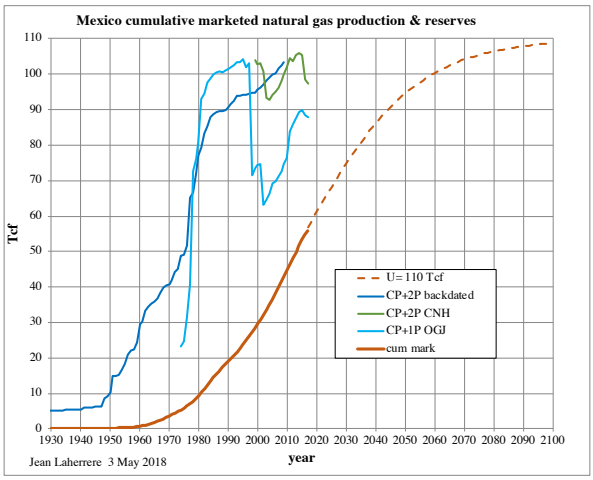


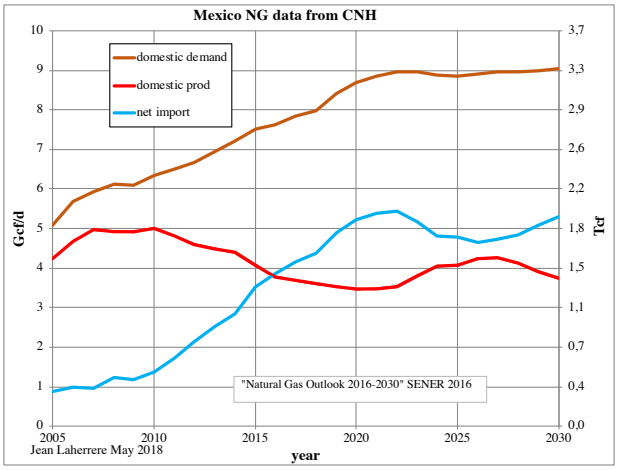
HL of NG marketed production trends towards 105 Tcf for the 1998-2017 period, but the creaming curve (1901-2009) trends towards 120 Tcf (20 Gboe) and the cumulative production plus 2P reserves is higher than 100 Tcf. An EUR of 110 Tcf is chosen.

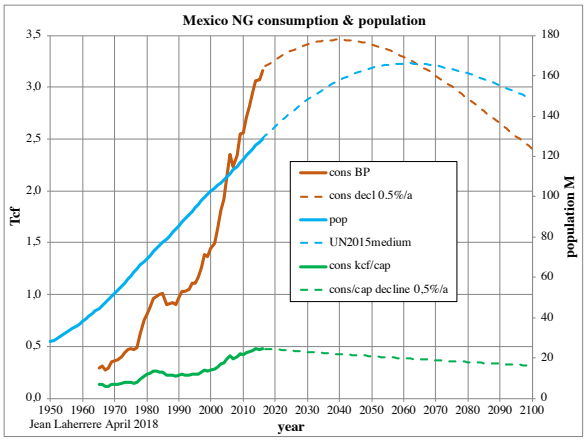




The SENER 2016 report "Natural gas outlook 2016-2030" forecasts that NG production decline will end in 2023 and will show a small peak in 2027 and that demand will increase and flatten after 2023 at 3.3 Tcf. My forecast on NG consumption assumes a decrease in consumption per capita of 0.5 %/a after 2018, leading to a peak of consumption at 3.5 Tcf in 2040 combined with the UN2015 medium fertility forecast.

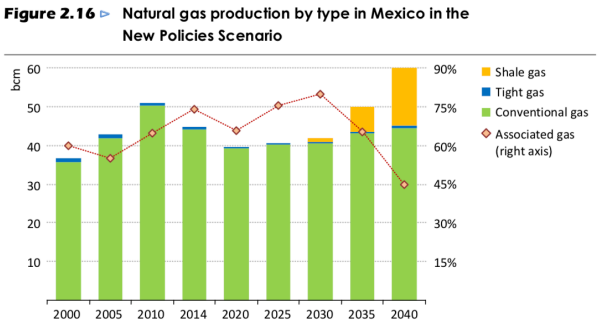


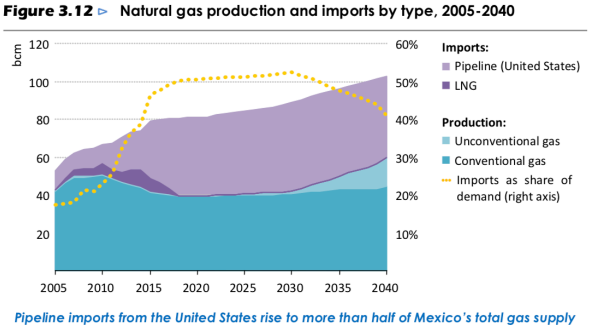




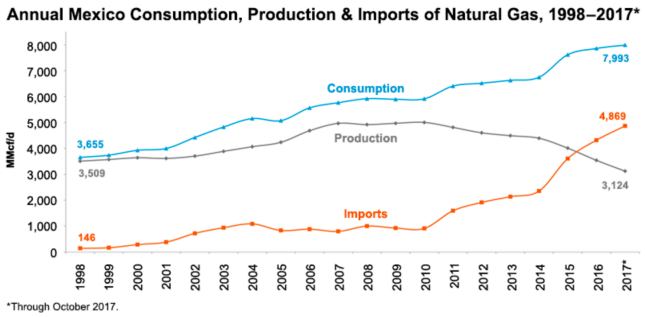
SENER forecasts a net NG import of 2 Tcf in 2030, my forecast is rather 2.7 Tcf and 3.3 Tcf in 2050

IEA/MexicoEO2016





SENER graphs displays discrepancy with time on NG balance



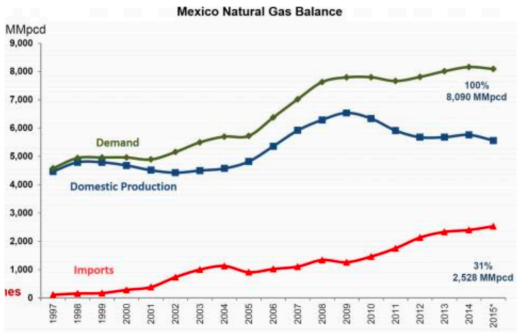
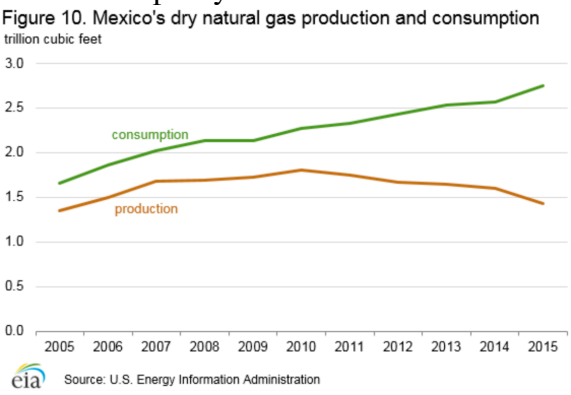
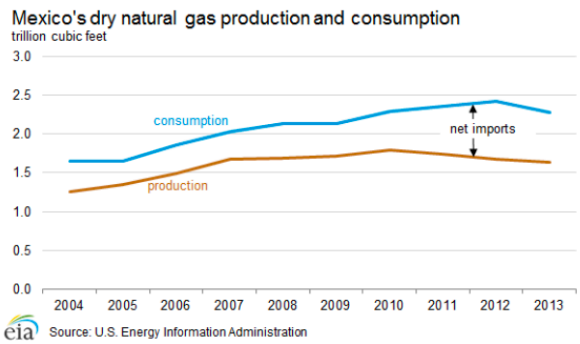


