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ASPO France

US NG production & forecast

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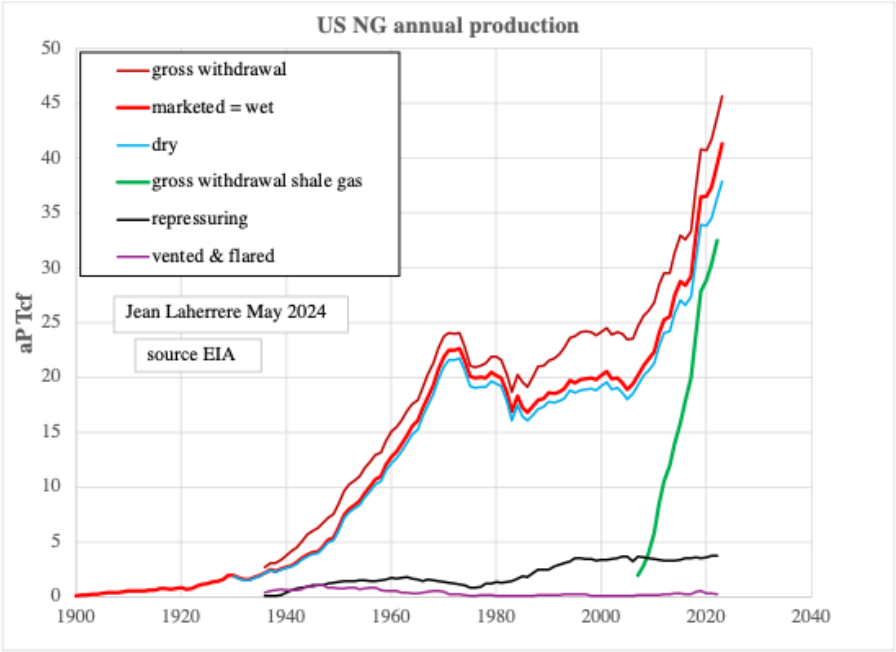
-introduction

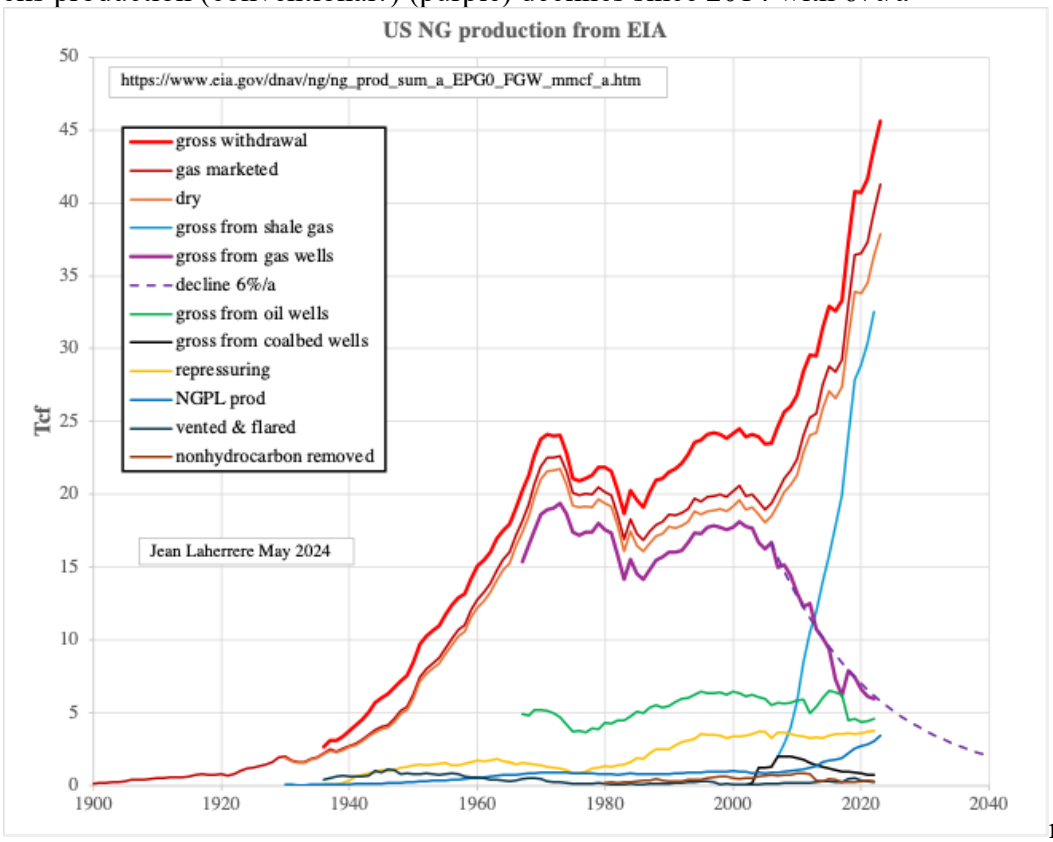
US NG production data is reported by EIA since 1900 with different products: gross, marketed, dry, repressuring, vented & flared and shale gas/

EIA reports marketed being wet

The dry production is after removal of NG liquids (NGL)

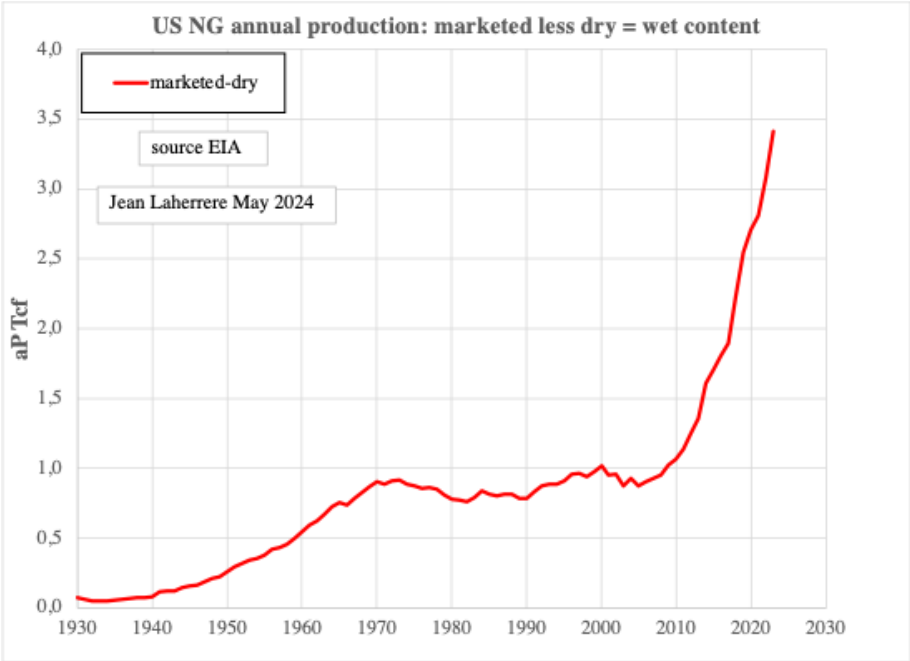


Another EIA site reports NG production from different kinds of wells where the gross from gas wells production (conventional?) (purple) declines since 2014 with 6%/a

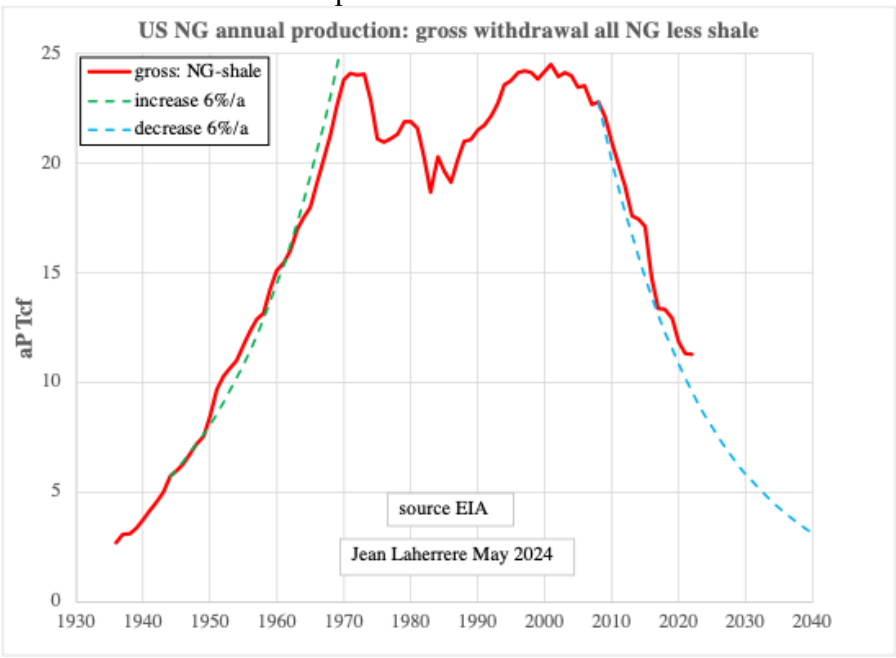


rent

The difference between marketed (wet) and dry production indicates the wet content in Tcf and has increased sharply since 2010 with shale gas from 1 Tcf to 3.5 Tcf



US conventional gas (gross withdrawal from all gas less from shale gas) displays a large decrease since 2008 with %/a symmetrical with the increase of 6%/a from 1945 to 1970. The decline of 6%/a should cover the period 2010-2050.



This beautiful symmetry, which is found also in USL49 oil production, is due to the large number of producers and fields. (not the case in Alaska)

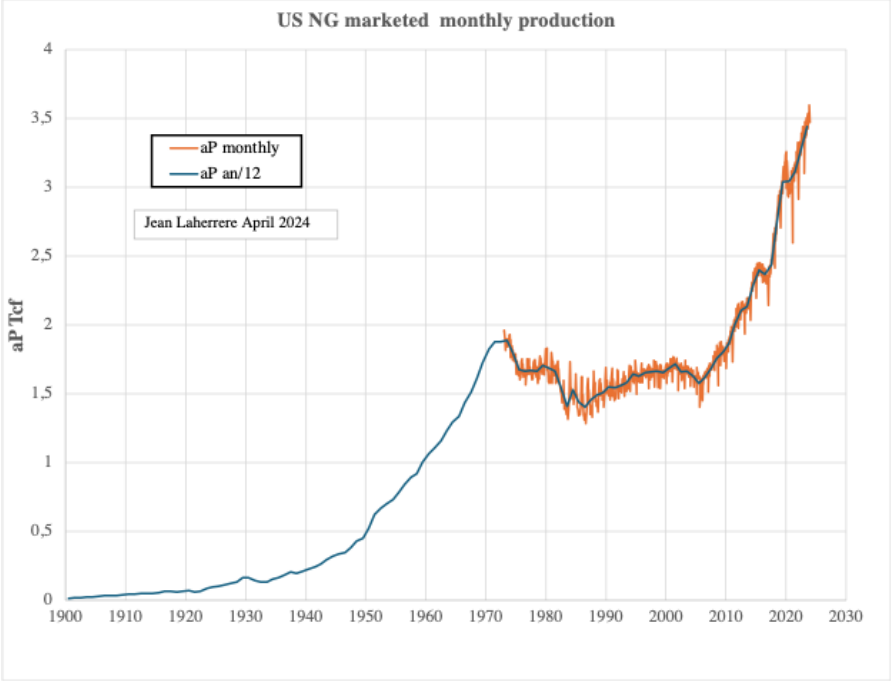
In 2023 US marketed shale production is 41 Tcf with 29 Tcf of shale gas = 71 %
Shale gas production, which started in 1821, is very important in the US gas market.
My previous paper on US shale gas is from 2023 where I remind that US shale gas production started in Fredonia (NY) in 1821 https://aspofrance.org/2023/03/17/https-aspofrance-files-wordpress-com-2023-03-ngultimatemarch2023-pdf/ well before the start of crude oil in 1859

Shale Gas History

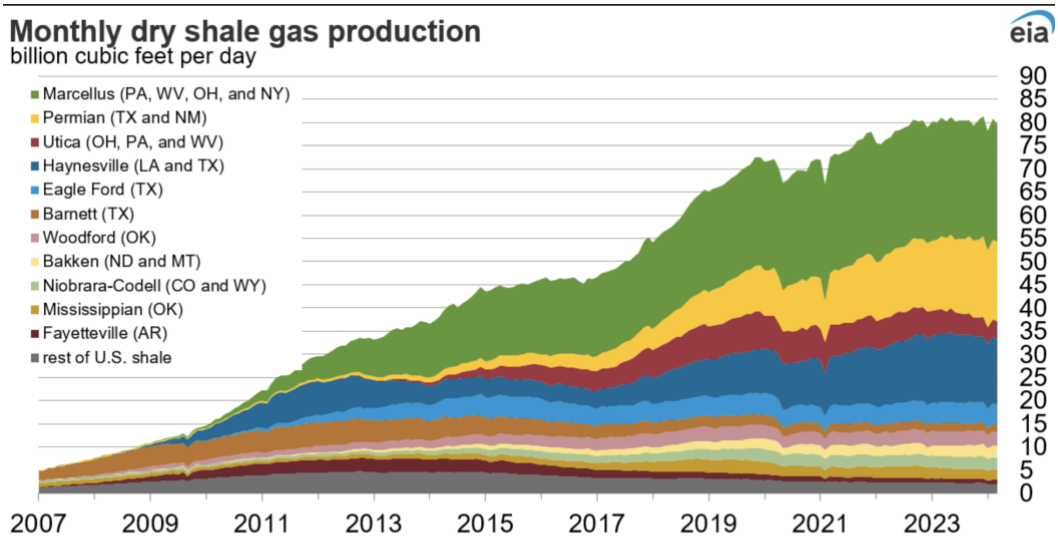
- First Commercial Gas well – Fredonia, NY (1821)
  - New York's "Dunkirk Shale" at a depth of less than 30 feet
- Ohio Shale – Big Sandy Field (1880)
- Hydraulic Fracturing used in the Oil & Gas Industry (1950-60s)
- Barnett Shale – Ft. Worth Basin Development (1982)
- Horizontal wells in Ohio Shales (1980s)
- Successful Horizontal Drilling in Barnett Shale (2003)
- Horizontal Drilling Technology Applied in Appalachian Basin, Ohio and Marcellus Shales (2006)
- Horizontal Drilling and Hydraulic Fracturing are key technologies in the economic success of modern Shale Gas Development

The success of shale gas production is due to horizontal wells and fracking.

US marketed NG production is reported by EIA monthly and annually, showing a peak in 1972 and a future one beyond 2023



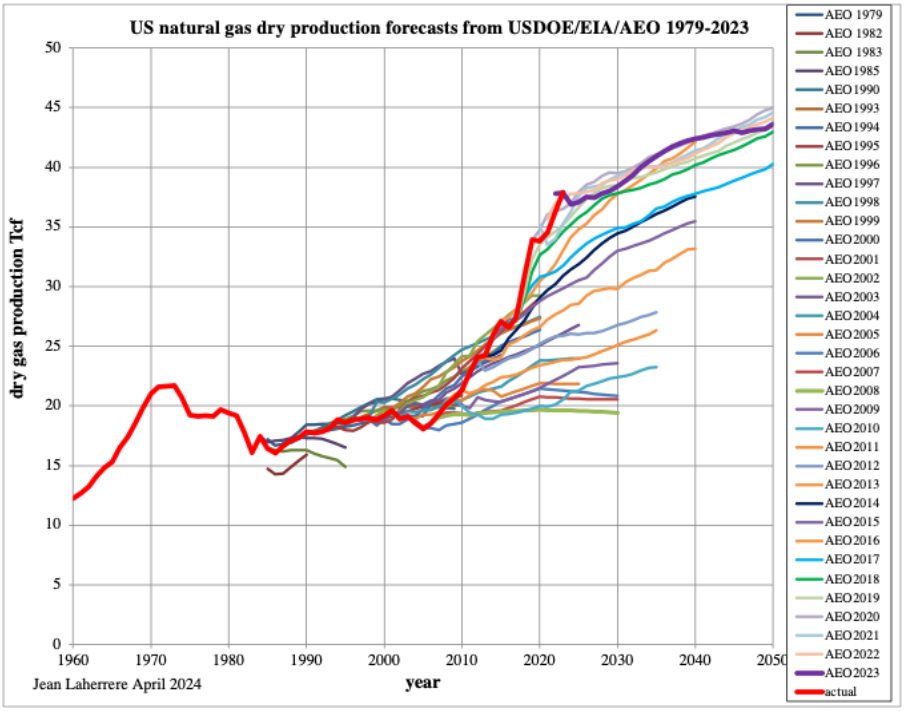
US monthly dry shale gas is displayed by EIA (source Enverus) from 2007 to March 2024 where it is flattening for many months:



Data source: Enverus.
Note: Starting on June 11, 2024, these estimates will be published in the *Short-Term Energy Outlook* data tables. We derived these shale gas estimates from Enverus state administrative data. Data are through March 2024. PA=Pennsylvania, WV=West Virginia, OH=Ohio, NY=New York, TX=Texas, NM=New Mexico, LA=Louisiana, OK=Oklahoma, ND=North Dakota, MT=Montana, CO=Colorado, WY=Wyoming, AR=Arkansas

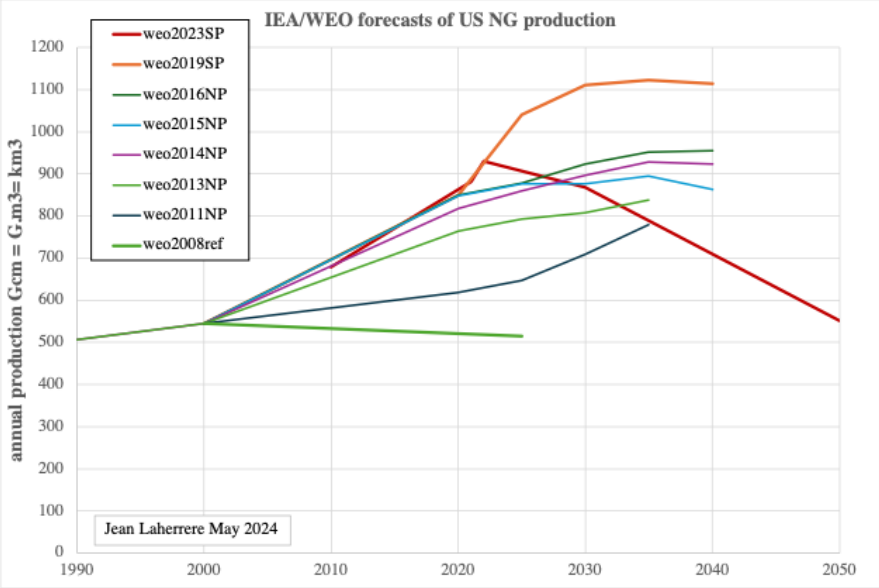
The main shale gas play is Marcellus
EIA reports monthly shale gas production for 12 plays in 2 different files (?) when the first one covers January 2000-February 2024 and the second January 2000-March 2024
https://www.eia.gov/energyexplained/natural-gas/where-our-natural-gas-comes-from.php
https://www.eia.gov/naturalgas/data.php#production
It is a waste of time and effort to have 2 different sets very close but different: where is the boss!

-past NG production forecasts
The past NG production forecast by EIA/AEO has varied sharply.
AEO2008 forecasted US dry gas production at 19.6 Tcf for 2023 when real = 37.9 Tcf= 94 % too low = about half!

