



The Role of Mining in a Transitioning World

June 2023

"Wealth is matter which has been consciously and intelligently transformed from a condition in which it is less to a condition in which it is more serviceable to human need. Without wealth man cannot exist."

Hilaire Belloc, "The Servile State", 1912

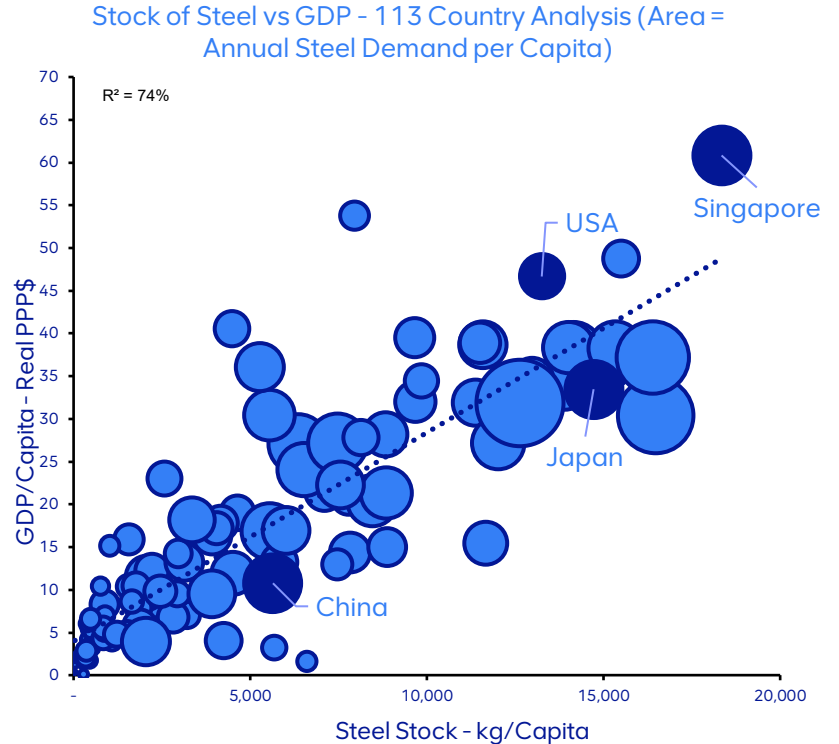
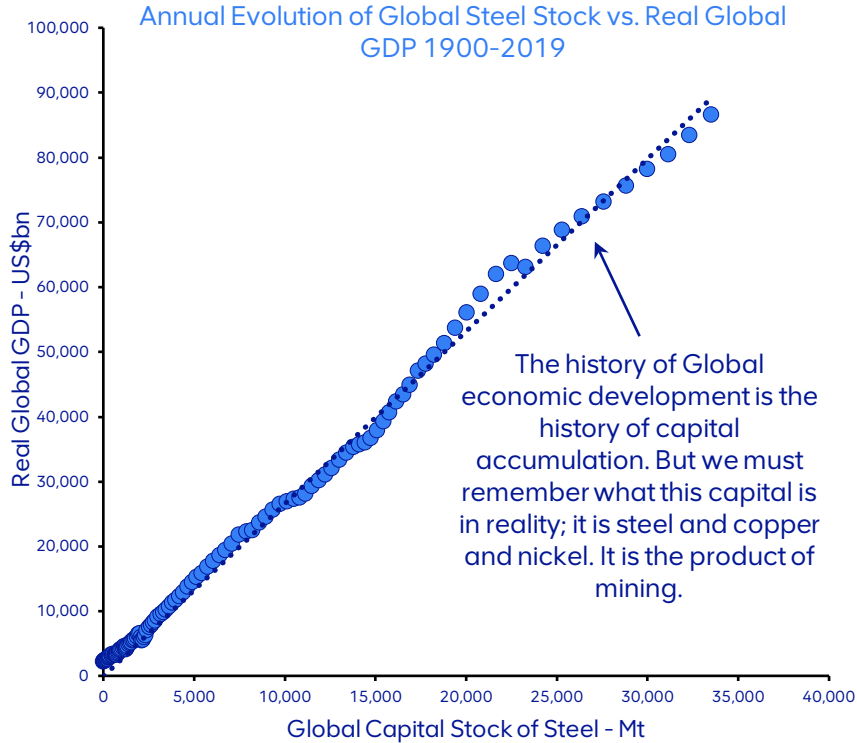
"The total volume of workable mineral deposits is an insignificant fraction of the earth's crust, and each deposit represents some geological accident in the remote past, each deposit has its limits; if worked it must be exhausted. No second crop will materialise. Rich mineral deposits are a nation's most valuable but ephemeral material possession."

T.S. Lovering, "Mineral Resources from the Land", 1969

"Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker."