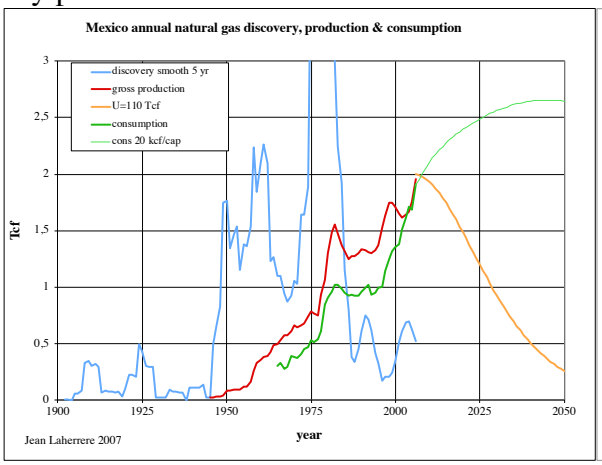
Figure 1; Source: SENER (Click to Enlarge)

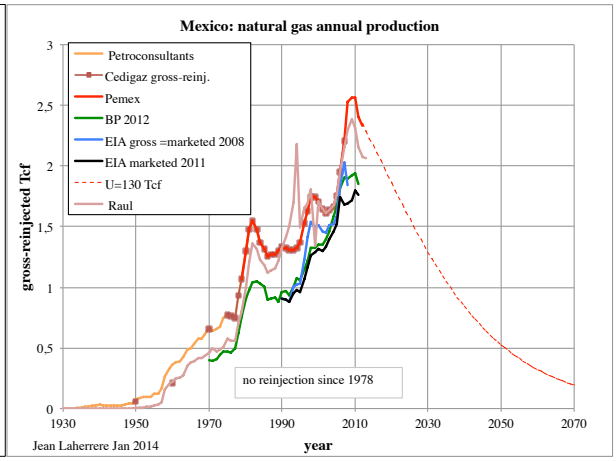
Same discrepancy for EIA





My past forecasts in 2007 and 2014

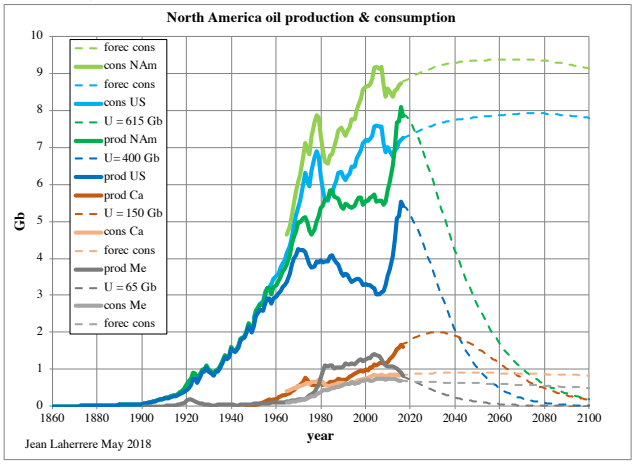


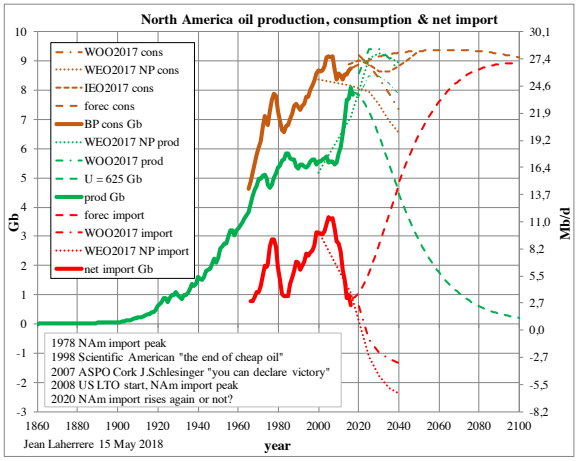


-North America oil

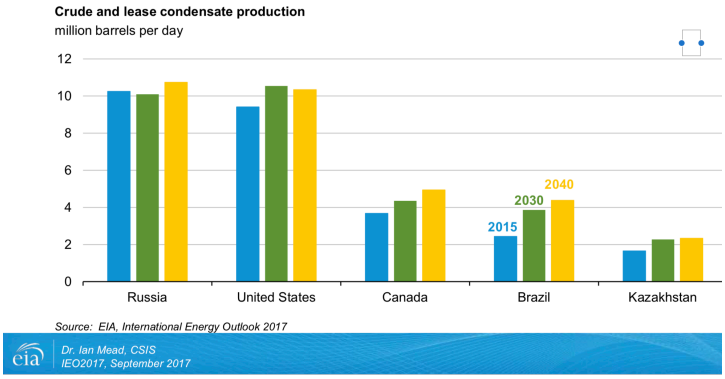
The aggregation of the three countries oil production and consumption for the 1860-2100 period is displayed in the first graph. The second graph compares North America future production and consumption with the available forecast from EIA, IEA and OPEC. The consumption less production difference represents the net import (in red). This curve is very bumpy with peaks in 1977 (2.7 Gb) and 2005 (3.6 Gb). The low point at less than 1 Gb in 1983 is equal to the 2017 value: IEA forecasts that the decline will continue and in 2020 the net import will be zero and will reach in 2040 a negative value of 2.4 Gb (net export). To me, in 2040 the net import will be about 14 Mb/d against -6 Mb/d for IEA: a huge difference of 20 Mb/d and against -3 Mb/d for OPEC.

In fact, the difference is due more to the forecast in consumption than that in production.