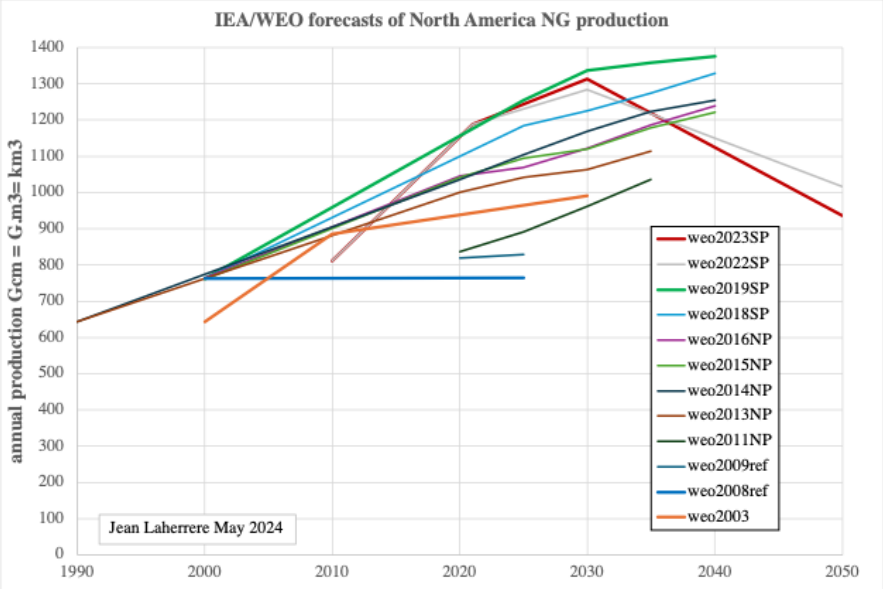


EIA does not forecast any production peak before 2050
EIA ignores production peak, except from 2006 to 2008 with a NG peak around 2020!

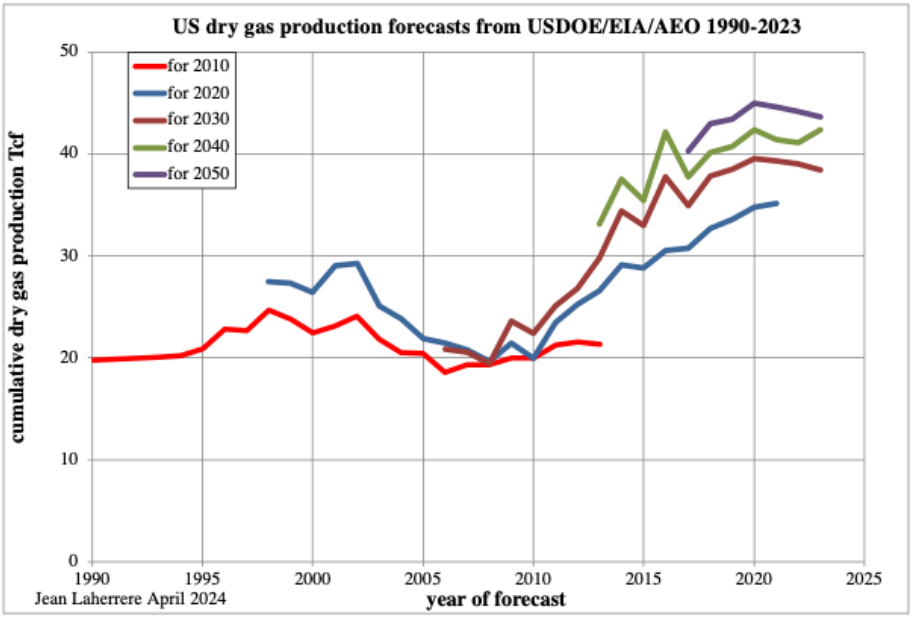
IEA with WEO displays a large range of US NG production forecasts.
The last forecast WEO2023 SP (brown) is a peak between 2022 and 2030; before it was beyond 2030



For North America: peak in 2030 for WEO2023SP, when before it was beyond 2040

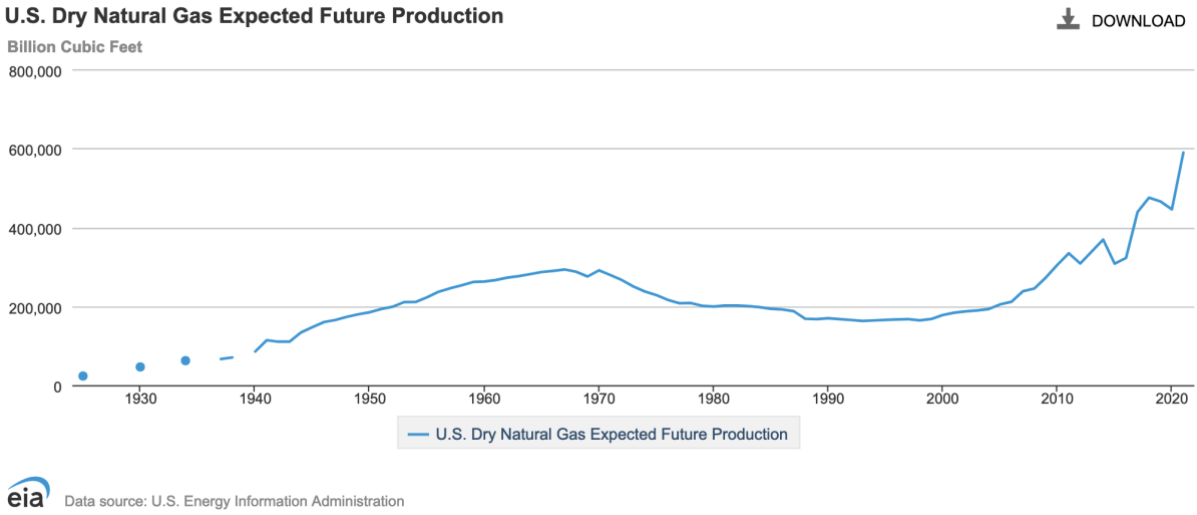


EIA forecast for US NG dry gas production for 2030 (brown) was 20 Tcf in 2008 against the double in 2023.
US shale gas burst was not forecasted before 2015!

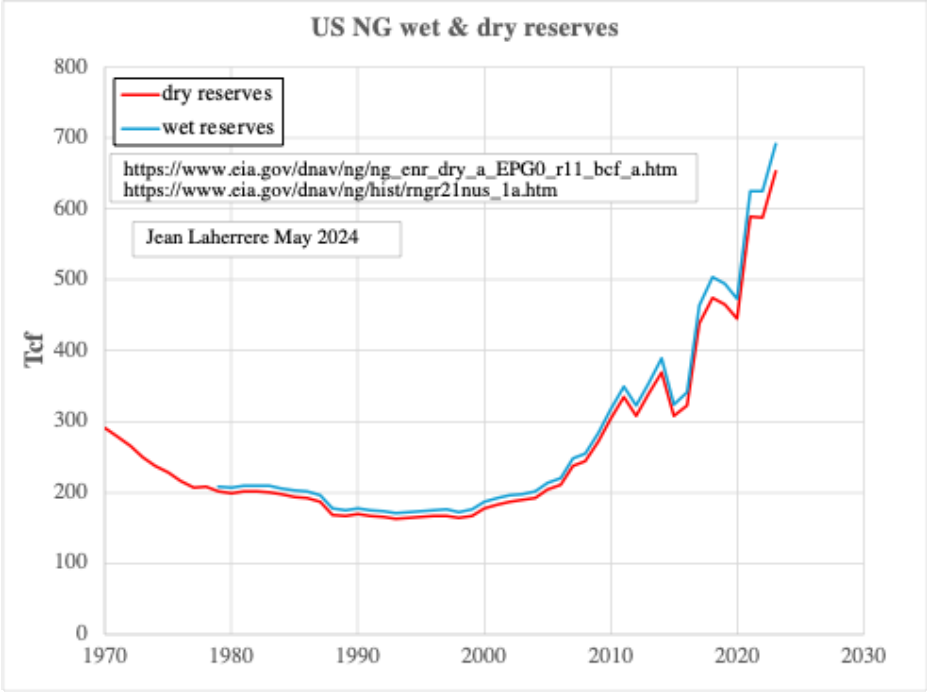


-US NG reserves

EIA reports since 1925 dry reserves as being dry natural gas expected future production
https://www.eia.gov/dnav/ng/hist/rngr11nus_1a.htm

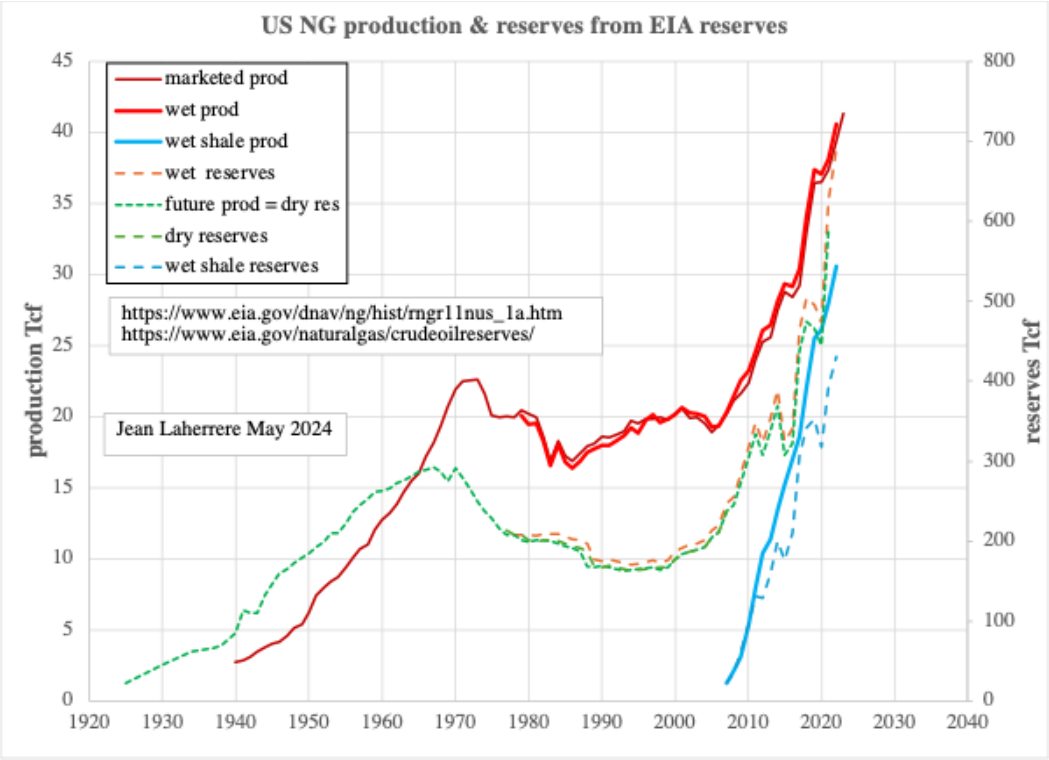


EIA reports both dry and wet NG reserves since 1979 and they are close about 5%

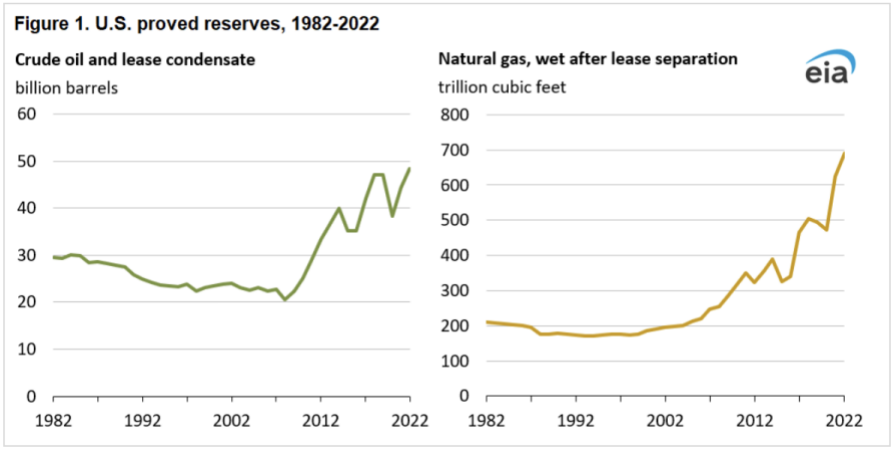


EIA/ARI 2013 “world shale gas and shale oil resource assessmen” estimated a risked gas in place of 35 782 Tcf (4644 for US) and reserves of 7795 Tcf (1161 for US)
This 2013 estimate looks very optimistic compared with present US reserves estimates

US NG production has a first peak in 1970 (as crude oil) when NG remaining reserves has a peak in 1968

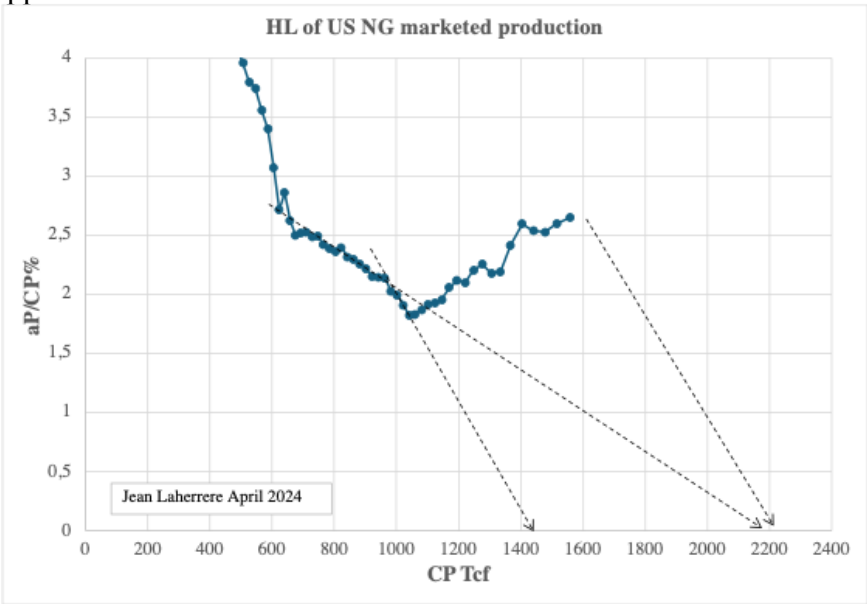


EIA reports NG proved reserves for crude oil and wet gas after lease separation
https://www.eia.gov/naturalgas/crudeoilreserves/

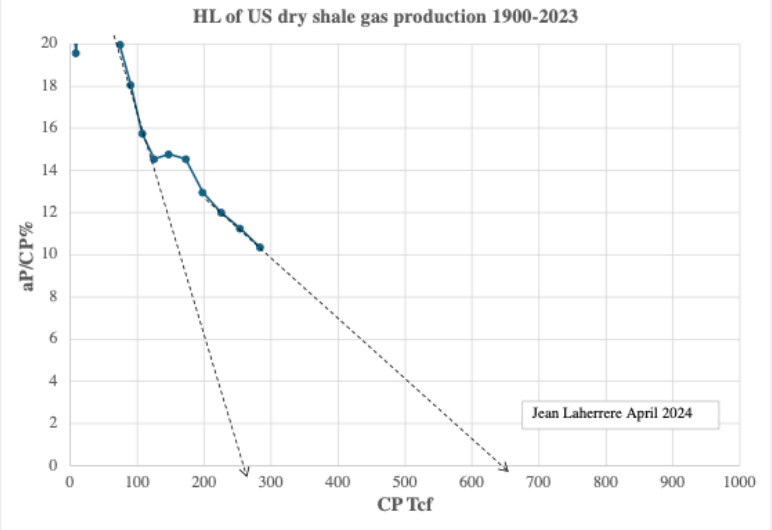


-US NG production forecasts

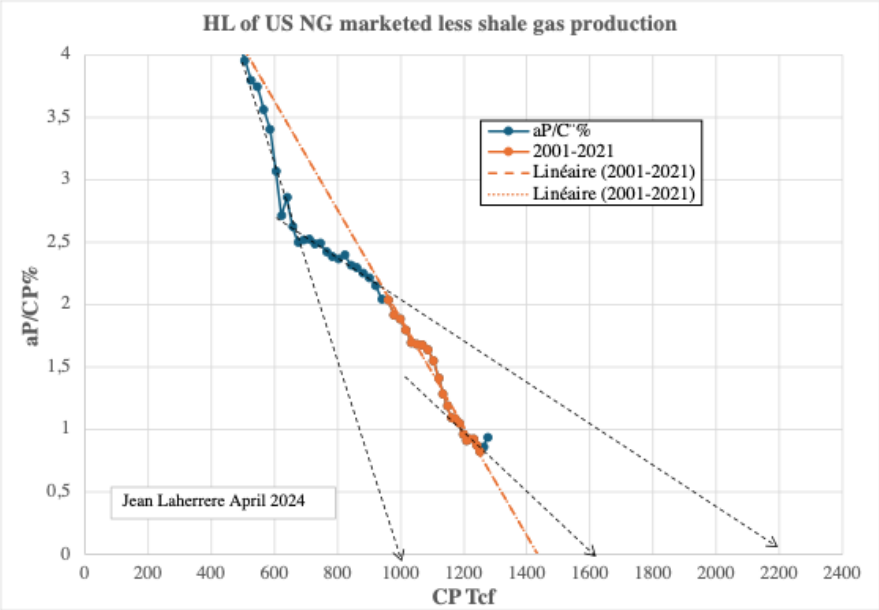
HL of US NG marketed production trends is useless and a value o of 2200 Tcf is guessed from other approaches.



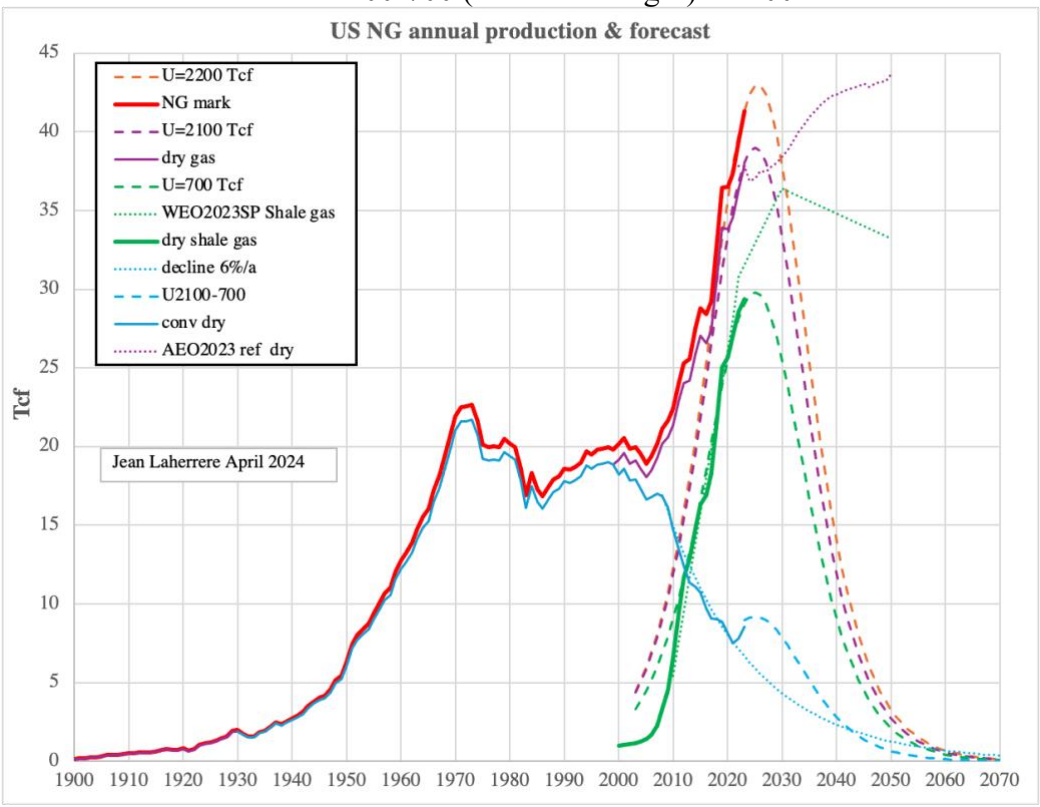
HL of US dry shale production trends towards 650 Tcf from the last 4 years period



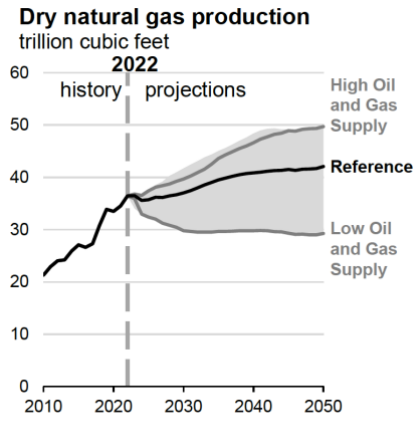
HL of US marketed (wet) less shale gas production = US conventional gas trends towards 1400 Tcf if forgetting the last 2 years



