Jean Laherrere 30 May 2023

Peaks from past data with HL: energy, fossil fuel, CO2, population & gold

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Forecasting future production peak needs to estimate the future production from 2023 towards the end of the production, which is called remaining reserves at end 2022. Future production from 2023 plus cumulative production at end 2022 is called ultimate.
Ultimate reserves are estimated by geologists and production engineers from known discoveries. But most of the past discovered real reserves (2P = proven + probable being the most likely value) with the range from 1P = proven = 90% probability value to 3P = proven + probable + possible = 10% probability value) are owned by private producers and are confidential. Most of private oil producers are listed on the US stock market and are obliged by the SEC (Security and Exchange Commission) to report only audited proven reserves (remaining as today) defined as the future production with a "reasonable certainty to exist with today technology and price", giving "financial reserves data" in case of bankruptcy to protect bankers and shareholders, but the future conditions will change. SEC rules on oil reserves are bad practices, giving later an important proven reserves growth which is artificial.
Oil producers in private apply SPE rules (WPRM) to estimate 2P reserves, which are confidential (SEC rules oblige to not report 2P reserves), but these data obtained (how?) by scouting can be bought from scout companies. But within a company there are several different sources of 2P reserves (geologists, reservoir engineers, producers, economists).

OPEC oil quotas are based on proven oil reserves and from 1985 to 1989 OPEC members fought on quotas and increased OPEC proven by 300 Gb of speculative resources, giving "political reserves data".
The discrepancy between the technical confidential 2P crude oil remaining reserves and the published political/financial1P remaining reserves is very large. Extra-heavy (XH) oil (heavier than water) has a different trap than crude oil field (water level below oil below gas below cap) and represents huge resources: Canada oilsands = bitumen produced by mining or with steam and Venezuela Orinoco.
2P world and 1P crude oil reserves are two different worlds and two different trends.
But 1P data is bad practice as the arithmetic sum of the field proven (minimum) reserves of a country is not the proven (minimum) reserves of the country: it is less as it is unlikely that all the field reserves would be at minimum.
See my 2021 paper World oil production: past & forecasts https://aspofrance.org/2021/06/27/world-oil-production-past-forecasts/:

Figure 1: deterministic versus probabilistic aggregation

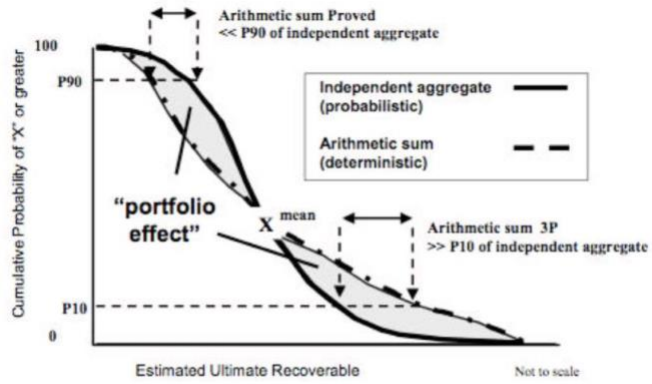
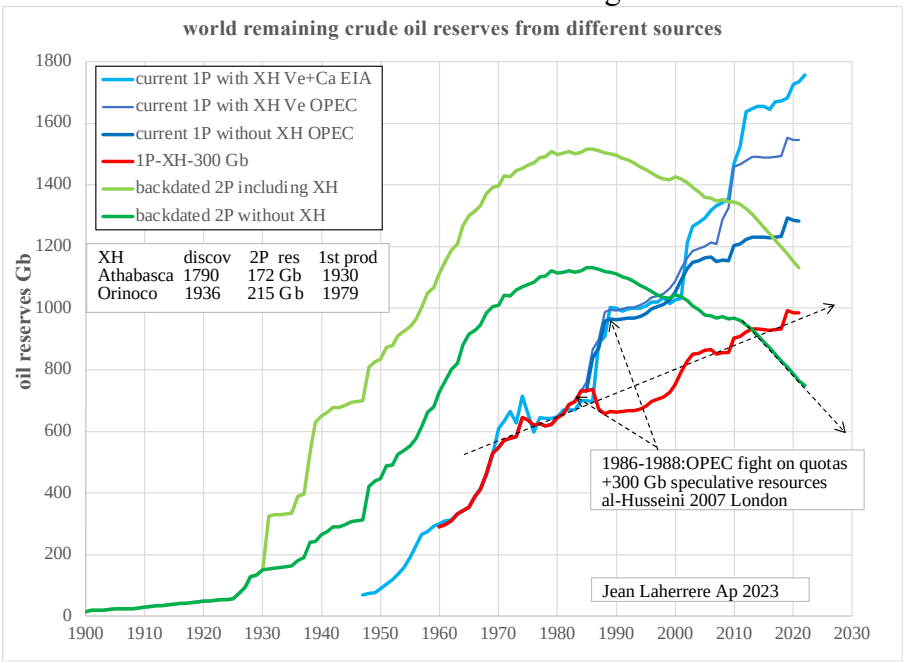


Figure 3-2: Deterministic versus Probabilistic Aggregation

Only the aggregation of 2P field reserves represents the 2P (probability 50%) of the country.
It means that the aggregation of world proven reserves as reported by all agencies is incorrect, but, as it is political (OPEC) or financial (SEC), nobody worries!

The crude oil reserves data from different sources is striking!



The only countries reporting 2P oil & gas estimates by field are the UK (UK oil & gas authority) and the US Federal Gulf of Mexico (BOEM).
Norway (NPD) reports reserves by field but there are not 2P but what is decided for the development by the producer without knowing their rules.
NPD reports only developed discoveries, in contrary to 2P for undeveloped discoveries.

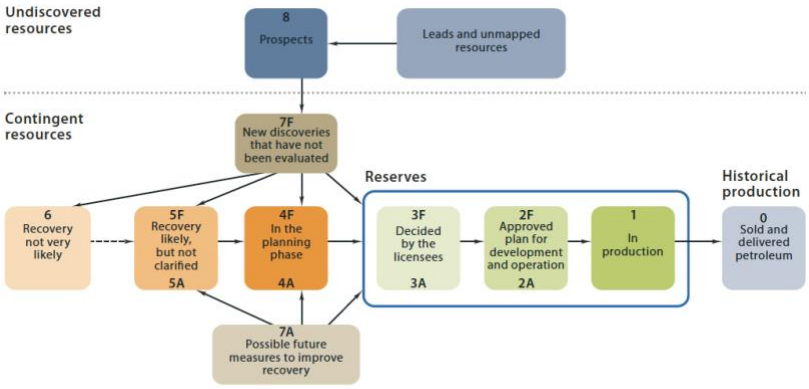
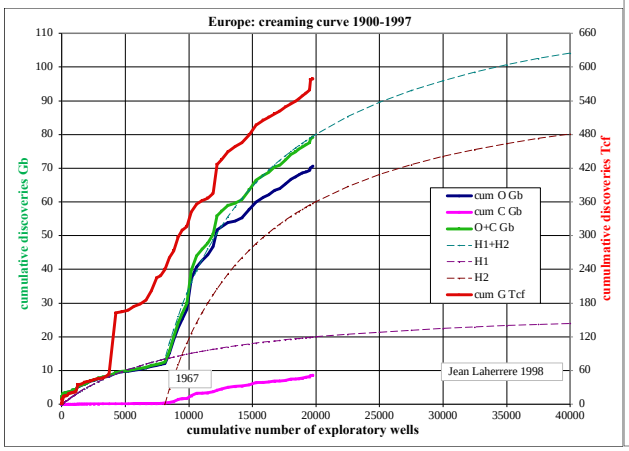
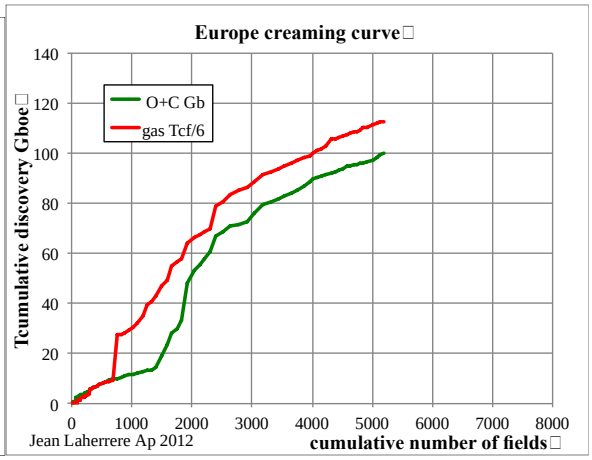


Figure 1.10 *The NPD's resource classification system (www.npd.no).*

2P reserves confidential data (obtained from producers) are sold by scout companies, as IHS or Rystad.

But future production will come from past discoveries but also from "yet to find" discoveries. These yet to find can be estimated using creaming curves: extrapolation of cumulative discoveries versus the cumulative number of exploratory wells (or new field wildcats or number of fields)
Creaming curve for Europe in 1998 in 2012





Because the unreliable reserves data to estimate ultimate, the approach of using past data to extrapolate the past annual production/cumulative production towards zero being the estimated ultimate was introduced by King Hubbert known as the Hubbert linearization: see https://en.wikipedia.org/wiki/Hubbert_linearization.
This approach could be pessimistic as forgetting new discoveries and new technology, despite that past data includes also the past evolution of discovery and technology.
This paper is based on ASPO France data.

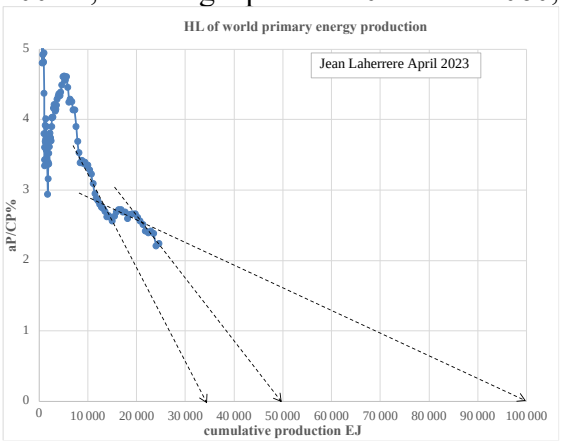
-ASPO France data

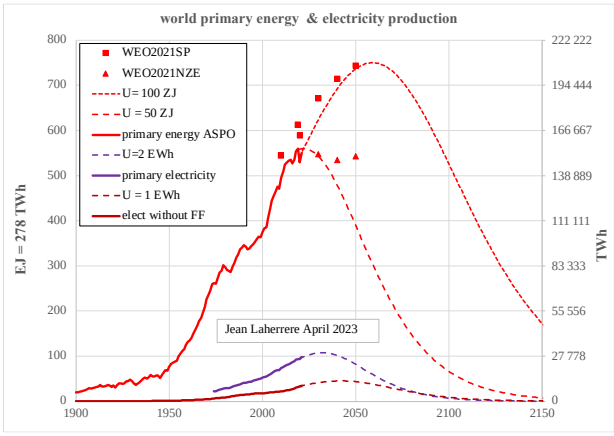
ASPO France data is found on https://www.gostatit.com/aspo_france.
The world and regions are studied from data from ASPO France (reported by Hugo Duterne) Data is broken down by regions (seven) and by political entities = OPEC, NOPEC (non-OPEC), European Union, Middle East and by producing countries.
Regions: 7 making the world
Africa, Asia (All Asia countries except CIS states, including Turkey), Europe (All Europe countries, except CIS states, including Georgia, excluding Turkey), CIS (CIS States includes Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Uzbekistan), North America (Refers to US + Canada, excluding Mexico), Latin America (All America countries except US and Canada), Oceania (Australia, New Zealand, Timor, Papua).

Items are Brown coal production, Hard coal production, Condensate production, Crude oil production, Extra-heavy oil production, NGPL production, Light tight oil production, Natural gas production, Hydroelectricity, Nuclear Power Generation, Solar power generation, Offshore wind generation, Onshore wind power generation, All liquids hydrocarbons production, Total primary electricity generation.

For comparison Petroconsultants (IHS later) was reporting 8 regions: Africa, Australasia, CIS, Europe, Fareast, Latin America, Middle East, North America but data excludes the USL48 onshore and West Canadian Sedimentary basin.

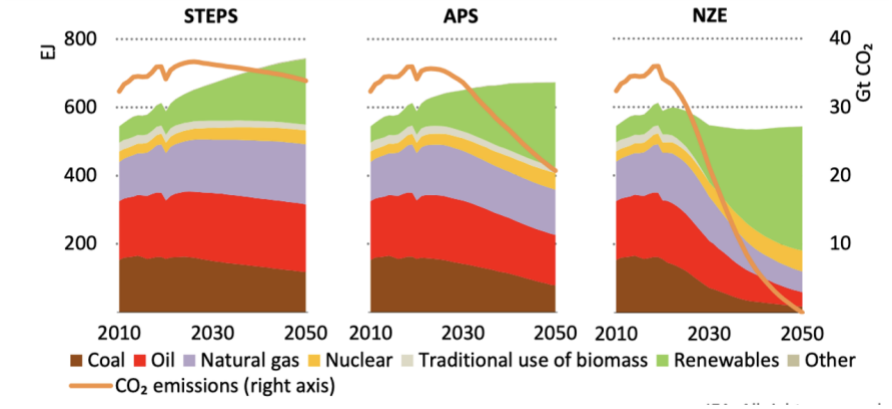
-world primary energy
HL of world primary energy trends towards 50 ZJ for the last few years, but could trends to 100 ZJ, meaning a peak in 2022 or in 2060, when WEO2021SP forecasts it well beyond 2050.





Primary energy is likely peaking and will decline in the future and the world is not prepared to this decline.
WEO2021 displays primary energy graphs for Stated Policies = STEPS and NZE = net zero emissions (unlikely forecast):

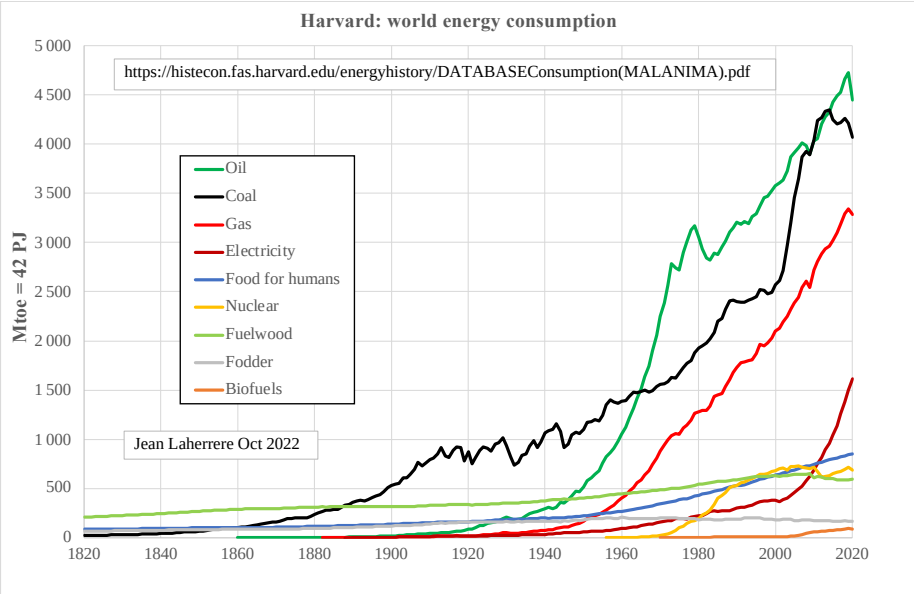
Figure 4.1 ▷ **Total primary energy supply by fuel and scenario**



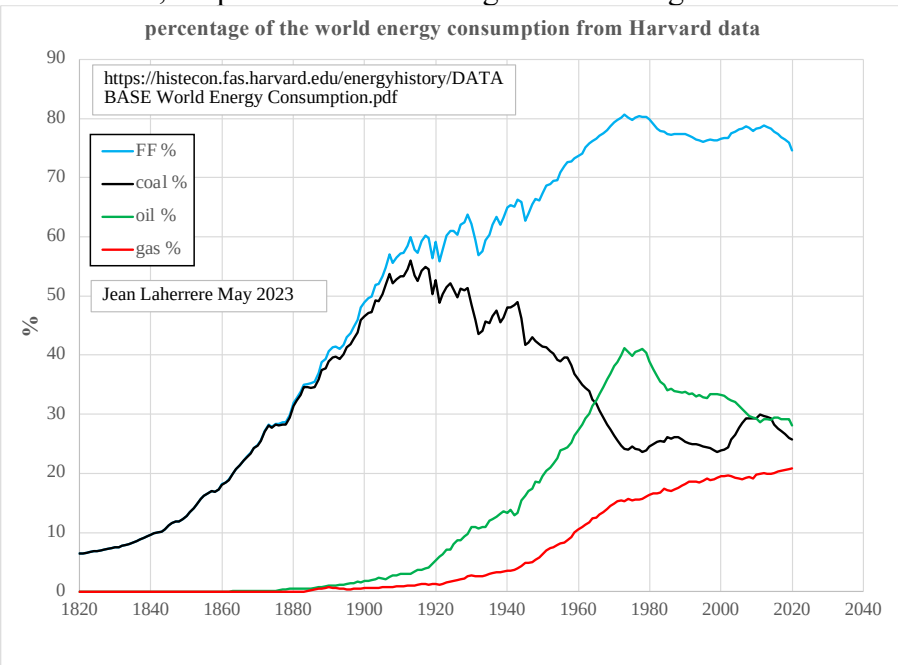
The world hopes to reduce the anthropic global warming by reducing the CO2 emissions, but most of the projects are by removing the CO2 = CCS = carbon capture and storage
CCS is used today to improve oil production by miscible gas injection (CH4 or CO2), but the volume of CCS is presently 1000 less than the CO2 fossil fuels emissions. CCS uses energy.
CCS technology is expected to use between 10 and 40 percent of the energy produced by a power station. Energy for CCS is called an energy penalty.
A recent paper by JP Morgan March 2023 finds that 80% of planned CCS projects were never built.
IEA https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage
There are around 35 commercial facilities applying CCUS to industrial processes, fuel transformation and power generation, with a total annual capture capacity of almost 45 Mt CO2. CCUS deployment has been behind expectations in the past, but momentum has grown substantially in recent years, with around 300 projects in various stages of development across the CCUS value chain.
Project developers have announced ambitions for over 200 new capture facilities to be operating by 2030, capturing over 220 Mt CO2 per year. However, only around 10 commercial capture projects under development have taken FID as of June 2022. Nevertheless, even at such level, CCUS deployment would remain substantially below what is required in the Net Zero Scenario.
While our country emits roughly 5 billion tons of carbon into the atmosphere every year, removing 1 billion tons of that through direct air capture would require nearly the entire electricity output of the United States.

WEO-NZE (see above) requires more energy to reduce CO2 emissions by CCS but at the same time forecasts a decrease in energy production: it is contradictory!

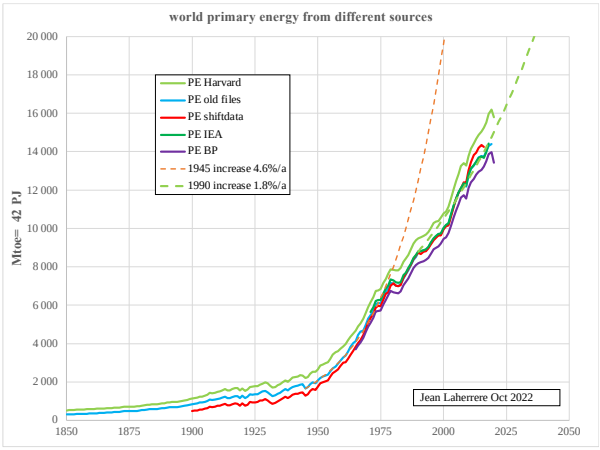
IEA primary energy does not include food for Humans (larger than nuclear and fuelwood), as fodder as it is done by Harvard University for energy consumption in Mtoe.

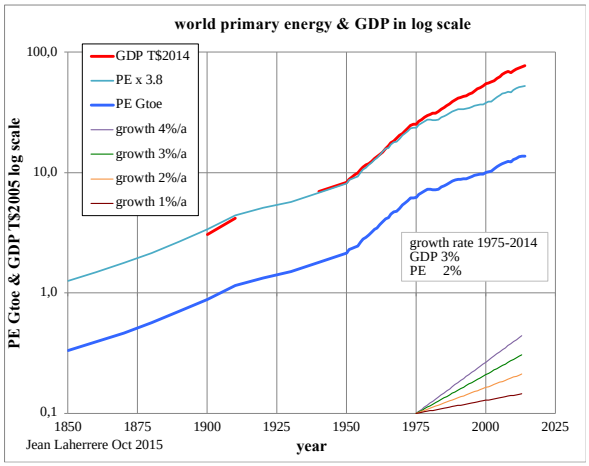


The percentage shows that fossil fuels represent more than 75% of the primary energy consumption since 1960, despite the 27 COPs on global warming!



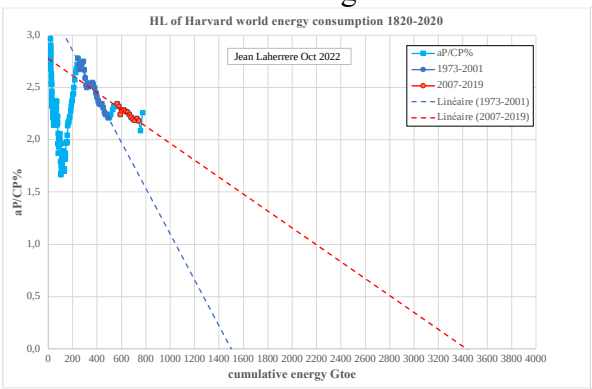
World primary energy from different sources displays similar trends, with a growth rate of 4.6%/a from 1945 to 1977 (oil shock) and from 1977 to 2019 of 1.8 %/a, quite a change! Primary energy correlates with GDP as shown in this graph in log scale to compare growth.

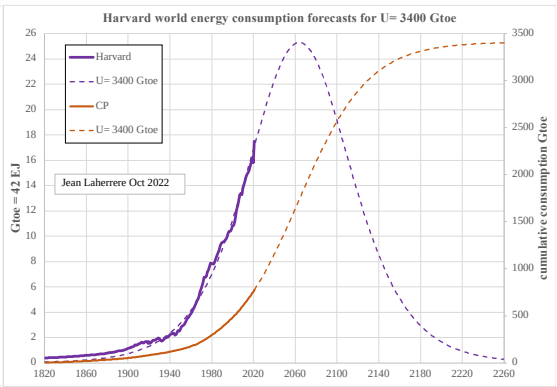




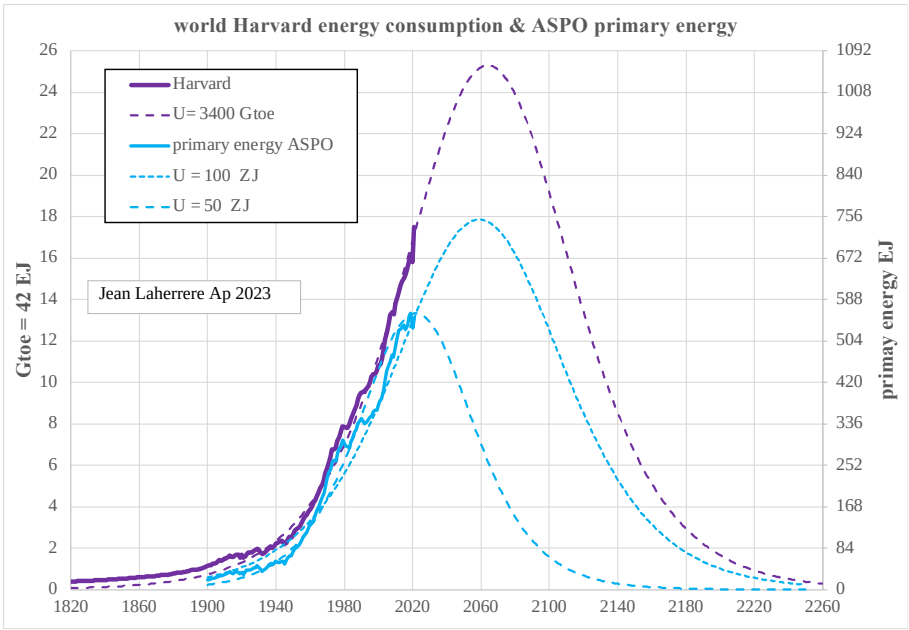
Since the oil shock of 1973 GDP is manipulated with hedonic factor and other items.

HL of Harvard world energy consumption trends towards 3400 Gtoe, meaning a peak around 2060, in contrary with a peak in 2020 from the above graph from ASPO data. This shows the uncertainty of forecasting peak from similar data. But both forecast a peak in energy, when the world seems to live as growth will be forever: earth is finite!



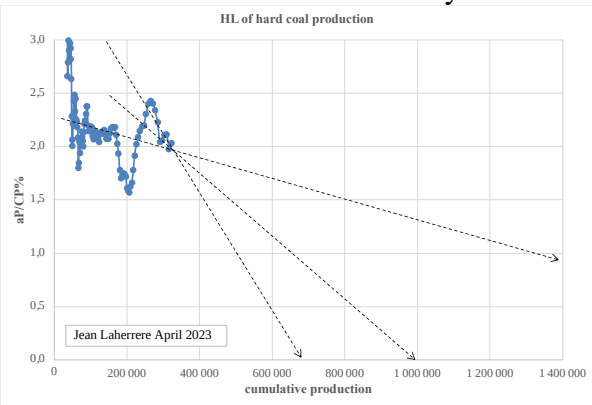


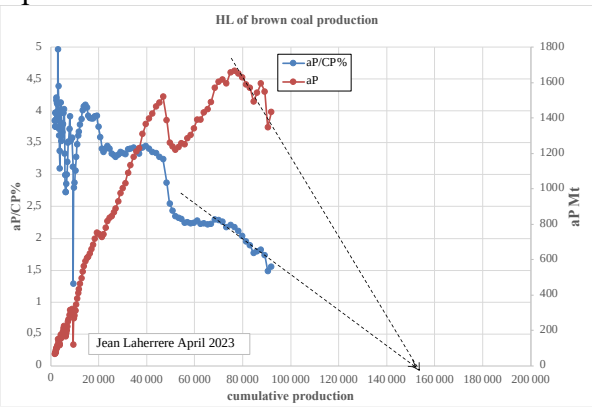
Harvard energy consumption forecast is compared with ASPO primary energy forecast. It appears that the ultimate of 100 ZJ looks better!



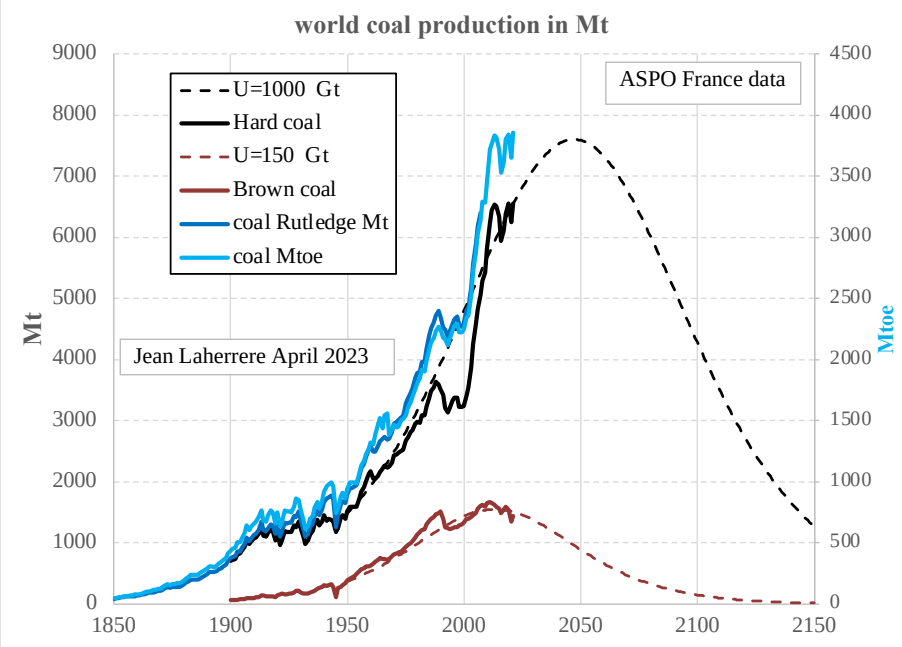
-world fossil fuels and electricity generation

HL of hard coal production in Mt trends poorly towards 1000 Gt, but HL of brown coal production is better trending towards 150 Gt, but the heat content by tonne of hard coal is about 50 % above brown coal. They should be reported in toe or Joule 1toe = 42 GJ.



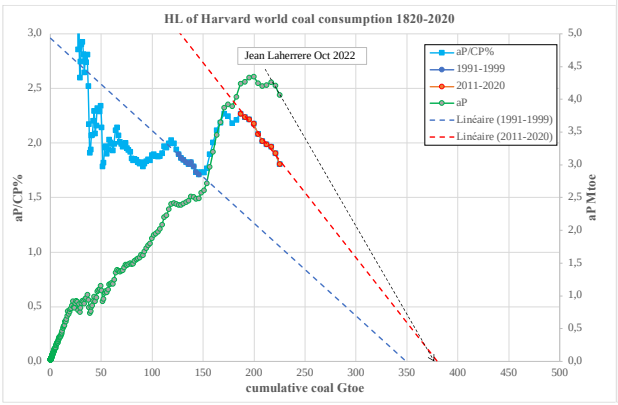


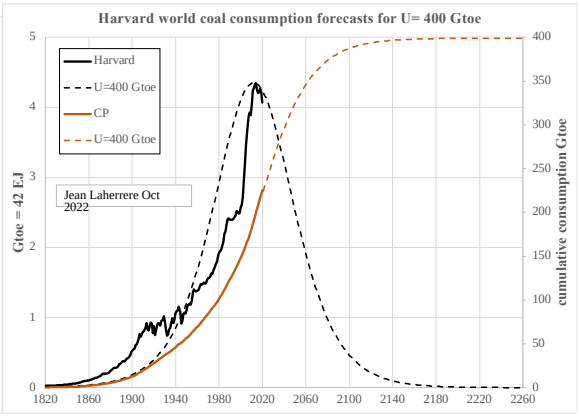
Brown coal production has peaked in 2011 and hard coal could peak around 2050:



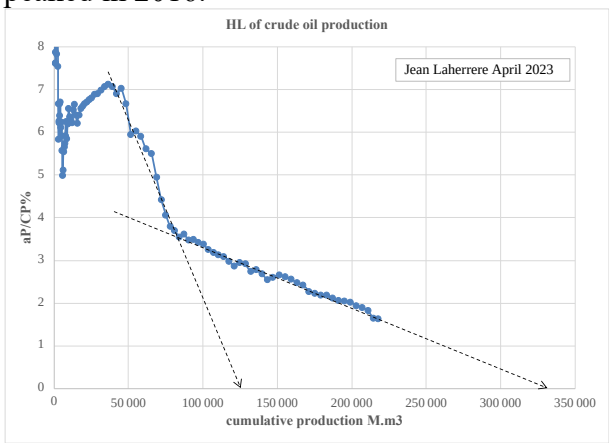
The amount of coal resources is huge, but production is limited by EROI= energy return in energy invested. Coal reserves are limited by the depth and the thickness of the seams. Coal is not reported be produced beyond 1500 m depth and only onshore, when gold is produced over 4000 m deep. The largest volume of gold (as uranium) is found in the sea waters (up to 20 Mt against a global cumulative gold production of 0.2 Mt), but presently no one tries to produce gold from sea waters, as the concentration is 1 g/100 Mt of water when presently gold is mined with 1 g/t of ore.

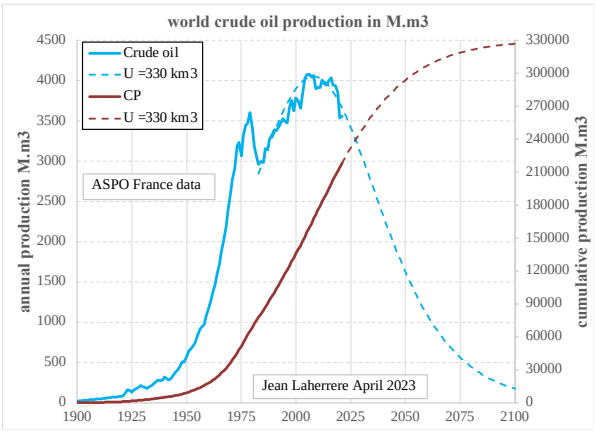
World coal consumption are reported by Harvard University in Mtoe and the HL trends towards 400 Gtoe; meaning a peak in 2013, in contrary with above, broken down into brown peak (peak 2013) and hard (peak 2047):



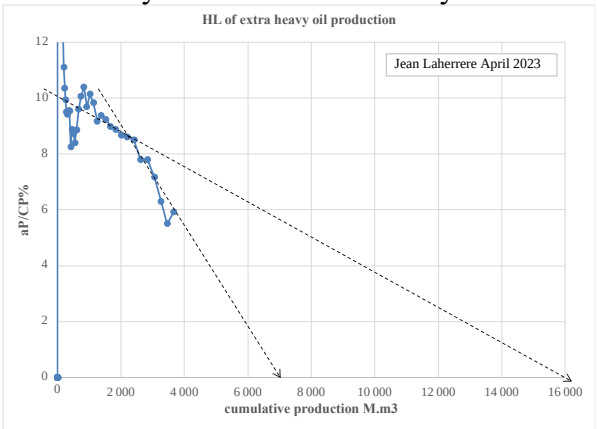


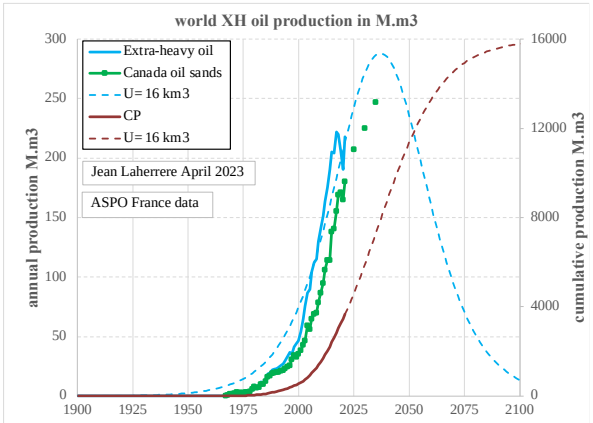
HL of world crude oil (excluding LTO and XH) production trends towards 330 G.m3 (km3), meaning the crude oil (unclear definition, here excluding LTO and XH) production has peaked in 2016.





HL of extra-heavy (XH) oil production is disturbed by the political problems of Venezuela and a past trend was taken for an ultimate of 16 km3 = 100 Gb
Extra-heavy oil reserves are mainly Athabasca oilsands and Venezuela Orinoco.





Orinoco XH, contrary to Athabasca XH known since centuries, does not outcrop and the 4 fields were found from 1936 to 1939 by drilling.
The first cross-section interpreted by Carlos Cramez displays the pinch-out of the Cretaceous (source rock in green) and Oficina XH

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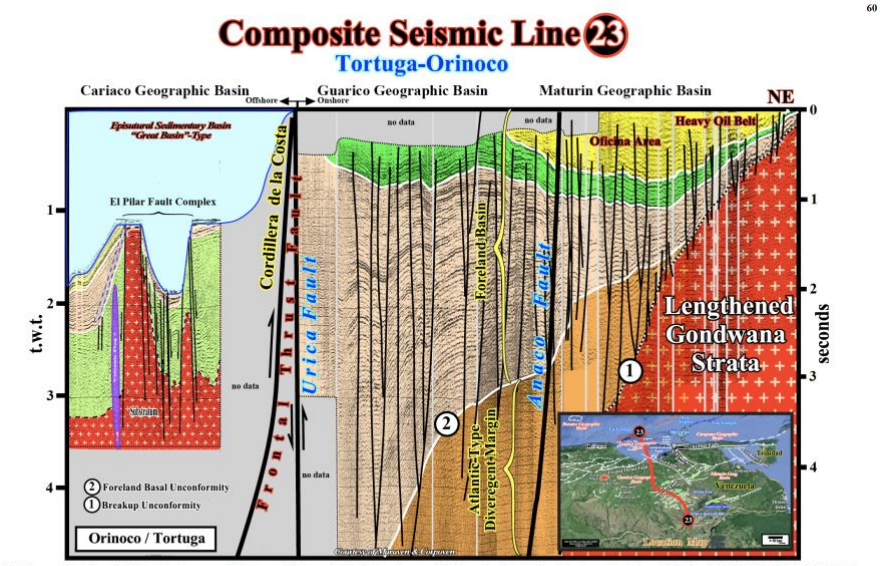

This long seismic line (> 400 km) between south Tortuga offshore and the Orinico heavy oil belt was built with the following seismic lines: ZB-11 ext + ZB-11 + FB-1 Ext + FB-1 + YDV-2 + V3 +FV-12 + OG-DV 21 + STC-DV10 + NAC-DV40 + NAC-DV4A + IV-R +VZ-33. The post Pangea continental encroachment stratigraphic cycle is, clearly, recognized,. The Gondwana strata (including the Permo -Triassic rift-type basins), the Atlantic-type divergent margin and the foreland basin are distinguished without major difficulty. In the offshore. the El Pilar fault compex and the associated episutural basin highlight the Cariaco Depression. Most of the oil found in this sedimentary prism was derived from the Upper Cretaceous La Luna Formation, in the west, and its equivalent, the Querecual Formation, in the east. Minor volumes of oil generated from Tertiary source-rocks occur in the Maracaibo, eastern geographic basins and in the Falcon area.

The second cross-section shows the complexity of the reservoirs:

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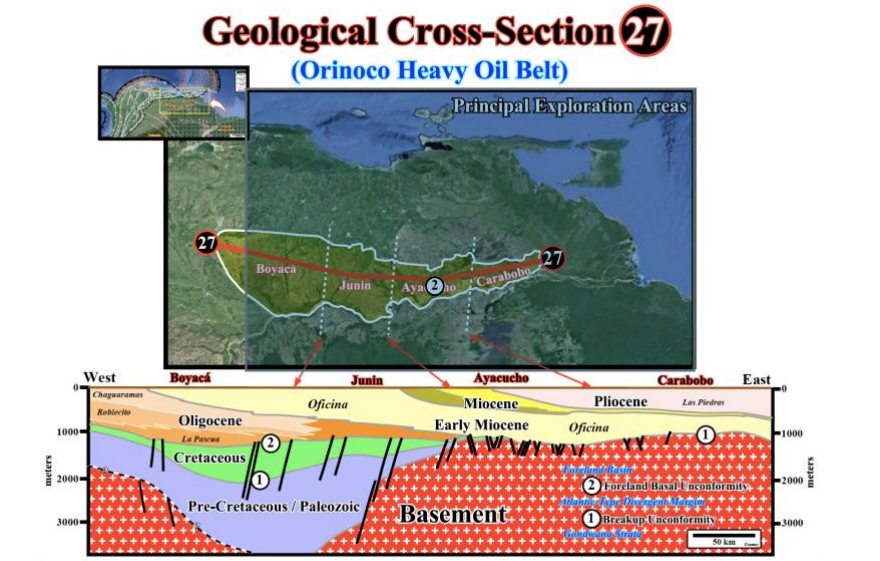

This W-E geological cross section, roughly, parallel to the Orinoco river, illustrates the distal section (southen area) of the foreland basin, which overlies, directly, the basement, in the eastern part of the cross-section, or the Mesozoic Atlantic-type basin sediments, which lies upon Gondwana strata, in the central and western part of the cross-section. As you can notice by the northward progradational geometry of the forleand sediments, particularly, during the Oligocene-Early Miocene time, the provenance of the terrigeneous influx, in this area, is from the south, that is to say, from the Guyana shield, what is not falsified by the Early Miocene paleogeographic map illustrated on the next plate.

The Oficina reservoirs

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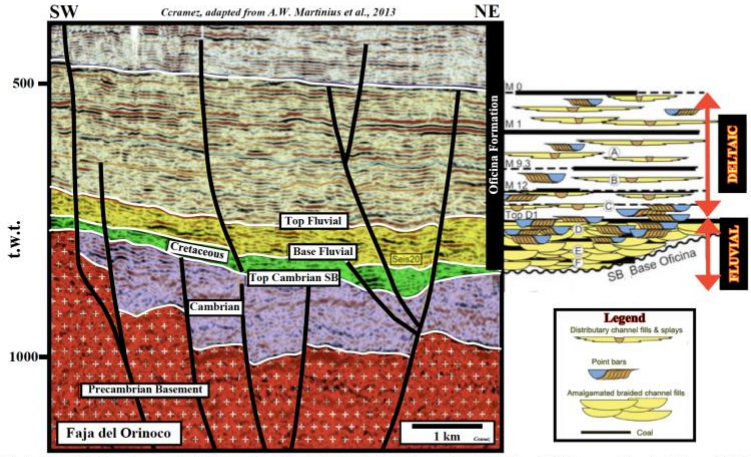
Petrocedeño Field Seismic Line

Orinoco HeavyOil Belt



This plate illustrates how the Petrocedeno geoscientists have calibrate the seismic lines shot in their exploration block. Above the Cretaceous sediments, which overly the Gondwana strata, that in this particular area are represented by Cambrian and Precambrian rocks, the Oficina seismic nterval was divided in two major packages : (i) Fluvial and (ii) Deltaic. The fluvial package is, mainly, composed of sandstones deposited in amalgamated braided channels with point bars in the top. In the deltaic interval there are a predominance of sandstone deposited in distributary channel fills and crevasse splays. The presence of obvious normal faults affecting the reservoir zones can enhanced the stratigraphi trapping developping morphological traps by juxtaposition. In such hypothesis, geoscientists must, imperatively, proposed stuctural maps of the local sealing-rocks (generally ,clay plugs) that confine the oil accumulations.

The net oil sand thickness is shown on the 4 XH areas but the recovery factor is poor in Boyaca, better in Junin and even more in Ayacucho and Carabobo

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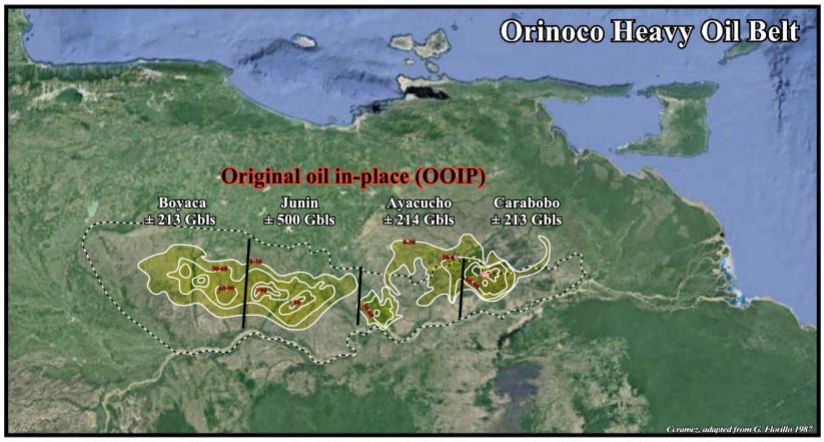
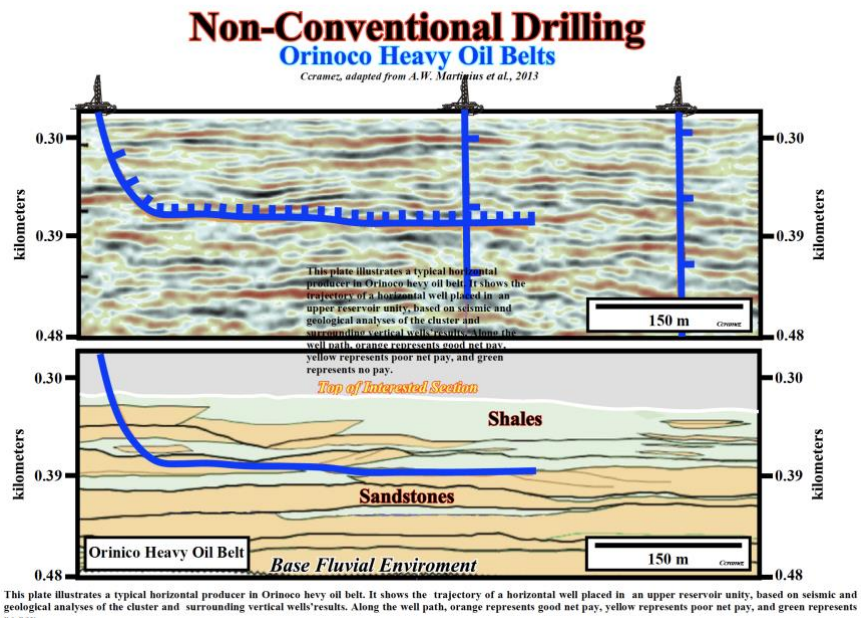
Net Oil Sand Thickness

(in meters)



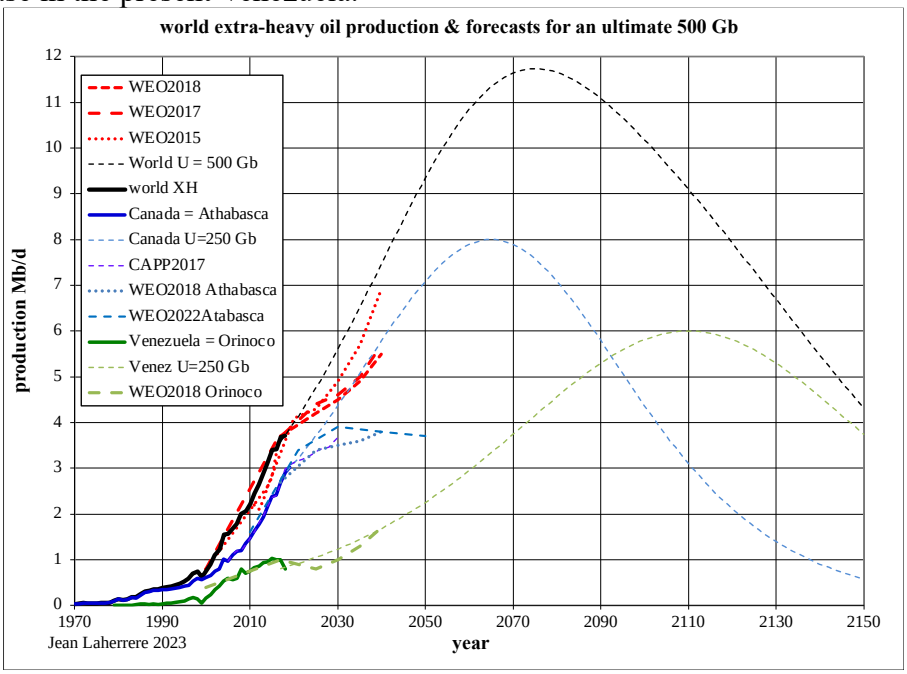
In Orinoco heavy oil belt, the oil trapped has an average gravity of 9.5° API (see next plate), with an average viscosity of 1500 cp at 99°C. The sulfur content is around 3.6%, vanadium 420 ppm, and nickel 95 ppm. Production tests suggest an average cold well rates between 100 and 800 b/d and a threefold increasing figures upon steam soak. The main reservoir-rocks are predominantly encountered in the basal section of the Tertiary and are formed of unconsolidated fluvio-deltaic sands. Some oil has been trapped in rocks of Upper Cretaceous age, especially toward the west. However, the trapping mechanism for oil in these conditions is, mainly, stratigraphic (pinch-out, truncation of a complex set of meanders with intercutting of previously deposited s, etc.). In some restricted areas, a combination of faulting and stratigraphy can work as an important trapping mechanism. The physical and chemical properties of the oil are, most likely a conasdequence of to long-distance southward migration (between 100-150 km) and the consequent loss of volatiles and oxidation during migration. Applying a recovery factor of 30% as a result of cyclic steam injection followed by steam drive, the recoverable oil in nthe Orinoco heavy oil belts was estimated, by several geoscientists, as, more or less, 245 x 10^9 bbl.

The good pay is in orange on this horizontal well.

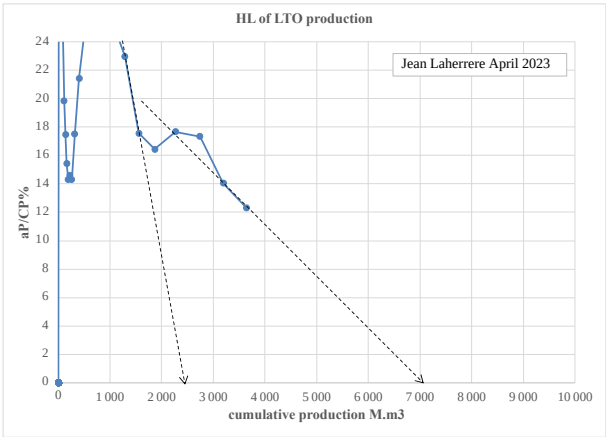


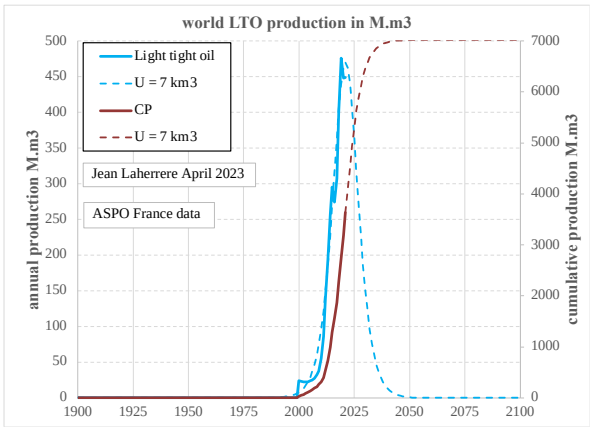
This plate illustrates a typical horizontal producer in Orinoco hevy oil belt. It shows the trajectory of a horizontal well placed in an upper reservoir unity, based on seismic and geological analyses of the cluster and surrounding vertical wells'results. Along the well path, orange represents good net pay, yellow represents poor net pay, and green represents

My 2019 XH forecast was based on ultimates of 500 Gb (5 more time), showing IEA/WEO2018 forecast. It is obvious that forecasting XH ultimate from past production will give pessimistic results. The problem of XH production is that it needs big energy to produce (steam) and big investments to transport (upgrader), needing long and stable contracts which is not the case in the present Venezuela.

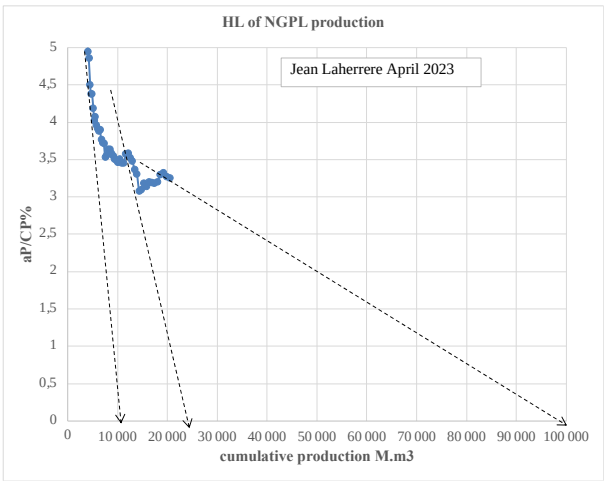


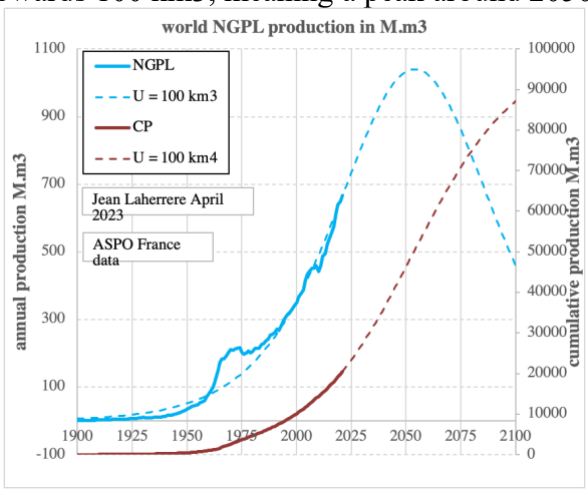
HL of world LTO (light tight oil) mainly in the US trends towards 7 km3 (45 Gb) (my estimate for US LTO ultimate is 35 Gb), meaning that world LTO production is peaking.





