Jean Laherrere 24 February 2024

Updated metal peaks

Table of contents page

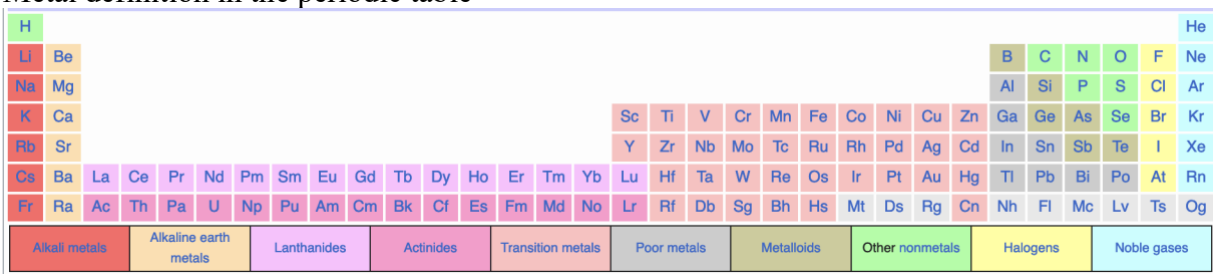
-Introduction

The world needs to survive energy and mineral where metals represent an important part.

This paper relies on annual metal production data by country reported by USGS and BGS: But I am obliged to consult each annual report because both do not provide complete updated historical data. Each annual data is reported by individuals for few years, with the last year being estimate and the next author will report different data also for few years. So, the agency does not provide updated historical data. It is bad to find the same problem of lack of historical mineral data in US (USGS-MCS =mineral commodity summaries since 1996 to 2023), in UK (BGS-WMP =world mineral production 1913 to 2021). It is the same in France where INSEE mission is collect and publish statistical data on France, but publishes articles

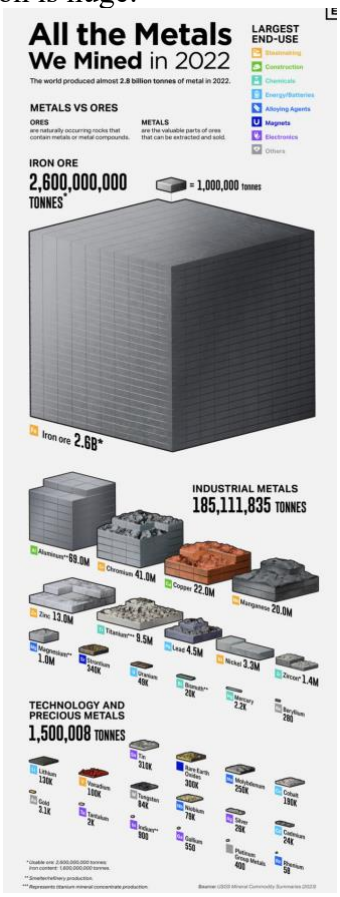
from individuals on limited periods, but no historical data as if data belongs to some individuals and not to the nation!
Historical series since 1900 are reported by USGS only for the US mineral in the Data series 140, but not updated beyond 2019! For the world mineral Data series 896 cover few minerals (see copper) for a short period 1990-2012 (lazy job!)
USGS seems to not care to provide updated US historical production data, worse for the world!
OWID (our world in data), founded by an individual, aims to report world historical data, which are not reported freely by international agency as IEA (founded to balance OPEC!).
It is only for oil that historical production data is reported by BP Statistical Review but only from 1965 to 2022 and by OPEC Annual Statistical Bulletin since 1960. ASPOFrance has collected oil annual production data since 1900.

Metal definition in the periodic table



This paper studies most of metals, but also nonmetals as N and P as they are combined with K in fertilizers.

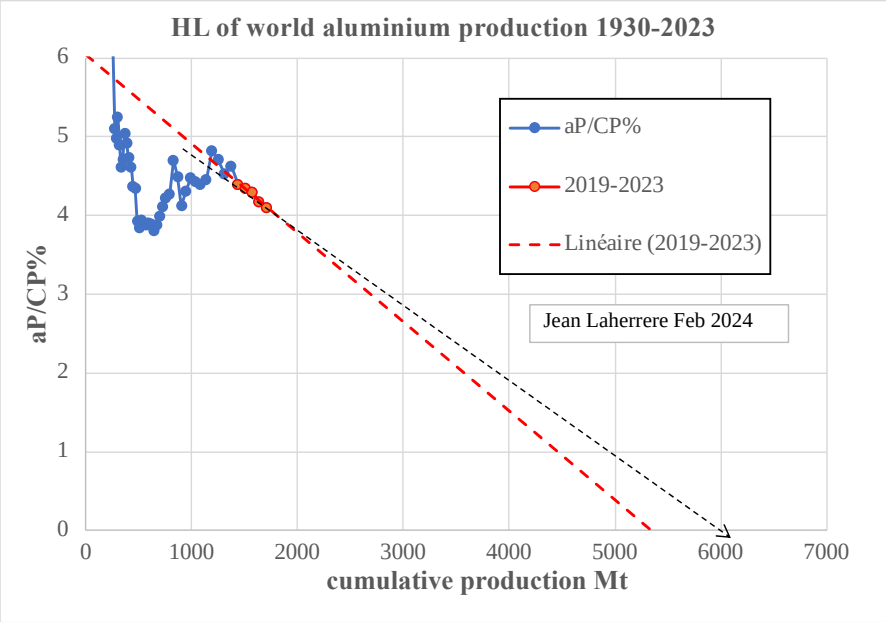
The range of 2022 metal production is huge:



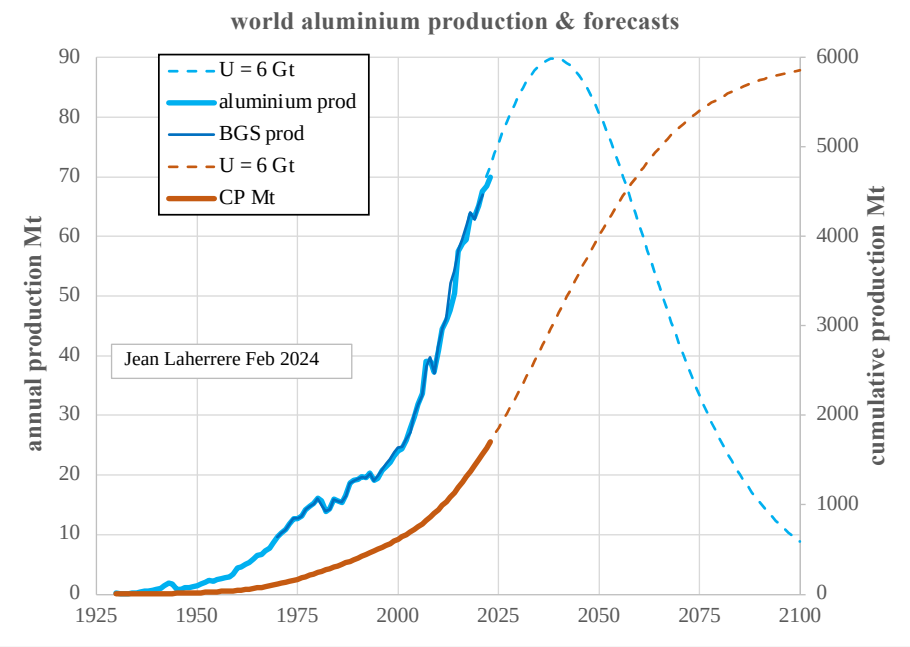
https://elements.visualcapitalist.com/all-the-metals-we-mined-in-one-visualization-2/

I remind my previous 2023 paper on metal peaks
« Updated metal peaks" https://aspofrance.files.wordpress.com/2023/08/metalpeaks2023.pdf
My new forecasts from new data are often different from last year paper because the uncertainty of metal ultimates from past production data.
My new ultimates from the extrapolation of the past production (HL) are always taken higher than the cumulate production plus remaining USGS reserves, except on few cases where USGS estimates look too high in country having a large majority of world reserves: Morocco for phosphates, South Africa for PMG, China for molybdenum

-aluminium
HL of world aluminium production trends (quality fair = F) towards 6000 Mt

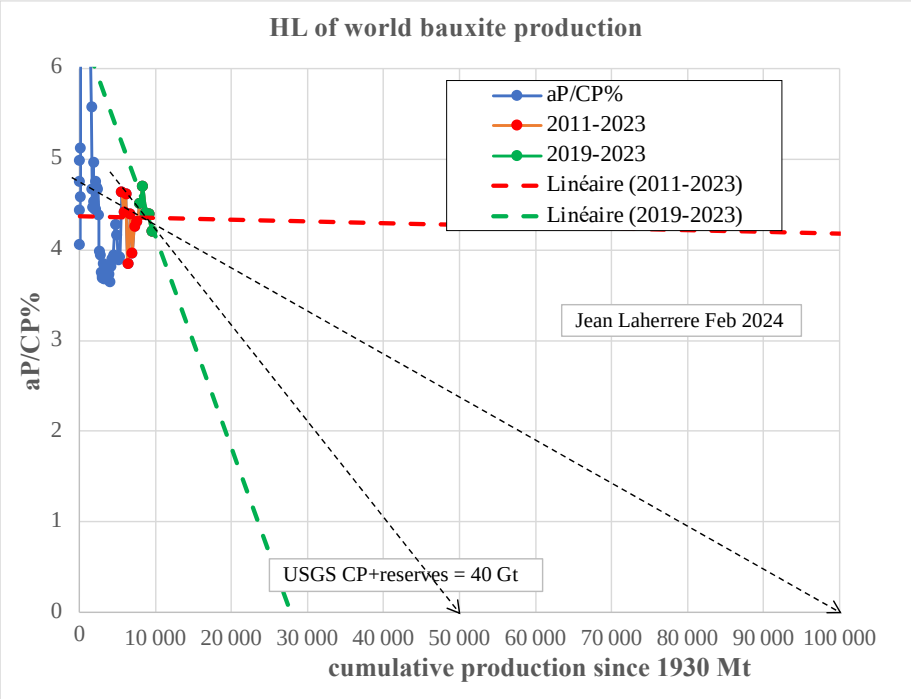


With a 6000 Mt ultimate, world aluminium production will peak about 2040 at 90 Mt

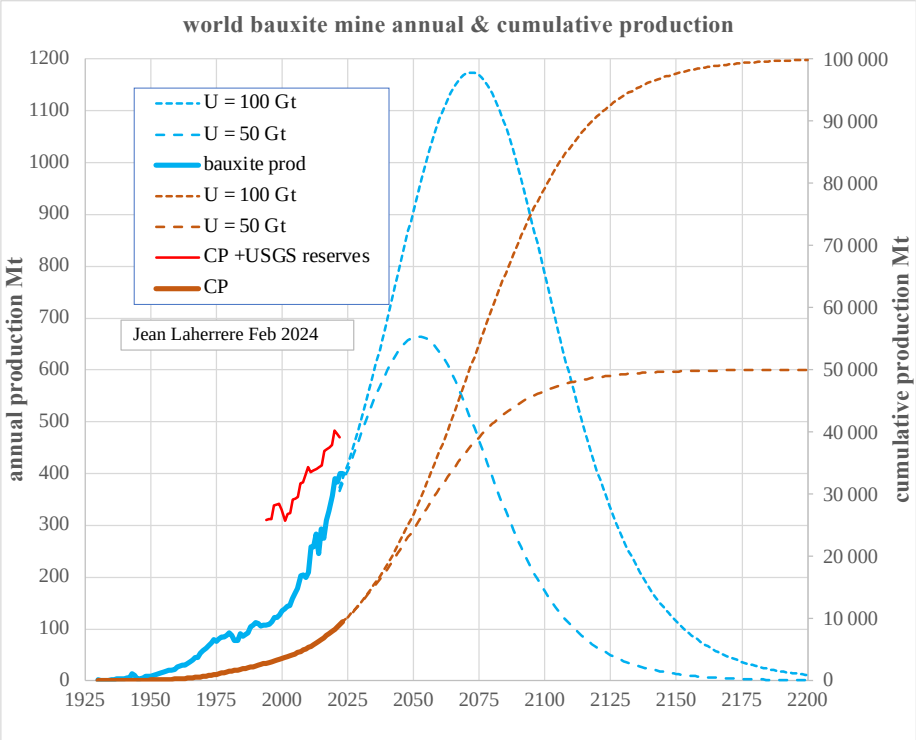


-bauxite

HL of world bauxite production is useless, and two ultimates are chosen: 50 and 100 Gt with a CP + USGS reserves of 40 Gt

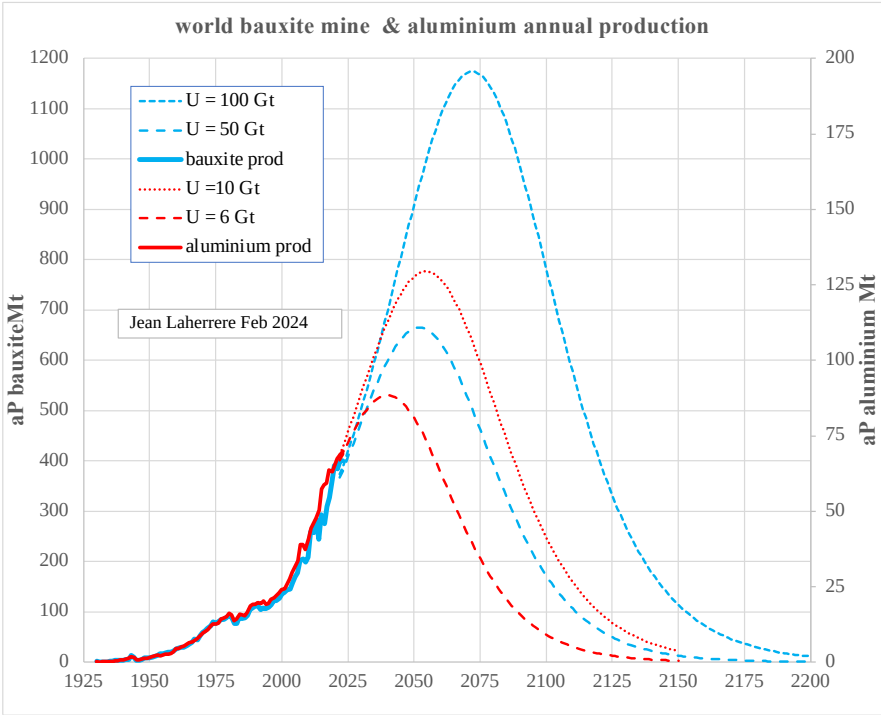


World bauxite production will peak around 2050 (U= 50 Gt) at 650 Mt or 2075 (U=100 Gt) at 1150 Mt

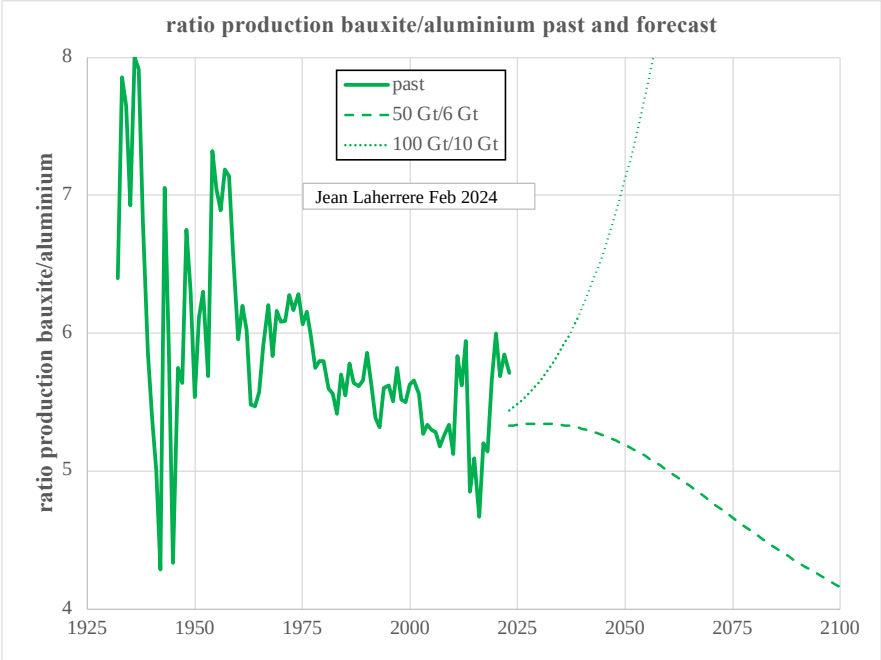


-bauxite/aluminium

Bauxite and aluminium production curves are compared

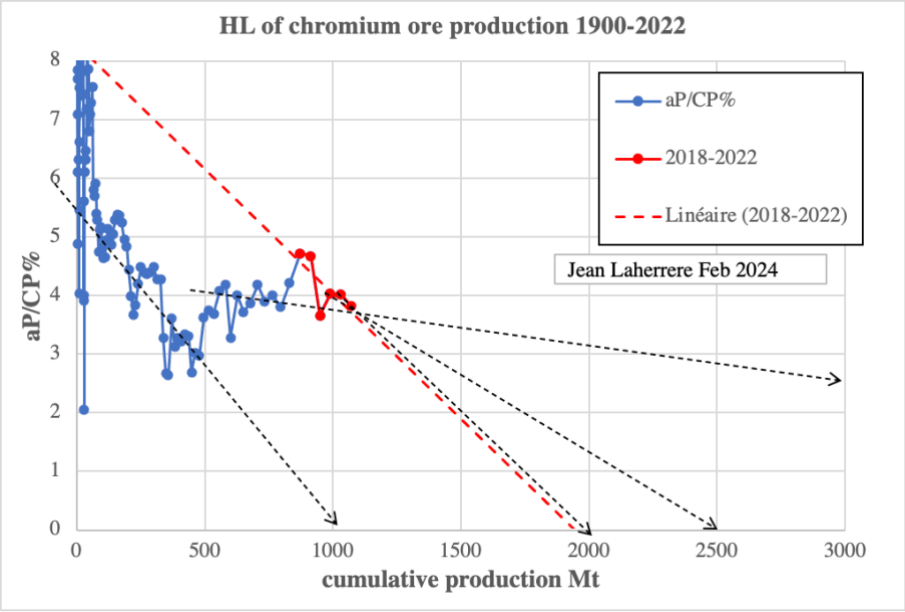


In the past the ratio bauxite/aluminium was declining from 7 to 5, but in our forecasts, it continues to decline for the forecast 50 Gt/6 Gt, but not for the forecast 100 Gt/10 Gt which then appears less realistic.

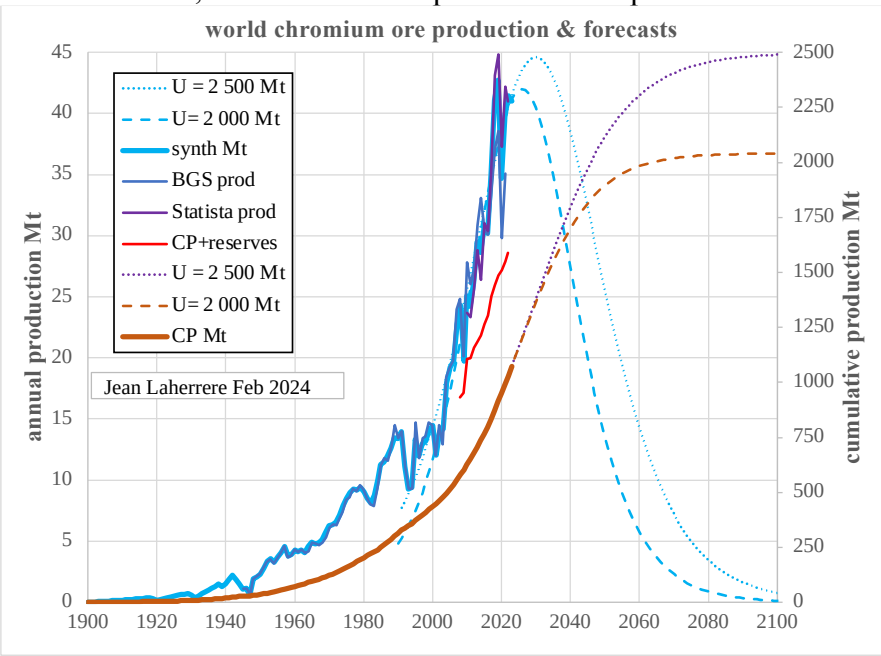


-chromium

HL of world chromium production trends poorly towards 2000 Mt, but an ultimate of 2500 Mt can be considered.

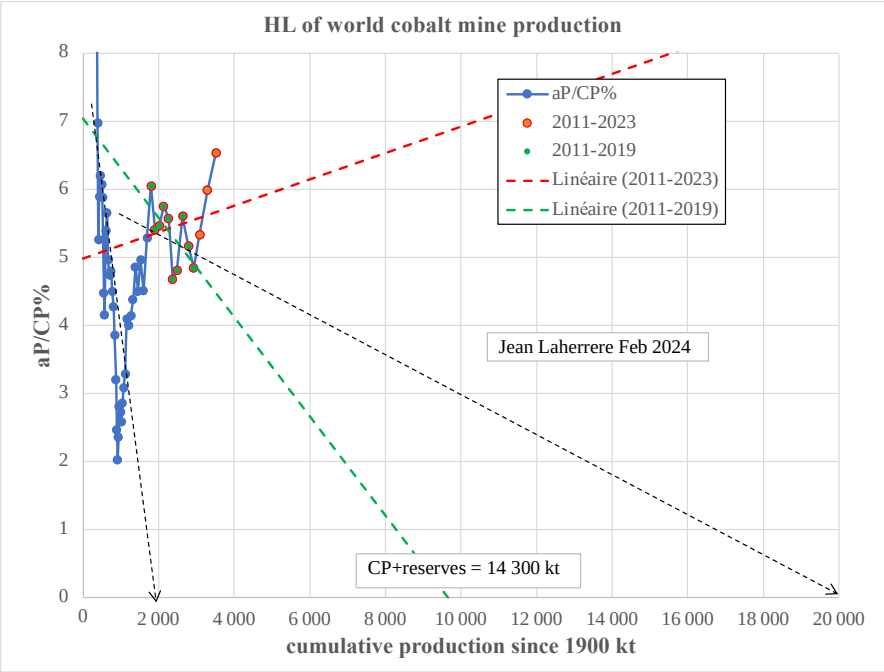


For an ultimate of 2000 Mt, world chromium production has peaked in 2010

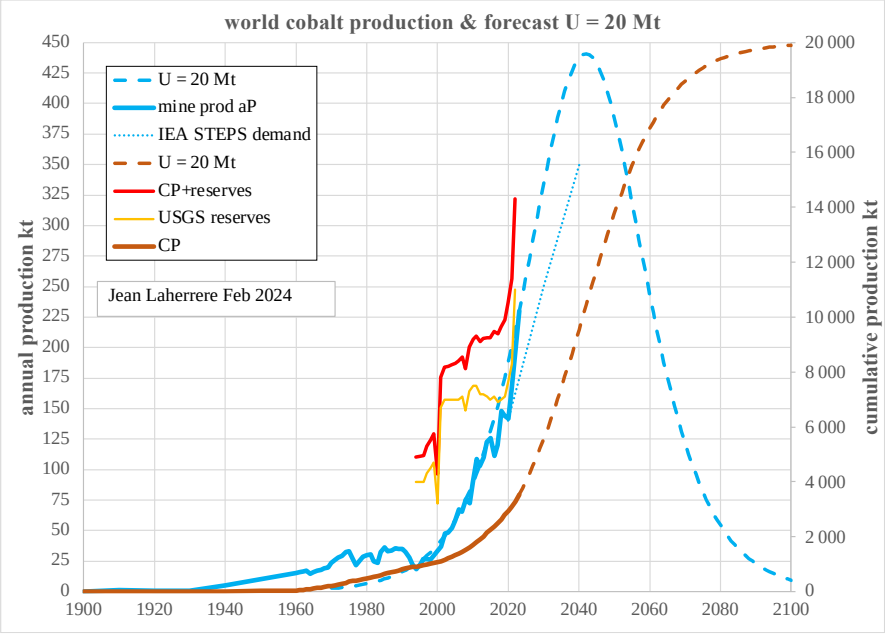


-cobalt

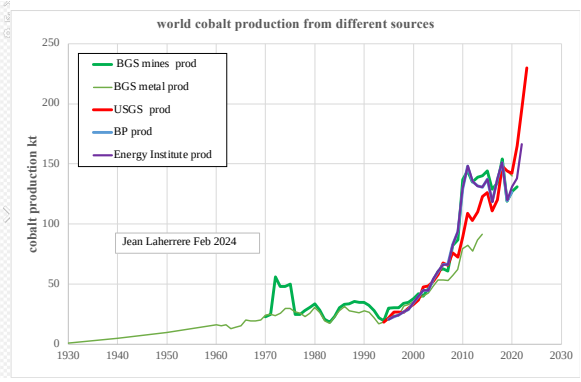
HL of world cobalt production is rather chaotic; useless after 2019. An ultimate of 20 Mt is considered because CP + reserves are over 14 Mt



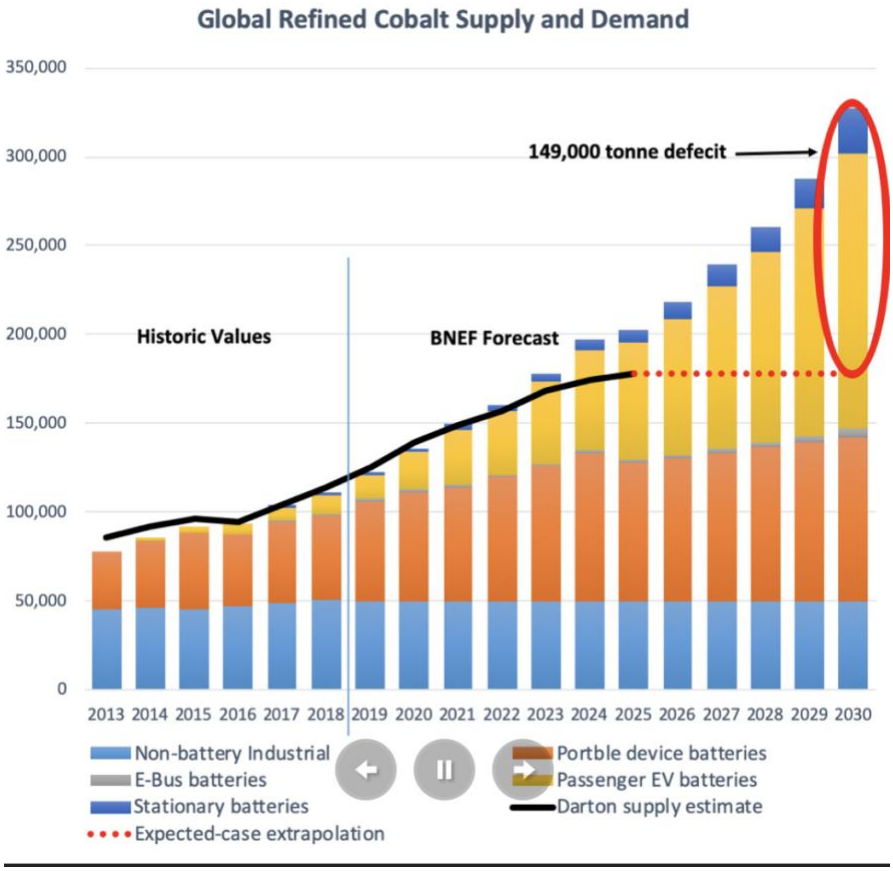
For an ultimate of 20 Mt the peak will be around 2040 at 450 kt