US conventional dry gas is plotted in blue, but the last 2 years is out of the past behavior, and it is forecasted for an ultimate of 2100-700 (all NG-shale gas) = 1400 Tcf

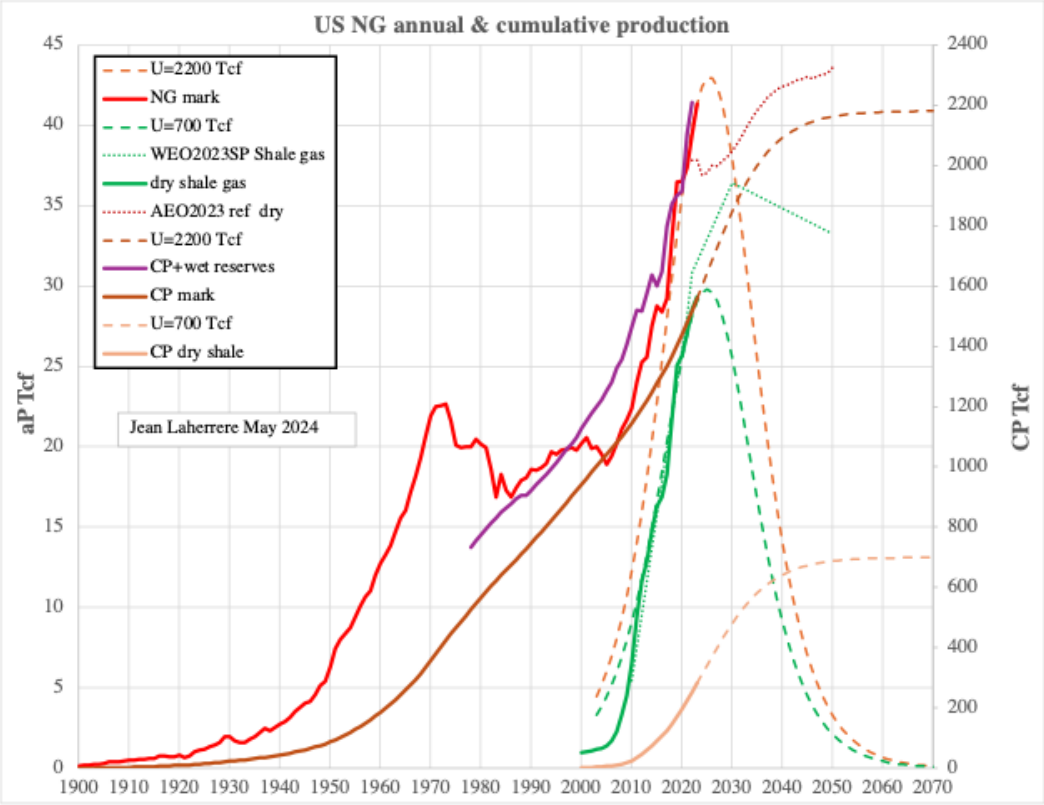


EIA-AEO 2023 forecasts no peak before 2050 for reference, only for low supply! But this forecast is contrary to real production in 2023.



ɔn, *Annual Energy Outlook 2023* (AEO2023)

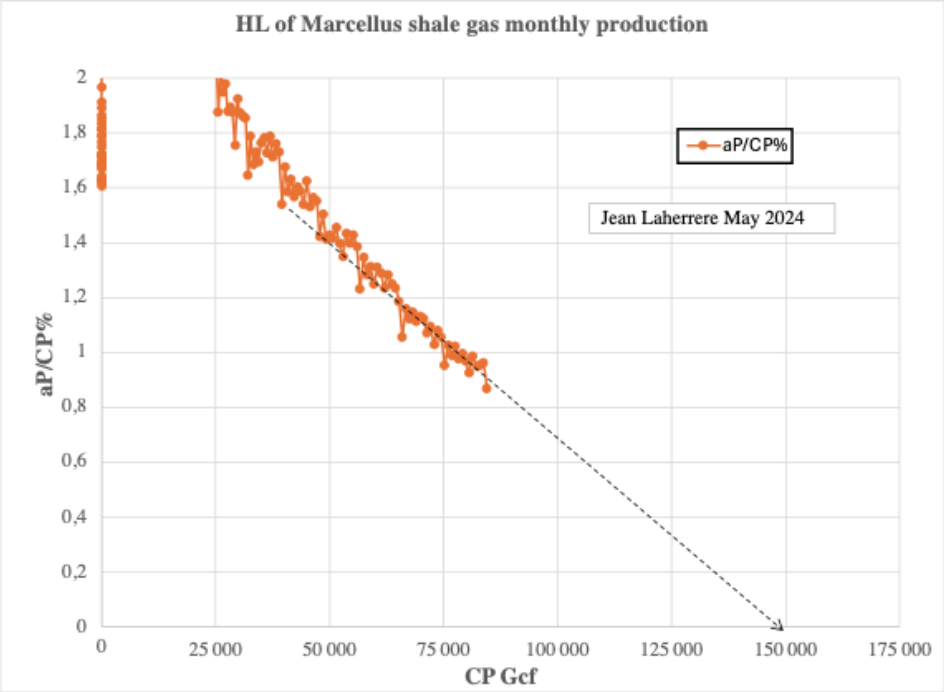
My forecast for US NG production is a peak around 2025, being due to shale gas peak.



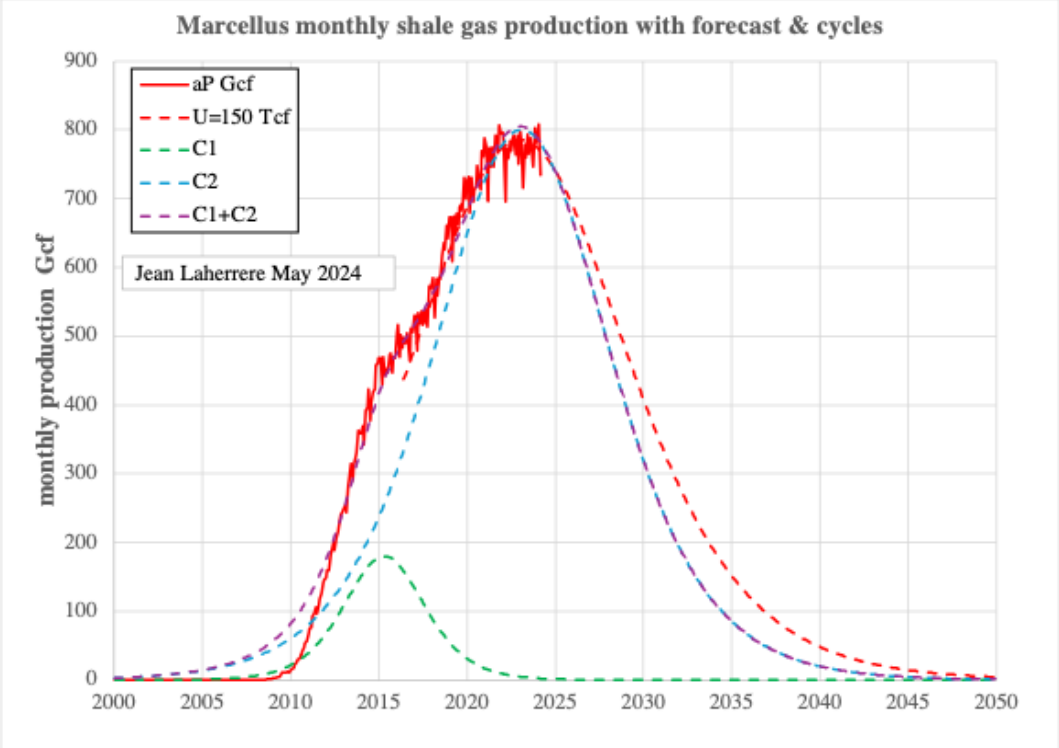
The forecast by shale play is given below:

-Marcellus

HL of Marcellus production trends towards 150 Tcf

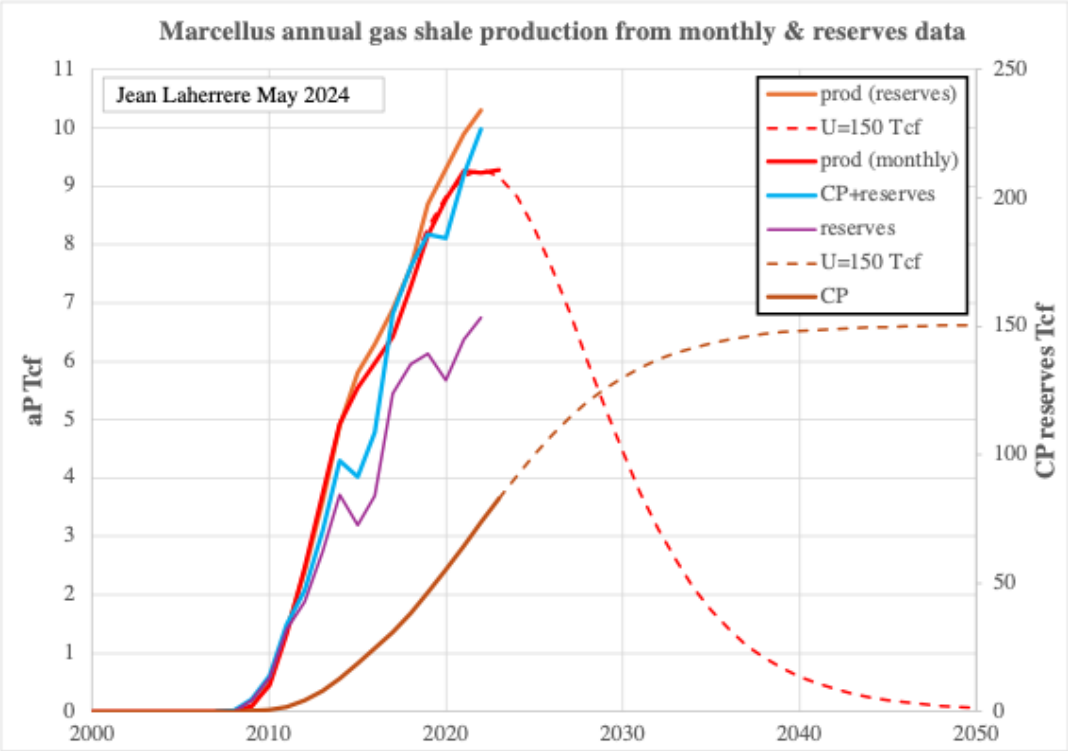


Marcellus production is modelled also with two cycles, close to the 150 Tcf forecast

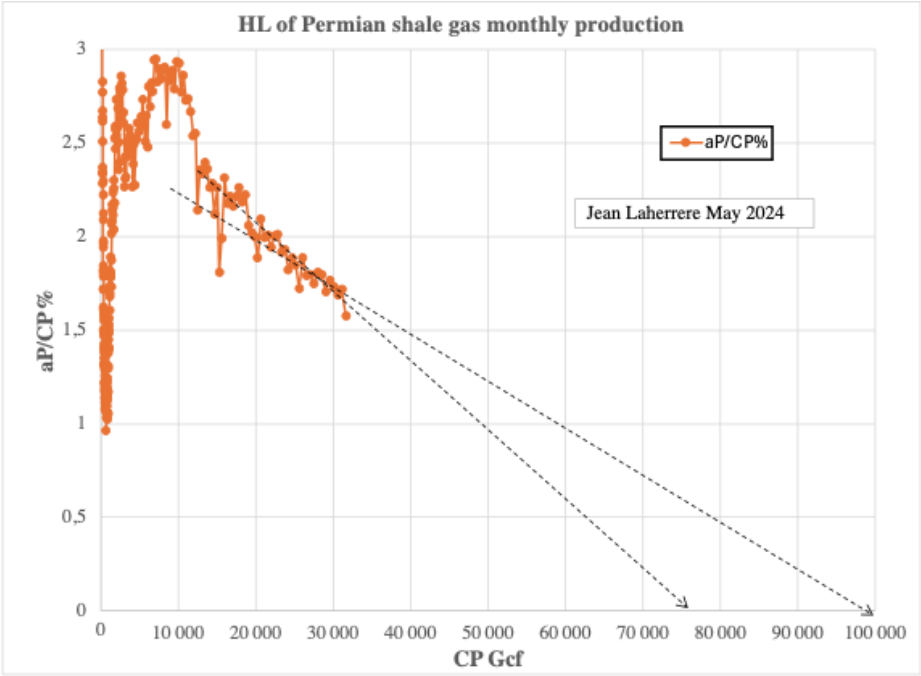


Nobody knows how to estimate shale gas reserves because there is not yet any depleted shale gas history to verify this practice! Barnett and Bakken ultimates are not far from CP+reserves, meaning close to depletion but their reserves have varied a lot: see further.
Furthermore, EIA does not report the way where reserves are estimated (volumetric, analog or performance)! There is no reliable study on shale gas recovery factor (range 5 to 60%?)
Neither how to well estimate shale gas in place: shale gas can be free or absorbed! Fracking works on fractures: how to measure the fractures? Up to now shale gas reserves estimates are guesses!

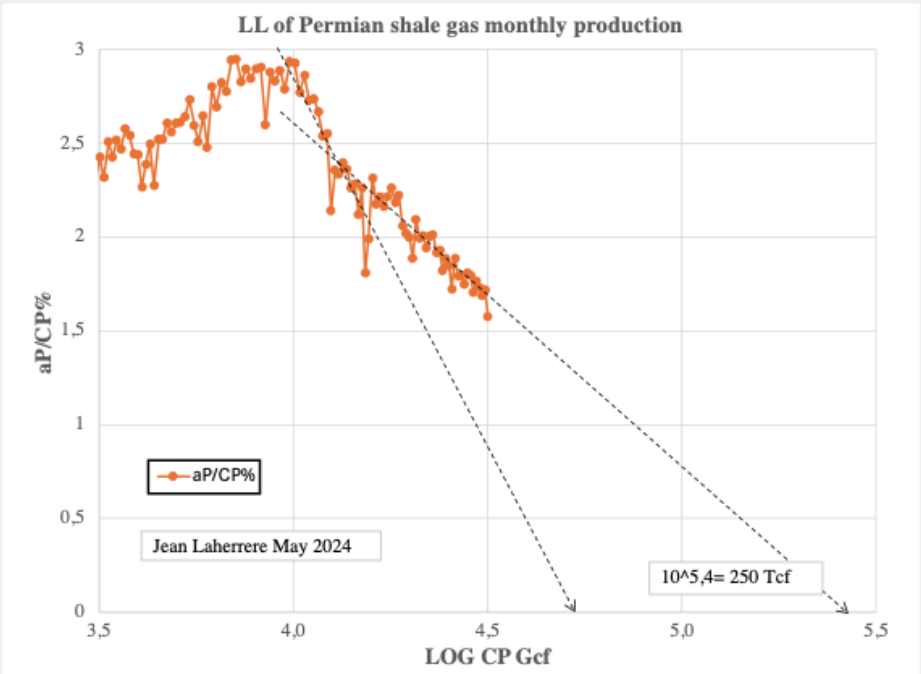
EIA annual reserves data reports annual shale production and reserves: production data are not too far, but the 2022 CP+reserves at 227 Tcf (blue curve) are too high compared with our 150 Tcf ultimate.
EIA/ARI 2013 Marcellus reserves were 369 Tcf!



-Permian
HL of Permian gas production trends towards 75 Tcf for the last 20 years but 100 Tcf for the last few years

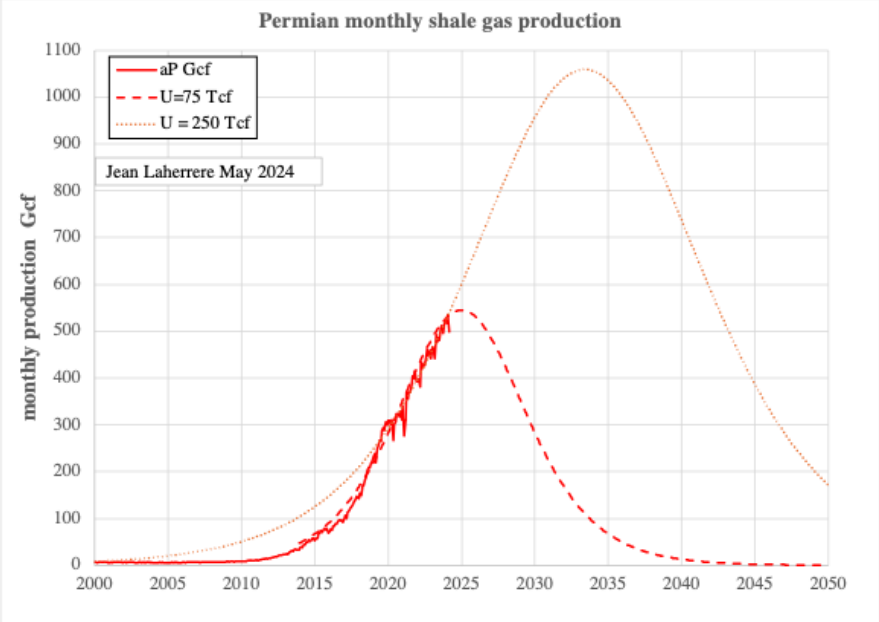


LL (log linear) trends towards 250 Tcf

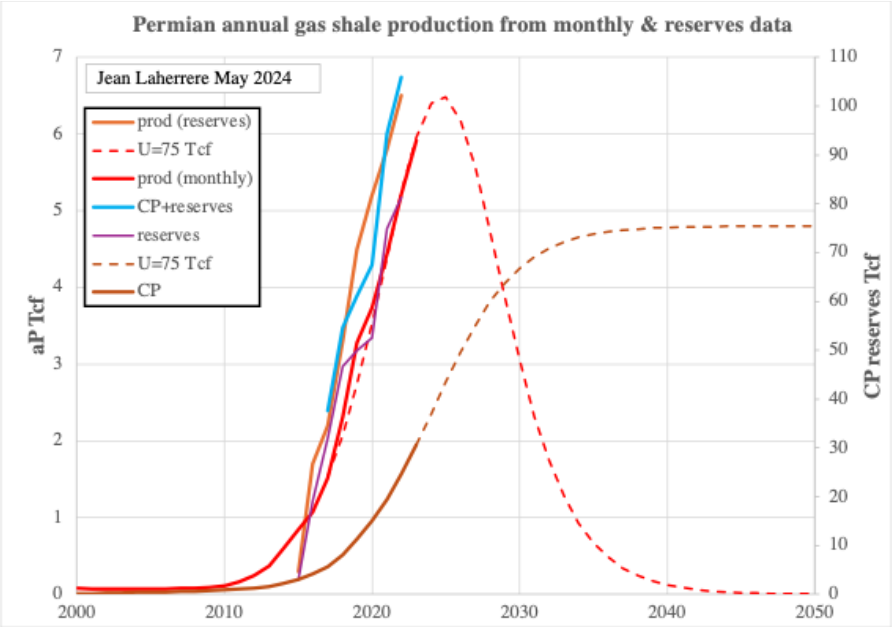


The forecast uncertainty range is huge!

With a 75 Tcf ultimate Permian production will peak soon in 2025 but with a 250 Tcf peak could be as far as in 2033!