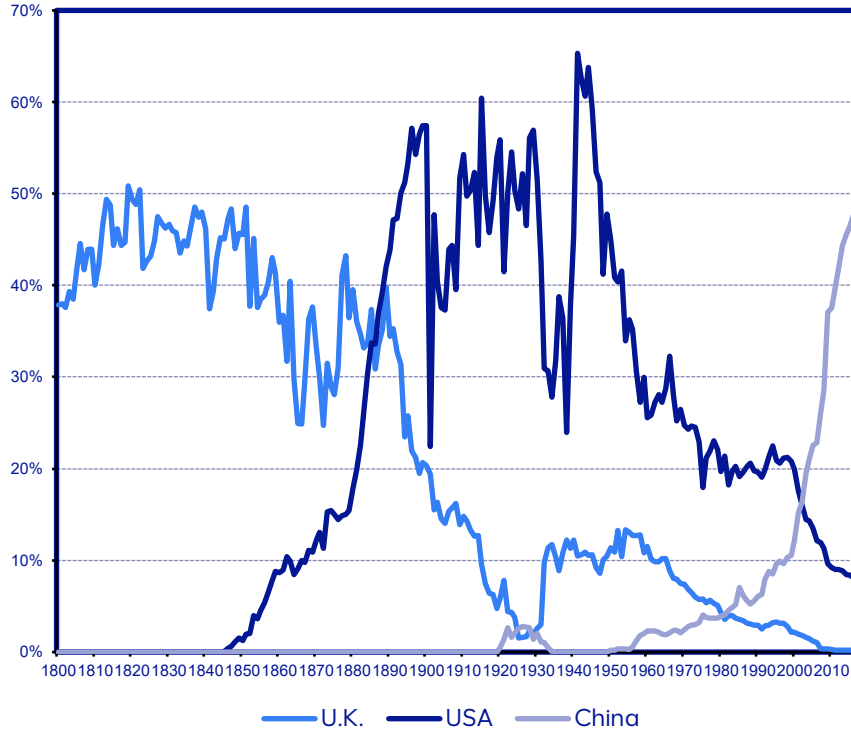
Paul Krugman, "The Age of Diminishing Expectations", 1994

The history of economic growth and development is synonymous with the accumulation of commodities in the world's physical capital stock

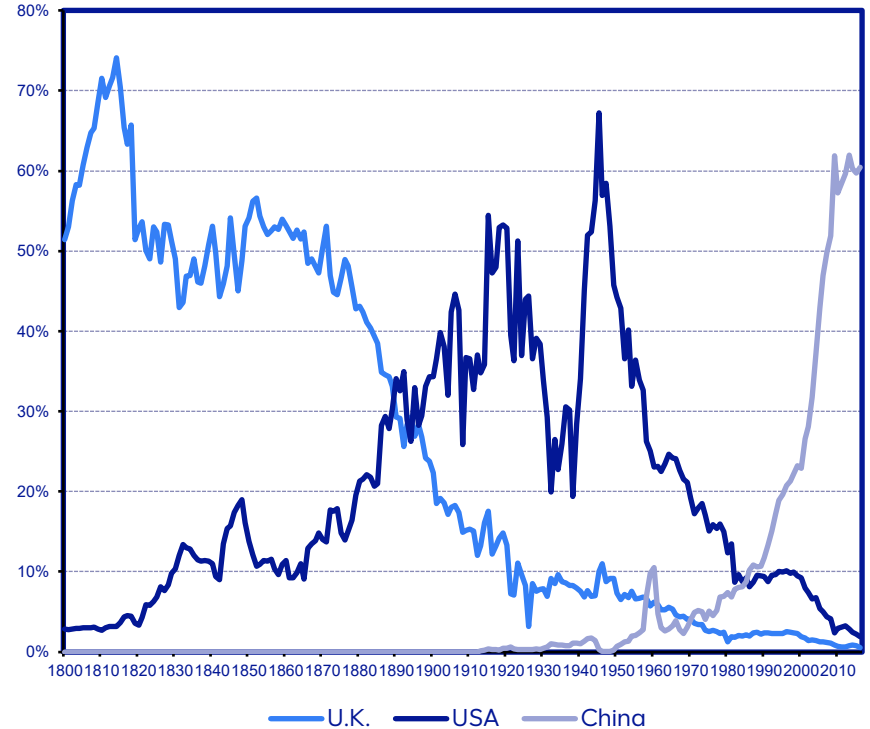


And while the rise of China has captured the headlines, it represents simply the sequential continuation of a well established historical pattern