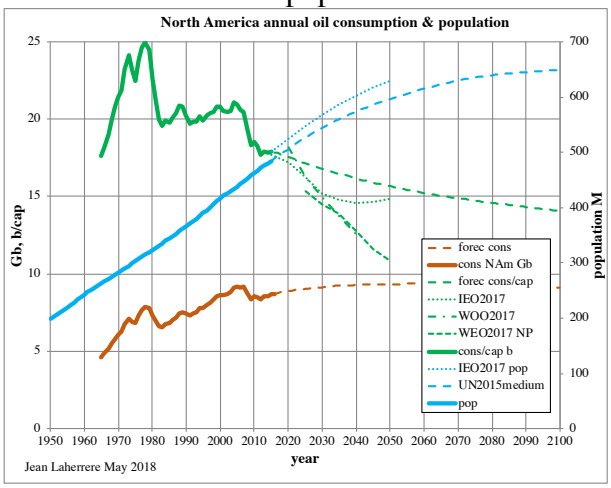




EIA in IEO 2017 does not report NAm future production (only consumption) except in this graph for US and Canada with an increase of 2 Mb/d from 2015 to 2040, compared to an increase of 4.7 Mb/d including Mexico



The consumption per capita was flat from 1981 to 2007, around 20 b per year, and from 2012 to 2015 at less than 18 b. IEA forecasts 10.8 b/cap in 2050 against 15.7 b/cap for me and 15.4 b/cap for EIA. IEA is very optimistic for the decrease in oil consumption (electric cars?) and for the oil increase in production (LTO). I am much more pessimistic on both and IEA agrees with me on consumption per capita for 2050. EIA forecasts NAm population in 2050 at 630 M against 597 M for UN 2015 medium fertility = 5% difference! But the difference in 2015 was already 501 M for EIA against 485 M for the UN: who is right? PRB reports for mid-2015 584 M: the EIA population value seems too high!

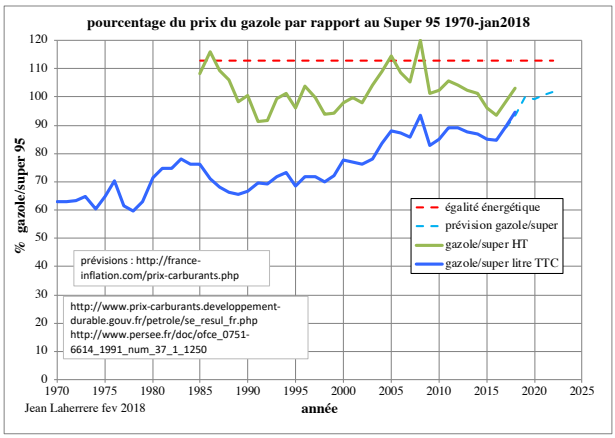


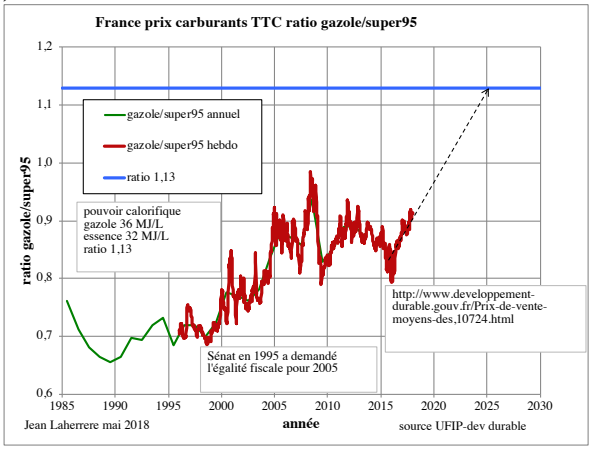
My forecast for NAm net import until 2040 is more of the same up and down trend as in the past: same lows and same peaks.
But in a few years, it should be easy to see who is right: if the net import increases, IEA is wrong, if not, I am wrong.

-unit of measure: barrel or toe?

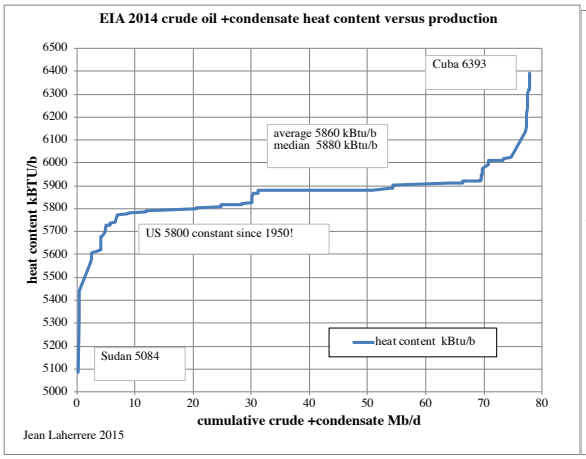
Xavier Chavanne, researcher at Université Paris Diderot, member of ASPO France, who has written "Energy efficiency, what it is, why it is important and how to assess it" 2013 ISBN 978-1-62808-764-2, criticizes my papers because I report oil data in volume (Gb), despite the fact that oil heat content varies largely and that data should be reported in energy (SI unit = Joule with 1 toe = 42 GJ). My reply is that oil is liquid and it is easy to measure volume with flowmeter, whereas measuring weight is more difficult, most data is in barrels, but he is right in principle. Yet, when you fill your tank you buy gasoline or diesel by volume. Every diesel car driver is convinced that he consumes less diesel fuel than a gasoline car (about 20% less), because of the better efficiency (higher compression) of the diesel engine, when in fact the majority of the saving is due to the fact that diesel is heavier than gasoline, therefore more calorific by 12-13.5% when sold by volume (gasoline 115.4 kBtu/gal, diesel 128.7 kBtu/gal

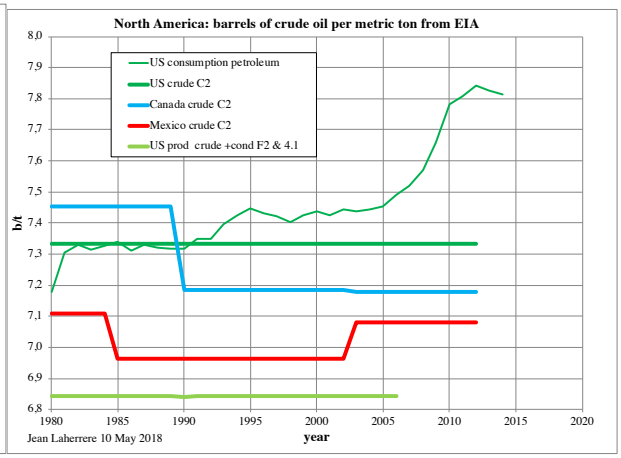
http://en.wikipedia.org/wiki/Gasoline, gasoline 114.0 kBtu/gal, diesel 129,5 kBtu/gal table GCE). If diesel were sold by weight, the story would be quite different.
France is the champion of diesel cars because diesel is much less taxed than gasoline per liter. The French Senate in 1995 requested that diesel should be equally taxed (but per liter when it should be per energy unit), but the diesel/gasoline price ratio is today very far from the true value of 1.13 and lower than the value in 2008. With the present trend it will take at least 7 years to reach 1.13. Excluding taxes, the diesel/gasoline price ratio has varied from 90% to 120% in the 1985 to 2017 period. It is impossible to get the precise value of the fuel gravity in France because each product is defined with a range: Total Super 95 = 720-775 kg/m3, Gazole B30= 825-865 kg/m3, Total Excellium 820-845 kg/m3: the uncertainty is 3 to 8%!
Any study comparing price and fuel quality in gas stations reports only the additives and services (in particular the toilets), never the gravity (the energy power) of the product, for the good reason that the petroleum product comes from the same nearest refinery for every station around (no competition on the subject of energy).