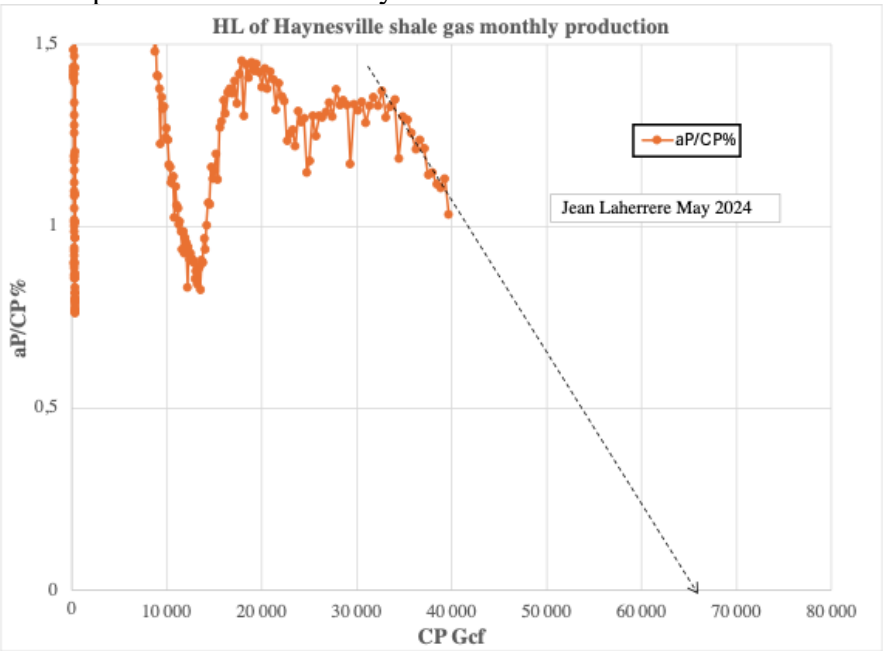


Permian gas annual production from EIA reserve (orange) s is higher than the data from monthly production (red) and the CP+reserves at 105 Tcf are high compared with the 75 Tcf from HL

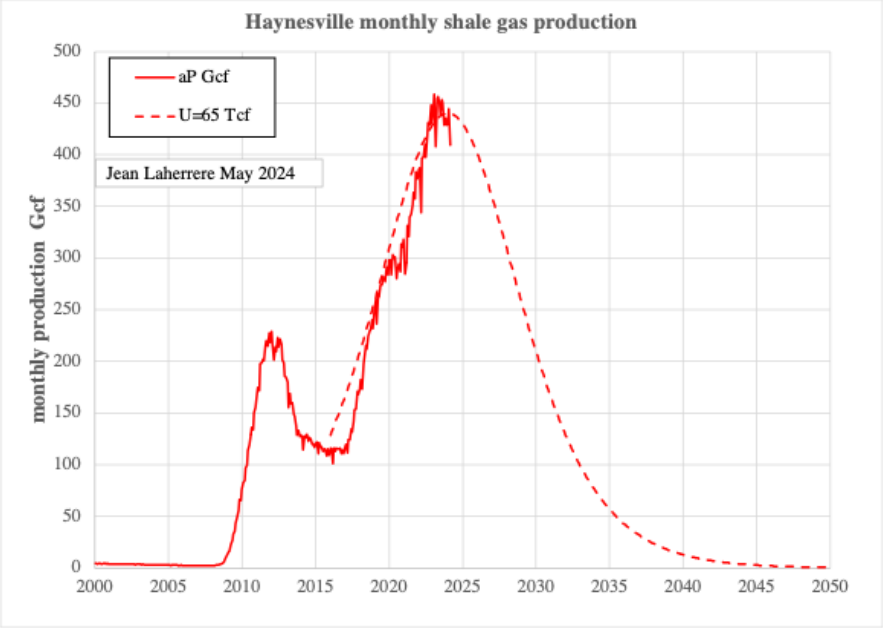


-Haynesville

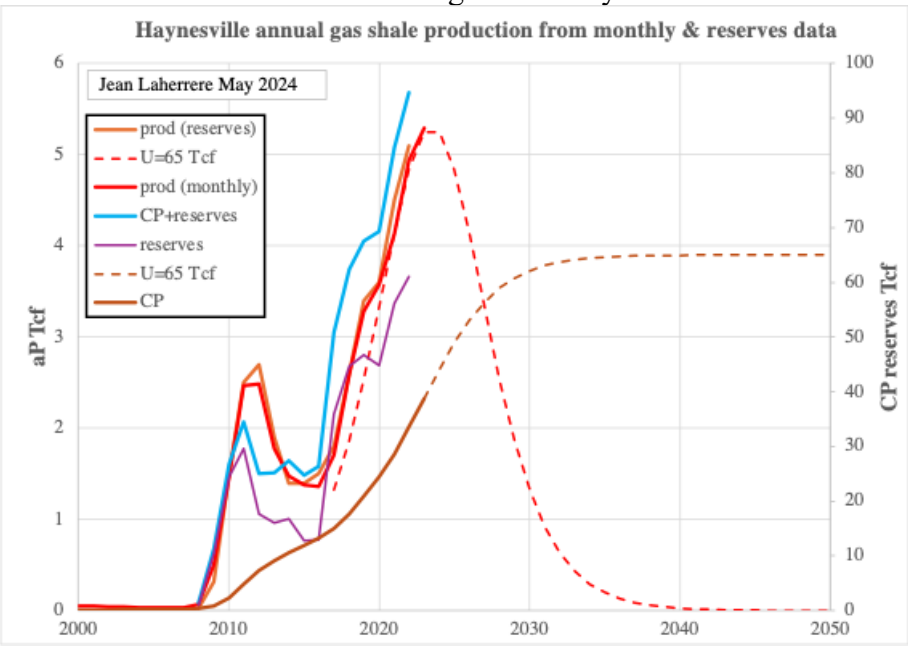
HL of Haynesville production trends fairly towards 65 Tcf



With a 65 Tcf Haynesville has peaked in 2023



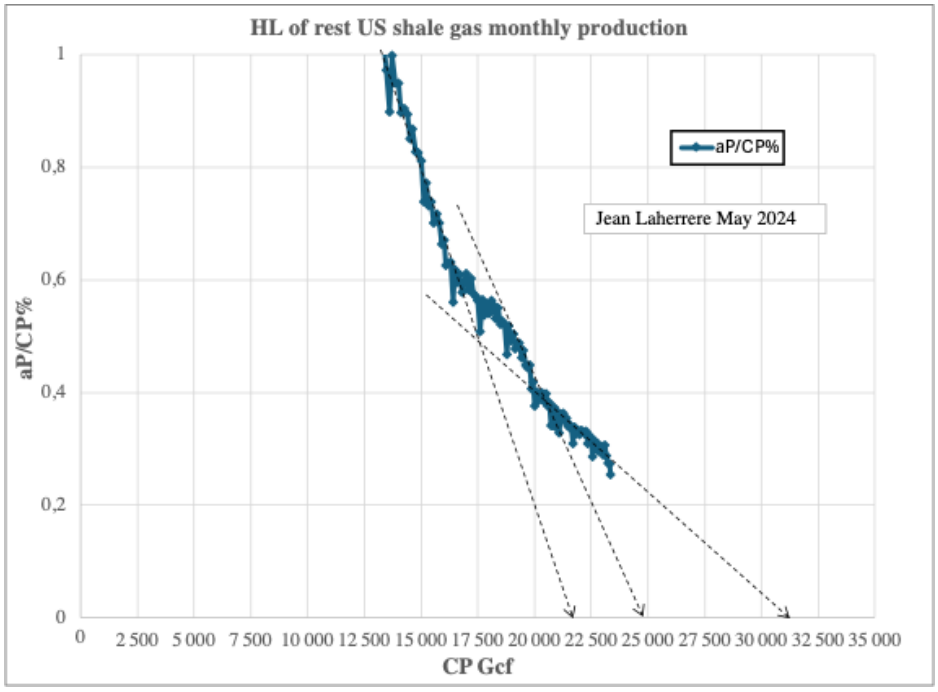
But EIA 2022 CP+reserves at 95 Tcf is 30 Tcf higher than my 65 Tcf ultimate



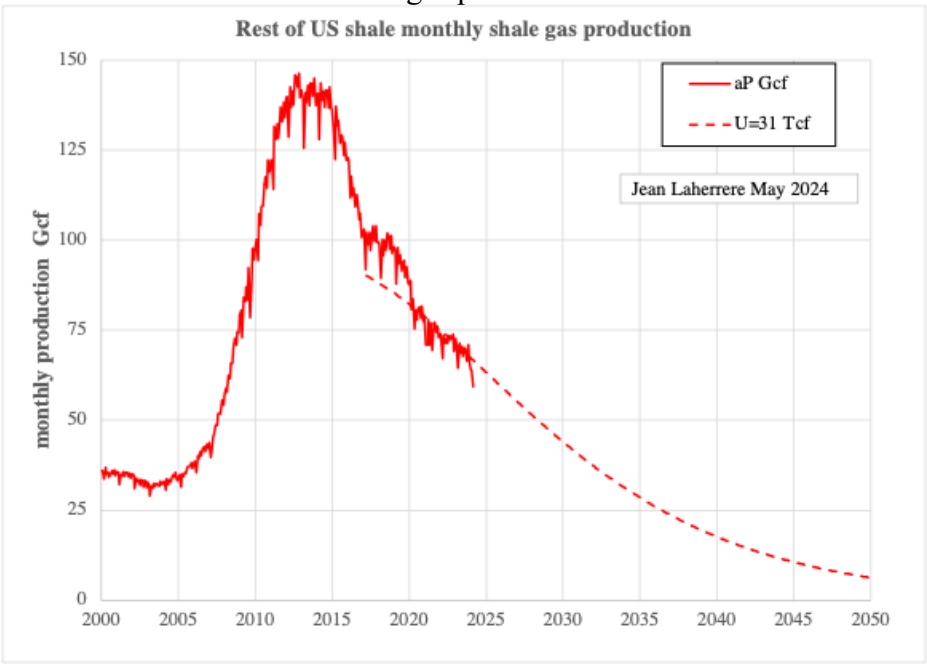
EIA shale gas 60 Tcf reserves are too high! But EIA/ARI 2013 reserves were higher with 161 Tcf!

-rest of shale plays

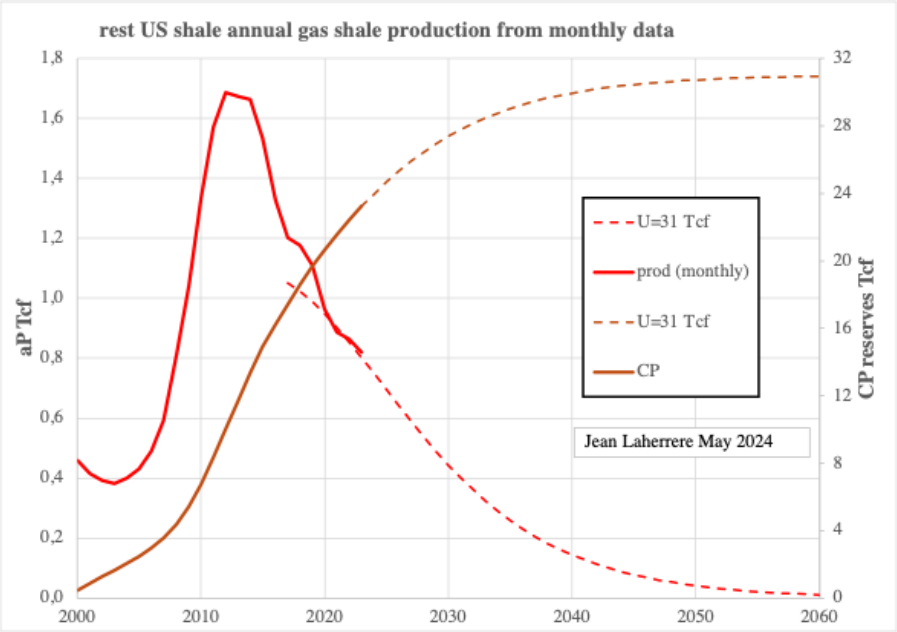
Hl of the rest of shale production trends towards 31 Tcf



With an ultimate of 31 Tcf US rest of shale gas production will continue to decline

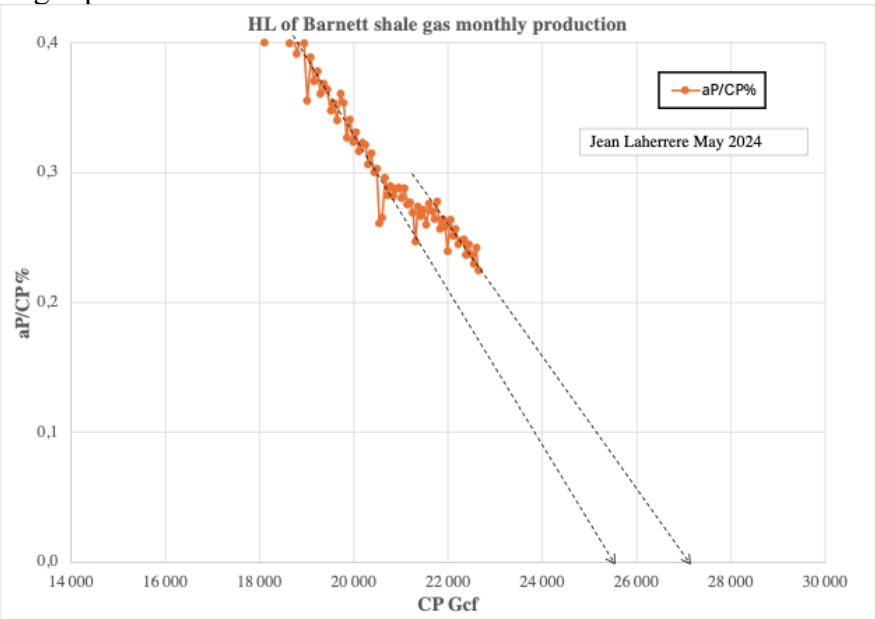


There is no data for rest of plays reserves. The annual data is displayed:

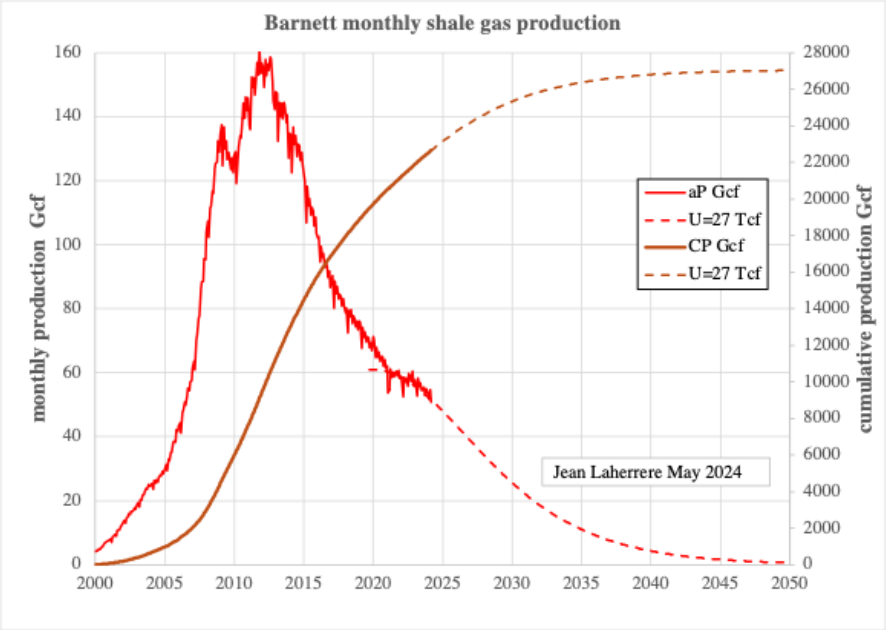


-Barnett

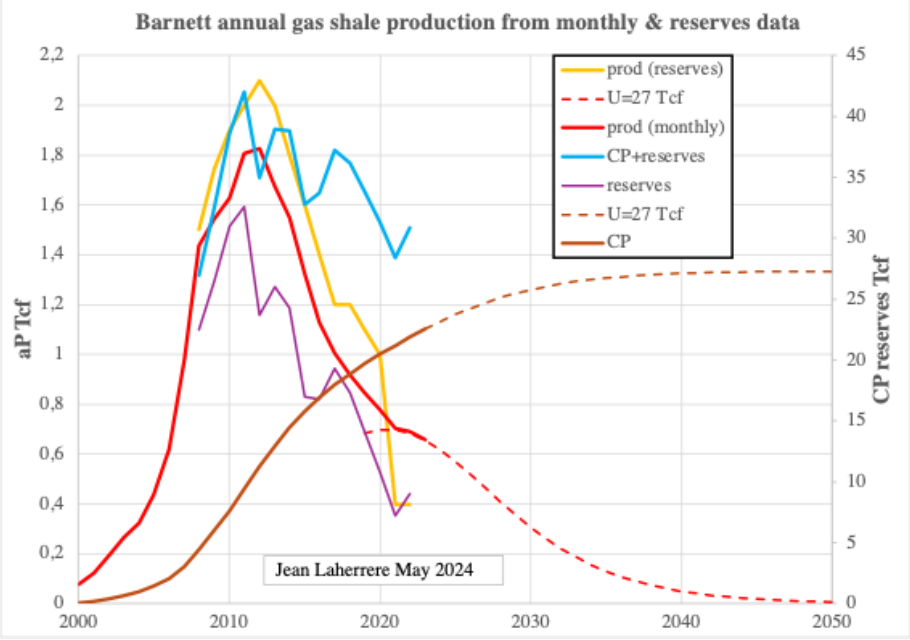
HL of Barnett gas production trends towards 27 Tcf



With a 27 ultimate Barnett production will continue to decline



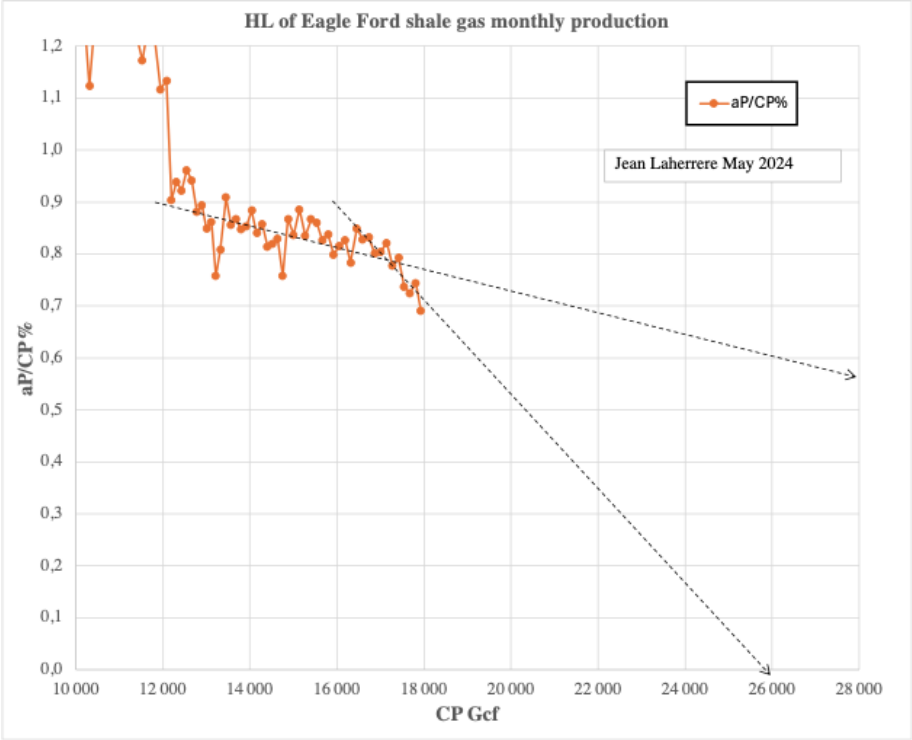
Barnett CP+reserves decline from 2011 to 2022, contrary with other shale plays: it means that the reserves estimate is not reliable, and our ultimate is taken lower



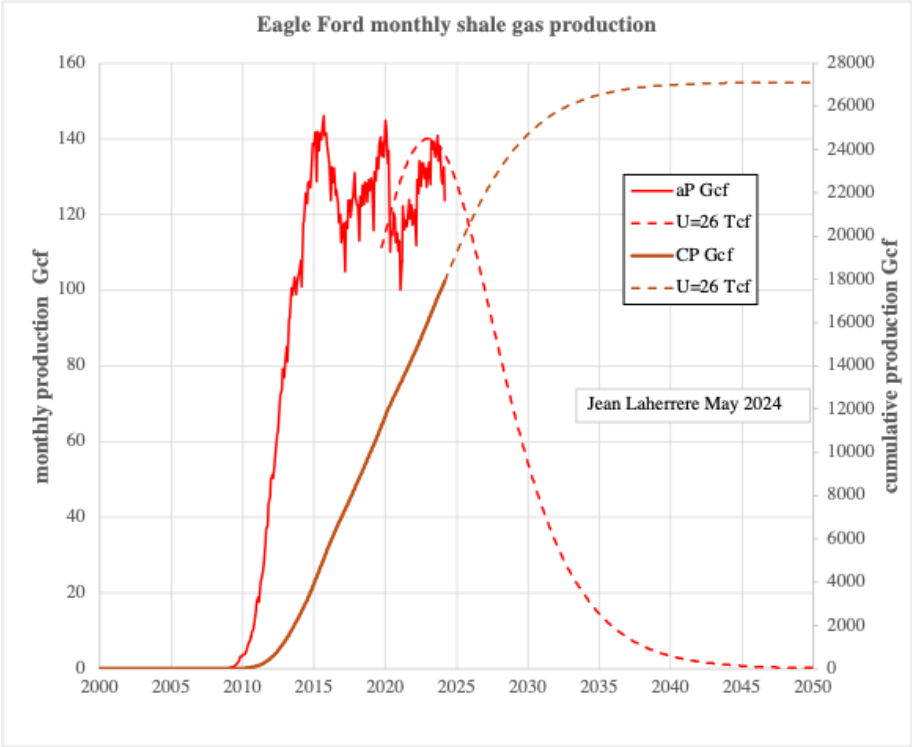
EIA/ARI 2013 Barnett reserves were 72 Tcf (25 Tcf now) : quite too high!