Percentage of Global Copper Consumption

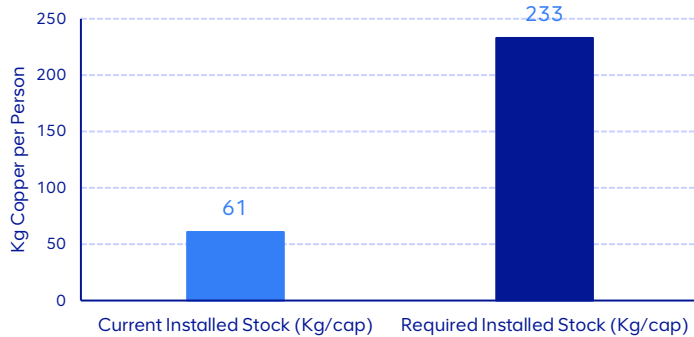


Percentage of Global Iron Ore Consumption

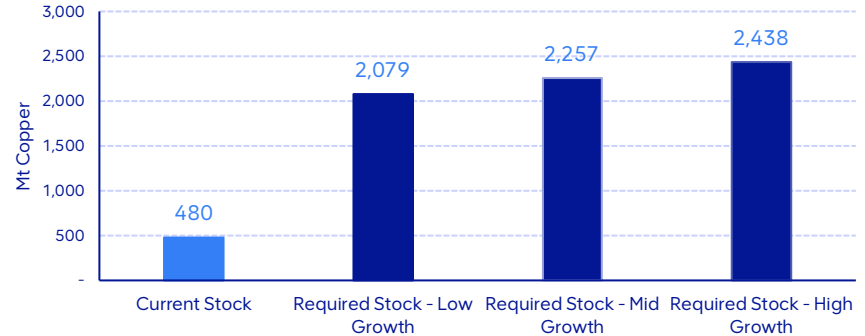


UN Sustainable Development Goal #1 "No Poverty"...What will it really take?

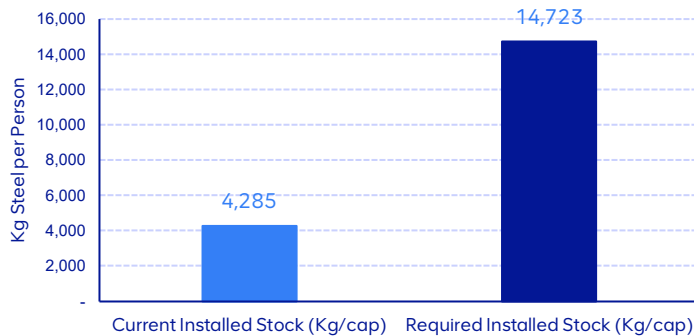
Required Per Capita Uplift in Physical Capital - Copper



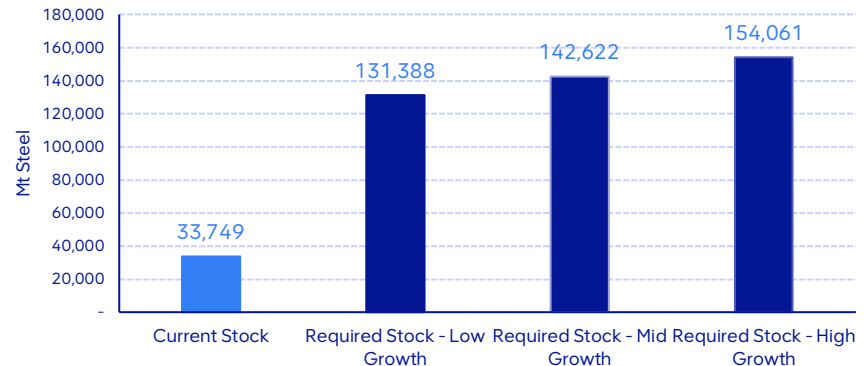
Copper Demand Implications of SDG#1 (excluding "green" copper)