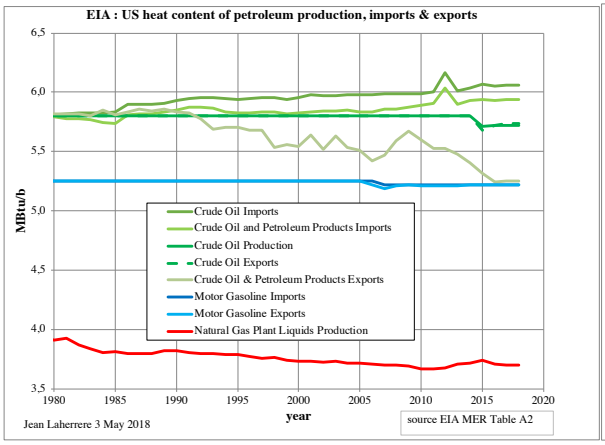


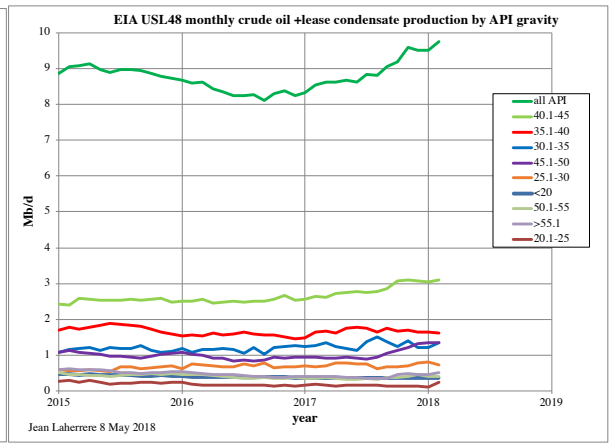


In practice oil is sold by volume, oil price is in $/b, despite that the oil barrel (42 US gallons) is not an official unit in the US. The official US liquid unit is a 31.5 US gallons barrel, EIA in their official reports is forced to add “42 US gallons” after barrel!
In Europe oil production is reported in cubic meters but also in tonnes. Oil production in France is reported only in tonnes. Oil was produced in France as soon as 1810 from Pechelbronn and Schistes d’Autun (shale oil) and the production was reported in tonnes. In 1859 France was producing ten times more oil than the US, but in 1860 it was a different story!
Each field produces a different oil with different heat content. Heat content of Sudan is the world smallest API gravity with 5.08 MBtu/b and Cuba the highest with 6.4 MBtu/b
But the heat content of crude oil from 1980 to 2013 is reported as constant by EIA for Mexico (6,01 MBtu/b), Canada (5.81 MBtu/b) and US (5.80 MBtu/b). US crude oil has slightly changed after 2015. EIA historical heat content values are arbitrary, because EIA was unable in the past to measure API gravity (States did not provide EIA with such data), it is only since 2015 that EIA reports monthly crude oil + lease condensate by API gravity. It is unlikely that precise historical values for US oil production in Mtoe could be provided.
In 2018, 40 to 45 °API was the most produced, followed by 35-40 °API but the largest increase in the last few months was 45-50 °API = condensate.
EIA reported arbitrary North America barrels of crude oil per metric ton (tonne) from 1980 to 2012 but they stopped beyond: in 2012 7.33 b/t for US, 7.18 for Canada and 7.08 for Mexico. It means that all EIA values of oil production in quad are unreliable. It is likely that it is the same for IEA.





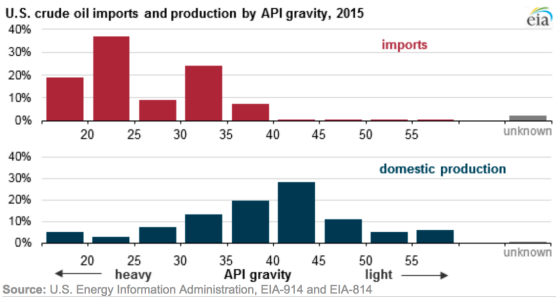


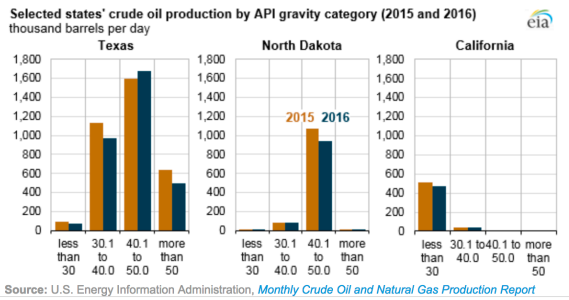


EIA 2016 displays few graphs on US crude oil production by API gravity

https://www.eia.gov/todayinenergy/detail.php?id=26132

https://www.eia.gov/todayinenergy/detail.php?id=30852





There is a good correlation between gravity and energy content: there is data, in particular in Canada, but few graphs except Chavanne in his book from Chevron data, I plot this one from Canada data