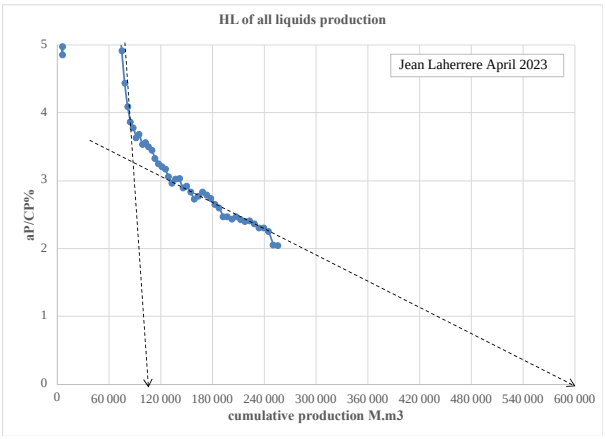
HL of world NGPL trends (very poor quality) towards 100 km3, meaning a peak around 2050



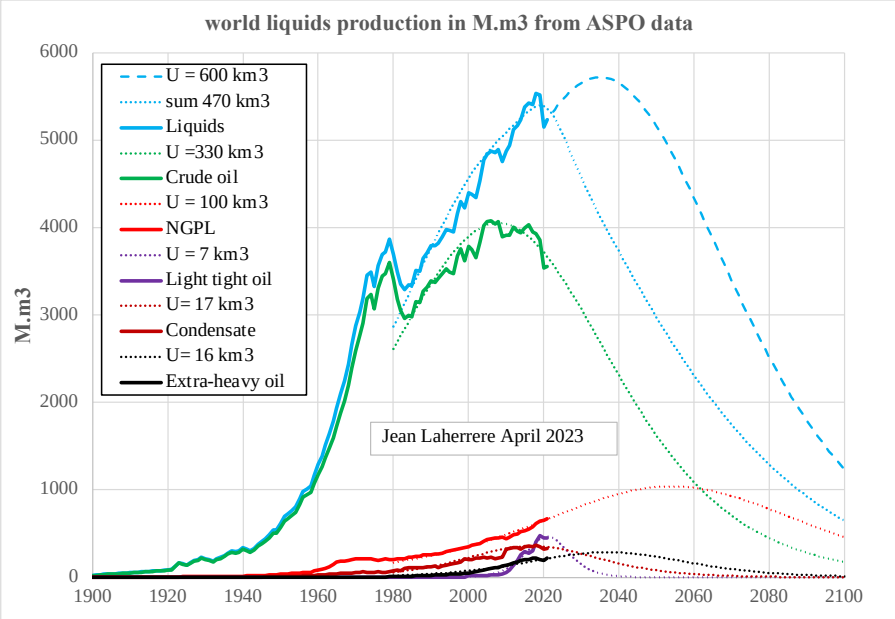


But see page 26 more detail on NGPL.

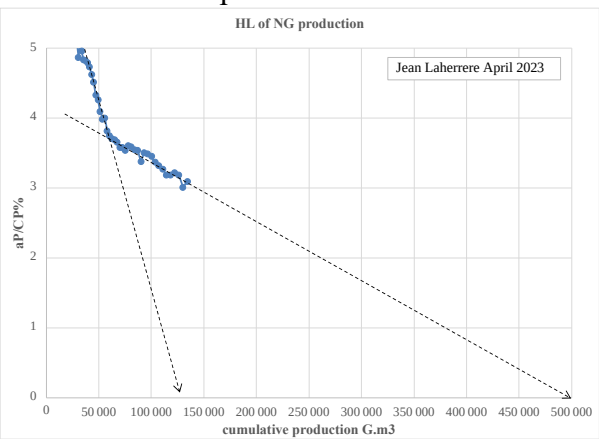
HL of world liquids production (not all as excluding refinery gain and other liquids as XTL (X to liquids, X being biomass, coal, NG, shale)) trends towards 600 km3, meaning a peak before 2040

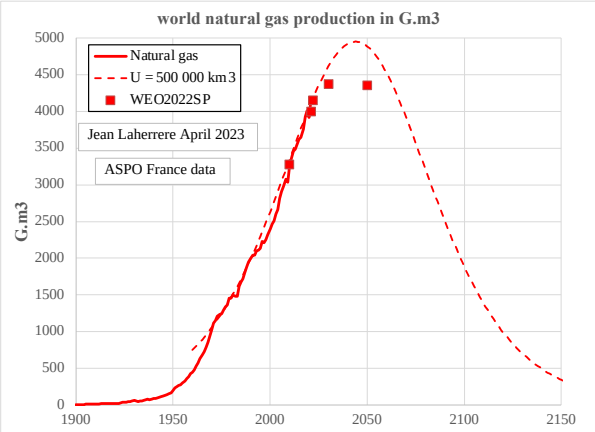


But this 600 km3 liquids ultimate (fair quality) is well above the sum of the different oils being 470 km3, but with different HL qualities (in particular for NGPL), giving a peak now



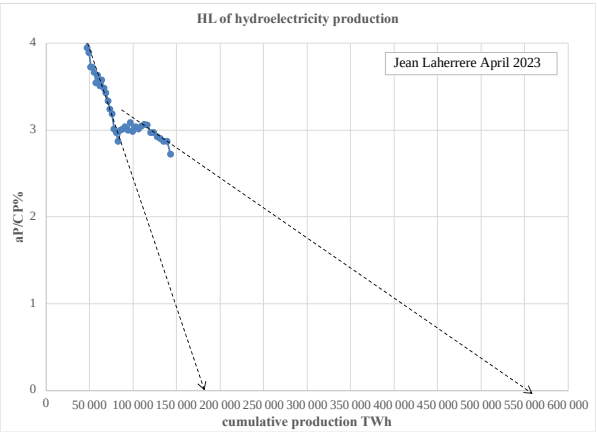
HL of NG world production trends towards 500 T.m3

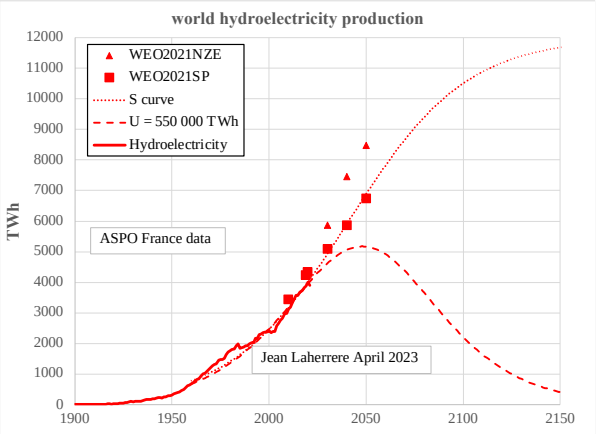




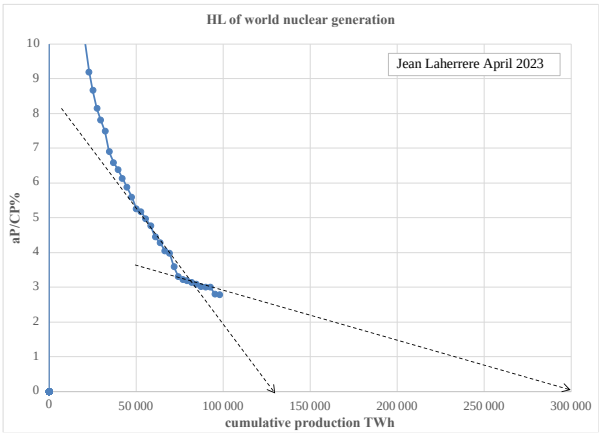
IEA/WEO2022 SP is less optimistic than the HL for the value of the NG peak!

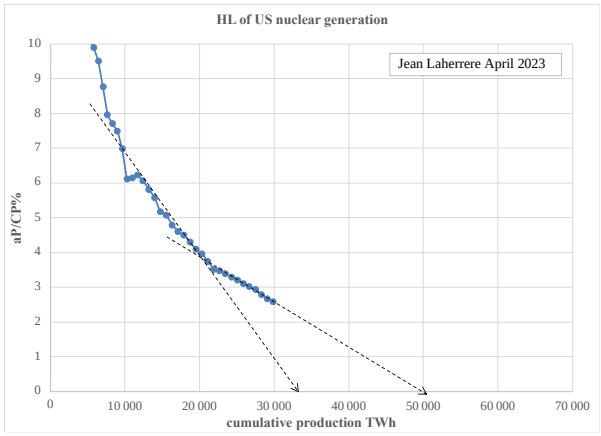
Hydroelectricity could be considered as renewable or not. The problem of renewables going to a peak with Hubbert curve or an asymptote with S curve is found page 65.
HL of world hydroelectric generation trends (poor) towards 550 PWh, meaning a peak in 2050 with a value lower than WEO2021 SP (which matches with S curve) and much lower than WEO2021 NZE



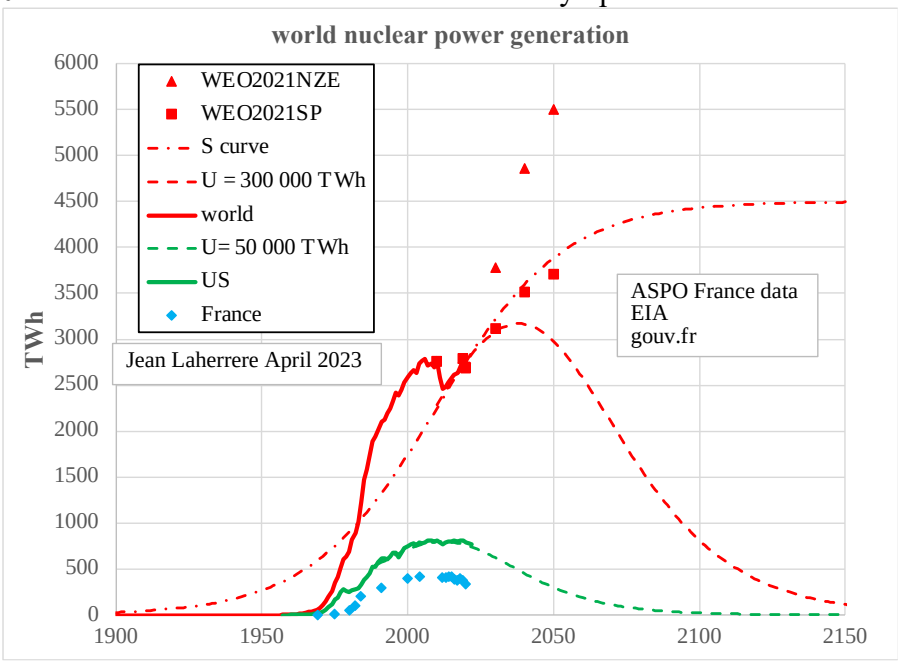


HL of world nuclear generation trends towards 300 PWh (HL US 50 PWh), meaning a peak about 2040.





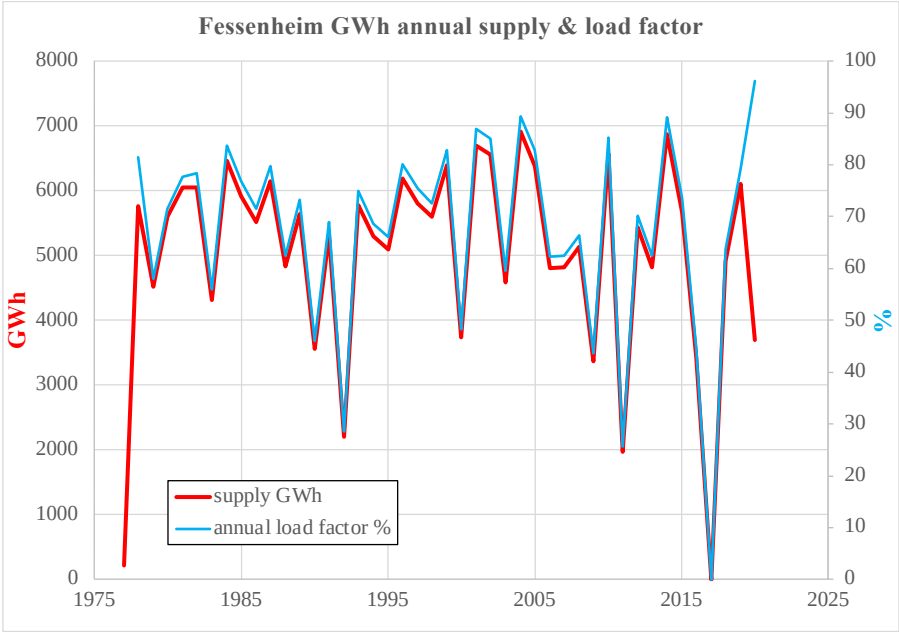
IEA/WEO2021 SP is in line with S curve and looks very optimistic:



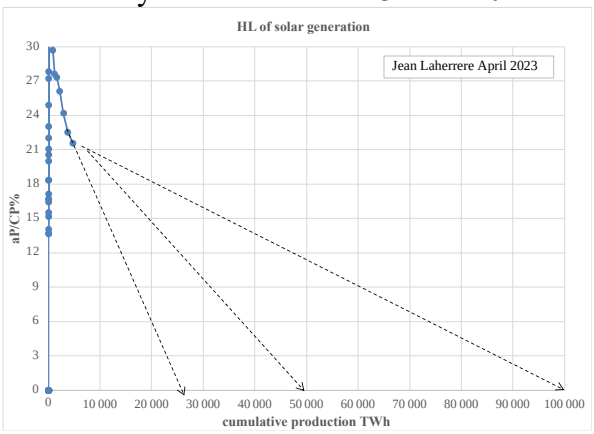
Obviously, the generation of a nuclear plant is quite different from the oil or NG production of an oil or NG field, as a nuclear plant has a certain capacity and can produce this capacity all the time, except when stopped for maintenance: its supply is in fact its load factor. The life of a nuclear plant can be 60 to 80 years. The nuclear generation of a country depends upon the number of nuclear plants and their sizes.

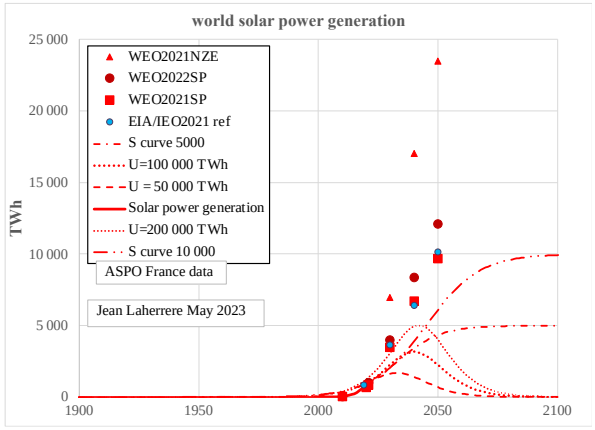
It appears that the modelling with Hubbert cycles of a country nuclear generation is not the best! It could be modelled with S curve: see further.

The production of Fessenheim in France from 1977 to 2020: its closure was a political decision.

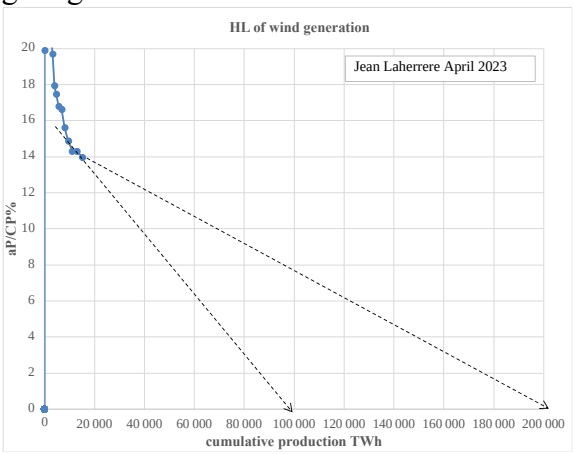


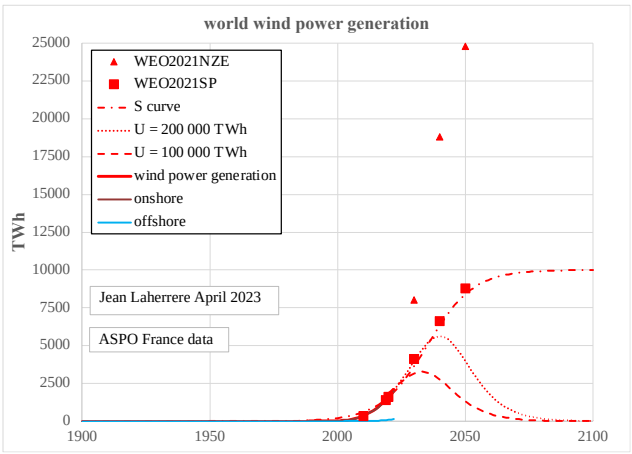
HL of the world solar generation is very poor as started only after 2000: an ultimate of 50 PWh was taken as 100 PWh and 200 PWh, even 5000 or 10 000 TWh S curves give a forecast below IEA/WEO2022 forecast, which looks very optimistic: solar energy is intermittent, in France only a load factor of 13 % in 2021:



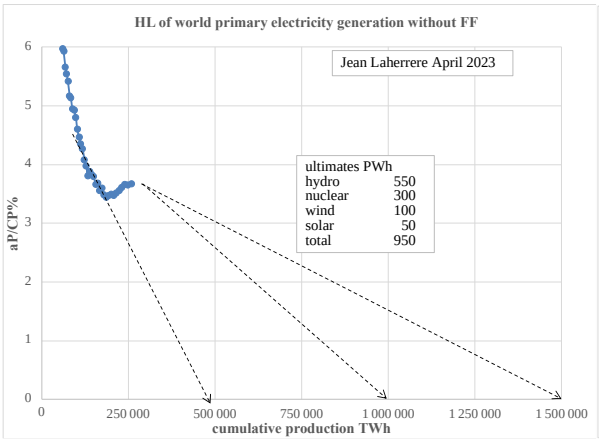


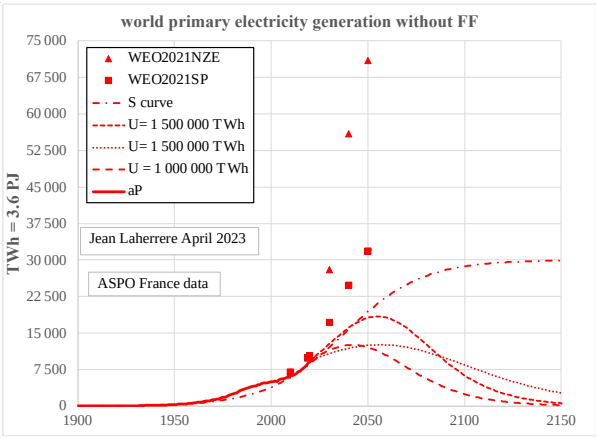
HL of world wind generation trends poorly towards 100 PWh, but 200 PWh is also taken, giving a S curve in line with IEA/WEO2021 SP:



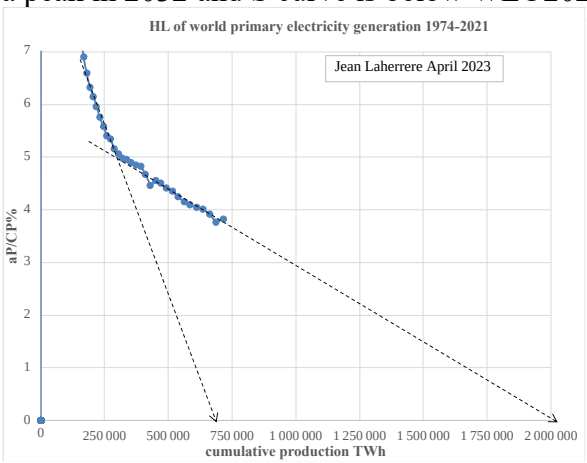


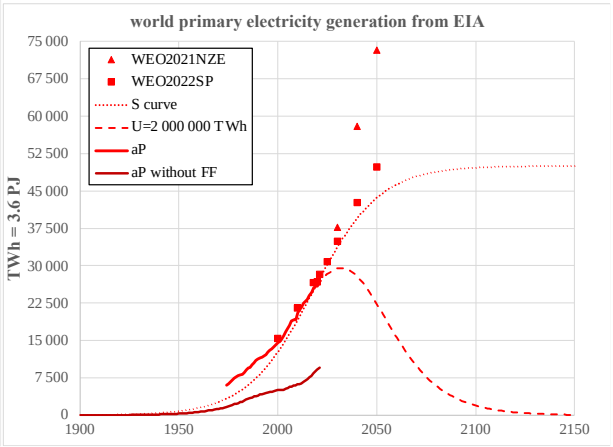
HL of world primary electricity generation excluding FF is useless and ultimates of 1000 and 1 500 PWh are chosen but giving peaks well below WEO2021:WEO2021NZE looks unrealistic.



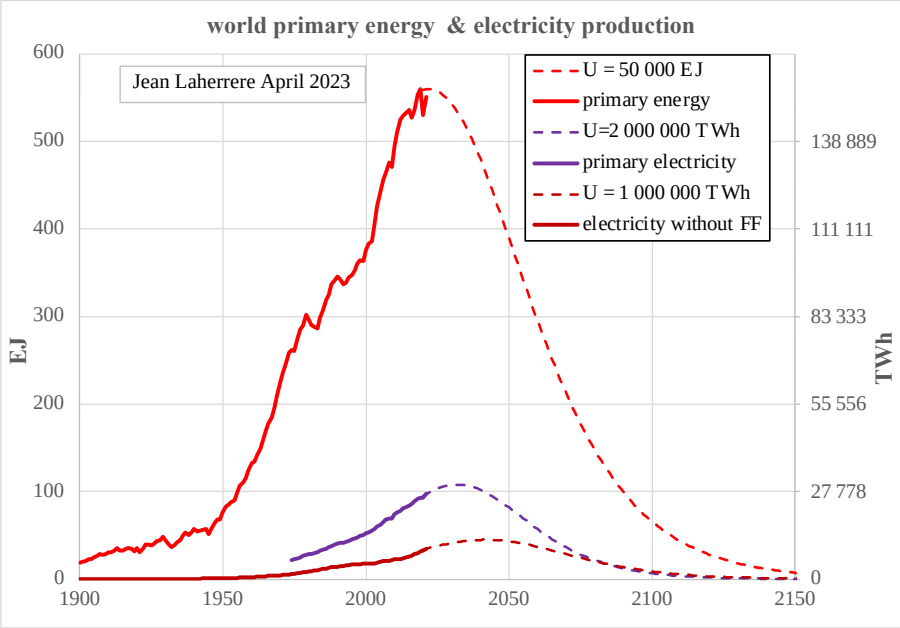


HL of world primary electricity generation from EIA trends fairly towards 2 000 PWh, giving a peak in 2032 and S curve is below WEO2022 SP:

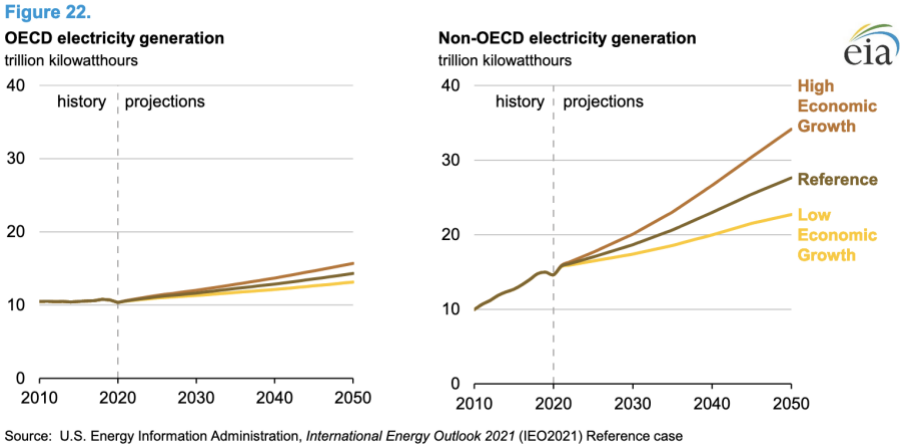




World primary energy is compared with primary electricity generation with and without fossil fuels, showing the small part of electricity 1 TWh = 278 EJ:

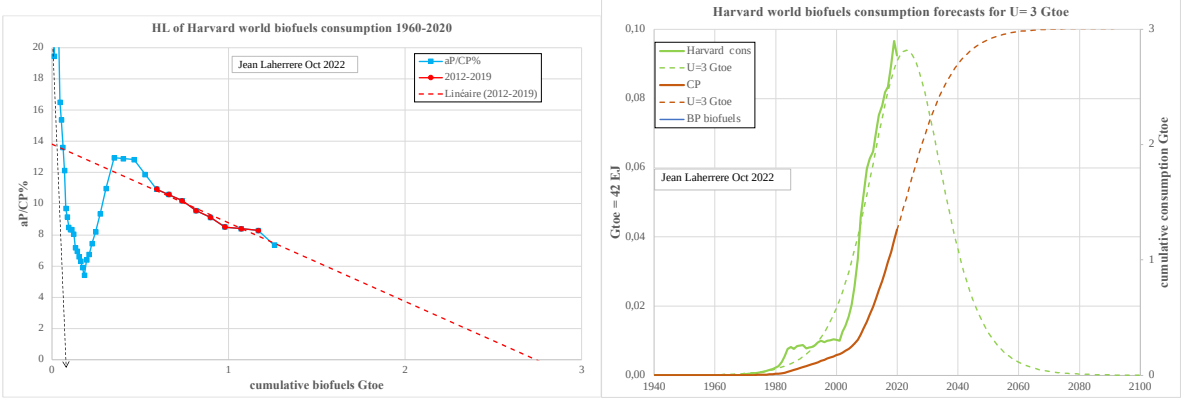


EIA forecasts for 2050 40 PWh (50 for IEA) and 23 PWh for my above forecast. Most of EIA growth is in Non-OECD:

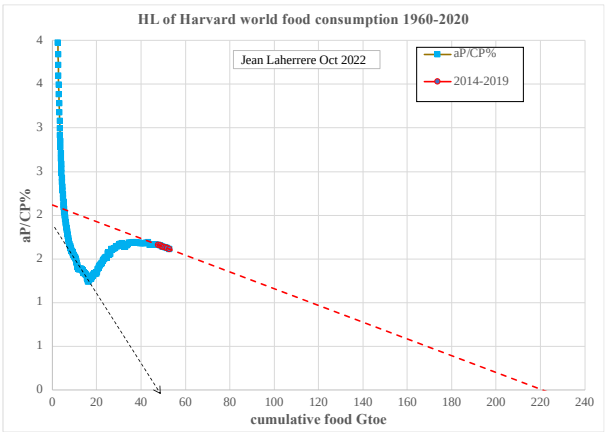


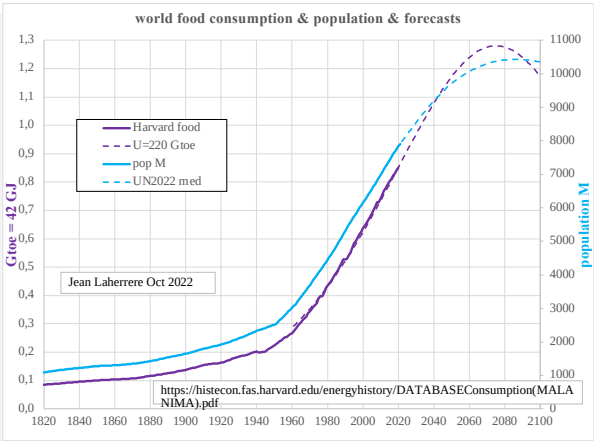
Source: U.S. Energy Information Administration, *International Energy Outlook 2021* (IEO2021) Reference case

HL of biofuels consumption from Harvard trends towards 3 Gtoe, meaning a peak (or an asymptote) in 2019

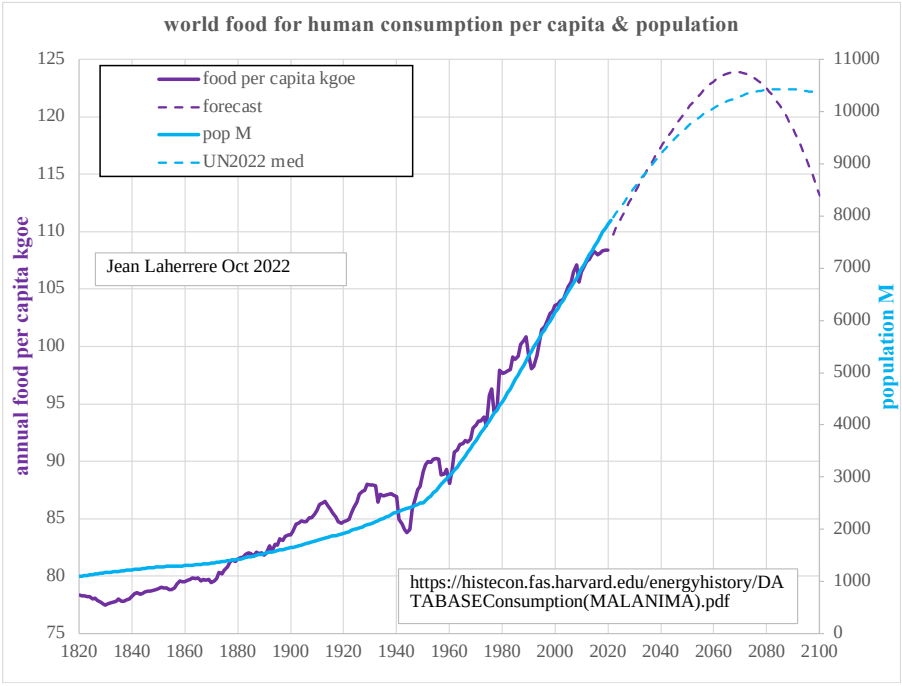


HL of Harvard world food for Humans consumption trends towards 220 Gtoe, meaning a peak around 2075:





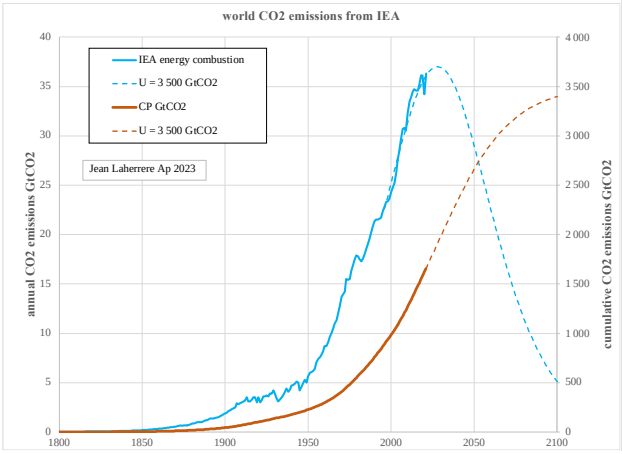
World food for human consumption per capita correlates fairly well with world population since 1820:

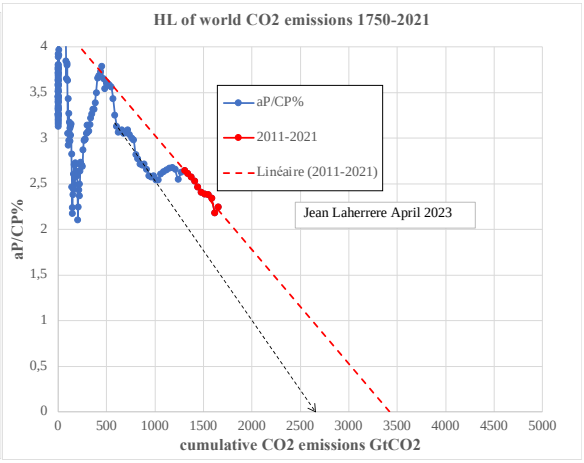


-CO2 emissions from energy combustion

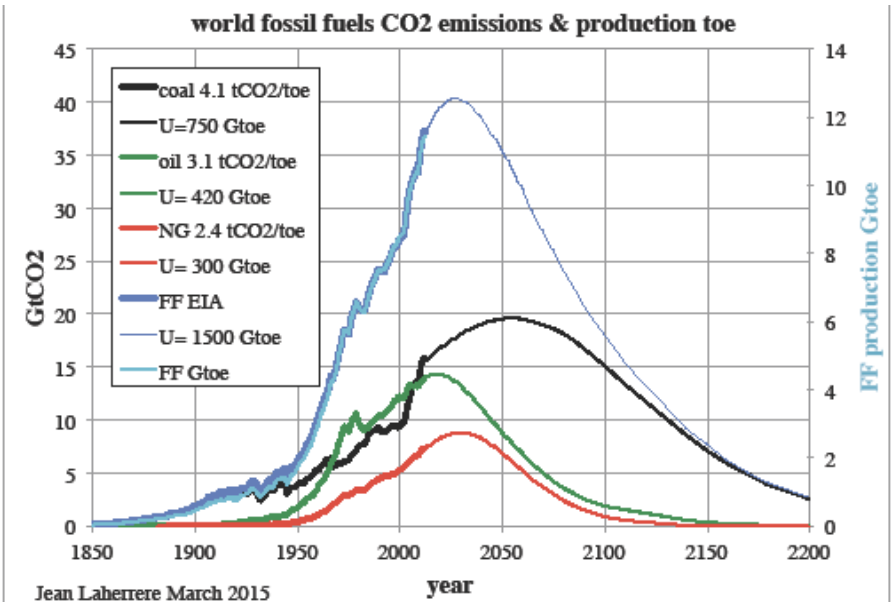
IEA reports CO2 emissions in GtCO2 from energy combustion 1899-2021 and before OWID data was used from 1750.

HL of world CO2 emissions trends (fair) towards 3500 GtCO2, giving a peak in 2028 at 37 GtCO2 (36.3 in 2021)





I remind my previous papers on CO2 emissions:
-Laherrere J.H. 2021 «COP21 commitments for CO2 emissions from 2019 data for world and main countries" February- https://aspofrance.org/2021/02/27/cop21-commitments-for-co2-emissions-from-2019-data-for-world-and-main-countries/
-Laherrere J.H. 2019 «Are there enough fossil fuels to generate the IPCC CO2 baseline scenario?" https://aspofrance.files.wordpress.com/2019/08/ipccco2rcp.pdf
-Durand B. & Laherrere J.H. 2015 « Fossil Fuels Ultimate Recovery Appraisal, Clue to Climate Change Modelling » International Scientific Conference 7-10 juin Paris https://aspofrance.org/2015/12/11/fossil-fuel-ultimate-recovery-appraisal-clue-to-climate-change-modeling-december-2015-bernard-durand/
My 2015 graph converting each fossil fuel past production and forecast into CO2 emissions, (for the COP21 in Paris) forecasted a peak of CO2 FF emissions in 2030 at 40 GtCO2, close to my present forecast above. It is good to find the same forecast 8 years later using a different approach.



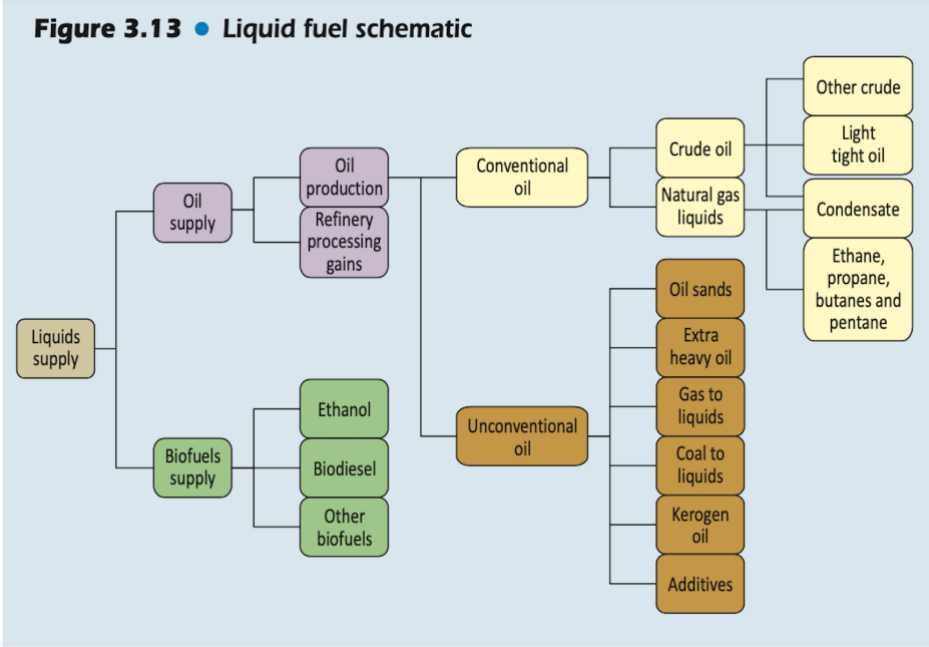
These forecasts are very far from the IPCC scenario SSP5 (shared socio-economic pathways) forecasting an increase of 4 °C!

-oil & gas data

Oil and gas production data is a jungle because the competition between producers which keep their data confidential. And energy agencies as EIA, IEA, OPEC have different goals.

OPEC oil production quotas were the reason for fight during the 1980s on reserves (300 Gb of speculative resources) and on production.
There is no consensus on most of the definitions.
Contrary to the football game with world rules, umpires and red cards, the oil industry has no world rules, no umpires and no red cards. Most oil reserves followed the SEC (Security and Exchange Commission) rules which are financial, other oil reserves followed the OPEC rules which are political. Every oil producer uses the SPE (Society of Petroleum Engineers) techniques (PRMS) to estimate their confidential reserves.
The only product with a world consensus is bitumen because the term was defined in 1982 at the II international conference on heavy crude and tar sands organized by Unitar (United Nations Institute for Training and Research), as an oil with a viscosity greater than 10 000 centipoise at original reservoir temperature.
But there is no world consensus on the definition of crude oil, condensate or natural gas liquids.

The IEA (International Energy agency) was created in opposition with the OPEC.
OPEC quotas for its members on oil production apply to crude oil, but not to condensate.
IEA bad definition on condensate is either crude oil if sold with crude or NGL if sold with NGL: it is ambiguous!



But EIA glossary distinguishes in production:
- Crude Oil: A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities
-Lease Condensate: A mixture consisting primarily of pentanes and heavier hydrocarbons which is recovered as a liquid from natural gas in lease separation facilities. This category excludes natural gas plant liquids, such as butane and propane, which are recovered at downstream natural gas processing plants or facilities.
-Natural Gas Plant Liquids: Those hydrocarbons in natural gas that are separated as liquids at natural gas processing plants, fractionating and cycling plants, and, in some instances, field facilities. Lease condensate is excluded. Products obtained include ethane; liquefied petroleum gases (propane, butanes, propane-butane mixtures, ethane-propane mixtures);

isopentane; and other small quantities of finished products, such as motor gasoline, special naphthas, jet fuel, kerosene, and distillate fuel oil.
EIA for US oil production reports lease condensate with crude oil, but natural gas plant field production called NGL (?) https://www.eia.gov/dnav/pet/pet_pnp_gp_dc_nus_mbbl_m.htm

Natural Gas Plant Field Production

Area: U.S. Period-Unit: Monthly-Thousand Barrels

Download Series History | Definitions, Sources & Notes

Show Data By: Product / Area	Graph / Clear	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	View History
Natural Gas Liquids		186,947	182,867	189,673	181,991	170,940	181,351	1981-2023
Ethane		73,220	71,002	75,799	75,162	67,240	73,381	1981-2023
Propane		59,355	58,806	60,194	57,165	55,505	57,841	1981-2023
Normal Butane		17,041	16,807	16,961	15,767	15,174	16,213	1981-2023
Isobutane		14,503	14,126	14,856	14,107	13,934	14,138	1981-2023
Natural Gasoline		22,828	22,126	21,863	19,790	19,087	19,778	1981-2023
Pentanes Plus		--	--	--	--	--	--	1981-2023
Liquefied Petroleum Gases		--	--	--	--	--	--	1981-2023

EIA for US consumption with products reports US monthly field production https://www.eia.gov/dnav/pet/pet_sum_snd_d_nus_mbbl_m_cur.htm dec2022 as crude = 375 Mb and NGL = 171 Mb

Show Data By: Product / Area	Field Production
Crude Oil & Petroleum Products	546,076
Crude Oil	375,136
Hydrocarbon Gas Liquids	170,940
Natural Gas Liquids	170,940
Ethane	67,240
Propane	55,505
Normal Butane	15,174
Isobutane	13,934
Natural Gasoline	19,087

EIA international browser https://www.eia.gov/international/data/world/petroleum-and-other-liquids/ reports crude oil with lease condensate.

Petroleum and other liquids

Data Options | Download Options | Notes & Sources | Show visua

SORT BY: Energy Source/Activity / Country/Region

PIN	API		2018	2019	2020	2021
		World				
		Production				
		Total petroleum and other liquids (Mb/d)	100,495	100,236	93,867	95,703
		Crude oil, NGPL, and other liquids (Mb/d)	98,127	97,889	91,760	93,441
		Crude oil including lease condensate (Mb/d)	82,986	82,170	76,013	77,157
		NGPL (Mb/d)	11,224	11,741	11,953	12,318
		Other liquids (Mb/d)	3,916	3,979	3,794	3,966
		Refinery processing gain (Mb/d)	2,369	2,347	2,107	2,263

Crude Oil data for Canada include Alberta oil sands production.
Other Liquids includes biodiesel, ethanol, liquids produced from coal, gas, and oil shale, Orimulsion, blending components, and other hydrocarbons.
Negative refinery processing gain data values indicate the reported volumetric output is lower than reported inputs.

In theory NGL = NGPL + condensate, but it is not always the case, as condensate can be reported within crude oil

OPEC general notes define crude oil as including lease condensate:
Crude oil: a mixture of hydrocarbons that exists in a liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. For statistical purposes, volumes reported as crude oil include:
- liquids technically defined as crude oil;
- small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs, but which are liquid at atmospheric pressure after being recovered from oil well (casing head) gas in lease separators;
- small amounts of non-hydrocarbons produced with the oil;
- very heavy and extra-heavy crude oils with viscosity less than 10,000 mPa-s (centipoises) at original reservoir conditions.

OPEC monthly report April 2023 has two sets of production data: secondary sources and direct communication (nothing from Iran and Libya

OPEC crude oil production

According to secondary sources, total **OPEC-13 crude oil production** averaged 28.80 mb/d in March 2023 lower by 86 tb/d m-o-m. Crude oil output increased mainly in Saudi Arabia, while production in Angola, Iraq and Nigeria declined.

Table 5 - 7: OPEC crude oil production based on *secondary sources*, tb/d

Secondary sources	2021	2022	3Q22	4Q22	1Q23	Jan 23	Feb 23	Mar 23	Change Mar/Feb
Algeria	913	1,017	1,040	1,030	1,015	1,016	1,017	1,013	-4
Angola	1,122	1,140	1,155	1,084	1,072	1,136	1,072	1,007	-64
Congo	263	261	265	252	268	257	278	270	-8
Equatorial Guinea	98	84	90	63	54	55	61	48	-12
Gabon	182	197	201	199	196	190	196	203	7
IR Iran	2,392	2,554	2,565	2,567	2,565	2,554	2,574	2,567	-8
Iraq	4,046	4,439	4,522	4,505	4,381	4,410	4,375	4,358	-18
Kuwait	2,419	2,704	2,801	2,712	2,682	2,692	2,676	2,678	2
Libya	1,143	981	976	1,153	1,157	1,148	1,163	1,161	-2
Nigeria	1,373	1,204	1,063	1,171	1,344	1,308	1,371	1,354	-17
Saudi Arabia	9,114	10,529	10,891	10,603	10,354	10,295	10,361	10,405	44
UAE	2,727	3,066	3,168	3,094	3,043	3,046	3,046	3,038	-8
Venezuela	553	678	662	667	693	691	692	695	2
Total OPEC	**26,345**	**28,856**	**29,400**	**29,100**	**28,824**	**28,798**	**28,883**	**28,797**	**-86**

Notes: Totals may not add up due to independent rounding, given available secondary sources to date. Source: OPEC.

Table 5 - 8: OPEC crude oil production based on *direct communication*, tb/d

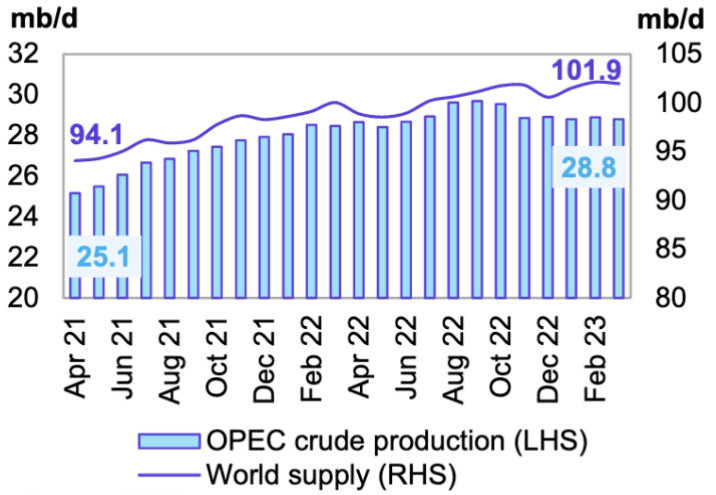
Direct communication	2021	2022	3Q22	4Q22	1Q23	Jan 23	Feb 23	Mar 23	Change Mar/Feb
Algeria	911	1,020	1,050	1,030	1,011	1,012	1,014	1,008	-6
Angola	1,124	1,140	1,151	1,076	1,046	1,105	1,064	972	-92
Congo	267	262	261	261	278	275	273	285	12
Equatorial Guinea	93	81	83	56	51	55	50	48	-2
Gabon	181	191	198	183	201	206	207	190	-16
IR Iran	..	..	..	..	..	..	..	..	..
Iraq	3,971	4,450	4,632	4,505	4,288	4,331	4,339	4,200	-139
Kuwait	2,415	2,707	2,799	2,721	2,676	2,676	2,676	2,676	0
Libya	1,207	..	..	..	..	..	..	..	..
Nigeria	1,323	1,143	999	1,145	1,277	1,258	1,306	1,268	-38
Saudi Arabia	9,125	10,591	10,968	10,622	10,456	10,453	10,450	10,464	14
UAE	2,718	3,064	3,170	3,093	3,041	3,038	3,041	3,045	4
Venezuela	636	716	673	693	731	732	704	754	50
Total OPEC	**..**	**..**	**..**	**..**	**..**	**..**	**..**	**..**	**..**

Notes: .. Not available. Totals may not add up due to independent rounding. Source: OPEC.

Why two sources? Which one is right?

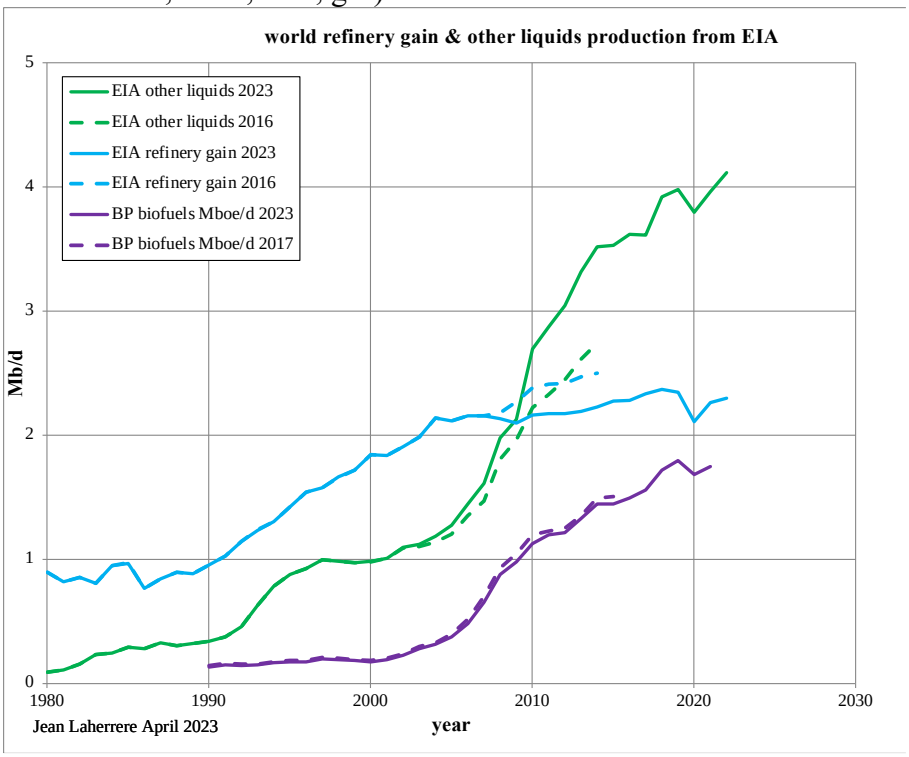
The world oil supply is given by OPEC monthly report as 101.9 Mb/d for March 2023

Graph 5 - 29: OPEC crude production and world oil supply development

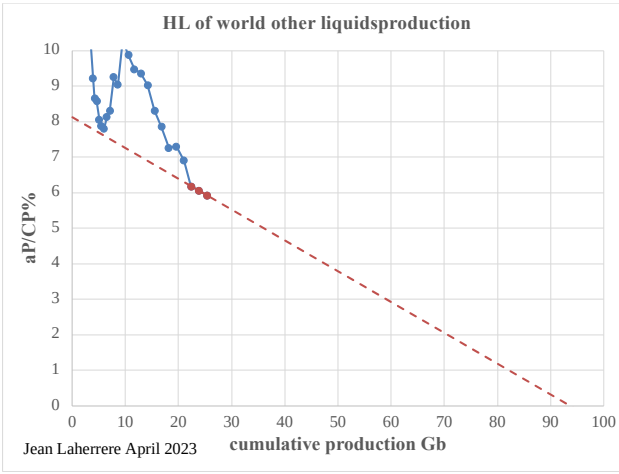


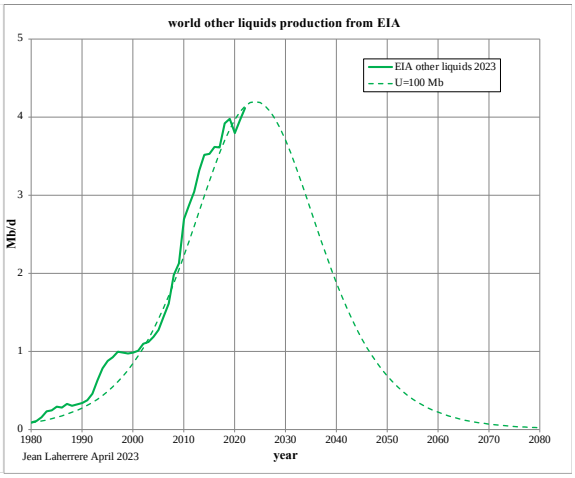
Source: OPEC.