Required Per Capita Uplift in Physical Capital - Steel

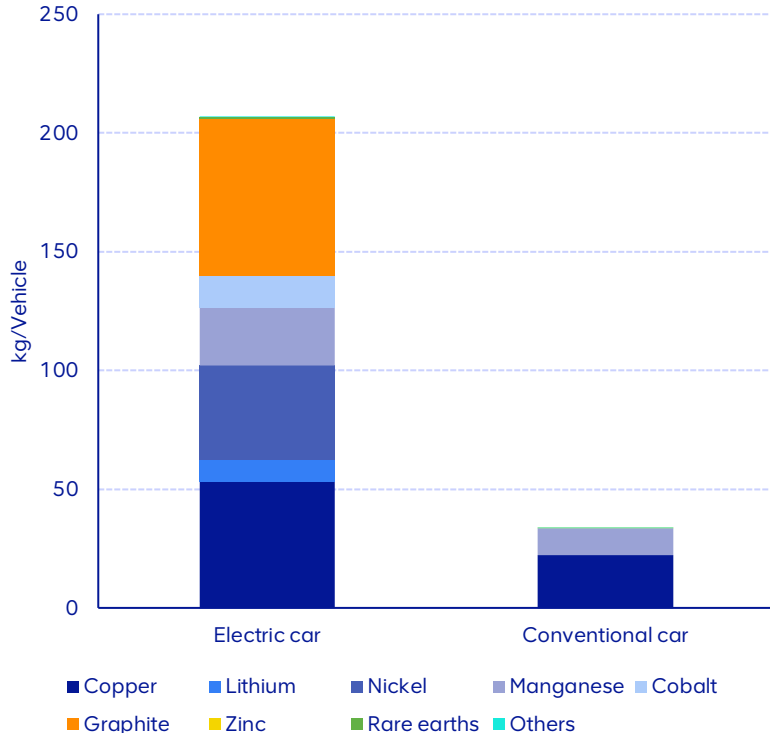


Steel (i.e. Iron Ore & Coal) Demand Implications of SDG#1

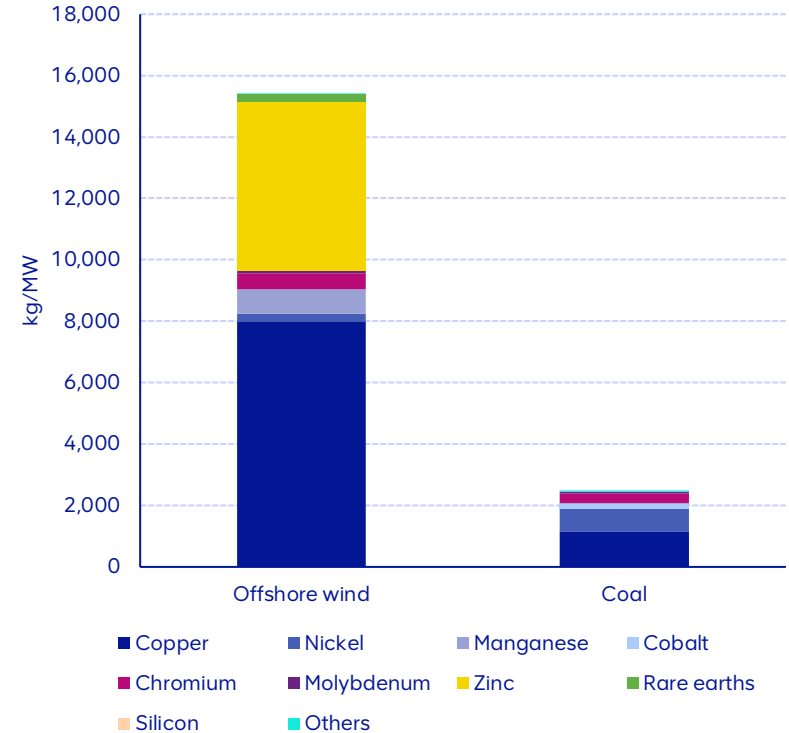


Whatever the precise form of the decarbonisation pathway for the global economy, the one fixed point is the huge increase in the material intensity of the process.