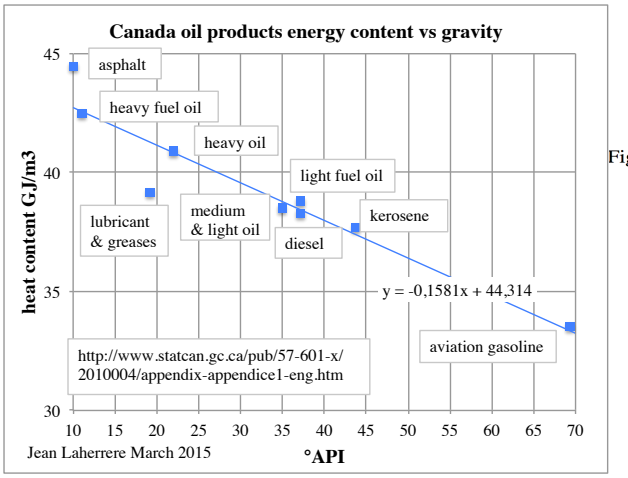
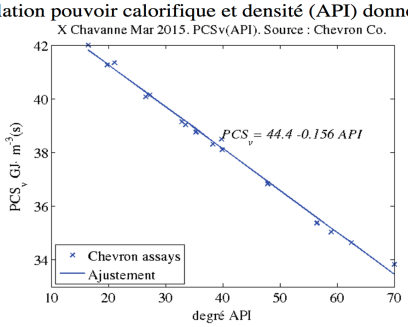
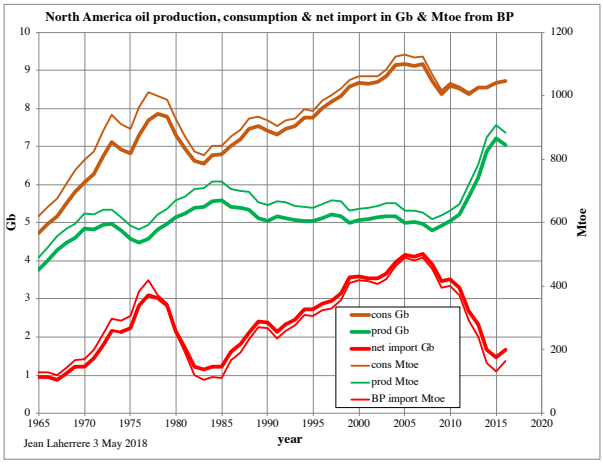
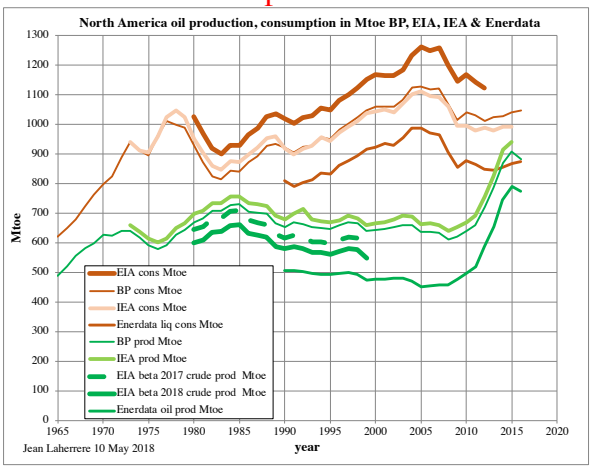


Fig 6: relation pouvoir calorifique et densité (API) données Chevron

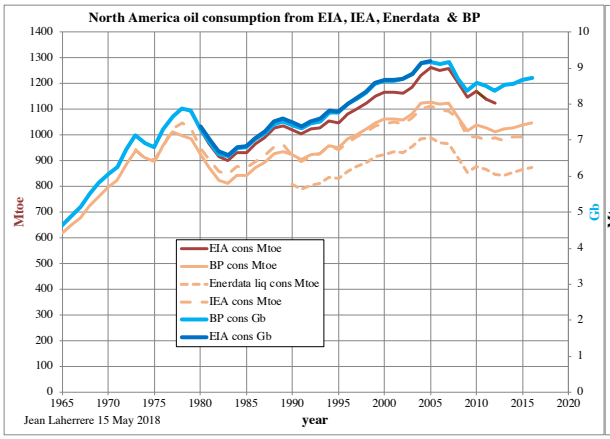


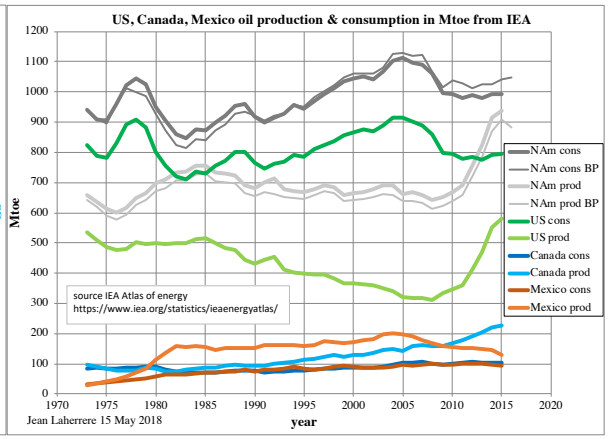
BP reports oil production, consumption in Mtoe (thin) and Gb (heavy) since 1965 to 2016: it is obvious that the consumption (brown) increases less in Mtoe than in Gb, that production does not change much, which is weird and questions the reliability of BP data, and net import (consumption less production) changes more in Mtoe.
Enerdata reports only production and consumption in Mtoe, but the comparison with BP and EIA is obvious: they do not deal with the same product or the same heat content.
IEA in the "atlas for energy" on Internet reports annual production and consumption, as net imports from 1973 to 2015 in several units. IEA Mtoe data is close to BP Mtoe data.
For consumption in Mtoe, BP is 90% of EIA and Enerdata is 50% of EIA! But for consumption in Gb, EIA and BP report the same data. It means that BP, IEA and EIA use a different calorific value. There are two calorific values: gross and net depending on the recovery of the condensation heat of water, but the difference is about 6%, when here the differences are higher. IEA uses net calorific value. The difference is on the definition of the "oil" or "petroleum". What is reported in Mtoe is not the same as reported in Mb/d.



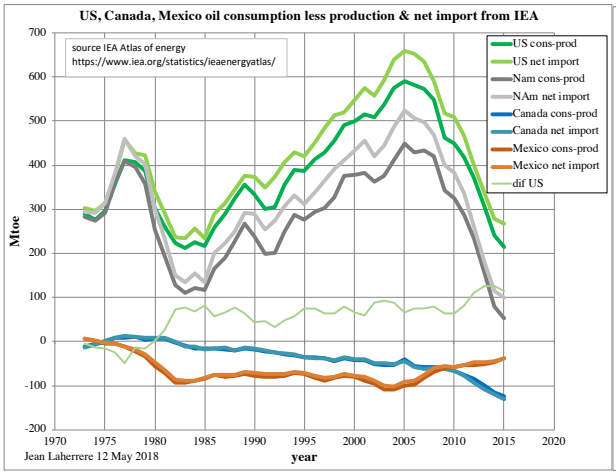


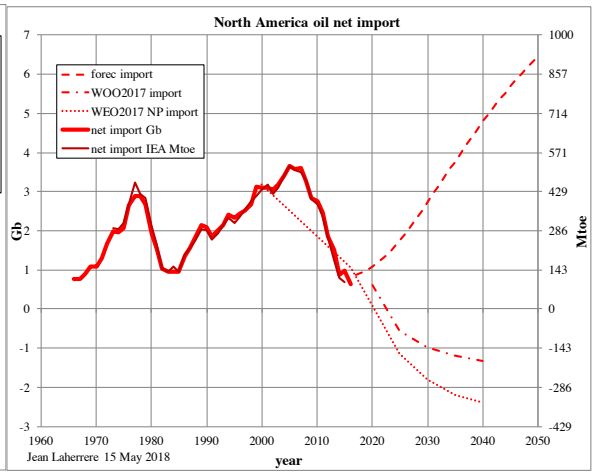
The comparison of consumption in Mtoe and Gb shows that oil in volume is getting less energetic.





IEA oil consumption less production is the same as net import for Canada and Mexico, but not for US: it means that IEA uses a different definition for oil production and oil consumption! The difference for the US between net import and consumption less production is about 100 Mtoe since 1982: it is a significant value, equal to the oil consumption of Canada or Mexico.