World cobalt production data varies with sources or definition:



The site https://nanthavictor.com/2020/07/22/nickel-demand-from-the-batteries-sector-to-account-for-over-25-percent-of-the-total-nickel-market-by-2030/ forecasts a peak on 2030 less than 200 kt with a demand well over 320 kt; but my forecast is over



Varlet in 2023 https://www.diva-portal.org/smash/get/diva2:1768110/FULLTEXT01.pdf forecasts a peak around 2030, but quite low compared with my forecast and 2022 data

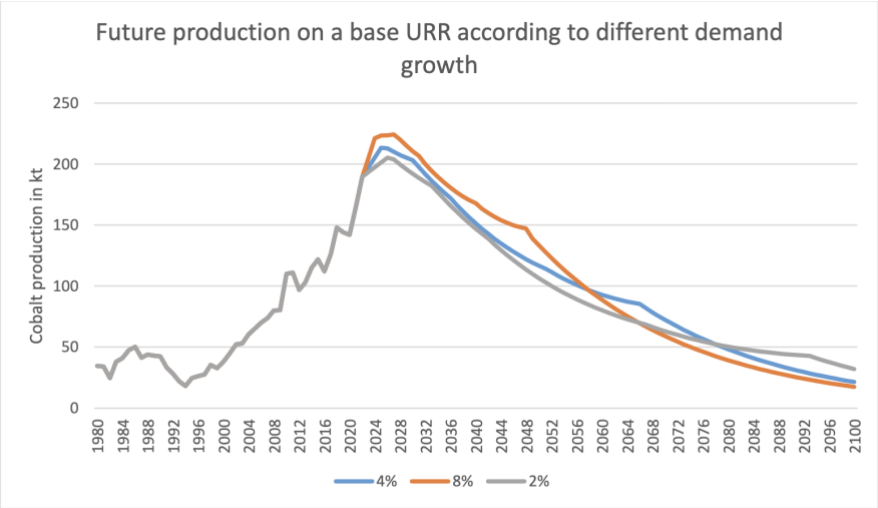
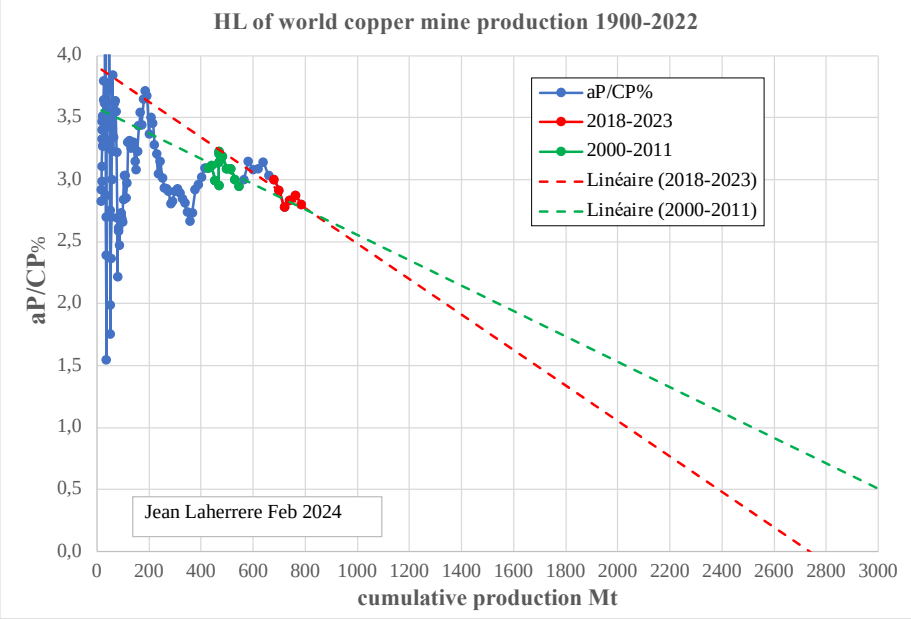


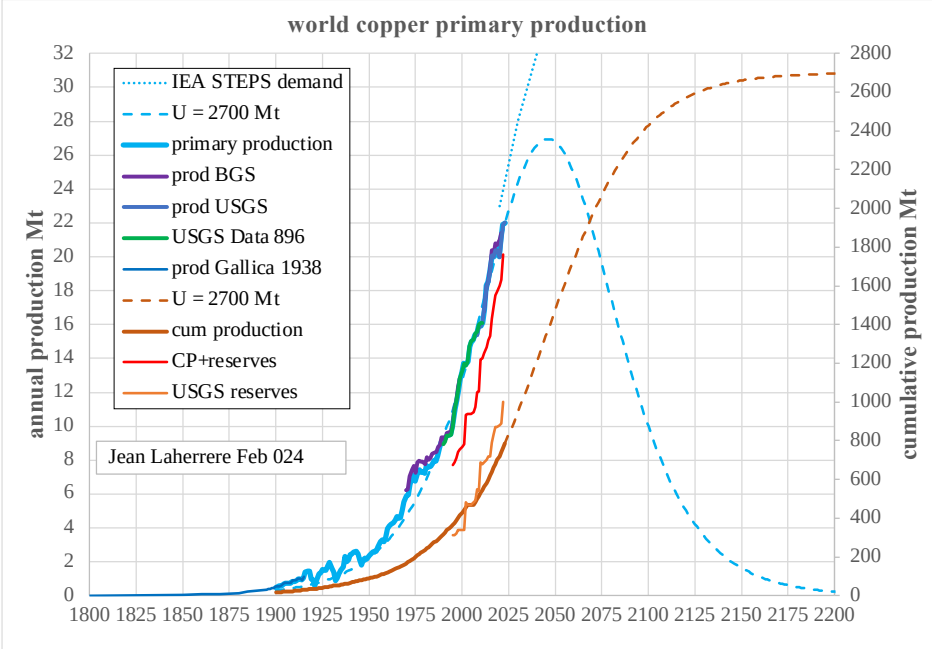
Figure 9: Projection of the worldwide cobalt production with a base URR under the assumptions of the different levels of demand

-copper

HL of world copper production trends poorly towards 2700 Mt

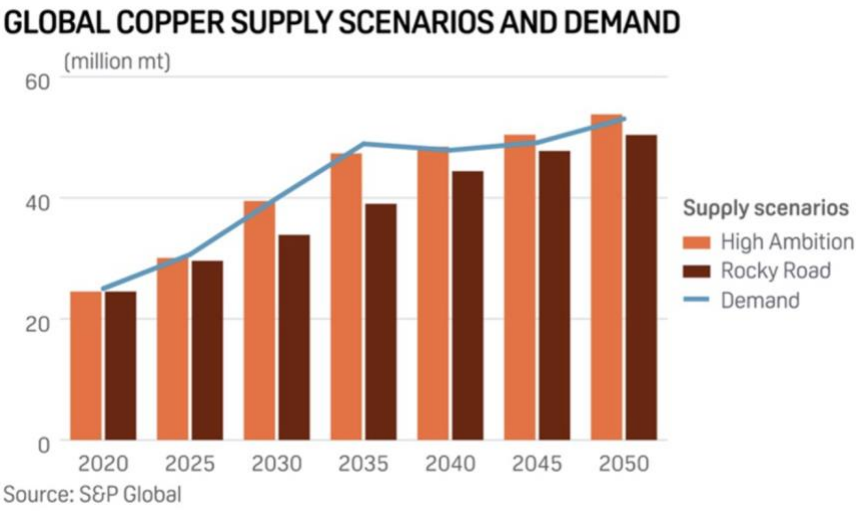


With a 2700 Mt world copper production will peak around 2050 at 27 Mt, well below the IEA demand STEPS forecast.

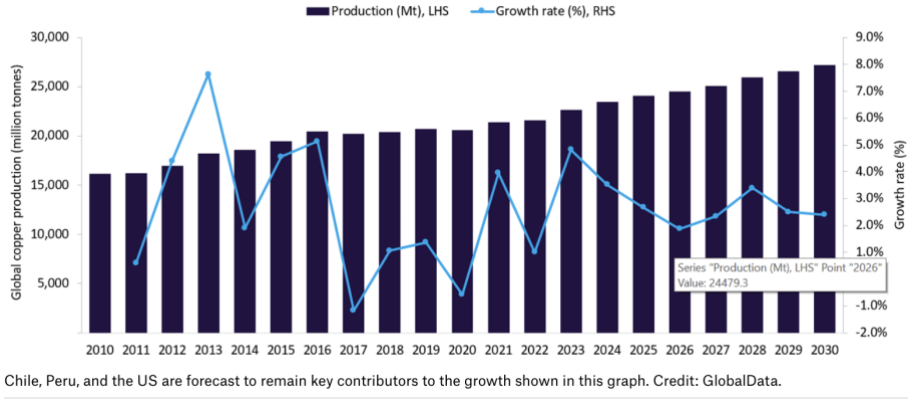


USGS data series 896 (giving the breakdown in concentrates and leaching) covers only a short period 1990-2011 (what a pity!).

S&P forecasts demand slightly higher than supply! But values of 50 Mt in 2050 looks too optimistic

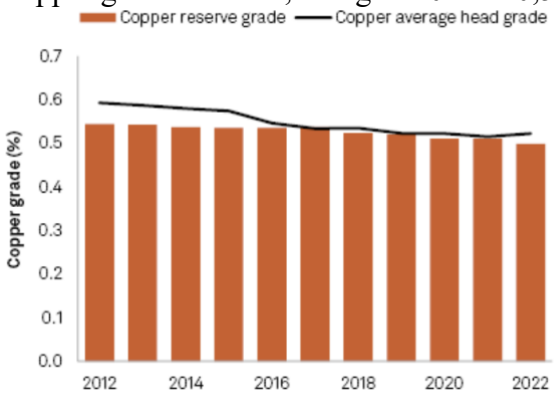


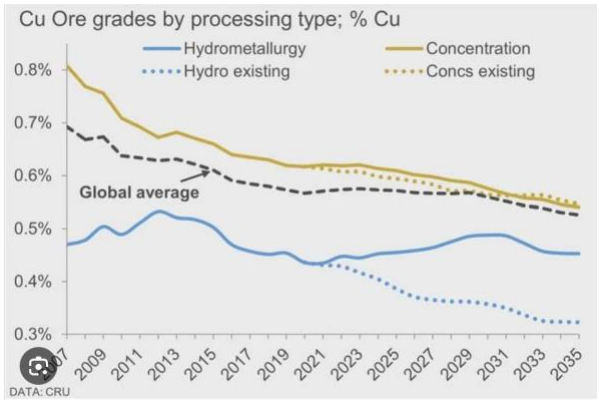
Global data is less optimistic

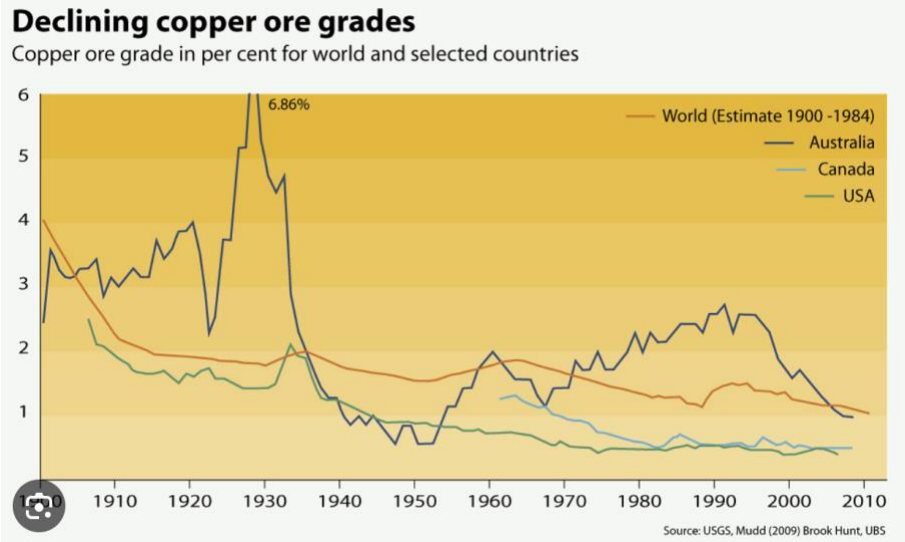


Chile, Peru, and the US are forecast to remain key contributors to the growth shown in this graph. Credit: GlobalData.

Copper grade declines, being in 2022 at 0,5% when about 2% in 1935

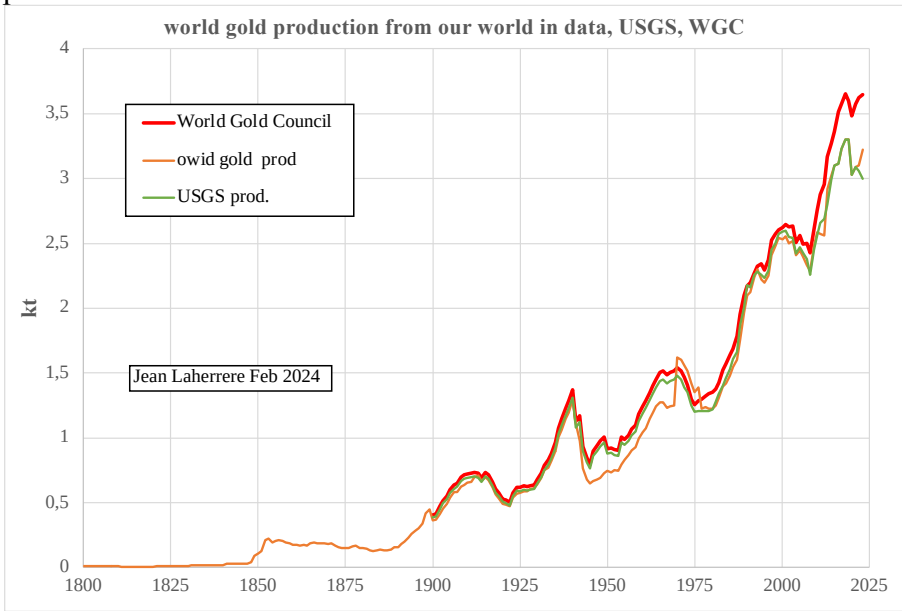




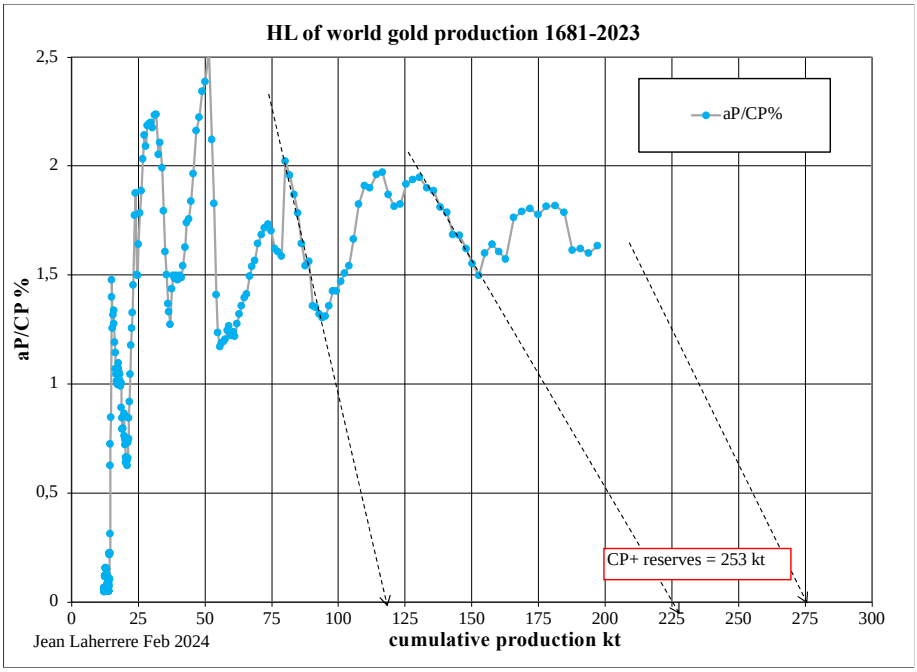


-gold

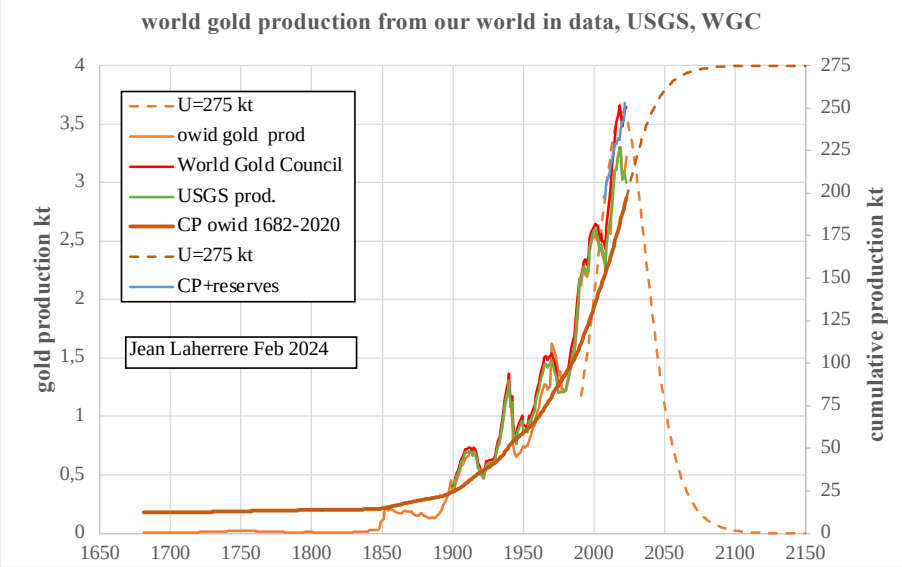
World gold production varies from sources



HL of world gold production is useless; but an ultimate of 275 kt is chosen as CP +reserves = 253 kt



An ultimate of 275 kt leads to a peak in 2019 and a sharp decline in future



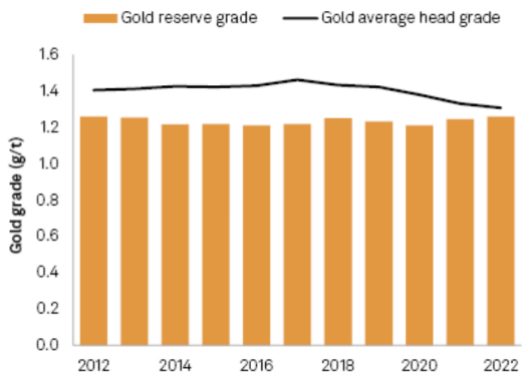
The gold grade is sharply declining being presently around one gramme per tonne

Open Pit:

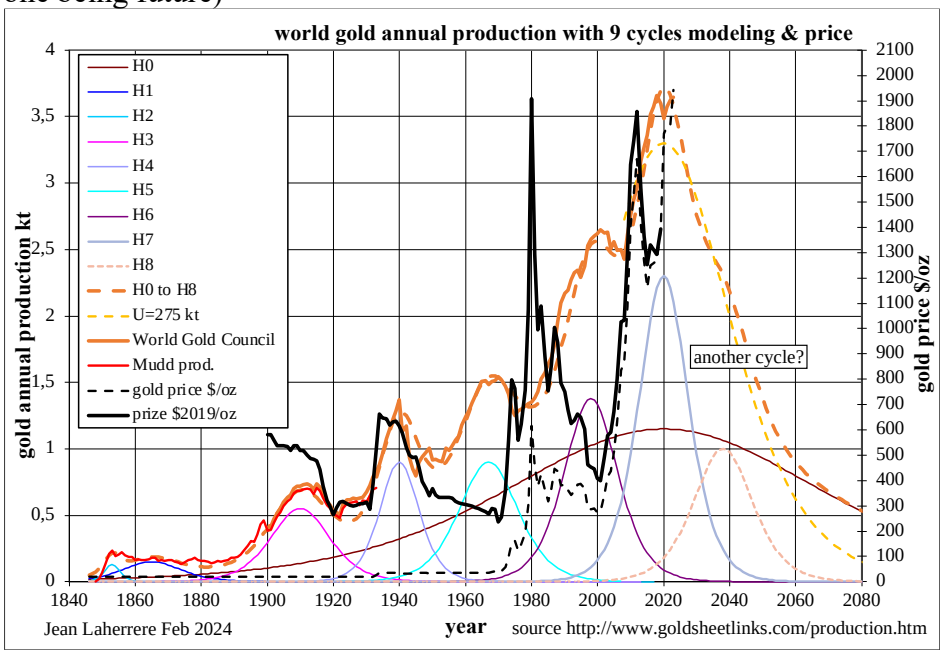
Low grade	0 - 0.5 gold grams per tonne
Average grade	0.5 - 1.5 gold grams per tonne
High grade	1.5 + gold grams per tonne

Underground Mine:

Low grade	0 - 5 gold grams per tonne
Average grade	5 - 8 gold grams per tonne
High grade	8 + gold grams per tonne
'Bonanza' grade	Troy Ounces (31.1 grams) per tonne



World gold production has peaked in 2018, past data since 1845 can also be modelled with 9 cycles (last one being future)



-iron & steel

https://pubs.usgs.gov/of/2005/1254/2005-1254.pdf

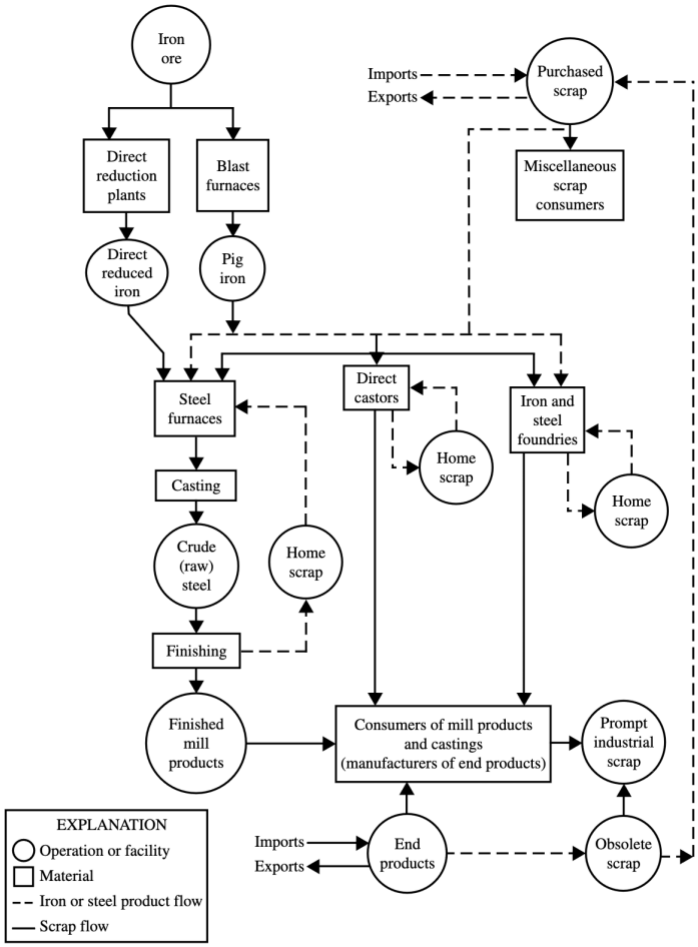
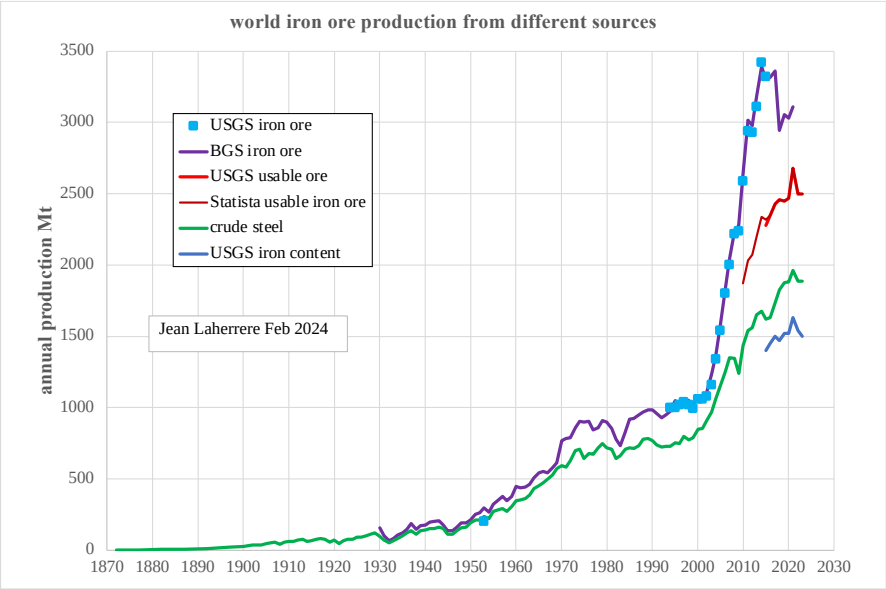
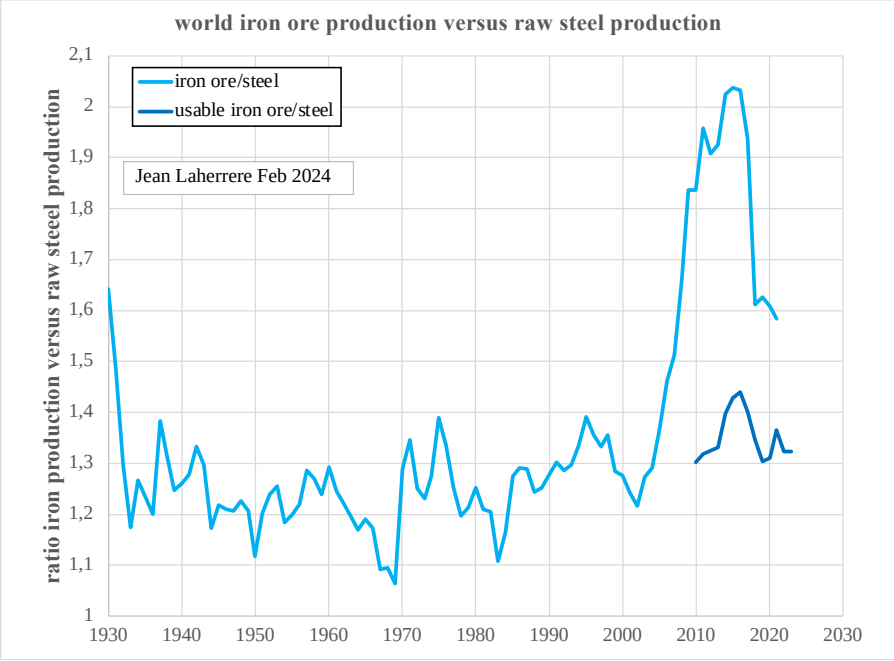


Figure 1. Iron and steel material flow diagram. Source: Schottman, 1985.