Material Intensity of Transportation - EVs vs ICEs

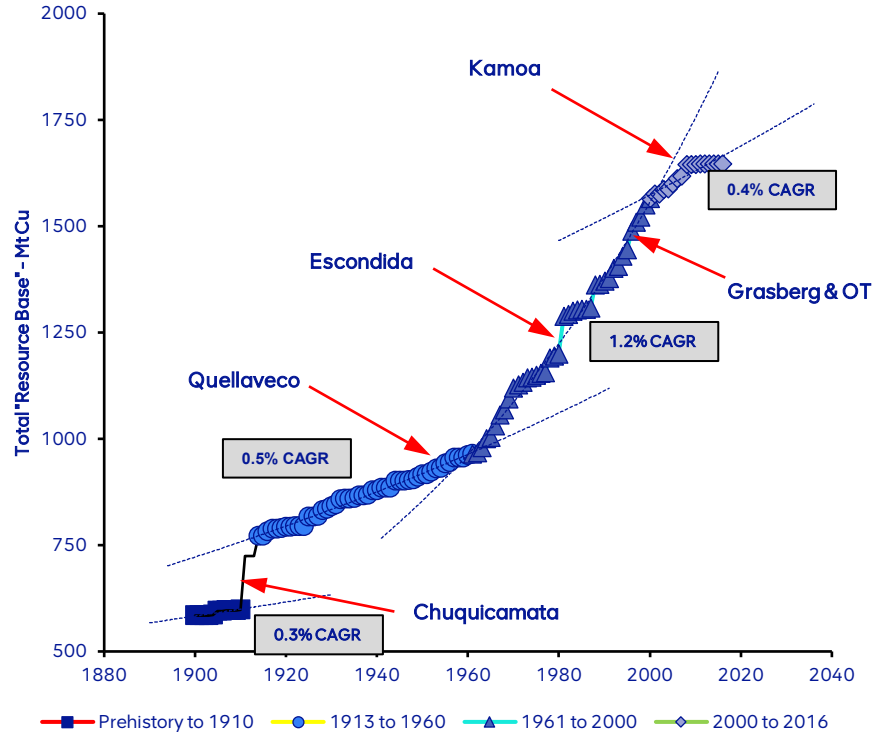


Material Intensity of Energy - Renewable vs Fossil

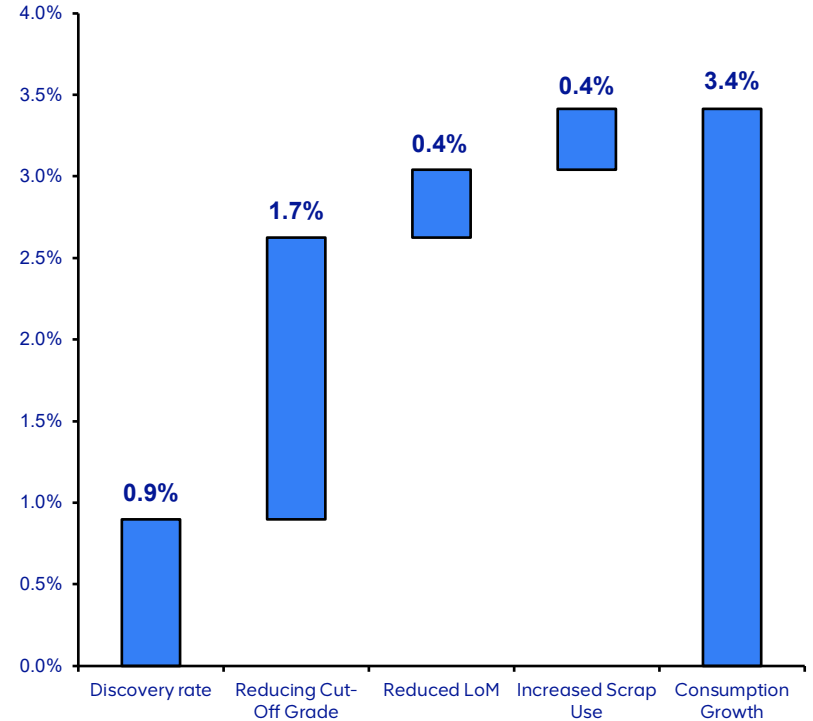


The real issue is not the future of demand but of the mining industry's ability to meet this demand.

Total Global Copper "Resource Base" Evolution



116-Year CAGR in Copper Consumption by Origin



The long run growth in supply, and hence economic development, rests on the interplay between incentives (i.e. price and cost of capital) and technology.

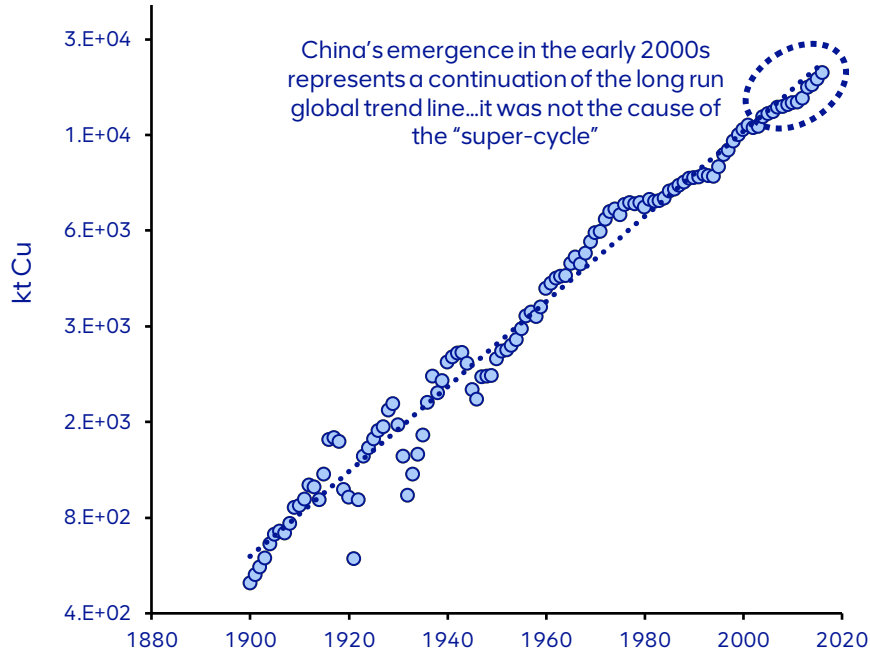
1918 - World's Largest Mines	Ore Reserves	Reserve Grade	Contained Metal
	Mt Ore	% Cu	Mt Cu
Chile Copper Co (Chuquicamata)	698	2.12%	14.8
Braden Copper Co (El Teniente)	264	2.26%	6.0
Utah Copper Co	374	1.37%	5.1
Ray Consolidated	86	2.06%	1.8
Chino Copper Co	97	1.63%	1.6
Andes Copper Co (Anaconda)	110	1.40%	1.5
Inspiration Consolidated	83	1.63%	1.4
Nevada Consolidated	69	1.57%	1.1
New Cornelia	51	1.58%	0.8
Miami	55	1.47%	0.8
Arizona Bagdad	21	1.44%	0.3
Consolidated Copper Co	20	1.33%	0.3
Howe	10	2.16%	0.2
Canada Copper Corp	12	1.74%	0.2
Ray Hercules	10	1.77%	0.2
Ohio Copper	15	0.80%	0.1
Burro Mount	4	2.20%	0.1
Total/Average	1,979	1.83%	36.2