All liquids in Mb/d include crude oil, NGL, but also refinery gain (in volume, not in weight) and other liquids = biofuels, coal to liquids, gas to liquids, shale to liquids = XTL= X to liquids with X= biomass, shale, coal, gas)

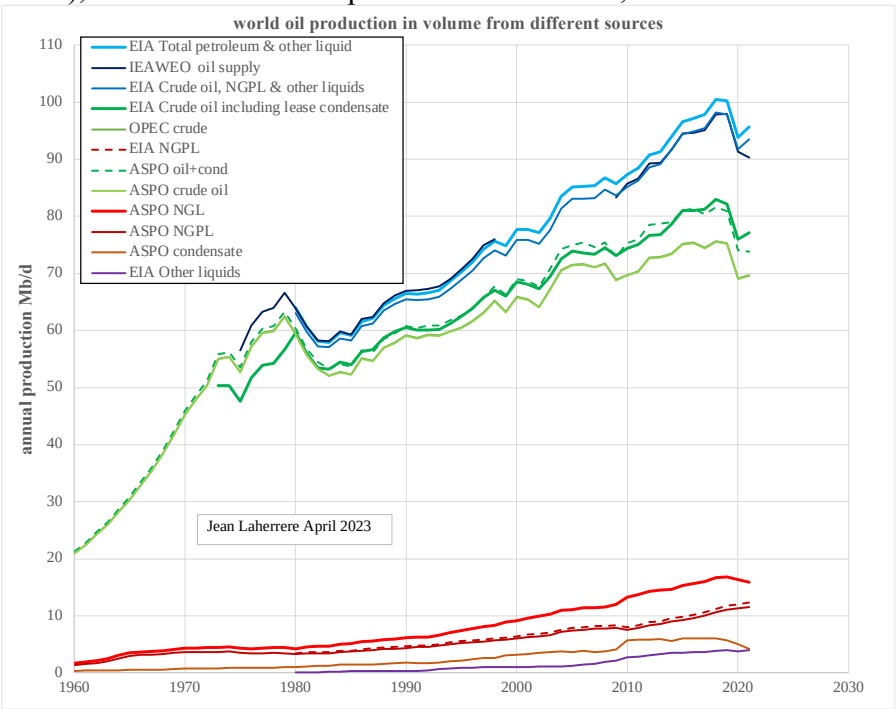


HL of world other liquids trends towards 100 Gb, meaning a peak in 2024 at 4.2 Mb/d

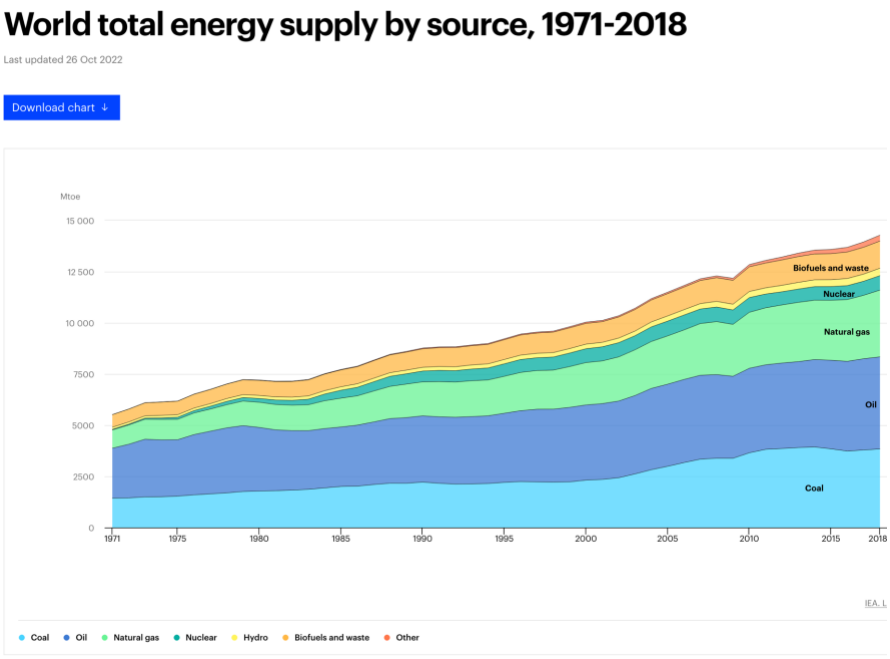




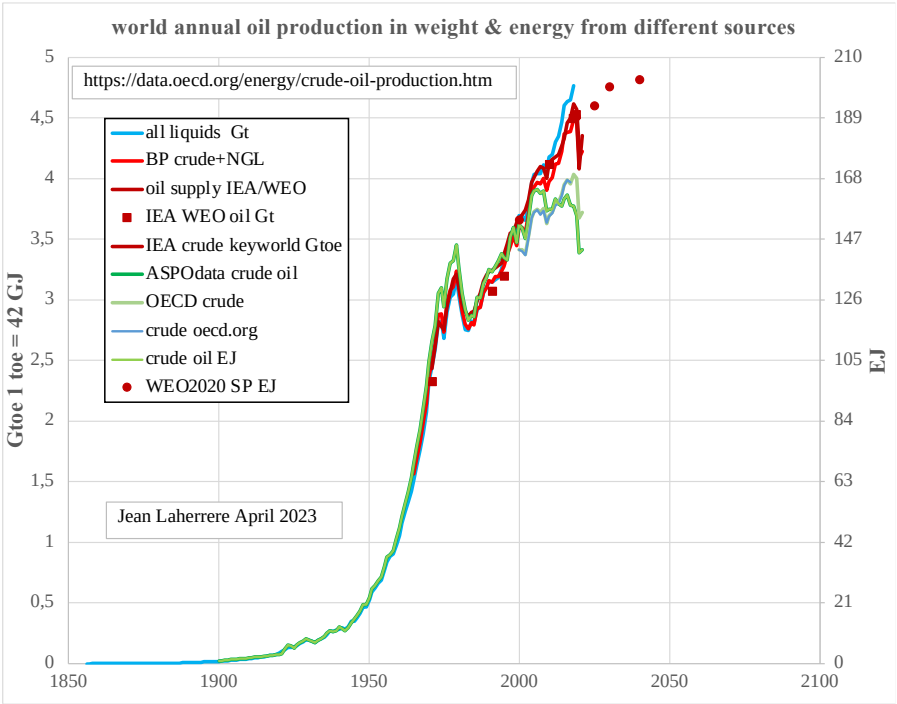
In volume (Mb/d), there is some discrepancies between EIA, IEA and OPEC data:



in weight (energy) 1 toe = 42 GJ
From IEA energy graph (Mtoe), in 2018 oil is the largest energy supply



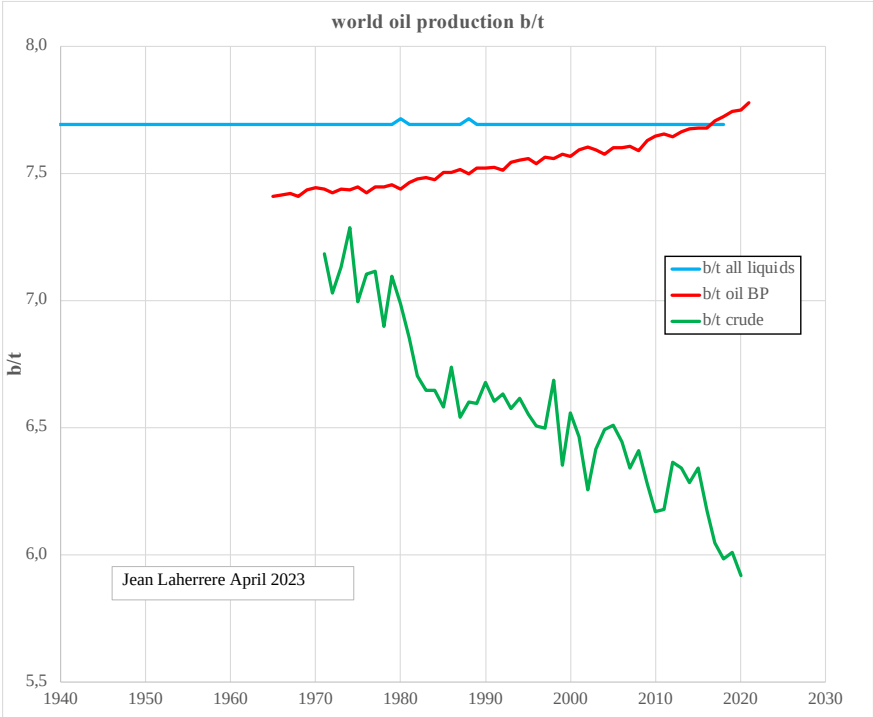
Oil production historical production varies from different sources because the poor definition of oil in these data.



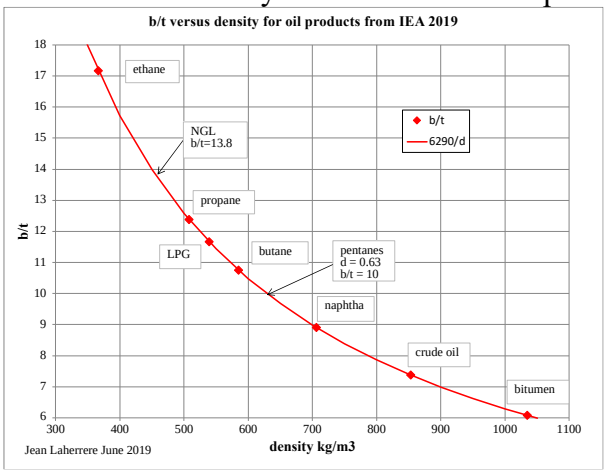
When plotting the ratio barrel/tonne from published data, it appears that for the all-liquids the source is in volume and the data in weight is done by using a conversion of 7.7 b/t
The all-liquids production data in weight is wrong., using a constant ratio to convert volume into energy.

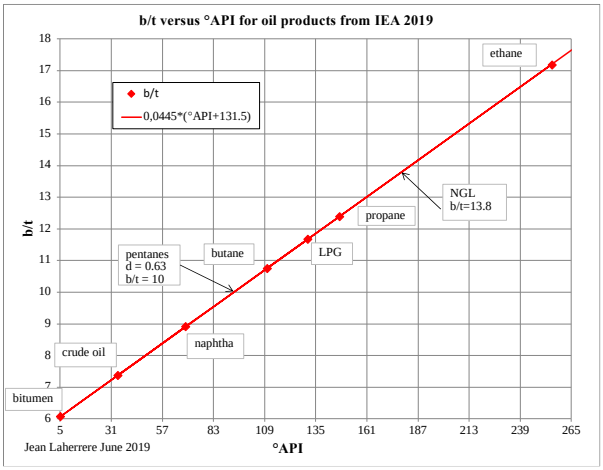
Using ASPO and BP data in volume, the b/t curves are contradictory: all liquids (red) b/t on increase (liquids barrel becoming lighter) and crude (green) b/t on the decrease (crude barrel becoming heavier)

It is a mess because of poor reliability of the weight data. It is obvious that most weight data are volume data converted with a constant ratio!

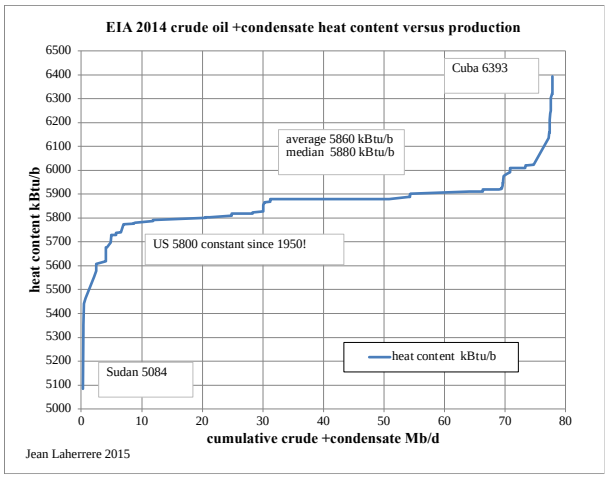


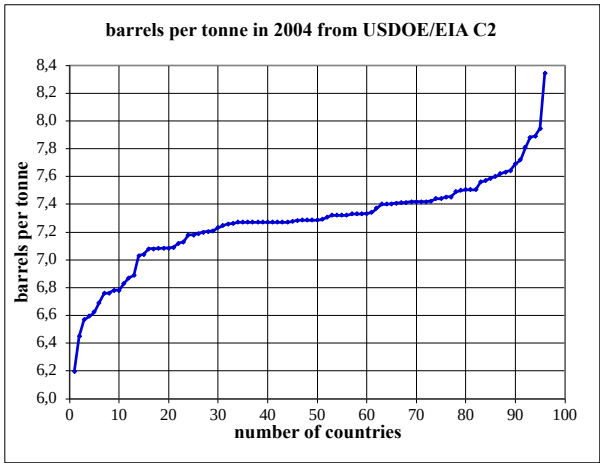
Other data on density and b/t for different products



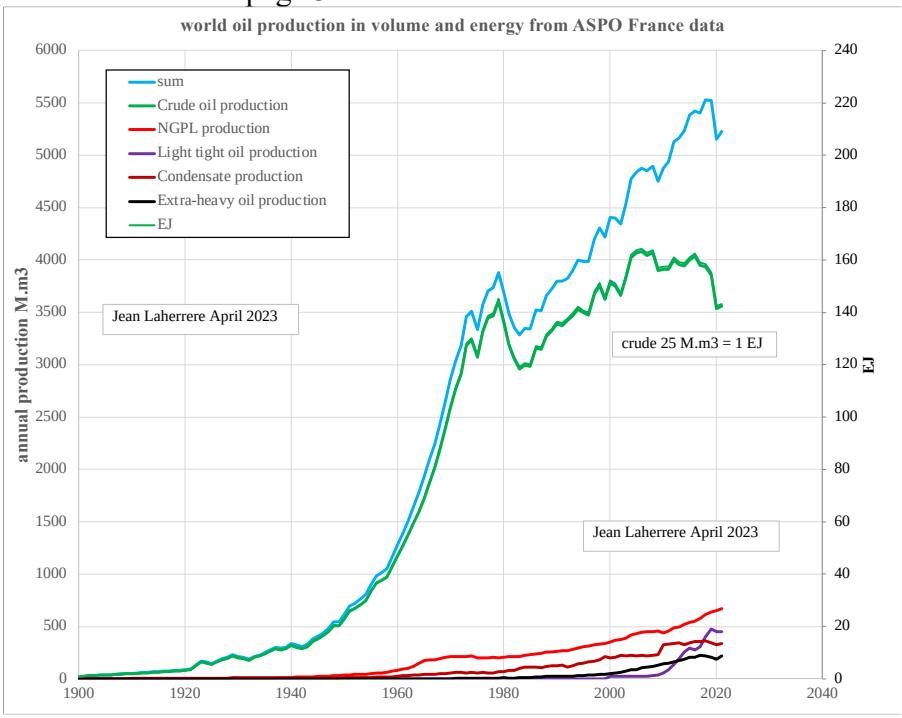


EIA 2014 world crude oil heat content by country and 2004 b/t

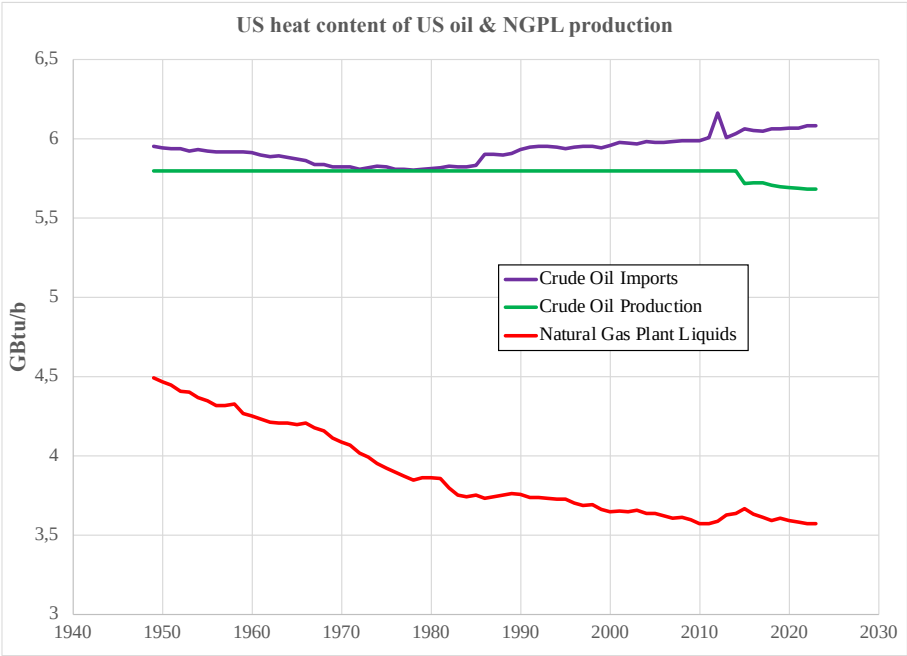




ASPO France data reports oil production in volume (M.m3) and energy but only crude is converted with a constant heat content, when usually heat content varies with field and with time for the sum of fields. See page 31 the forecast.



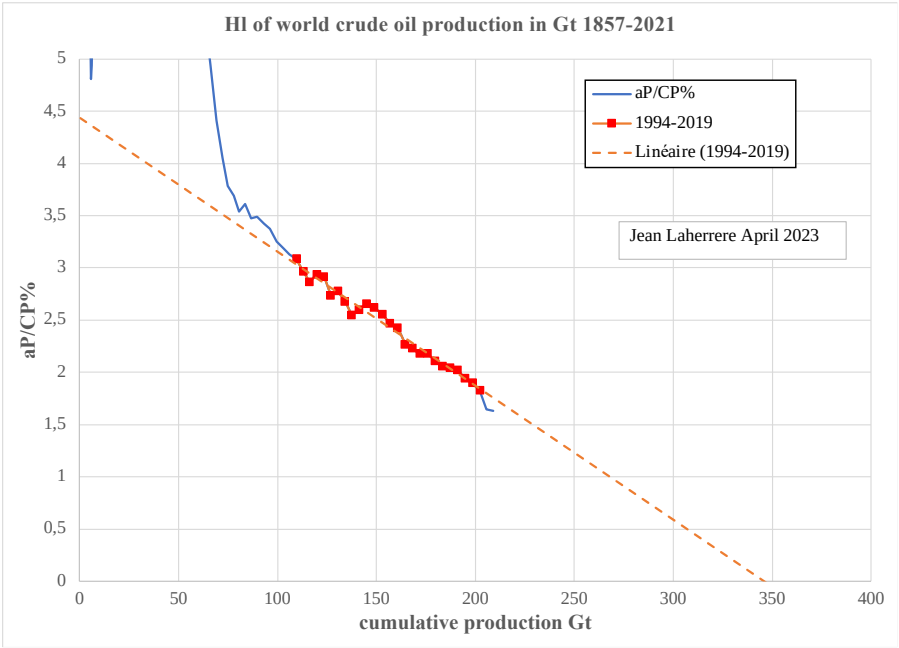
For the US production EIA last monthly report displays heat content changes in crude production since 2015 and for NGPL since 1949. Crude oil imports are heavier since 1985. NGPL heat content has sharply declined from 1950 to 1985!



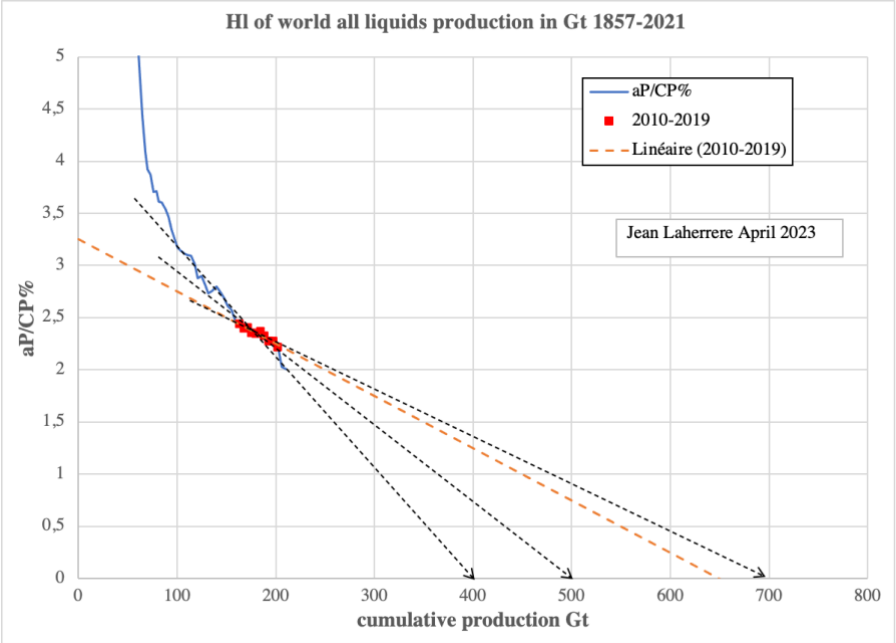
The constant US crude oil production heat content at 5.8 GBtu/b from 1949 to 2014 looks queer, compared with the variation of crude imports, but EIA is used to report estimate and not real data (form 910)!

-oil in weight

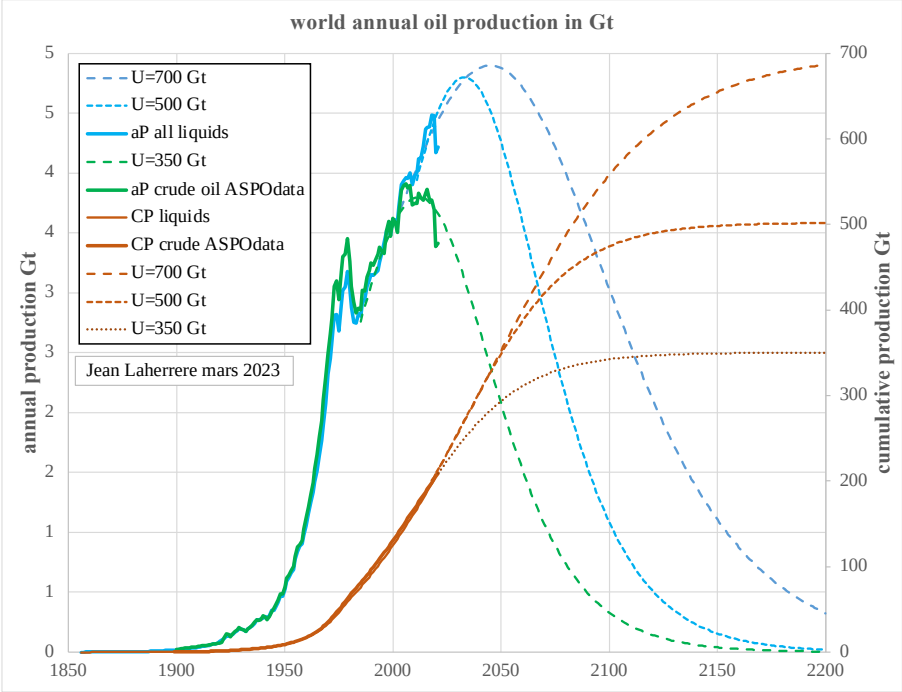
HL of world crude oil production in weight is good from 1994 to 2019 trending towards an ultimate of 350 Gt



HL of world all liquids in weight is more difficult to extrapolate: the plot 2010-2019 trends towards 650 Gt:

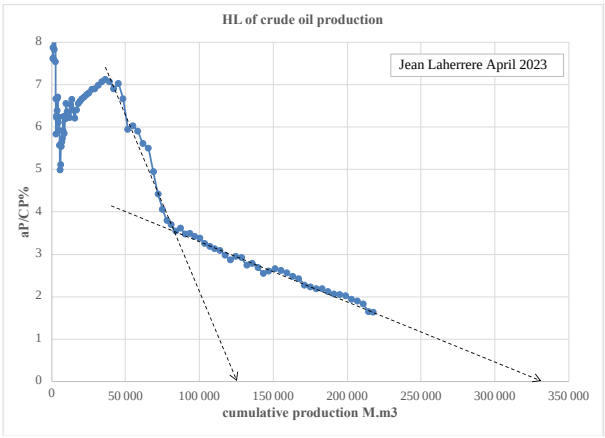


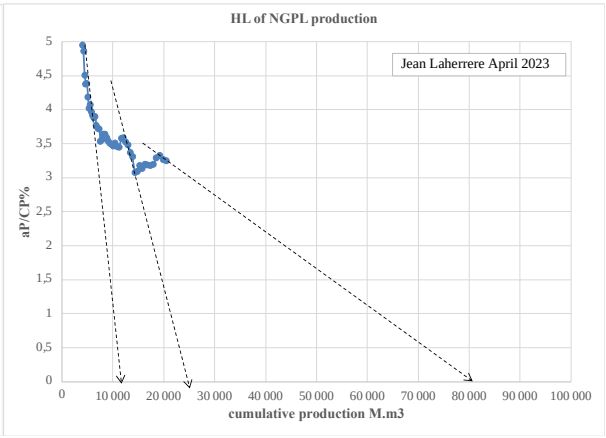
For an ultimate of 350 Gt for crude and 700 Gr for all liquids, the peak is past for crude and 2040 for all liquids.

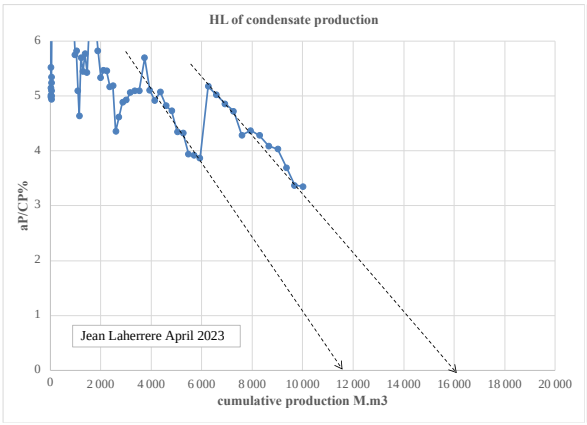


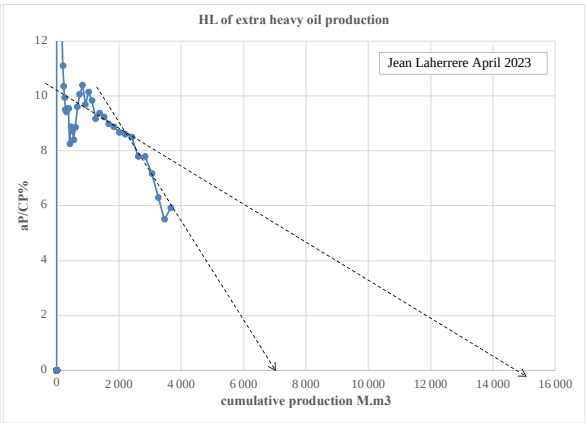
-oil in volume

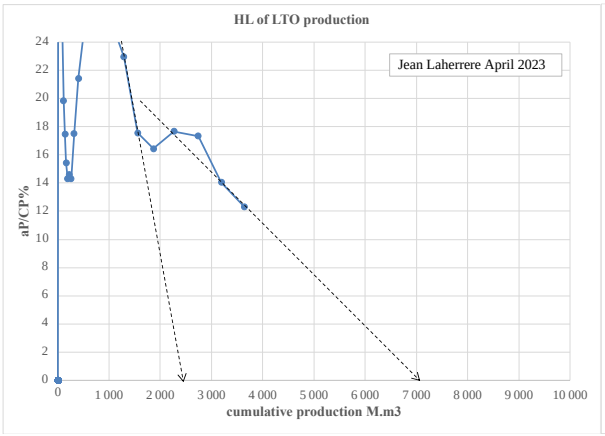
HL of world oil production in volume from ASPO data
The quality of HL varies widely.

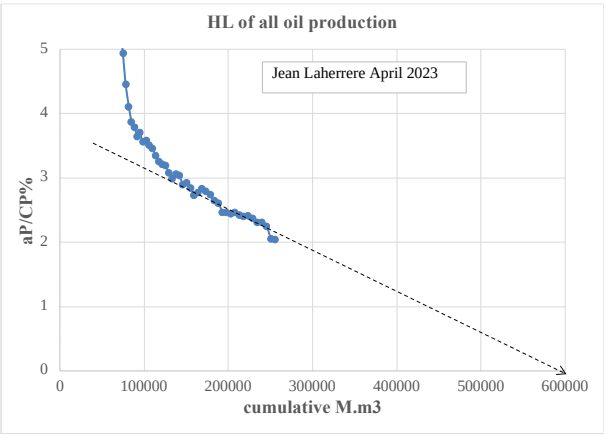




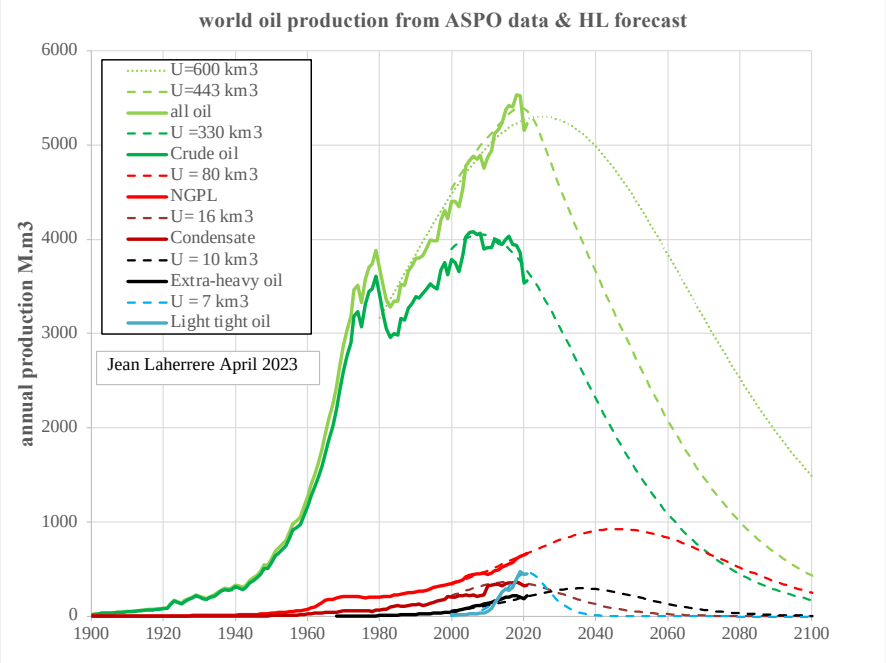








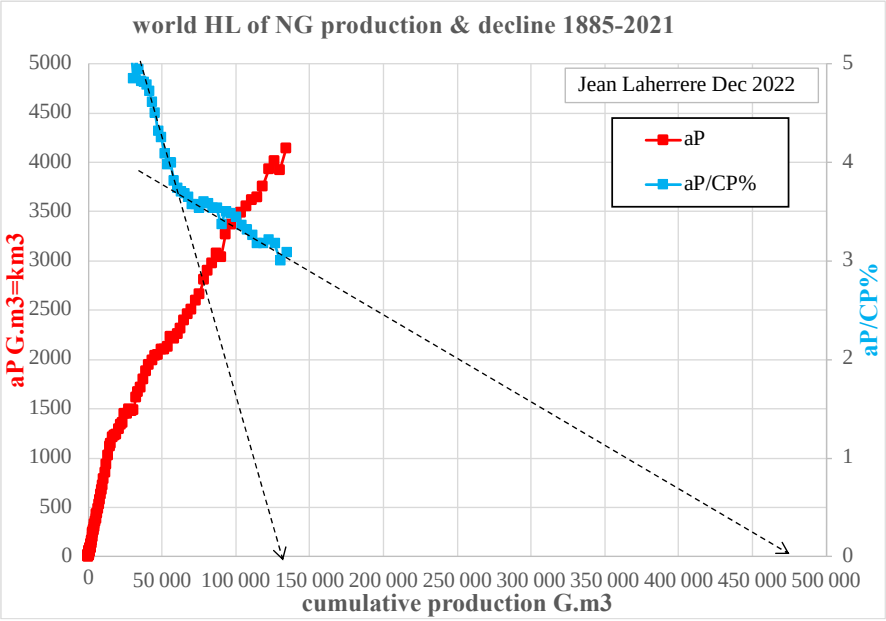
World forecast from the above ultimates:



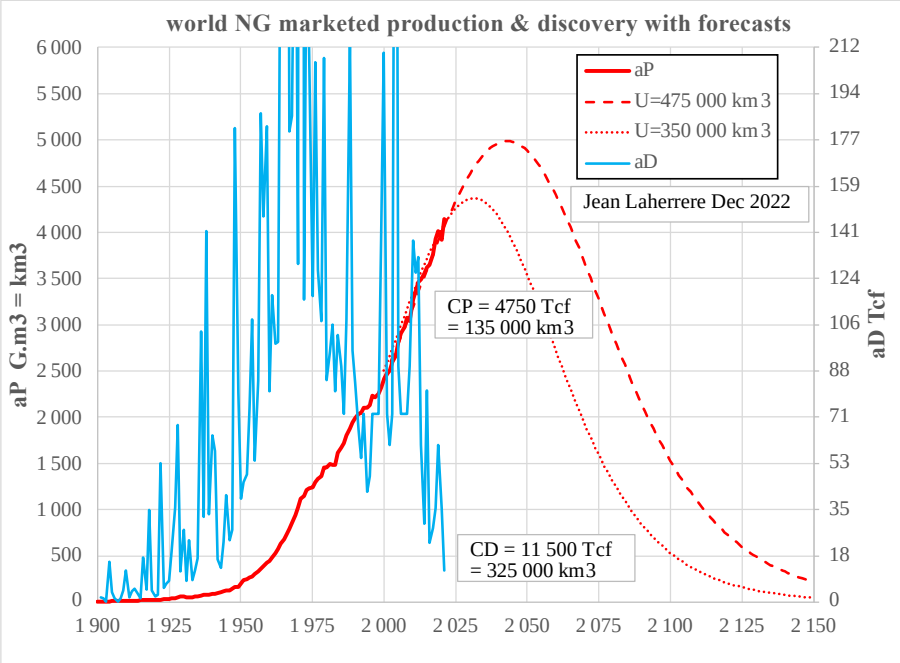
The sum of the 5 ultimates is 330+80+16+10+7 =443 km3 when the HL of all oil is rather 600 km3, showing the uncertainty of the estimates
But the HL for crude oil is rather of fair quality and it is for NGPL and extra-heavy that ultimates should be increased. NGPL is forecasted further below with more detail.

-NG in volume

My March 2023 paper NG ultimate reserves: creaming curve, parabolic fractal, HL or decline
https://aspofrance.org/2023/03/17/https-aspofrance-files-wordpress-com-2023-03-ngultimatemarch2023-pdf/

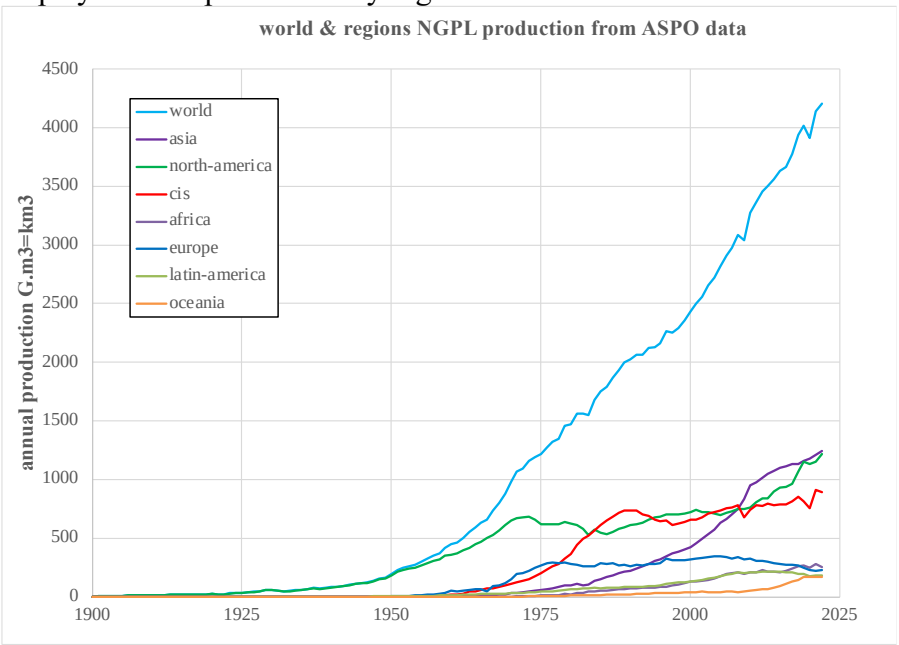


world NG ultimate = 475 000 km3 (17 Pcf) giving a peak in 2040

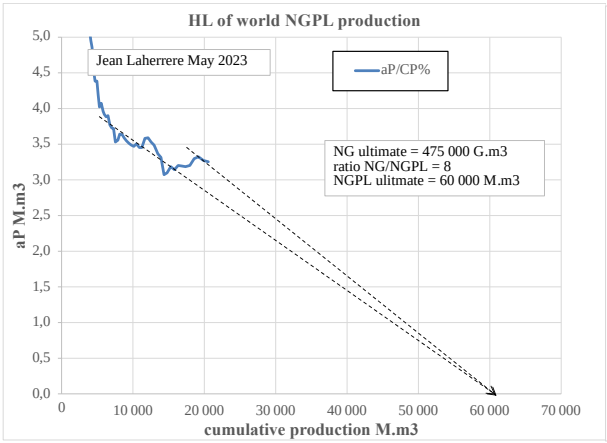


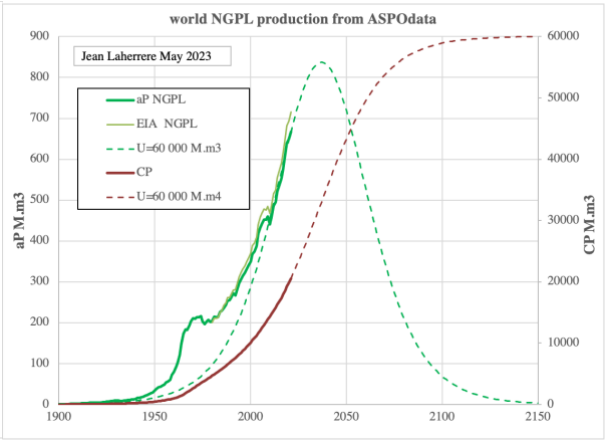
-NGPL in volume

ASPO data displays NGPL production by regions

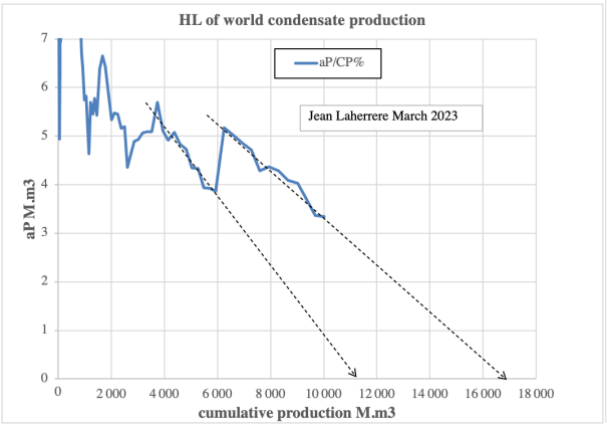


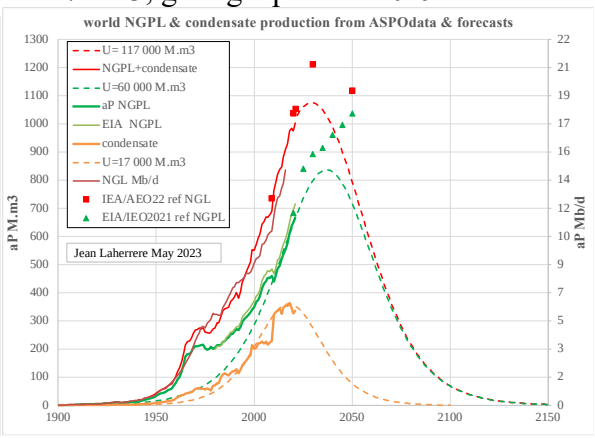
HL of world NGPL production is very poor and an ultimate of 60 km3 was chosen, giving a peak in 2040:.



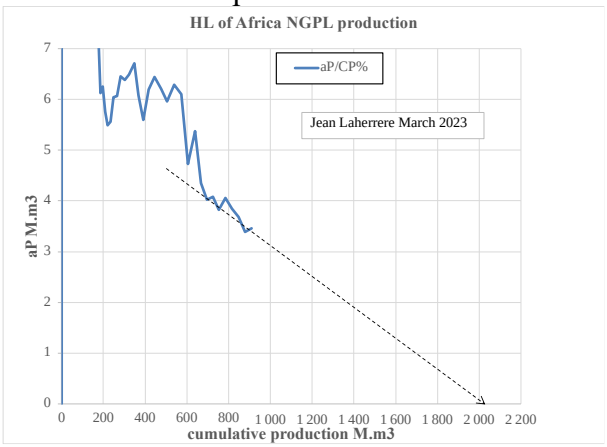


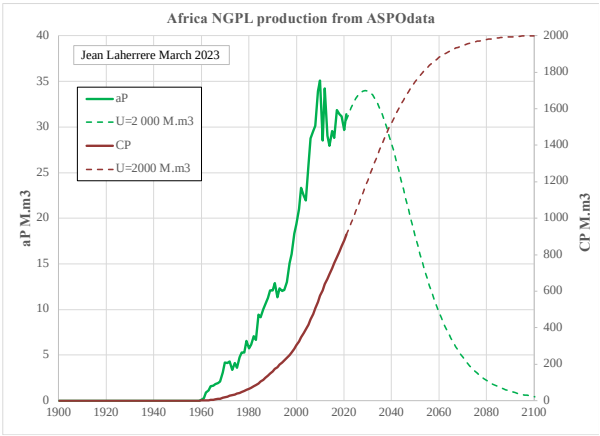
Hl of world condensate production trends towards 17 km3, giving a peak in 2019:



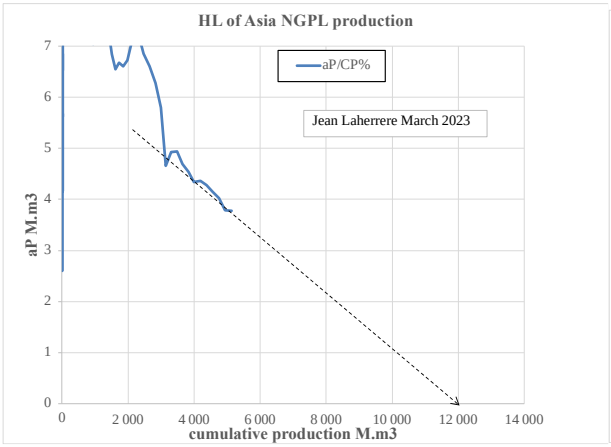


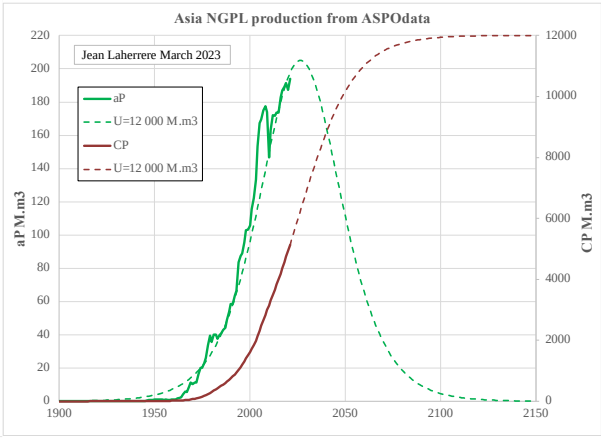
HL by regions:
Africa NGPL has peaked in 2010:



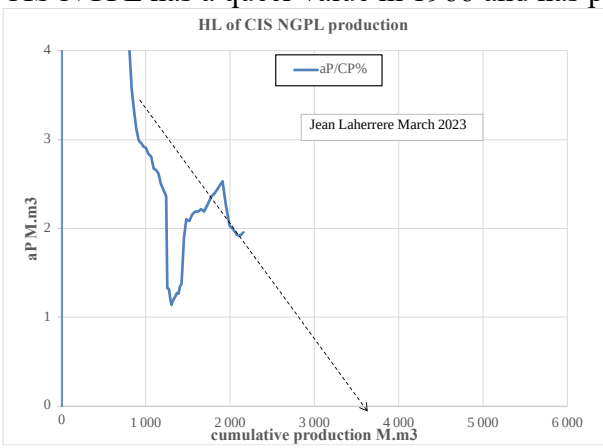


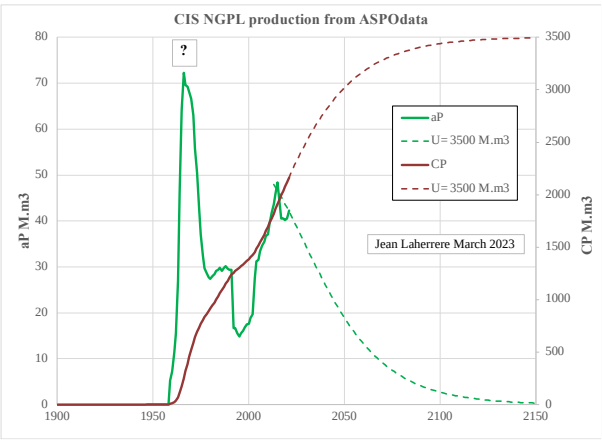
Asia NGPL will peak in 2026



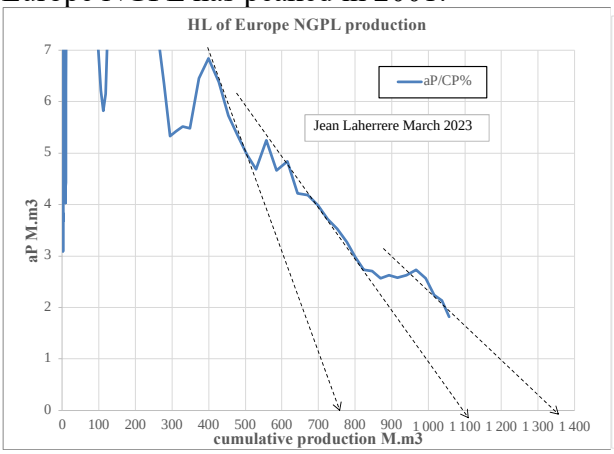


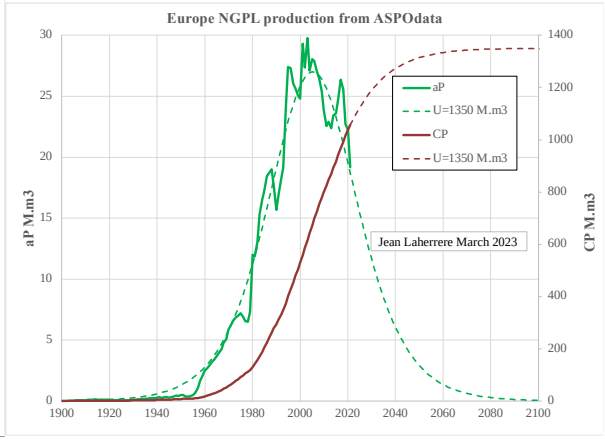
CIS NGPL has a queer value in 1966 and has peaked in 2015:



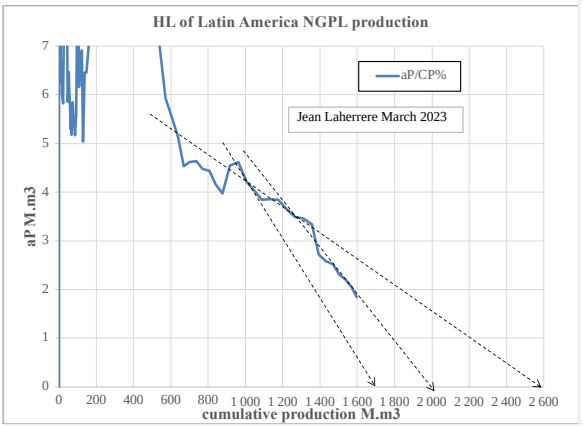


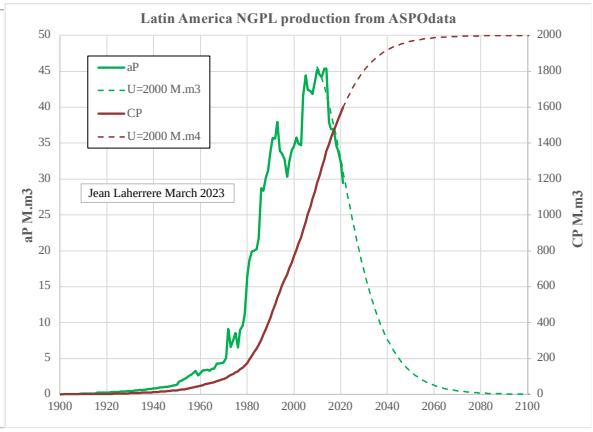
Europe NGPL has peaked in 2001:



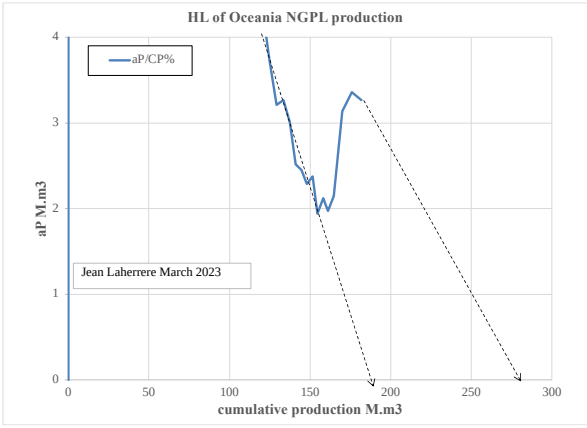


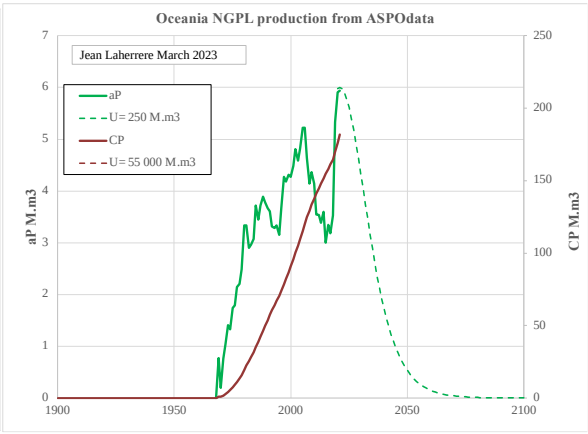
Latin America NGPL has peaked in 2013:



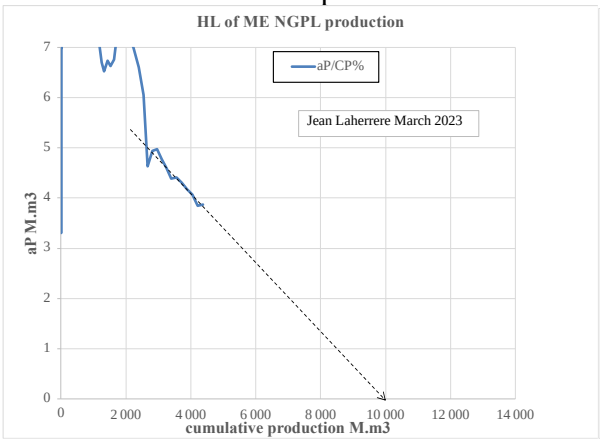


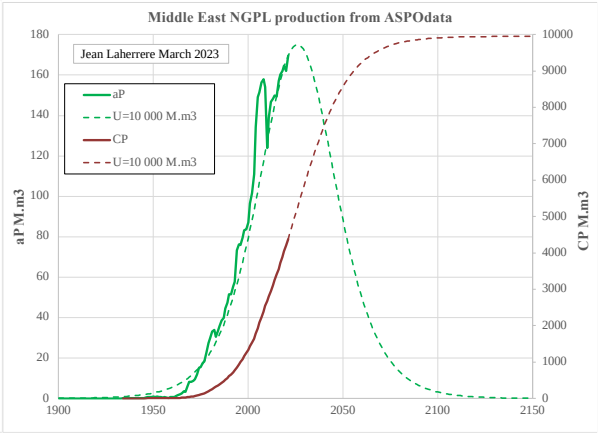
Oceania NGPL has peaked in 2021:



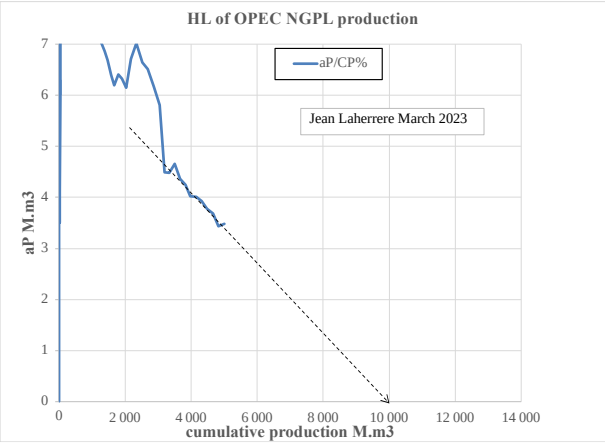


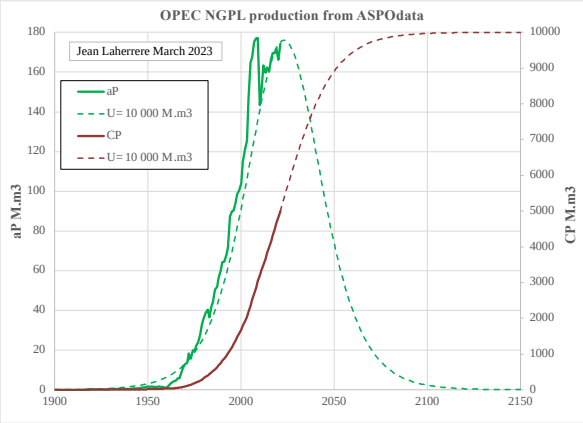
Middle East NGPL will peak in 2026



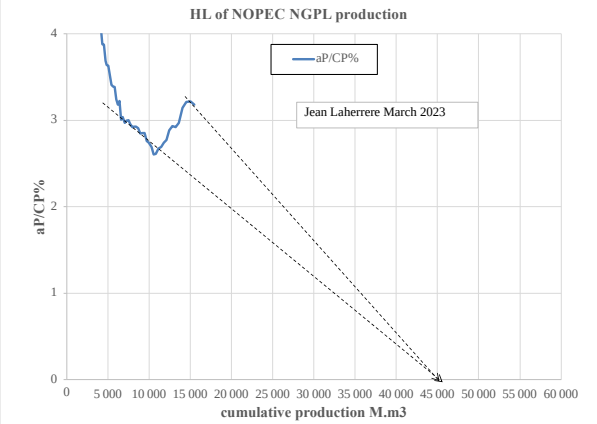


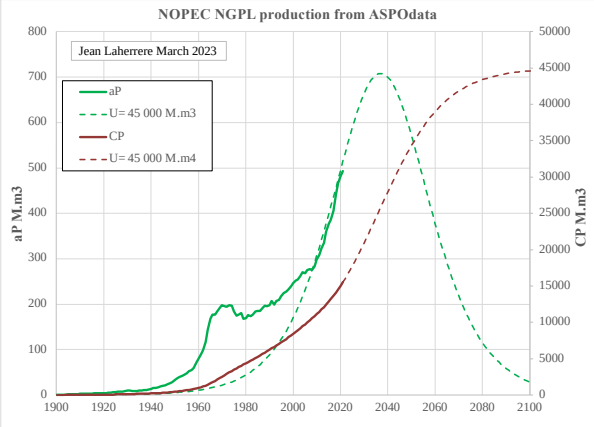
OPEC NGPL will peak in 2023:



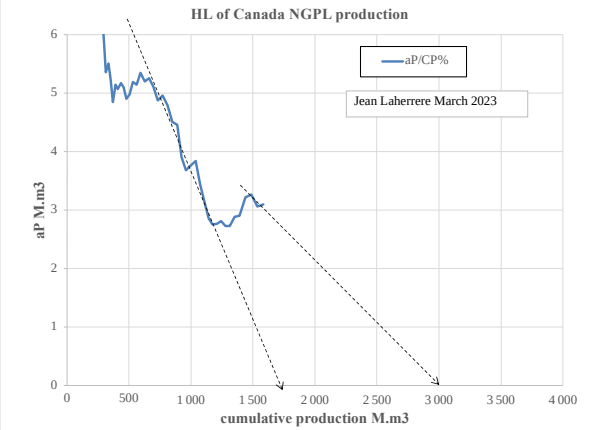


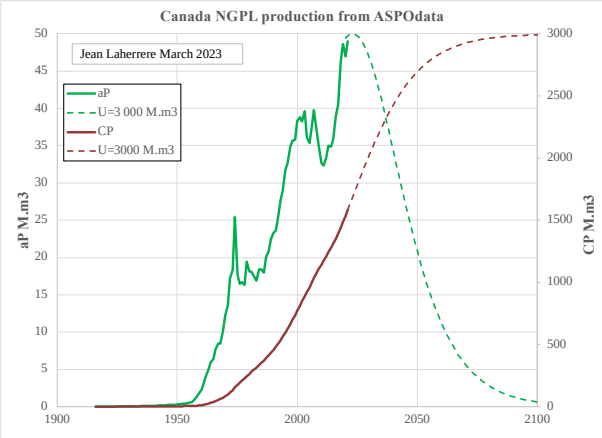
Non-OPEC NGPL will peak in 2037:



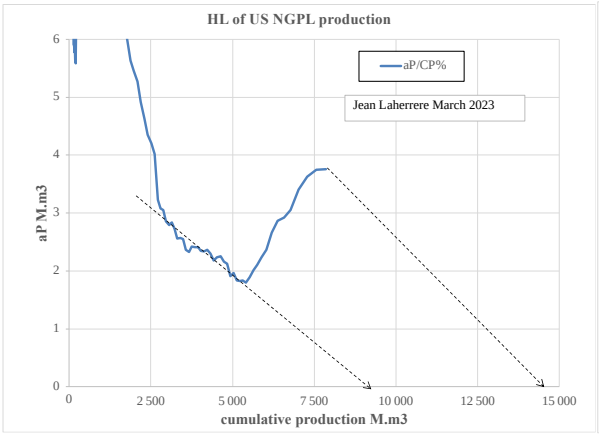


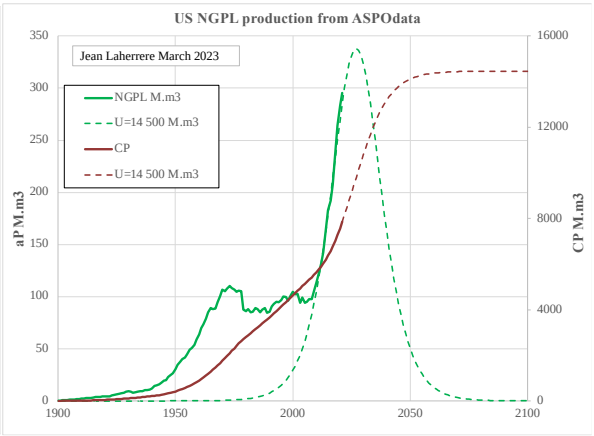
Canada NGPL will peak in 2023:





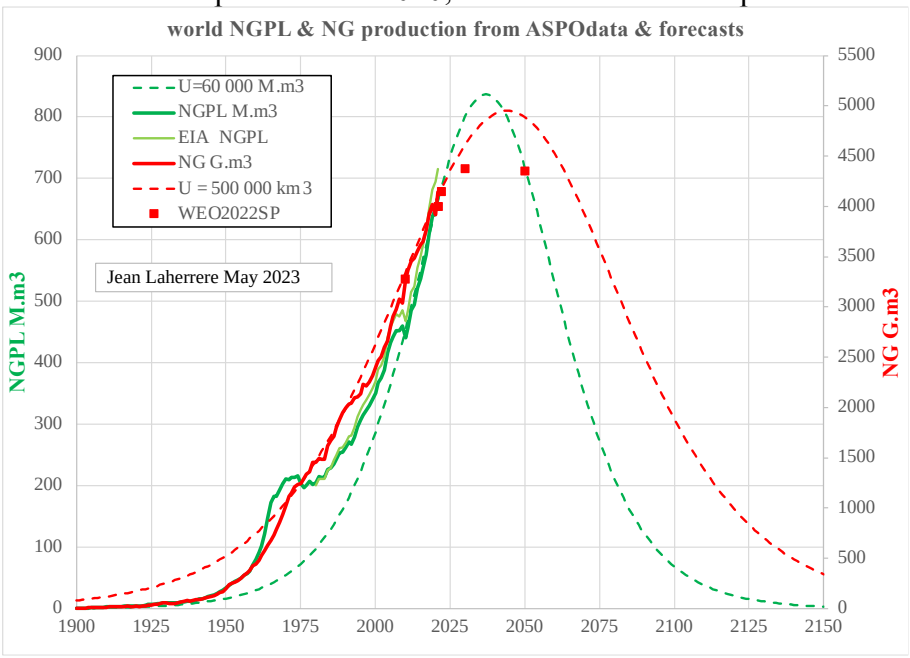
US NGPL will peak in 2027:



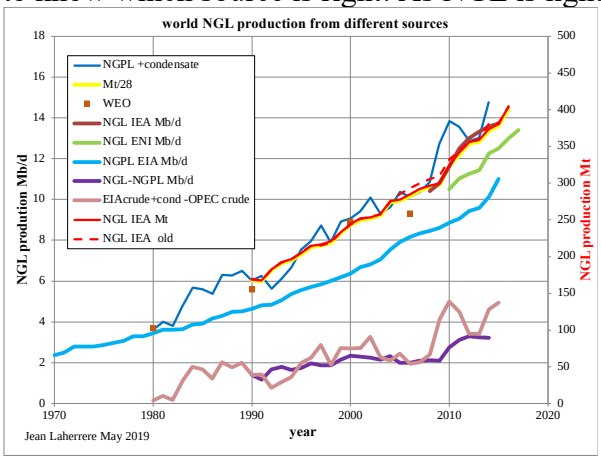


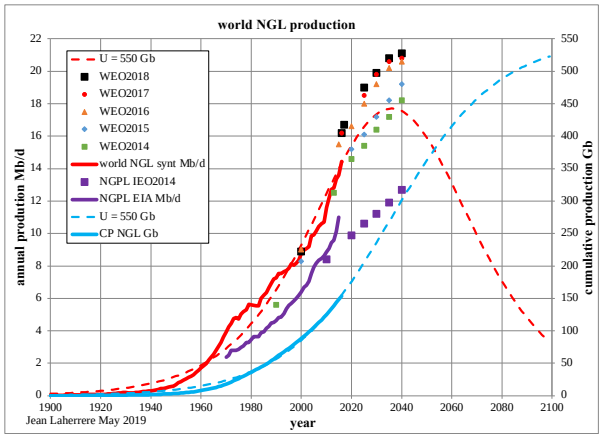
-comparison NG & NGPL forecasts

The comparison of NGPL (M.m3) and NG (G.m3) allows to see better data problems.
Most of comparisons are good, meaning that their forecasts are reliable.
World NG and NGPL could peak around 2040, when IEA forecasts a peak sooner

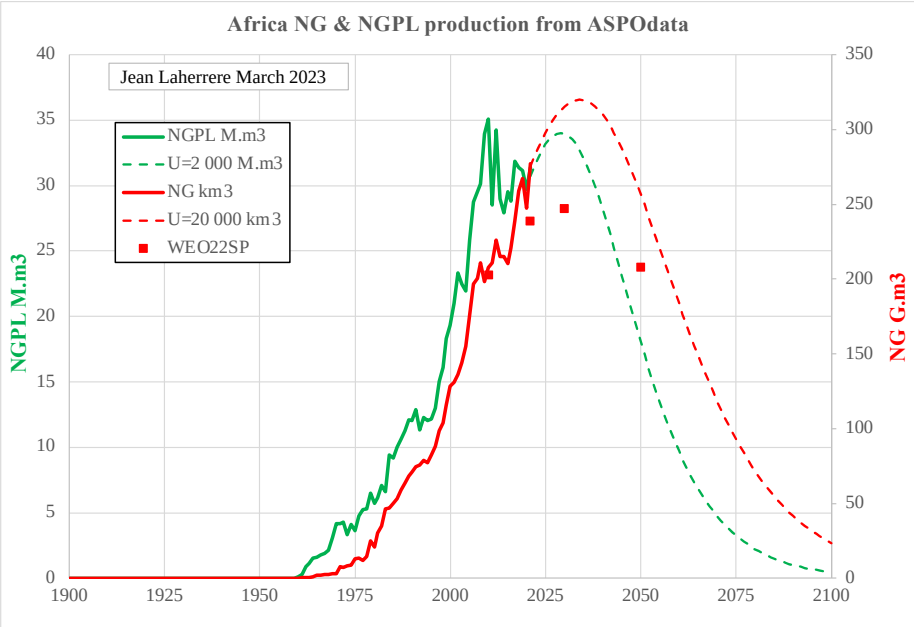


But IEA world NGL data and EIA NGPL data show in 2019 large discrepancies and it is hard to know which source is right! As NGL is lighter than crude, the right data is in weight

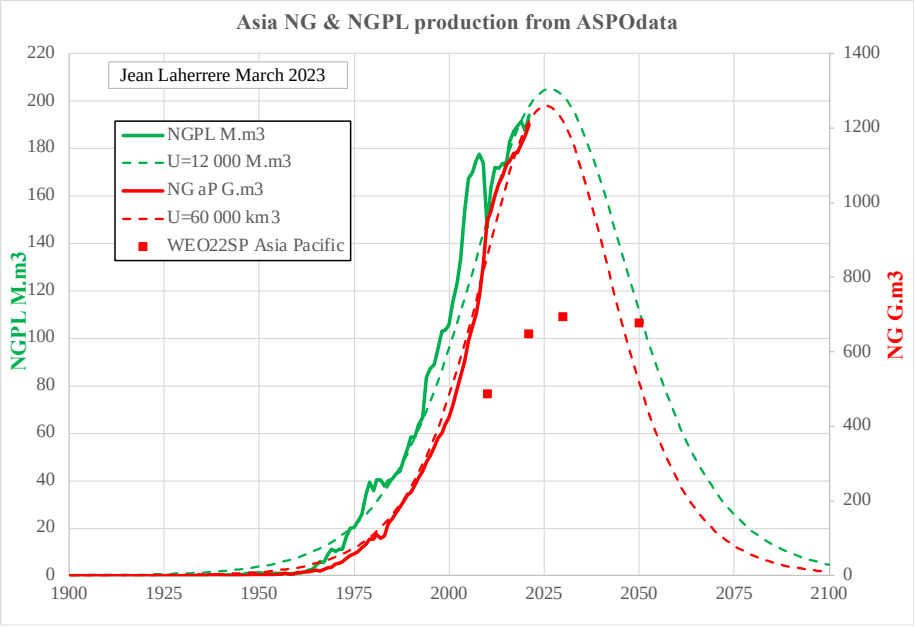




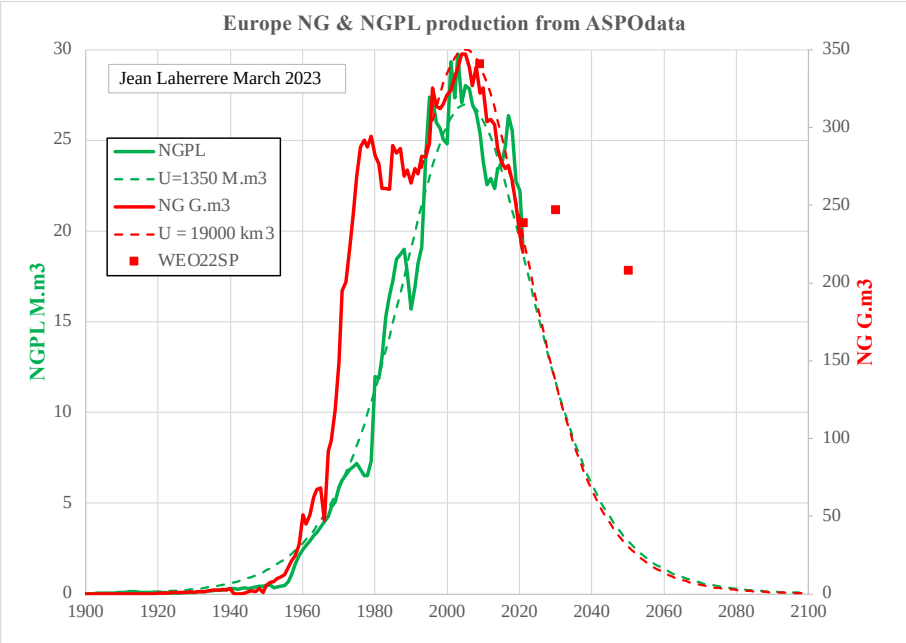
Africa HL is very poor for NG and NGPL and many giant gas fields have been discovered lately in deep water around Africa.
Africa NG and NGPL could peak around 2030. IEA forecasts a peak at the same time but lower::



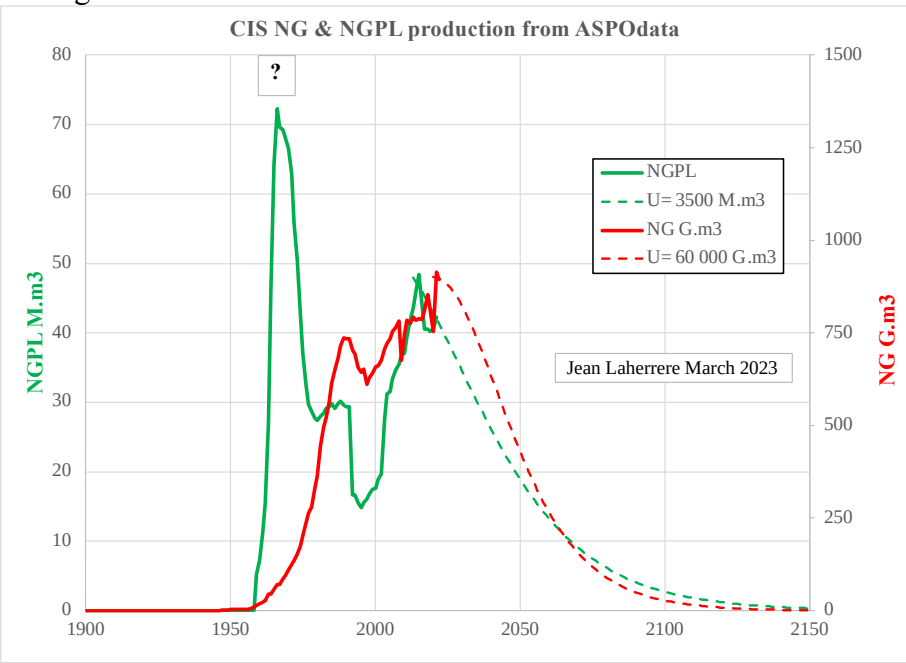
Asia NG & NGPL could peak around 2025: IEA reports only Asia Pacific, with a smaller decline:



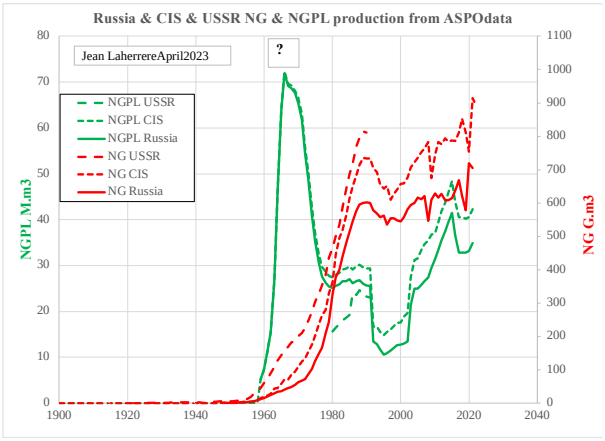
Europe NG & NGPL have peaked about 2005: again IEA forecasts a smaller decline:

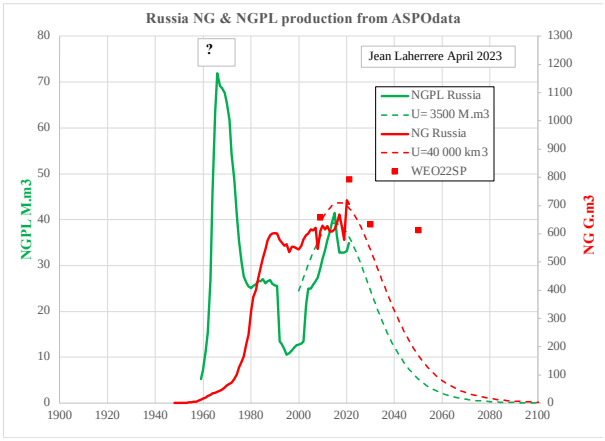


CIS NGPL peak in 1966 looks very questionable: it is well known that Russian data during the cold war was not reliable.
CIS NG is peaking:

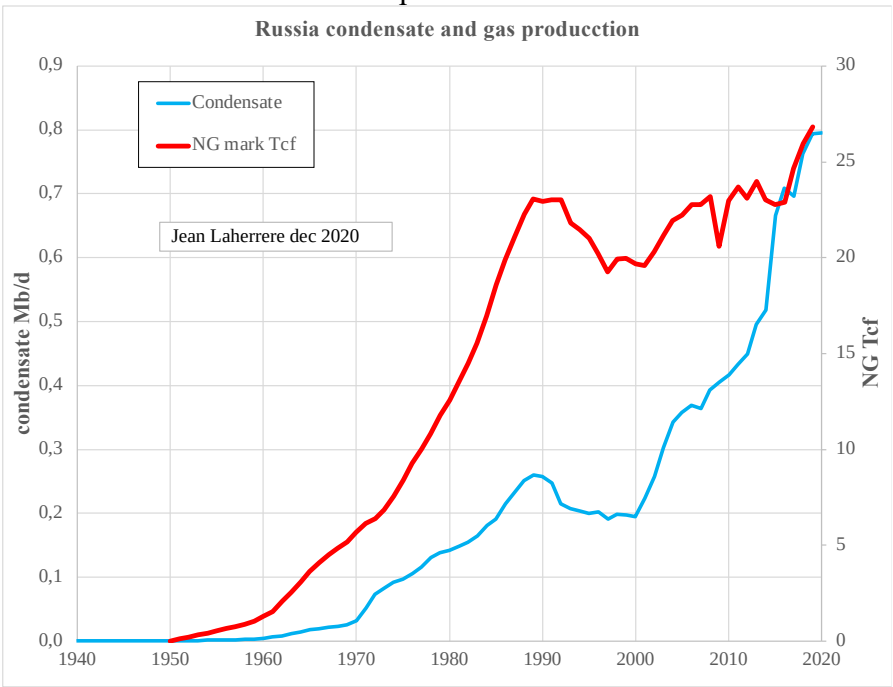


The comparison with NGPL and NG data for Russia and USSR confirms the bad data before 1980.
Russia NG & NGPL have peaked:

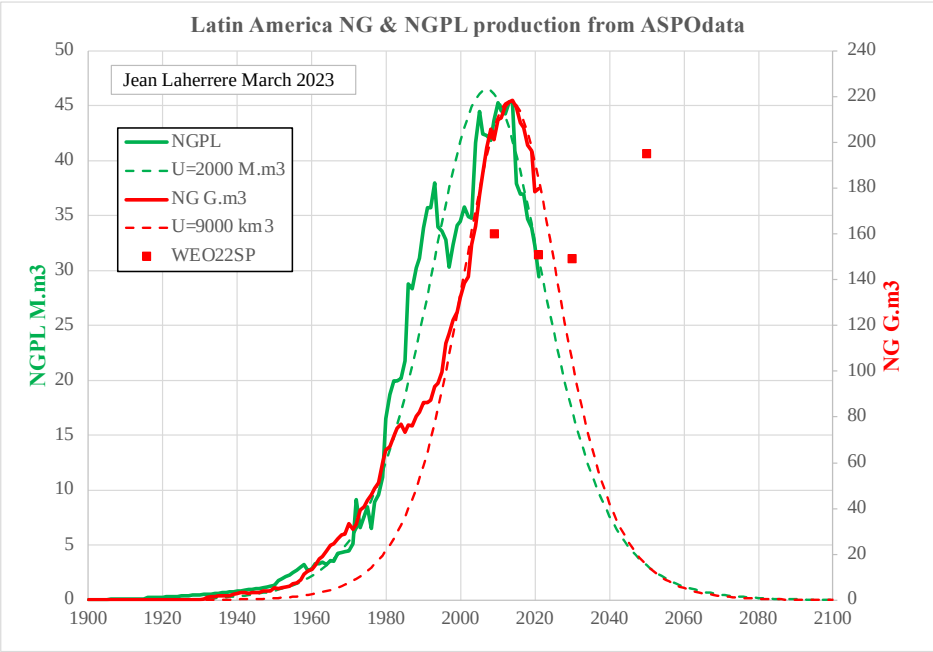




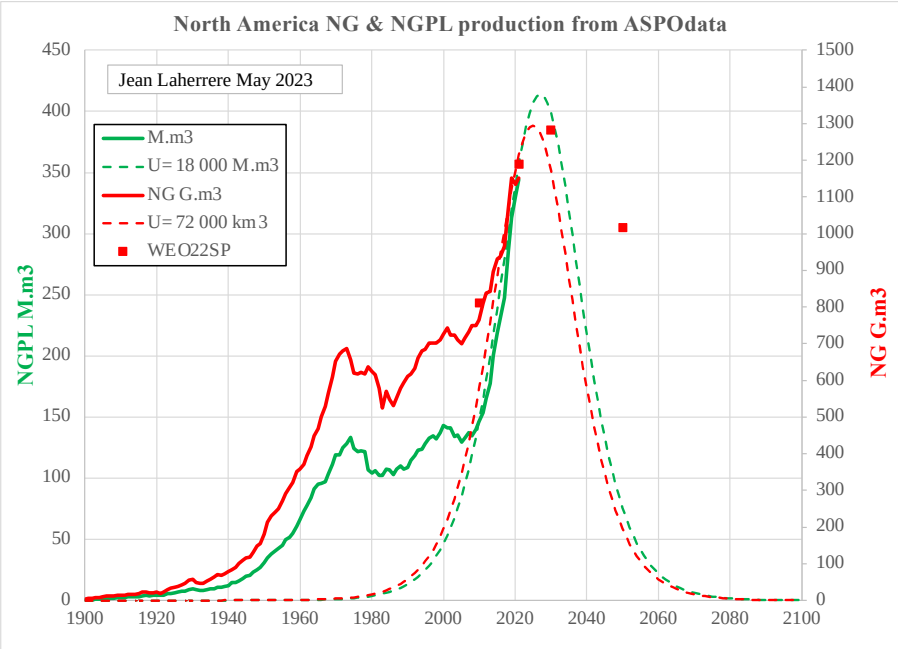
Russia old data from other sources show a peak in 1990 for NG and condensate:



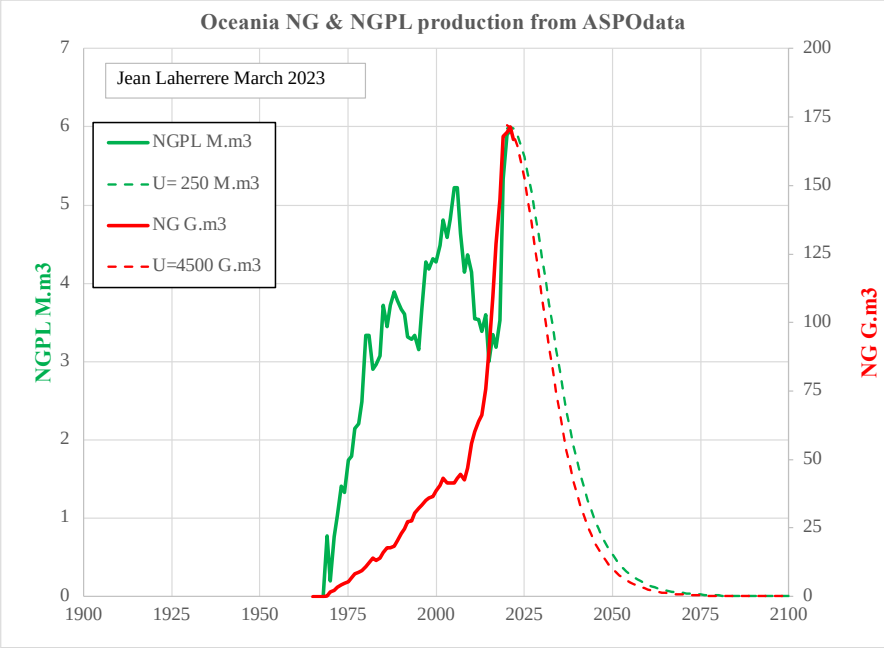
Latin America NG & NGPL productions have peaked when IEA forecasts a peak beyond 2050, with a trough in 2030?



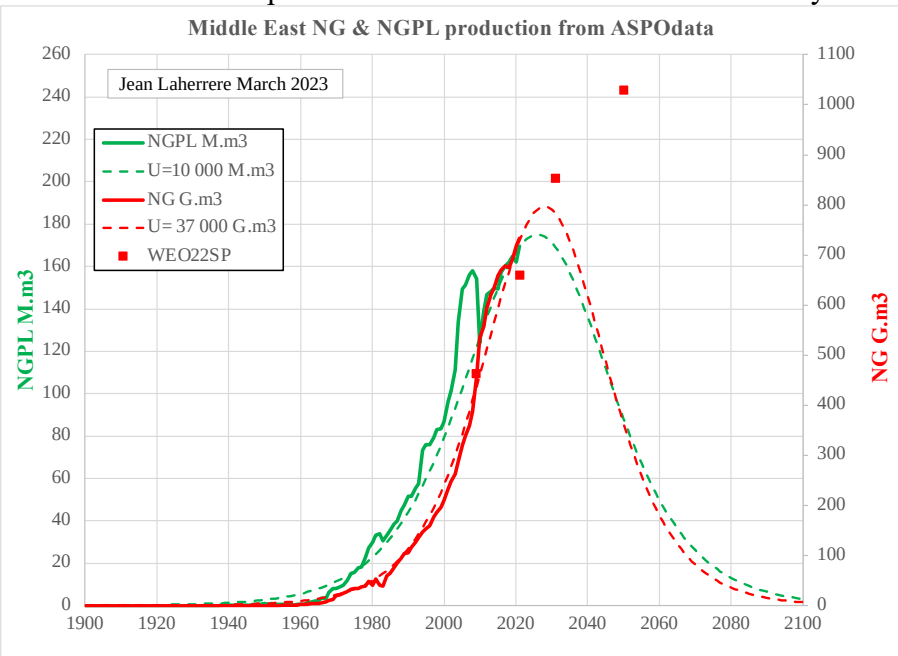
North America NG & NGPL could peak around 2030, in line with IEA/WEO22SP, but the decline is smaller:



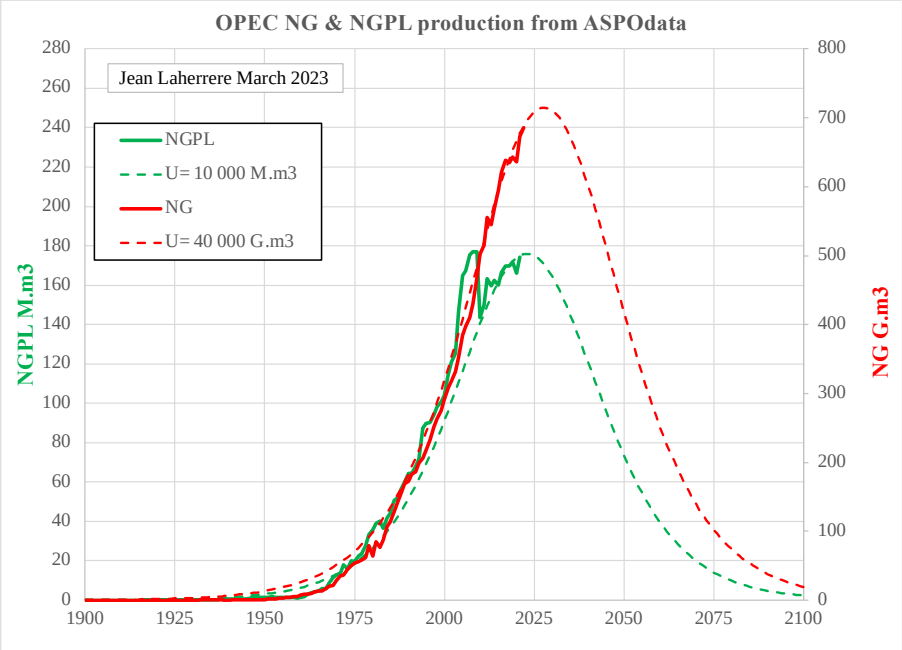
Oceania NGPL trough in 2015 looks queer in comparison with NG:
Oceania NG & NGPL have peaked in 2020:



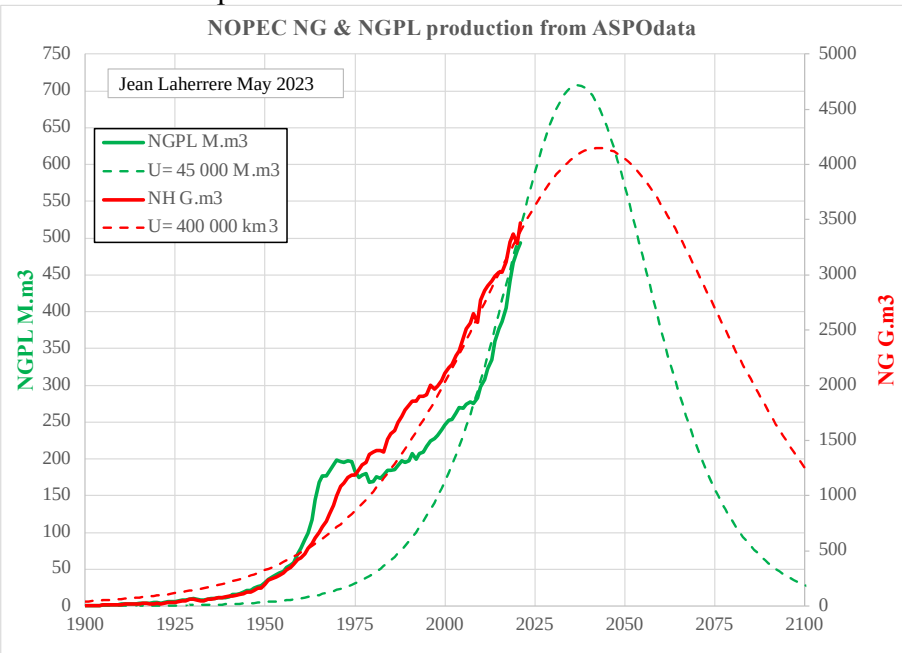
Middle East NG & NGPL could peak around 2030 when IEA forecast is beyond 2050:



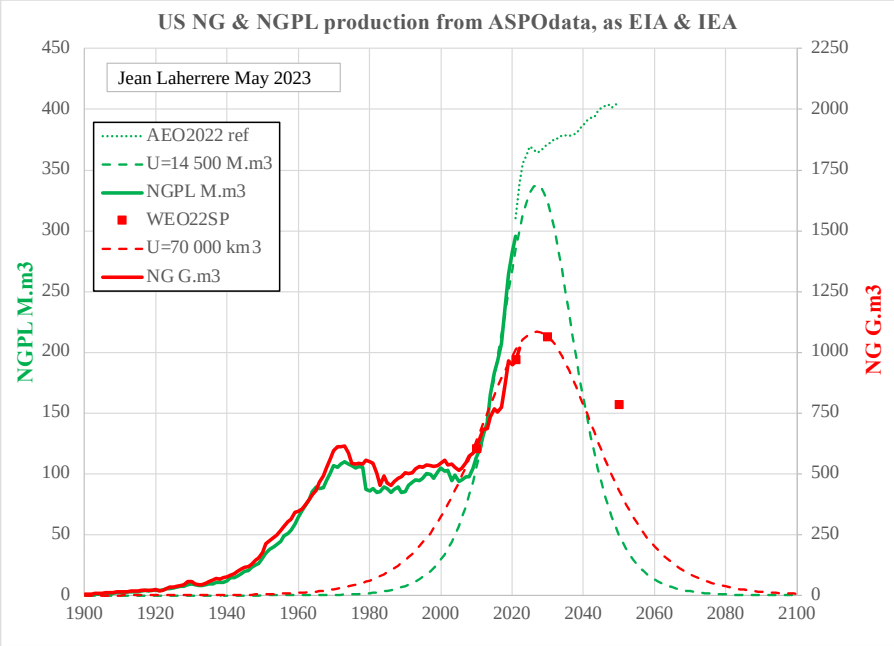
OPEC NG & NGPL could peak around 2025:



NOPEC NG & NGPL could peak around 2040:



US NG & NGPL could peak in 2027, in line with WEO22SPfor NG but not with AEO2022 for NGPL:

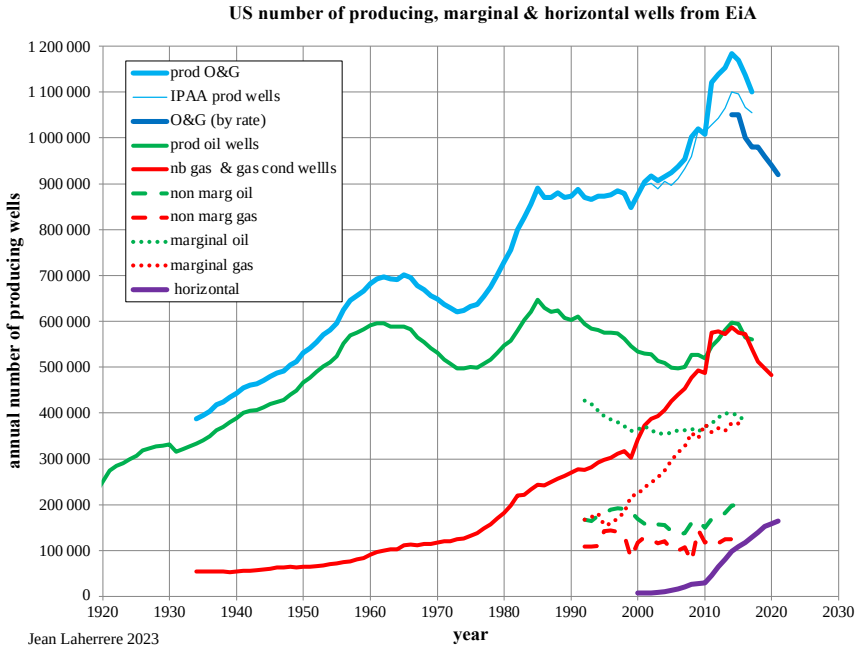


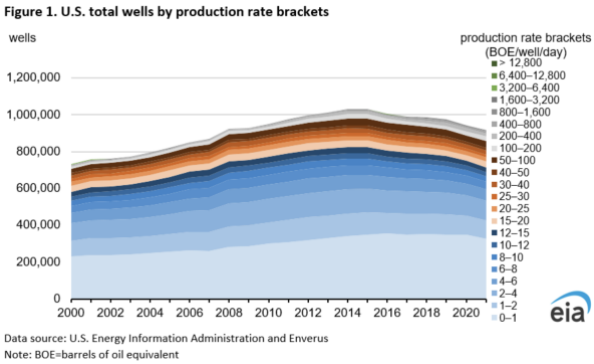
Canada NG & NGPL could peak around 2025 when WEO22P forecast is beyond 2050:

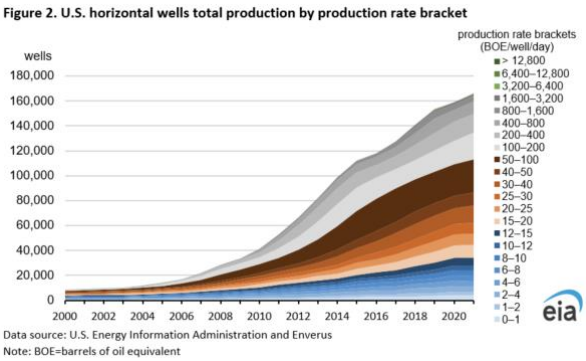
The comparison of the scales of NG and NGPF of the above graphs shows that the correlation varies with regions as the heat content of the volume of NG and NGPL varies with the composition of the production (different amount of C and of H in the produced hydrocarbons CnHm).

-US production

US number of producing wells 1920-2021 shows the switch after 1985 from oil to gas. Oil & gas producing number declines after the peak of 2014, but the number of horizontal producers starts to increase sharply since 2010:



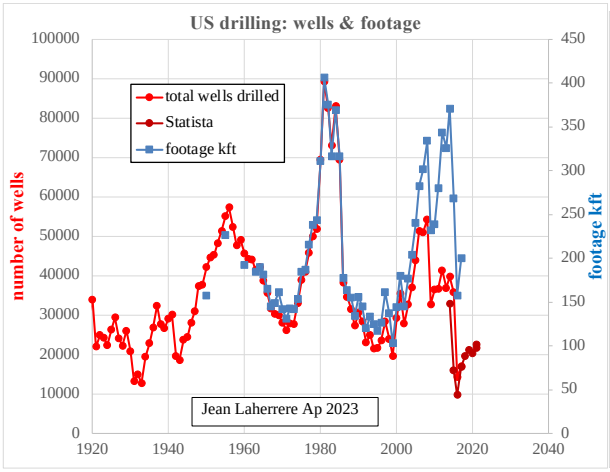


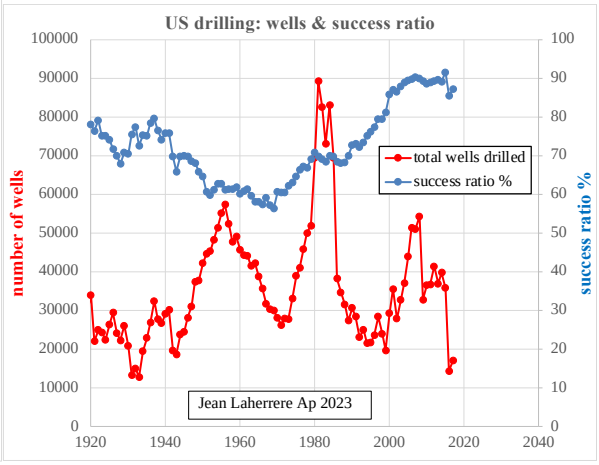


US number of oil and gas wells drilled: the number of drilled wells correlates well with the footage up to 2005 when the shale play increases widely the footage with long horizontal extents.

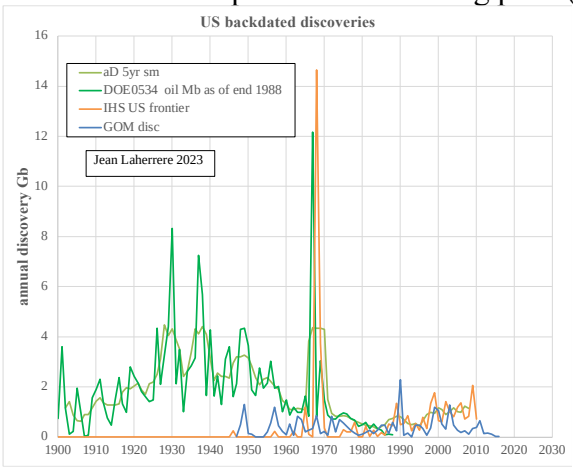
The success ratio of oil and gas wells varies from 60 to 90% now with almost no exploration left, only development drilling with LTO.

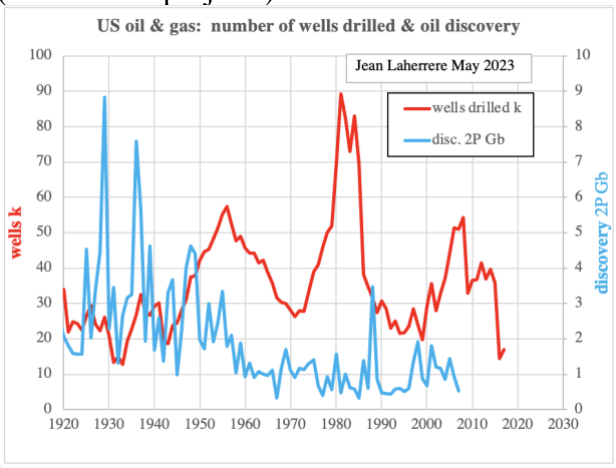
The peak 1981-1984 in wells drilling was due to the high oil price of 1979, drilling all the old poor oil projects flattens the success ratio which resumes from 70% to 90 % on 2010.



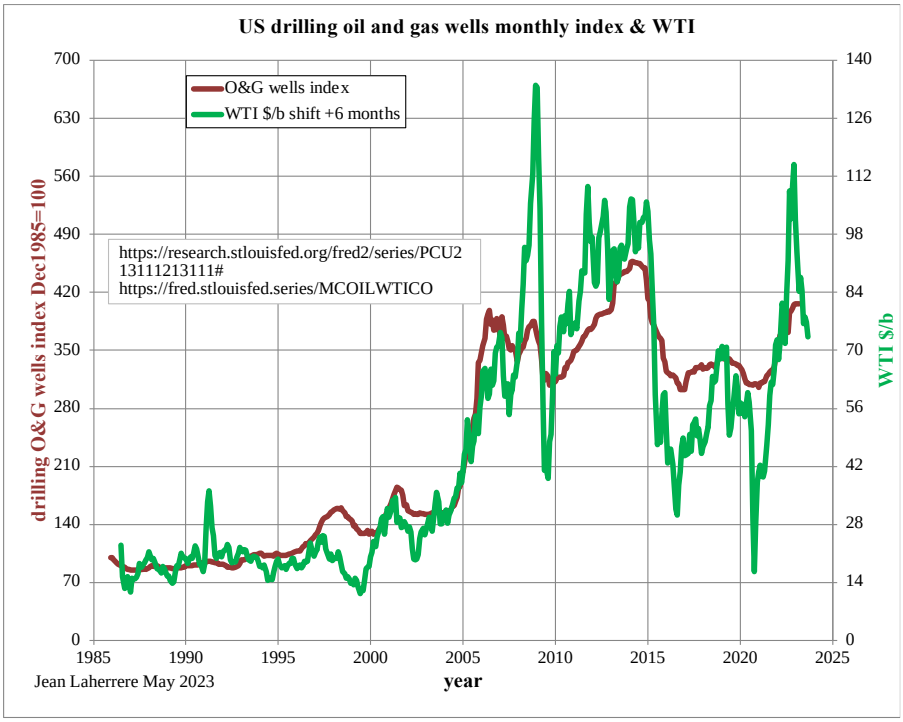


The US oil 2P discovery (EIA/DOE0534) and UD number of wells. The 1983 minimum of discoveries corresponds in the drilling peak (all left over projects).

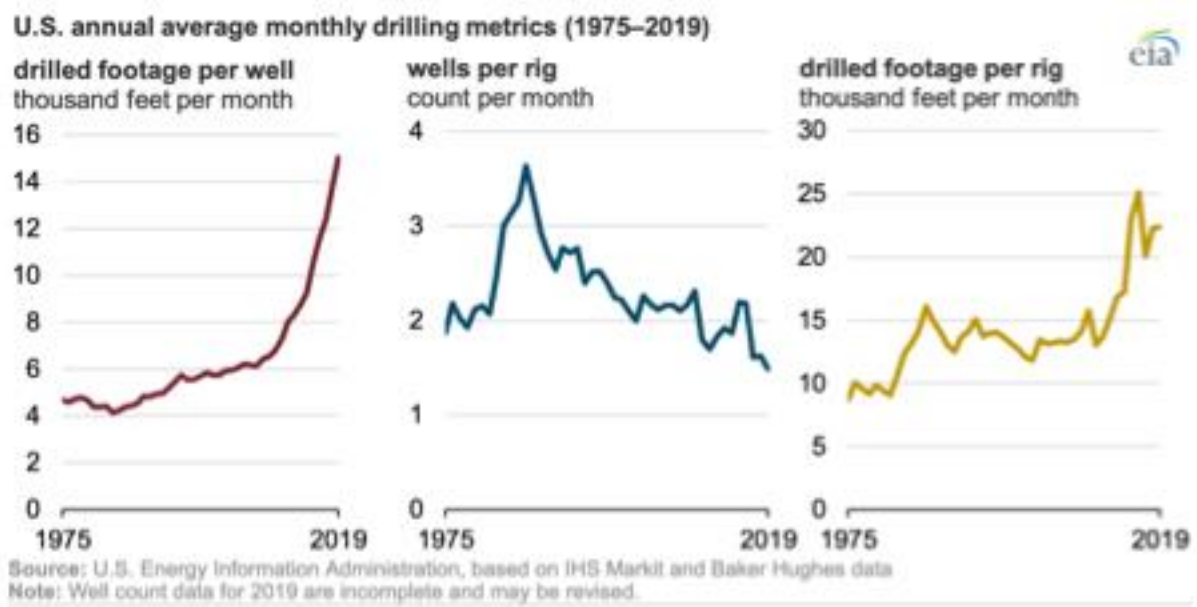


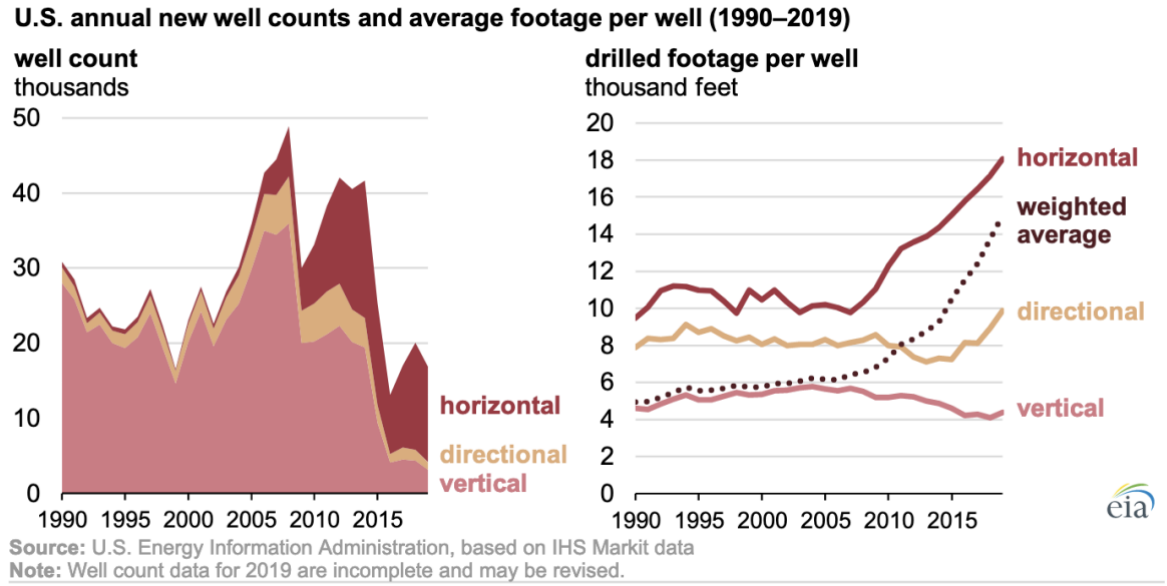


Fred St Louis reports an oil & gas wells price index which correlates well with oil price WTI after a shift of 6 months.

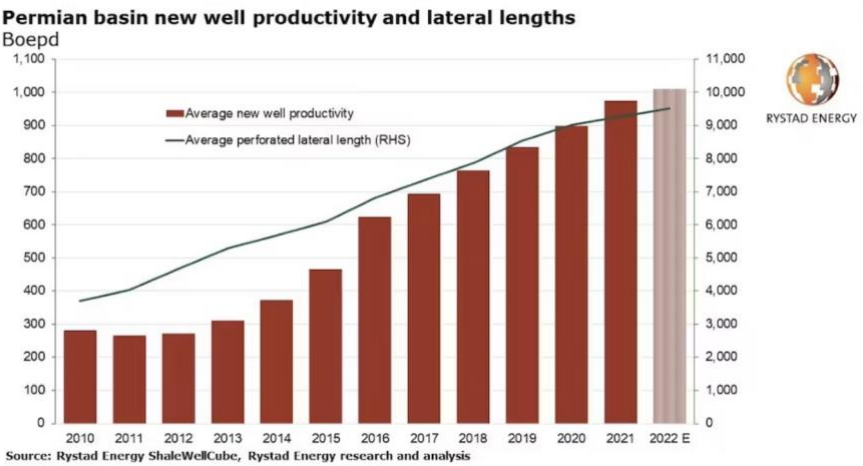


US drilled footage par well increases sharply since 2008 with LTO (lateral length up to 10 000 ft), when the number of wells per drilled decreases.



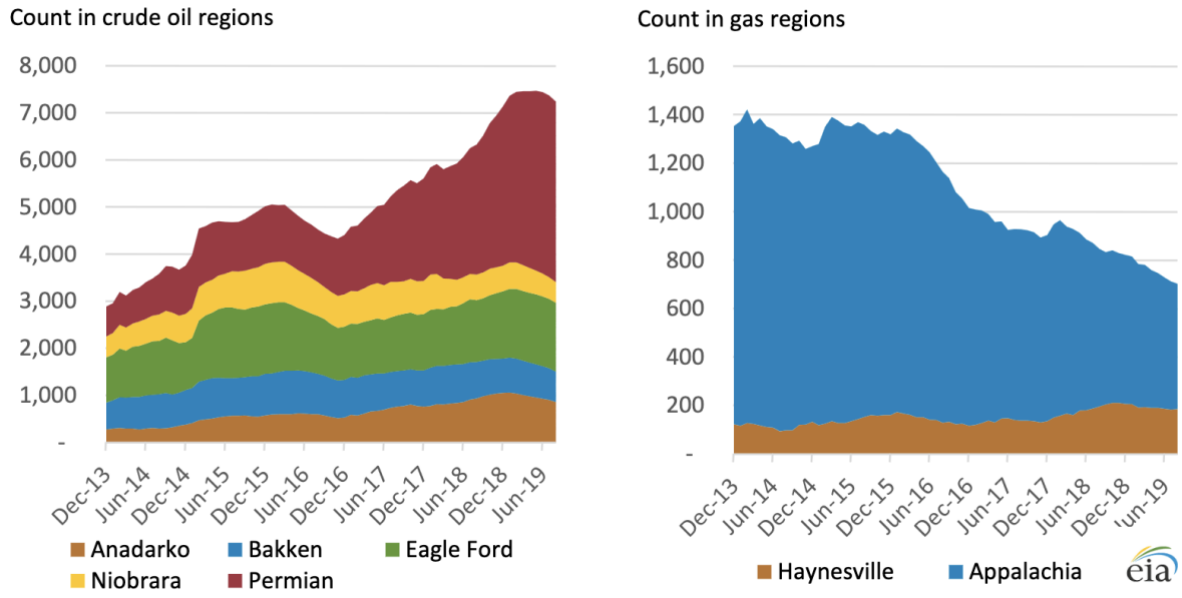


Permian productivity and lateral length.



But the problem with LTO is that the completion of LTO is done later with horizontal fracking and the number of DUC= drilled but uncompleted wells varied sharply on oil (8000 in 2019) and gas (700 in 2019) regions.

Figure 1. DUCs in crude oil and natural gas regions



Most of US wells are now horizontal and their number are increasing, but most of the shale plays are almost drilled and there is now interference between parent and child wells.
Shale play displays quick decline after few years, needing new wells to replace declining wells. It is called the “Red Queen Effect”.
EIA/AEO 2022 oil and gas forecasts see 2050 production not yet on decline, because EIA assume that there is no problem to drill new wells, but it is a huge problem as shown by David Hughes in his "Shale reality check 2021".
The best shale play areas are almost fully drilled in 2021, except the Marcellus, but drilling is forbidden in the New York State because the problem of earthquakes created by high injection of water in fracking.