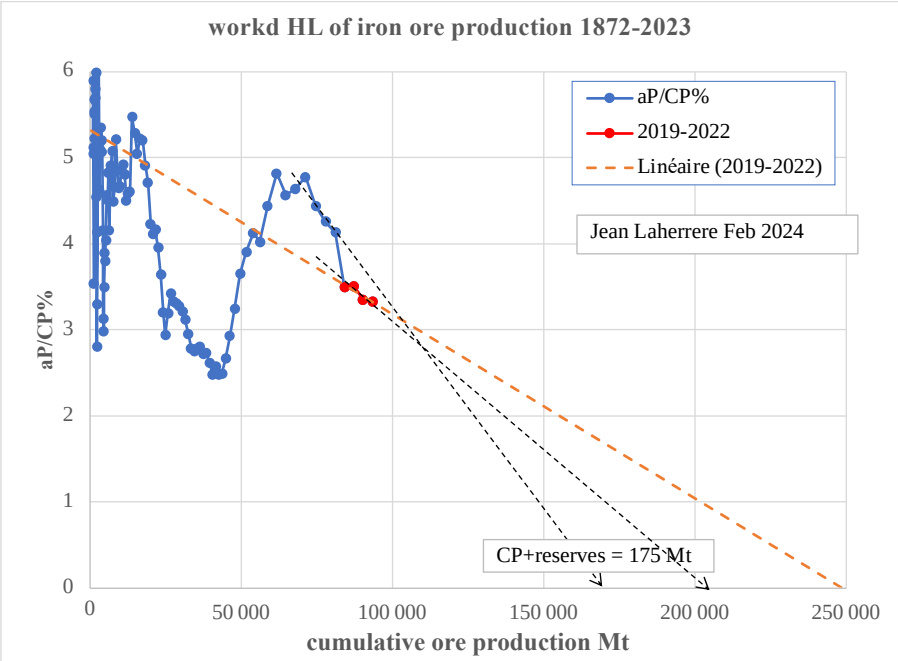
The problem is the discrepancy of iron ore production data form different sources, with iron ore and usable iron ore.
World iron ore increase displays a huge increase in 2002 and in 2015 USGS introduces a usable iron ore as no need to be further processed
The definition of usable iron ore is *The product of a mine, or of a beneficiating or agglomerating plant, which is shipped without further processing to the consumer.*



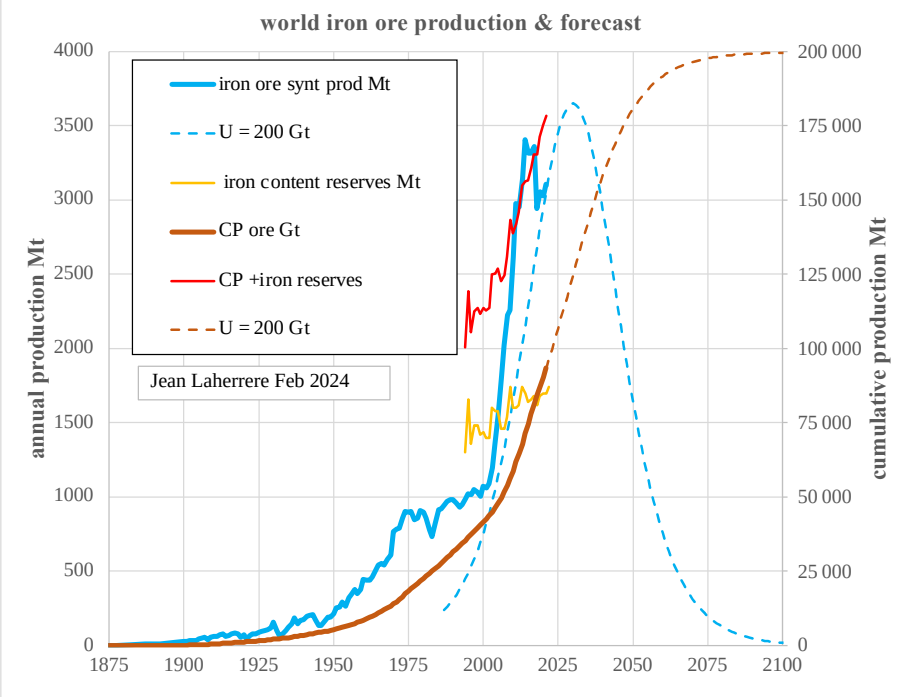
The ratio of iron ore/raw steel ranges from 1.2 to 1.4 from 1933 to 2004, with a sharp rise 2005-2010, coming back to normal with usable ore/steel



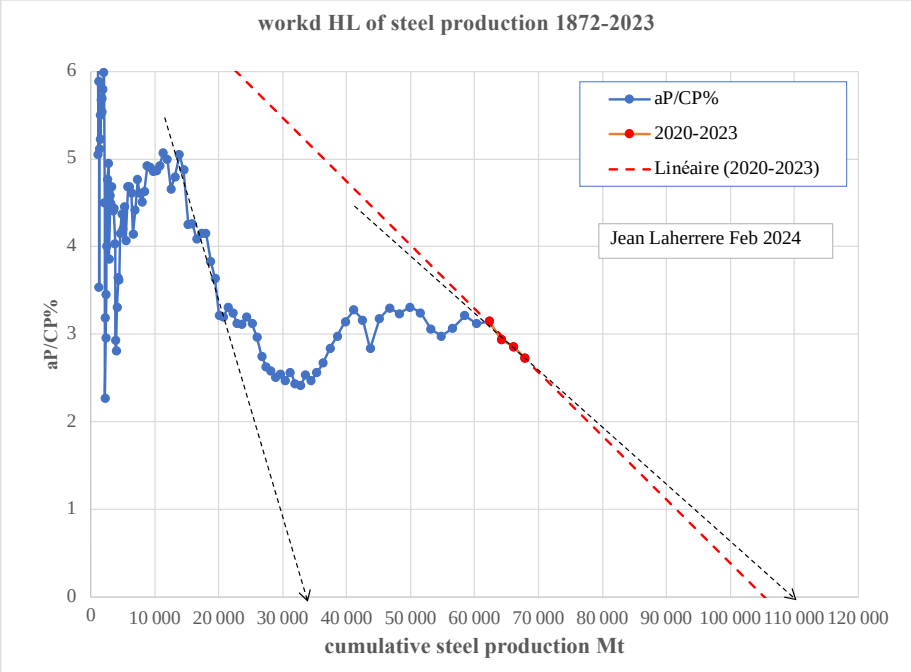
HL of world iron mine trends poorly towards 200 Gt



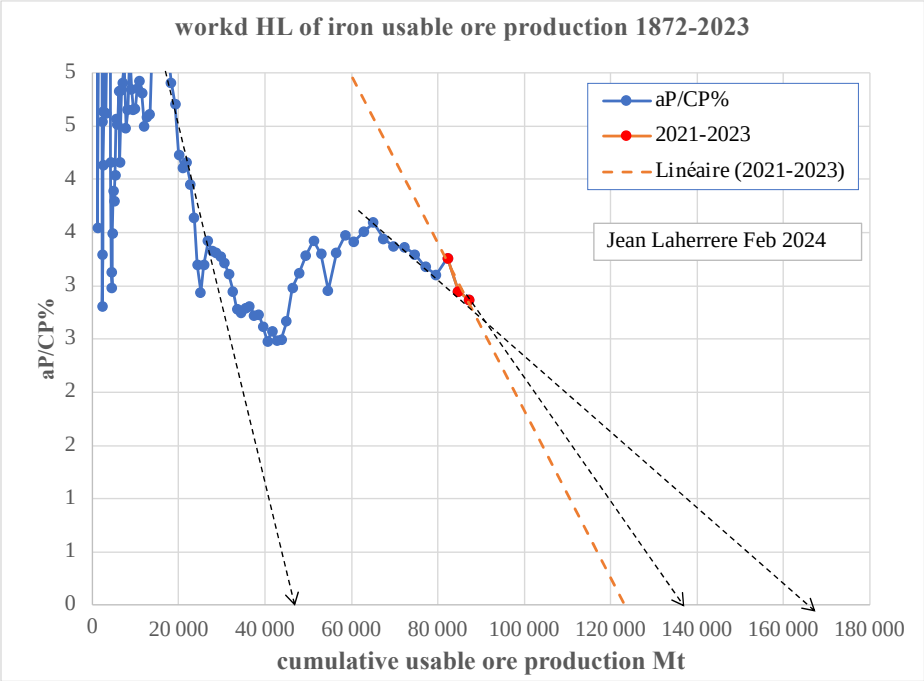
For a 200 Gt ultimate world iron ore will peak around 2030 at 3600 Mt



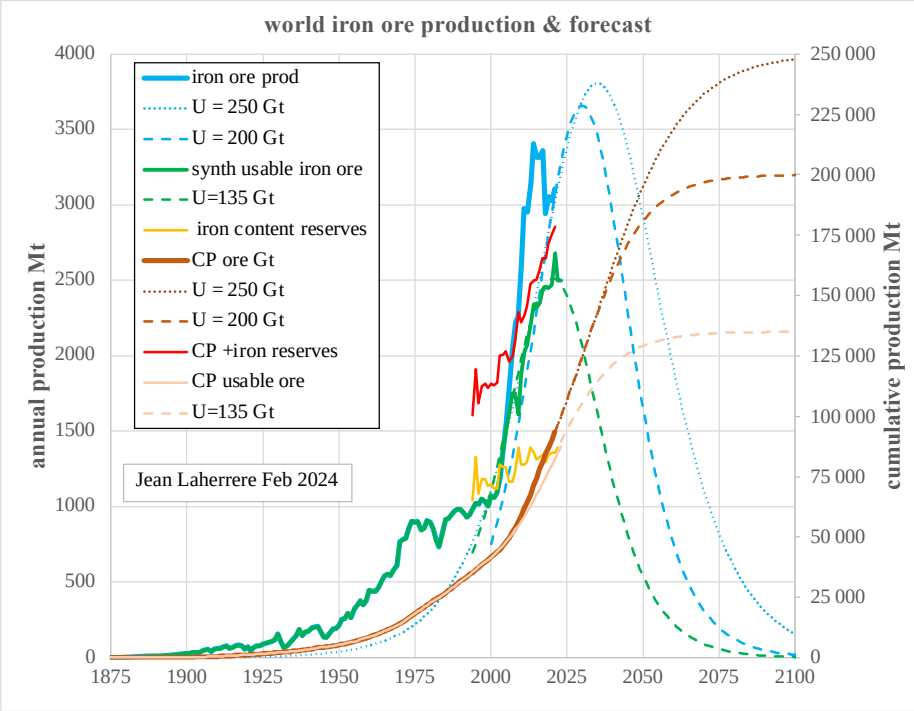
HL of world steel production trends towards



I estimate a synthetic usable ore production before 2015 and the HL trends poorly towards 120 Gt

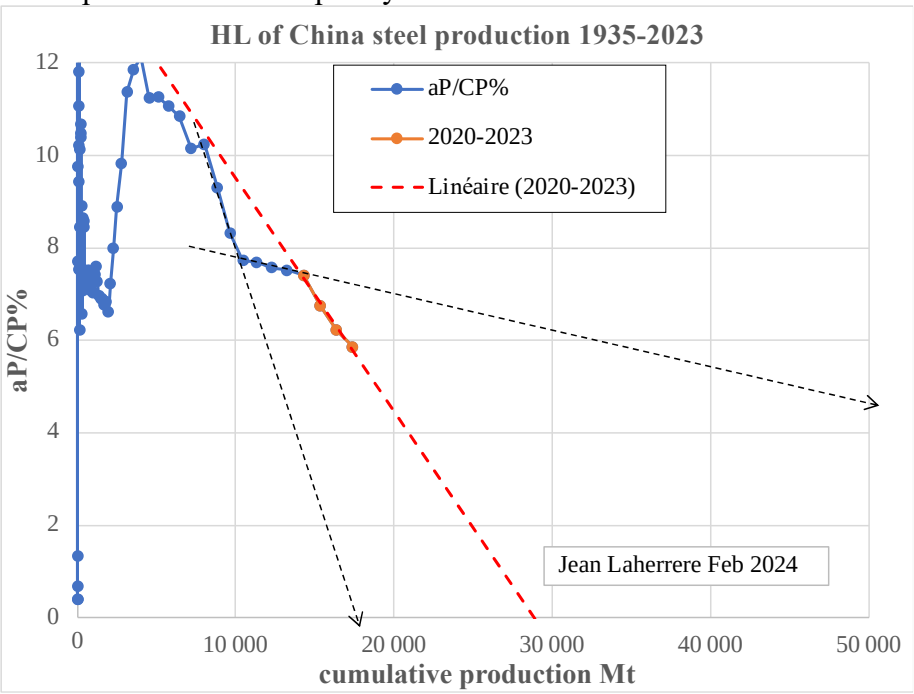


The forecast for world iron ore is a peak in 2030, but 2020 for usable:

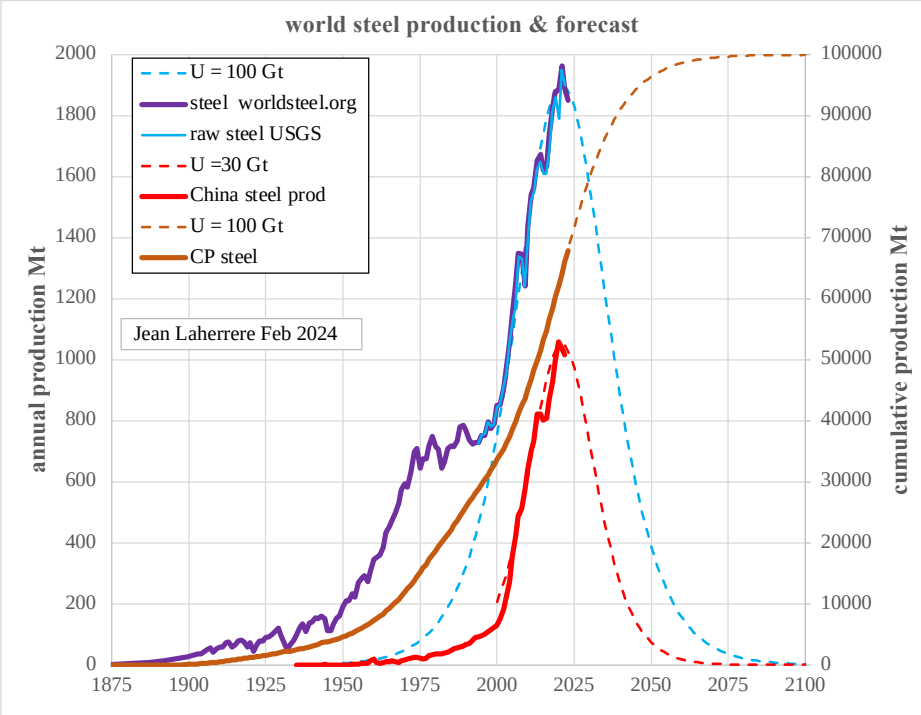


-China steel

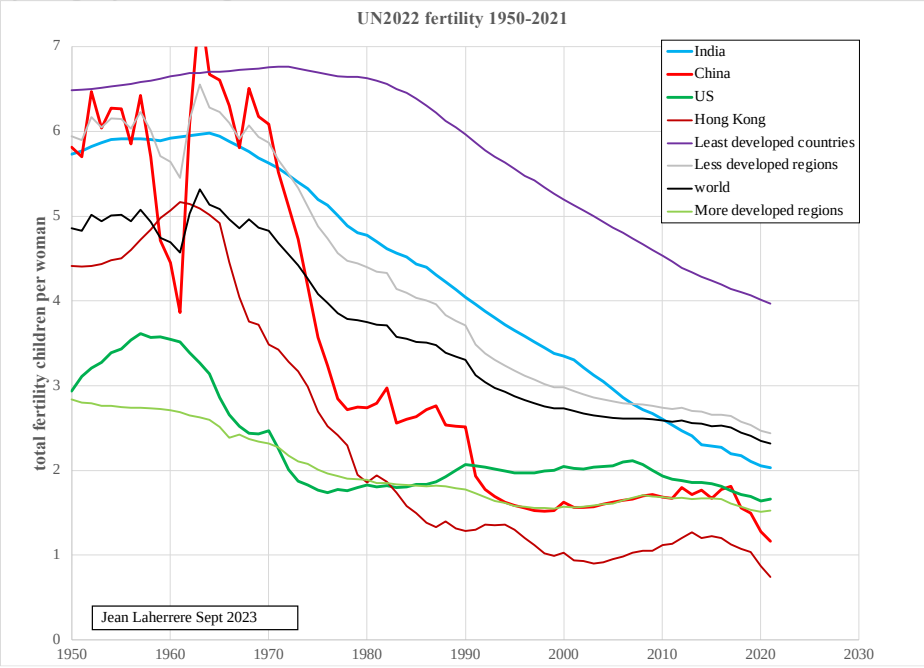
HL of China steel production trends poorly towards 30 Gt



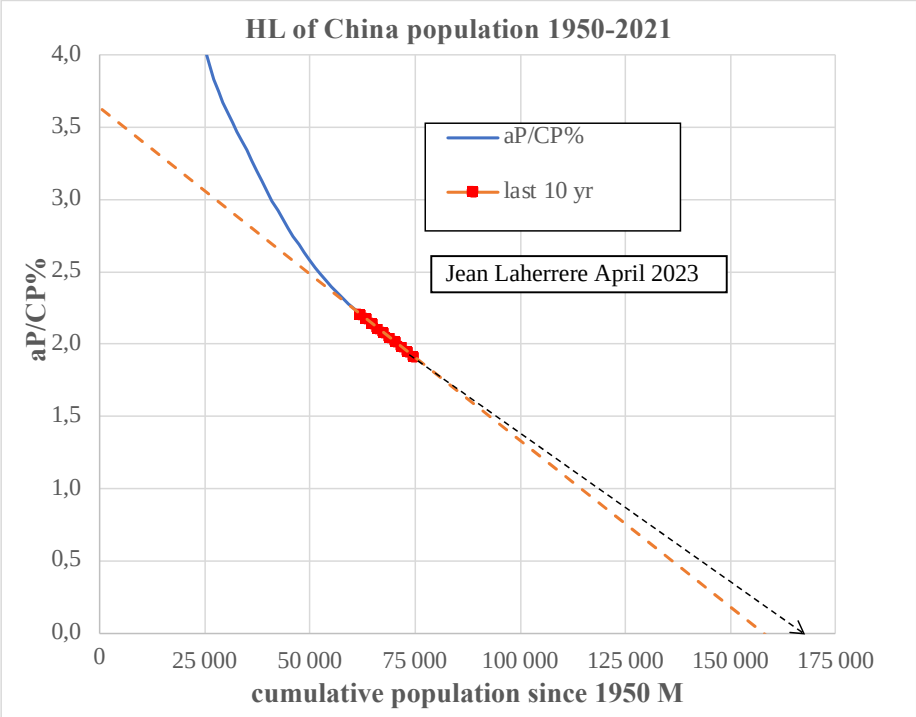
The world steel production forecast is for a peak in 2021: the sharp decline (corresponding to a sharp increase 2000-2020 due to China) looks pessimistic, but China future is doubtful with present Xi Jinping policy (against successful Jack Ma) and declining population since 2020



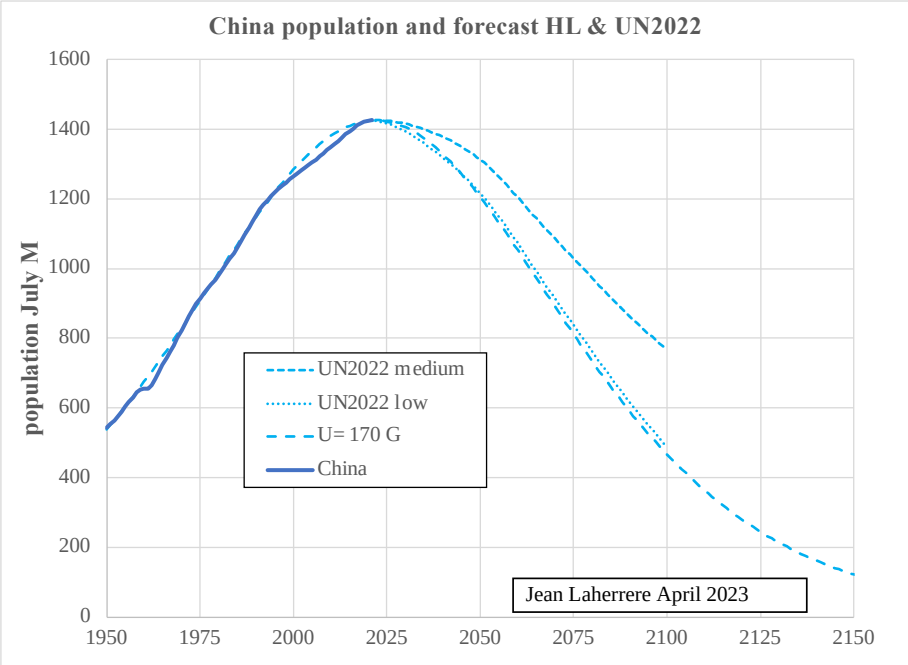
China steel production must be compared with China population and fertility
China fertility displays a sharp decline



HL of China population trends towards 175

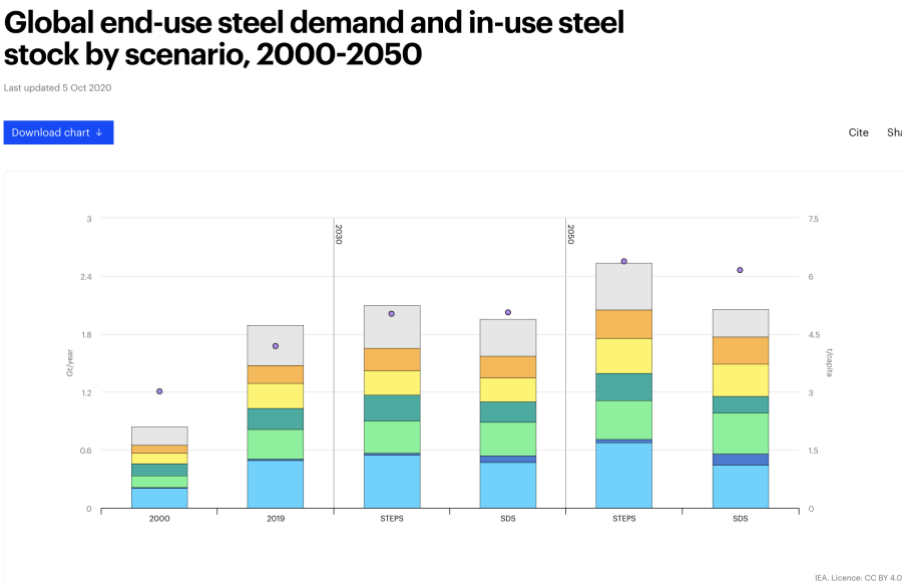


giving a decline in line with UN2022 low fertility scenario



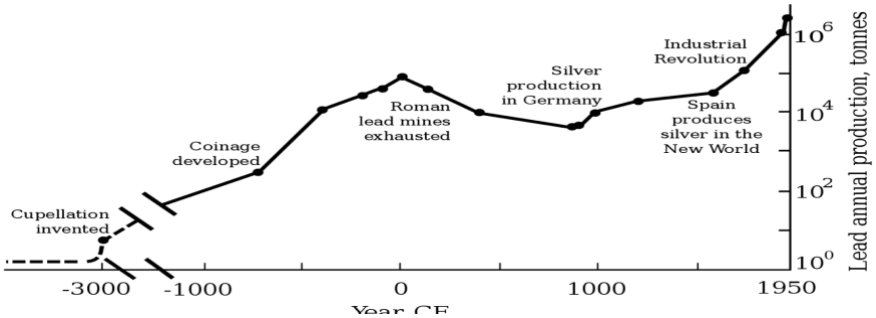
China housing industry is in deep collapse with Evergrande and Country Garden: https://en.wikipedia.org/wiki/Chinese_property_sector_crisis_(2020-present)

IEA 2020 STEPS forecasts global steel demand rising in 2050!

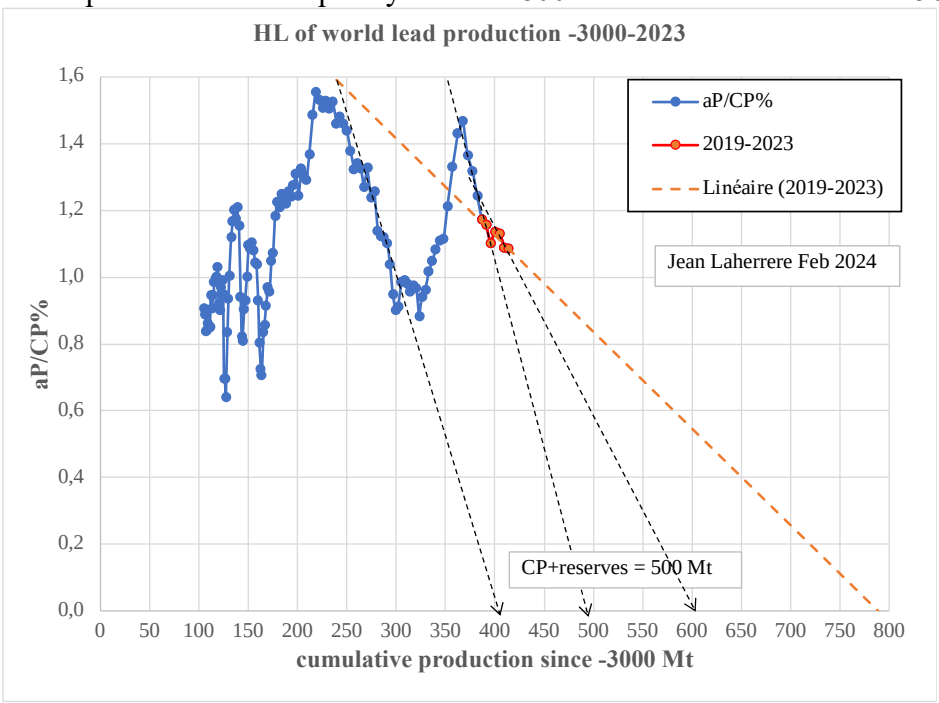


-lead

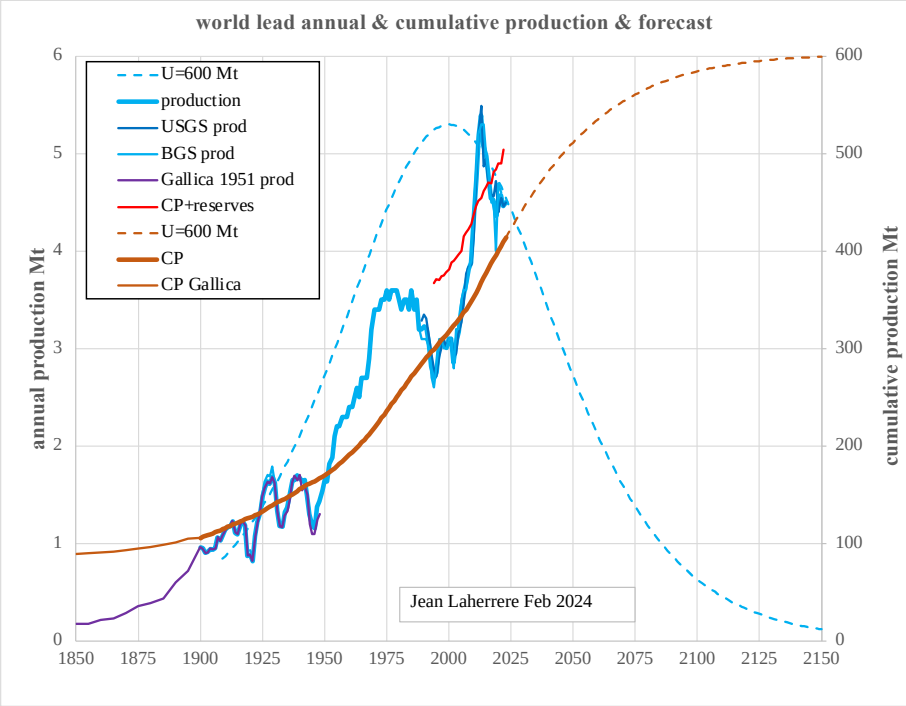
Lead production started 5000 years ago!