-Eagle Ford

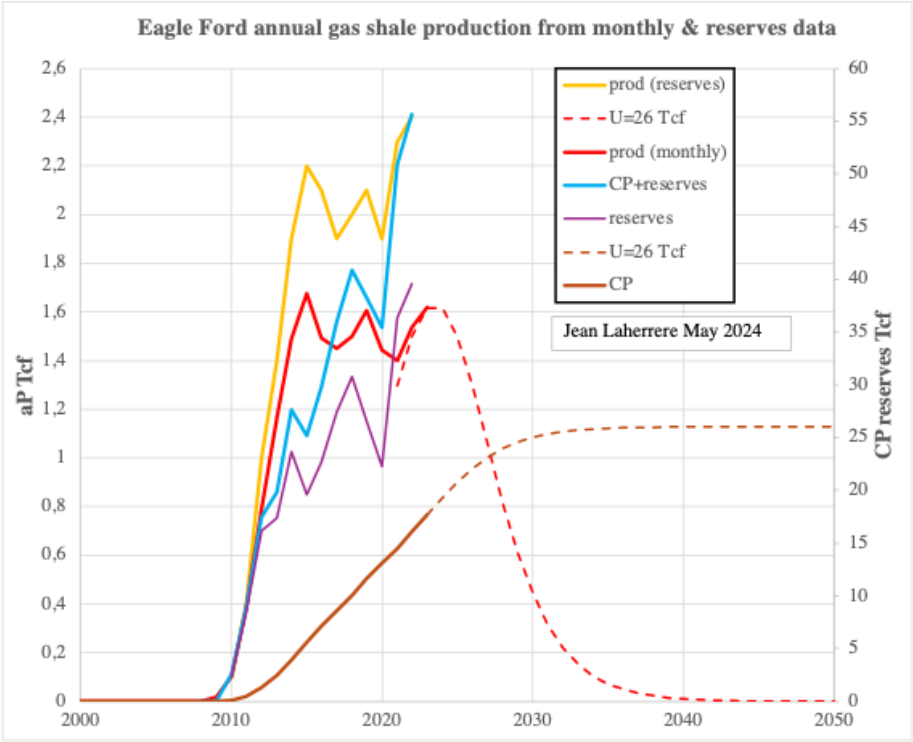
HL of Eagle ford production trends towards 26 Tcf



With an ultimate of 26 Tcf, Eagle Ford gas monthly production will decline from a peak in 2023



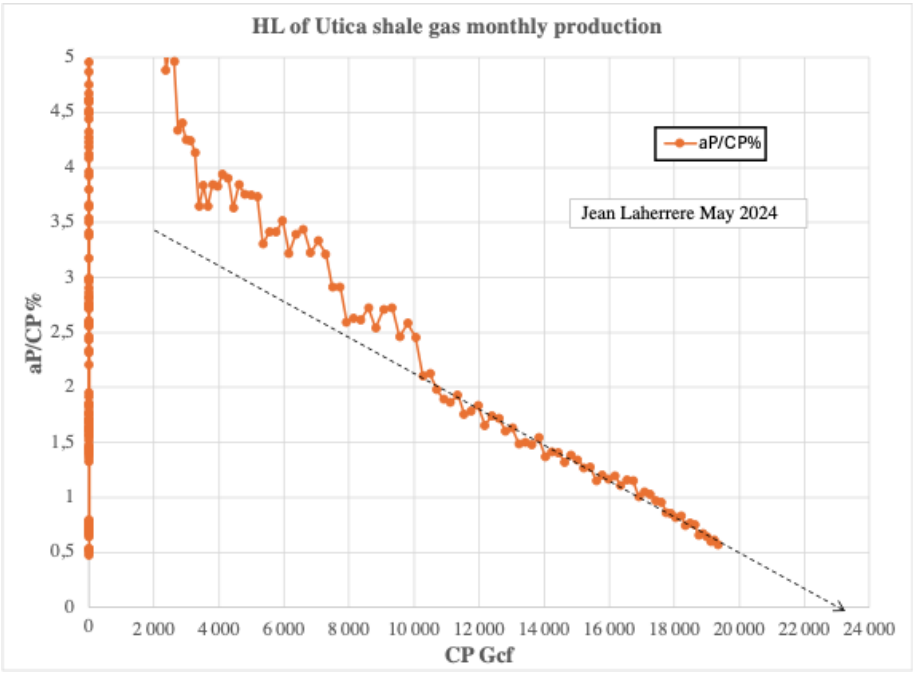
EIA reserves data reports Eagle Ford shale gas annual production larger than monthly data. Why?
CP+reserves at 56 Tcf are larger than the HL ultimate of 26 Tcf



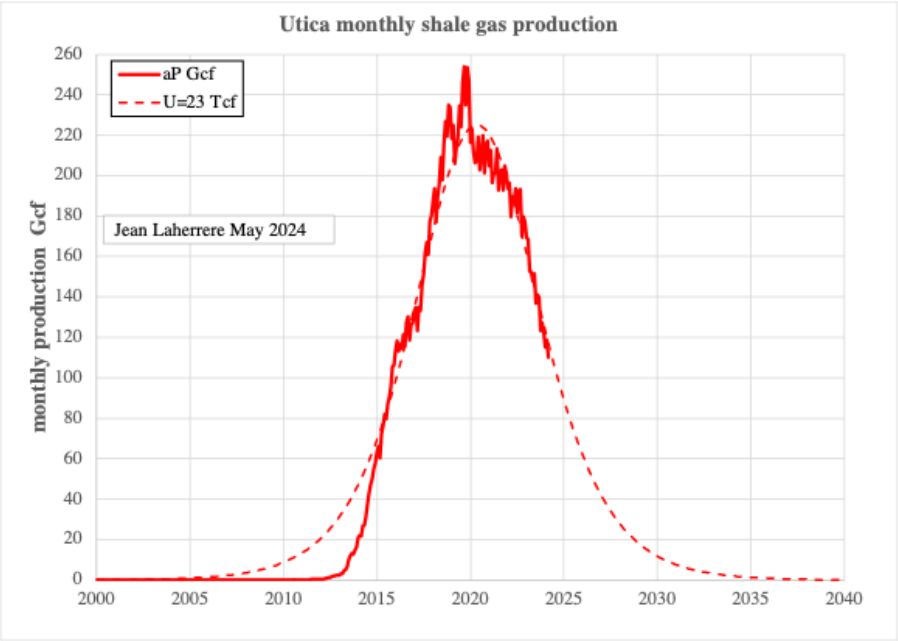
EIA reserves are too much optimistic!

-Utica

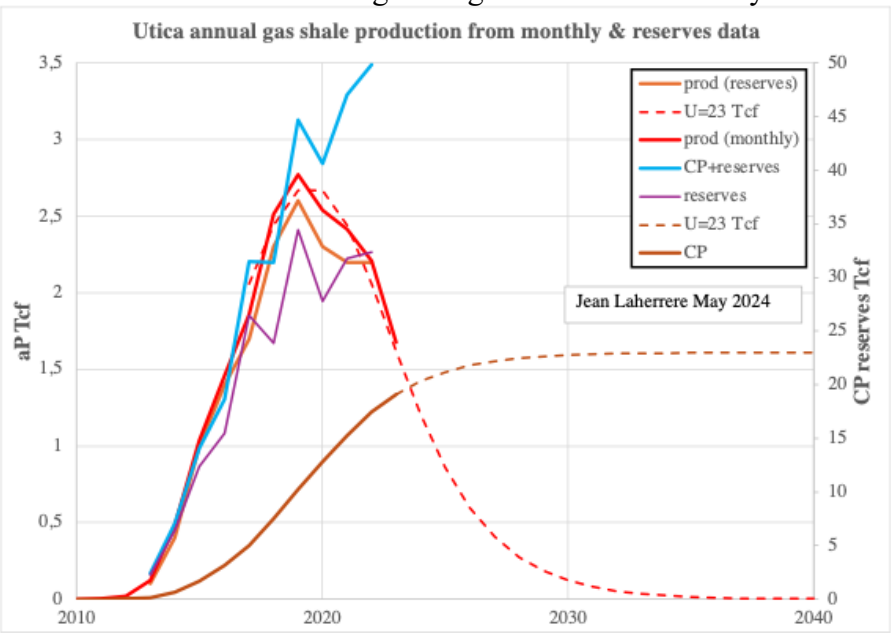
HL of Utica shale trends towards an ultimate of 23 Tcf



With an ultimate of 23 Tcf Utica shale gas production will continue to decline

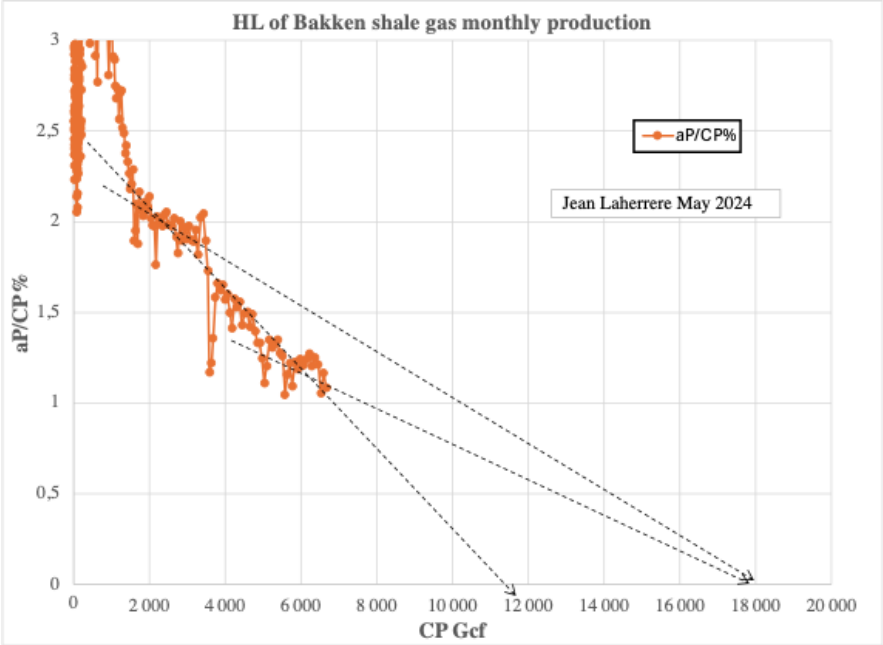


EIA 2022 CP+reserves at 50 Tcf is too high being the double that of my ultimate

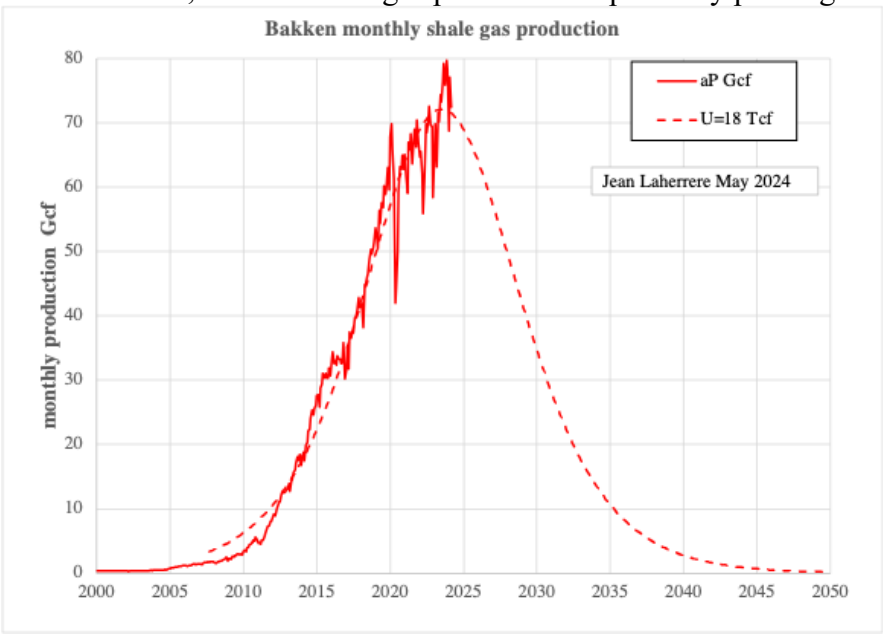


-Bakken

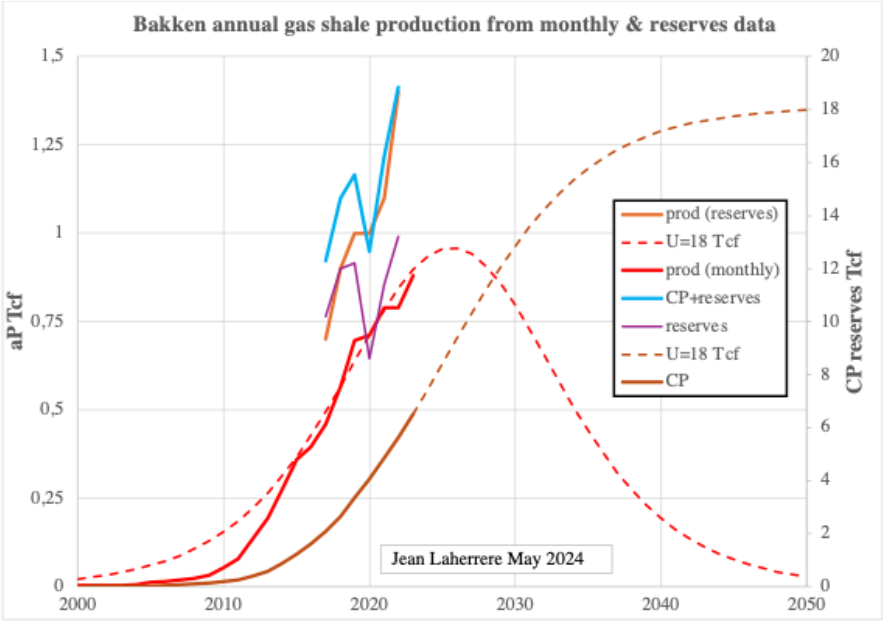
HL of Bakken shale gas production trends very poorly towards 18 Tcf



With an ultimate of 18 Tcf, Bakken shale gas production is presently peaking

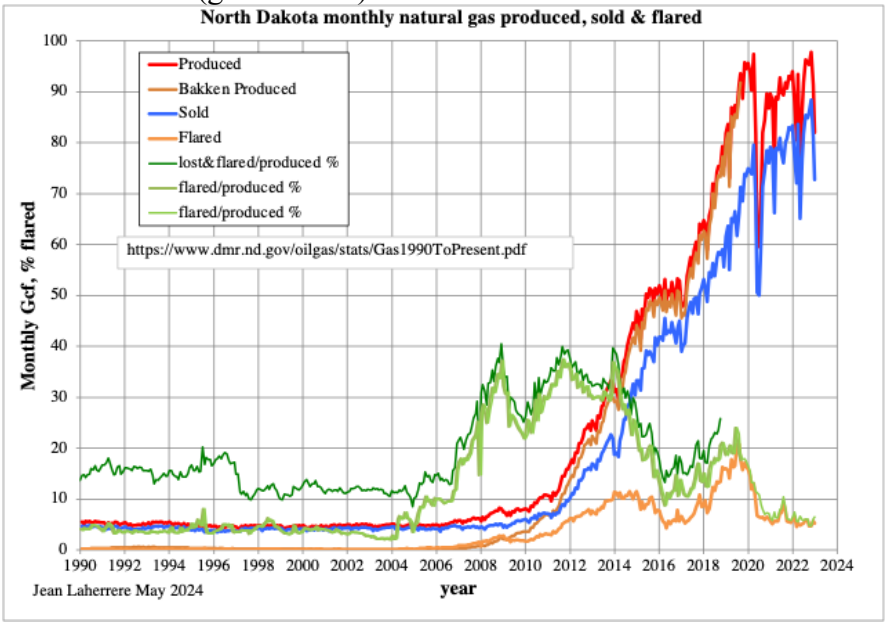


EIA reserves data reports 2022 CP+reserves of 19 Tcf close to the HL ultimate



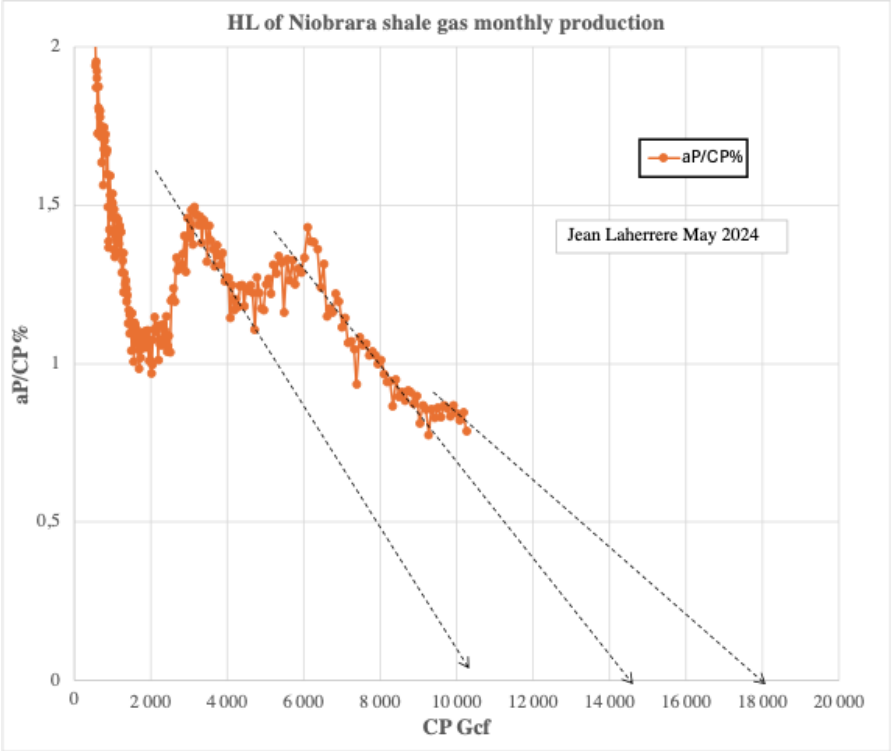
For once EIA is not too optimistic as Bakken shale is mainly oil and gas production

On the past Bakken in North Dakota, lacking gas pipeline has flared gas (orange curve) with a peak in 2014 close to 40% (green curve)