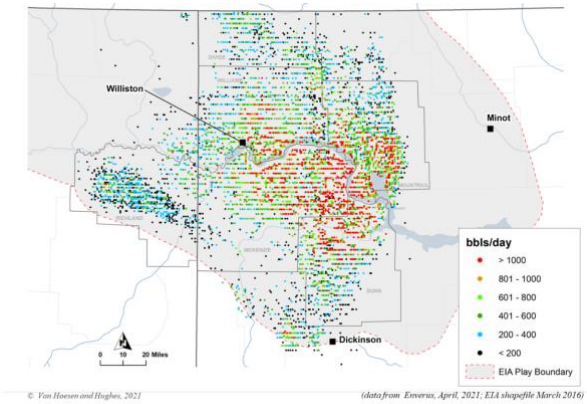


Figure 7. Bakken Play well locations showing peak oil production in the highest month.

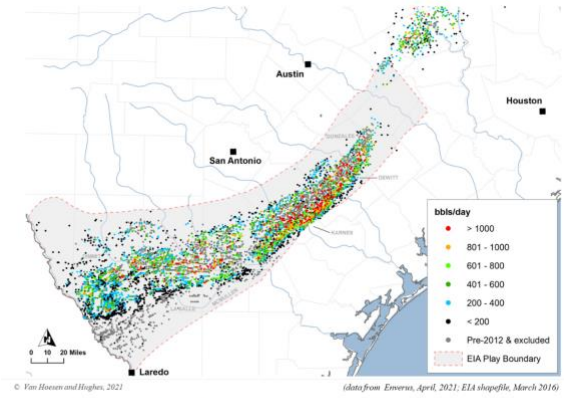


Figure 16. Eagle Ford Play well locations showing peak oil production in the highest month.

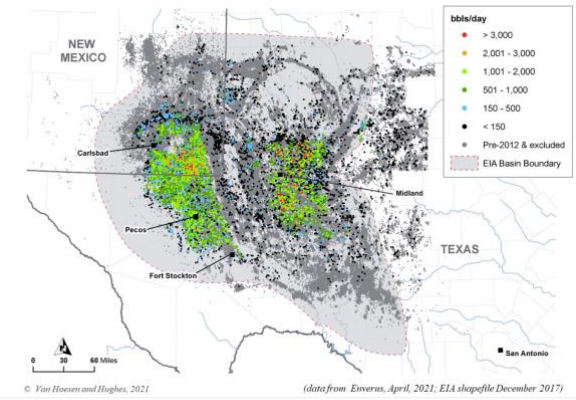


Figure 26. Post-2011 Permian Basin wells showing peak oil production in the highest month.[58]

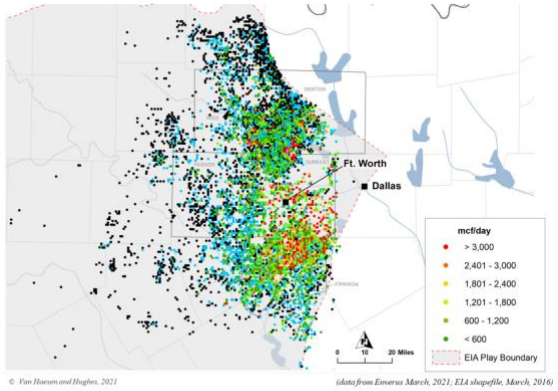


Figure 79. Barnett Play well locations showing peak gas production in the highest month.[150]

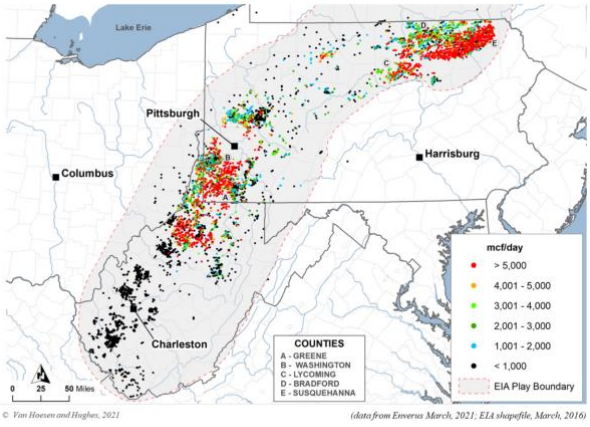


Figure 93. Marcellus Play well locations showing peak gas production in the highest month.

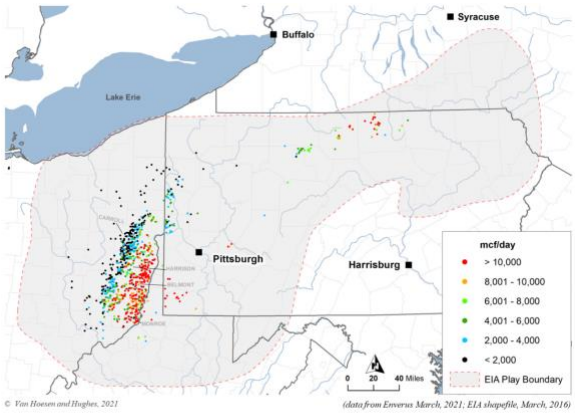
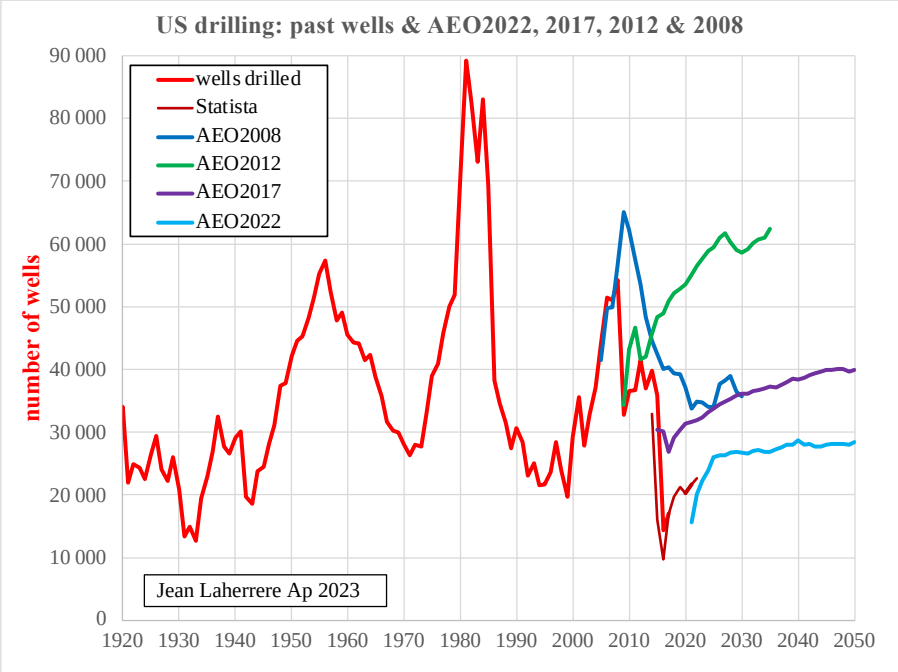


Figure 101. Utica Play well locations showing peak gas production in the highest month.

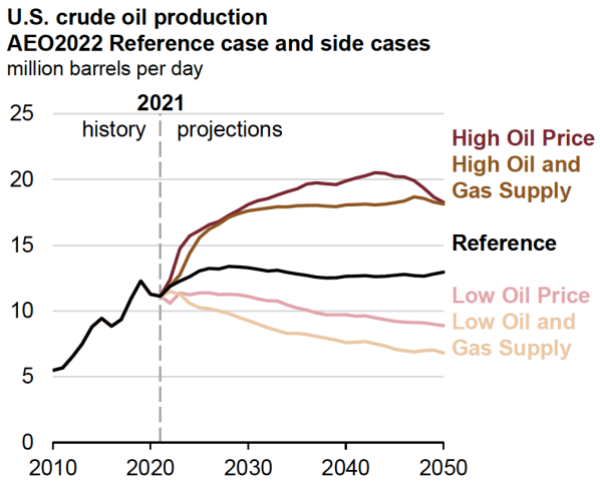
EIA/AEO reports in table 14 oil and gas supply the forecast for future number of wells in USL48.

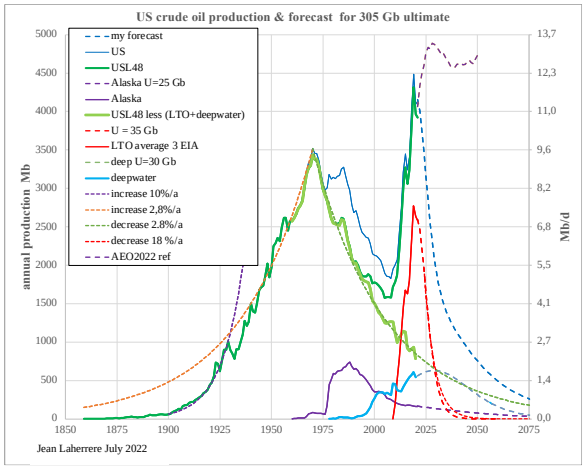
The plot for AEO 2012, 2017 and 2022 number of wells shows that these reference forecasts are completely unrealistic and contrary to recent data for AEO 2012 with forecast of 55 000 wells in 2021 against half in real data. Any LTO horizontal well produces more than a vertical wells. Adding horizontal and vertical wells is adding apples and oranges.

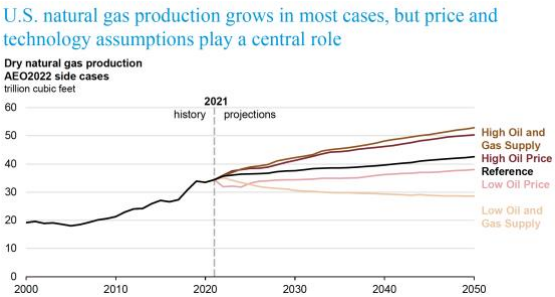
But EIA does not learn from their past mistakes and continue to be unrealistic as their goal is to deny any decline, hoping an eternal increase!

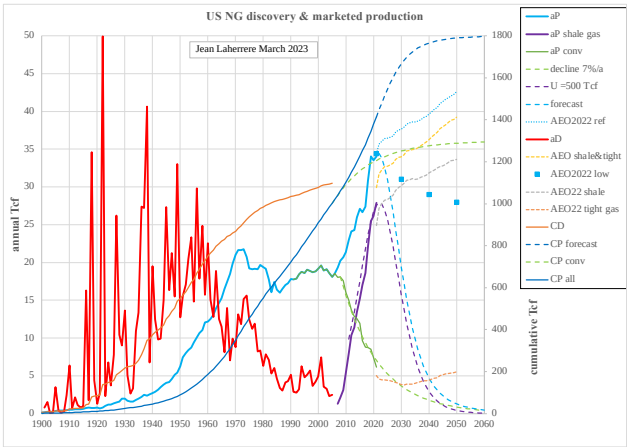


AEO 2022 reference does not forecast any decline in the 2050 number of wells, ignoring the geology of the shale plays: it is unrealistic, it is mad!
Furthermore, the low and gas supply scenario is still high in 2050 compared with my forecast.







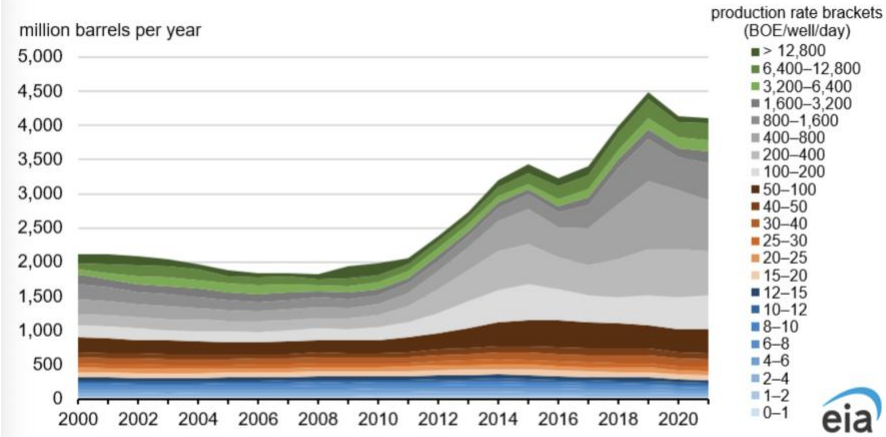


The comparison of AEO2022 with my HL forecasts for 2050 is huge: for oil: 30 times the reference, 20 times the low supply; for gas 6 times the reference, 3 times the low supply.

US production	2021 Tcf	2050 Tcf	2021 Mb/d	2050 Mb/d
AEO2022 ref	34.4	42.6	11.1	13.0
AEO2022 low	34.4	28.0	11.1	7.0
HL forcast	34.0	1.4	11.2	2.1
ref/HL		30		6
low/HL		20		3

Most of the US 2021 oil production comes from wells producing between 100 and 1000 b/d (grey area).

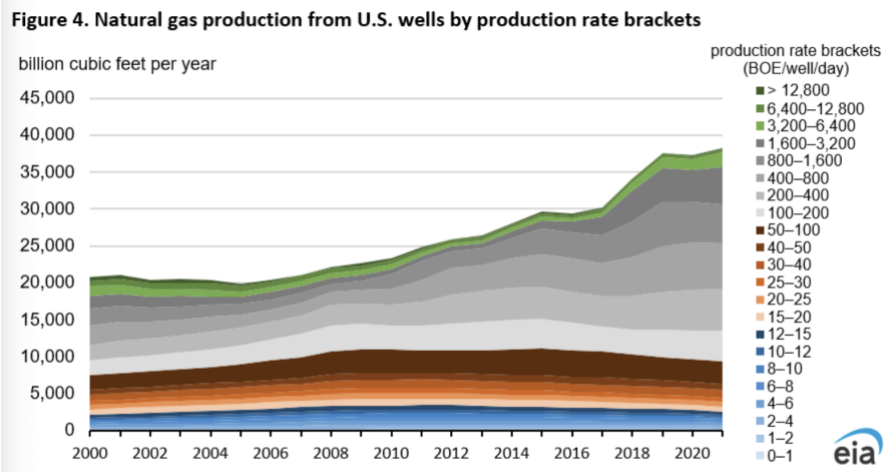
Figure 3. Oil production from U.S. wells by production rate brackets



Data source: U.S. Energy Information Administration and Enverus
Note: BOE=barrels of oil equivalent

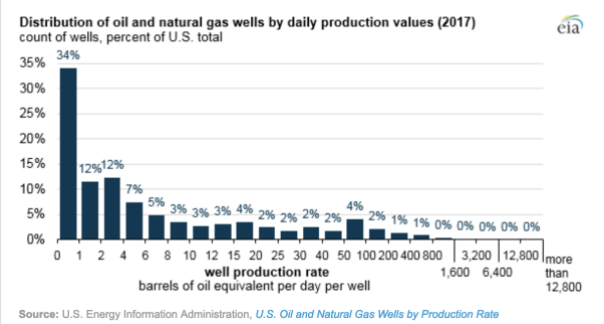
Most of the US NG production comes from wells producing between 100 and 1000 boe/d, same as oilwells: these oil and gas wells represents about 40 0000 wells or 40% of the wells.

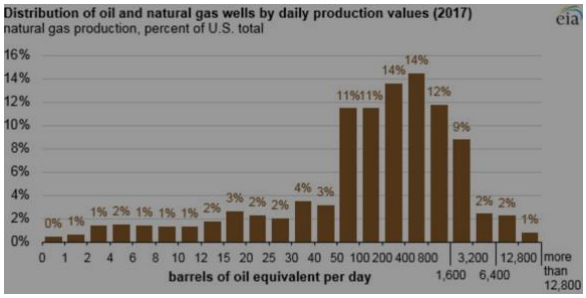
Figure 4. Natural gas production from U.S. wells by production rate brackets



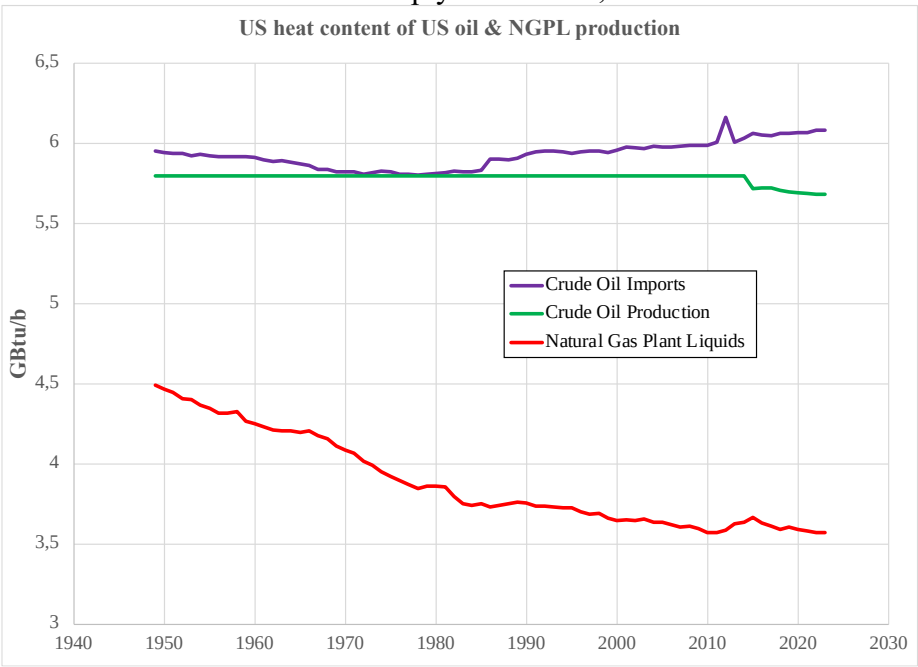
Data source: U.S. Energy Information Administration and Enverus
Note: BOE=barrels of oil equivalent

The distribution of US wells by daily production in 2017 from EIA displays contradictory data ?

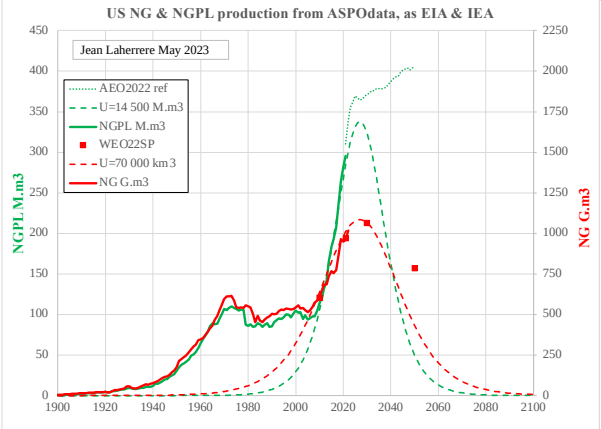


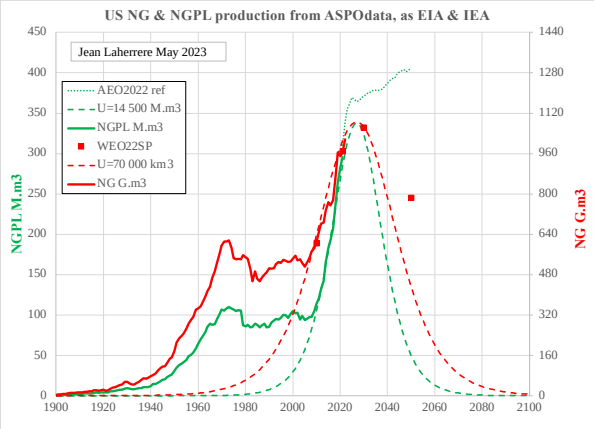


The US heat content of crude oil production is constant from 1949 to 2014 (queer?) and presently declining with LTO, when the heat content of imported crude increases since 1985. The heat content of US NGPL declines sharply since 1949, less since 1980.



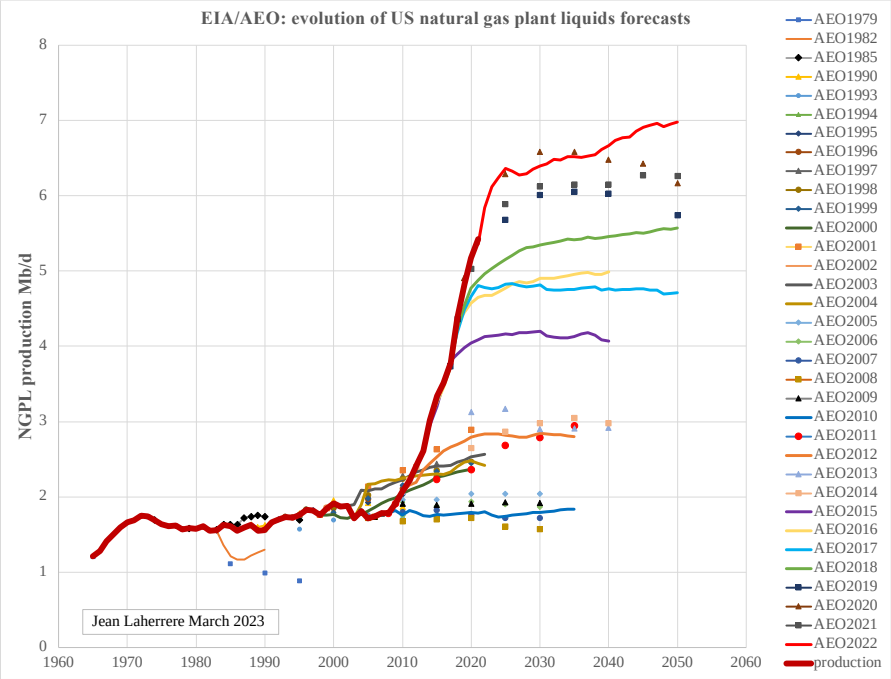
The comparison of US NG & NGPL production and forecast is good with peak in 1973 and 2023. In the next display, US NG production correlates well with US NGPL from 1900 to 2015 and beyond NGPL grows faster than NG. In the second display NG and NGPL correlate fairly well from 2015 to the end.





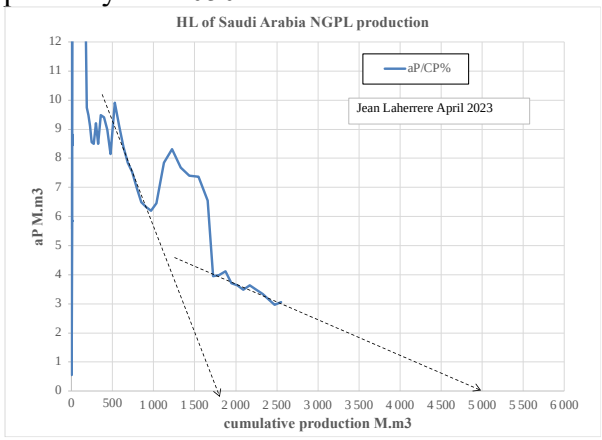
IEA/WEO2022 SP is too optimistic for NG in 2050 and EIA/AEO2022 ref is unrealistic for NGPL beyond 2025. US NG and NGPL production will decline after their peak in 2027 as fast as they increased since 2008.

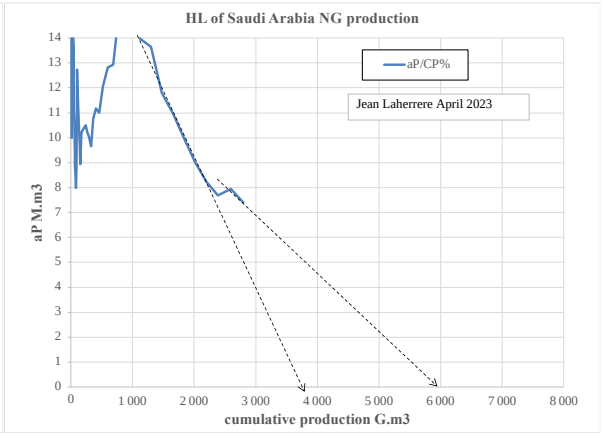
The evolution of EIA/AEO reference NGPL forecasts from the editions of 1979 to 2022 displays very poor estimates. For AEO2022 NGPL peak is beyond 2050: completely unrealistic!

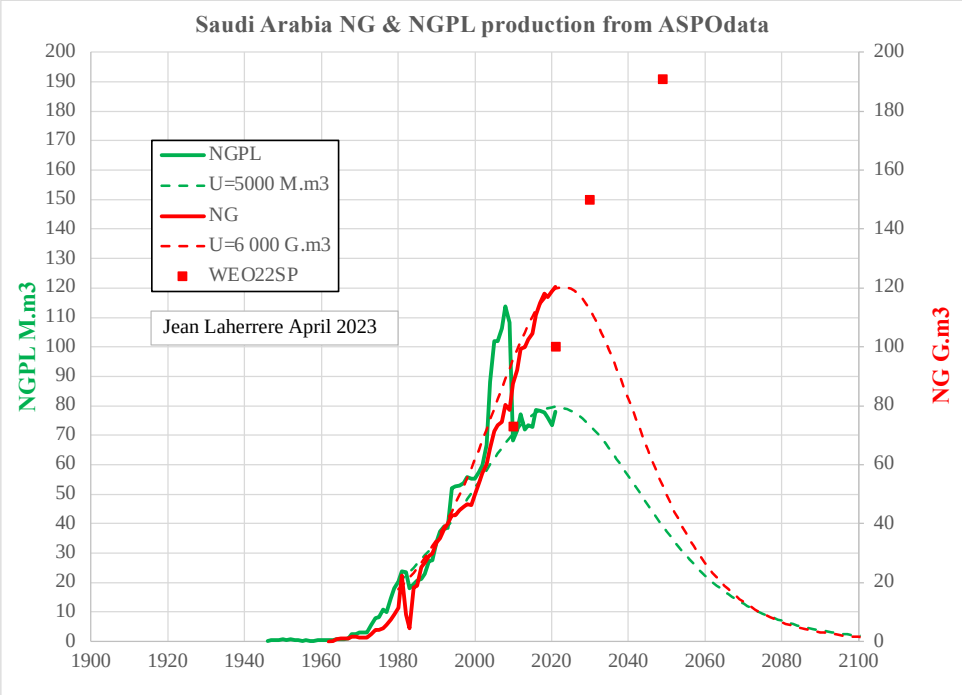


-Saudi Arabia NG & NGPL production

HL of SA NGPL production trends fairly towards 5 km3 and HL of SA NG production trends poorly towards 6 km3, both giving a peak in 2023, when WEO2022SP forecasts for NG a peak beyond 2050!







Saudi Arabia claims the discovery of an unconventional gas field: Jafurah with 200 Tcf (in place?)

Offshore
Technology

Market Data April 28, 2022

Jafurah Phase 1 Unconventional Gas Field, Saudi Arabia

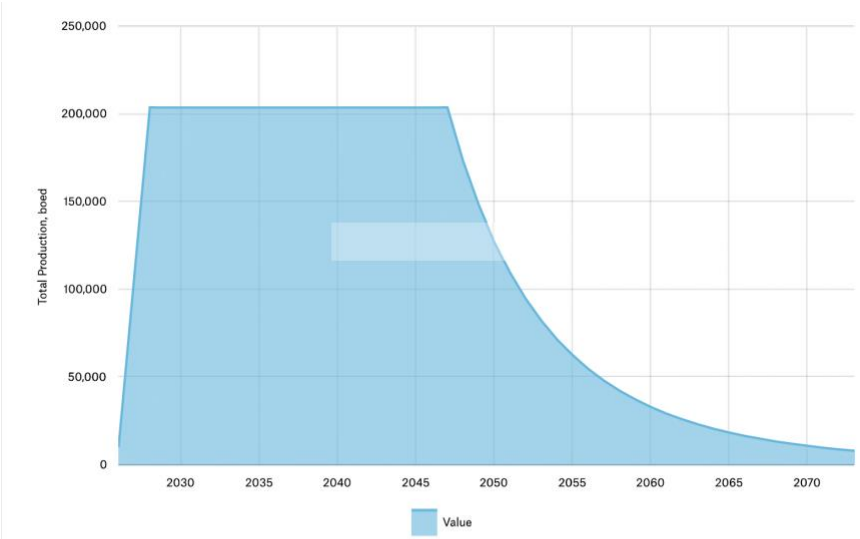
By Carmen

Jafurah Phase 1 is a unconventional gas development located onshore Saudi Arabia and is operated by Saudi Arabian Oil. Discovered in 2016, Jafurah Phase 1 lies in block Saudi Aramco Concession Area.

The project is currently in construction stage and is expected to start commercial production in 2026. The development cost is expected to be $24,000 m.

1. Jafurah is the largest liquid-rich — containing condensates and Natural Gas Liquids (NGL) — shale gas play in the Middle East. Beneath its basin lies an estimated 200 trillion scf of natural gas — which can help reduce emissions and provide feedstock for lower-carbon future fuels.
2. Covering an area of approximately 17,000 km², the Jafurah basin creates a unique opportunity for Aramco to build a large-scale project that aims to contribute to the energy transition.
3. $10 billion of contracts are already in place to develop the initial phase of the project. When completed, the Jafurah facility aims to ensure the reliable delivery of natural gas and condensates

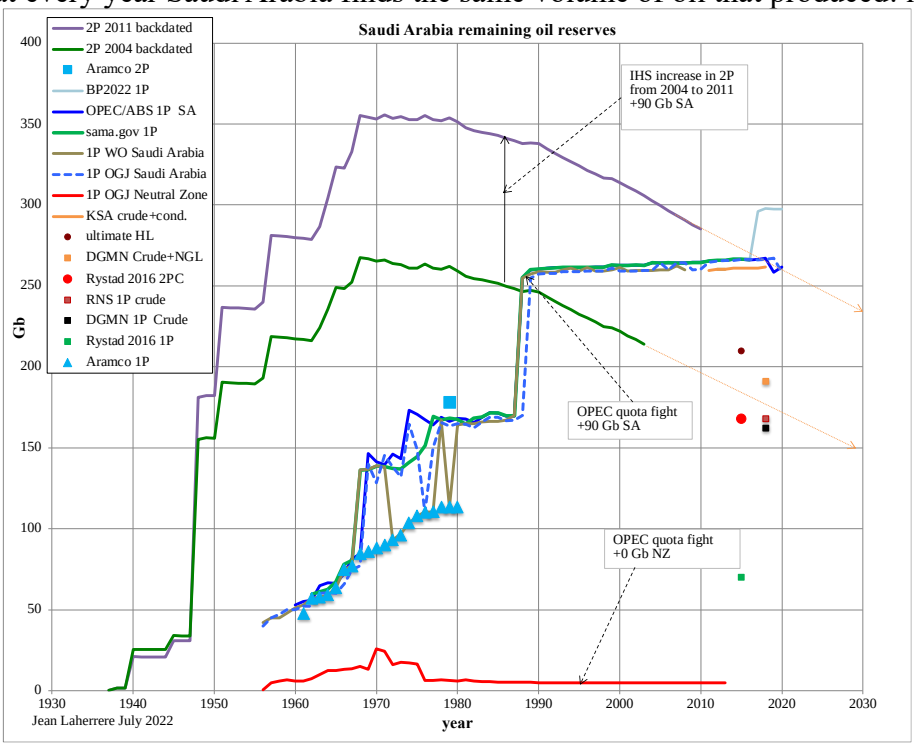
Offshore technology forecasts Jafurah cumulative future production of 1 Gb of crude +condensate, 4.5 Tcf of NG (where are the 200 Tcf?) and 0.1 Gb of NGL: those reserves with 6 significant digits mean that this study knows little on uncertainty!



Remaining recoverable reserves

The field is expected to recover 2,006.3 Mmboe, comprised of 1,113.86 Mmbbl of crude oil & condensate, 4,493.85 bcf of natural gas reserves and 143.45 Mmbbl of natural gas liquid reserves.

I remind that Saudi Arabia oil proven reserves have been around 260 Gb for the last 30 years, meaning that every year Saudi Arabia finds the same volume of oil that produced: it is a joke!

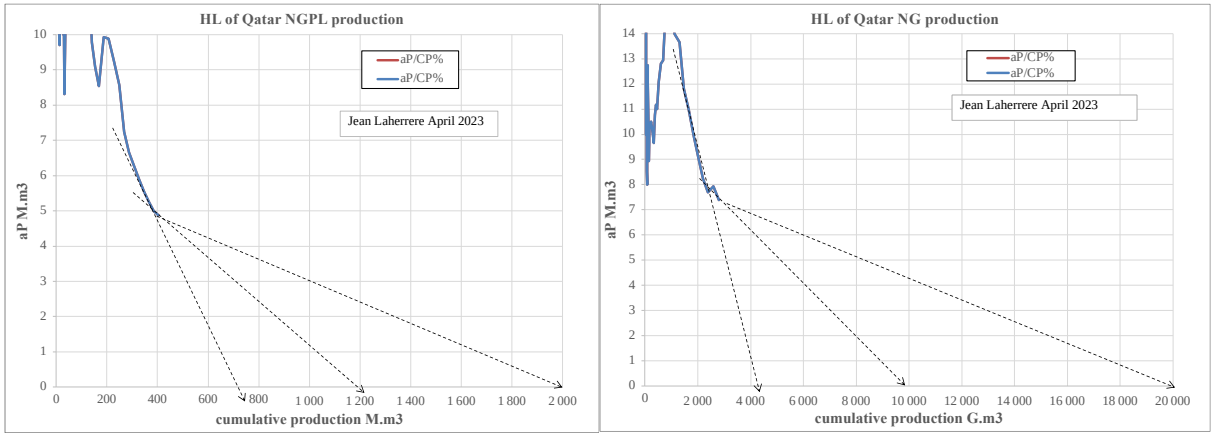


Publishing oil reserves in Saudi Arabia is a political act and no other government can say that they lie!

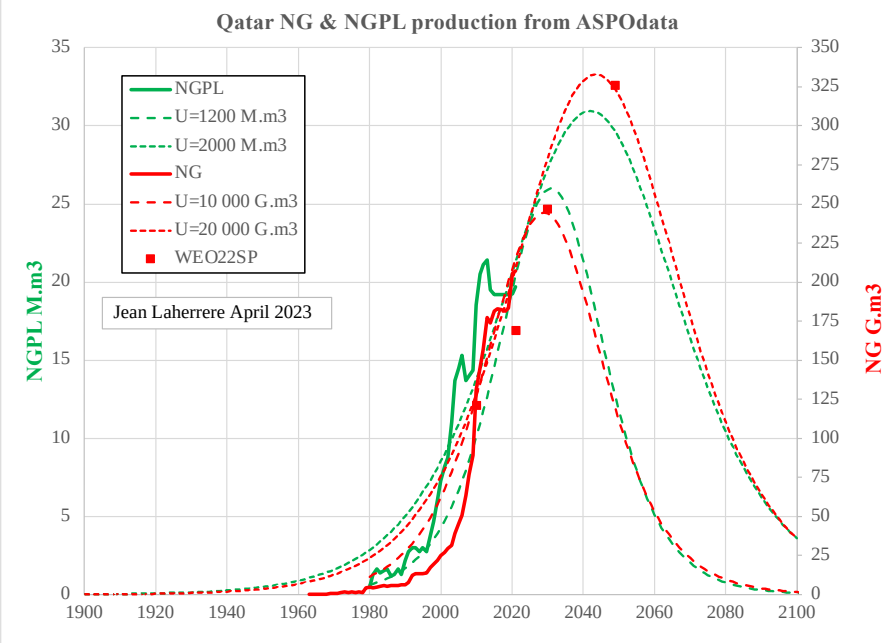
-Qatar NG & NGPL production

Qatar has with North Field two thirds of the largest gas field in the world: North Dome (larger than the largest oil field Ghawar in Gboe).

Hl of Qatar NGPL production trends poorly towards 1.2 km3 or 2 km3 and HL of Qatar NG production trends poorly towards 10 000 km3 (350 Tcf) far from the North field 2P of 1000 Tcf or towards 20 000 km3.

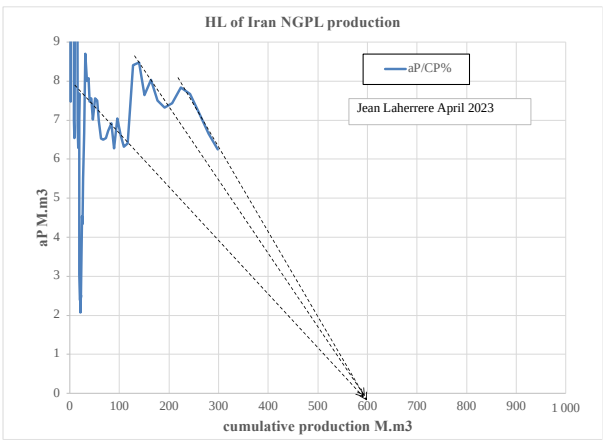


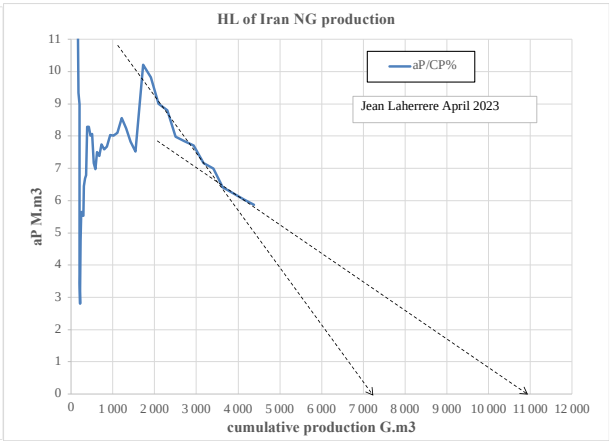
North Field is a huge gas field developed by phase and it is likely that the extrapolation of past production with HL cannot deliver the right value of Qatar NG ultimate.
Qatar NGPL a NG peak could be about 2030 to 2050 and IEA/WEO2022SP forecast NG peak beyond 2050!



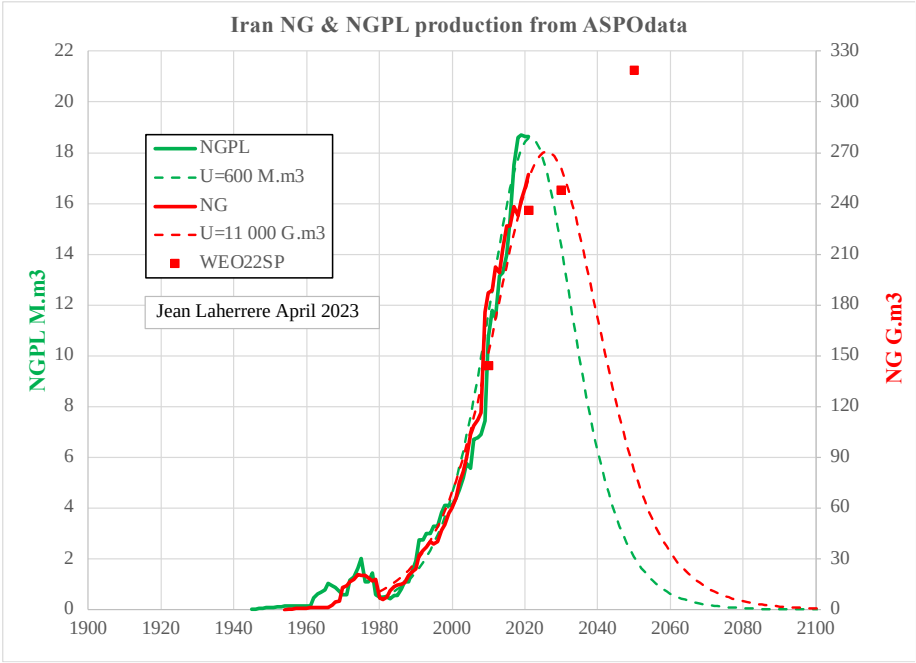
-Iran NG & NGPL production

HL of Iran NG production trends towards 600 M.m3 and HL of NGPL trends towards 11 000 G.m3:

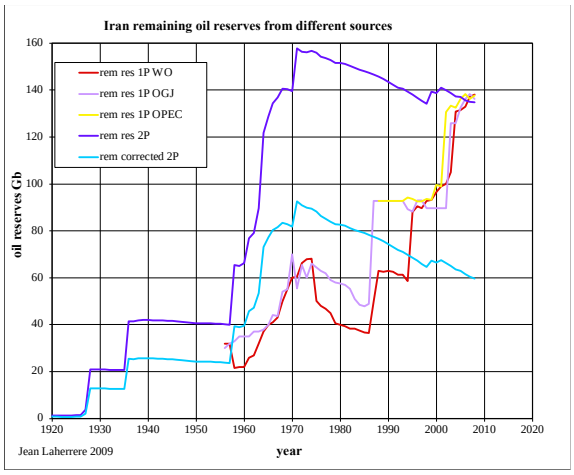


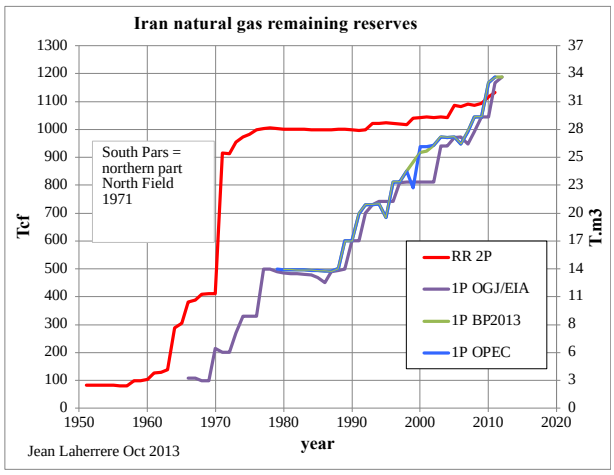


With those ultimates Iran NG and NGPL will peak before 2030 (South Pars could change this forecast)



I remind that Iran oil reserves vary widely with sources as shown in 2009 and Iran gas reserves in 2013.





-recap on NGPL & NG

	M.m3	M.m3	M.m3		M.m3	Gb	M.m3	
NGPL	2021	CP 2021	U	quality	rem 2021	rem 2021	peak	peak yr
world	668	20500	60000	VP	39500	248	837	2037
Africa	31	900	2000	P	1100	7	35	2010
Asia	194	5100	12000	F	6900	43	205	2026
CIS	42	2150	3500	VP	1350	8	48	2015
Europe	19	1050	1350	P	300	2	29	2001
Lat Am	29	1600	2000	F	400	3	45	2013
North Am	345	9500	20000	VP	10500	66	414	2027
Oceania	6	190	265	VP	75	0	6	2021
sum 7	666	20490	41115		20625	130		
world-sum	2	10	18885		18875	119		
Mid East	170	4400	10000	F	5600	35	175	2026
OPEC	174	5000	10000	F	5000	31	176	2023
NOPEC	493	5500	45000	VP	39500	248	700	2037
US	296	7900	14500	VP	6600	42	338	2027
Canada	49	1600	3000	VP	1400	9	50	2023

	G.m3	G.m3	G.m3		G.m3	Tcf	G.m3	
NG	2021	CP 2021	U	quality	rem 2021	rem 2021	peak	peak yr
world	4146	134000	500000	F	366000	12928	4950	2044
Africa	277	6000	20000	P	14000	495	312	2034
Asia	1210	24500	60000	F	35500	1254	1260	2025
CIS	897	32700	60000	P	27300	964	914	2021
Europe	220	15700	19000	F	3300	117	350	2005
Lat Am	180	6700	9000	F	2300	81	218	2014
North Am	1153	47300	72000	VP	24700	872	1295	2025
Oceania	167	2400	4500	P	2100	74	72	2020
sum 7	4104	135300	244500		109200	3857		
world-sum	42	-1300	255500		256800	9071		
Mid East	734	13400	37000	P	23600	834	797	2026
OPEC	685	15500	40000	P	24500	865	715	2028
NOPEC	3473	119400	400000	F	280600	9912	4150	2043
US	1016	41000	70000	VP	29000	1024	1086	2027
Canada	203	7900	12000	VP	4100	145	218	2025

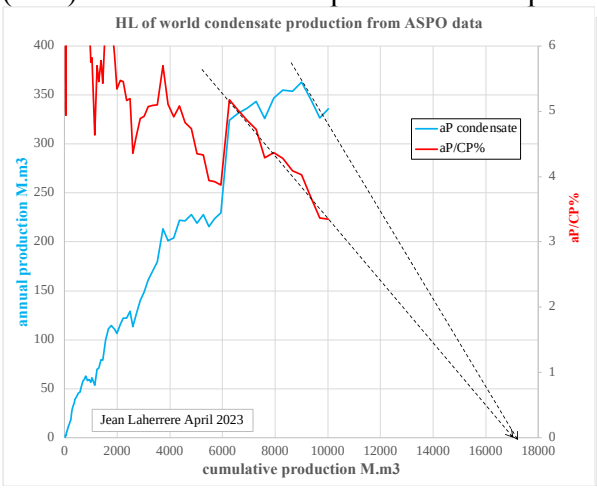
HL for the world NG production is good with an ultimate of 500 000 km3 (G.m3) when the sum of the seven regions is only about half, showing the uncertainty of the method.

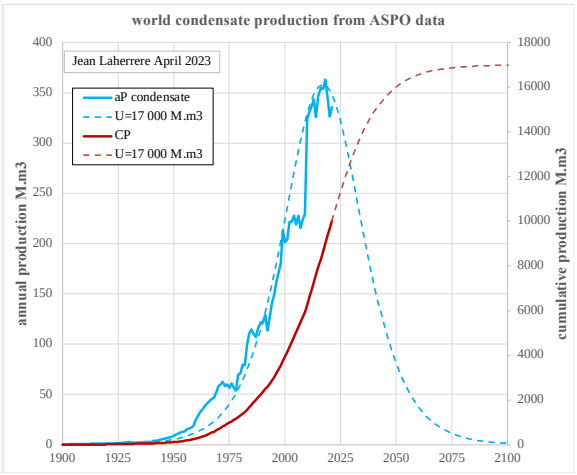
The ratio NG/NGPL in k.m3 for cumulative production 2021 and ultimate varies between 2 and 10

	G.m3	G.m3	M.m3	M.m3	k.m3	k.m3
NG	NG CP	U NG	NGPL CP	U NGPL	NG/NGPL CP	NG/NGPL U
world	134000	500000	30500	77000	4	6
Africa	6000	20000	2200	3700	3	5
Asia	24500	60000	8800	17000	3	4
CIS	32700	60000	3450	6500	9	9
Europe	15700	19000	1550	1950	10	10
Lat Am	6700	9000	2200	2800	3	3
North Am	47300	72000	11800	23000	4	3
Oceania	2400	4500	460	715	5	6
sum 7	135300	244500	30460	55665	4	4
Mid East	13400	37000	7600	14500	2	3
OPEC	15500	40000	8500	15000	2	3
NOPEC	119400	400000	12000	57000	10	7
US	41000	70000	10000	17000	4	4
Canada	7900	12000	1760	3300	4	4

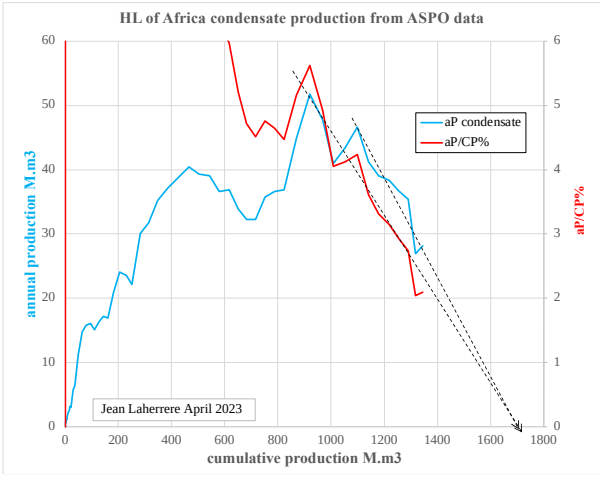
-condensate production

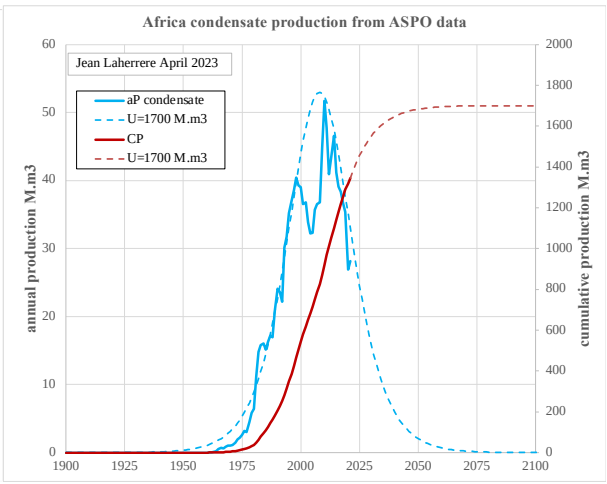
HL of world condensate production (red) trends towards 17 km3, in line with annual decline (blue). World condensate production has peaked in 2019.