HL of world lead production trends poorly towards 800 Mt when CP + reserves at 500 Mt

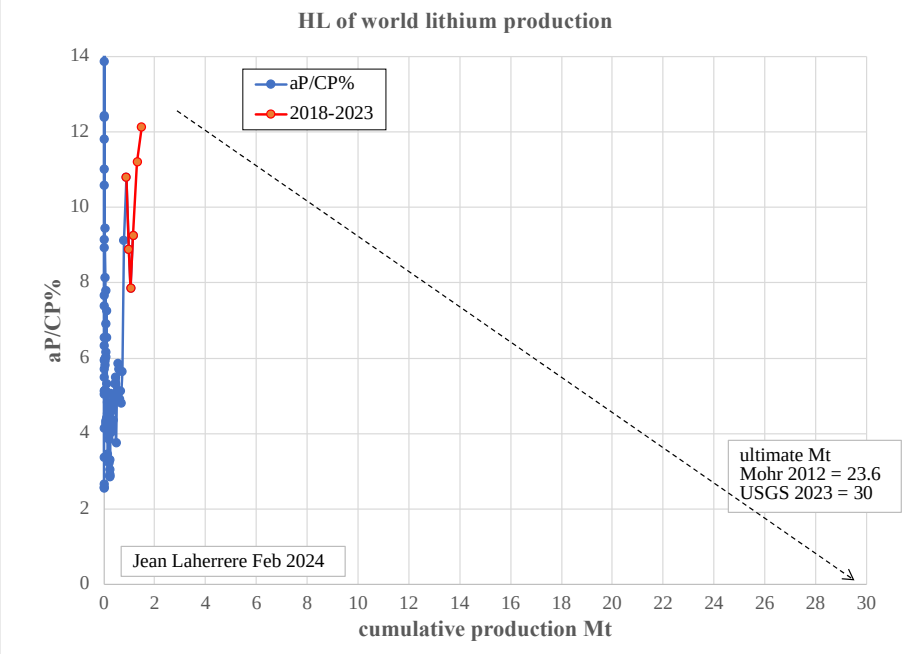


An ultimate of 600 Mt is chosen, giving a peak in 2013

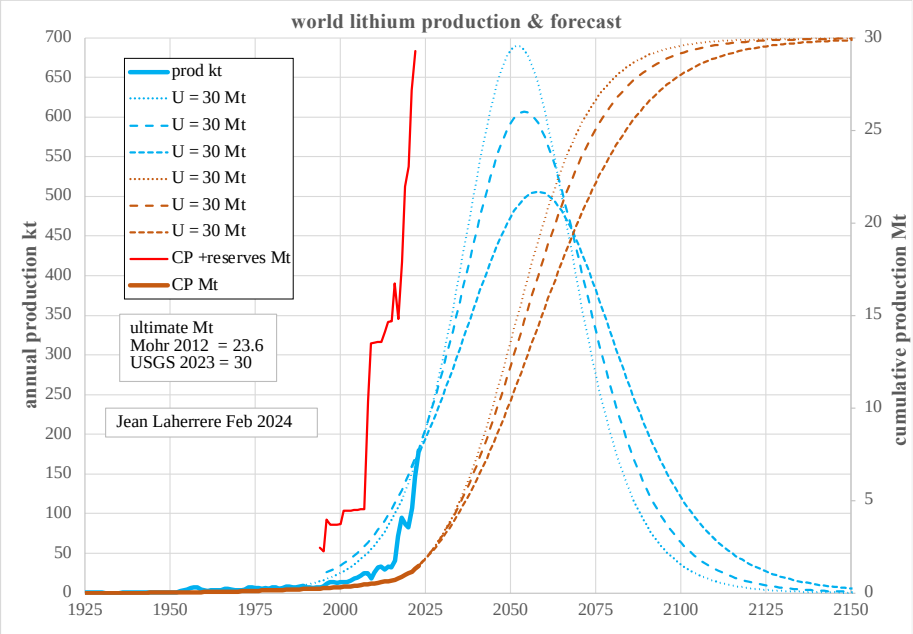


-lithium

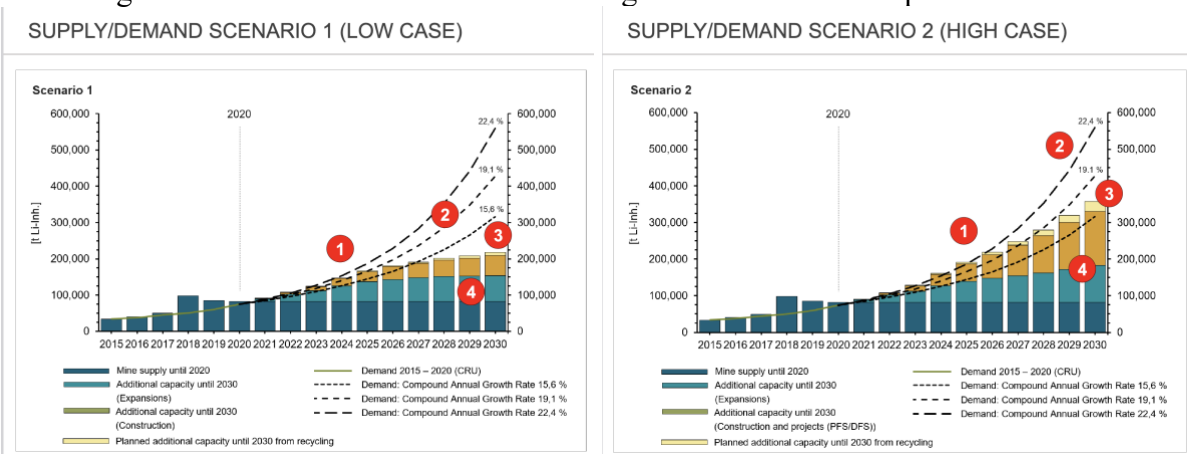
HL of world lithium production is useless, but CP + reserves are about 30 Gt



With a 30 Mt ultimate world lithium production could peak between 2050 and 2060 depending upon the slope of increase



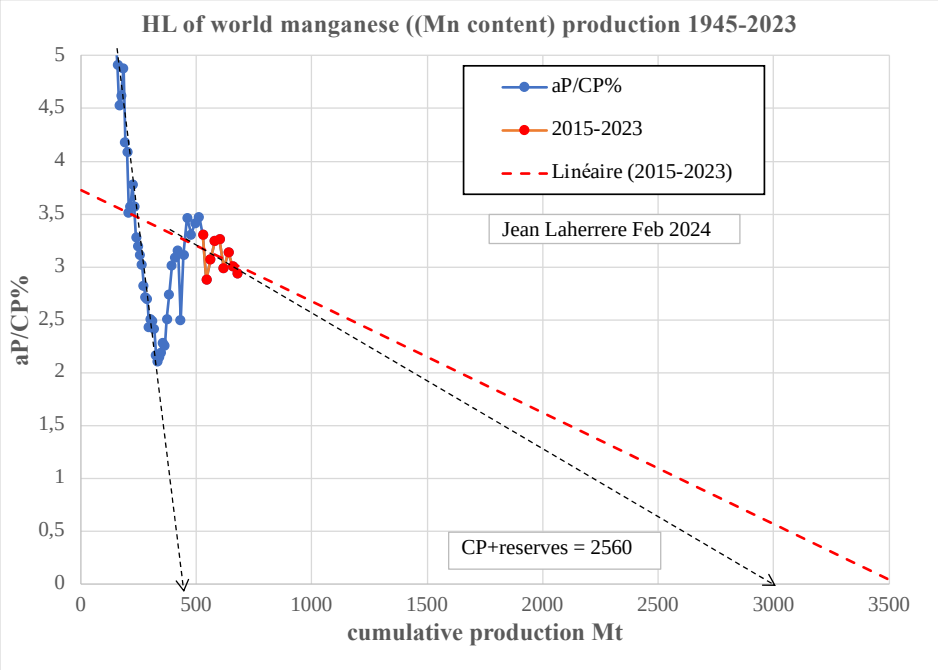
Michael Schmidt Deutsche Rohstoffagentur (DERA) in der Bundesanstalt für Geowissenschaften und Rohstoffe https://www.deutsche-rohstoffagentur.de/DERA/DE/Downloads/vortrag-lithium-schmidt-22.pdf



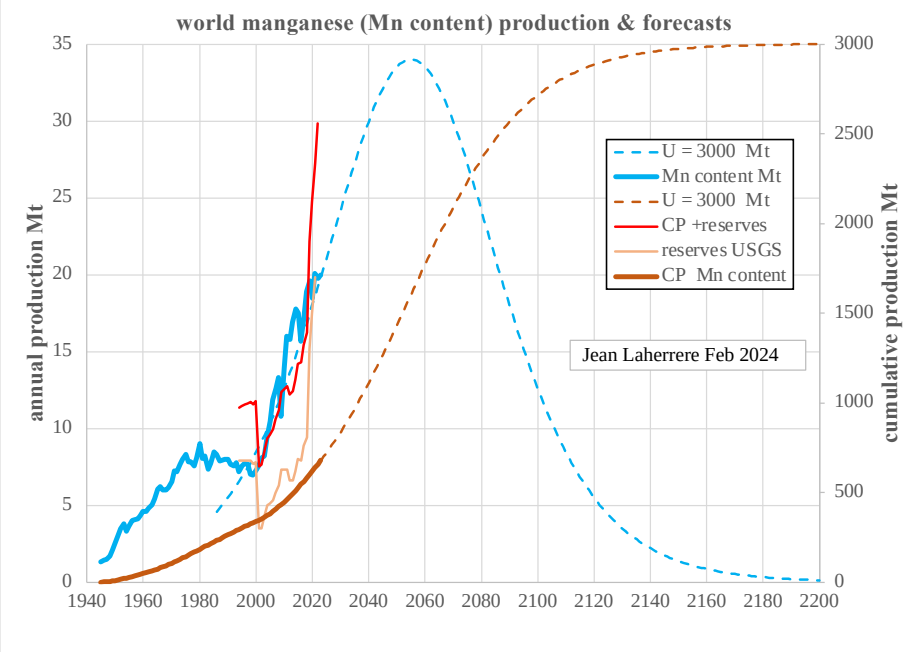
Nature reports today that a new calcium-oxygen battery could replace the lithium-ion battery, being cheaper. This new battery could remove the pressure on Li future production.

-manganese = Mn

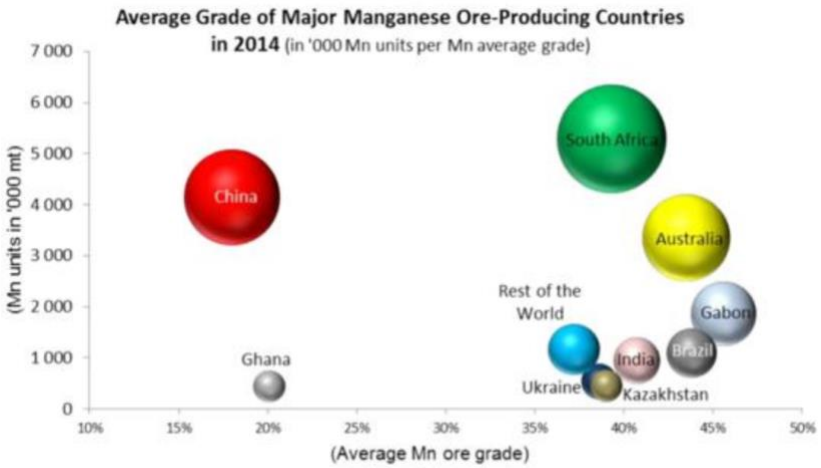
HL of world manganese production trends towards 3500 Mt when CP = reserves are at 2560 Mt



A 3000 Mt ultimate gives a peak around 2050 at 35 Mt



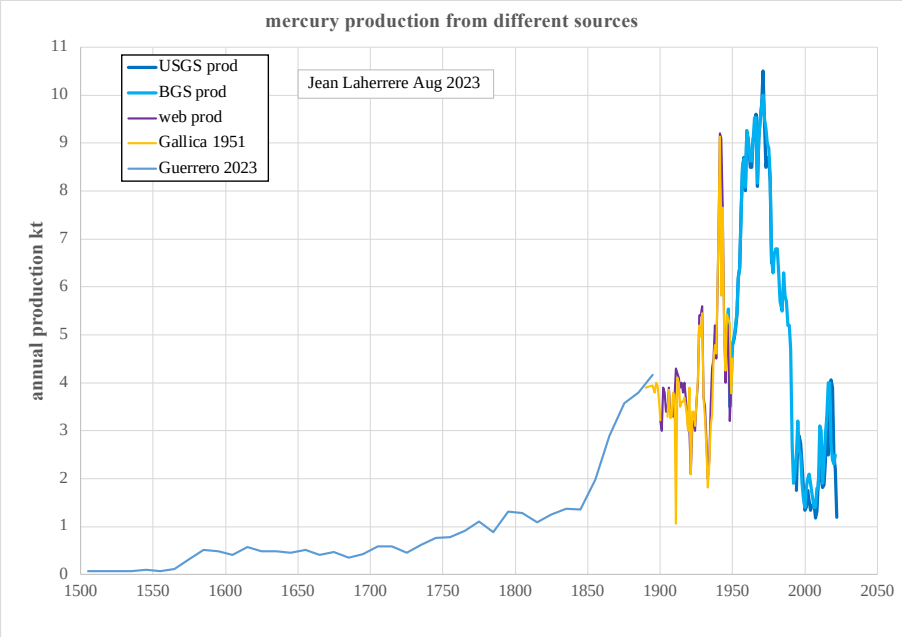
In 2014 Mn grades and reserves vary a lot within countries:



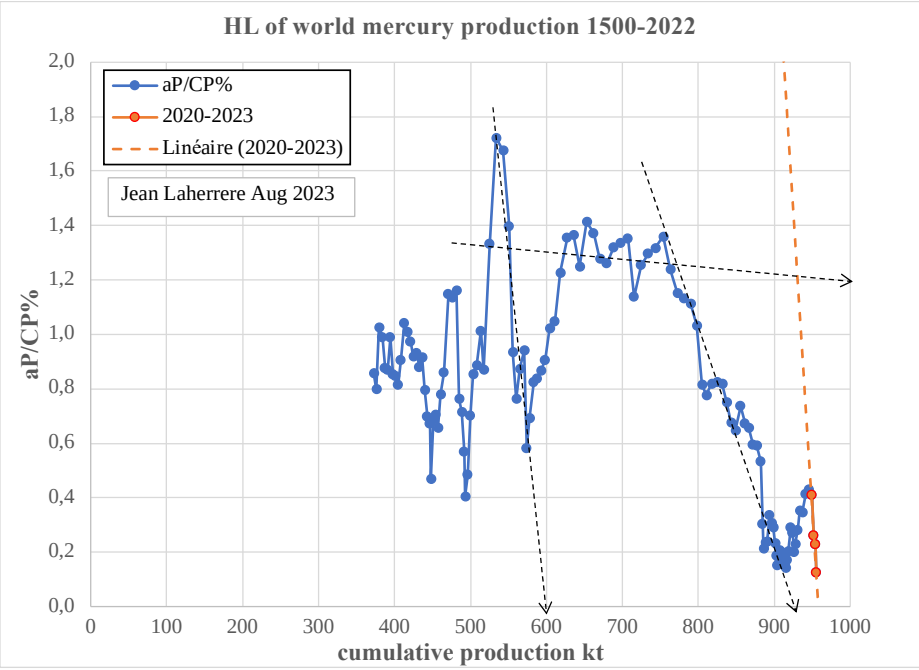
(Source: Manganese.org)

-mercury

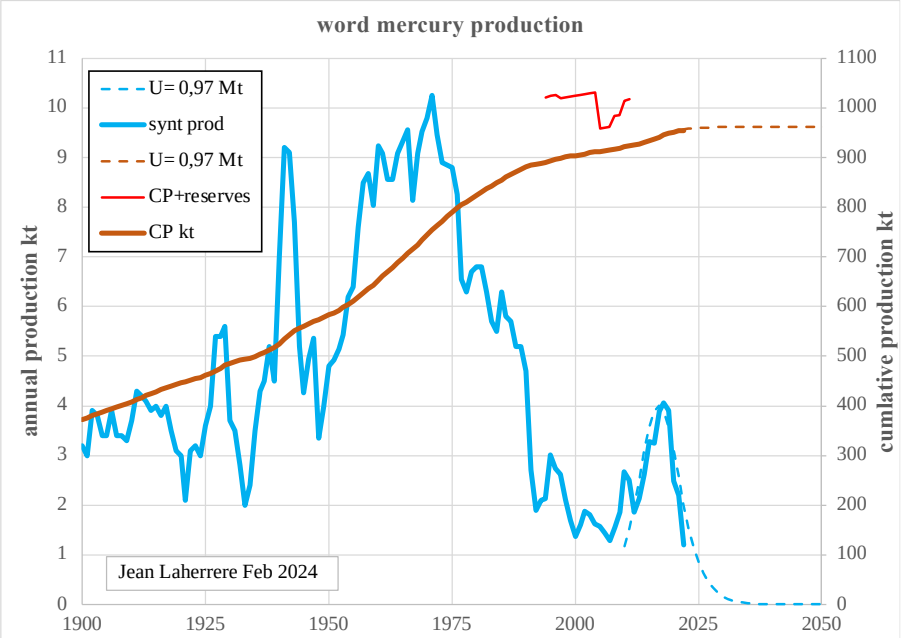
Mercury production is reported since 1500



HL of mercury production trends fairly towards 650 kt

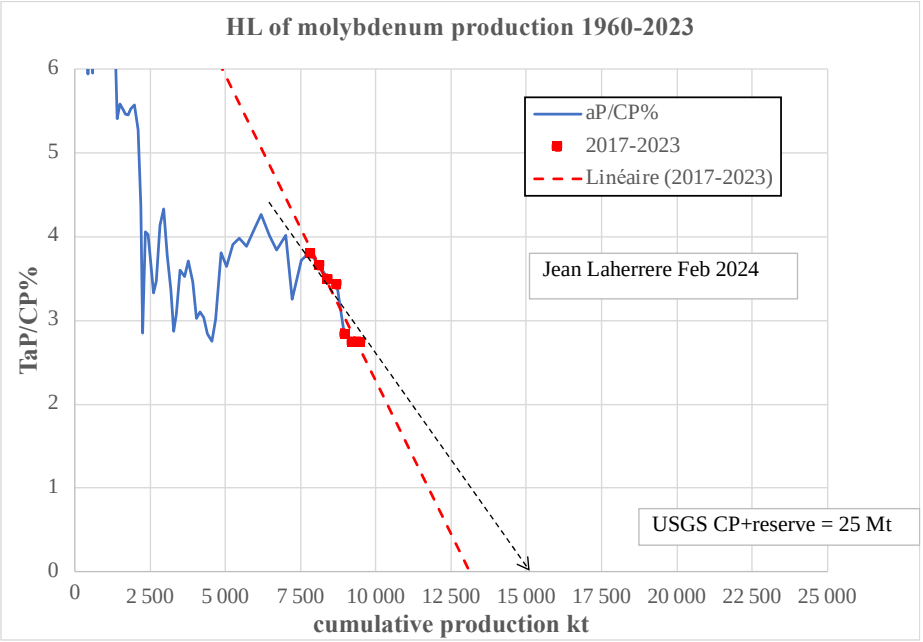


World mercury production peaked in 1971 and after a minor peak in 2019 looks to decline towards its end because its toxicity despite its use in gold mining when often illegal

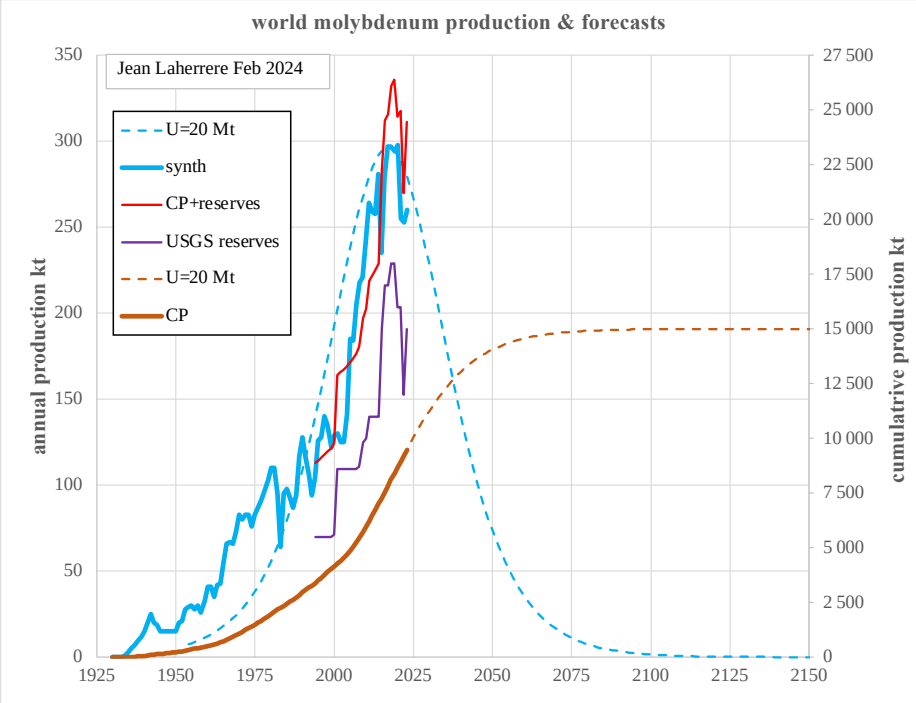


-molybdenum = Mo

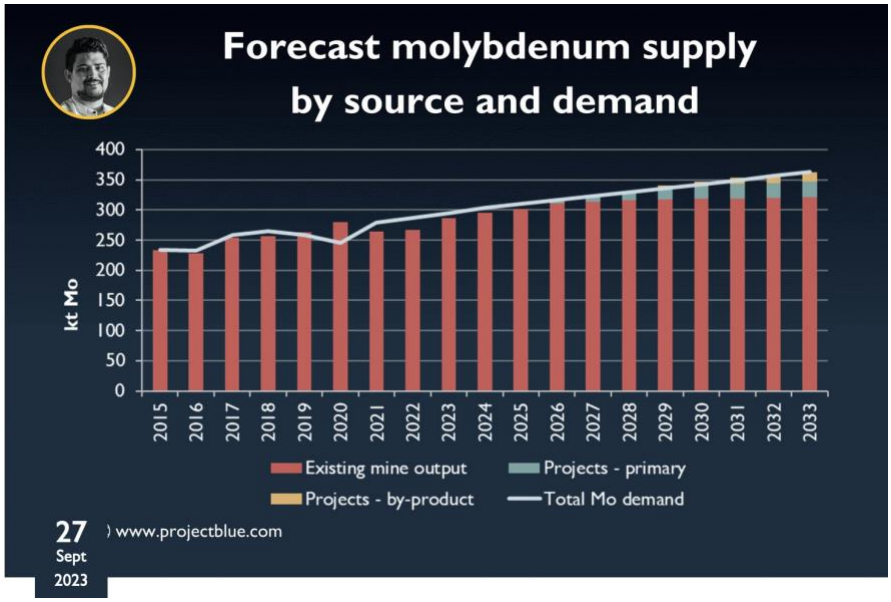
HL of world Mo production trends fairly towards 13 Mt but CP +reserves are 25 Mt (decreasing largely in China!) with China the main producer