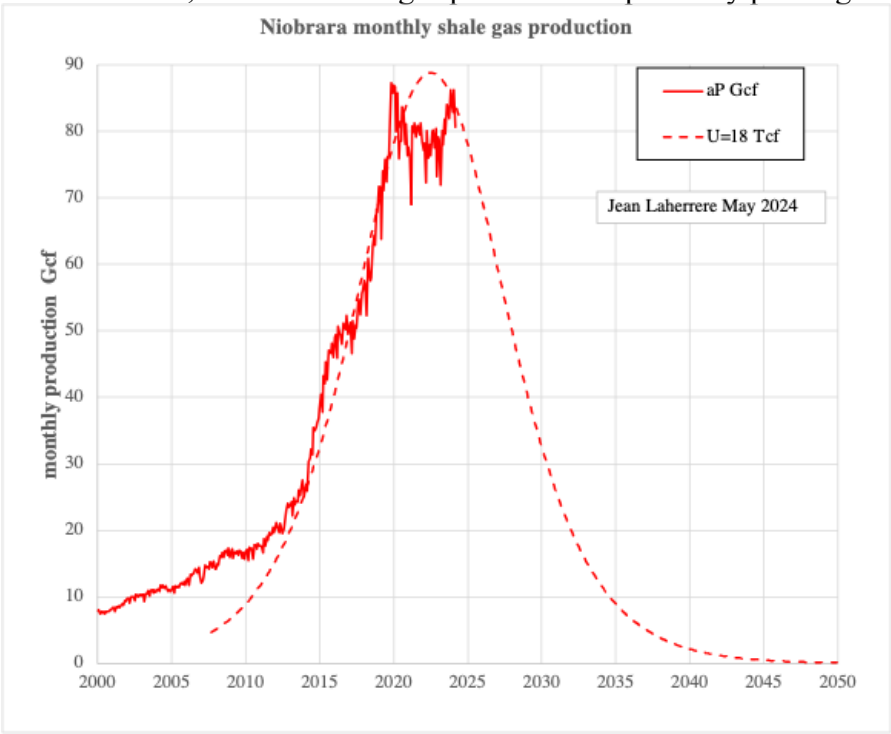


-Niobrara-Codell (CO and WY)

HL of Niobrara gas shale production trends very poorly towards 18 Tcf



With an ultimate of 18 Tcf, Niobrara shale gas production is presently peaking



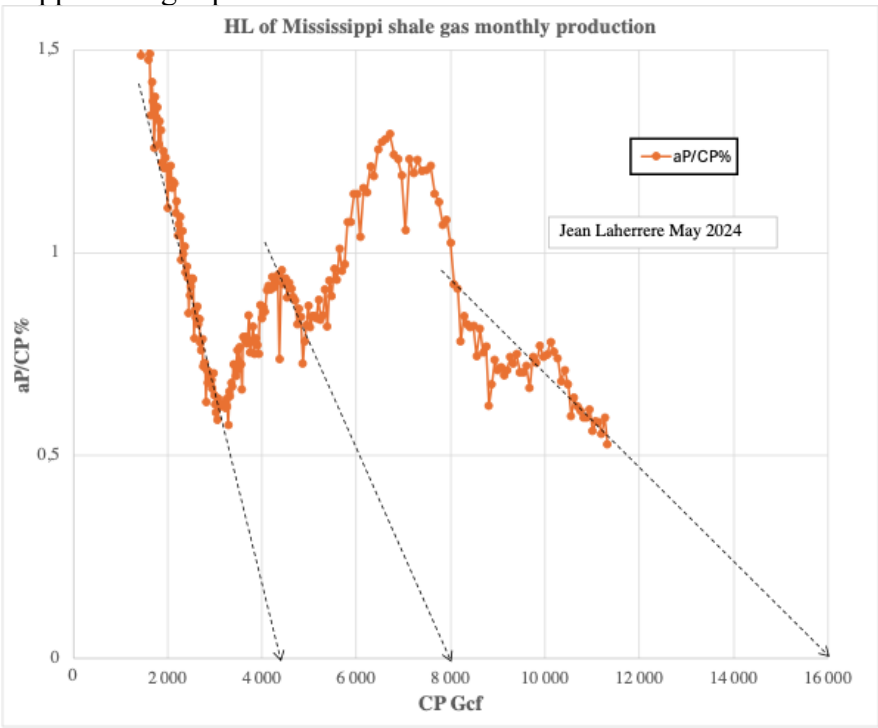
EIA 2022 does not report Niobrara, neither Mississippi!

Table 4. Natural gas, wet after lease separation, production and proved reserves, from shale plays, 2021–22 (trillion cubic feet)

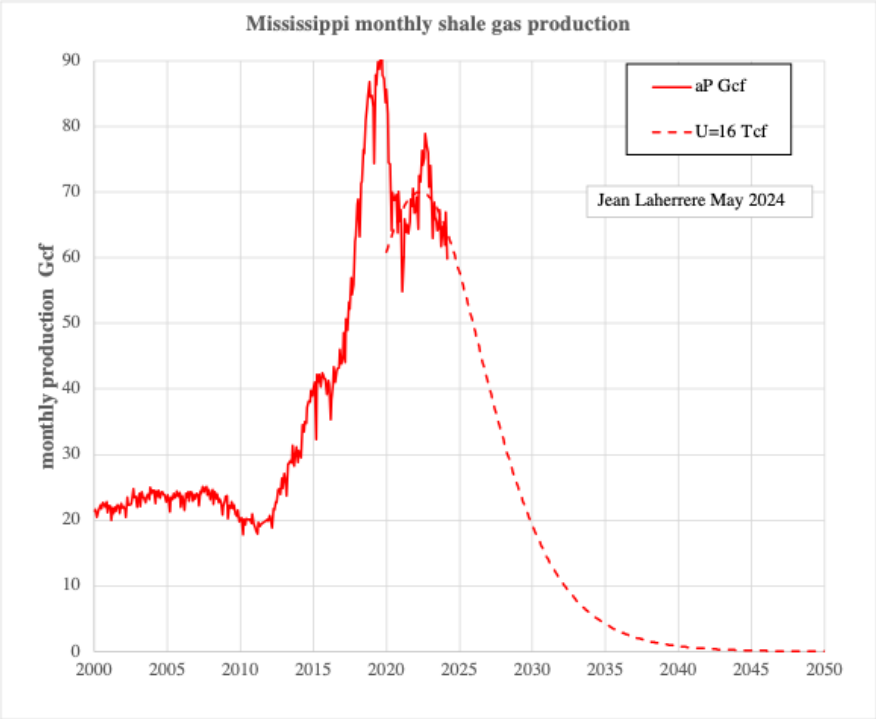
			2021		2022		Annual change	
Basin	**Shale Play**	**State(s)**	**Production**	**Reserves**	**Production**	**Reserves**	**Production**	**Reserves**
Appalachian	Marcellus	PA,WV	9,9	144,7	10,3	153,2	0,4	8,5
Permian Basin	Wolfcamp, Bone Spring	NM, TX	5,8	75,0	6,5	81,3	0,7	6,3
Texas-Louisiana Salt	Haynesville/Bossier	LA, TX	4,3	56,1	5,1	61,1	0,8	5,0
Western Gulf	Eagle Ford	TX	2,3	36,4	2,4	39,6	0,1	3,2
Appalachian	Utica/Pt. Pleasant	OH	2,2	31,8	2,2	32,4	0,0	0,6
Anadarko, S. Oklahoma	Woodford SCOOP/STACK	OK	1,2	20,8	1,4	24,0	0,2	3,2
Williston	Bakken/Three Forks	MT, ND	1,1	11,4	1,1	13,2	0,0	1,8
Fort Worth	Barnett	TX	0,4	7,2	0,4	9,0	0,0	1,8
Arkoma	Fayetteville	AR	0,4	5,1	0,4	5,3	0,0	0,2
Subtotal			**27,6**	**388,5**	**29,8**	**419,2**	**2,2**	**30,6**
Other shale plays			0,4	5,2	0,8	12,2	0,4	7,0
U.S. total			**28,0**	**393,8**	**30,6**	**431,4**	**2,6**	**37,6**

-Mississippi

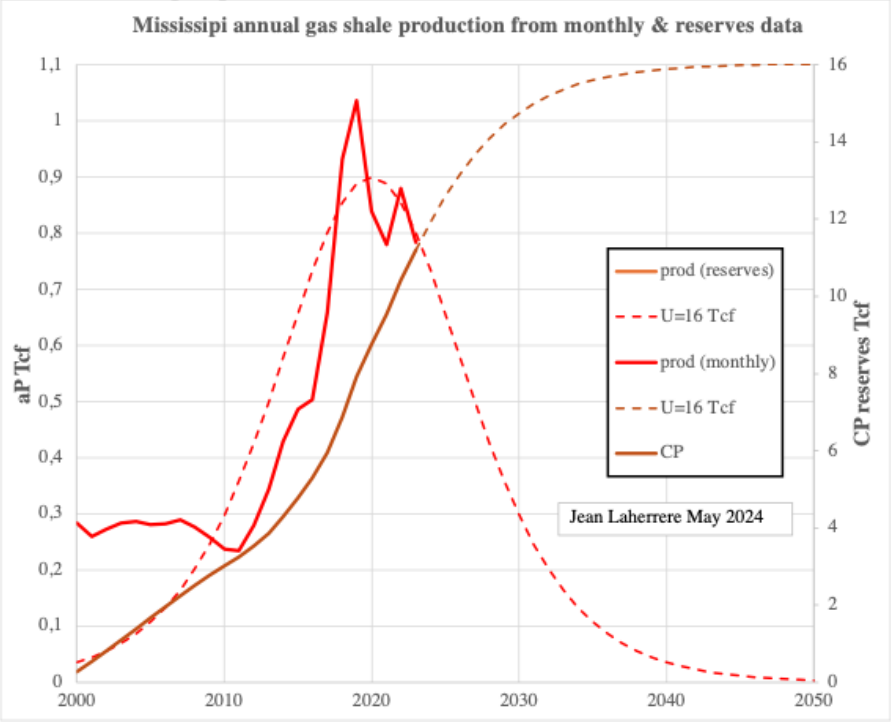
HL of Mississippi shale gas production trends towards 16 Tcf



With an ultimate of 16 Tcf; Mississippi shale gas production will continue to decline with a peak in 2020

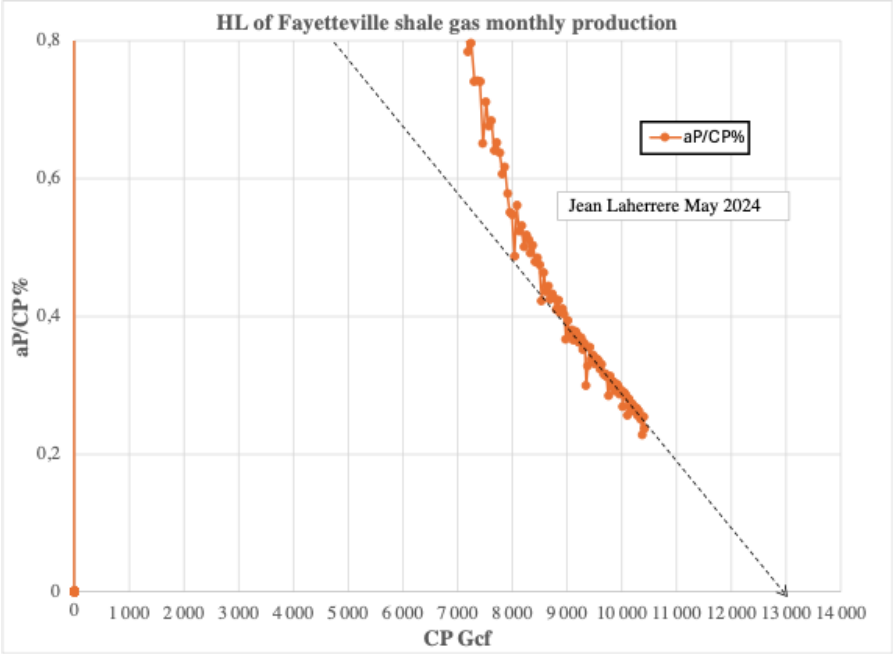


Mississippi annual shale gas production

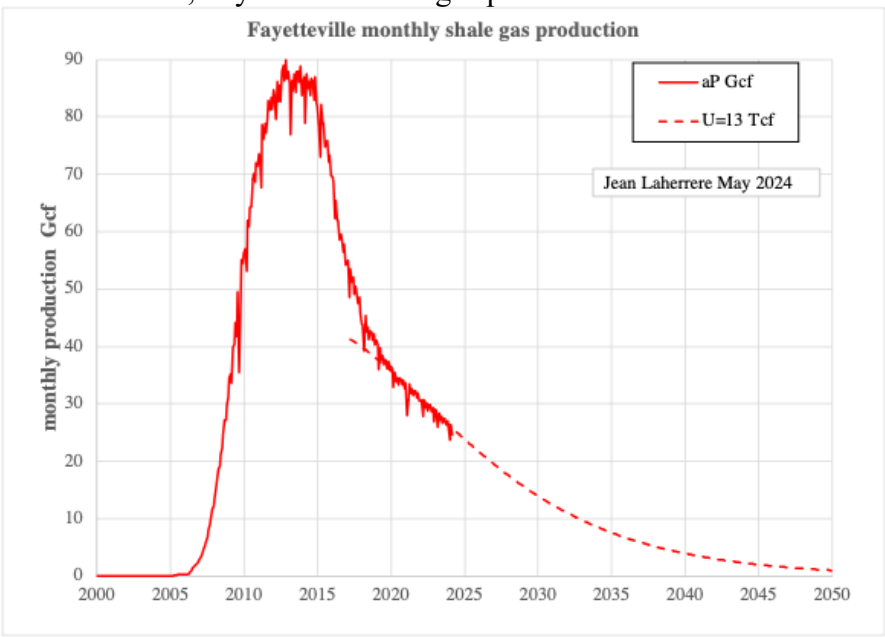


-Fayetteville

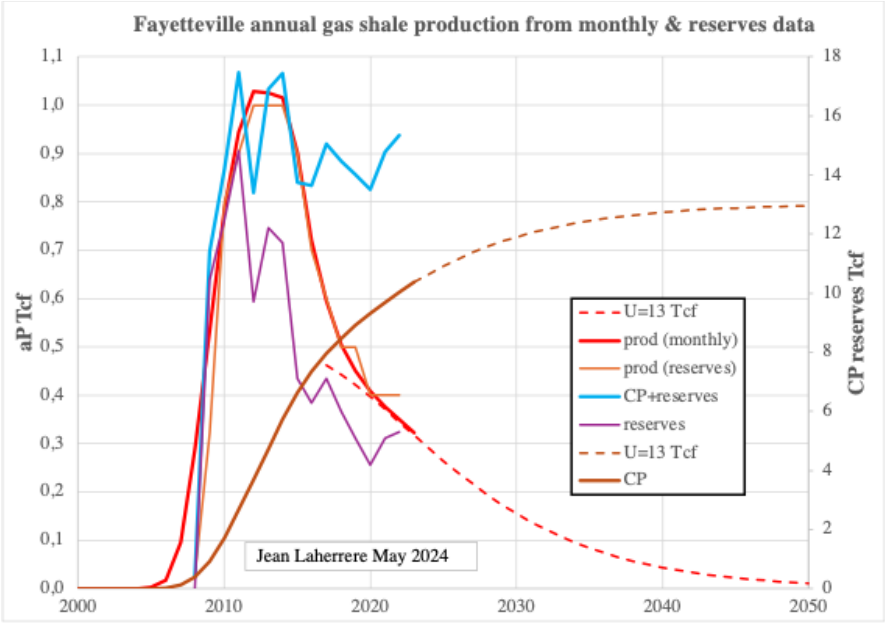
HL of Fayetteville shale gas production trends towards 13 Tcf



With an ultimate of 12 Tcf, Fayetteville shale gas production will continue to decline

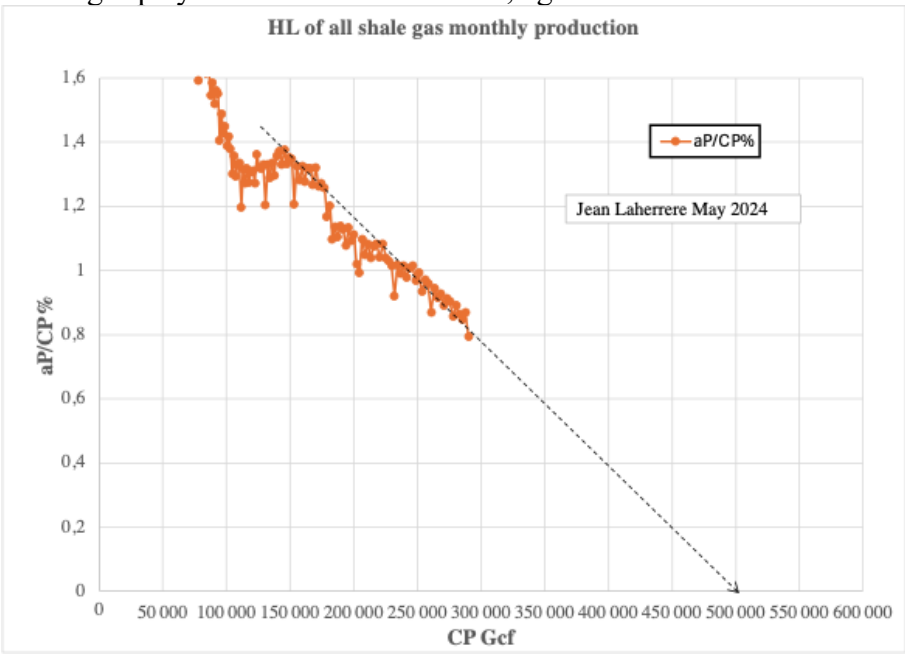


EIA reports 2022 CP+reserves of 15 Tcf, a little higher than my ultimate of 13 Tcf

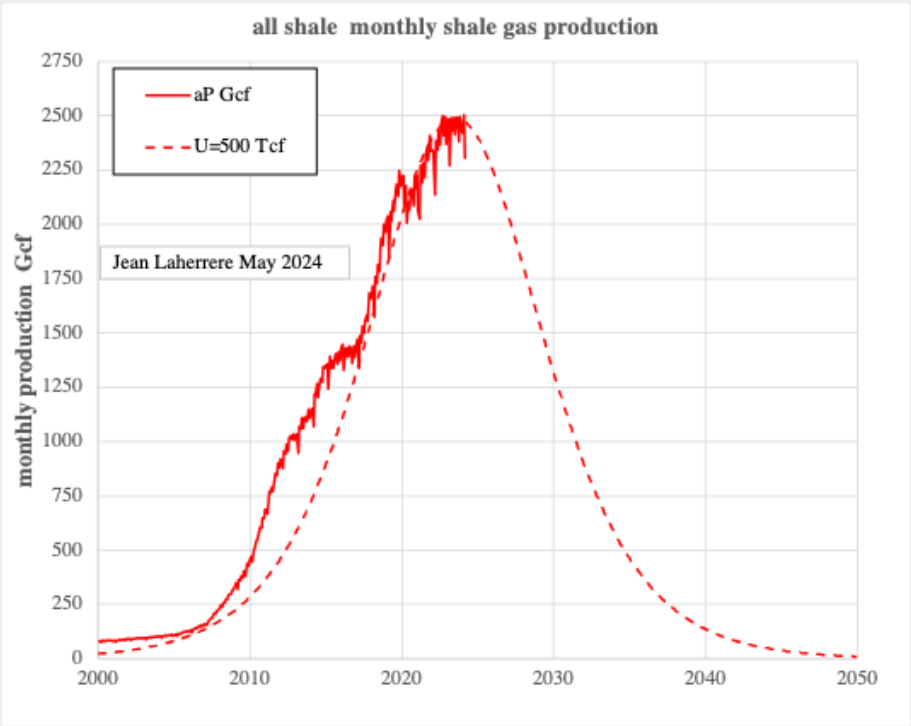


-all 12 shale plays

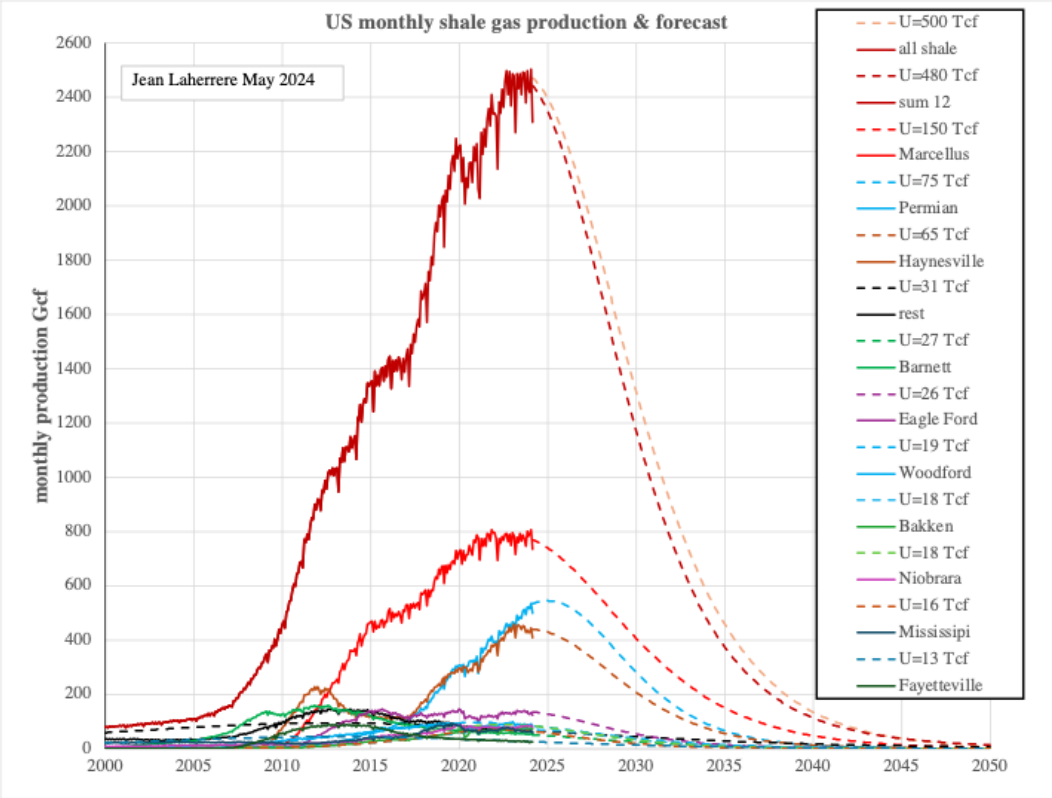
HL of all 12 shale gas plays trends towards 500 Tcf, against a sum of 480 for the 12 plays