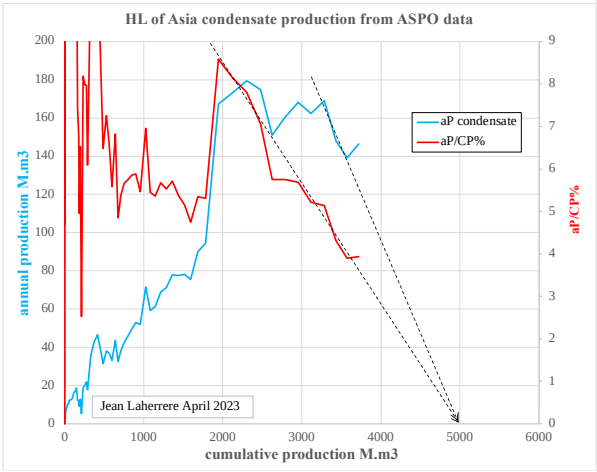


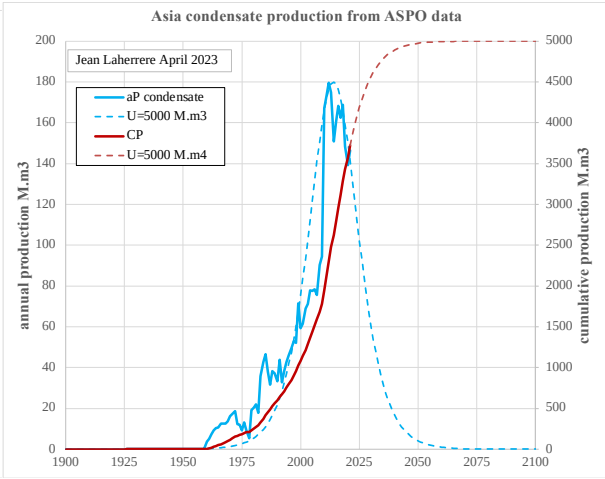
Africa condensate production has peaked in 2010:



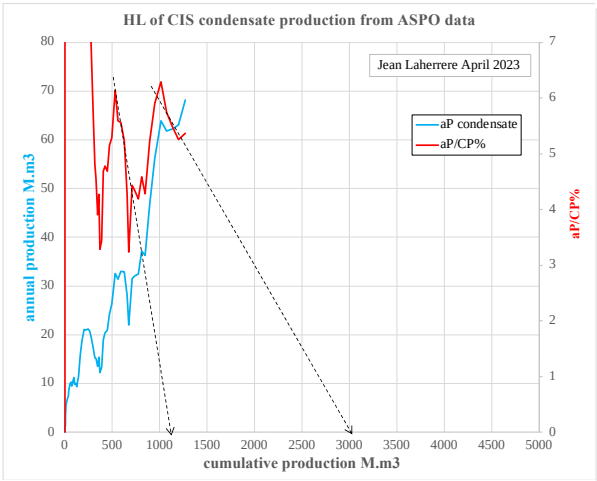


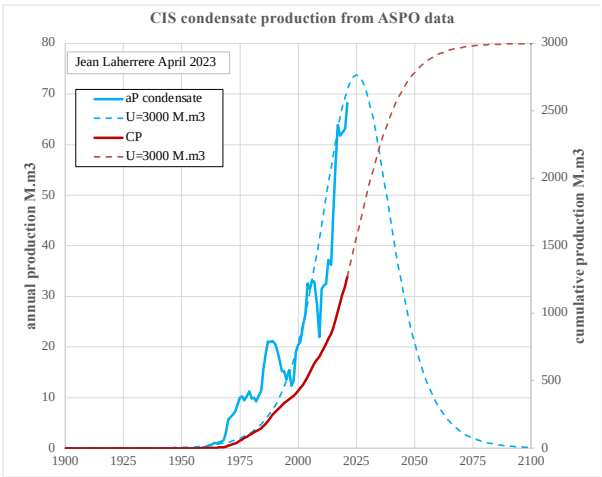
Asia condensate production has peaked in 2013:



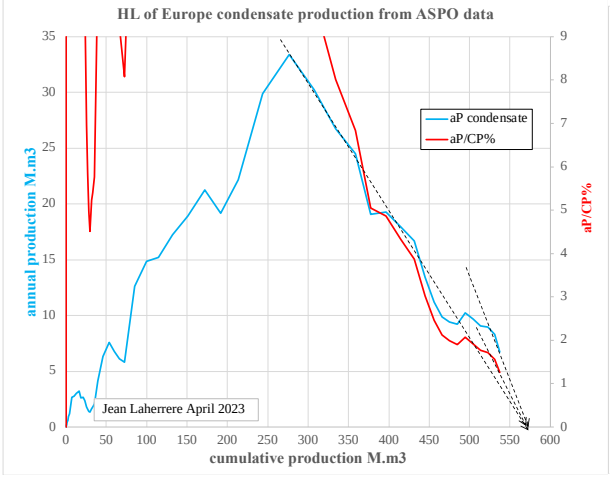


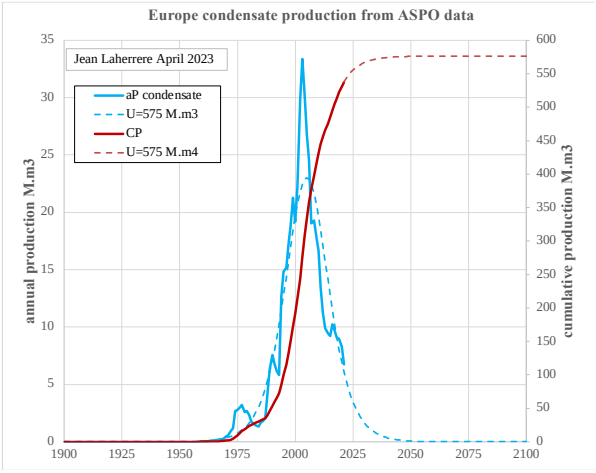
CIS condensate production will peak in 2025:



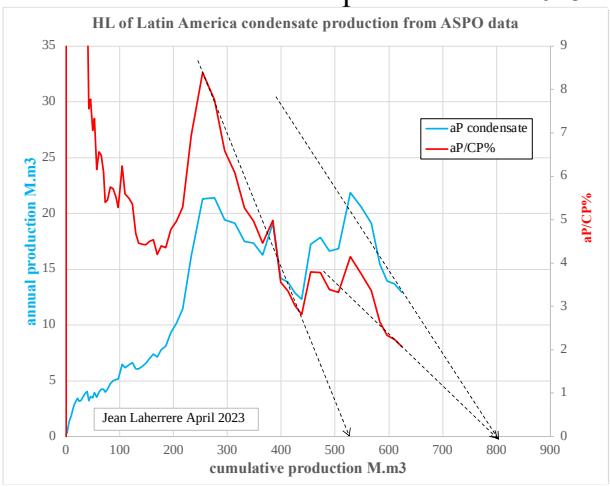


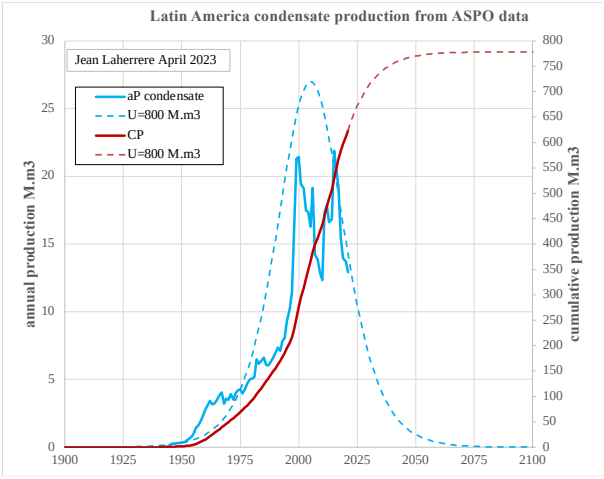
Europe condensate production has peaked in 2003:



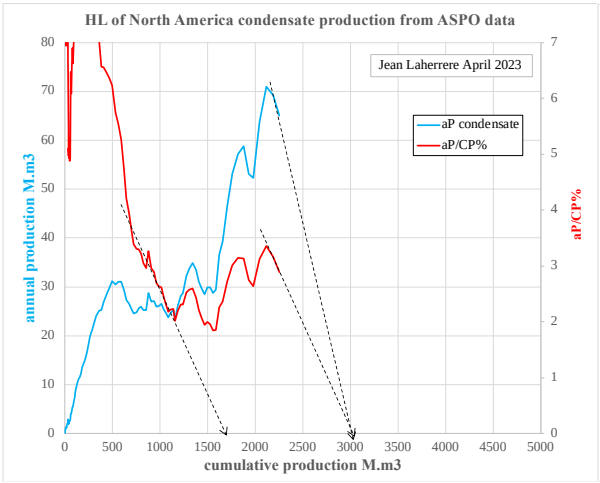


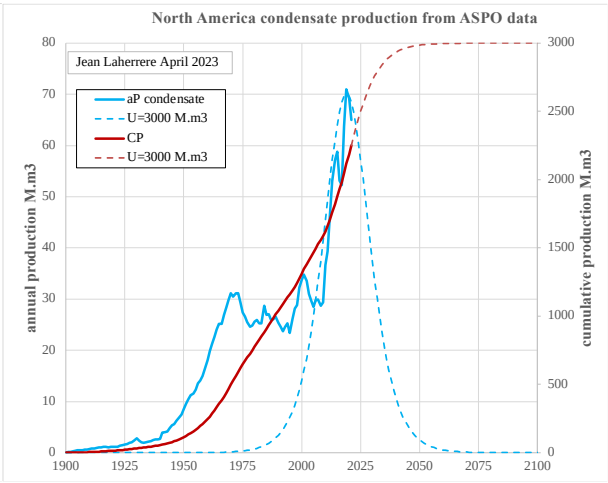
Latin America condensate production in 2015



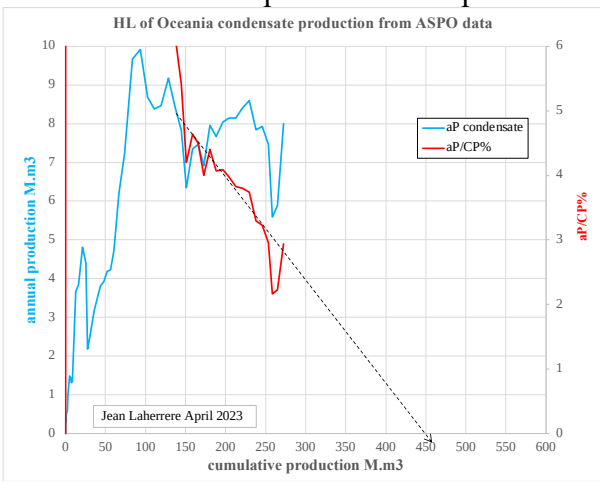


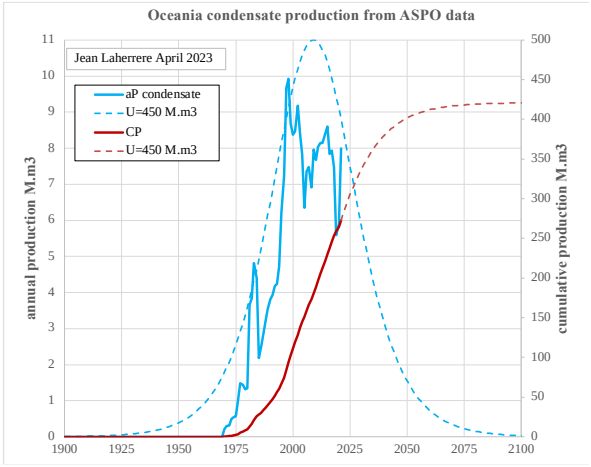
North America condensate has peaked in 2019:



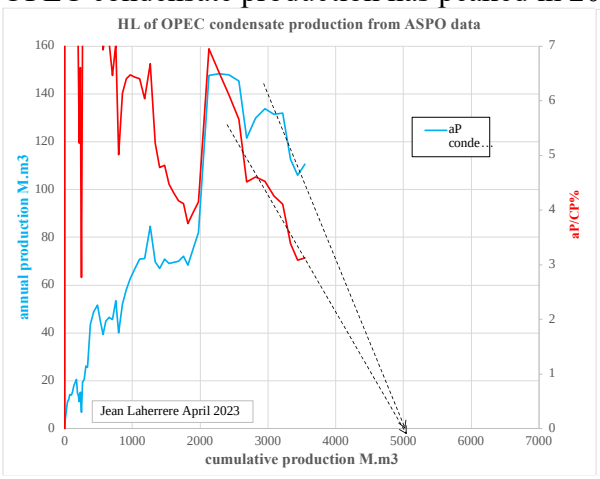


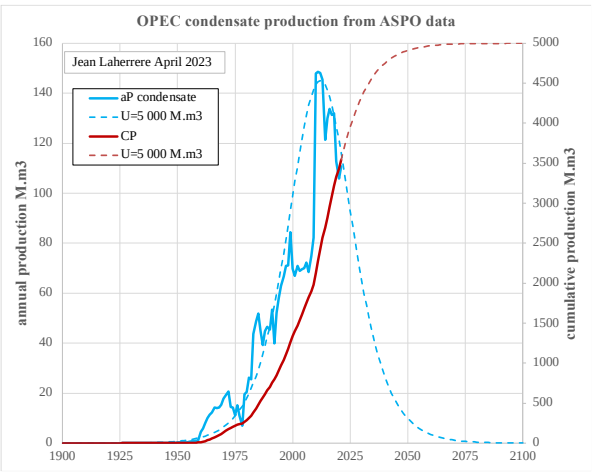
Oceania condensate production has peaked in 1998:



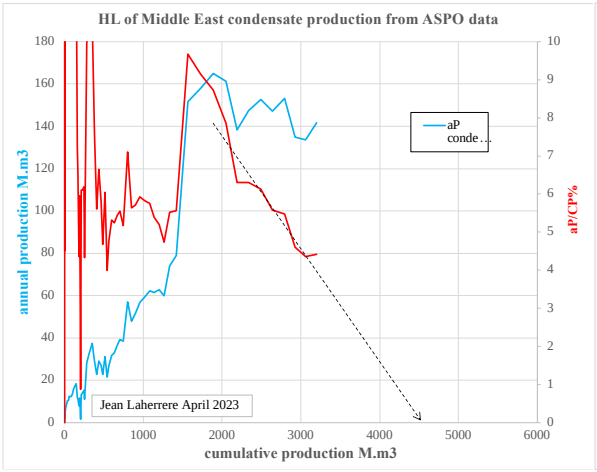


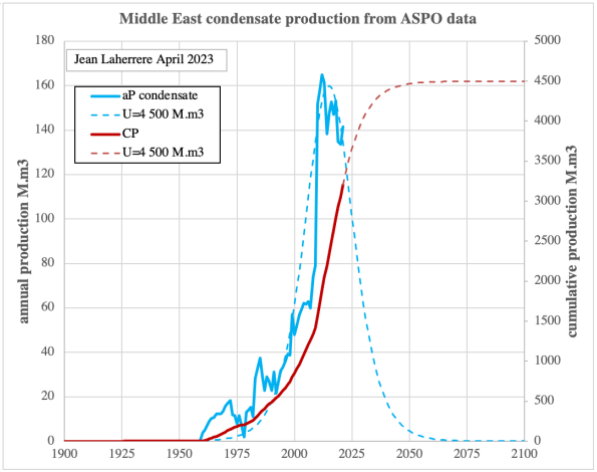
OPEC condensate production has peaked in 2011:



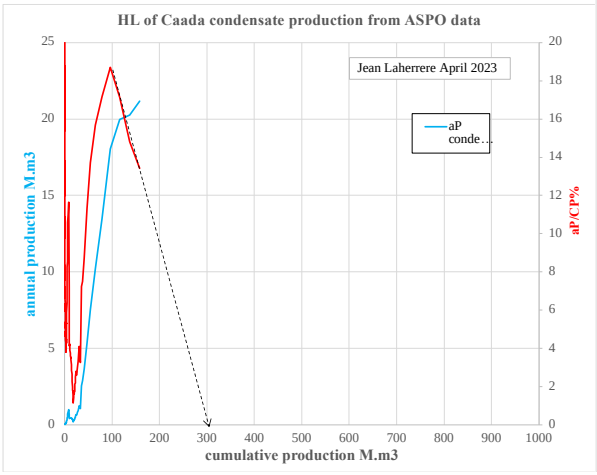


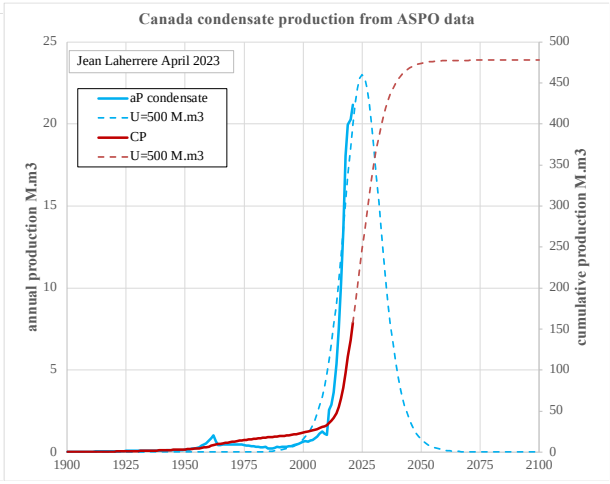
ME condensate production peaked in 2012:



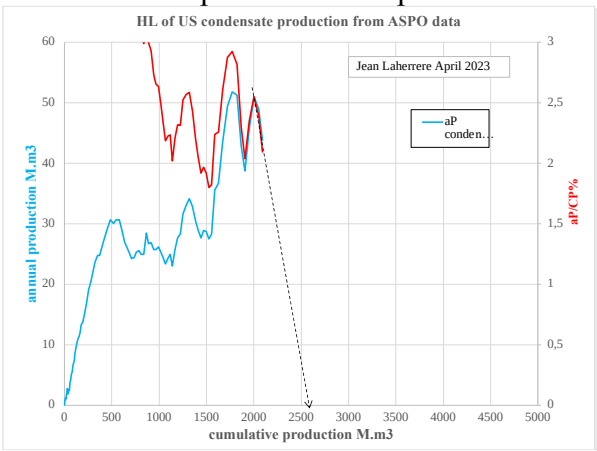


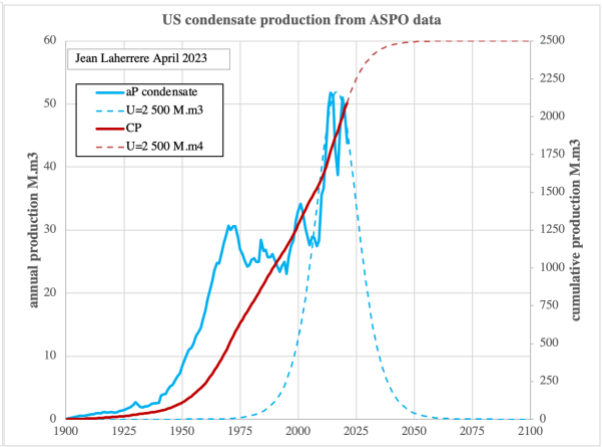
Canada condensate production should peak in 2025:





US condensate production has peaked in 2014:



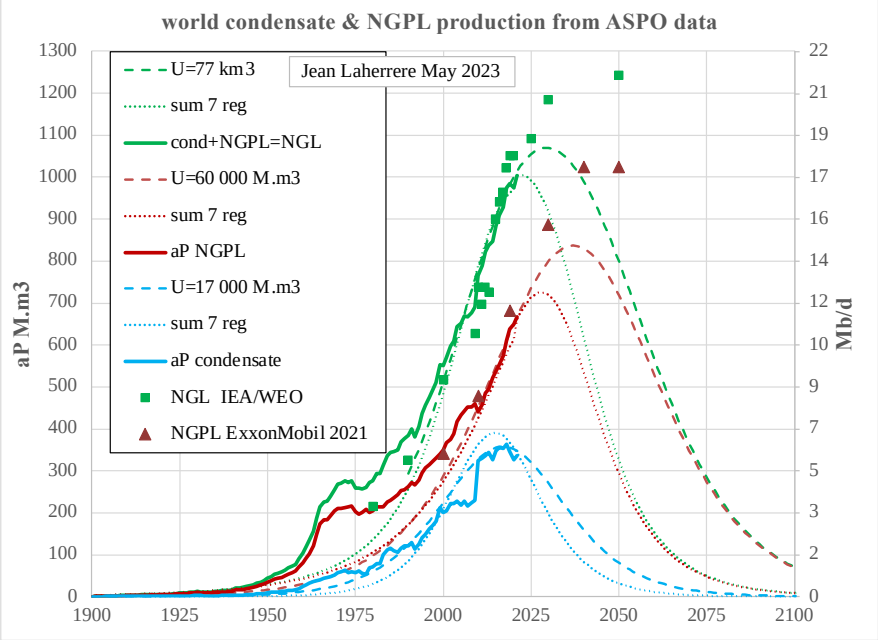


-condensate + NGPL production = NGL

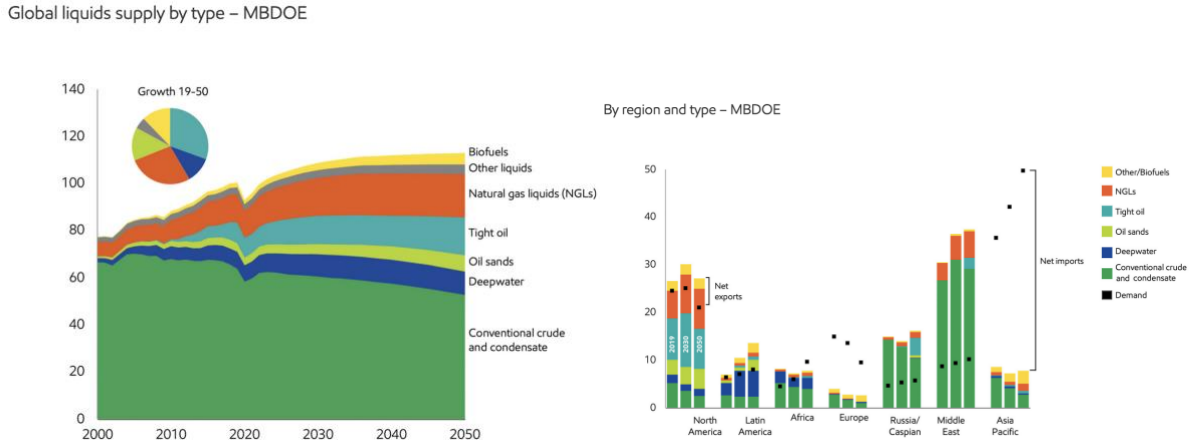
The forecast for condensate and NGPL is added to get the NGL, and the sum of the 7 regions is added to get the world production but it appears clearly that the sum of the 7 regions is far less than the forecast of the world.

It is more reliable to forecast the total than a part of it.

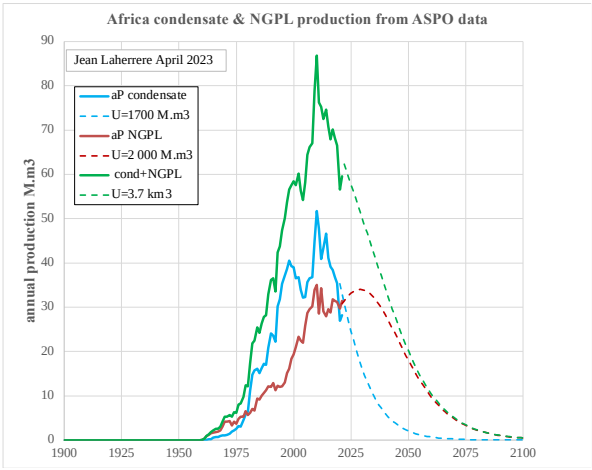
World condensate production is lower than NGPL production and has peaked when NGPL will peak around 2040.
World NGL will peak between 2025 and 2030 with less than 19 Mb/d when IEA/WEO 2021 SP forecasts beyond 2050 above 21 Mb/d: quite a difference!
ExxonMobil energy outlook 2021 sees a peak in NGPL in 2050

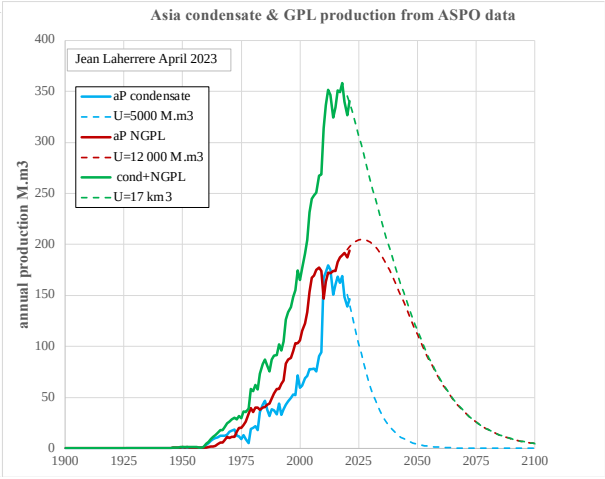


ExxonMobil Energy outlook 2021 displays global liquids supply where NGL are in fact NGPL because condensate is included with crude oil:

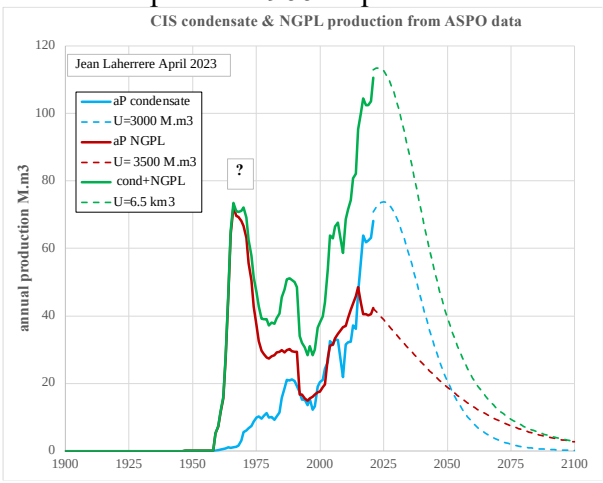


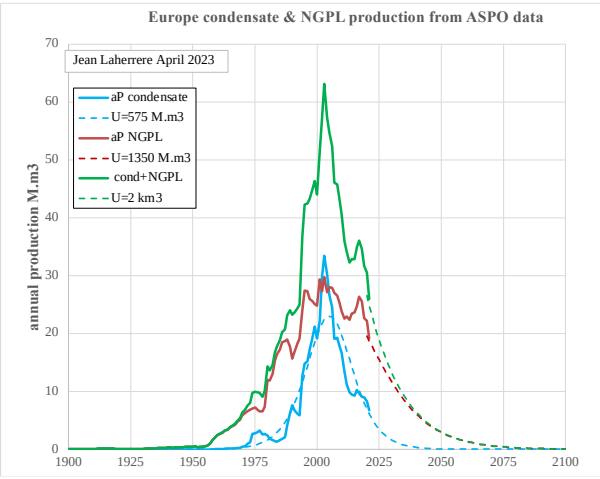
Africa condensate production is higher than NGPL production in contrary with Asia and Europe

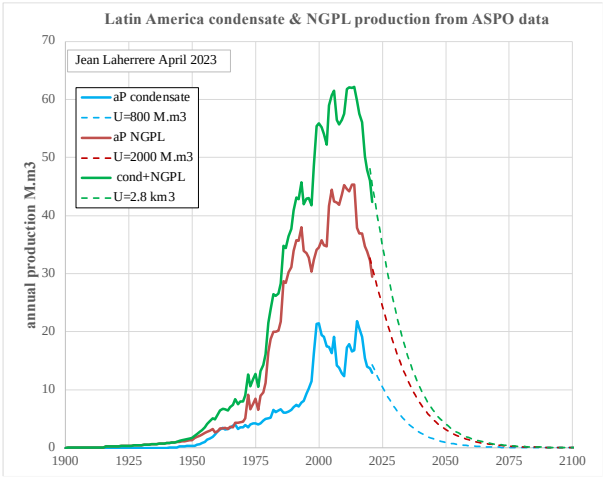


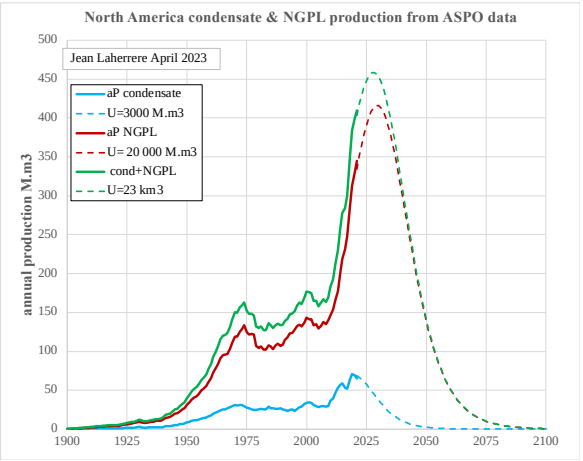


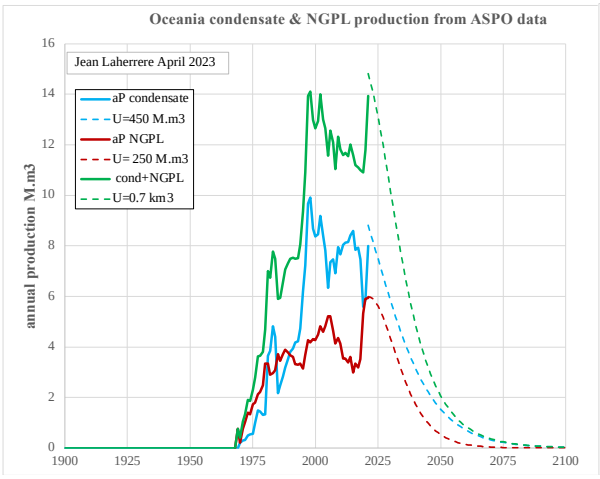
CIS NGPL peak in 1966 is questionable.

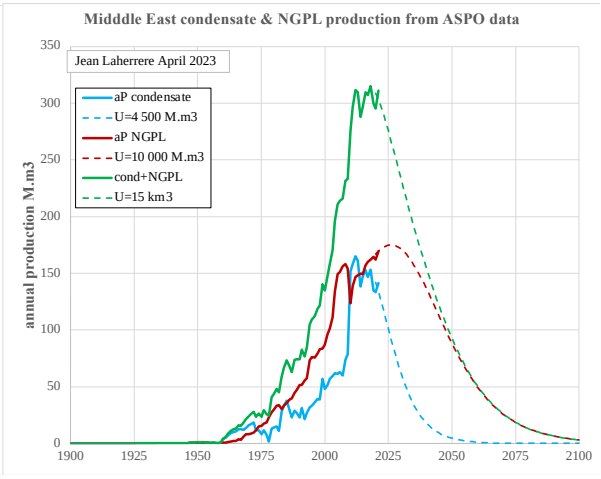


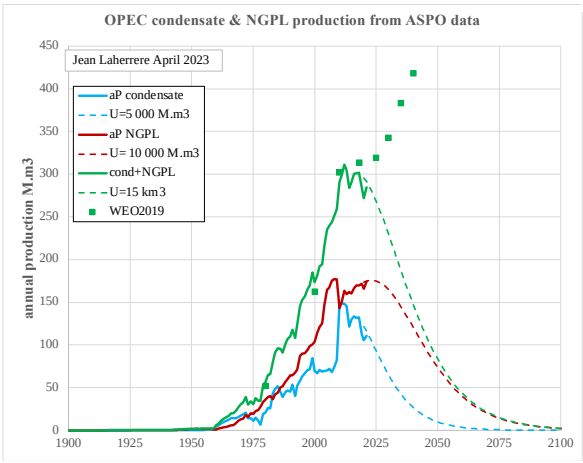


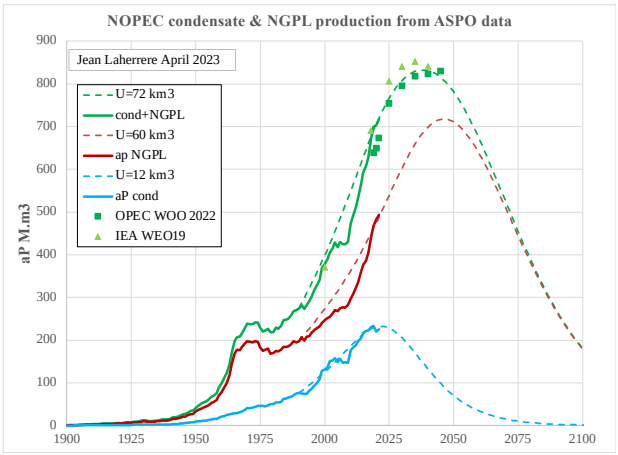




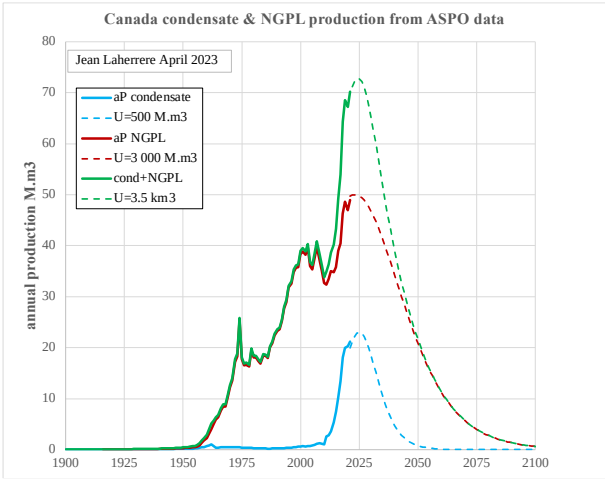


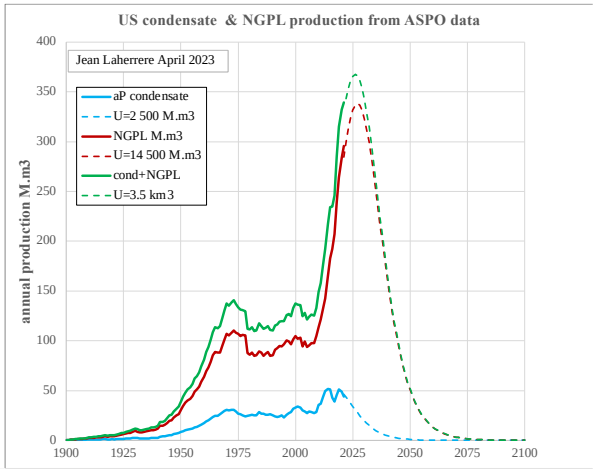






OPEC NGL production forecast with HL declines when IEA/WEO2019 increases with no peak before 2040, looking unrealistic.
In contrary, NOPEC HL forecast agrees with OPEC WWO 2022 and WEO 2019





-recapitulation on condensate, NGL and NG

The recapitulation of condensate data and ultimates is combined with NGPL to give NGL.
For condensate:

	M.m3	M.m3	M.m3		M.m3	Gb	M.m3	
condensate	2021	CP 2021	U	quality	rem 2021	rem 2021	peak	peak yr
world	335	10000	17000	F	7000	44	2018	363
Africa	28	1300	1700	F	400	3	2010	52
Asia	146	3700	5000	F	1300	8	2012	180
CIS	68	1300	3000	VP	1700	11	2025	74
Europe	7	500	600	F	100	1	2003	33
Lat Am	13	600	800	P	200	1	2015	22
North Am	65	2300	3000	P	700	4	2019	71
Oceania	8	270	450	P	180	1	1998	10
sum 7	335	9970	14550		4580	29		
world-sum	0	30	2450		2420	15		
Mid East	142	3200	4500	F	1300	8	2012	165
OPEC	110	3500	5000	F	1500	9	2011	1490
NOPEC	225	6500	12000	F	5500	35	2019	233
US	44	2100	2500	P	400	3	2014	52
Canada	21	160	300	P	140	1	2025	23

For NGPL:

	M.m3	M.m3	M.m3		M.m3	Gb	M.m3	
NGPL	2021	CP 2021	U	quality	rem 2021	rem 2021	peak	peak yr
world	668	20500	60000	VP	39500	248	837	2037
Africa	31	900	2000	P	1100	7	35	2010
Asia	194	5100	12000	F	6900	43	205	2026
CIS	42	2150	3500	VP	1350	8	48	2015
Europe	19	1050	1350	P	300	2	29	2001
Lat Am	29	1600	2000	F	400	3	45	2013
North Am	345	9500	20000	VP	10500	66	414	2027
Oceania	6	190	265	VP	75	0	6	2021
sum 7	666	20490	41115		20625	130		
world-sum	2	10	18885		18875	119		
Mid East	170	4400	10000	F	5600	35	175	2026
OPEC	174	5000	10000	F	5000	31	176	2023
NOPEC	493	5500	45000	VP	39500	248	700	2037
US	296	7900	14500	VP	6600	42	338	2027
Canada	49	1600	3000	VP	1400	9	50	2023

For NGL:

	M.m3	M.m3	M.m3	M.m3	Gb
cond+NGPL	2021	CP 2021	U	rem 2021	rem 2021
world	1003	30500	77000	46500	292
Africa	59	2200	3700	1500	9
Asia	340	8800	17000	8200	52
CIS	110	3450	6500	3050	19
Europe	26	1550	1950	400	3
Lat Am	42	2200	2800	600	4
North Am	410	11800	23000	11200	70
Oceania	14	460	715	255	2
sum 7	1001	30460	55665	25205	159
world-sum	2	40	21335	21295	134
Mid East	312	7600	14500	6900	43
OPEC	284	8500	15000	6500	41
NOPEC	718	12000	57000	45000	283
US	340	10000	17000	7000	44
Canada	70	1760	3300	1540	10

In 2021 the remaining ultimate for condensate is 7 km3 = 44 Gb and for NGL 40 km3 = 248 Gb, giving for NGL about 300 Gb

-renewables = S curves

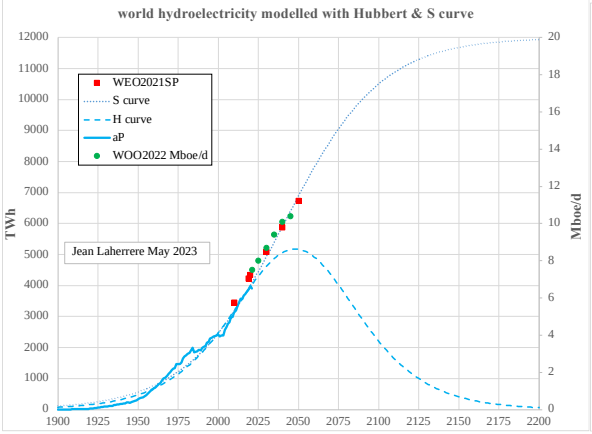
Renewables are different from fossils fuels which are limited reserves. FF should be modelled with Hubbert curves, when renewables with S curves (same exponential growth but going towards an asymptote and not a peak

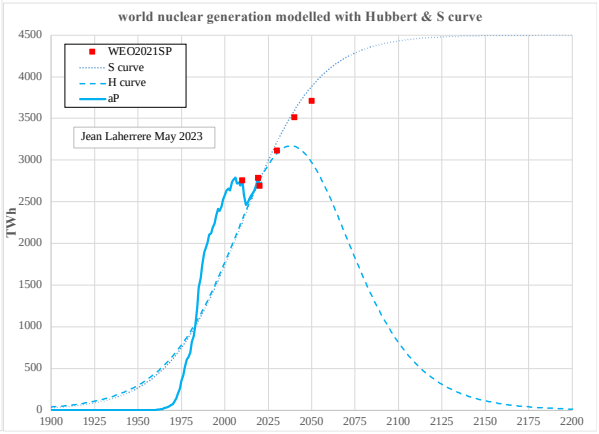
However, if the lifetime of an oil field is about 20-100 years, the lifetime of a wind turbine is about 20 years, and the intermittency range is 23-30 % onshore and 35-39 % offshore https://www.sciencedirect.com/science/article/pii/S0196890421004520.

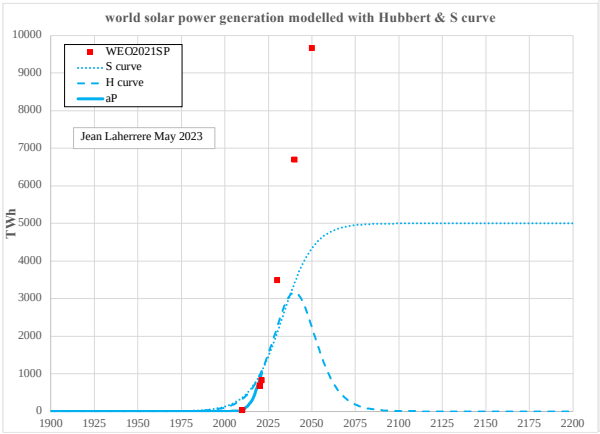
In the past the number of windmills has peaked and declined

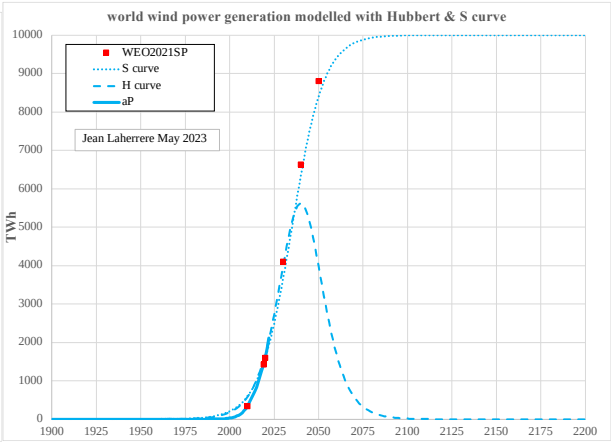
The lifetime of a solar cell is 25-30 years.

For all renewables, the range between S curve and H curve is huge, showing the uncertainty of the forecast. WEO2022 SP is identical to the S curve, meaning that their reference (Stated policies) scenario is rather on the upper range, making WEO2022 NZE unrealistic.

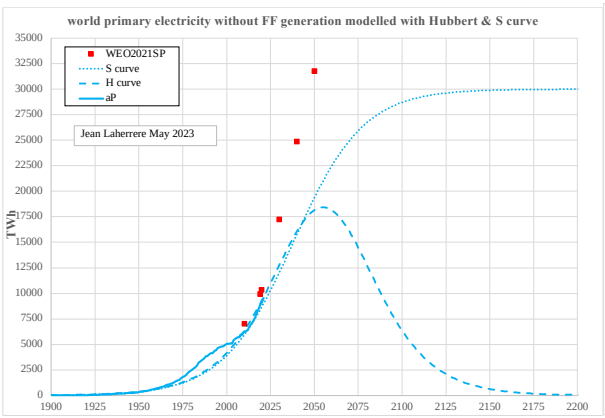


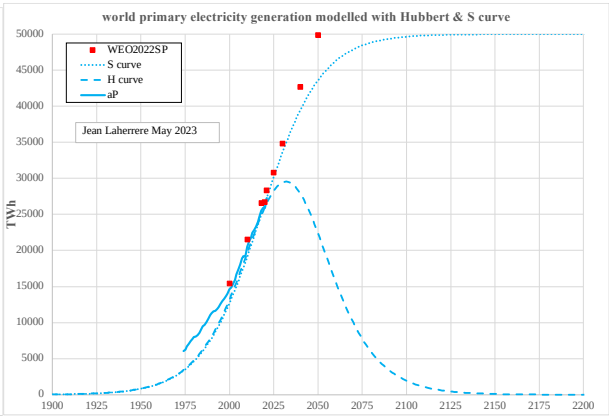






It is very hard to find any historical data on the number of wind or water mills. In France there was from 16th to 18th century about 75 000 mills, today only about 100 water mills left!





UK share of energy consumption 1500-2000 www.lse.ac.uk/.../wp-content/.../Working-Paper-209-Fouquet.pdf Lessons from energy history for climate policy shows that food for labour, provender for animals, biomass and wind has peaked on the period 1500-2000 and disappeared!
Renewables production had peaks!

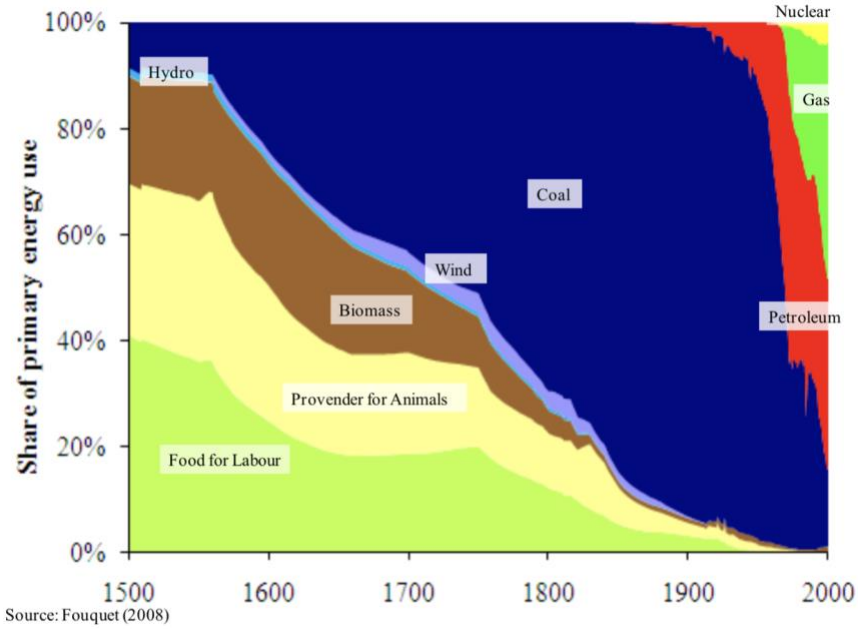
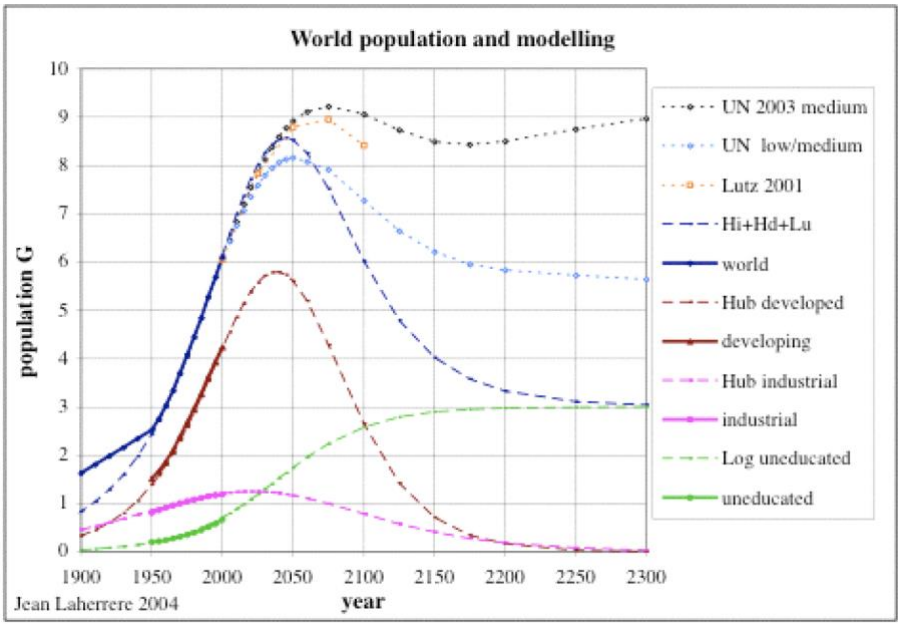
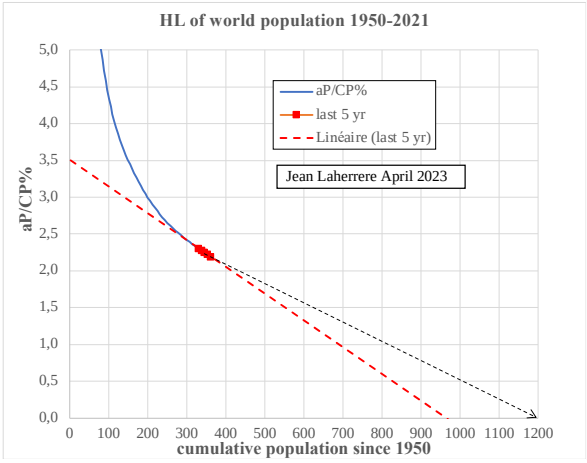


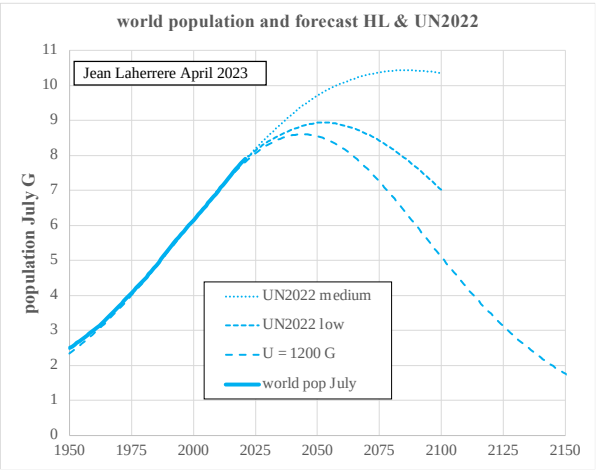
Figure 9. Share of Primary Energy Consumption in the United Kingdom (1500-2000)

-population
My 2005 paper "Réflexions sur les lois de la nature et les prévisions énergétiques" UMR Espace 6012, Université d'Avignon 9 décembre 2005 www.hubbertpeak.com/laherrere/Avignon-1.pdf, www.hubbertpeak.com/laherrere/Avignon-2.pdf, http://www.groupe-dupont.org/Seminaire.htm displayed a graph using the HL approach as done by Bourgeois-Pichat (INED) in 1988
My 2004 forecast using Bourgeois-Pichat's approach was a peak around 2050 at 8.5 G when UN2003med was a peak on 2060 at 9.2 G

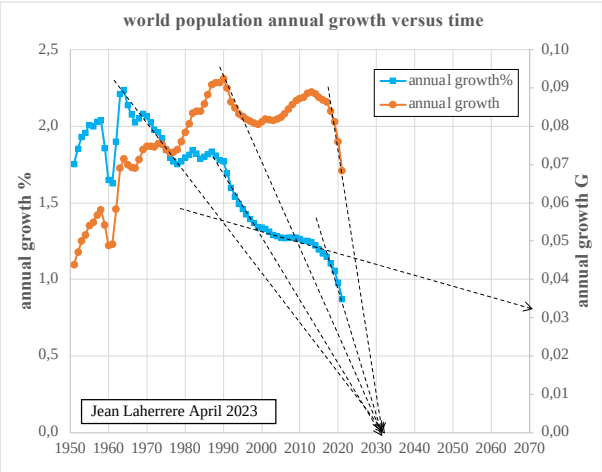


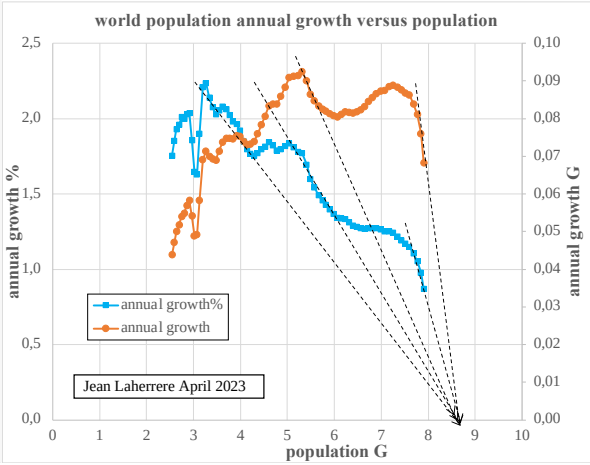
UN2022 forecasts the world population peaking around 10.5 G on 2080 for medium scenario, 9 G on 2050 for low and the HL forecast is 8.5 G in 2040





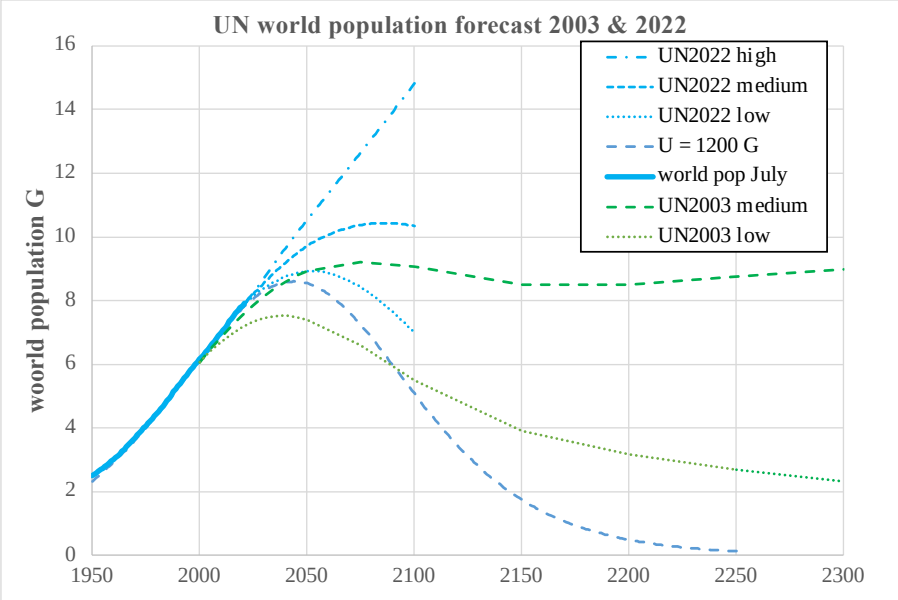
HL extrapolates towards zero to get the peak, but annual population growth in percentage and in number G versus time and versus annual population can be extrapolated towards zero being the peak (time and value).
The last past three years of world annual population growth percentage trends towards a peak in 2030 at 8.5 G, far from UN2021 medium (2080-10.5 G), which corresponds with the trend of annual growth before 2000:





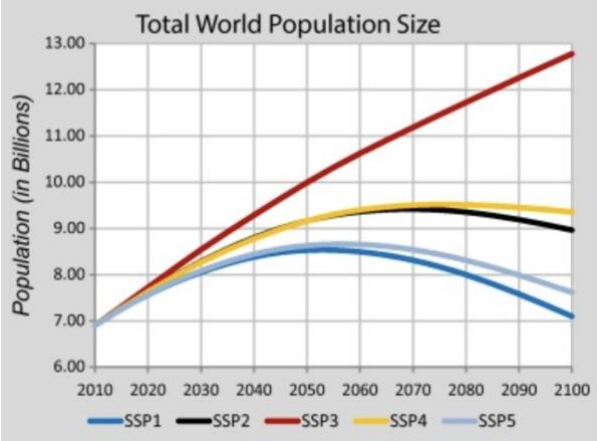
The plot of world population growth versus time and population gives the same result for a peak in 2030 at 8.5 G

UN 2022 and 2003 forecasts are compared for medium and low, as my forecast for U= 1200 G



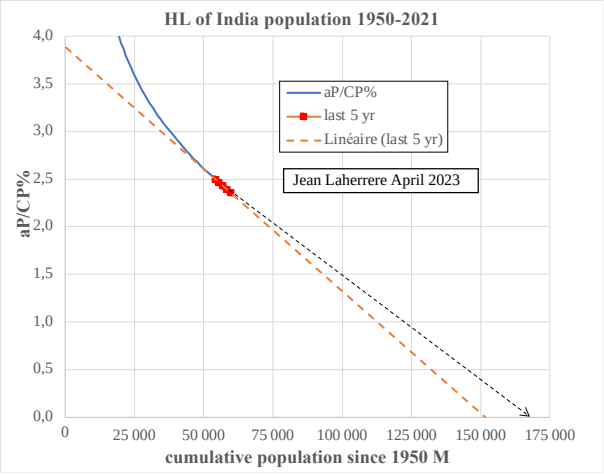
World 2100 medium population is forecasted 10.3 G for UN2022 but 9 G for UN2003, when 5 G in my forecast.
World 2100 low fertility population is forecasted 7 G for UN2022 but 5.5 G for UN2003, when 5 G in my forecast
UN became more optimistic on population forecasts.

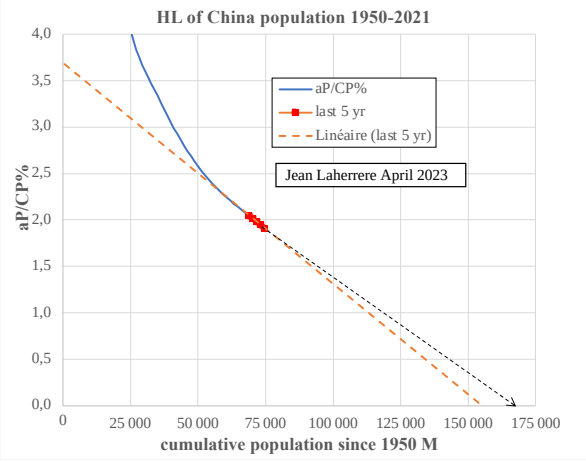
IPCC scenarios for AR6 are SSP = shared socio-economic pathways display a range for population: SSP3 (a rocky road) looks too high, SSP1 (taking the green road)) and SSP5 (unrealistic fossil-fueled development) look more in line with UN2022 low and my forecast. SSP2, considered as the most likely looks high for population.