A 20 Mt ultimate is chosen giving a peak in 2020

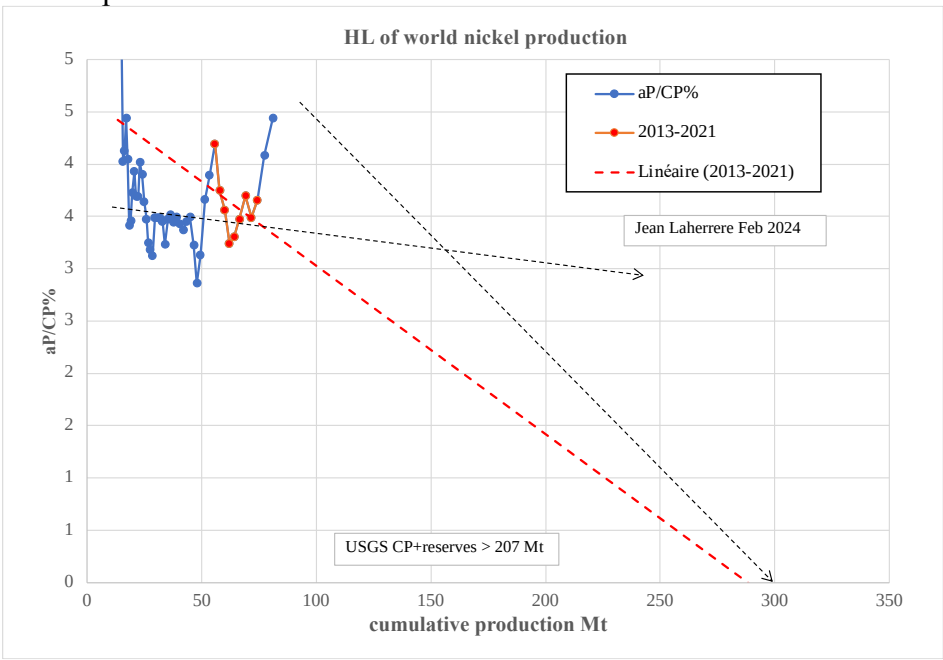


This forecast from projectblue.com is more optimistic, with a peak beyond 2033

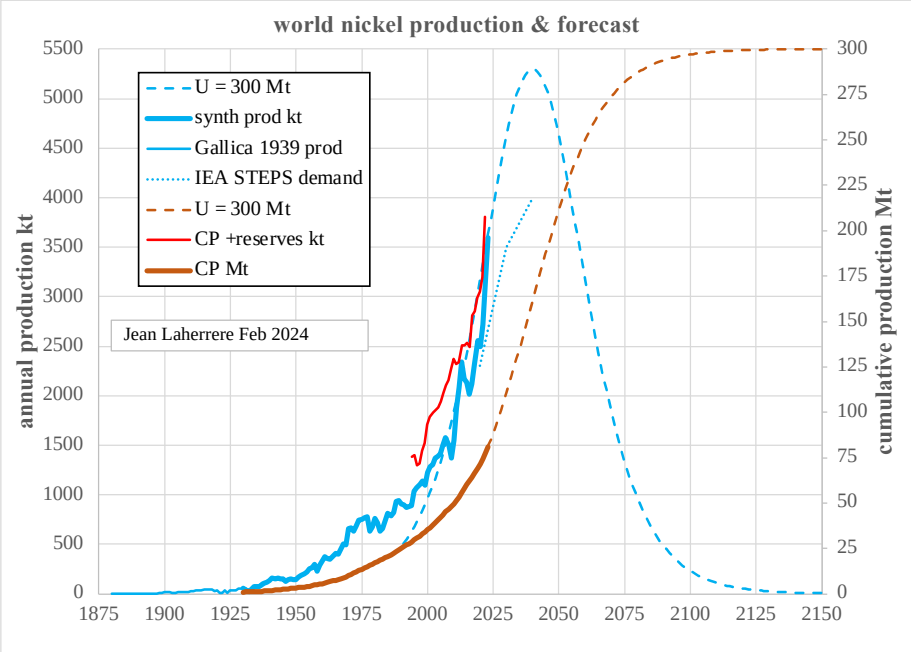


-nickel

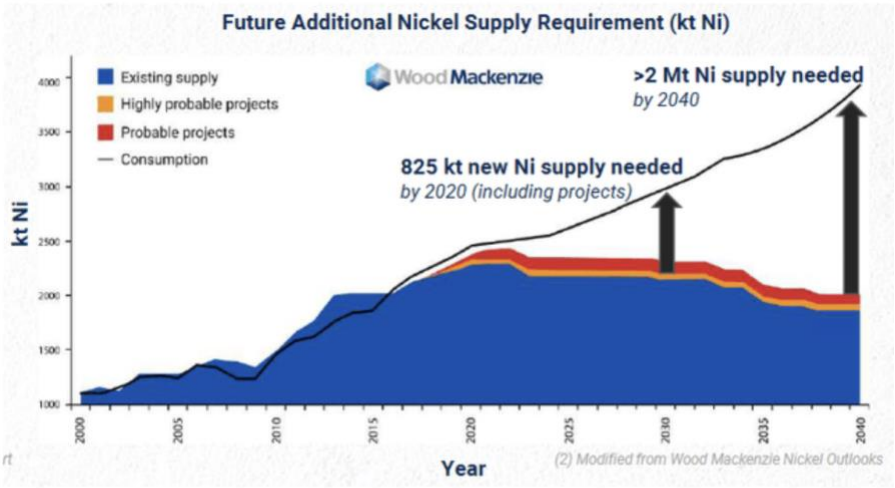
HL of world nickel production is useless when CP + reserves are over 207 Mt



A 300 Mt ultimate is chosen giving a peak around 2040 at 5300 kt



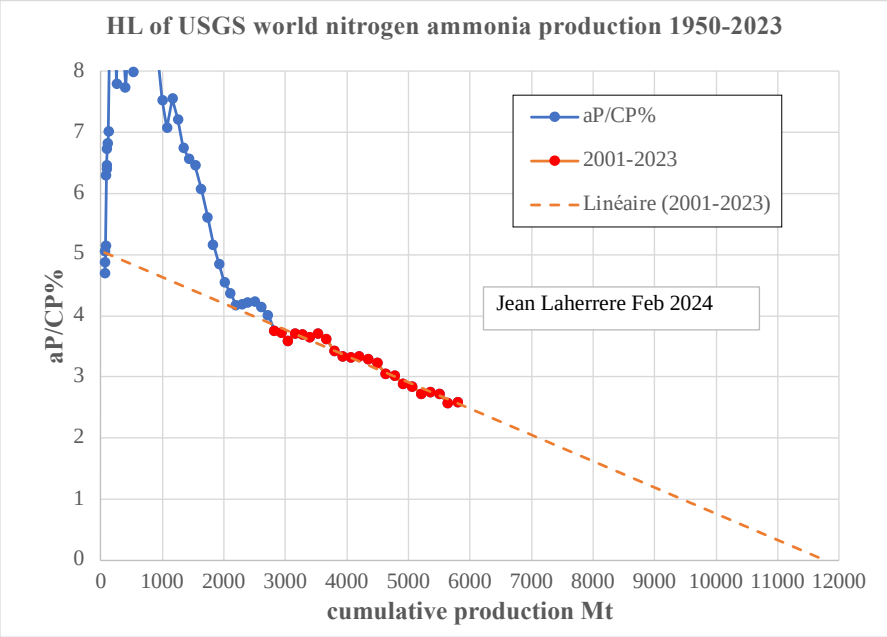
The 2021 forecast looks too pessimistic for supply versus demand



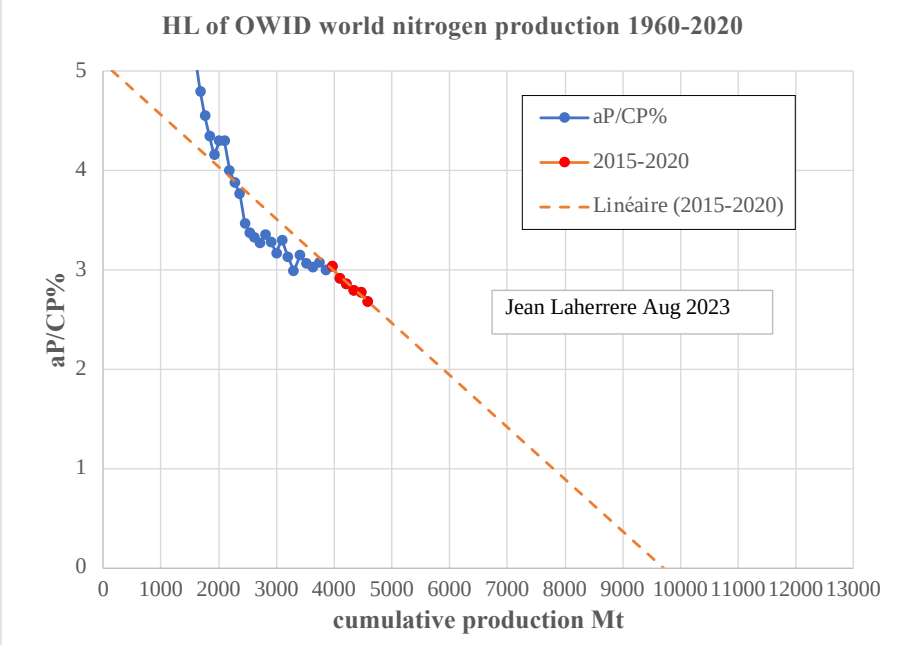
Source: Garibaldi Resources March 2021 presentation and courtesy of Wood Mackenzie

-nitrogen (N not a metal)

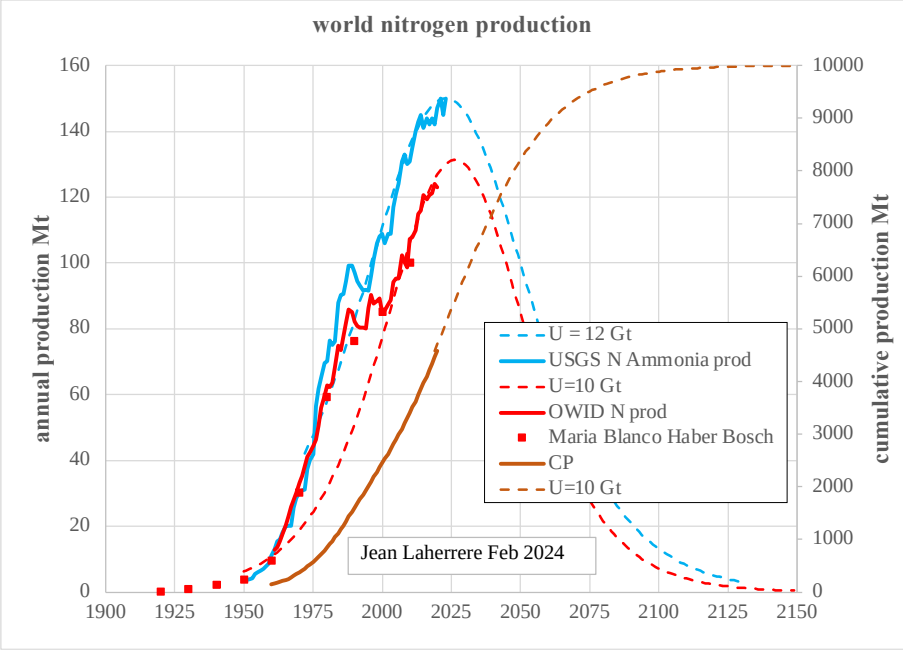
HL of USGS world nitrogen ammonia production trends with a good quality towards 12 Gt



HL of OWID (our world in data) nitrogen production trends towards 10 Gt



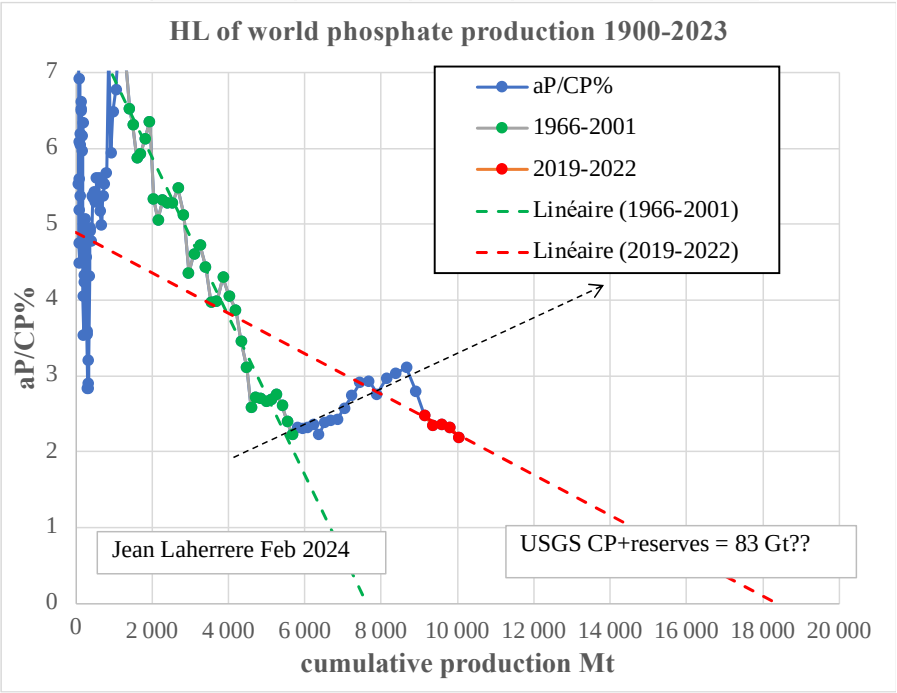
This 12 Gt ultimate means a peak in 2025 for UGS data as the 10 Gt ultimate for OWID data

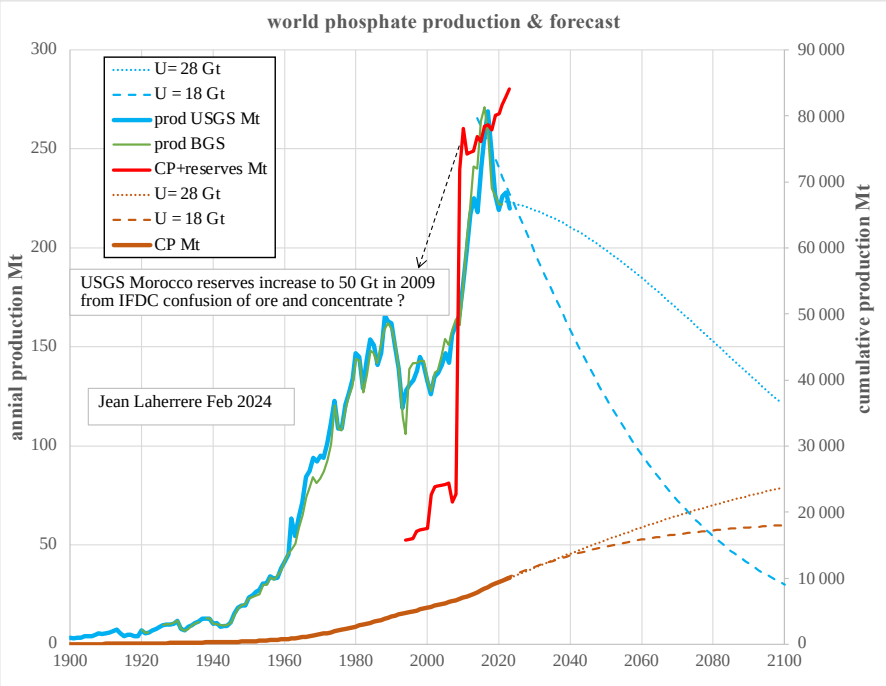


-phosphate (P not a metal)

HL of phosphate production trends fairly towards 18 Gt when CP +reserves are 83 Gt, but USGS has increased in 2009 Morocco reserves by 50 Gt (70% of the world) when its production was only 16% of the world

2019	prod Mt	%	reserves Gt	%
world	227	100	71	100
China	95	42	3,2	5
Morocco	35,5	16	50	70
US	23,3	10	2,2	3
Russia	13,1	6	1,4	2
Jordan	9,2	4	0,6	1
Saudi Arabia	6,5	3	1,4	2





USGS 2022 phosphate remaining reserves look too high for Morocco (50 Gt) with 68 % (50/74) of the world reserves when the production is only 17 % (39/228)

World Mine Production and Reserves: Reserves for China, India, Russia, and Turkey were revised based on Government reports. Reserves for South Africa were revised based on company reports.

	Mine production		Reserves[4]
	2022	2023[e]	
United States	[e]19,800	20,000	1,000,000
Algeria	[e]1,800	1,800	2,200,000
Australia	[e]2,500	2,500	[5]1,100,000
Brazil	[e]6,200	5,300	1,600,000
China[6]	[e]93,000	90,000	3,800,000
Egypt	[e]5,000	4,800	2,800,000
Finland	923	950	1,000,000
India	[e]1,740	1,500	31,000
Israel	2,170	2,500	60,000
Jordan	11,300	12,000	1,000,000
Kazakhstan	[e]1,500	2,000	260,000
Mexico	442	500	30,000
Morocco	39,000	35,000	50,000,000
Peru	4,200	4,200	210,000
Russia	[e]14,000	14,000	2,400,000
Saudi Arabia	[e]9,000	8,500	1,400,000
Senegal	[e]2,600	2,500	50,000
South Africa	1,990	1,600	1,500,000
Syria	[e]1,100	800	250,000
Togo	[e]1,500	1,500	30,000
Tunisia	3,560	3,600	2,500,000
Turkey	[e]900	800	71,000
Uzbekistan	[e]900	900	100,000
Vietnam	[e]2,000	2,000	30,000
Other countries	750	800	800,000
World total (rounded)	228,000	220,000	74,000,000

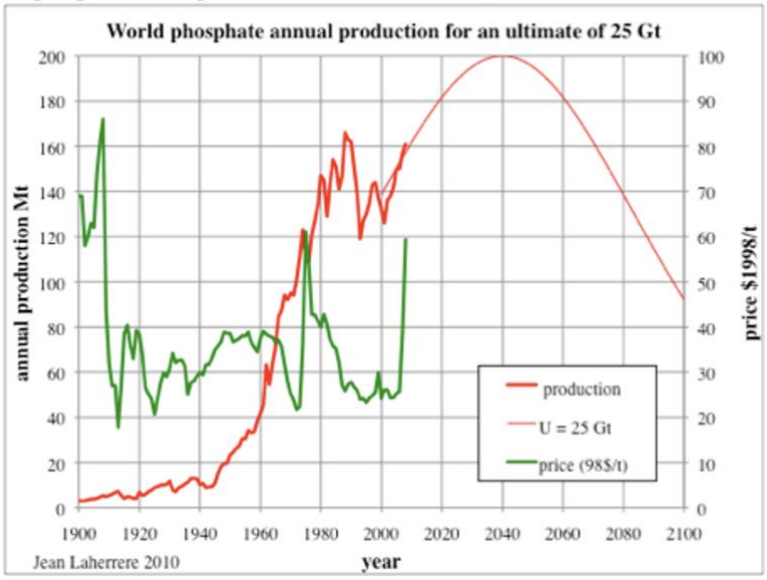
J.D. Edixhoven et al. « Recent revisions of phosphate rock reserves and resources: a critique" (2014) challenges USGS Morocco reserves (from the International Fertilizer Development Center IFDC) with a confusion between PR ore and PR concentrate
However, USGS keeps reporting high Morocco phosphate reserves at the same high level of 50 Gt for 15 years, far from the world production percentage: it is hard to understand why such negligence!

In 2010 my paper “Peaks in Argentina, Latin America and the world” http://aspofrance.viabloga.com/files/JL_BsAs-long.pdf forecasted an ultimate of 25 Gt and a peak around 2040: I was too optimistic:

-Phosphate peak

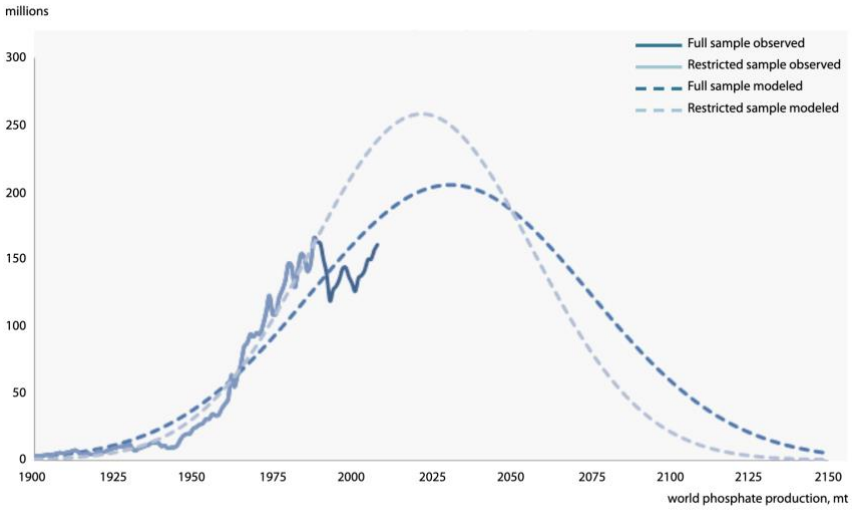
Phosphate is an important mineral for agriculture and its production will peak around 2040

Figure 69: world phosphate annual production & forecast U=25 Gt



In 2011 this paper “Applying Hubbert Curves and Linearization to Rock Phosphate” Cullen S. Hendrix, College of William & Mary, Peterson Institute for International Economics https://www.piie.com/sites/default/files/publications/wp/wp11-18.pdf forecasted world phosphate production in 2025: this forecast was not too far from reality, much better than my 2010 forecast

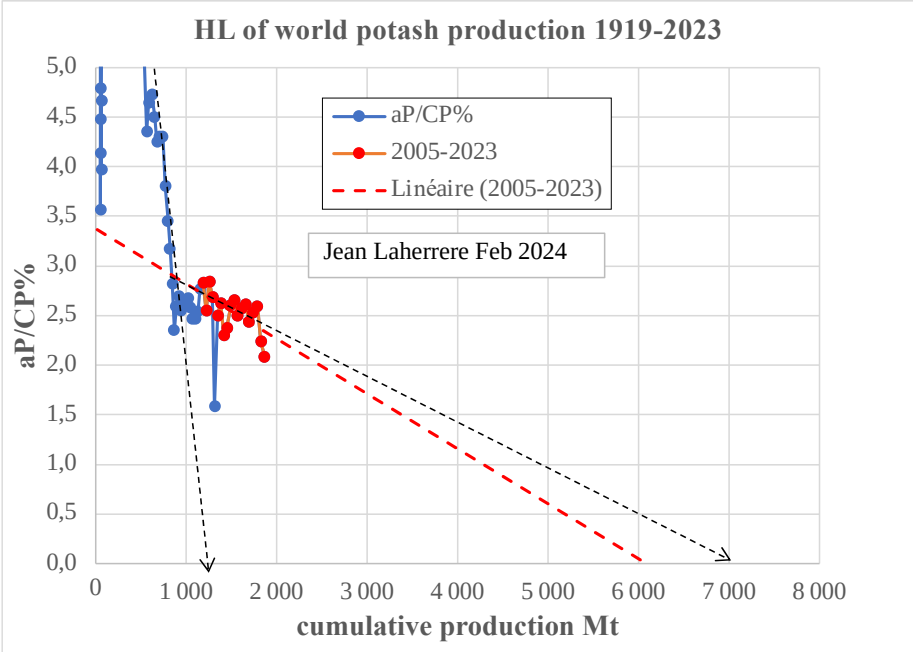
Figure 1 Hubbert curves for world rock phosphate production, 1990–2008



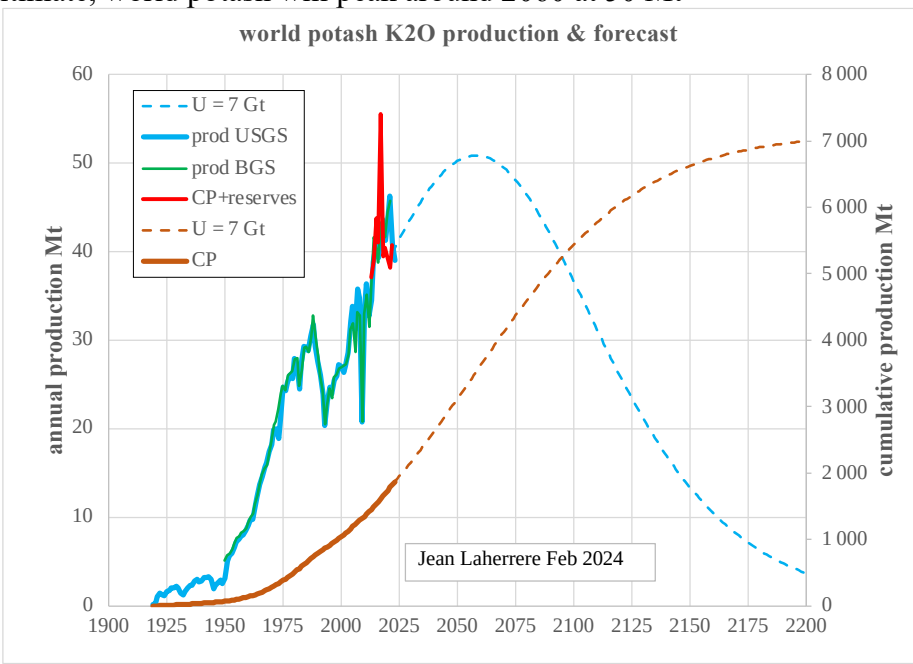
Source: Author's calculations based on USGS estimates (2010).

-potash = K2O

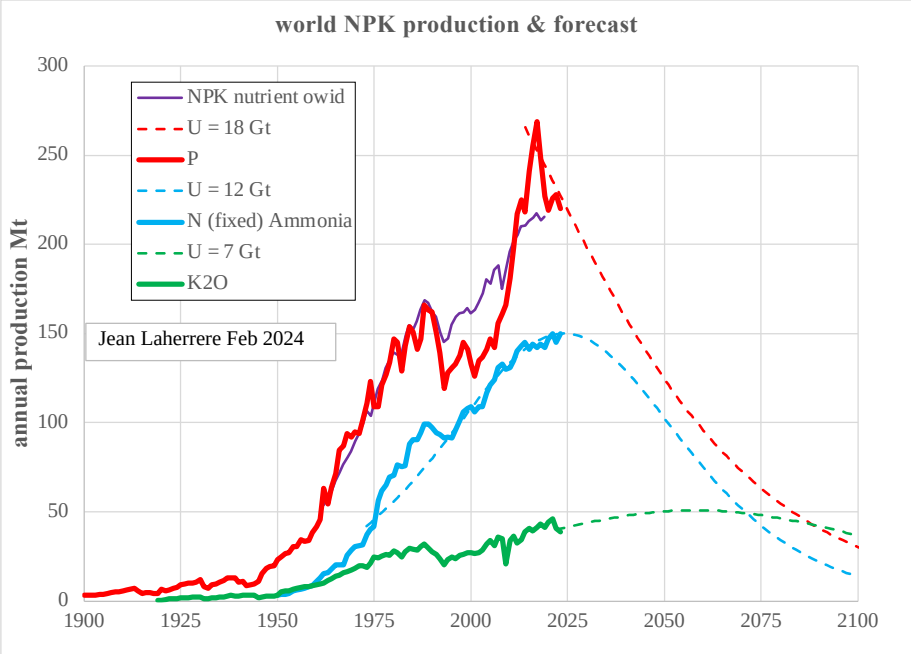
HL of world potash production trends poorly towards 6 Gt and a 7 Gt ultimate is chosen



With 7 Gt ultimate, world potash will peak around 2060 at 50 Mt



Fertilizers use a combination of NPK: unfortunately, P and N will decline soon when K will peak much later



-platinum

USGS reports more PGM (platinum group metal) production than platinum and palladium data and only PGM reserves. The six platinum group metals are iridium, osmium, palladium, platinum, rhodium, and ruthenium,

World Mine Production and Reserves: Reserves for the United States were revised based on company reports.