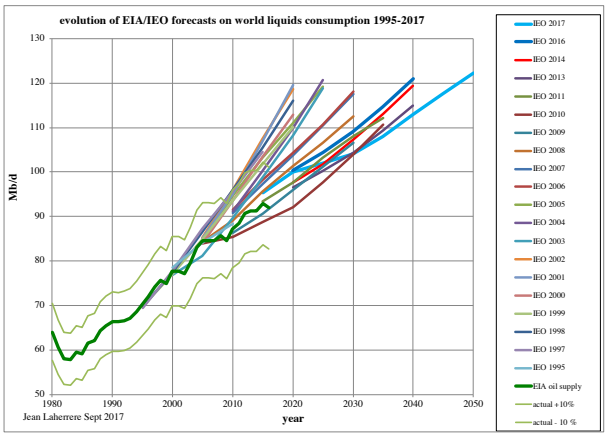


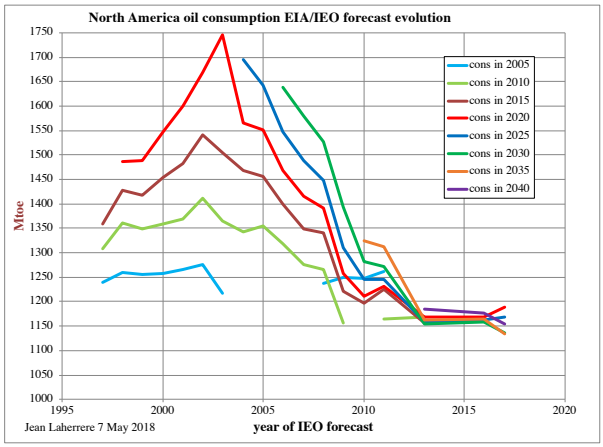
The graph of NAm oil net import in Gb and Mtoe from 1965 to 2016 shows that the gravity is around 7 b/toe and it displays a range from about 1 and 3 Gb, when IEA & OPEC forecasts for 2040 is about -2 Gb, and ExxonMobil about -3 Gb, when my forecast is +5 Gb.

In brief, oil production and oil consumption data in Mtoe differ largely between IEA, EIA, BP and Enerdata, it is due to different definitions of the product and to different heat contents. EIA was unable to measure the heat content of the crude production and used arbitrary values. It is only since 2015 that EIA does report crude oil production per gravity.
Sources do not try to define exactly their values and never comment on their inaccuracy. The variations are huge, inaccuracy could be 5 to 10 % and the 5 significant digits of IEA values in their atlas of energy seem ridiculous!

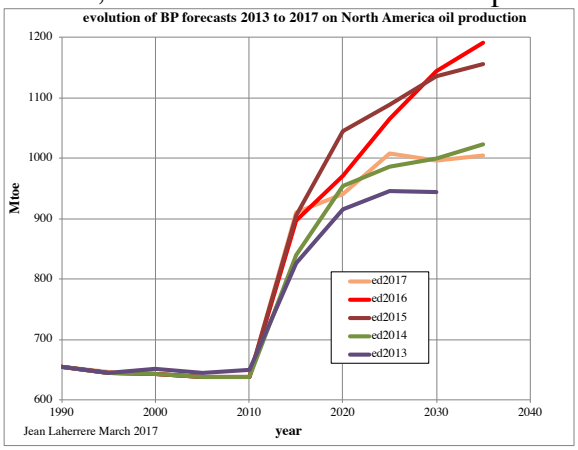
-forecasts by BP, EIA & ExxonMobil

EIA forecasts for world oil consumption in Mb/d are poor, when looking at past forecasts from 1995 to 2017. EIA NAm consumption in Mtoe for 2020 was chaotic, ranging from 1.5 Gtoe in the 1998 edition to 1.75 Mtoe in the 2003 edition and down to 1.2 Gtoe in the 2017 edition

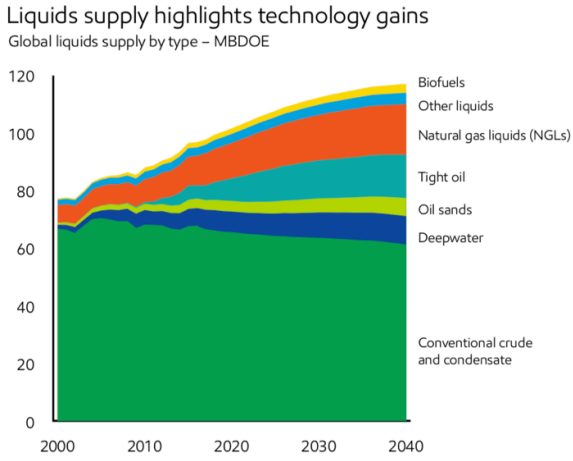


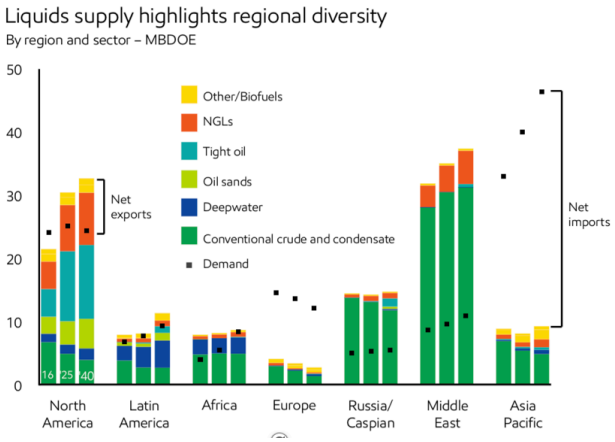


The evolution of BP forecasts for NAm oil production from 2013 to 2017 in Mtoe is also chaotic, the 2017 edition is down compared to the 2016 edition.



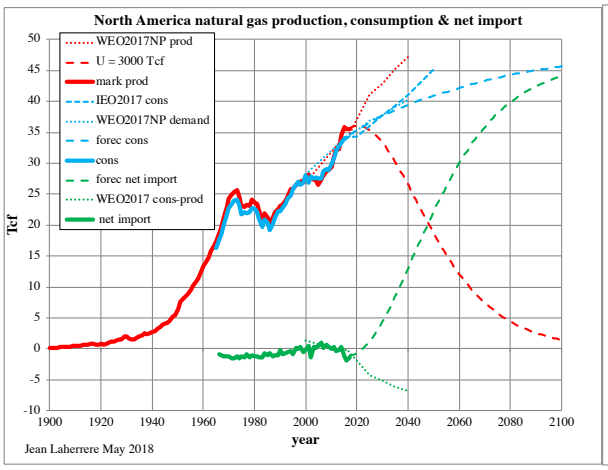
ExxonMobil Energy Outlook 2018 displays the 2000-2040 world all liquids supply, mainly tight oil, showing that the world conventional crude and condensate has peaked in 2005.
Unconventional oil in 2040 is first tight oil (shale oil is not mentioned), second deepwater and third oil sands, but tight oil is less than NGLs.
North America liquids supply is forecasted in 2040 at 33 Mboe/d, with net exports at 9 Mboe/d = 3.3 Gb