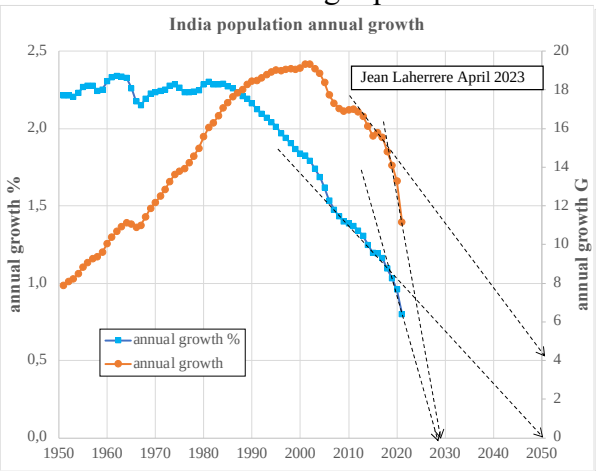
It is obvious that the HL extrapolated dotted linear lines can be plotted giving different peak times and different peak values, depending on the time period: it shows the uncertainty range about peak time (2030-2070) and peak value (8.3->10 G)

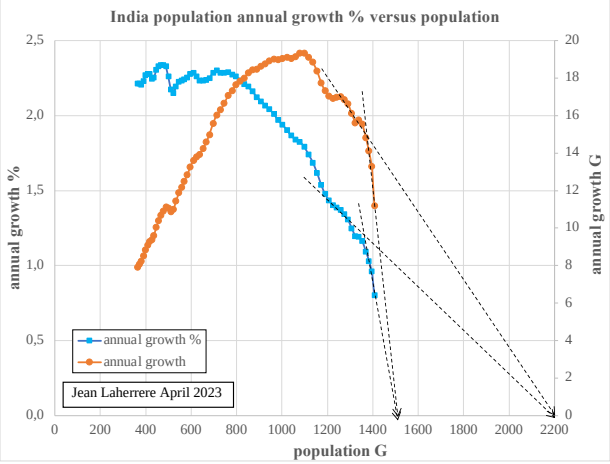
For India and China
HL of India and China population are hyperbolic and hard to extrapolate, an ultimate of 170 G was chosen for both.

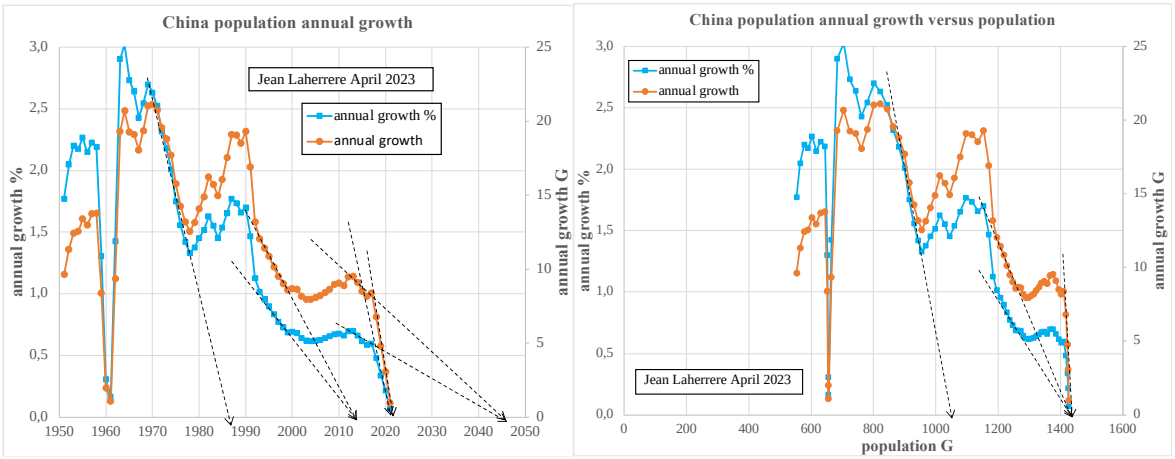




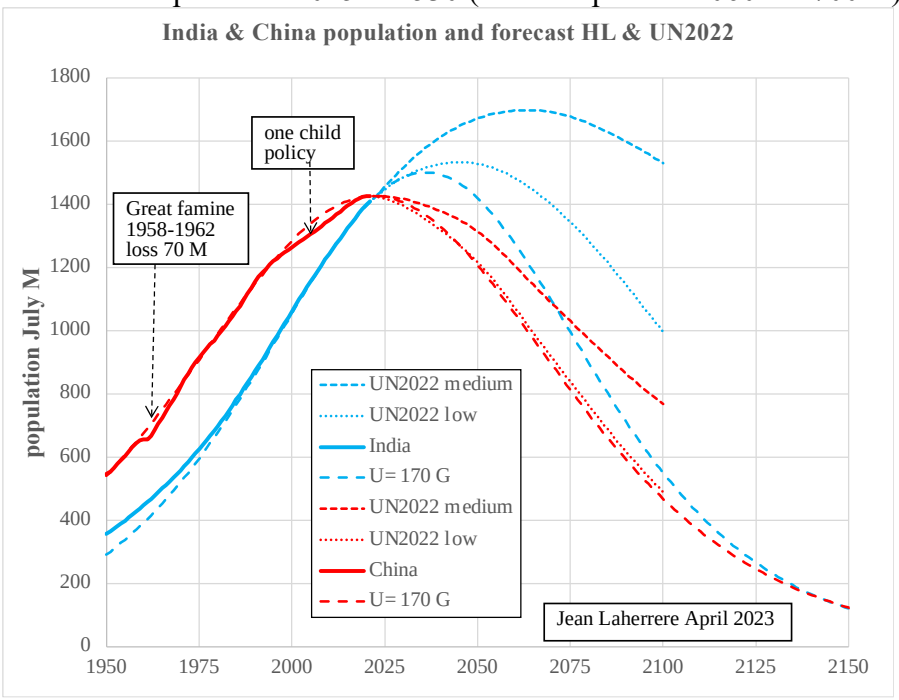
India annual population growth & % trend towards a peak around 2030 for the last few years but around 2050 for a longer period before.



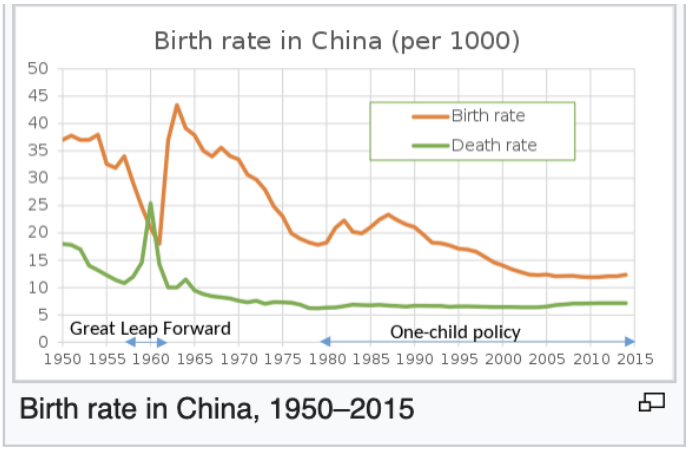




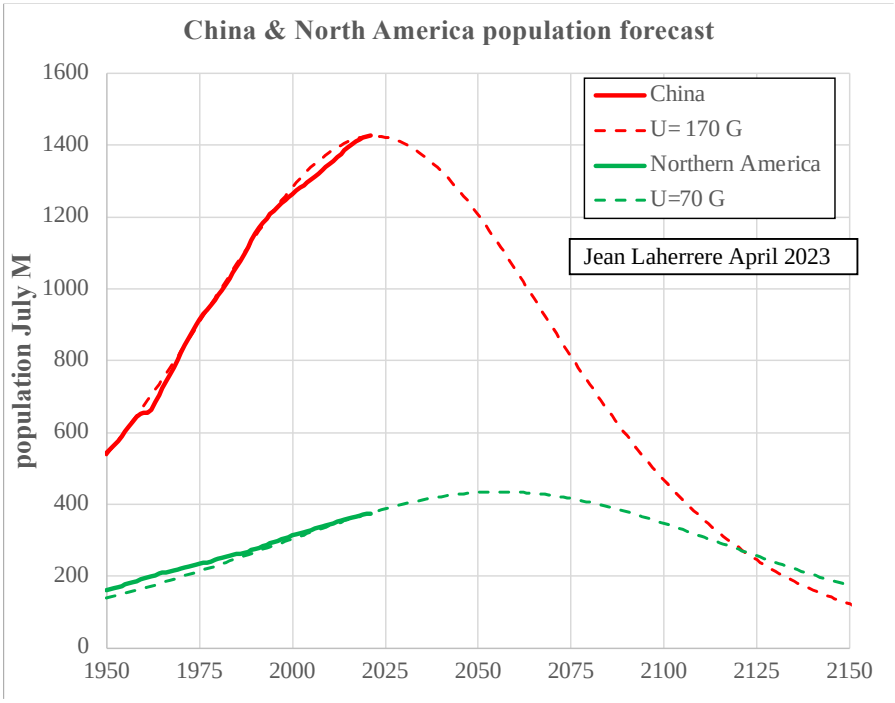
China population peak is 2022 at 1425 G when India will peak around 2035 at 1500 G less than UN2021 low which peaks on 2045 at 1530 (medium peak in 2060 at 1700 G)



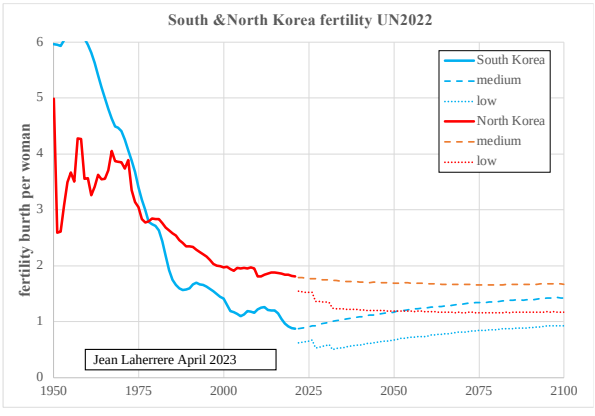
China population was disturbed in 1958-1962 by the Great Chinese famine (Great Leap Forward!) and in1980-2015 by one child policy.
wikipedia.org

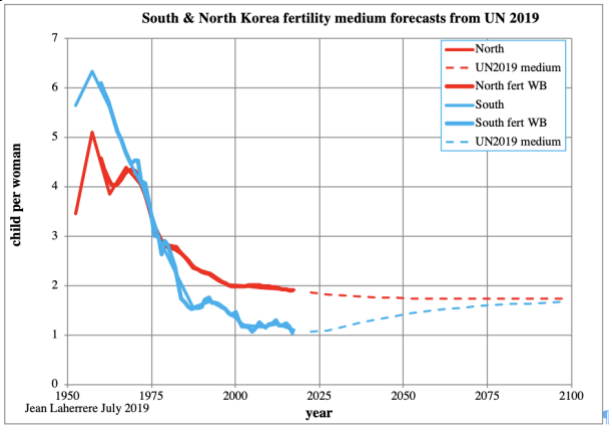


Comparing China and North America population forecast; it appears that the goal of China to have before 2047 the largest GDP will not succeed, because its poor demography, the bankruptcy of Evergrande (housing), the bad behavior on covid and the present control of Internet successes (Alibaba. Tencent).
Under our HL forecast, China population should be in decline in 2050, when North America peaking and in 2150 should be below North America.

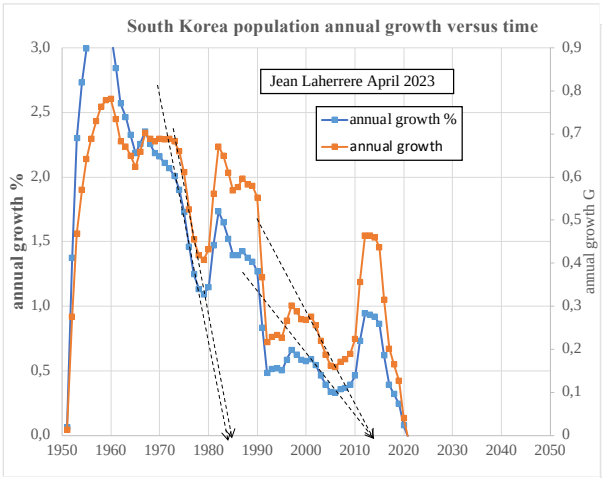


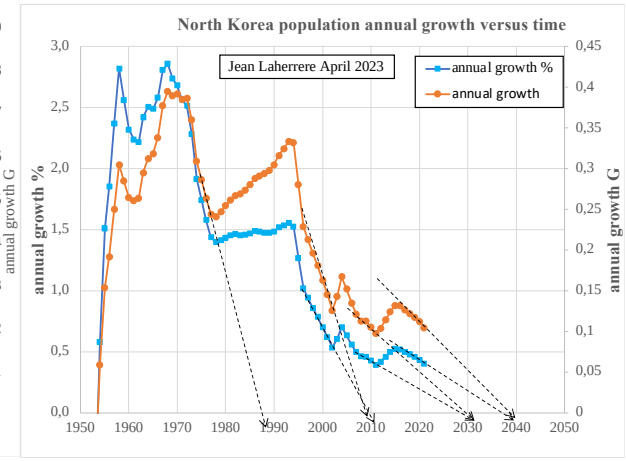
South Korea displays a very low fertility of 0.88 birth per woman in 2021, being in 2018 the first country below 1 birth per Woman. But UN2022 forecast a utopic rise in fertility from today to 2100, South Korea (blue) is compared with North Korea (red) where the fertility will decline. UB2019 forecasted same 2100 fertility for both.



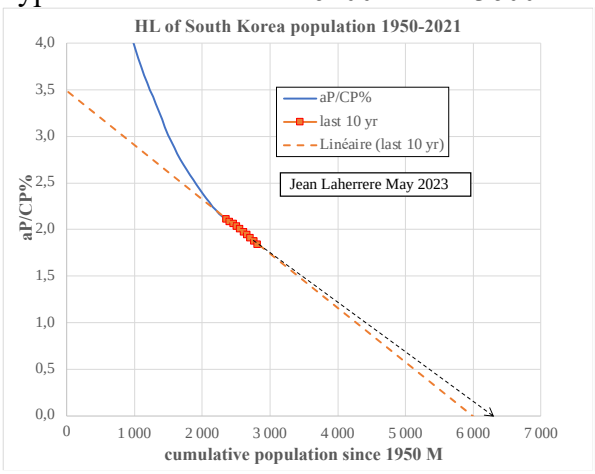


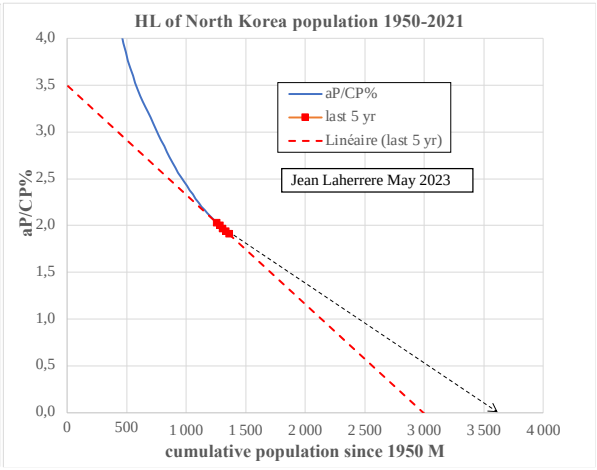
South Korea growth is today at zero, being at peak. North Korea growth trends to zero before 2040



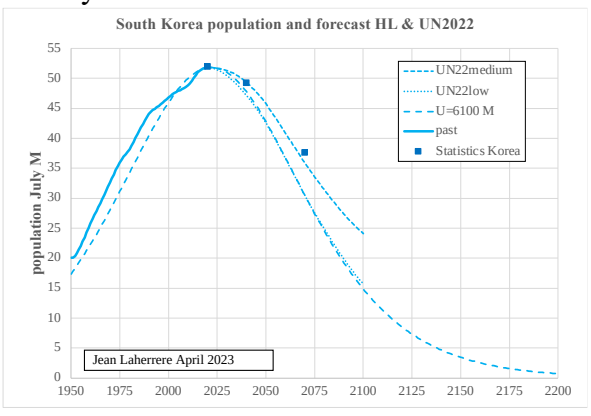


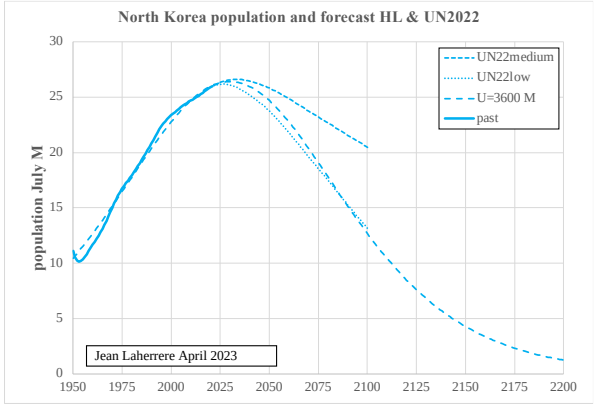
HL trends towards 6000 M for South Korea and 3000 M for North Korea, but both clearly hyperbolic: ultimates at 6100 M and 3600 M are chosen:



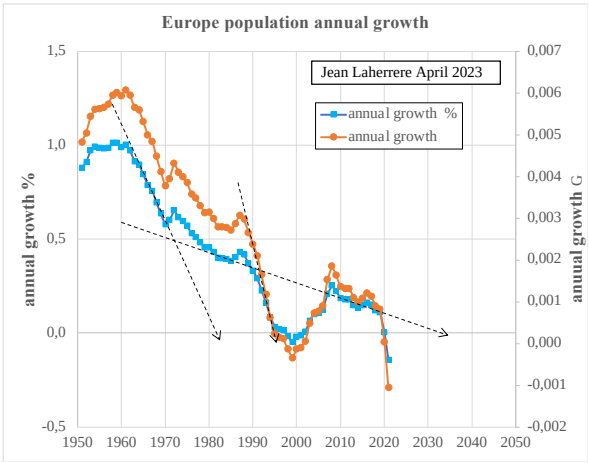


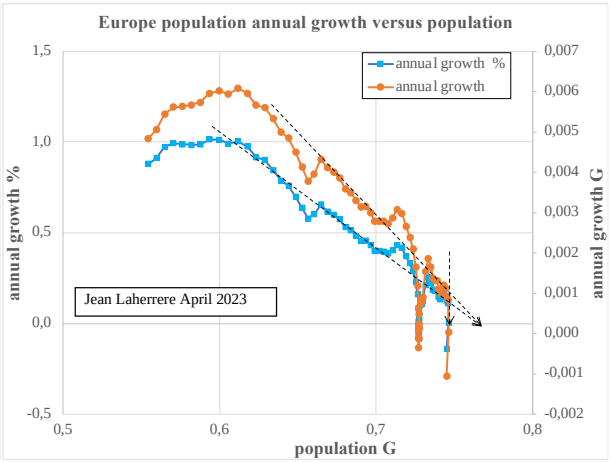
With ultimates of 6100 M and 3600 M population, my forecast is identical with UN2022 low fertility and South Korea would be almost extinct in 2200:

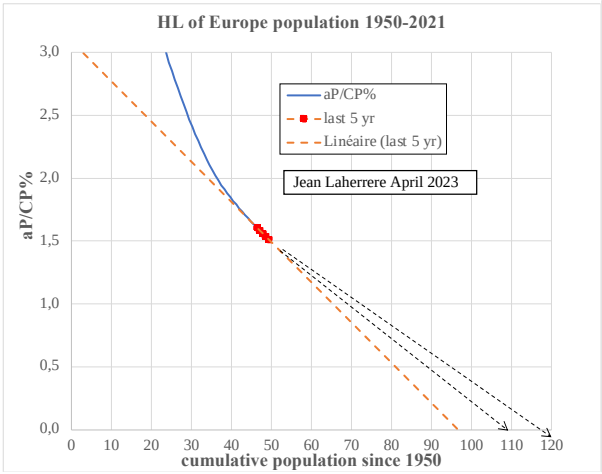


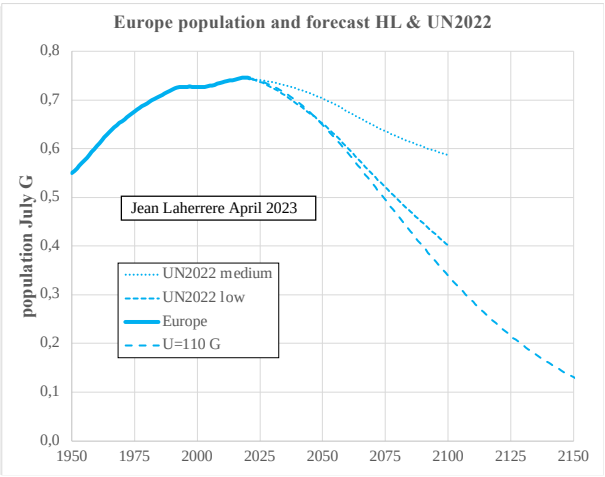


Europe population has peaked:

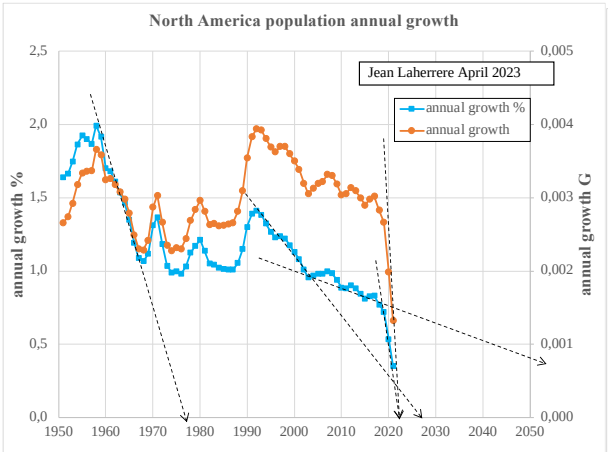


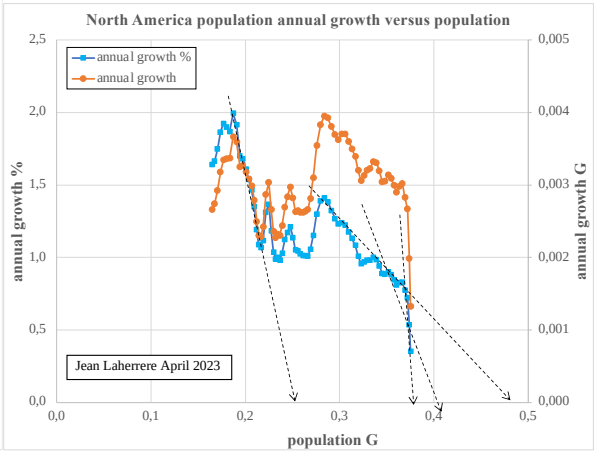


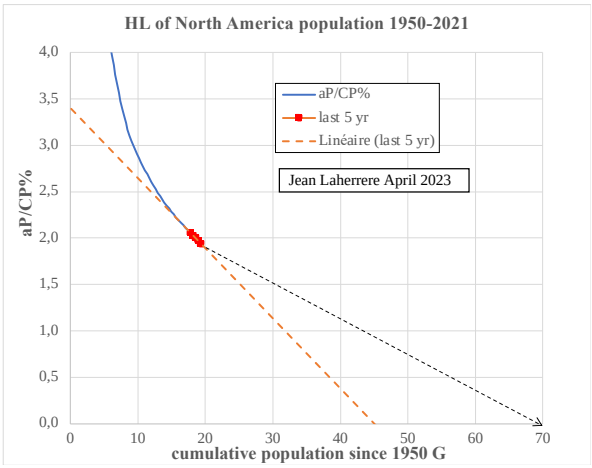


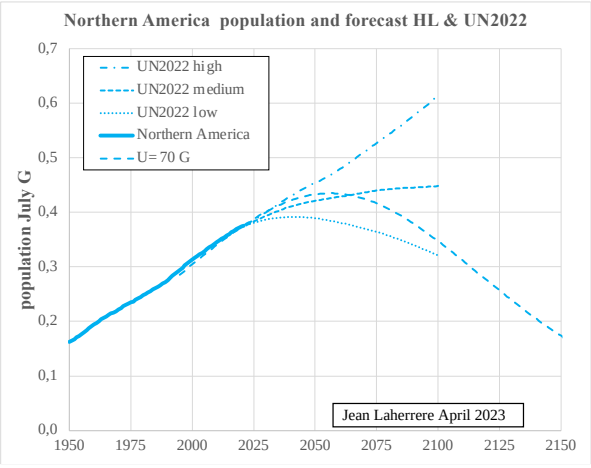


North America displays for the last 3 years a sharp decrease in annual growth, but before the trend is for a peak beyond 2050.

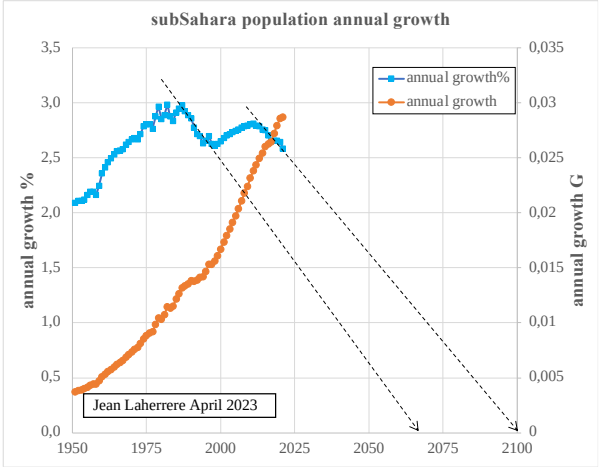


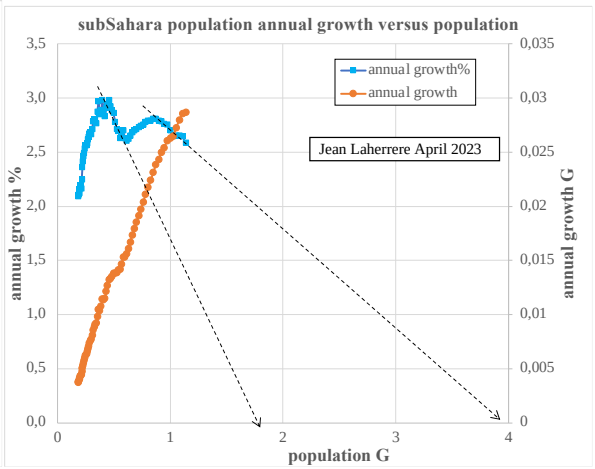


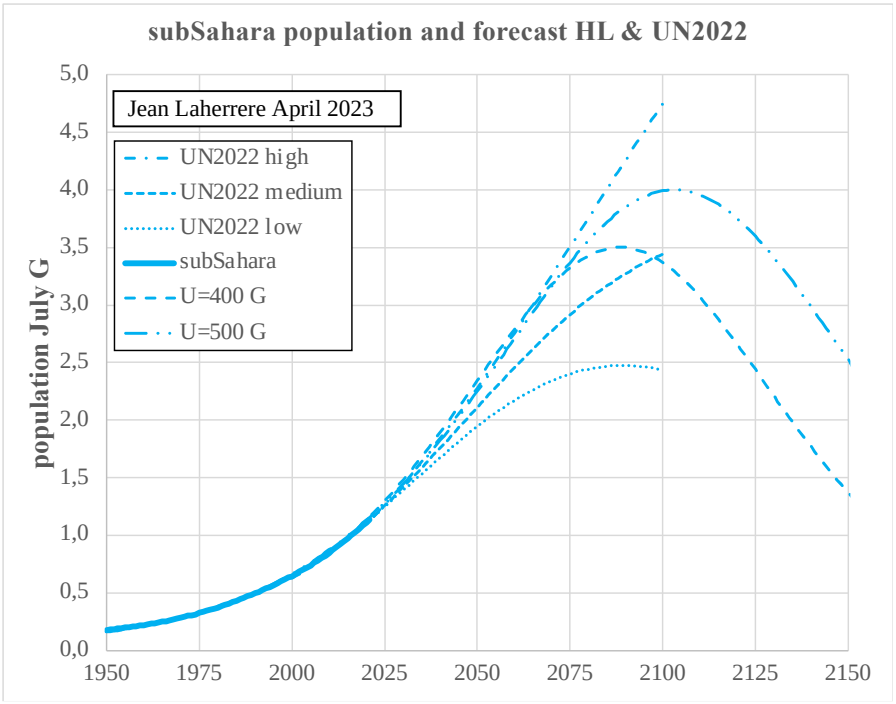




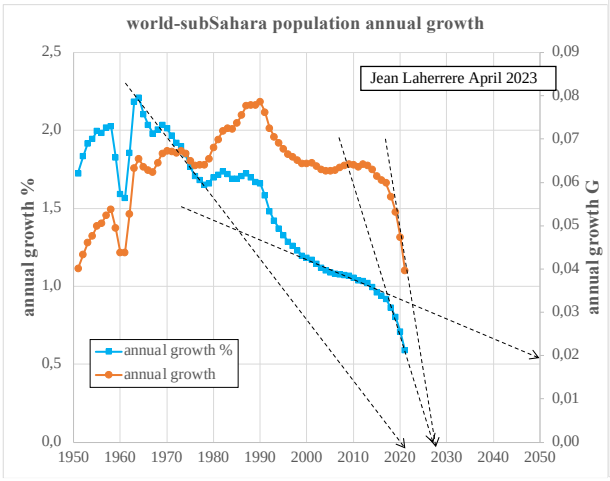
Most of present population growth comes from sub-Sahara countries:

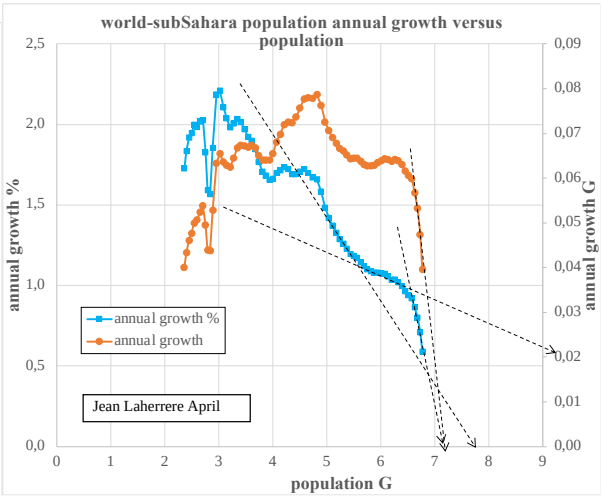




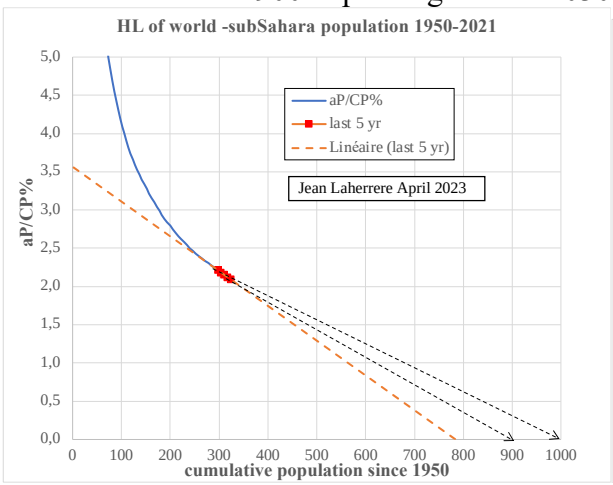


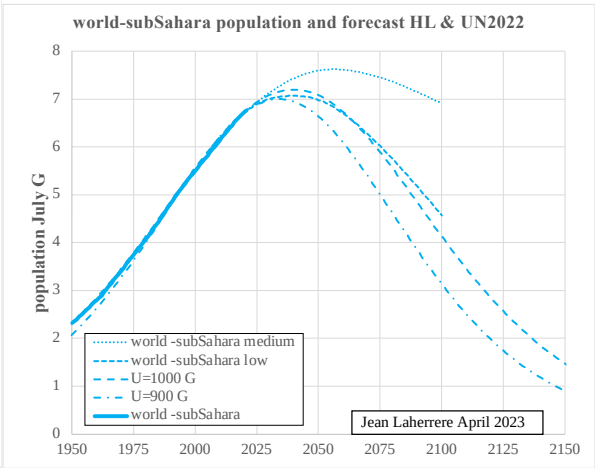
The data for world less sub-Sahara trends for a peak around 2030 at 7.1 G:





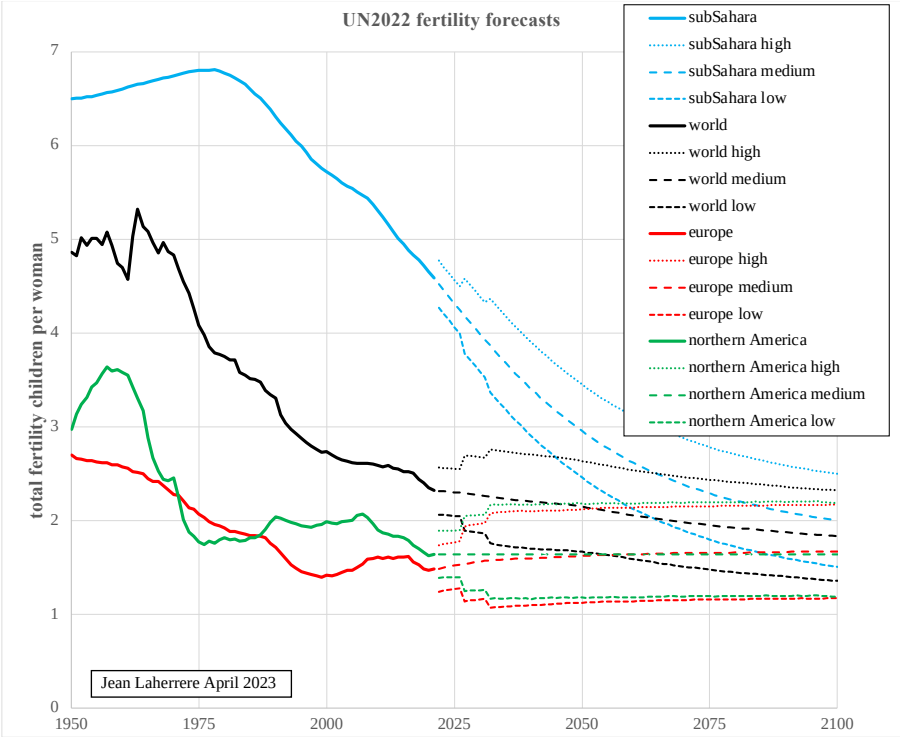
The forecast for U=900 G peaking around 2030 is less than the UN2021 low forecast



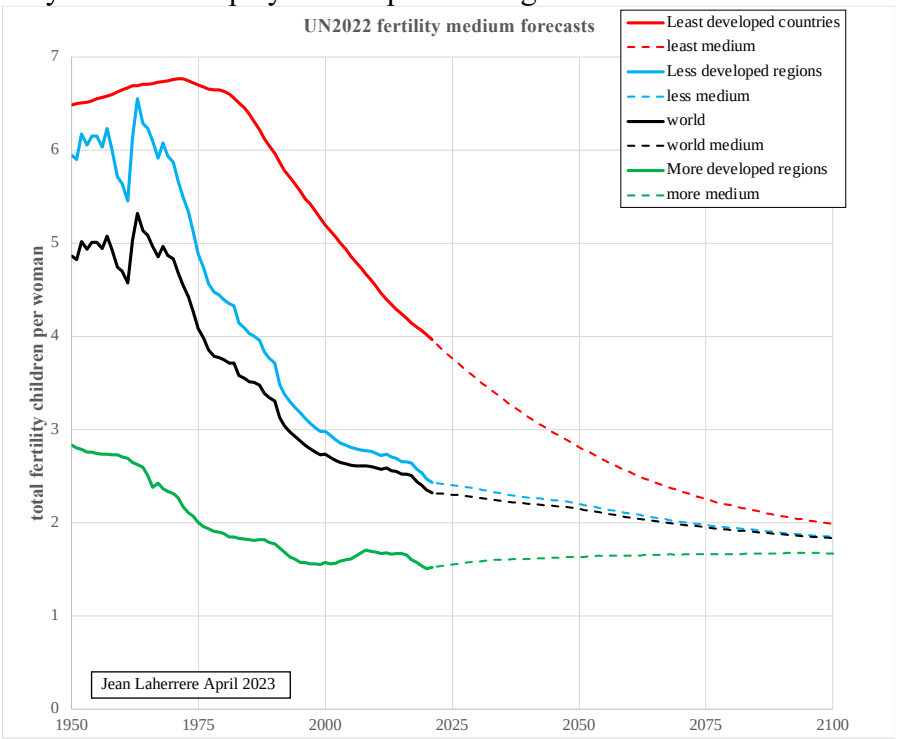


Past recent population data is not very reliable as needing census, which are difficult to run.

UN forecasts are based on optimistic fertility scenarios where in the long term every country will trend towards the replacement ratio of 2 children per woman! It is just wishful thinking!
Fertility is going down in most educated countries, well below the replacement ratio.
The sub-Sahara fertility (in blue) is still in 2021 above 4.5 children per woman, being double of the world fertility and three times the Europe fertility!



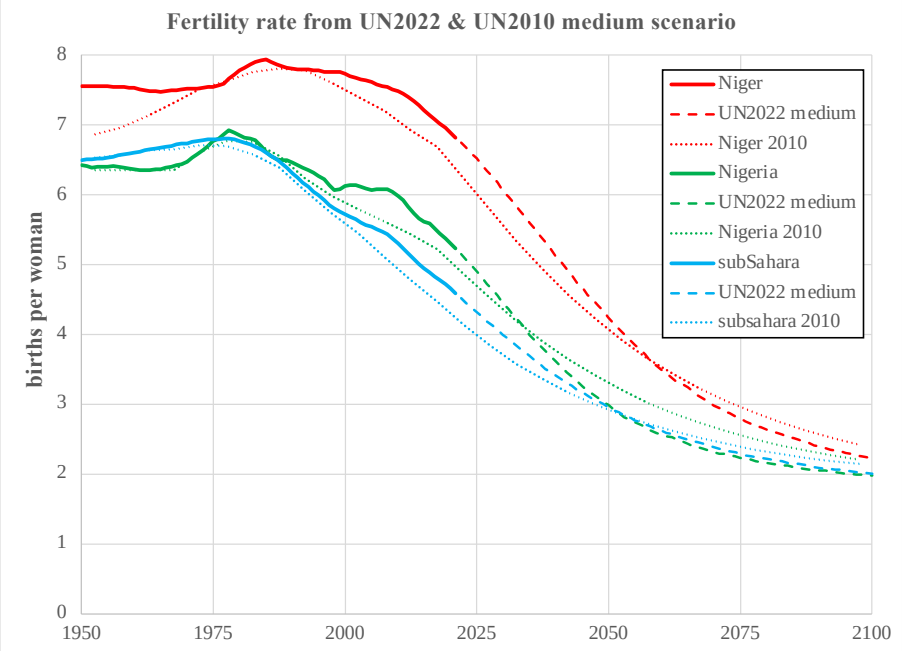
Medium fertility forecasts display this utopic convergence:



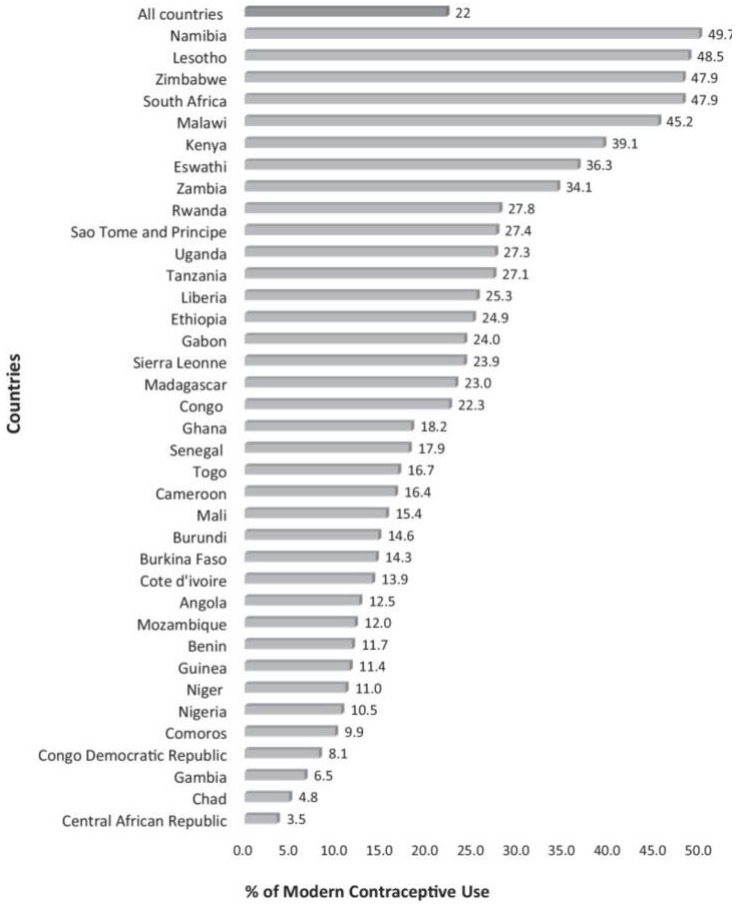
The world fertility medium forecast in 2100 is 1.8 birth per woman, well below the replacement ratio of 2.1, meaning that the world is going into extinction in few centuries!

UN utopic views on Sub-Sahara fertility is obvious when comparing UN2010 data with UN2022 data: fertility data are estimated optimistically (low for emerging countries) against the real value.
Niger fertility for 2012 was reported at 6.9 in 2010 edition in contrary to 7.4 in the 2022 edition.

Nigeria fertility for 2007 was reported at 5.6 in 2010 edition in contrary to 6.1 in the 2022 edition.

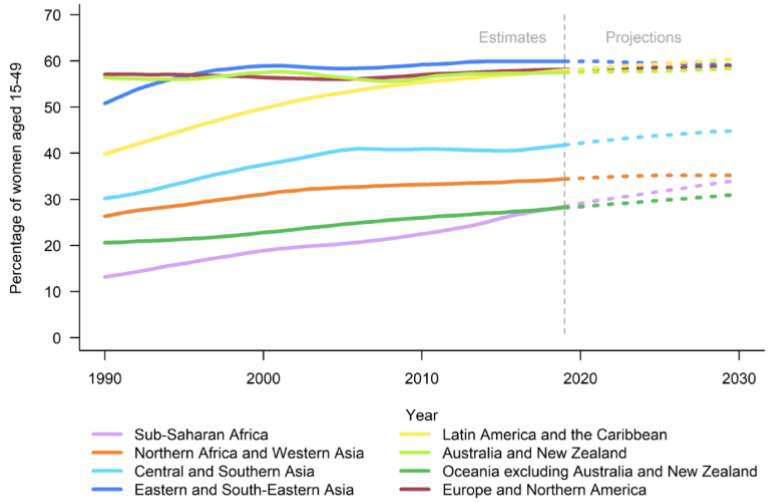


The use of modern contraceptives in sub-Sahara is only 3.5% in Central African Republic, 4.8 % in Chad, 10% in Nigeria, 11% in Niger. but 44 % in Namibia: "Coverage and determinants of modern contraceptive use in sub-Saharan Africa: further analysis of demographic and health surveys" Isaac Boadu 2022. The world use is about 44 %, when it is 60 % for high educated regions.



The UN2019 displays the prevalence of contraceptive from 1990 to 2030: https://www.un.org/en/development/desa/population/publications/pdf/family/World_Fertility_and_Family_Planning_2020_Highlights.pdf

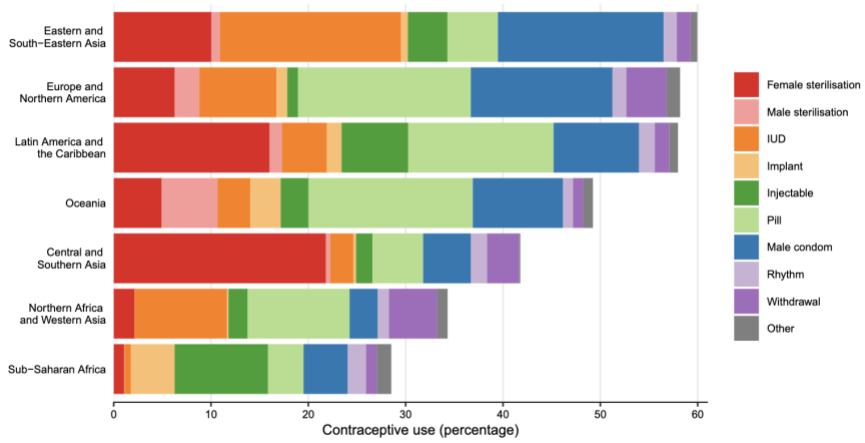
Figure 5.
Prevalence of contraceptive use among women aged 15-49 by region, estimates and projections, 1990-2030



Source: United Nations Department of Economic and Social Affairs, Population Division (2019b). *Estimates and Projections of Family Planning Indicators 2019.*

The method of contraception varies with region:

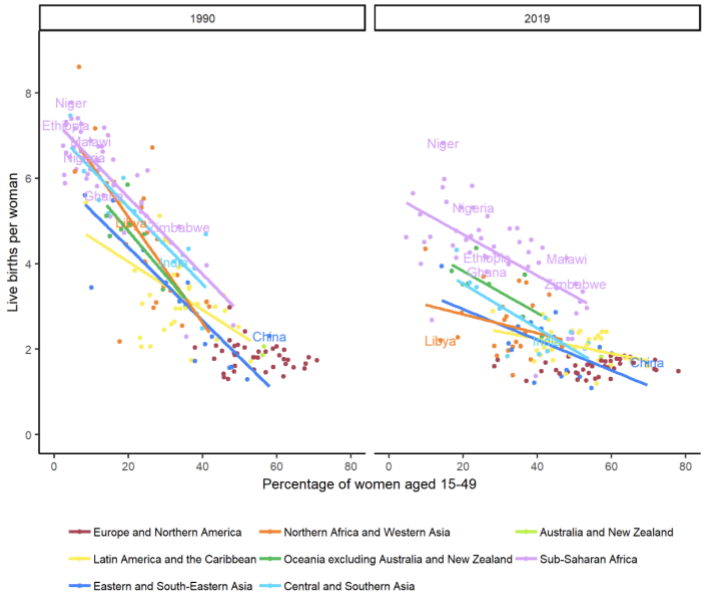
Figure 7.
Contraceptive use by method among women of reproductive age (15-49 years), by region, 2019



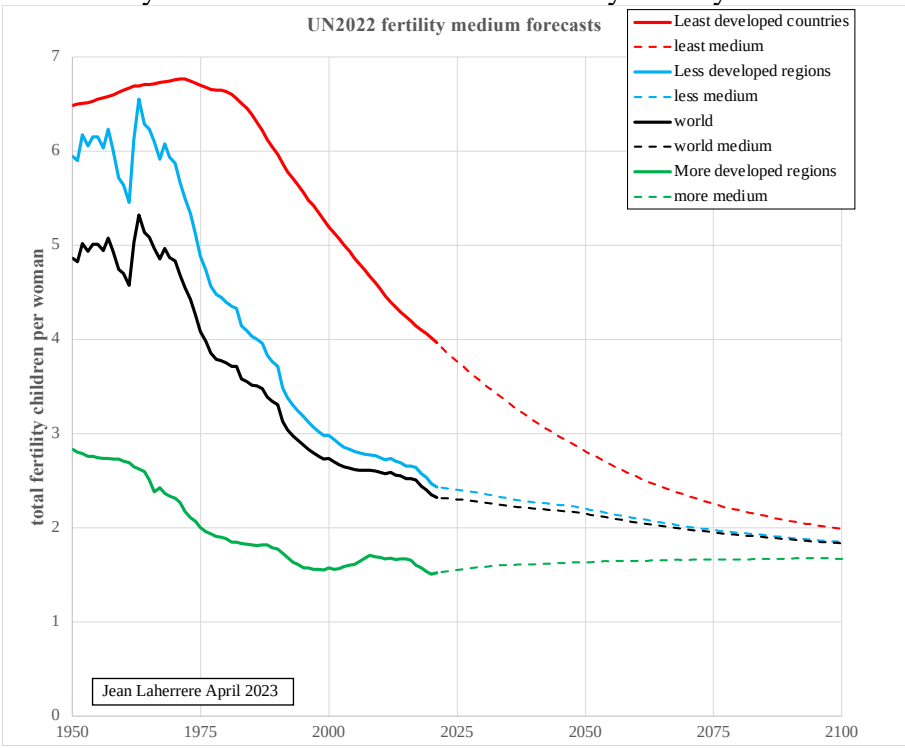
Source: United Nations Department of Economic and Social Affairs, Population Division (2019d). *Contraceptive Use by Method 2019: Data Booklet*.
Note: In this figure, Oceania includes Australia and New Zealand.

The plot contraception versus fertility in 1990 and 2019 shows the evolution of sub-Sahara (purple), quite different from the rest of the world:

Figure 10
Total fertility rate compared to prevalence of contraceptive use among women aged 15-49, 185 countries or areas by region, 1990 and 2019

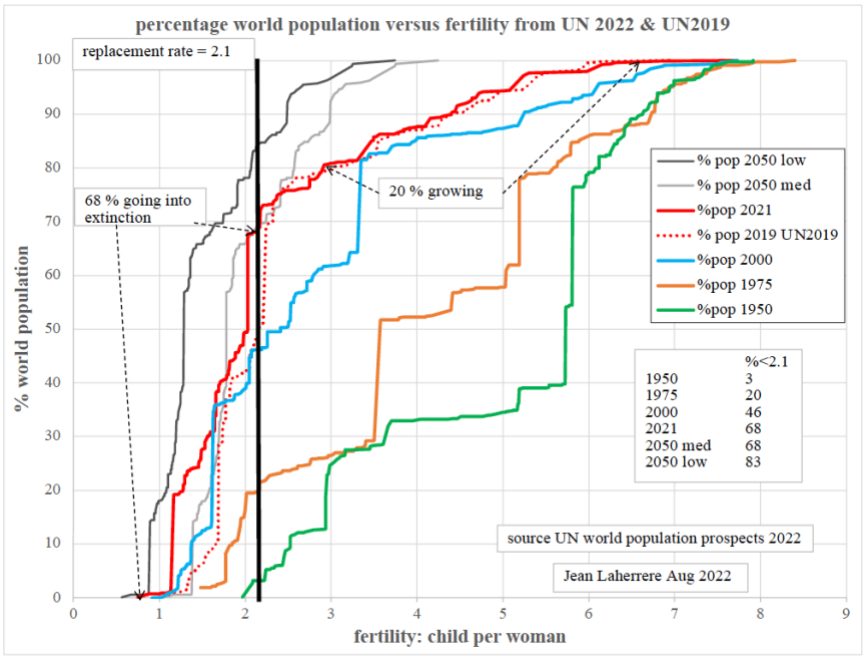


UN2022 fertility medium forecasts are utopic, too low for the least developed countries and too high for the more developed countries (increasing fertility since 2022?) and for the world, wishing that the fertility will be the same after 2011 in every country= wishful thinking!