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2022	2023[e]	2022	2023[e]	
United States	10,100	9,800	3,000	2,900	820,000
Canada	16,100	16,000	5,400	5,500	310,000
Russia[e]	87,000	92,000	20,000	23,000	5,500,000
South Africa	73,100	71,000	124,000	120,000	63,000,000
Zimbabwe	14,300	15,000	17,000	19,000	1,200,000
Other countries	2,700	2,700	4,580	4,600	NA
World total (rounded)	203,000	210,000	174,000	180,000	71,000,000

In 2002 (USGS open file 2004-1224 Platinum-Group Metals—World Supply and Demand By David R. Wilburn and Donald I. Bleiwas) PGM reserves (economically extracted or produced at the time of determination) were 14 000 kt when USGS regular annual report were 71 000 kt U.S. Geological Survey Open-File Report 2004-1224

Table 1. Estimates of 2002 platinum-group metal reserves and reserve base [kilograms]

Location[2]	Reserve	Reserve base
Canada……..	400,000	910,000
Russia……...	NA[3]	6,100,000
South Africa…….	12,000,000	34,000,000
United States……	780,000	900,000
Zimbabwe…….	530,000	5,300,000
Other areas……	NA[3]	380,000
World total……..	14,000,000[4]	48,000,000[4]

USGS 2003 commodity reports

World Mine Production, Reserves, and Reserve Base:

	Mine production				PGM	
	Platinum		Palladium		Reserves[5]	Reserve base[5]
	2002	2003[e]	2002	2003[e]		
United States	4,390	4,100	14,800	14,600	900,000	2,000,000
Canada	7,000	7,000	11,500	11,000	310,000	390,000
Russia	35,000	36,000	84,000	74,000	6,200,000	6,600,000
South Africa	134,000	135,000	64,000	64,800	63,000,000	70,000,000
Other countries	3,400	5,000	6,900	7,000	800,000	850,000
World total (rounded)	184,000	187,000	181,000	171,000	71,000,000	80,000,000

This 2017 USGS report: Platinum-Group Elements By Michael L. Zientek, Patricia J. Loferski, Heather L. Parks, Ruth F. Schulte, and Robert R. Seal II https://pubs.usgs.gov/pp/1802/n/pp1802n.pdf reports PGE (platinum group element) resources but added to gold : it is very confusing: why to change PGM in PGE and why adding PGM and gold

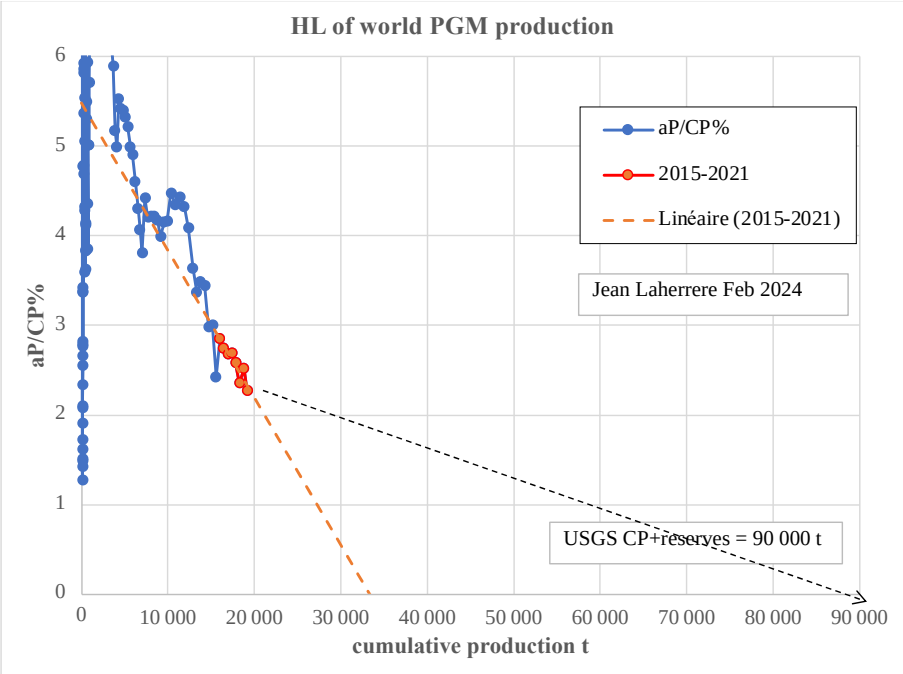
Table N4. Identified platinum-group-element and gold resources, summarized by deposit type and location.

[Data are from table N10 at the end of this chapter. Numbers may not add to totals because of rounding]

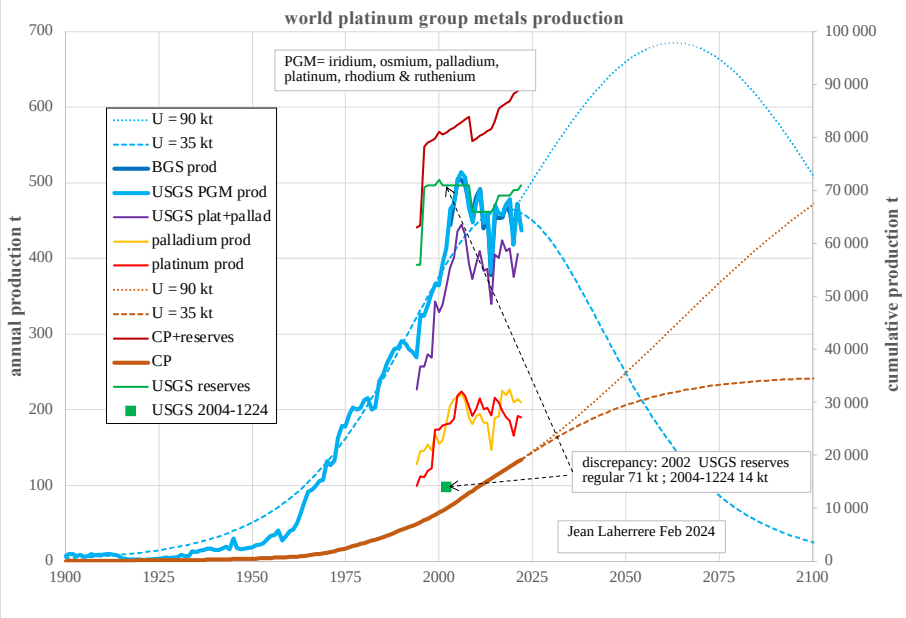
Deposit type	Deposit	PGE and gold resources compiled for this chapter (metric tons)	PGE and gold resources compiled by Mudd, 2012 (metric tons)
Reef	Merensky Reef and UG2 Chromitite, Bushveld Complex, South Africa	58,000	56,000
	Main Sulphide Zone, Great Dyke, Zimbabwe	8,200	8,700
	J–M Reef, Stillwater Complex, Montana	2,200	620
	Other areas	2,700	1,700
	Total, reef-type deposits	**71,000**	**67,000**
Contact	Platreef, Bushveld Complex, South Africa	17,000	7,700
	Other areas	3,100	1,600
	Total, contact-type deposits	**20,000**	**9,300**
Conduit	Noril'sk-Talnakh area, Russia	10,000	11,000
	Other areas	1,200	2,100
	Total, conduit-type deposits	**11,000**	**13,000**
Other	All other areas	990	1,200
	Grand total, all three types of deposits	**100,000**	**91,000**

It appears that USGS PGM reserves reports could be conflicting!

HL of world PGM production trends fairly towards 35 kt when USGS regular CP + reserves are 90 kt in 2022, but in 2002
Again, as for Morocco phosphate, South Africa (Bushveld Complex) USGS PGM reserves are overestimated with 89 % of the world reserves.

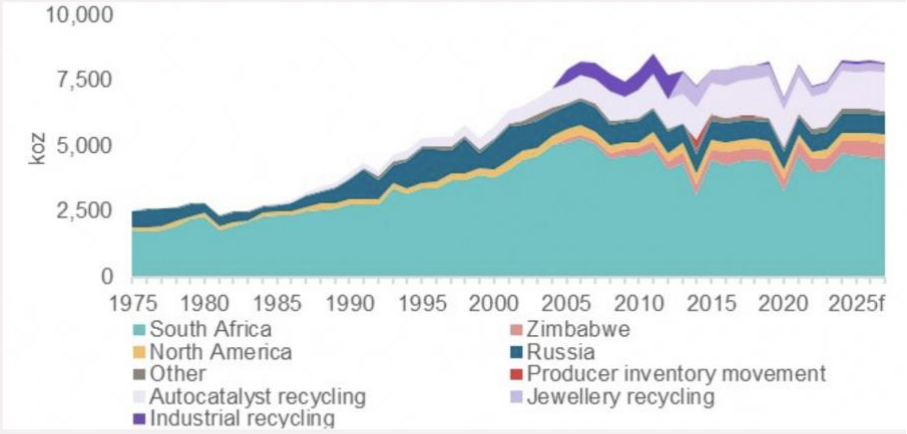


With 35 kt ultimate PGM production has peaked in 2007; with 90kt ultimate PGM will peak around 2060



Platinum production by continent 1975-2025: South Africa peak was in 2007 despite the claim of huge reserves!

Figure 2: Total platinum supply



Source: Johnson Matthey (to 2012) SFA (2013-2018), Metals Focus (2019-2023f), WPIC Research (2024-2027)

USGS 2022 remaining reserves look too high for South Africa with 89 % of world reserves

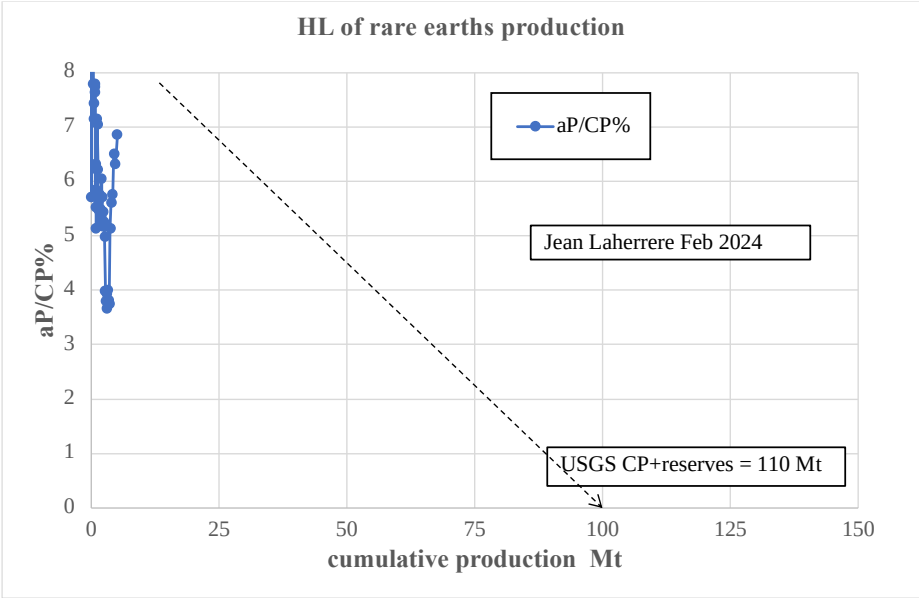
World Mine Production and Reserves: Reserves for the United States were revised based on company reports.

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2022	2023[e]	2022	2023[e]	
United States	10,100	9,800	3,000	2,900	820,000
Canada	16,100	16,000	5,400	5,500	310,000
Russia[e]	87,000	92,000	20,000	23,000	5,500,000
South Africa	73,100	71,000	124,000	120,000	63,000,000
Zimbabwe	14,300	15,000	17,000	19,000	1,200,000
Other countries	2,700	2,700	4,580	4,600	NA
World total (rounded)	203,000	210,000	174,000	180,000	71,000,000

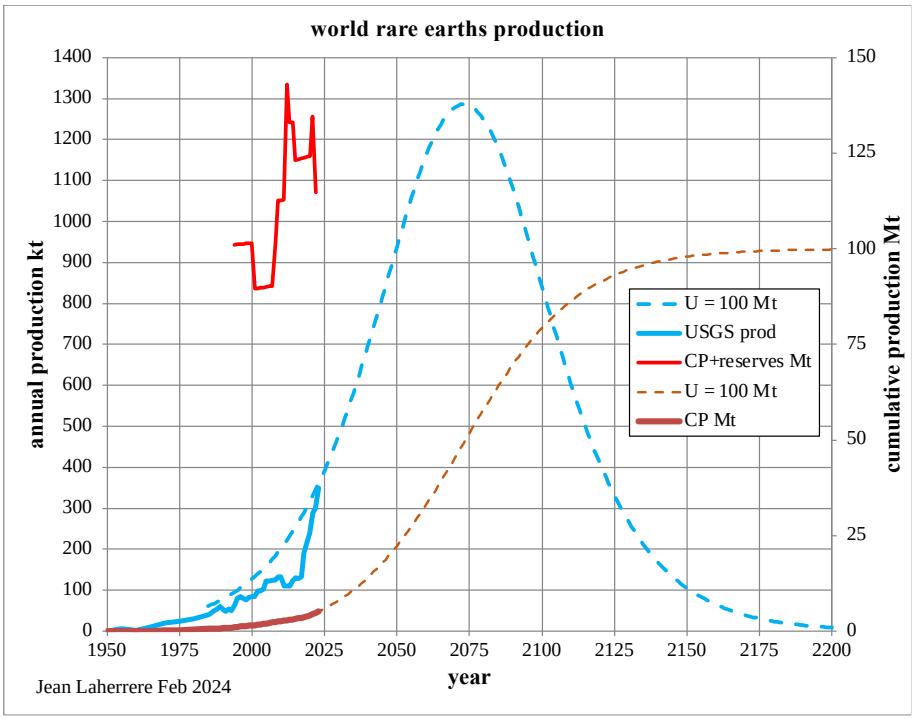
-rare earths

HL of world rare earths production is useless and CP + reserves are declining at 110 Mt: rare earths are not rare!

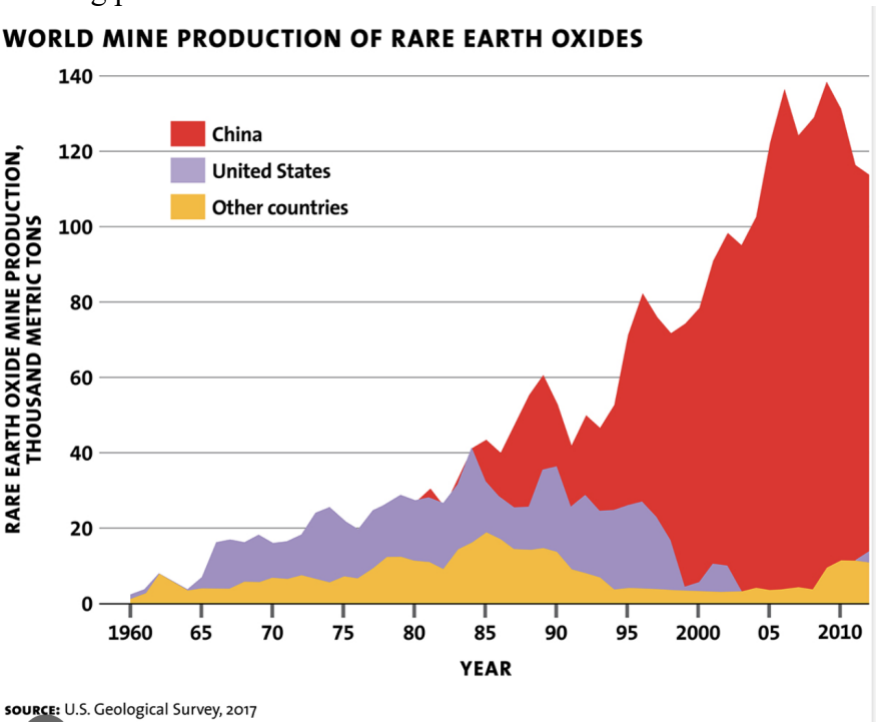
A 100 Mt ultimate is chosen.



With a 100 Mt ultimate, world rare earths productions will peak around 2075 at 1300 kt

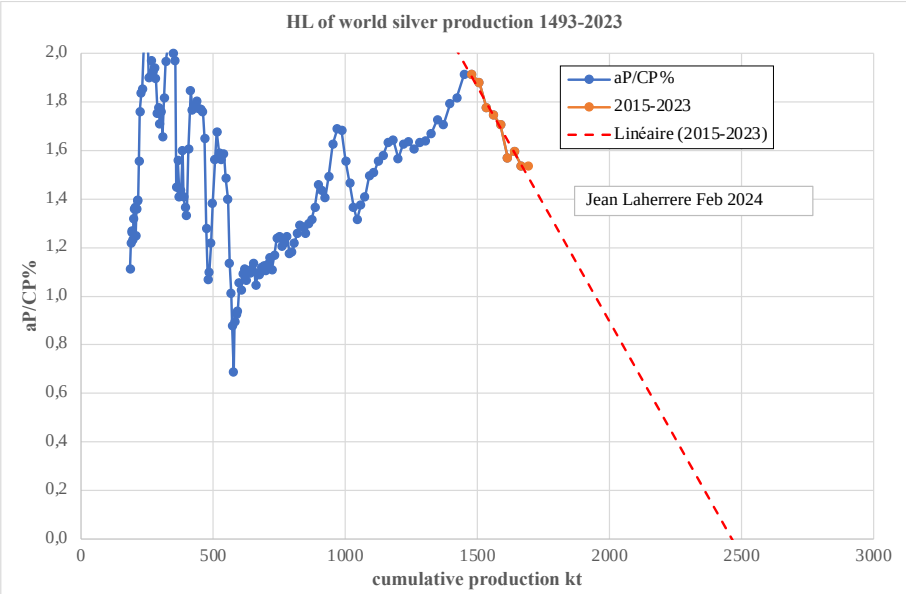


The problem of rare earths is not its resources but the pollution of production.
In the 1980s US was the main producer, but today they prefer to buy rare earths than to produce it, avoiding pollution.

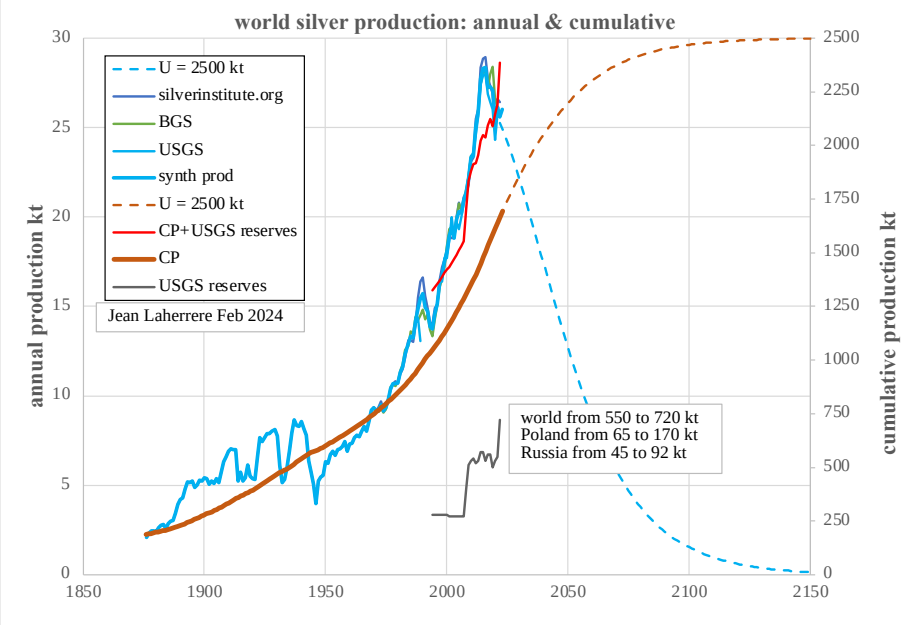


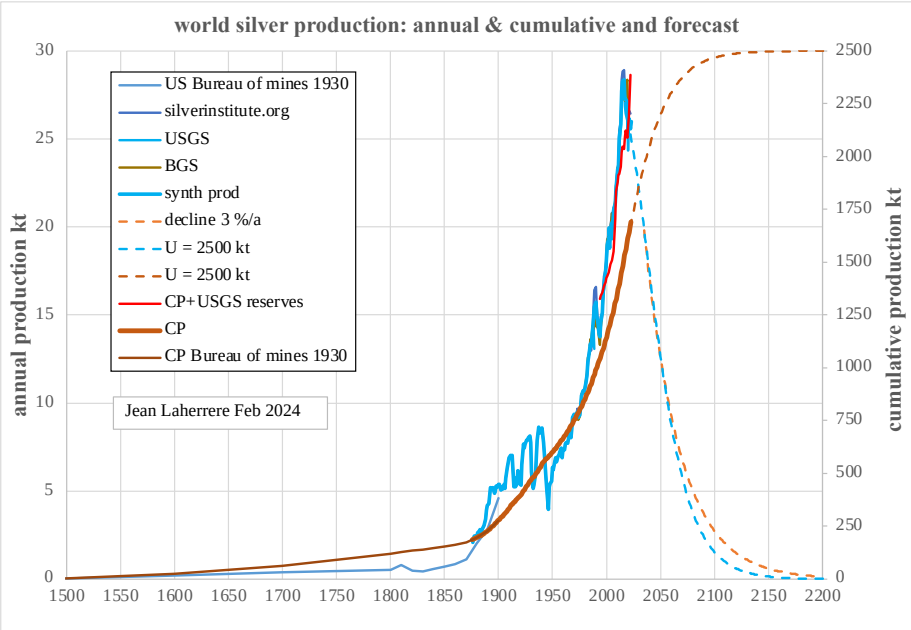
-silver

HL of world silver production trends fairly towards 2500 kt



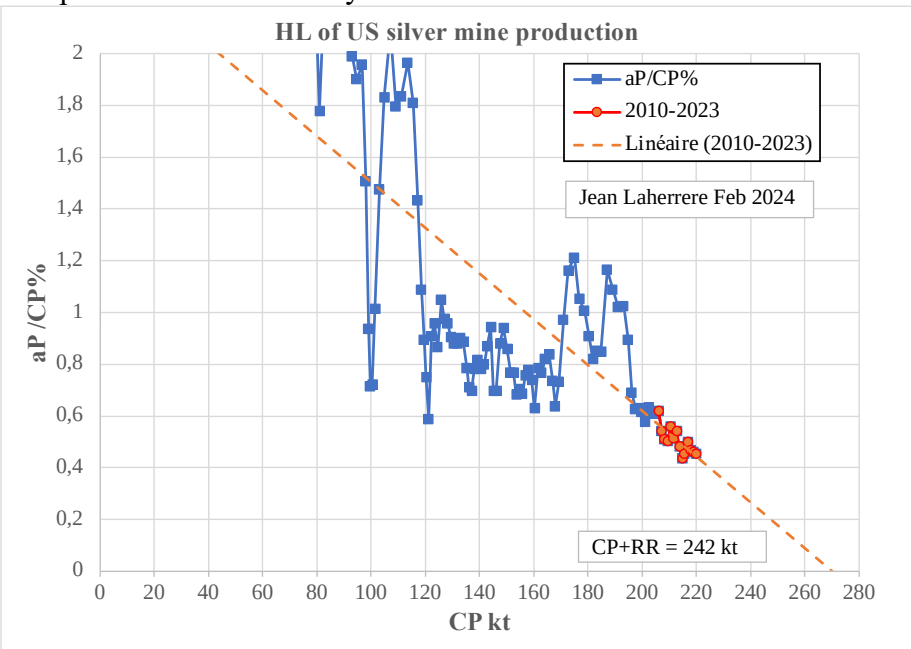
With a 2500 kt ultimate, world silver production has peaked in 2016



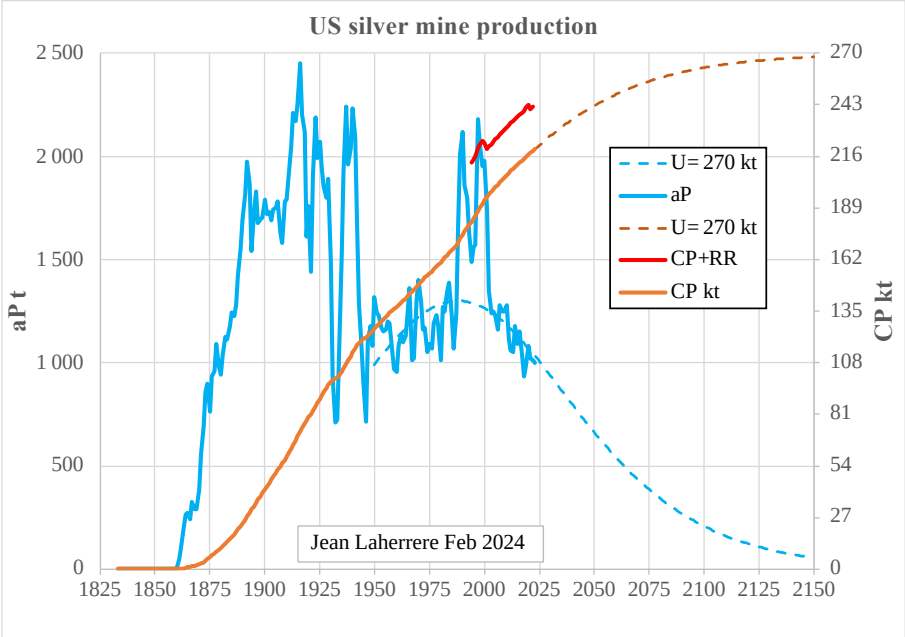


-US silver

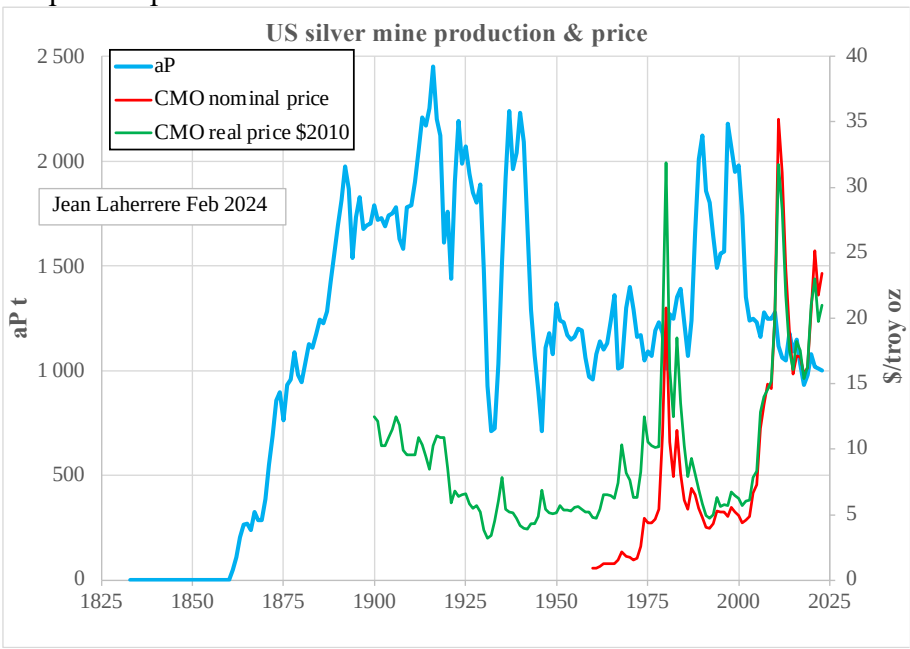
HL of US silver production trends fairly towards 270 kt



With a 270 kt ultimate US silver production has peaked in 1916 and minor peaks in 1990 and 1997: these two peaks look queer.