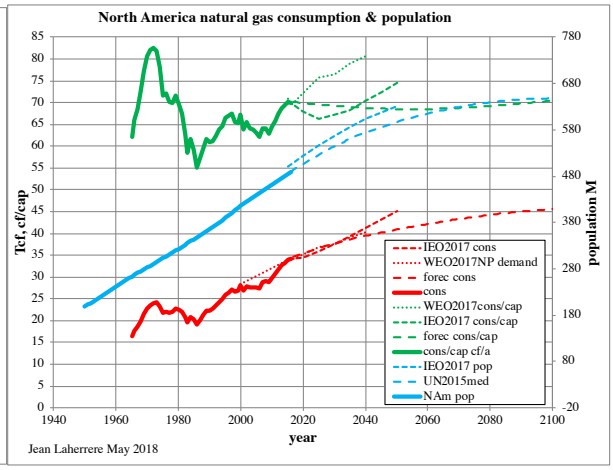




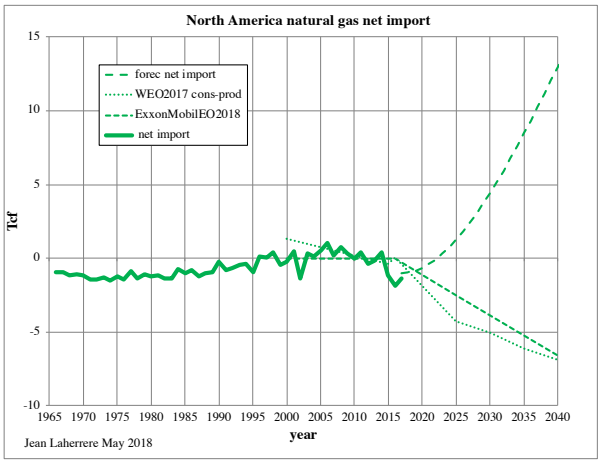
-**North America gas**

NAm marketed natural gas production has peaked in 1973 at 25 Tcf and is at 35 Tcf in 2017. With an EUR of 3000 Tcf (US2500, Canada 400 and Mexico 110) the NG production will peak soon and will decline to 26.5 Tcf in 2040 against a forecast of 47 Tcf for WEO 2017 NP. NG consumption was close to the NG production from 1965 to 2015. My forecast based on the UN population forecast and consumption per capita in 2050 is 41 Tcf against 45 Tcf in IEO2017.

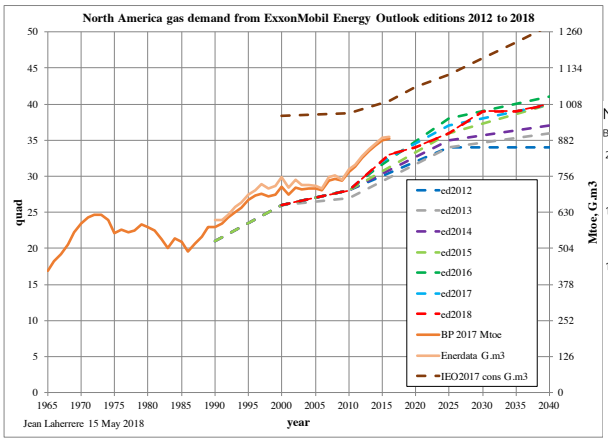




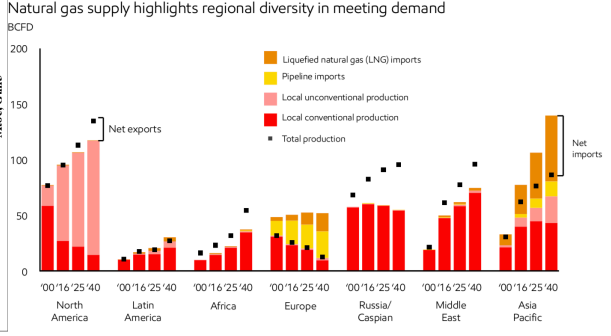
North America natural gas import in 2040 is forecasted to be 12 Tcf by me, but -7 Tcf by IEA/WEO2017NP and ExxonMobilEO2018: the difference is huge = 19 Tcf



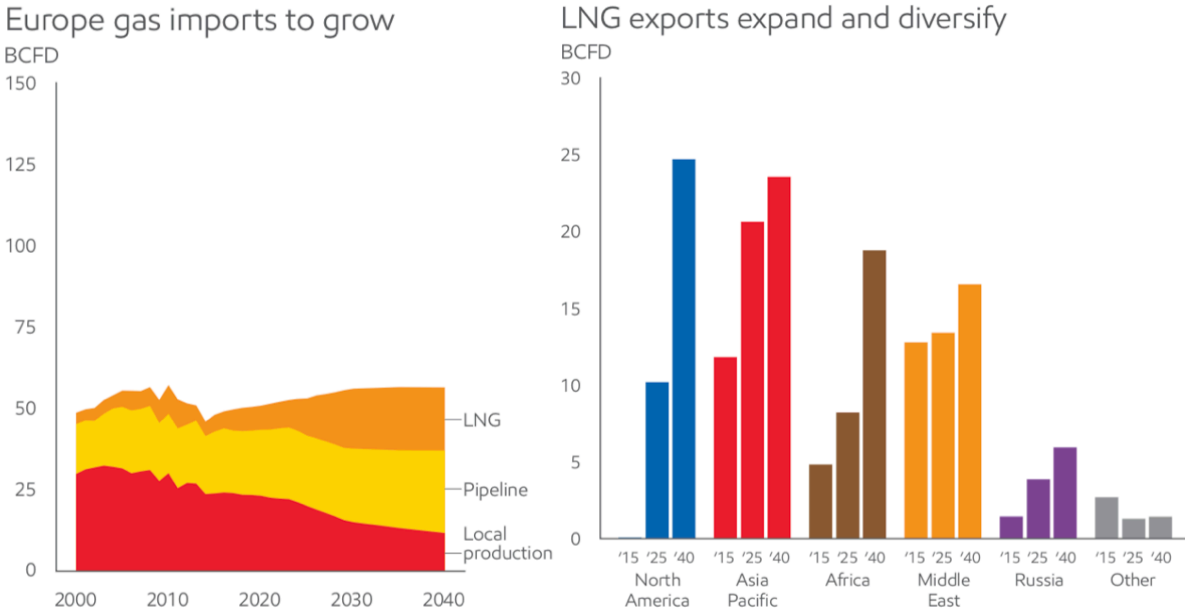
ExxonMobil Energy outlook forecasts North America gas demand in quad since the edition of 2012 and the forecast for 2040 did vary from 34 to 41 quads (0.85 to 1 Gtoe), against 1.3 Gtoe for EIA/IEO 2017