2023 - World's Largest Mines	Ore Reserves	Reserve Grade	Contained Metal
	Mt Ore	% Cu	Mt Cu
Escondida	6,919	0.58%	40.4
Collahuasi	4,166	0.80%	33.3
Polish Copper	1,017	2.01%	20.5
PT Freeport Indonesia	1,725	1.03%	17.8
Toquepala Minesite	5,681	0.28%	16.2
Norilsk	1,293	1.20%	15.5
Cerro Verde	4,077	0.36%	14.6
Chuquicamata Minesite	1,953	0.67%	13.1
Cobre Panama (Petaquilla)	2,936	0.38%	11.1
El Teniente	1,346	0.80%	10.7
Buenavista	3,334	0.32%	10.5
Kamoa-Kakula	235	4.47%	10.5
Oyu Tolgoi	1,213	0.85%	10.3
Andina	1,236	0.79%	9.7
Morenci	3,918	0.23%	8.9
Quellaveco	1,667	0.53%	8.8
Olympic Dam	441	2.00%	8.8
Total/Average	43,156	0.60%	260.9

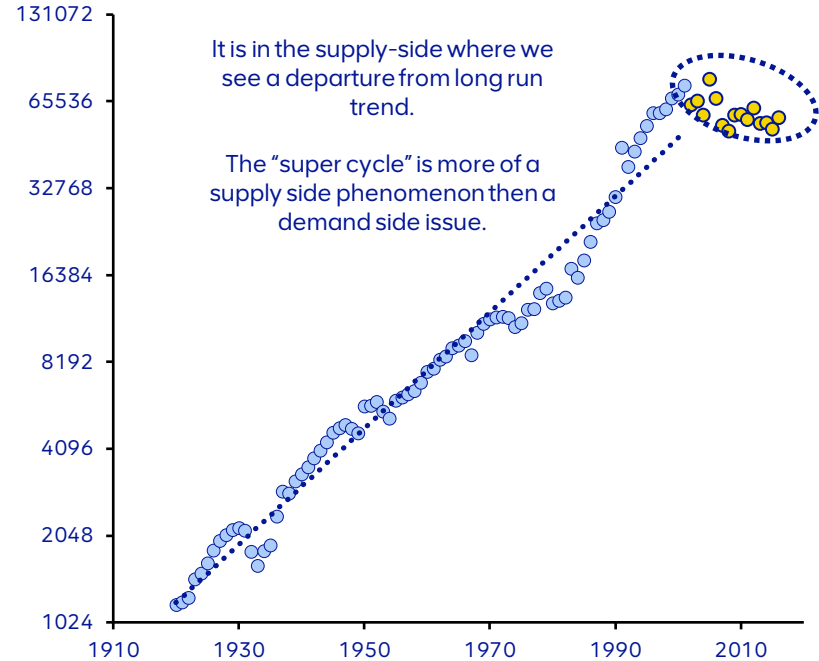
The ability to drop head grades by ~70% in an economically viable manner has enabled an extraordinary exponential (620%) increase in reserves and hence output

The recent “super-cycle” saw a return to long run demand growth trend but, more importantly, an inflection in the long run trend in mining productivity.