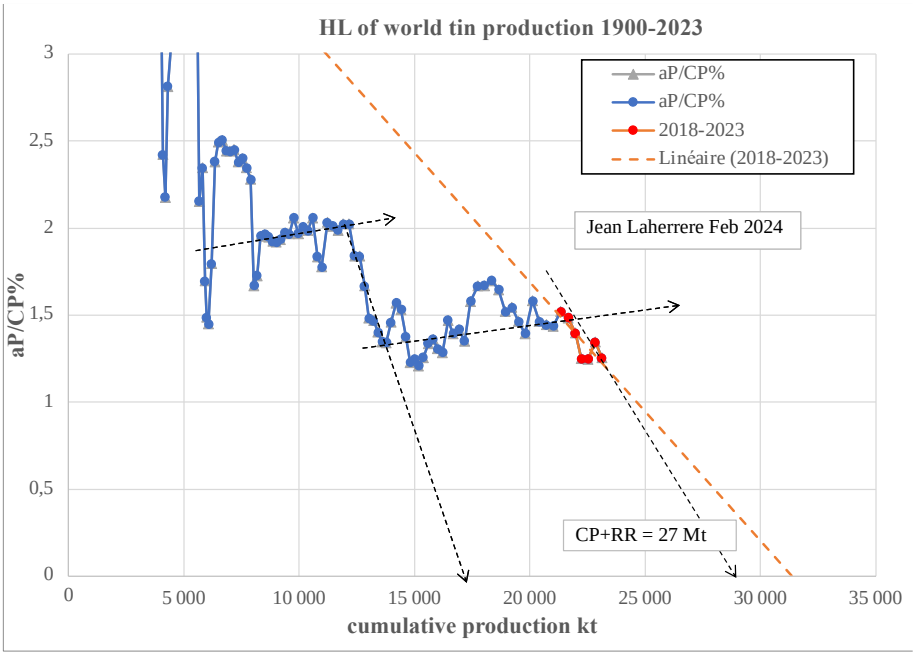


The 1990 production peak is due to a sharp increase in silver price in 1980, but the 2011 peak price had no impact on production

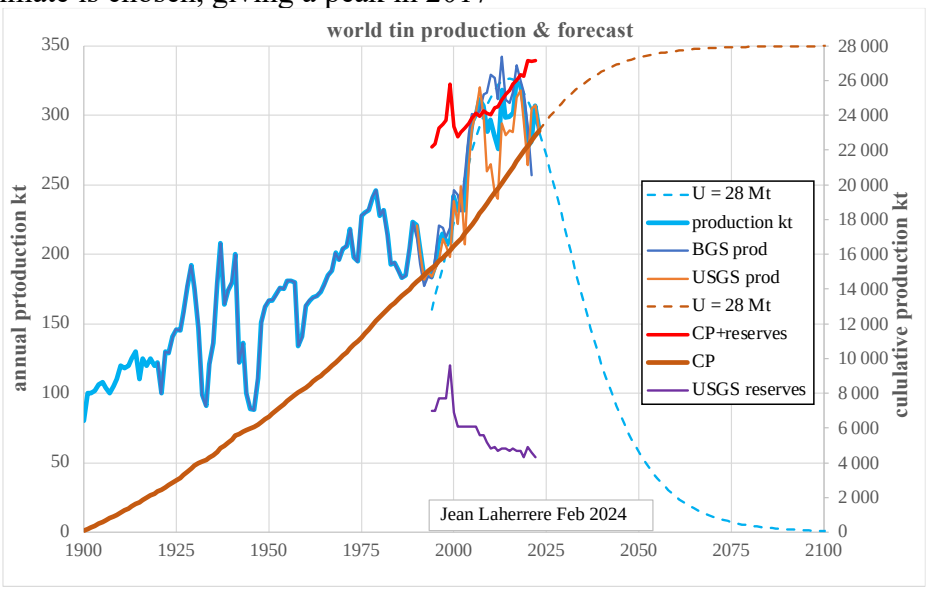


-tin

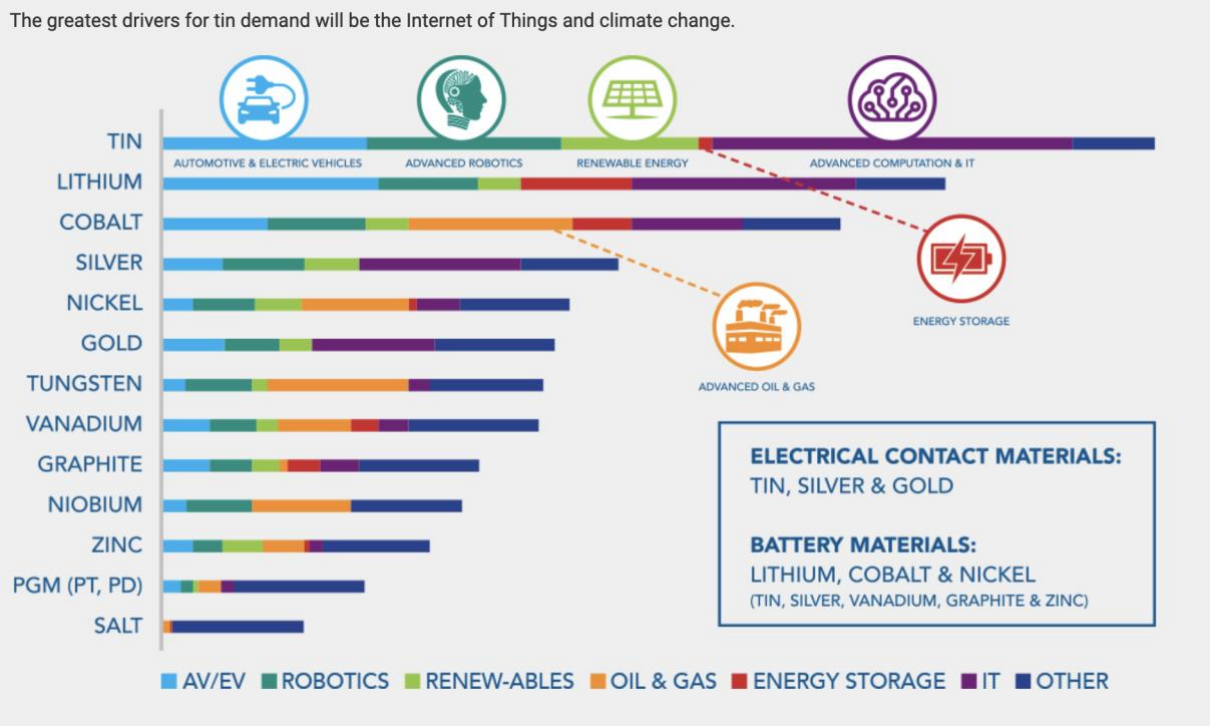
HL of world tin production trends very poorly towards 31 Mt



A 28 Mt ultimate is chosen, giving a peak in 2017

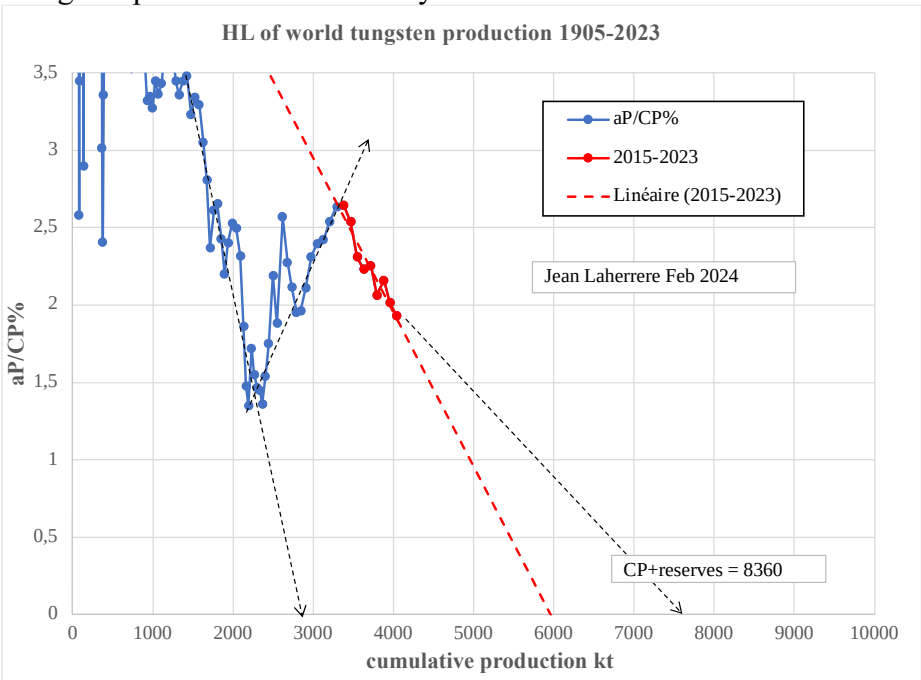


The site https://www.alphaminresources.com/tin-market/ displays its views on tin demand which to my surprise is on the first position

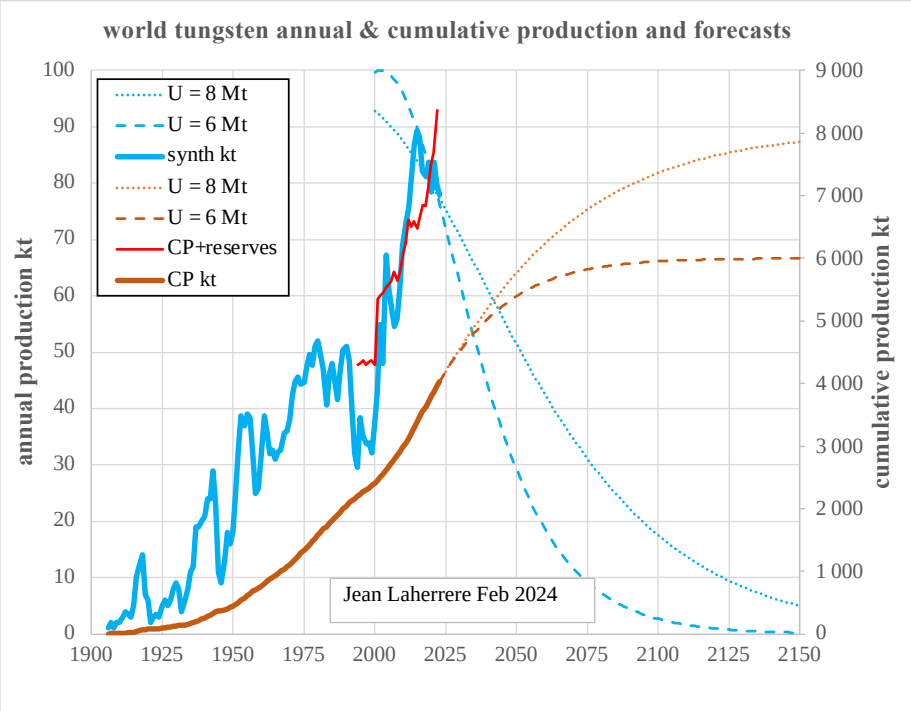


-tungsten

HL of world tungsten production trends fairly towards 6000 kt when CP+RR = 8360 kt



With a 6 Mt ultimate (even 8 Mt) world tungsten production has peaked in 2015



USGS reserves look too high: most tungsten reserves are in China and China data are unreliable! With such high reserves, China tungsten production should rise but is on decline!

World Mine Production and Reserves: Reserves for Australia, China, Portugal, Spain, Vietnam, and "Other countries" were revised based on academic, company, and Government reports.

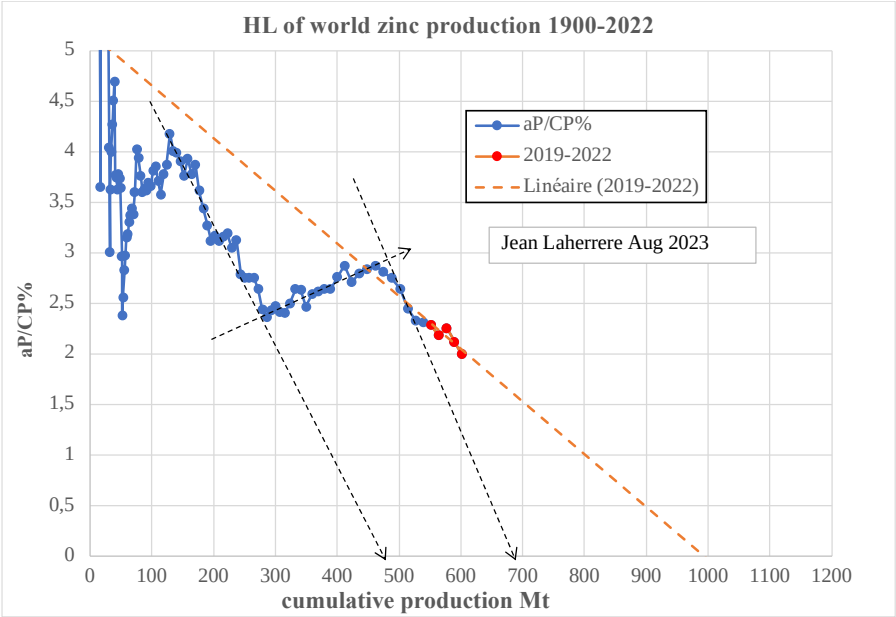
	Mine production[e]		Reserves[10]
	2022	2023	
United States	—	—	NA
Australia	200	800	[11]570,000
Austria	910	910	10,000
Bolivia	1,360	1,500	NA
China	66,000	63,000	2,300,000
Korea, North	1,520	1,700	29,000
Portugal	500	500	4,000
Russia	2,000	2,000	400,000
Rwanda	1,400	1,400	NA
Spain	800	1,500	66,000
Vietnam	4,000	3,500	74,000
Other countries	1,080	1,100	950,000
World total (rounded)	79,800	78,000	4,400,000

This site https://projectblue.com/blue/news-analysis/661/can-new-tungsten-projects-offset-chinese-declines?- writes

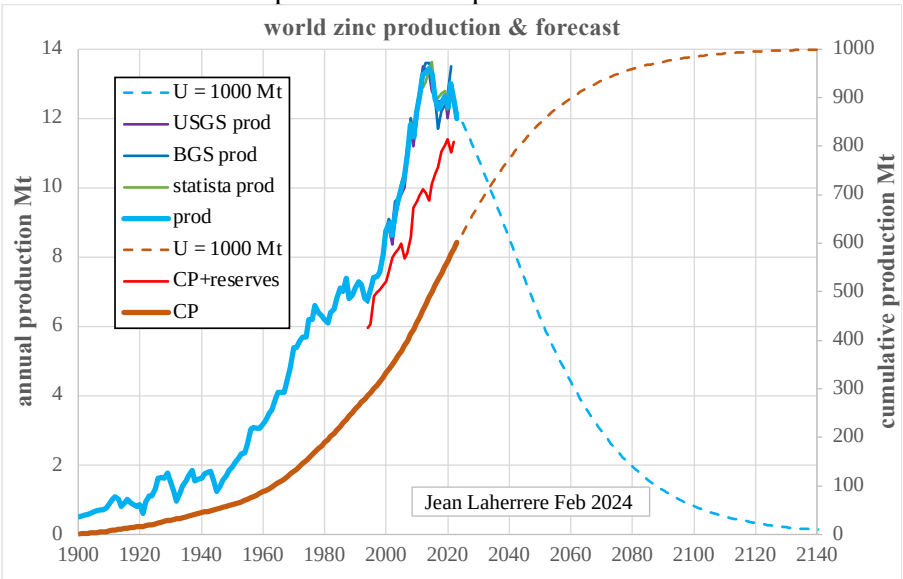
However, China's current primary production levels are likely not sustainable in the long term. Reserves are dwindling and grades are declining, and at current rates of production (assuming no new discoveries) China will have exhausted its current reserves by 2050.

-zinc

HL of world tin production trends fairly towards 1000 Mt

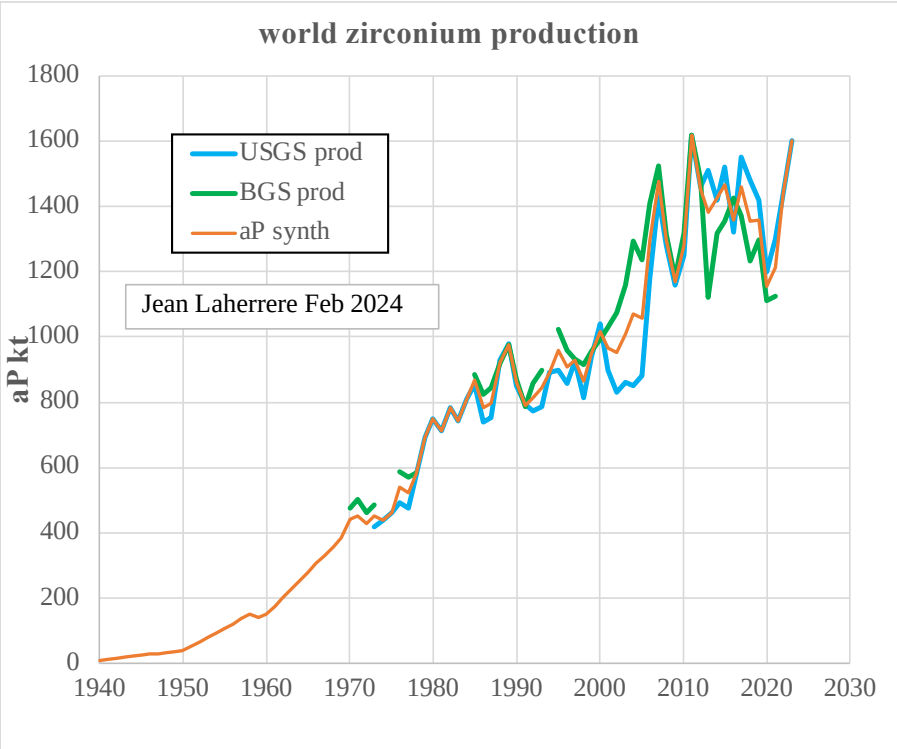


With 1000 Mt ultimate world tin production has peaked in 2017

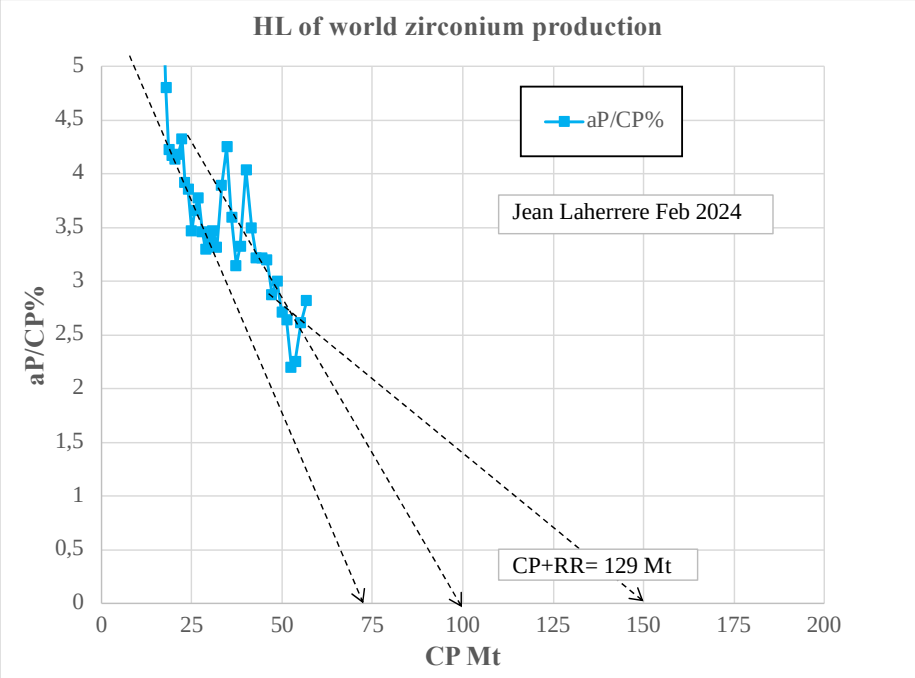


-zirconium

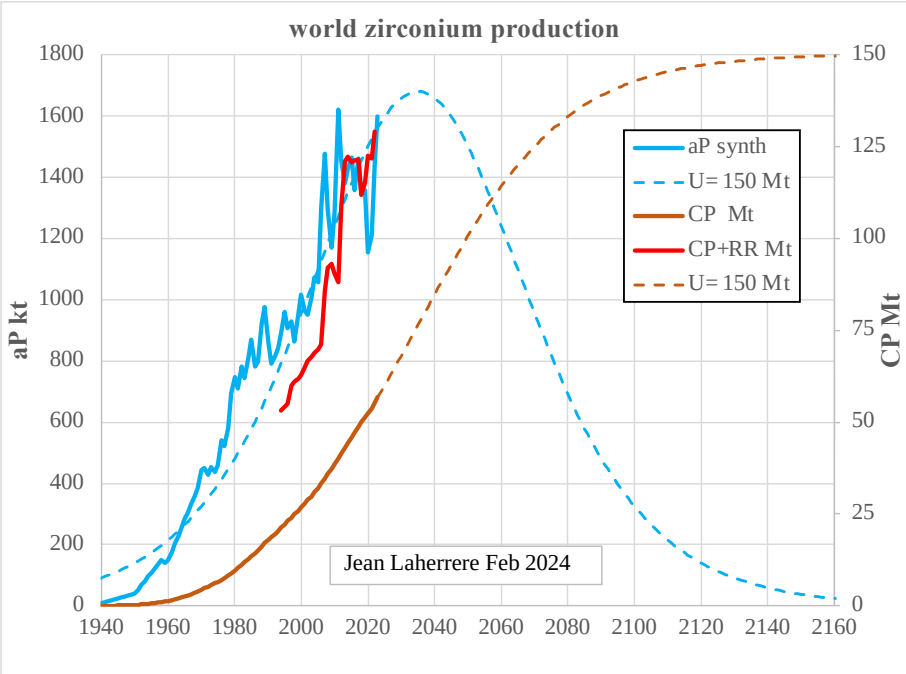
World zirconium production varies with source



HL of world zirconium production is useless. CP +reserves are 129 Mt, and a 150 Mt ultimate is chosen

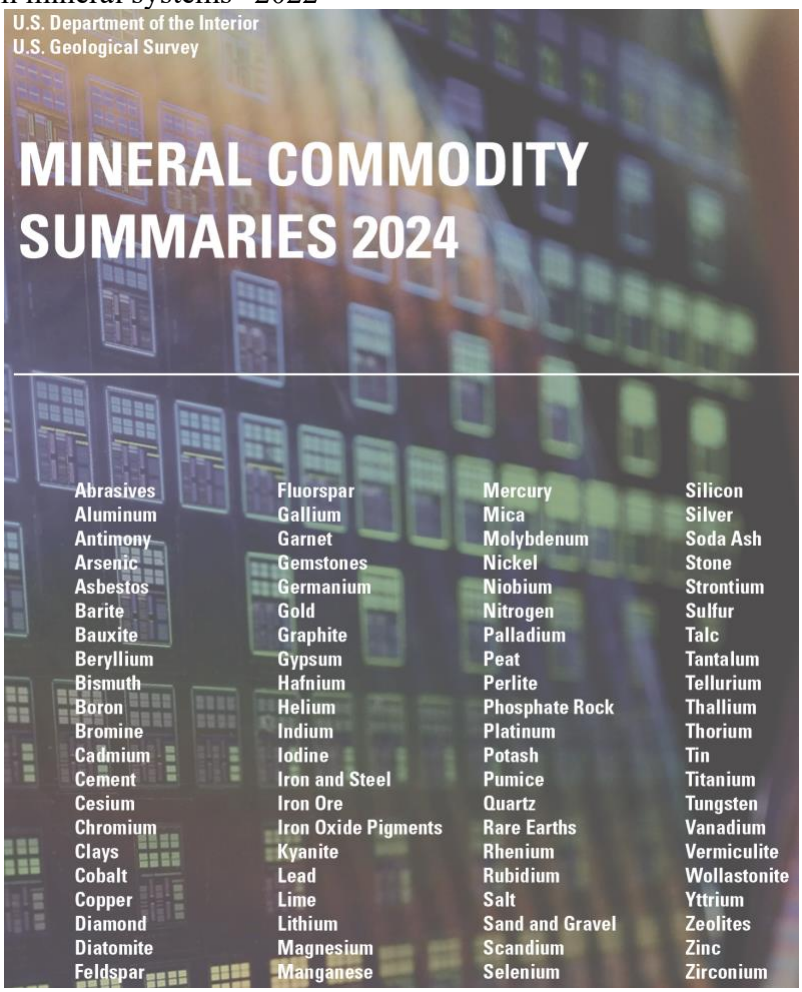


For a 150 Mt ultimate, world zirconium will peak around 2035



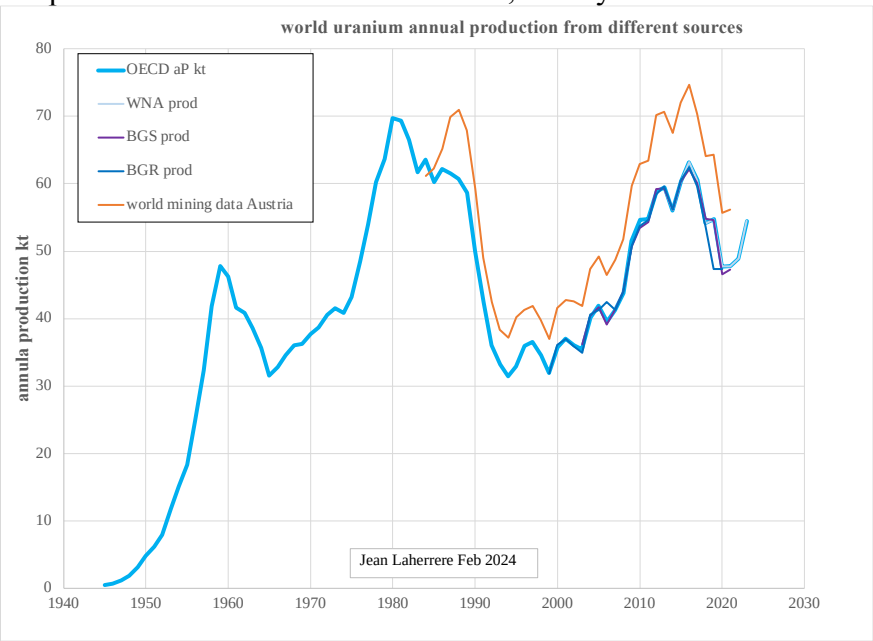
-uranium

Uranium is not in the USGS mineral commodities list and USGS reports only US uranium data in “Uranium mineral systems” 2022