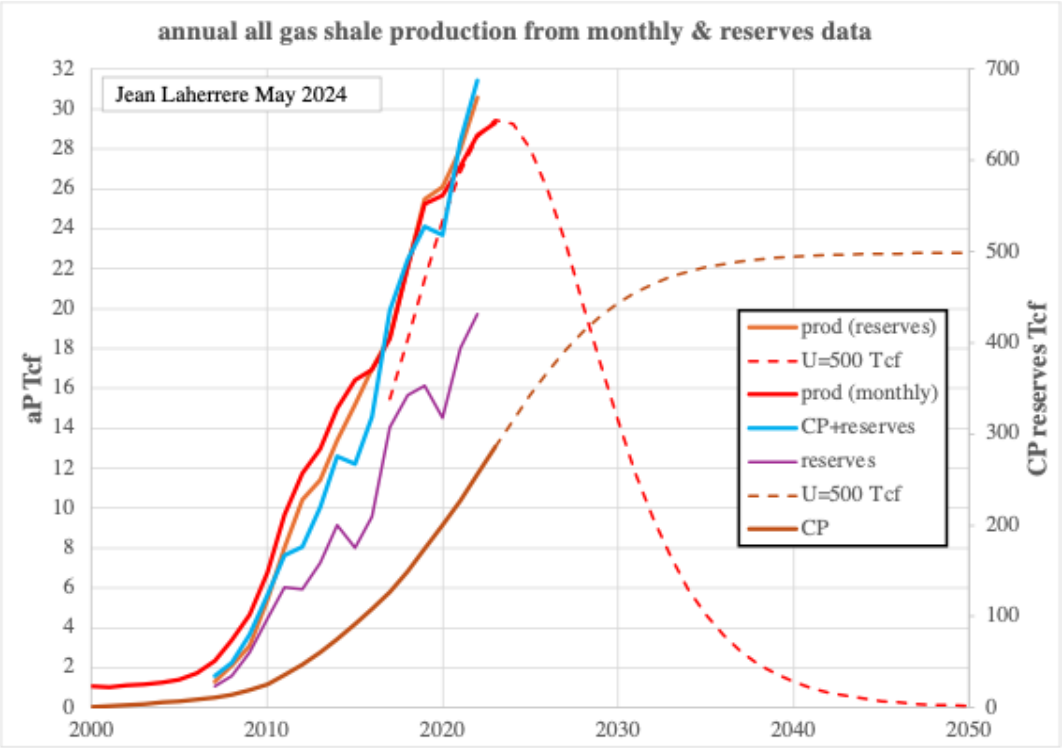
With an ultimate of 500 Tcf US shale gas production is presently peaking



The graph with all shale plays production & forecast shows the importance of Marcellus play, followed by Permian play.



EIA 2022 CP+reserves are 688 Tcf higher than my ultimate of 500 Tcf



EIA reserves estimate is unreliable.
Conventional gas reserves are based on a century of practice; with thousands of gasfields being at production end where previous reserves practices being compared with reality and corrected.
But there is not yet any shale gas field being depleted and where shale gas reserve practice could be compared with real.
Shale gas reserves come from fracking the reservoir and it is hard to estimate the volume of fractures., as the recovery factor (25 %?).
It appears from the above graphs that EIA proven reserves overestimate shale gas reserves by 40 % (700 compared 500)
I remind that EIA definition of proven: *Proved reserves of crude oil as of December 31 of the report year are the estimated quantities of all liquids defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.*
This definition forgets to define what is reasonable: 50 % probability or 90%?

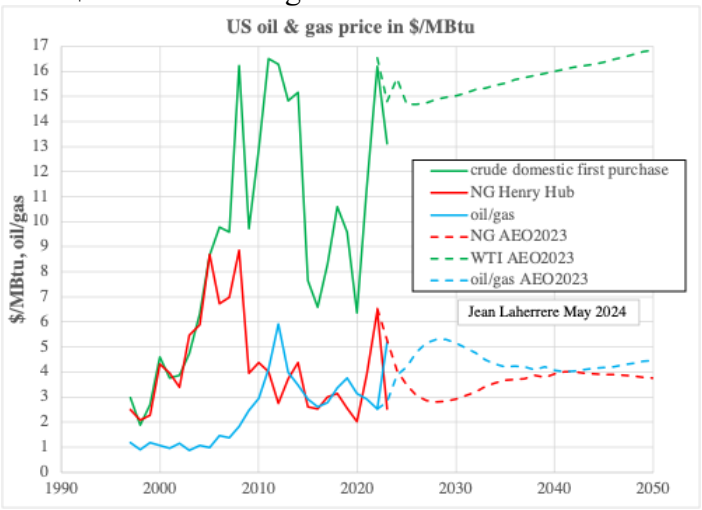
-recapitulation
The synthesis of all previous forecasts is given in this table

year	2023	2023	2022	2022					2023
Tcf	aP	CP	reserves	CP+reserves	U	peak	peak time	U/CP+reserves	CP/U
marketed	41,3	1558	691	2208	2200	43	2025	1,0	0,7
dry	37,9	1481	653	2133	2100	39	2025	1,0	0,7
shale	29,3	285	431	687	700	30	2025	1,0	0,4
Marcellus	9,3	82,9	153	227	150	9,3	2023	0,7	0,6
Permian	5,9	30,6	81	106	75	6,5	2025	0,7	0,4
Haynesville	5,3	39	61	95	65	5,3	2023	0,7	0,6
rest of shale plays	0,8	23	?	?	31	1	2014		0,7
Barnett	0,7	23	9	31	27	1,8	2012	0,9	0,9
Eagle Ford	1,6	18	40	56	26	1,7	2015	0,5	0,7
Utica	1,7	19	32	50	23	2,8	2019	0,5	0,8
Woodford	1	12	24	35	19	1,1	2019	0,5	0,6
Bakken	0,9	7	13	19	18	1	2025	0,9	0,4
Niobrara	1	10	?	?	18	1	2024		0,6
Mississippi	0,8	11	?	?	16	1	2019		0,7
Fayetteville	0,3	10	5	15	13	1	2012	0,9	0,8
sum	29	285	418	?	481				0,6
all 12	29	285	431	687	500	29	2023	0,7	0,6

The most depleted play is Barnett followed by Fayetteville and the least Bakken and Permian

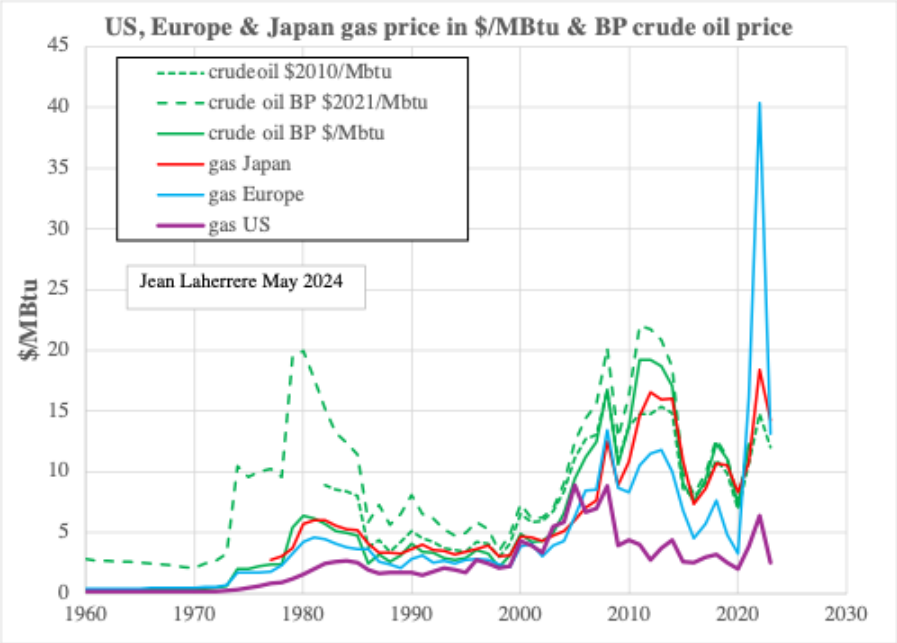
-oil & gas price

NG price was equal to oil price in $/MBtu from 1997 to 2005 but was 5 times less in 2012 as in 2023: AEO2023 forecast to be around 4 times less in 2050: is it reliable?
Oil price is converted in $/MBtu assuming a heat content of 5800 Btu/b

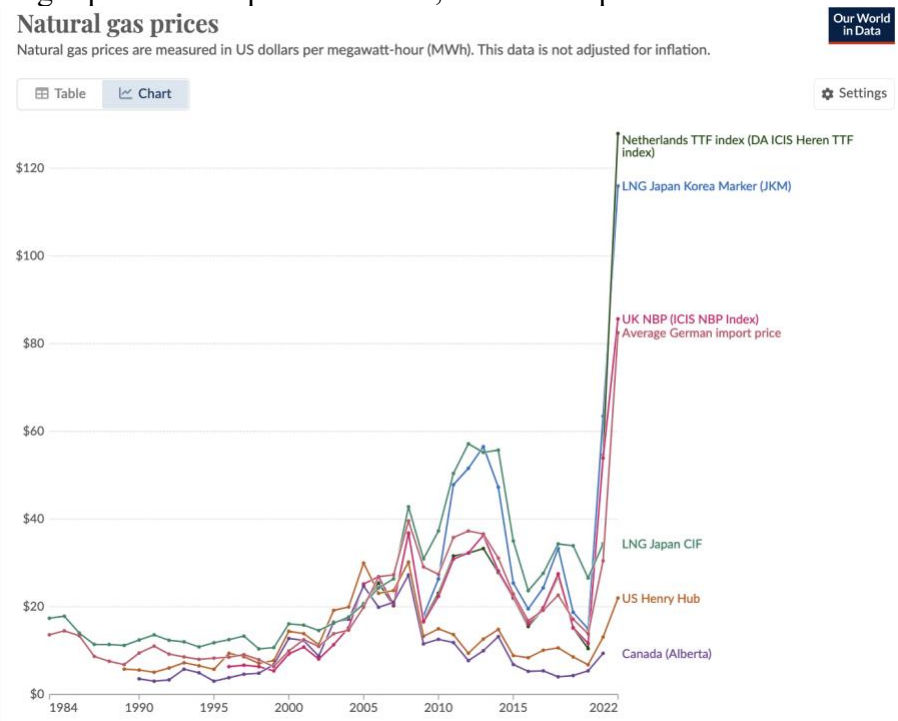


The comparison with gas price in Europe and Japan (World Bank data) shows that US price (green) was since 2009 much lower than in Europe & Japan.
In 2023 US industry has a huge advantage over the rest of the world with a gas price 5 times lower! This advantage stays since 2009 and could continue for a certain time, but I believe that shale gas production will decline and that its price could change!
NG represents in 2022 33% of US primary energy consumption!

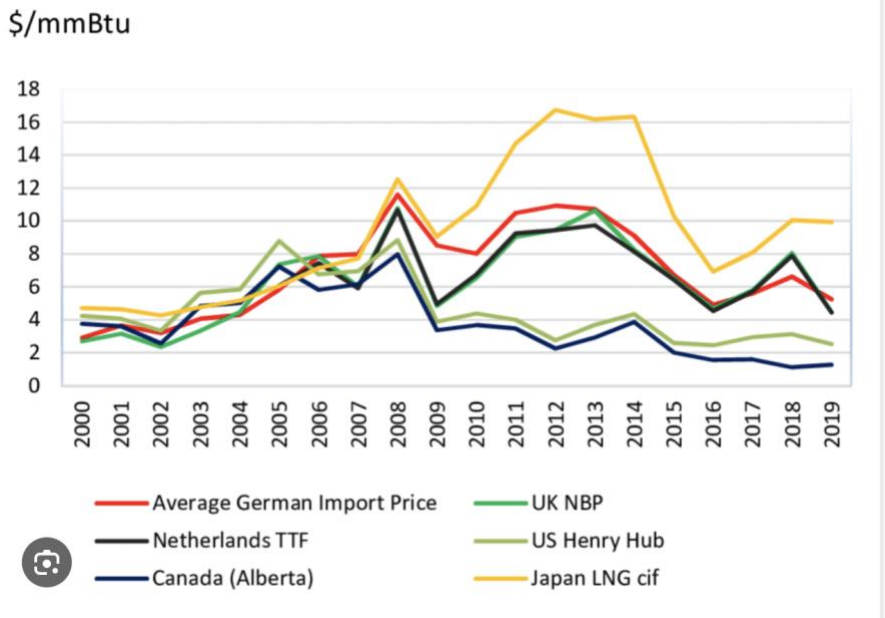
Europe gas price jumped in2022 to 40 $/MBtu, but back to Japan in 2023.



Our world in data displays the NG prices from 1984 to 2022 ($/MWh, with 1Wh = 3.4 Btu) where Canada gas price is cheaper than in US; the most expensive is Netherlands in 2022

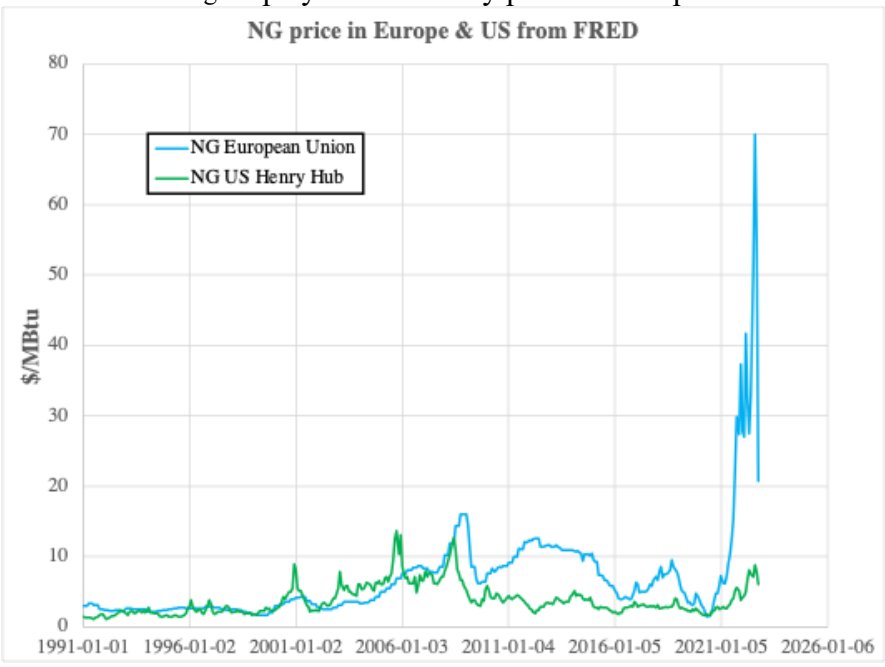


US and Canada enjoy lower gas price since 2009, not so much in 2020, but a lot in 2022!
This graph by Liptakova displays gas price in $/MBtu from 2000 to 2019



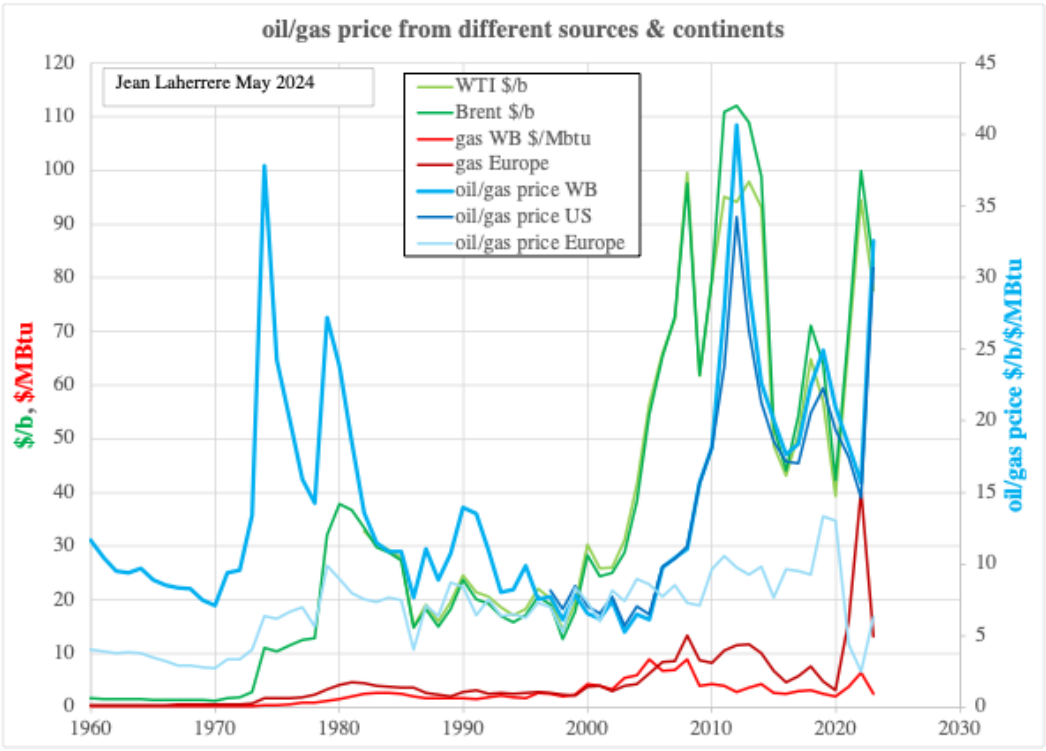
US (as Canada) gas price was lower from other continents since 2009

FRED https://fred.stlouisfed.org displays NG monthly price in Europe and US 1991-2022



US & Europe NG prices were equal from1991 to 2008 and diverge beyond except in 2021!