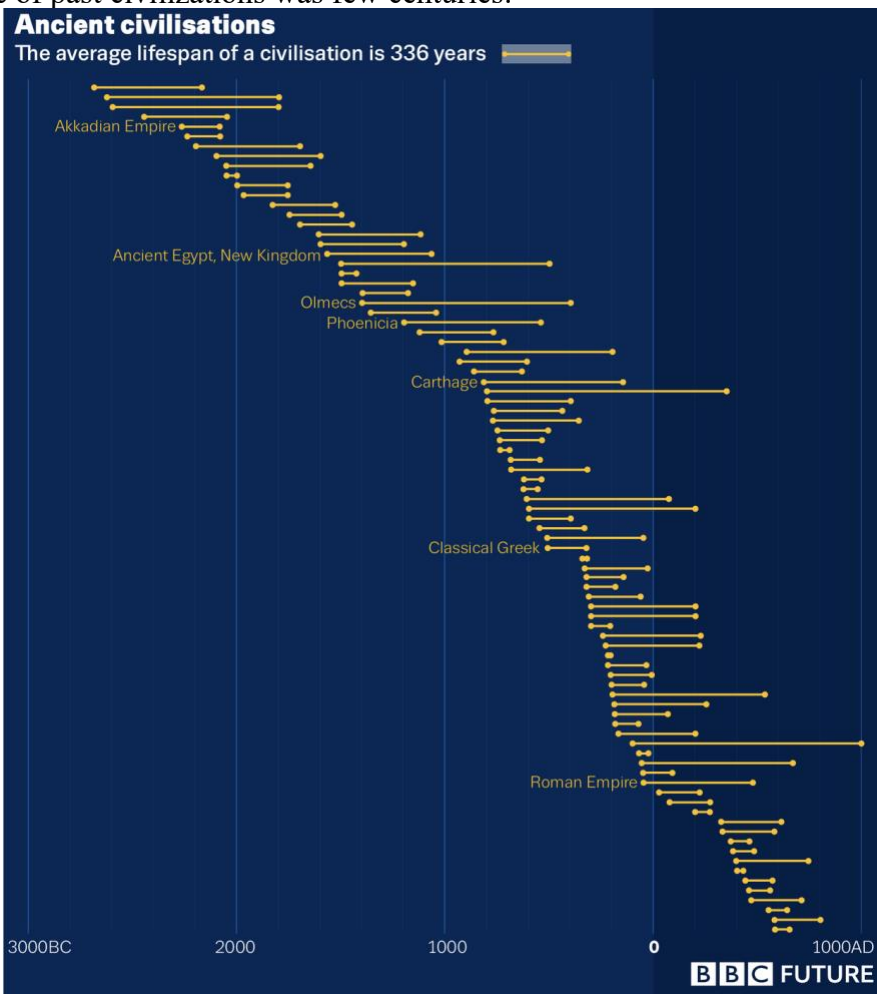
But after 2100 UN2022 medium scenarios are below the replacement rate of 2.1, meaning that for UN the world is going into extinction in few centuries!

I remind my 2022 paper "In 2021, 68% of the world is going into extinction" when almost no one in 1950! https://aspofrance.org/2022/09/18/in-2021-68-of-the-world-is-going-into-extinction/



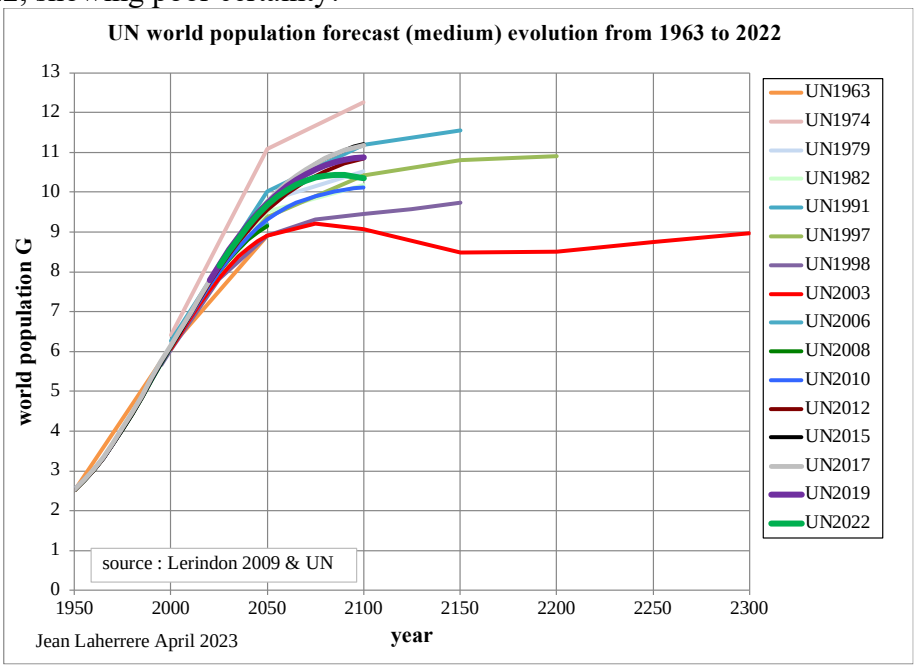
The rapid evolution of percentage of the world trending towards extinction confirms my forecast for a sooner and lower world population peak.
Some forecasts that human population will disappear because lack of resources, it is likely that it will be by lack of births.

The lifetime of past civilizations was few centuries:

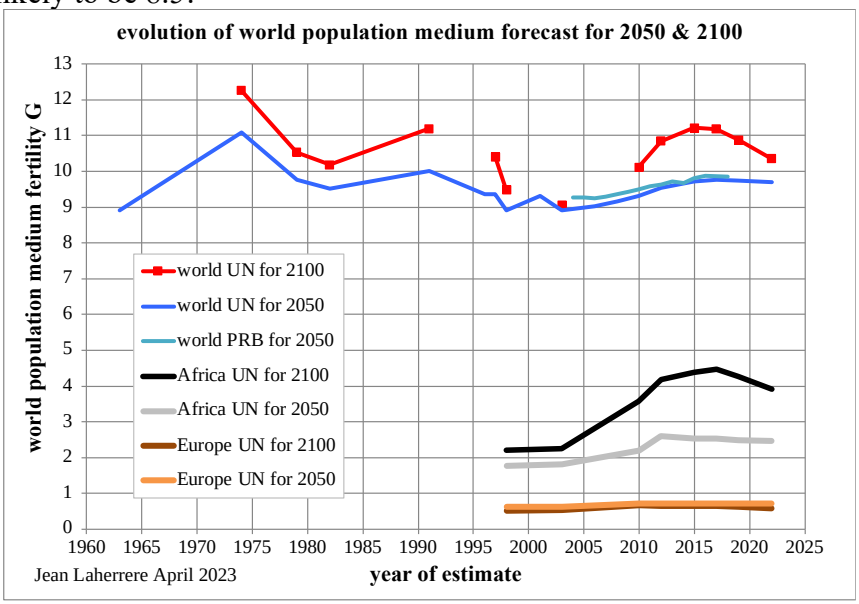


The world relies now on digital data computers using magnetic disks. But the lifetime of hard disks is less than 5 years, magnetic tape less than 20 years. It is necessary to update magnetic data every 5 years. Paper is abandoned despite a very long lifetime. We are going towards a dangerous magnetic world! As a geophysicist I started in 1956 to work on seismic paper recording, then on photographic recording and later on magnetic recording, but most of the first magnetic tapes were moved to optical disks before being obsolete.

The evolution of UN world population medium fertility forecasts has widely varied since 1963 to 2022, showing poor certainty!

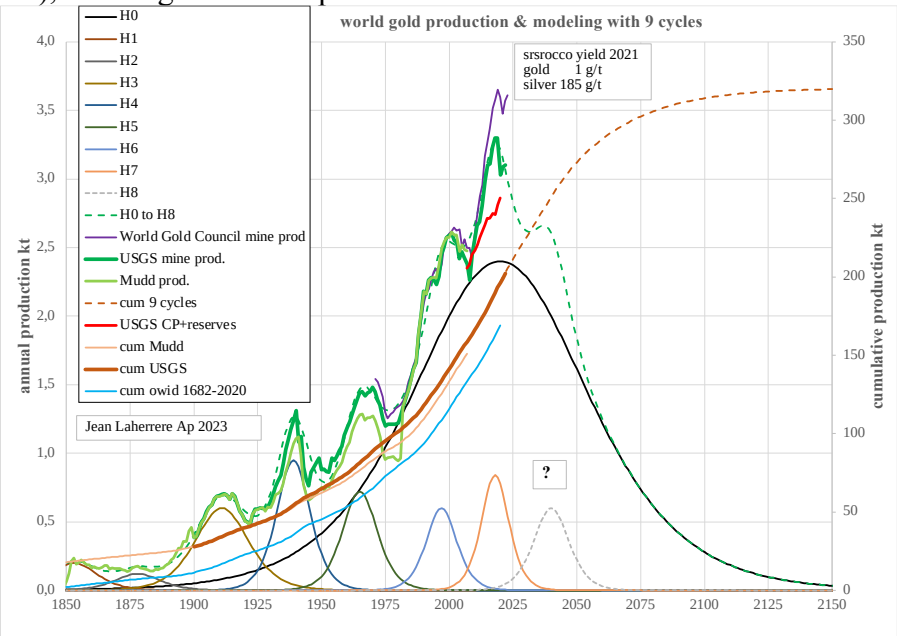


The medium forecast for 2050 has varied in UN editions since 1963 to 2022 between 9 and 11 G, but it is likely to be 8.5!

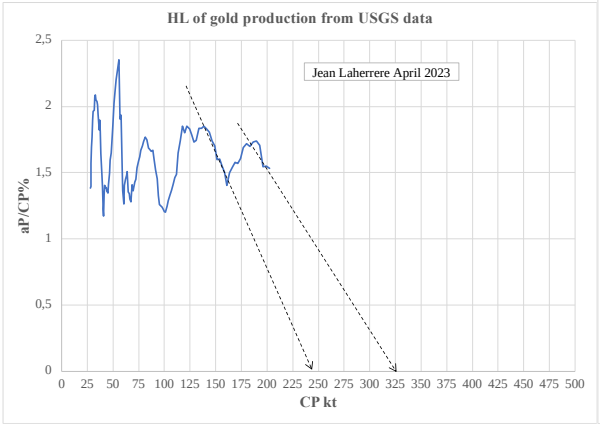


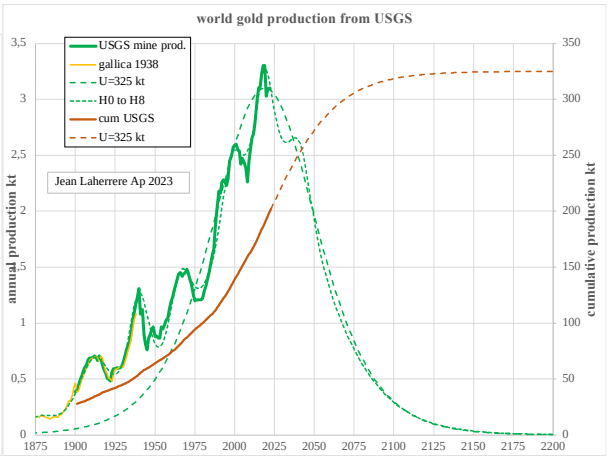
-gold modelling with Hubbert curves

World gold production since 1850 is modelled with 9 cycles (the last one with a peak in 2040 is questionable), showing a absolute peak in 2019:

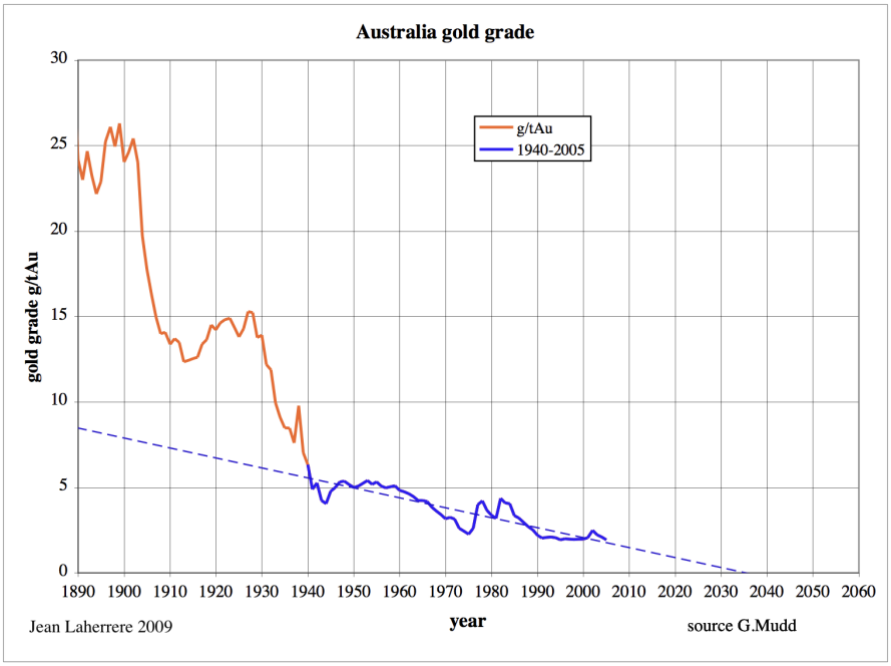


HL of world gold production trends poorly towards 325 kt:





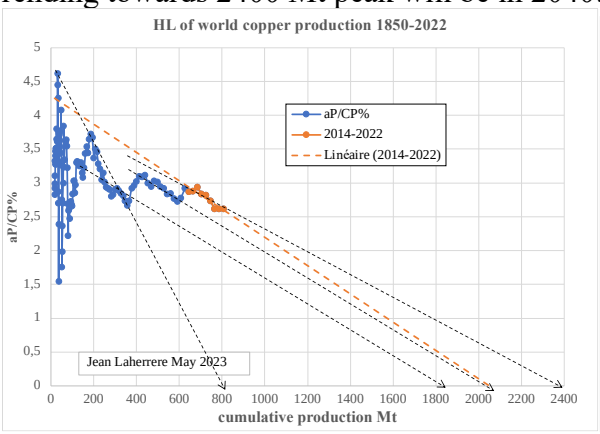
World gold grade is sharply declining and presently around 1 g per ore tonne.
The decline of Australian gold grade from 1890 to 2005 is obvious:

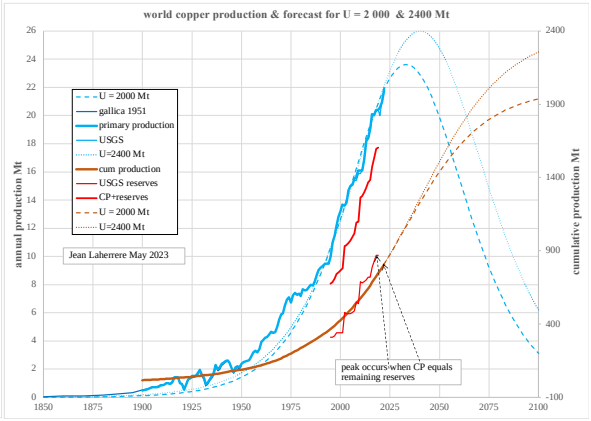


Gold price increases today (2000 $/oz) as production declines and the cost increases (1700 $/oz today against 700 $/oz in 2010.)

-copper peak

HL of world copper production trends towards 2000 Mt, meaning a peak in 2033, but if HL rending towards 2400 Mt peak will be in 2040:

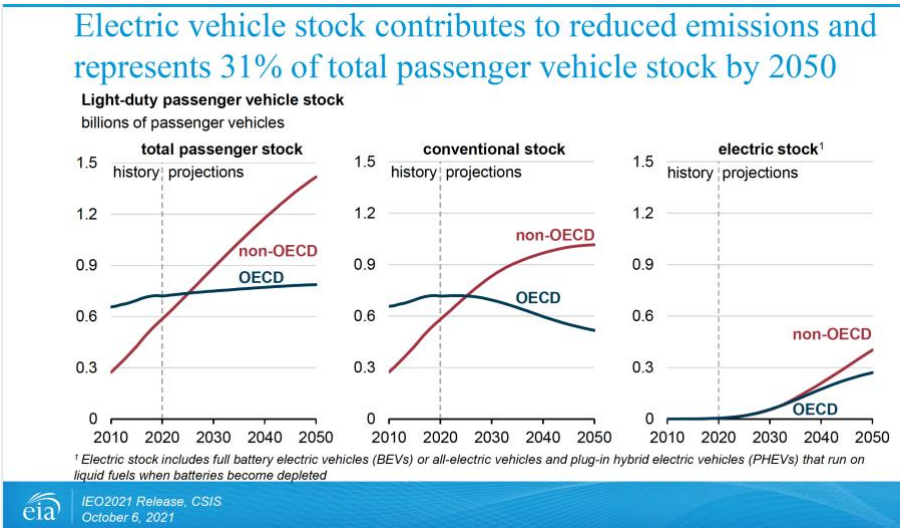




The world expects that the electric cars will take over in the medium term, with a ban on the sale of thermic cars in 2035 in Europe. An electric car needs 4 times more copper than a thermic car.

My forecast page 11 on world electric generation is a peak around 2050, making the goal of replacing thermic cars by electric cars.

EIA passenger vehicle forecast in 2050 is 2.2 G (only 0.7 electric cars) against 1.3 G in 2020



-Conclusion

Forecasting the peak of any commodity is hard because often there are several peaks. King Hubbert, using reserves, forecasted in 1956 USL48 crude oil peak in 1970, but he missed the 2019 peak due to LTO, as horizontal well practice was low in the fifties!

Furthermore, published reserves are often financial or political data (best example with the Saudi Arabia remaining oil reserves staying around 260 Gb for the last 30 years, meaning every year finding as much as produced = unrealistic!) are unreliable and technical reserves are confidential.

Using past data is a way to get a minimum estimate for peak and future production. By past data can hardly forecast new technology (as LTO).

HL is the only way to forecast peak before peak and only estimate for a linear trend for more than the last 10 years should be qualified of fair quality with reliable value. HL is very often not linear, but hyperbolic.

To improve the forecast of the poor quality, it should be compared with similar product, for example NGL and NG.

But HL forecasts appear to be too pessimistic, being rather a low scenario.

Renewables can be modelled with S curves (H curve is the derivative of S curve) going towards an asymptote and not a peak. Most of IEA forecasts follow S curves, even for fossil fuels. It appears that IEA refuses to see the world declining.

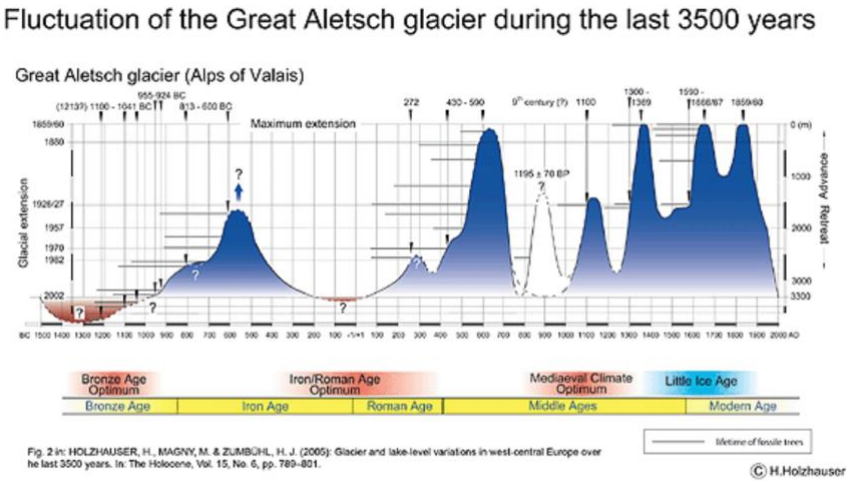
HL forecast for world population is a peak in 2040 around 8.6 G against a UN2022 medium forecast in 2085 at 10.3 G.

UN medium fertility forecasts are utopic (wishful thinking toward future fertility equality): too low for less developed countries and too high for developed countries (increasing again!). However, UN2022 medium fertility forecasts beyond 2100 are below the replacement ratio of 2.1, leading to world extinction in few centuries! Human population will disappear, not by lack of food or resources, but by lack of births.

Annex

-CO2 emissions

Those who claim that the present climate change is without precedent without any rule ignore the Little Ice age, the medieval optimum shown by the fluctuation of the largest Alps Aletsch glacier and the last glaciation 12 000 years ago where the sea was 120 m below.



Item 1: Aletsch curve.

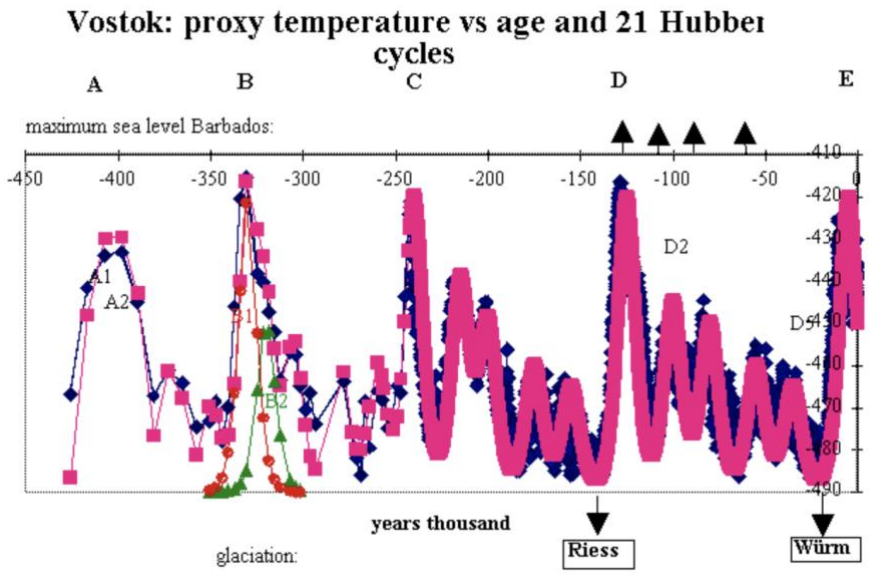
There is only one rule for climate: always changing as shown by the variation of the temperature measured in Vostok for the last 400 000 years modelled with 21 cycles of 20 000 years.

My 1999 modelling with 21 Hubbert cycles from Petit JR. et al 1997 "Four climate cycles in Vostok ice core" Nature, v387, 22 May p359.

https://www.ogj.com/home/article/17230569/world-oil-supplywhat-goes-up-must-come-down-but-when-will-it-peak

World oil supply-what goes up must come down, but when will it peak? Feb 1999

Consider the pattern in greater detail (Fig. 13). It is evident that the climate curve may be modeled by 21 Hubbert curves of the same width (c=16) but with decreasing peaks in a cycle of five peaks and with different intervals. Cycles A and B seem different from C and D, but it is due to the fact that the intervals are smaller and that the asymmetrical peak at 335 000 years ago is the sum of two Hubbert cycles B1 (red) and cycle B2 (green). It is the same for the large first peak of Cycle A made of two close Hubbert cycles.



Blue is data, red is Hubbert cycles
As there are 21 Hubbert cycles for 400 000 years, there is a cycle every 20 000 years. Where is this 20 000 year cycle coming from?
The climate variation depends first on the three astronomical parameters of the orbit of the earth around the sun:

Excentricity of the ellipse going from 0 to 7% with a period of around 100 000 years;

Precession of the axis of the poles (axis of rotation), which describes a cone with a period of 21 000 years; and

Obliquity of the polar axis with the perpendicular to the ecliptic plane going from 22% to 25% with a period of 40 000 years.

Its precession variation of 21 000 years was discovered in 1842 by Adhemar, and the other parameters were largely known in 1930 as the Milankovitch periodicities. The combination of these three orbital variations, combined with the internal phenomena as the ice sheet dynamics and the deep oceanic currents (El Niño and the North Atlantic Deep Waters), controls the size and intervals of the cycles. There are many glaciations occurring during the Quaternary but few during the Tertiary and the Secondary!

Jean Jouzel (former VP IPCC) has cosigned in 2003 an article on Vostok where CO2 follows temperature with a shift of 800 years, when now he claims the contrary for present temperature: https://www.science.org/doi/10.1126/science.1078758
"Timing of Atmospheric CO2 and Antarctic Temperature Changes Across Termination III"
CO2 is shifted by 800 years to fit temperature proxy (Ar)

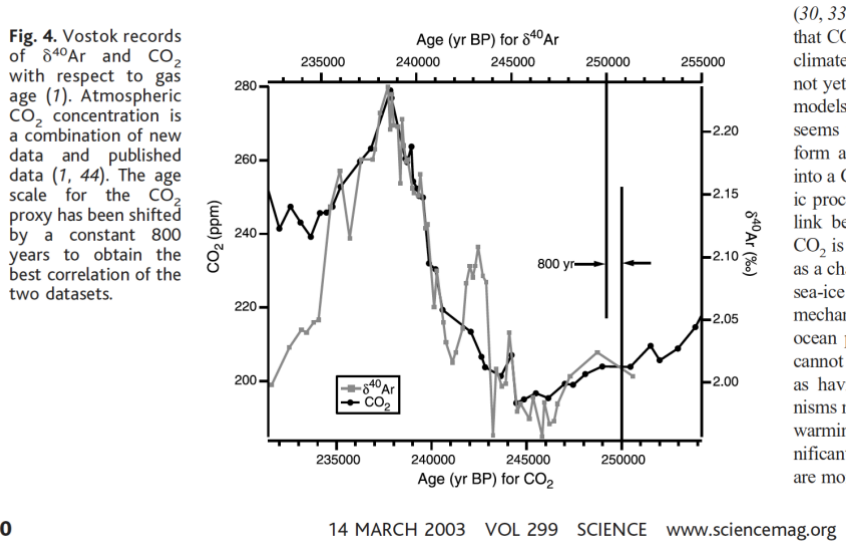


Fig. 4. Vostok records of δ^{40}Ar and CO_2 with respect to gas age (*1*). Atmospheric CO_2 concentration is a combination of new data and published data (*1*, *44*). The age scale for the CO_2 proxy has been shifted by a constant 800 years to obtain the best correlation of the two datasets.

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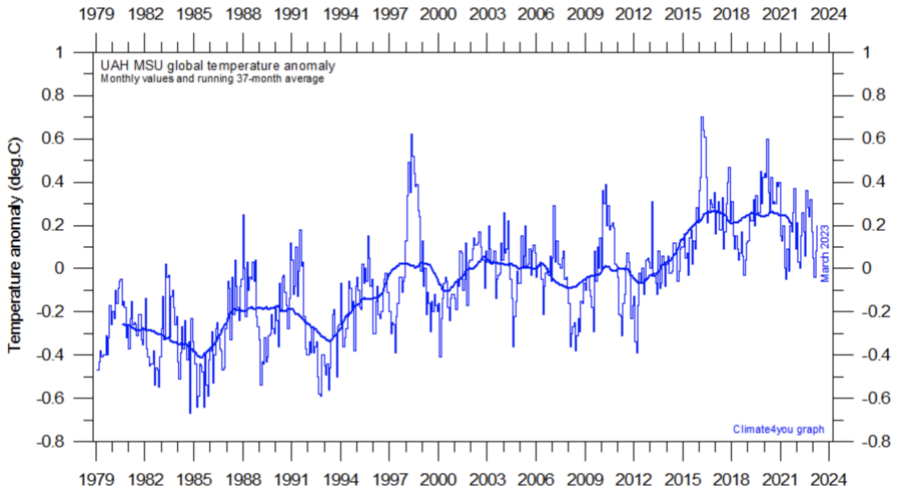
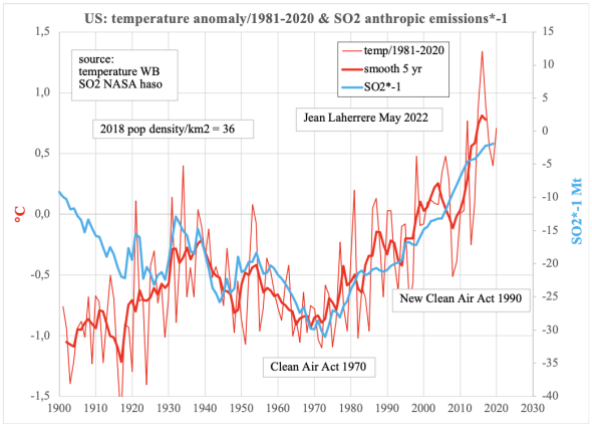
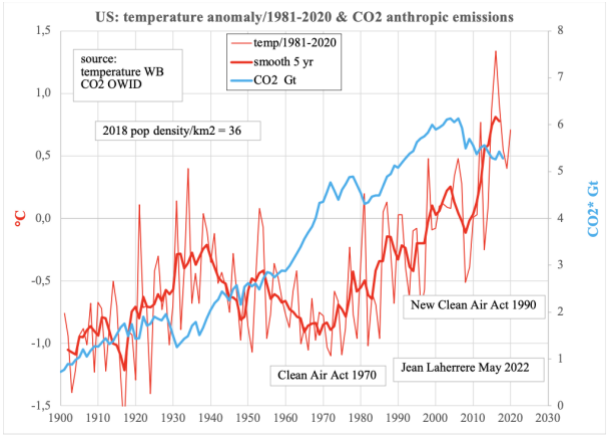
Using land station to get global warming is misleading because their number has changed with time and most of land stations are disturbed by the urban warming due to the artificial ground, only satellite data is reliable and the last temperature peak is 2016 (El Nino) (before 1998also El Nino).
Temperature increases by step, in contrary with CO2 concentration in Mauna Loa
UAH global monthly temperature anomaly 1979-March 2023

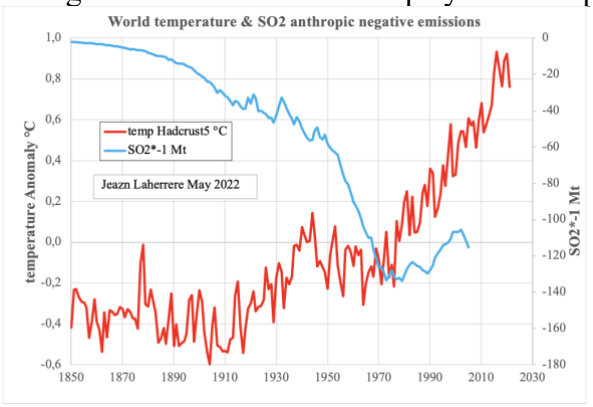


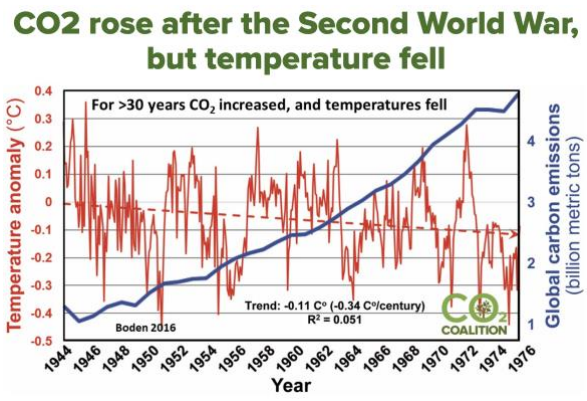
My 2022 paper: "France et le monde : température, population & SO2"
https://aspofrance.org/2022/05/30/france-et-le-monde-temperature-population-so2/ US temperature correlates very well from 1930 to 2015 with negative SO2 US emissions as SO2 cools the atmosphere and there is no correlation with US CO2 emissions:





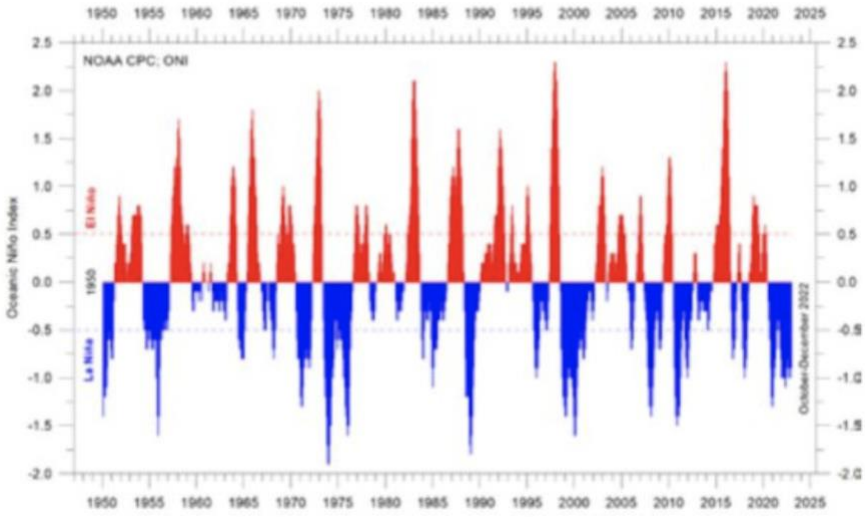
World temperature fell from 1945 to 1975 when world negative SO2 emissions were the strongest and CO2 coalition displays this temperature decrease when CO2 emissions increase:



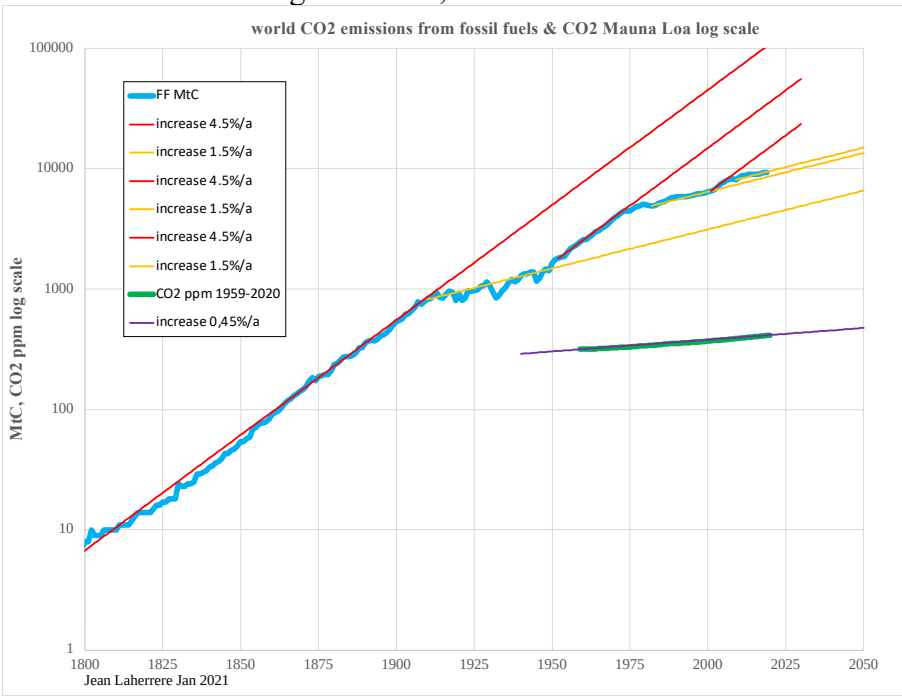


Most of medias being politically correct claims that the anthropic global warming is proven with CO2. The CO2 emissions need to be reduced to decrease the climate change. One of the rules of climate is constant change with several cycles. Many will be disappointed in the future to see that the climate will not follow the CO2!
For China and India particles pollution is more important than CO2 increase which increases the yield of cereals.
Plastics pollution looks for many more important than CO2 pollution.

The world last temperature peak is 2016 being due to El Nino which occurs without any correlation to known events. No one can forecast when will be the next El Nino!
El Nino and El Nina 1950-2022



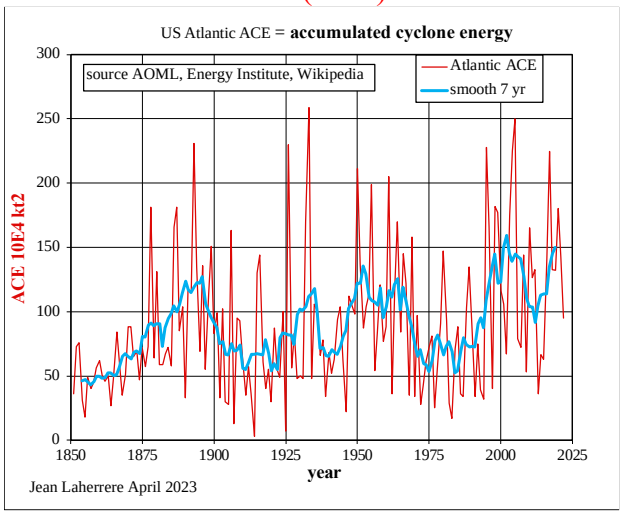
Fossil Fuels CO2 emissions since 1850 are plotted in log scale to compare growth: CO2 concentration at Mauna Loa has a growth of 0,45 %/a

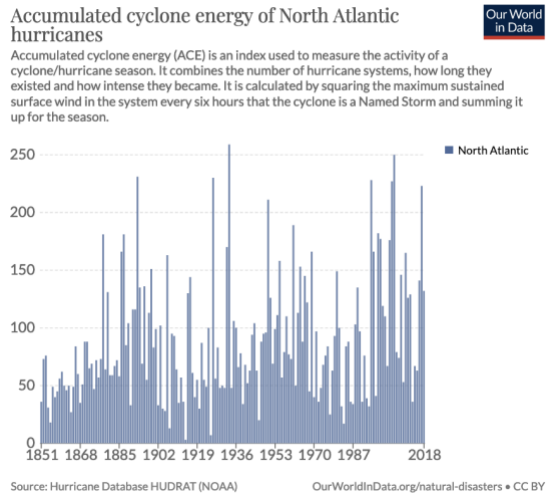


It is amazing to see that the growth rate of FF CO2 emissions since 1975 ((oil shock) is the same for the period 1914-1949 = 1.5 %/a, when it was at 4.5%/a for the period 1800-1914 as the period 1947-1977 known as the 30 Glorious !
It is hard to find an explanation for these similarities! No correlation with CO2 concentrations!

In US Atlantic, cyclone (hurricane) energy has been measured since 1850 (only anemometer for wind speed and clock are necessary) = ACE = accumulated cyclone energy: it is hard to see a trend on annual data, only cycles! Smooth curve sees peak around 1895, 1935, 1952, 2002.
The annual ACE record is 259 in 1933, second 250 on 2005.
The strongest hurricane was in 1899 ACE = 73.6 with 28 days, second in 2004 70.4 with 23 days

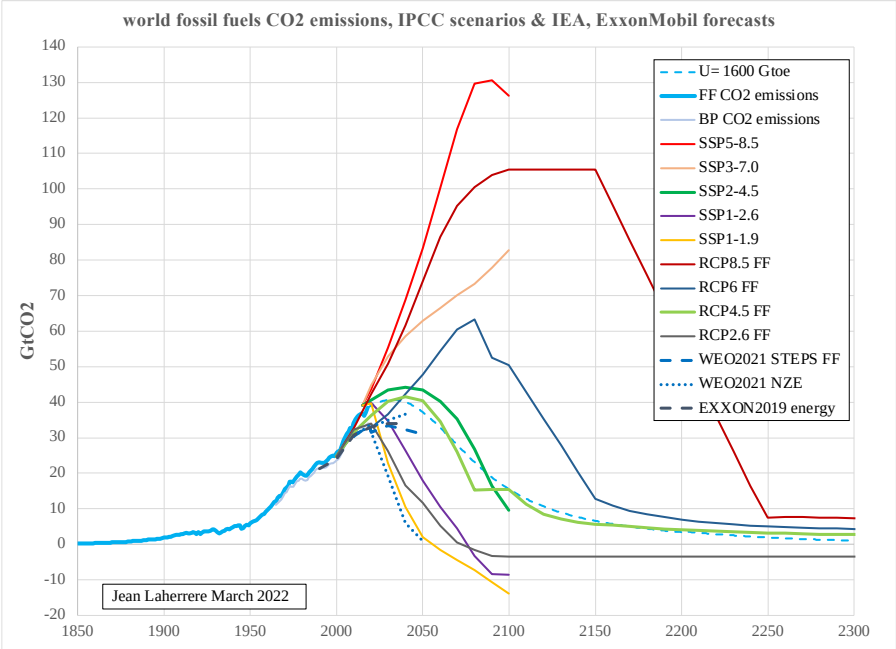
No correlation of ACE (wind) with CO2 emissions, as El Nino (wind)!



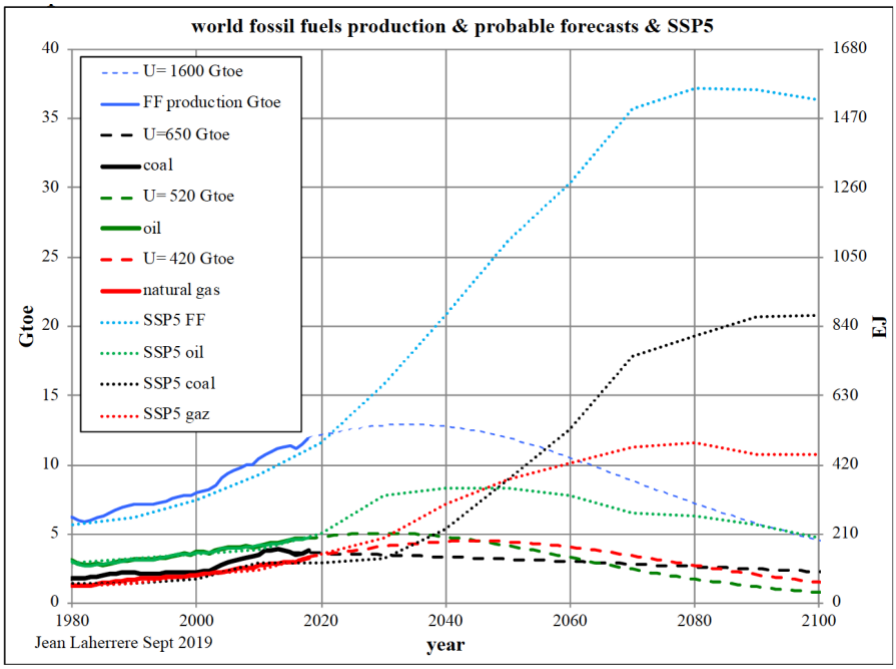


-IPCC scenarios

Most of medias quotes IPCC SSP5 scenarios giving an increase of 5°C in 2100, but SSP5 is very unrealistic forecasting CO2 FF emissions in 2050 at 86 GtCO2 against 31 for IEA/WEO2022SP:



SSP5 scenario forecasts for 2100 a FF production of 36 Gtoe against my 2019 forecast of 5 Gtoe: it is crazy!



Dr. John F. Clauser, recipient of the 2022 Nobel Prize in Physics, has been elected to serve on the board of directors of the CO2 Coalition,
https://co2coalition.org/publications/nobel-laureate-john-clauser-elected-to-co2-coalition-board-of-directors/
*On May 8, 2023, Clauser was elected to the Board of Directors of the CO2 Coalition, a non-profit composed largely of scientists who disagree with the claimed consensus of climate change and global warming. When elected, Clauser offered that the common narrative about climate change is a corruption of science, and stated "**In my opinion, there is no real climate crisis**. There is, however, a very real problem with providing a decent standard of living to the world's large population and an associated energy crisis. The latter is being unnecessarily exacerbated by what, in my opinion, is incorrect climate science.*
https://en.wikipedia.org/wiki/John_Clauser

On 23 September 2019 Professor Guus Berkhout send a letter to the secretary of the United Nations "there is no climate emergency" cosigned by 500 knowledgeable and experienced scientists and professionals in climate and related fields
Most of these scientists are retired, free to speak: active scientists at University cannot search on politically incorrect subjects because funding will be refused.
I was censured twice on the national French TV TF1 (Yann Arthus-Bertrand) and France 2 (Elise Lucet) after interview on energy. My last TV energy interview on TV was for RT-France (Russia today) in 2020.

In France, ecologists attack Totalenergies for producing fossil fuels, but do not attack the consumers who buy Totalenergies products (being also themselves).

Almost all medias say on global warming that the science is settled, because it is politically correct to put all the blame on anthropic CO2 emissions, but the impact on climate (by clear sky) of CO2 is only 26 % (Trenberth 1997 Earth's Annual Global Mean Energy Budget) when H2O is 60%, but 0% by cloudy sky; when ozone 15%!

TABLE 3. Clear and cloudy sky radiative forcing (W m^{-2}) and the contribution of individual absorbers to this total. Cloudy sky results are in parentheses.

Gas	Individual contribution	Combined with overlap effects	Percent contribution clear sky
H_2O	71 (49)	75 (51)	60
CO_2	29 (22)	32 (24)	26
Overlap H_2O–CO_2	7 (4)		
O_3	8 (7)	10 (7)	8
Overlap with O_3	2		
$CH_4 + N_2O$ + ovlp	8 (4)	8 (4)	6
Total	**125 (86)**	**125 (86)**	**100**

Table 4. Contribution of individual gases to shortwave absorption within the atmosphere. Fluxes are in W m^{-2}.

Gas	Clear sky	Cloudy sky
H_2O	43	38
CO_2	1	0
O_3	14	15
O_2	2	2
Overlap effects	0	12
Total	**60**	**67**

I did not find any more recent estimate on contribution of greenhouse effect.

It is impossible to model water with a grid of 150 km size (taking months to run a complete model with present computers), with a grid 100 times smaller on 1D, it will take in 3D millions of months!

The last IPCC report AR6 is unable to measure the lifetime of CO2 = multiple!

5.2.4 *The Relative Importance of CO2, CH4, and N2O*

The total influence of anthropogenic greenhouse gases (GHGs) on the Earth's radiative balance is driven by the combined effect of those gases, and the three most important were discussed separately in the previous sections. This section compares the balance of the sources and sinks of these three gases and their regional net flux contributions to the radiative forcing. CO_2 has multiple residence times in the atmosphere from one year to many thousands of years (Box 6.1 in Ciais et al. (2013)), and N_2O has a mean lifetime of 116 years. They are both long-lived GHGs, while CH_4 has a lifetime of 9.0 years and is considered a short-lived GHGs (see Chapter 2 for lifetime of GHGs, Chapter 6 for CH_4 chemical lifetime, and Chapter 7 for effective radiative forcing of all GHGs).

amount. The radiative efficiencies are as described in Section 7.3.2 and include tropospheric adjustments where assessed to be non-zero in Section 7.6.1.1. The climate response function is from Supplementary Material 7.SM.5.2. Uncertainty calculations are presented in Supplementary Tables 7.SM.8 to 7.SM.13. Chemical effects of CH_4 and N_2O are included (Section 7.6.1.3). Contributions from stratospheric ozone depletion to halogenated species metrics are not included. Supplementary Table 7.SM.7 presents the full table.

# Species	Lifetime (years)	Radiative efficiency (W m^{-2} ppb^{-1})	GWP-20	GWP-100	GWP-500	GTP-50	GTP-100	CGTP-50 (years)	CGTP-100 (years)
CO2	Multiple	1.33±0.16 ×10^{-5}	1.	1.000	1.000	1.000	1.000		
CH_4-fossil	11.8 ±1.8	5.7±1.4×10^{-4}	82.5 ±25.8	29.8 ±11	10.0 ±3.8	13.2 ±6.1	7.5 ±2.9	2823 ±1060	3531 ±1385
CH_4-non fossil	11.8 ±1.8	5.7±1.4×10^{-4}	80.8 ±25.8	27.2 ±11	7.3 ±3.8	10.3 ±6.1	4.7 ±2.9	2701 ±1057	3254 ±1364
N_2O	109 ±10	2.8±1.1 ×10^{-3}	273 ±118	273 ±130	130 ±64	290 ±140	233 ±110		
HFC-32	5.4 ±1.1	1.1±0.2 ×10^{-1}	2693 ±842	771 ±292	220 ±87	181 ±83	142 ±51	78175 ±29402	92888 ±36534
HFC-134a	14.0 ±2.8	1.67±0.32 ×10^{-1}	4144 ±1160	1526 ±577	436 ±173	733 ±410	306 ±119	146670 ±53318	181408 ±71365
CFC-11	52.0 ±10.4	2.91±0.65 ×10^{-1}	8321 ±2419	6226 ±2297	2093 ±865	6351 ±2342	3536 ±1511		
PFC-14	50000	9.89±0.19 ×10^{-2}	5301 ±1395	7380 ±2430	10587 ±3692	7660 ±2464	9055 ±3128		

The earth is not a greenhouse, as greenhouse does not work when air moves. The model should be only on absorption and not on greenhouse!
Winds and clouds are always present on earth!
It is hard to forecast rain beyond a week, it is hard to model precipitation for a century!
Science cannot model properly climate changes: maybe with quantum computers?

-NB
Sorry for my broken English, but my use of unit follows the rule of SI (metric system) followed by 95 % of the world (except US and Liberia).
SI is clear for writing numbers, decimal and thousand:
USDOC/NIST 881 report requires using for thousand a spare and not a comma.

Guide for the Use of the International System of Units (SI)

10.5.3 Grouping digits

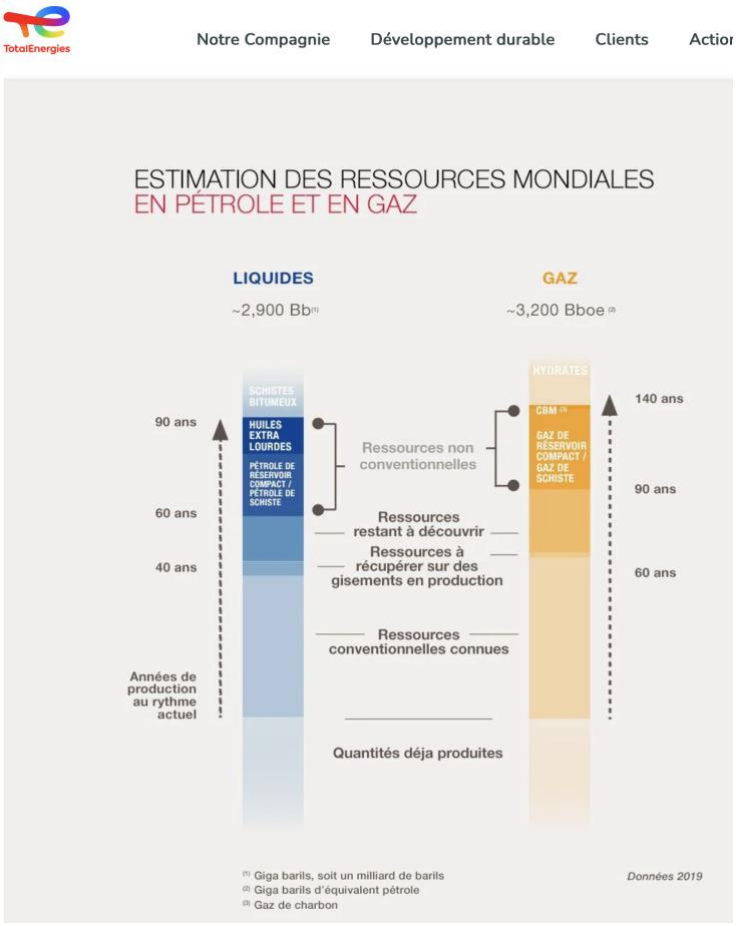
Because the comma is widely used as the decimal marker outside the United States, it should not be used to separate digits into groups of three. Instead, digits should be separated into groups of three, counting from the decimal marker towards the left and right, by the use of a thin, fixed space. However, this practice is not usually followed for numbers having only four digits on either side of the decimal marker except when uniformity in a table is desired.

Examples:	76 483 522	*but not*:	76,483,522
	43 279.168 29	*but not*:	43,279.168 29
	8012 or 8 012	*but not*:	8,012
	0.491 722 3	*is highly preferred to*:	0.4917223
	0.5947 or 0.594 7	*but not*:	0.59 47
	8012.5947 or 8 012.594 7	*but not*:	8 012.5947 or 8012.594 7

Note: The practice of using a space to group digits is not usually followed in certain specialized applications, such as engineering drawings and financial statements.

Some confuse G.m3 and Gm3.
Billion (US = 10 power 9) of cubic meter (Gcm) is often written Gm3 = cubic Gm = 10 power 27 cm, when it should be written km3 or G.m3

Total reported in 2019 their NG sales in Gm3 and not in km3 or G.m3
Totalenergies reports the world oil reserves in 2019 in Bb instead of Gb:



Total ignores that the billion US is thousand million = G (and not B), when the billion SI is square million = T

Furthermore, the world liquids 2019 proven reserves should be written 2 900 Gb and not 2,900 Gb, which means in SI 2.9 Gb

Totalenergies 2022 annual report uses G (GW) and B (Bboe) in the same paragraph: it is against SI rules, which is the law in France and for 95 % of the world population!

Resources and ecosystem

Proven expertise

- **101,279** employees
- Nearly **160** nationalities
- More than **740** business-related competencies
- **470,000** days of training
- More than **400** talent developers to help employees along their professional development path

A responsible innovation

- R&D budget: **$762 million**
- **18** R&D centers worldwide
- More than **200** patent applications in 2022

Top-tier industrial and commercial assets

- **16.8 GW**(1) of gross installed renewable power generation capacities
- More than **42,000** EV operated charging points
- Proved reserves of **10.2 Bboe** and hydrocarbon production of **2,765 kboe/d**
- **16** refineries including **1** biorefinery **29** petrochemical sites including **6** integrated platforms (refining-petrochemicals) **84** specialty chemicals production sites **36** production sites operated (lubricants and greases)
- More than **14,600** service stations in close to **65** countries

I sent a mail to the president of TotalEnergies about the bad use of SI, which is the law in France as Europe: he did not reply!
It will be interesting to see if TotalEnergies 2023 reports correctly oil and gas data!
In 1995, I had already sent a letter to Total HR manager (Pierre Proust) on the SI violation, in particulier for Gm3 instead of km3 (14 times) in TOTAL UPSTREAM n°8: no result!

This paper is too long, but the reader can jump over many paragraphs, when others will find some graphs of interest. My goal is to update many of my old graphs with present data and to show some new ones.
As today is my 92nd birthday, I am not sure to write many papers in the future.