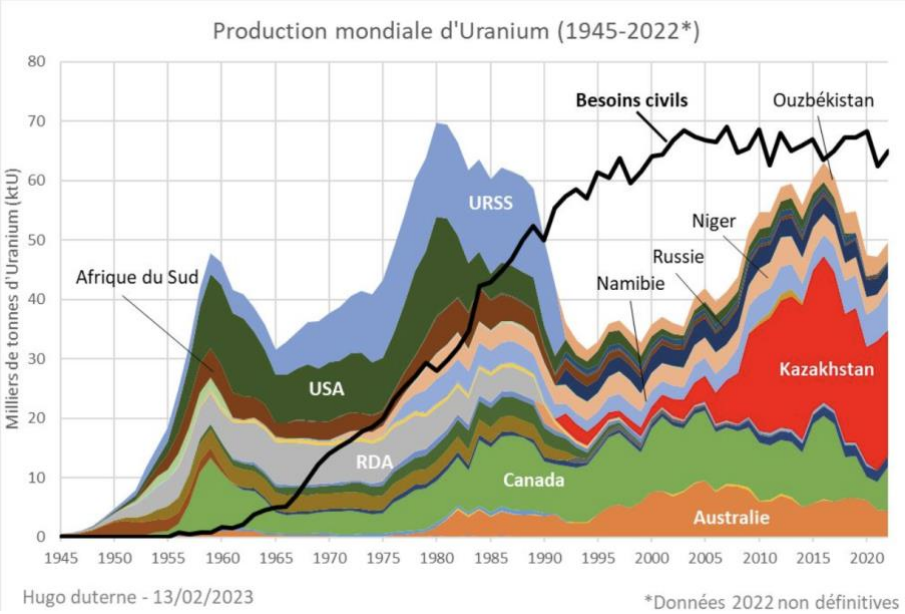


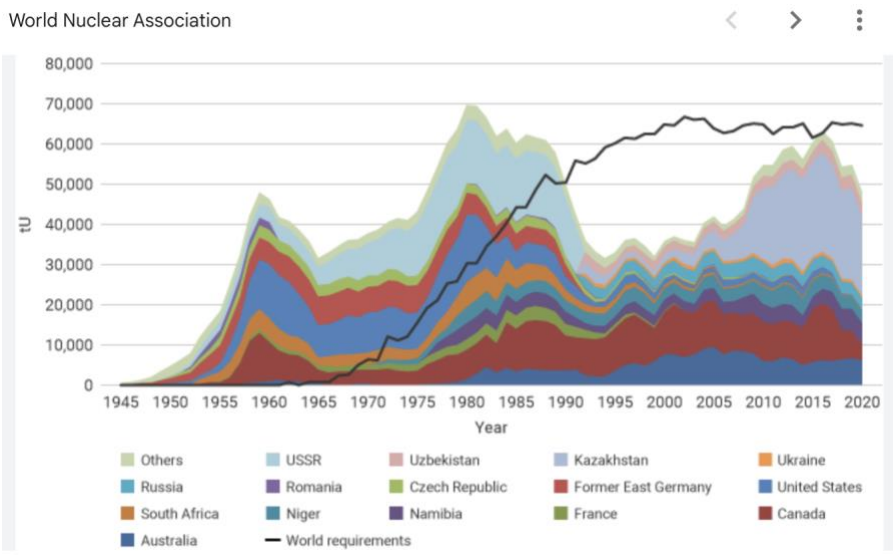
The last USGS report on world uranium is 2012-5239 “Critical analysis of world uranium resources” with the conclusion: *This analysis indicates that mine development is proceeding too slowly to fully meet requirements for an expanded nuclear power reactor fleet in the near future (to 2035), and unless adequate secondary or unconventional resources can be identified, imbalances in supply and demand may occur.*

World uranium production data varies from sources, mainly from Austria world mining data

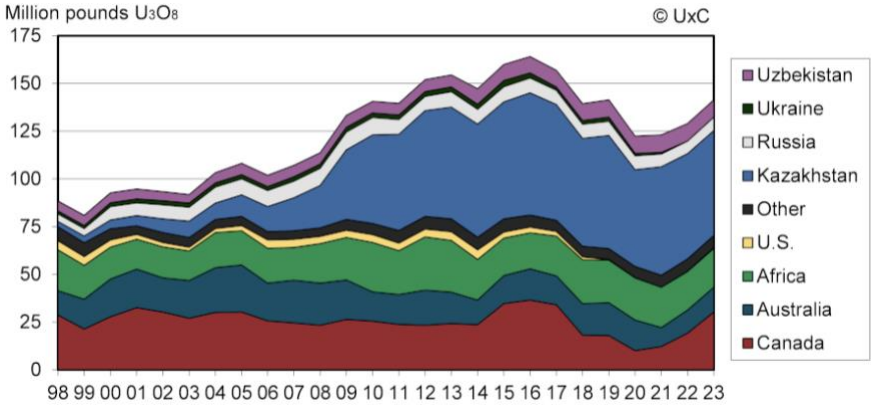


World uranium production varies widely with peaks in 1958, 1981 and 2017

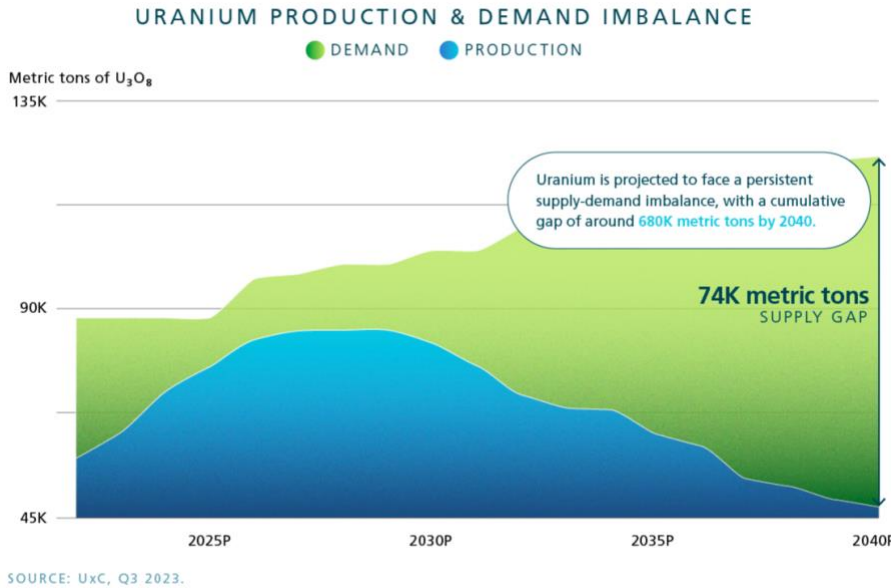




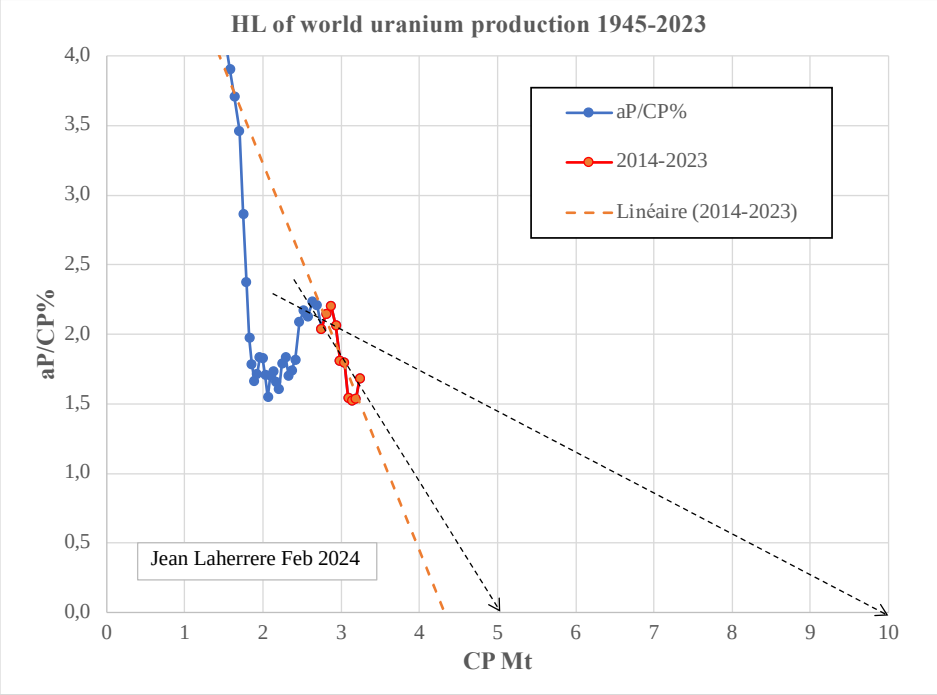
UxC https://www.uxc.com/p/products/rpt_usa.aspx



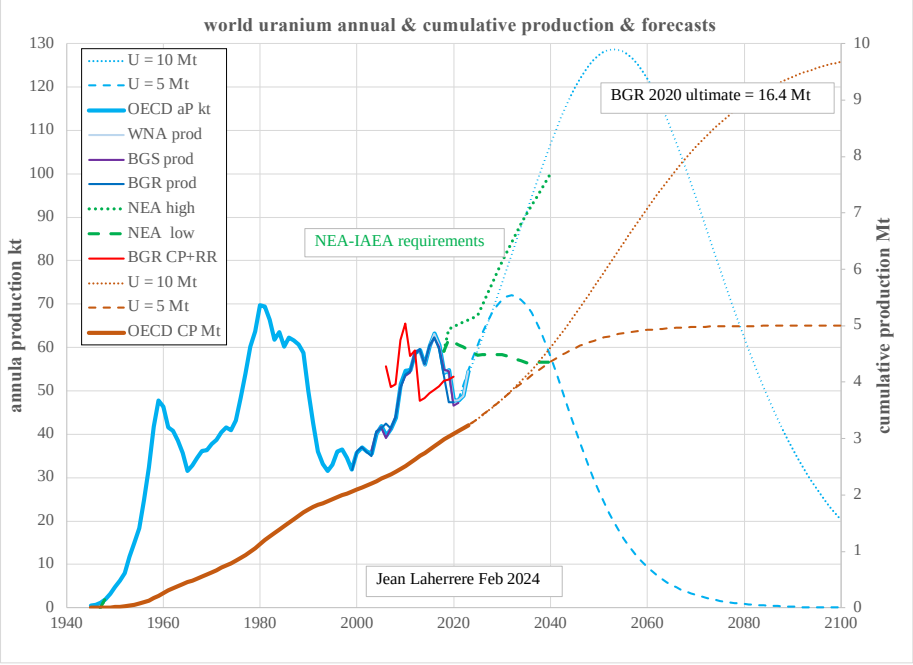
UxC forecasts up to 2040 uranium production and demand



HL if world uranium production trends very poorly towards 4.2 Mt, but an ultimate of 5 or 10 Mt is taken, when BGS 2020 reports an ultimate of 16.4 Mt, but BGS CP+RR are less than 5 Mt

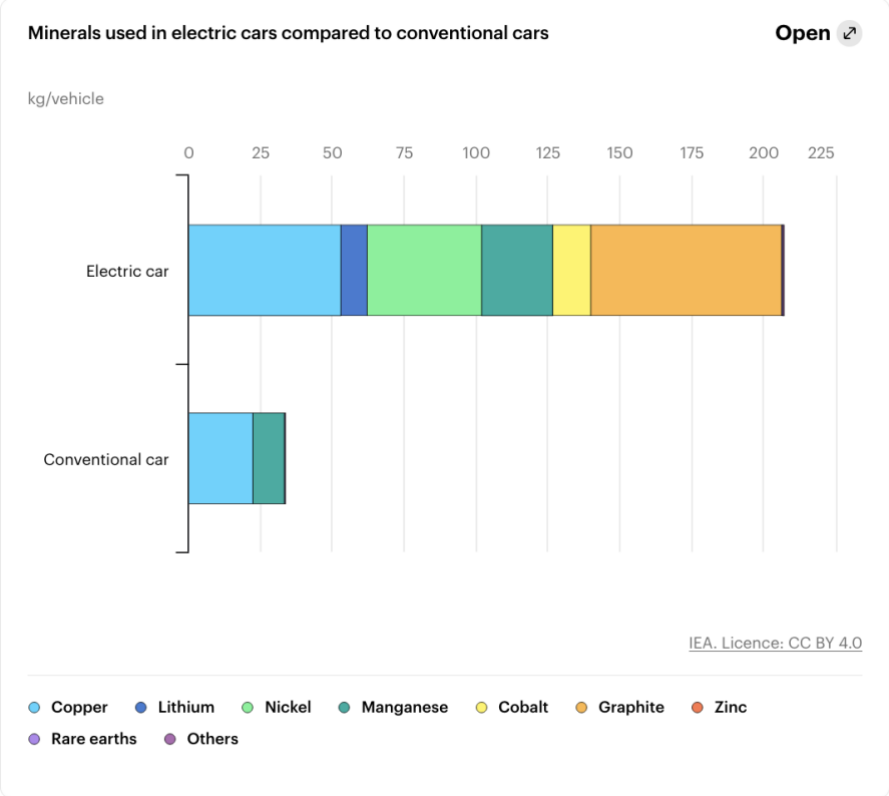


With a 5 or 10 Mt ultimate world uranium production will peak around 2030 or 2050

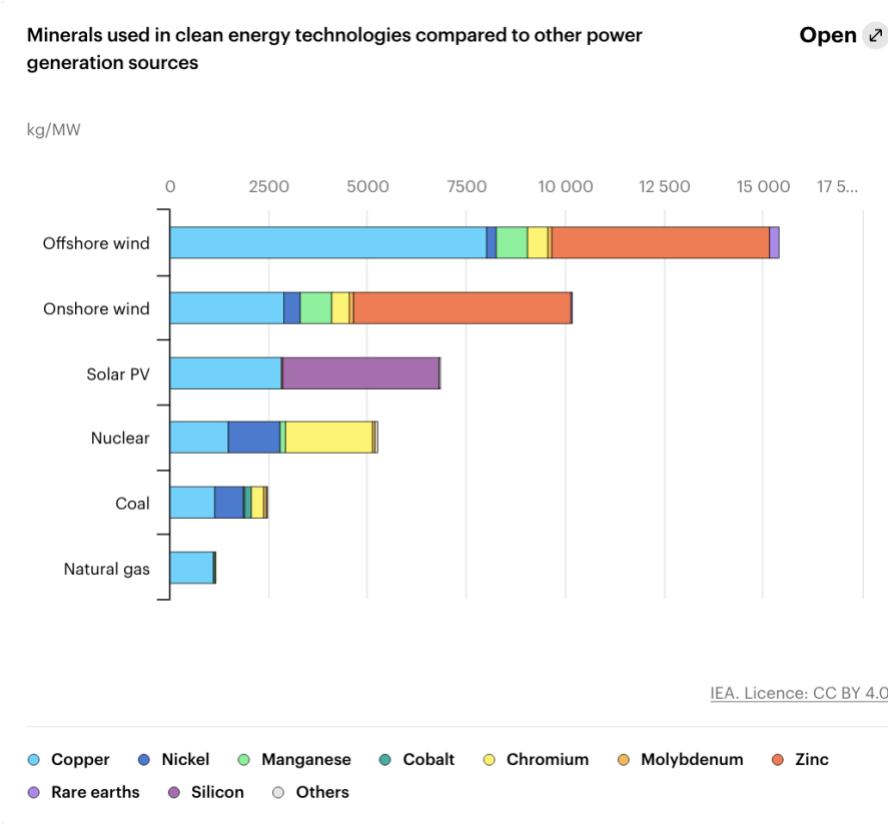


-IEA demand forecast

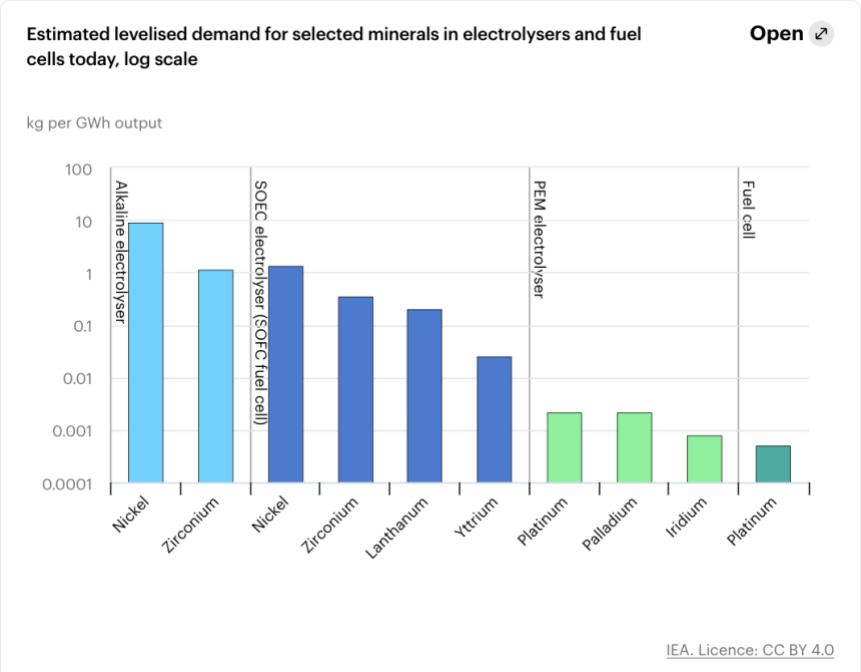
-metal need for clean energy

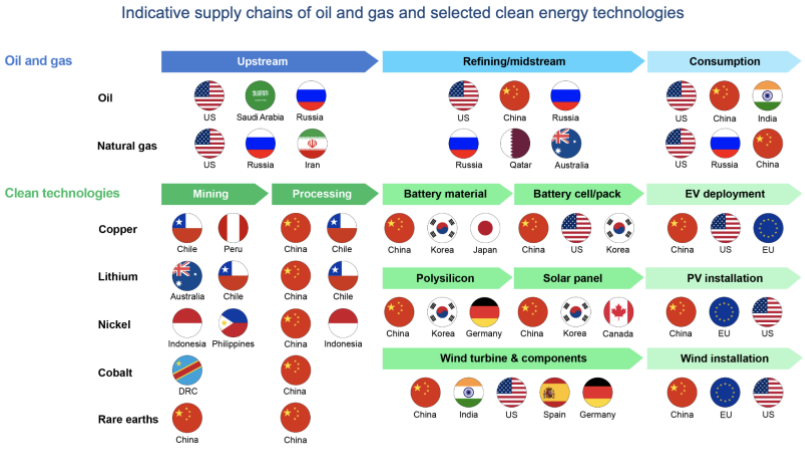


Copper and nickel represent 90 kg in an electric car!

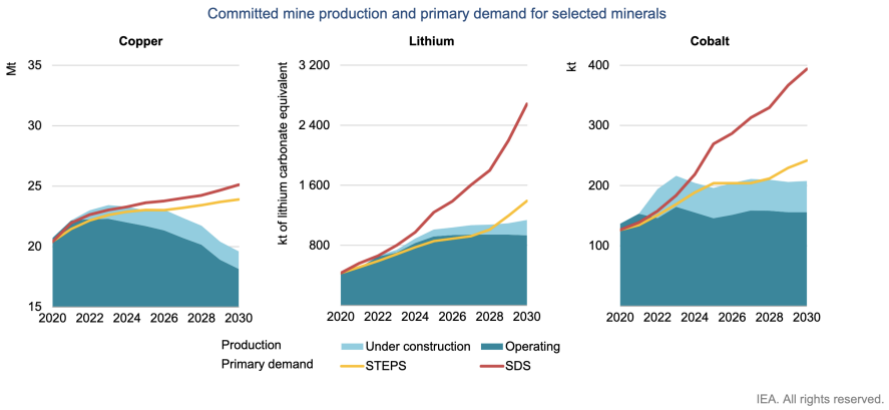


Copper and zinc represent 15 t/MW in offshore wind!





IEA forecasts for 2030 that copper, lithium and cobalt production will be less than demand!



-synthesis

The 25 items of my study are ranked by ultimate comparing 2023 and 2024 estimates

	2023	Mt	Mt	Mt	2024	Mt	Mt	Mt				Mt			
rank	metal	aP2022	CP 2022	U		aP2023	CP 2023	U	quality	CP+reserves	peak time	peak	U/CP+RR	U24/U23	Abundance %
1	iron	4200	103000	240000		3108	93500	200000	P	178000	2030	3650	1,1	0,8	5
2	steel	1885	66000	150000		1850	67900	110000	P	?	2021	1950		0,7	
3	bauxite	380	9000	50000		400	9500	50000	?	39000	2050	660	1,3	1,0	
4	phosphate	220	9800	14000		220	10000	18000	P	83000 ?	2017	269	0,2	1,3	0,1
5	nitrogen	180	5600	12000		150	5795	12000	G	?	2021	150		1,0	0,002
6	potash	40	1800	7000		39	1870	7000	P	5400	2058	51	1,3	1,0	2,2
7	aluminium	67	1600	5000		70	1708	6000	F	?	2040	89		1,2	8,1
8	manganese	20	660	3000		20	680	3000	P	2560	2055	30	1,2	1,0	0,1
9	copper	21,8	800	2400		22	785	2700	P	1763	2046	27	1,5	1,1	0,008
10	chromium	40	1000	2000		0,04	1071	2000	P	1590	2019	45	1,3	1,0	0,01
11	zinc	13	590	1250		0,01	601	1000	F	809	2012	13	1,2	0,8	0,007
12	lead	4,5	300	450		4,5	414	600	P	504	2013	5,3	1,2	1,3	0,001
13	nickel	3,2	77	200		3,5	81	300	?	200	2040	6,3	1,5	1,5	0,01
14	zirconium					1,6	57	150	?	129	2035	1,7	1,2		0,013
15	rare earths	0,3	5	135		0,35	5	100	?	115	2075	1,3	0,9	0,7	0,02
16	tin	0,3	23	35		0,29	23	28	VP	27	2018	0,3	1,0	0,8	0,0006
17	lithium	0,13	1,3	27		0,18	1,5	30	?	29	2055	0,6	1,0	1,1	0,002
18	molybdenum	0,25	9,2	20		0,25	9,2	12	P	25	2017	0,3	0,5	0,6	0,0003
19	cobalt	0,19	3,5	14		0,23	3,5	20	?	14	2042	0,4	1,4	1,4	0,002
20	uranium	0,05	3,2	10		0,05	3,2	5	VP	4	2032	0,07	1,3	0,5	0,0003
21	tungsten	0,08	4	8,5		0,08	4	6	F	8,4	2015	0,09	0,7	0,7	0,0001
22	silver	0,026	1,7	2,5		0,026	1	2,5	F	2,4	2016	0,027	1,0	1,0	0,007
23	mercury	0,002	0,6	0,65		0,001	1	1	G	1	1971	0,01	1,0	1,5	0,000007
24	gold	0,003	0,19	0,33		0,003	0,2	0,28	VP	0,25	2018	0,004	1,1	0,8	0,0000003
25	PGM	0,001	0,002	0,035		0,0001	0,02	0,035	VP	0,09 ?	2005	0,0005	0,4	1,0	0,0000003

The ultimate 2024 versus 2023 ratio ranges from 0.5 to 1.5, showing the uncertainty of the estimates.

During my oil exploration career (1956-1991) on every continent (excluding Antarctica) I was used to drill 9 dry wildcats out of 10: our management which has agreed to the prospect giving the size and the probability accepted such failures, because each time we have tried to find the reasons of the failure in order to be better next time.

Forecasting metal production is as risky as oil exploration, but oil exploration techniques, mainly seismic has improved drastically ("Memories and thoughts on 50 years of oil and gas geophysics" http://aspofrance.viabloga.com/files/JL_Memories50years2005.pdf. My first seismic interpretation was on photographic films, and I have seen all the improvements with magnetic recording, common depth points, depth migration, bright spots, flat spots, AVO

In ultimate estimate, outside using reserves, HL = Hubbert linearization from production data described by Hubbert in 1982 https://en.wikipedia.org/wiki/Hubbert_linearization was used in 2011 to forecast world phosphate peak “Applying Hubbert Curves and Linearization to Rock Phosphate” Cullen S. Hendrix, College of William & Mary, Peterson Institute for International Economics https://www.piie.com/sites/default/files/publications/wp/wp11-18.pdf and their forecast was good as shown above. But there was no improvement in the ultimate estimate since.

Past production data does not provide a good way to estimate ultimate. The progress should come from better and more recent geological studies, but the agencies which report production and reserves data for limited periods without any updated historical sets should be more critical against their own data in order to improve their future studies.

Out of the 25 minerals, 13 are past peak as shown by this table ranked by peak time:

		Mt	Mt	Mt			Mt
rank	metal	aP2023	CP 2023	U	quality	peak time	peak
1	mercury	0,001	1	1	G	1971	0,01
2	PGM	0,0001	0,02	0,035	VP	2005	0,0005
3	zinc	0,01	601	1000	F	2012	13
4	lead	4,5	414	600	P	2013	5,3
5	tungsten	0,08	4	6	F	2015	0,09
6	silver	0,026	1	2,5	F	2016	0,027
7	phosphate	220	10000	18000	P	2017	269
8	molybdenum	0,25	9,2	12	P	2017	0,3
9	tin	0,29	23	28	VP	2018	0,3
10	gold	0,003	0,2	0,28	VP	2018	0,004
11	chromium	0,04	1071	2000	P	2019	45
12	steel	1850	67900	110000	P	2021	1950
13	nitrogen	150	5795	12000	G	2021	150
14	iron	3108	93500	200000	P	2030	3650
15	uranium	0,05	3,2	5	VP	2032	0,07
16	zirconium	1,6	57	150	?	2035	1,7
17	aluminium	70	1708	6000	F	2040	89
18	nickel	3,5	81	300	?	2040	6,3
19	cobalt	0,23	3,5	20	?	2042	0,4
20	copper	22	785	2700	P	2046	27
21	bauxite	400	9500	50000	?	2050	660
22	manganese	20	680	3000	P	2055	30
23	lithium	0,18	1,5	30	?	2055	0,6
24	potash	39	1870	7000	P	2058	51
25	rare earths	0,35	5	100	?	2075	1,3

-conclusion

Unfortunately, USGS and BGS do not provide complete updated historical annual production data and it is necessary to use each annual past reports. They should provide complete upgraded historical data.

Production data varies with sources, showing a poor quality.

Forecasting future production needs to estimate ultimates from Hubbert Linearization of annual/cumulative versus cumulative: but this ratio is rarely linear, and the extrapolation is very uncertain. Artificial Intelligence has not yet improved such technique!

25 mineral world productions are forecasted and 13 are past peak, as steel, silver, gold.

Some wants to replace before 2035 thermic cars by electric cars which need much more metal.

The peak of nickel, cobalt, and copper in the 2040s will cause problems to the production of electric cars.

Technical progresses are needed to diminish the dependence to such metals.

Norway, short of finding more large oil fields, is now looking for metallic nodules on its deepwater sea floor, the problem since the 1970s is economy and pollution.

The future of world vehicles will not be an easy path!