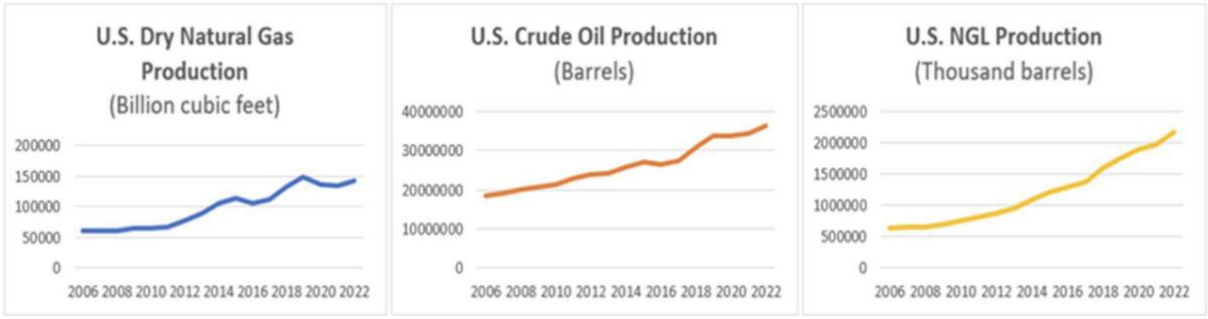
The crude oil-to-natural gas price ratio is calculated by dividing the spot price of Brent crude oil ($/barrel) by the spot price of natural gas at the Henry Hub ($/MBtu.)
The world oil/gas price is reported using World Bank data (1960 to 2023) as EIA data
The oil/gas price from WB shows a large variation with a first peak in 1974 at 38, a low at 5 in 2003 and a second peak at 41 in 2012, a low at 15 in 2022 but 33 in 2023. US oil/gas price is very close with WB oil/gas price.
Europe oil/gas price (light blue) is much lower than US oil/gas price



Europe gas price (dark red) was close to WB gas price up to 2007, but far in 2022.

-NGL

Natural gas liquids are used in the chemical industry: in the 2024 Kinder Morgan paper "The Role of Natural Gas Liquids (NGLs) in the American Petrochemical Boom" https://www.kindermorgan.com/getmedia/1ce6d409-3a38-4f49-bb78-96ae35ceb944/NGLs-and-Petrochemicals-Industry.pdf for the period 2006-2022 the growth of NGL looks more than dry gas or crude oil



The US NGL use is given in the next graph: ethane for petrochemical, isobutane for motor gasoline

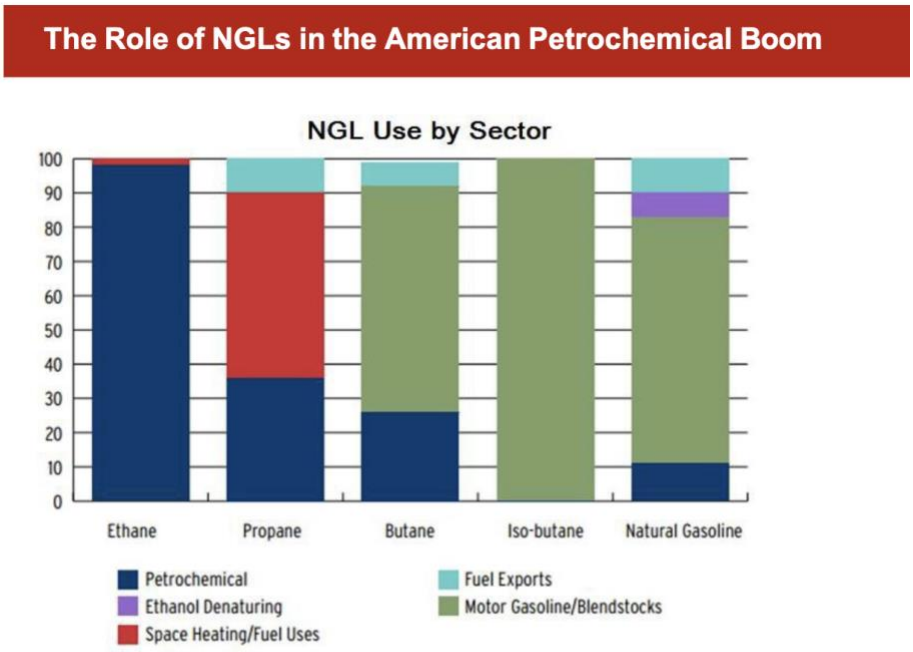
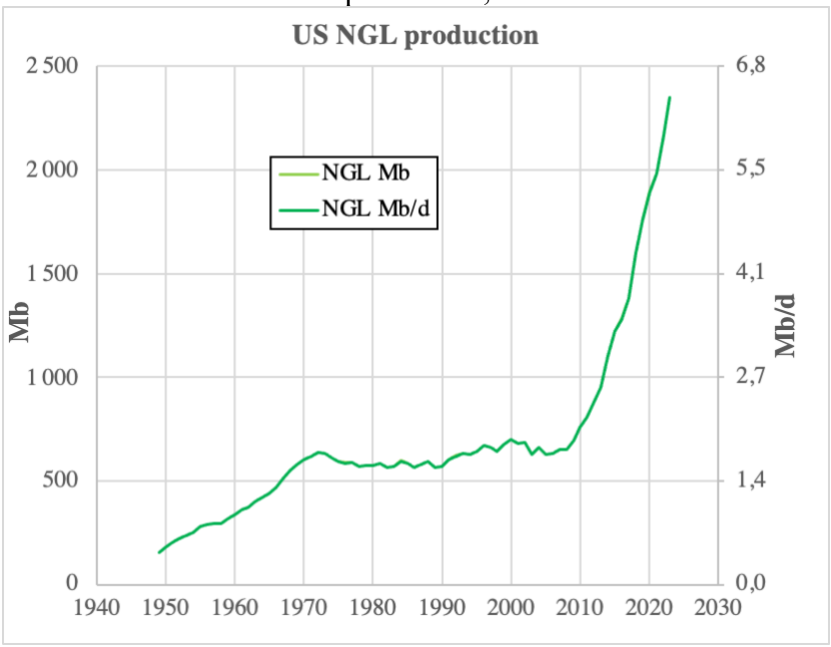
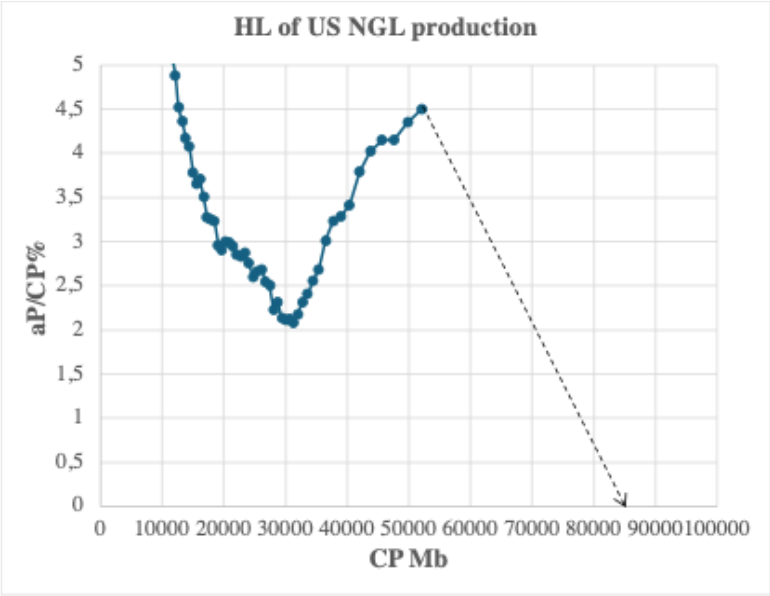


FIGURE 4: U.S. NGL use by sector. (Source: Brookings Institution, 2013).[14]

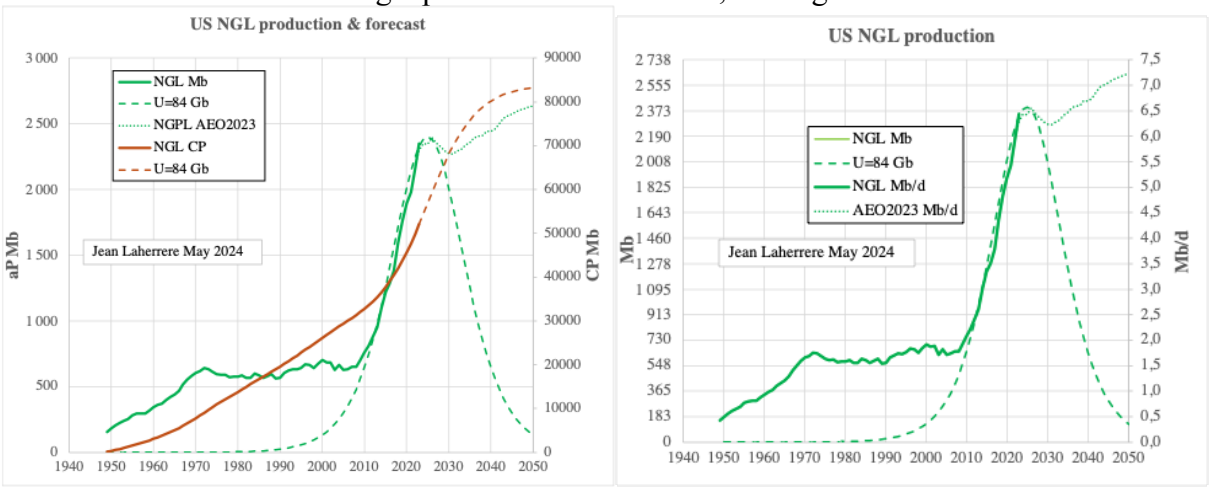
It is important to forecast also US NG production, but difficult to find data before 1950



HL of USNGL production is useless as since 2010 shale gas plays produce a lot of liquids.



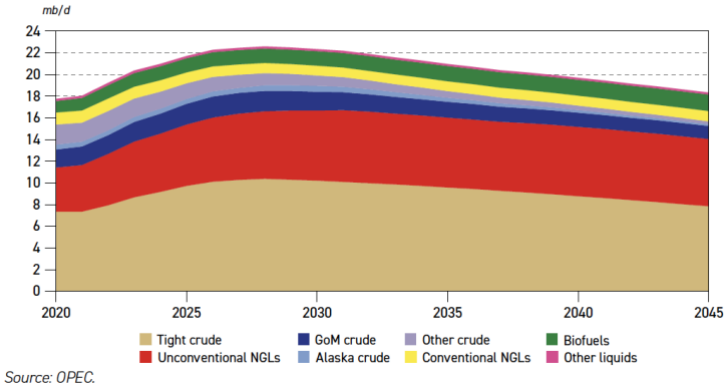
USNGL is modelled assuming a peak in 2025 as USNG, leading to an ultimate of 84 Gb



My forecast looks good, but it is very far from EIA/AEO2023: for 2050 EIA forecasts 7,2 Mb/d when my forecast is 0,4 Mb/d: quite a difference
EIA present administrator Joseph DeCarolis has no experience in energy only in engineering!

OPEC in its 2023 WOO US total liquids outlook believes also that in 2045 US NGL production (red & yellow) will be 7.1 Mb/d: is it its own forecast or a EIA copy?

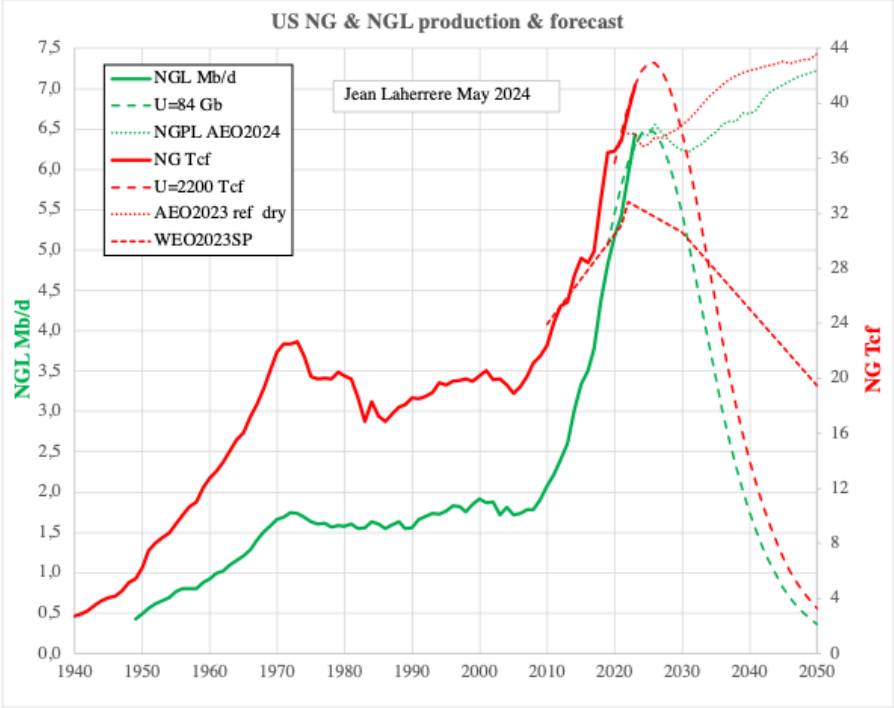
Figure 4.6
US total liquids supply outlook



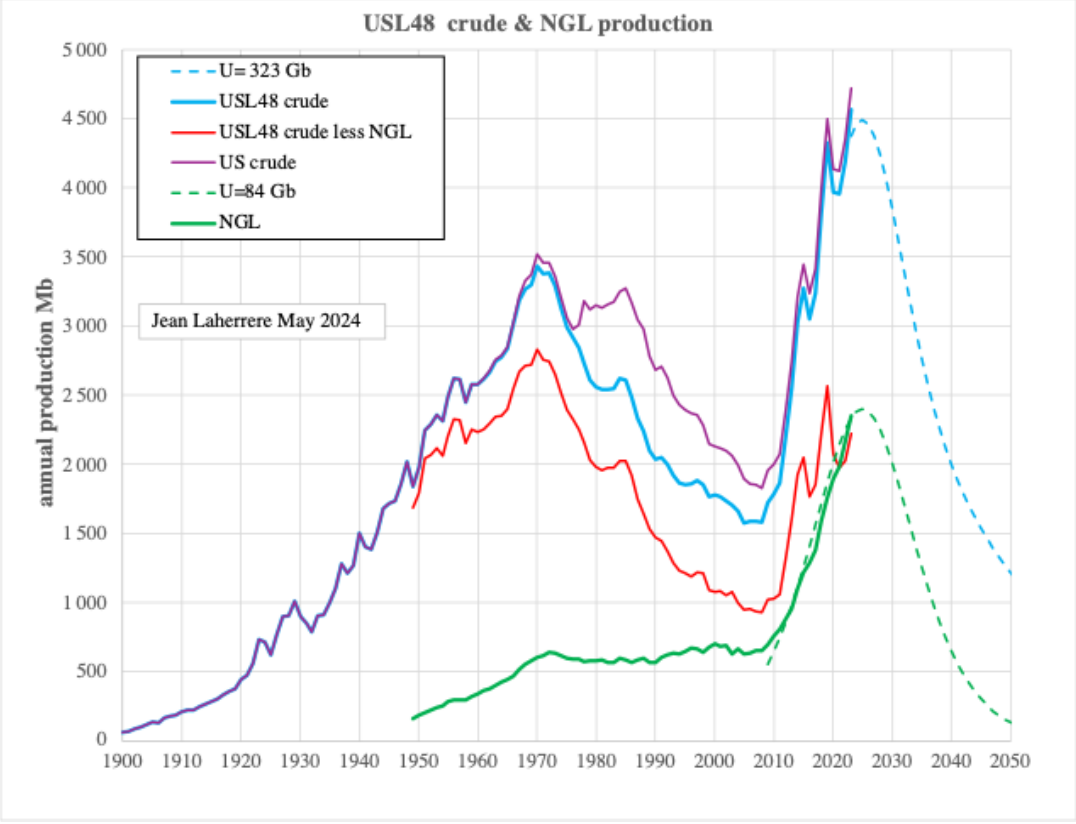
Source: OPEC.

-NG, NGL & crude oil production & forecast

The comparison of NG (marketed) and NGL production displays a very good correlation. But my forecast for NG production (red) is quite different from EIA (no peak before 2050 and IEA (peak between 2022 and 2030)



US NGL is compared with US crude oil production



US NGL future decline is in line with US crude decline

-Conclusion

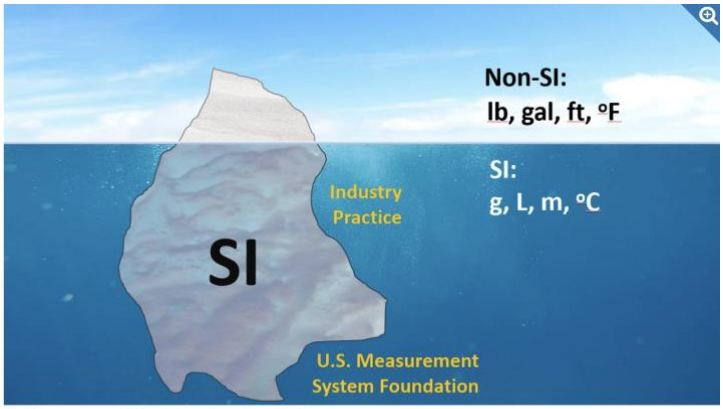
In 2023 US shale gas production represents 71% of US NG production, as conventional NG production is declining after a first peak in 1973 and a second in 1998
EIA monthly shale gas production data is not reliable, with two different sets and with different annual production data given with reserves
US shale gas reserves are unreliable as there is not yet any depleted shale gas play to verify the uncertain technique.
US shale gas production should have peaked with the largest play Marcellus in 2023.
My forecast for USNG in 2050 is less than 5 Tcf when EIA/AEO 2023 reference is 43 Tcf
EIA forecasts no peak before 2050 but IEA/WEO SP forecasts a peak before 2030.
The difference is huge and the consequence on US economy will be great.
EIA appears unreliable both for past data and for forecast
US and Canada enjoy a present NG price much lower than the rest of the world, but this big advantage will disappear in few years, sooner than EIA forecast!
The correlation between NG and NGL production is very good for the past, as the forecast.

NB

The International System of Unit (SI) or metric system is used in every country in the world buying gasoline by liter except US and Liberia (by gallon)
It means that SI used by 95 % of the world population.
In SI thousand = 10^3 =k, million =10^6 =M, US billion = 10^9 =G, US trillion = 10^12 =T
https://en.wikipedia.org/wiki/International_System_of_Units
https://www.antidote.info/en/blog/reports/millions-billions-and-other-large-numbers
There are two sets of large number: long scale and short scale:
US billion = milliard = thousand millions = 10^9
SI billion = square million = thousand US billion = 10^12
US trillion = thousand billions = SI billion = 10^12
SI trillion = cubic million = million US trillions = 10^18

USA Outdoor Track and Field Championships = metric
Sprint: 100 m, 200 m, 400 m
Middle distance track events: 800 m, 1500 m
Long distance track events: 5000 m, 10 000 m
Hurdles: 100 m hurdles, 110 m hurdles, 400 m hurdles, 3000 m steeplechase

It's impossible to avoid using the metric system in the United States. All our measurement units, including U.S. customary units you're familiar with (feet, pounds, gallons, Fahrenheit, etc.), are defined in terms of the SI—and mass, length, and volume have been defined in metric units since 1893! The SI's influence is pervasive and felt even if most people don't know it. I envision U.S. metric practice like a huge iceberg. Above the water's surface, U.S. customary units appear to still be in full effect. In actuality, below the water's surface, we find that all measurements are dependent on the SI, linked through an unbroken chain of traceable measurements. https://www.nist.gov/blogs/taking-measure/busting-myths-about-metric-system



The U.S. measurement infrastructure depends on the SI.
Credit: E. Benham/NIST

The nuisance is the use of dot for decimal in US when it is comma for other countries

Decimal separator

https://en.wikipedia.org/wiki/Decimal_separator

The 22nd General Conference on Weights and Measures declared in 2003 that "the symbol for the decimal marker shall be either the point on the line or the comma on the line".

It further reaffirmed that "numbers may be divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups"[27]

Countries using a comma = 84, countries using a dot = 60