Demand for Copper - 1900 to 2017

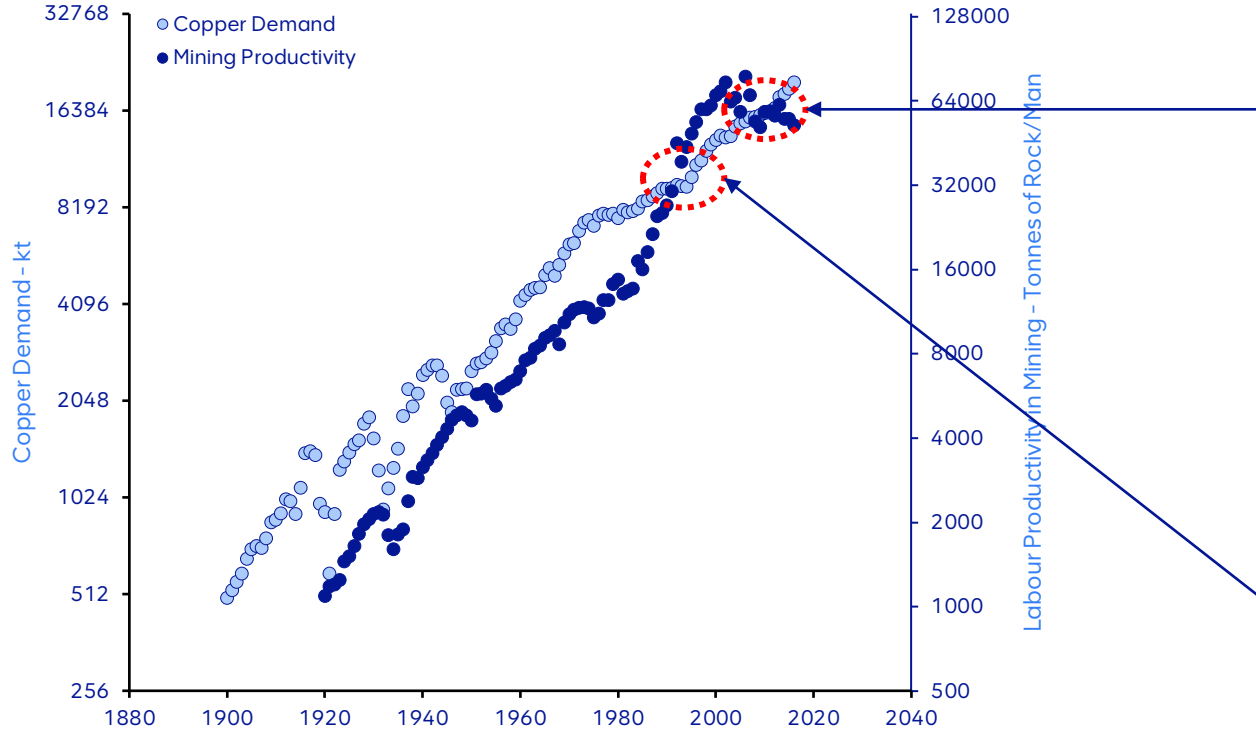


Productivity in Mining (Copper)- 1910 to 2017



It is this interplay that explains the emergence of new structural periods in the price of commodities.