ExxonMobilEO2018



ExxonMobil EO2017 (not EO2018) displays for Europe in 2040 an LNG import of 20 Gcf/d (7.3 Tcf) and for North America a LNG export of 25 Gcf/d (9 Tcf), against my forecast of a negative export of – 12 Tcf



-Conclusion

The IEA/WEO2017 NP forecasts that North America in 2040 will export 7 Tcf of NG (ExxonMobil forecast is 9 Tcf of export for LNG alone) and 6 Mb/d of oil, against my forecast of an import of 12 Tcf and of 14 Mb/d: the difference is drastic, like day and night. Our society of consumption is based on future growth and it is politically correct to forecast growth: it is what every energy agency is doing, without real justification of their forecasts (which have no relationship with their reserves estimates). Unfortunately, extrapolation of past production data with precise assumptions shows different forecasts.
The IEA is very optimistic in reducing NAm oil and gas consumption (much more than the EIA) and in increasing oil and gas production, thanks to shale plays, believing that there is no limit in increasing the number of wells, when the present sweet spots are already well drilled and new wells interfering with old ones (frac hits). As Mark Papa said "technology improvements can't cure bad rocks". Shale play activity is based on cheap loans and the amount of debt is very high.

The forecast of large North America LNG exports to Europe appears unlikely and the competition with North Stream II unfounded (present pressure of Donald Trump on Angela Merkel). Europe is counting on LNG from North America in 2040, but North America will need to import NG instead and to reduce their consumption.

Oil and gas production and consumption data should reflect energy use and data in volume (Gb & Tcf) is misleading because of the variation of heat content, but it appears that the US main energy consumers and producers are unable to provide reliable historical values of heat content. Inaccuracy of energy data could be as high as 10% and energy data should be reported only with 2 significant digits. IEA data with 5 significant digits shows that the sources do not realize how bad their data is (bad in definition, bad in measures & bad in lack of historical annual & cumulative series).

The first thing is that data used for production forecast should be better defined with only few items as crude oil, crude oil + NGL and all liquids.
It is a shame that not a single energy agency provides good historical and reliable energy data. In the past the EIA was the most reliable & friendly world data open source. Unfortunately, due to budget cuts and lack of good management, EIA data quality is deteriorating.

NB on units
- EIA (Annual Energy Review) AER 1993 to AER 2010, Appendix B
Data presented in the Annual Energy Review and in other Energy Information Administration publications are expressed predominately in units that historically have been used in the United States, such as British thermal units, barrels, cubic feet, and short tons. However, because U.S. commerce involves other nations, most of which use metric units of measure, the U.S. Government is committed to the transition to the metric system, as stated in the Metric Conversion Act of 1975 (PublicLaw94–168), amended by the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100–418), and Executive Order 12770 of July 25, 1991.
Public Law 100–418, the Omnibus Trade and Competitiveness Act of 1988, states: "It is the declared policy of the United States—
(1) to designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce. . . .
(2) to require that each Federal agency, by the end of Fiscal Year 1992, use the metric system of measurement in its procurements, grants, and other business–related activities."{45}
It is a dead declared policy!

AER was replaced in 2012 by MER= Monthly Energy Review
-MER-April 2018 Appendix B:
Data presented in the Monthly Energy Review and in other U.S. Energy Information Administration publications are expressed predominately in units that historically have been used in the United States, such as British thermal units, barrels, cubic feet, and short tons. The metric conversion factors presented in Table B1 can be used to calculate the metric-unit equivalents of values expressed in U.S. Customary units. For example, 500 short tons are the equivalent of 453.6 metric tons (500 short tons x 0.9071847 metric tons/short ton = 453.6 metric tons).

-US-metric.org http://www.us-metric.org/a-chronology-of-the-metric-system/
1982 President Ronald Reagan disbanded the U.S. Metric Board and canceled its funding. Responsibility for metric coordination was transferred to the Office of Metric Programs in the Department of Commerce.
198 The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) amended and strengthened the Metric Conversion Act of 1975, designating the metric system as the preferred measurement system, and requiring each federal agency to be metric by the end of fiscal year 1992.
1991 President George H. W. Bush signed Executive Order 12770, Metric Usage in Federal Government Programs directing all executive departments and federal agencies implement the use of the metric system. The Executive Order is also available as an appendix to: Interpretation of the SI for the United States and Federal Government Metric Conversion Policy

1994 The Fair Packaging and Labeling Act (FPLA) was amended to add a requirement for metric units on most consumer products.
1996 April 15 All four Canadian Stock Exchanges began decimal trading, the first exchanges in North American to abandon the old "pieces-of-eight" trading system and welcome the new decimal system. The old tradition of trading stocks in increments of one-eighth of a dollar, or 12.5 cents, dates back to when the Spanish mille dollar was divided into "pieces of eight".
1996 July All surface temperature observations in National Weather Service METAR/TAF reports are now transmitted in degrees Celsius.
2000 September 30 Now suspended, the deadline for metricating highway construction, including all agreements, contracts, and plans processed by individual states for federally-funded highway construction to be in metric units, was canceled by Congressional action, leaving metric conversion as voluntary but still recommended to comply with the Omnibus Trade and Competitiveness Act of 1988.
2001 April 09 U.S. Stock Exchanges finalized the change to decimal trading. The Securities and Exchange Commission has ordered that all stocks must be quoted in dollars and cents rather than fractions by this date. The switch to decimal trading brought the U.S. in line with the rest of the world's major exchanges. This follows the change of the Canadian Stock Exchanges to decimal trading in 1996.
2004 July 08 UK Metric Association (UKMA) issued a comprehensive report, A Very British Mess, on the need to complete UK metrication.
2005 January 20 Speed limits in Ireland were converted from miles per hour to kilometers per hour (km/h). To accompany this, new cars have kilometers as the primary speed displayed on their speedometers. Wind speeds in weather reports were also changed to kilometers per hour. See the Irish Department of Transport announcement.
2007 January 08 "Metric Moon" press release: NASA has decided to use metric units for all operations on the lunar surface when it returns to the Moon. See the NASA announcement. NASA's Constellation Program is to be metric, according to a Program Management Directive issued on 19 December 2007, with the metric system as the "primary system of measure" for the Constellation Program, Projects, Systems, and Mission.
2009 December 31 Now suspended indefinitely, the EU measurement directive that would have banned non-metric units in Europe (with limited exceptions, and with dual-labeling of products not permitted), has been canceled by the EU Commission, hoping in return that U.S. regulations will allow voluntary metric-only labeling on consumer products. The U.S. should allow metric-only packaging by amending the Fair Packaging and Labeling Act (FPLA). This would be a good response to the elimination of EU requirements for SI-only labels which had been planned to take effect at the end of 2009.

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The US, Liberia and Myanmar are the only countries where the SI (International System of units) is not the law (except for the next US trip to the moon: with the 2007 Metric Moon). Mars Climate Orbiter probe has crashed on Mars in 1998 when NASA sent the instructions in SI (Newton) but Lockheed had built the probe to receive instructions in pounds!