Metal Demand and Mined Productivity

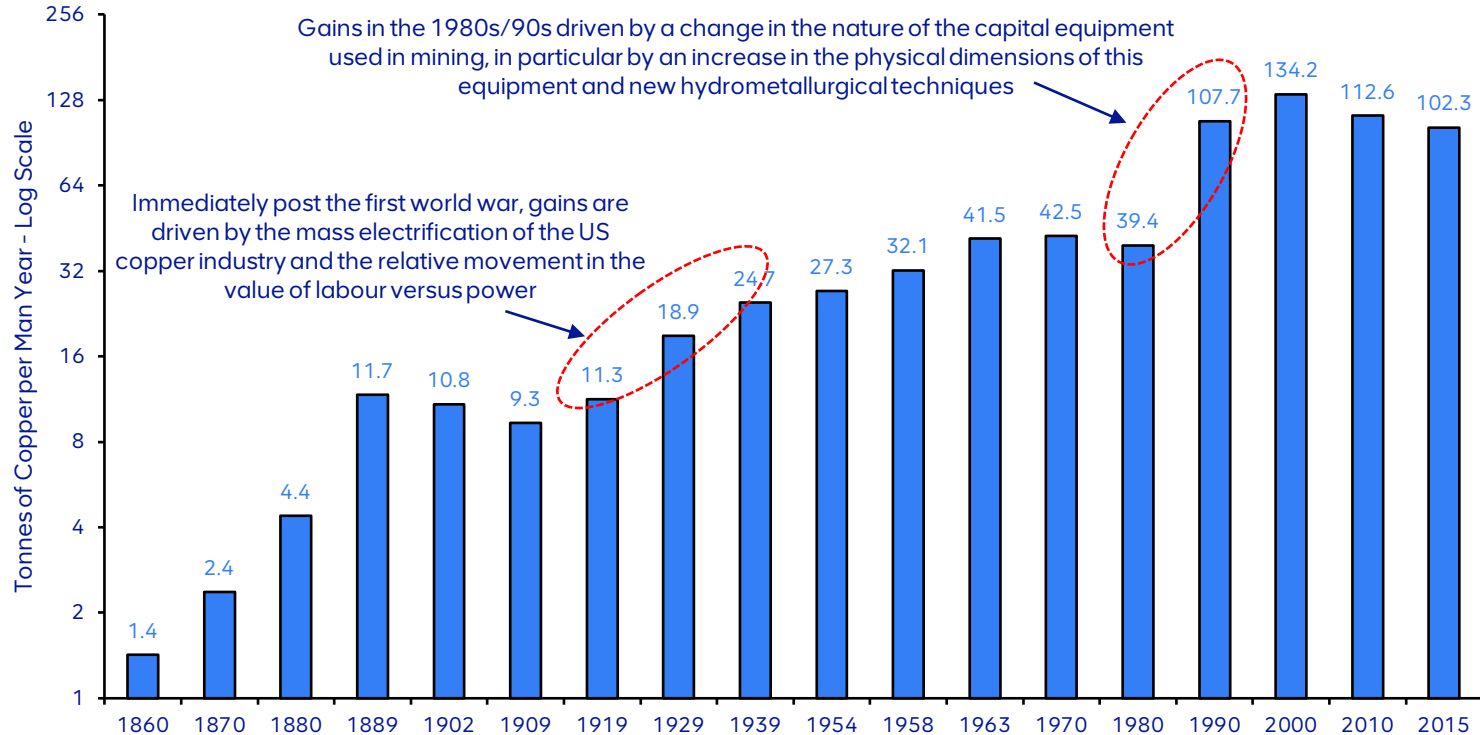


2000s on – mining productivity starts to flat line, “low hanging fruit” has been picked. Easy gains in reducing the material intensity (i.e. lightweighting and substitution) have run their course and non-Western centres of demand (with markedly different philosophical attitudes to those in the West) start to emerge – **real prices rise**.

1970s-1990s – following the oil shocks of the 1970s and the emergence of neo-Malthusian economics as captured in the Limits to Growth and the Club of Rome, Western World industrial activity and growth declines just as mining productivity starts to accelerate – **real prices fall**.

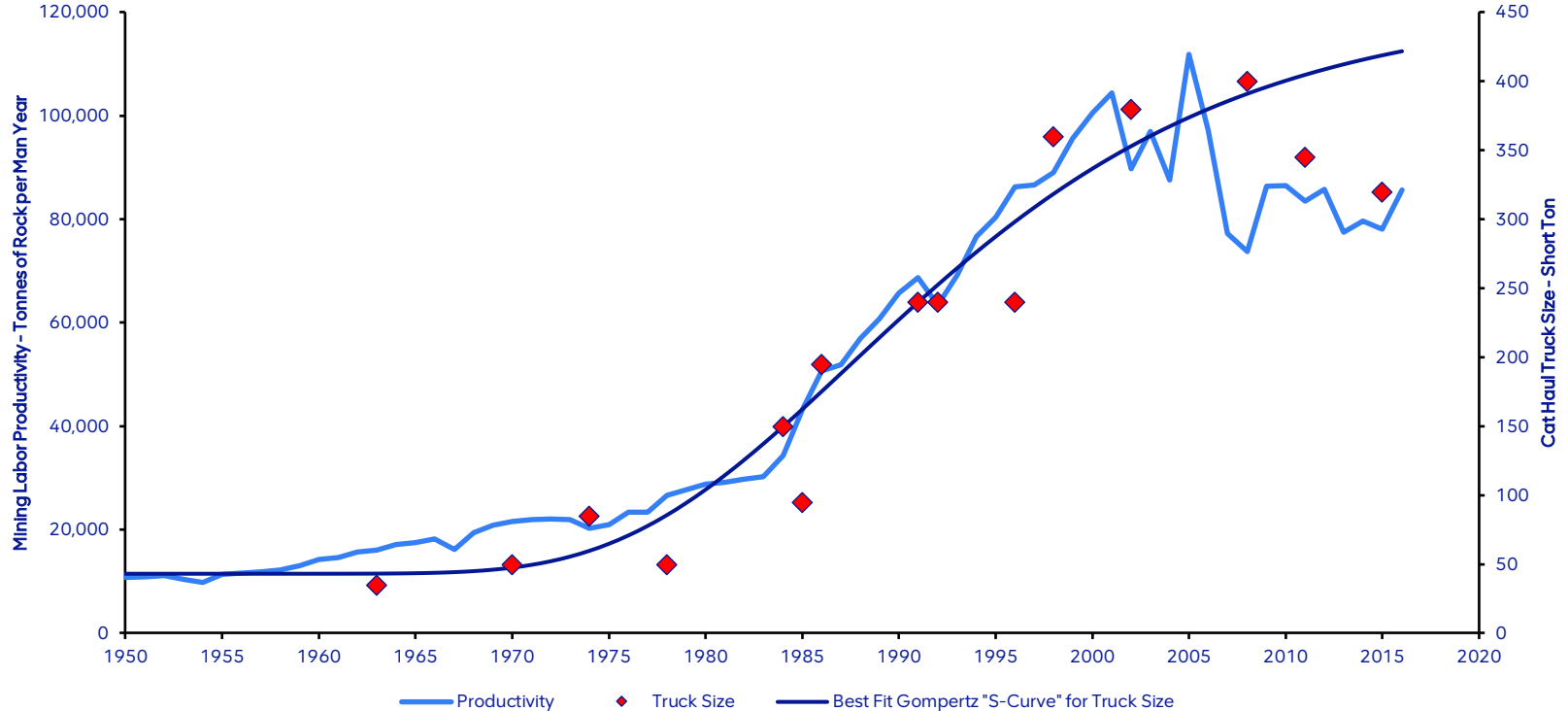
We must be careful to distinguish between incremental gains and true “Schumpeterian” moments of creative destruction in the industry.

Labour Productivity in U.S. Copper Mining



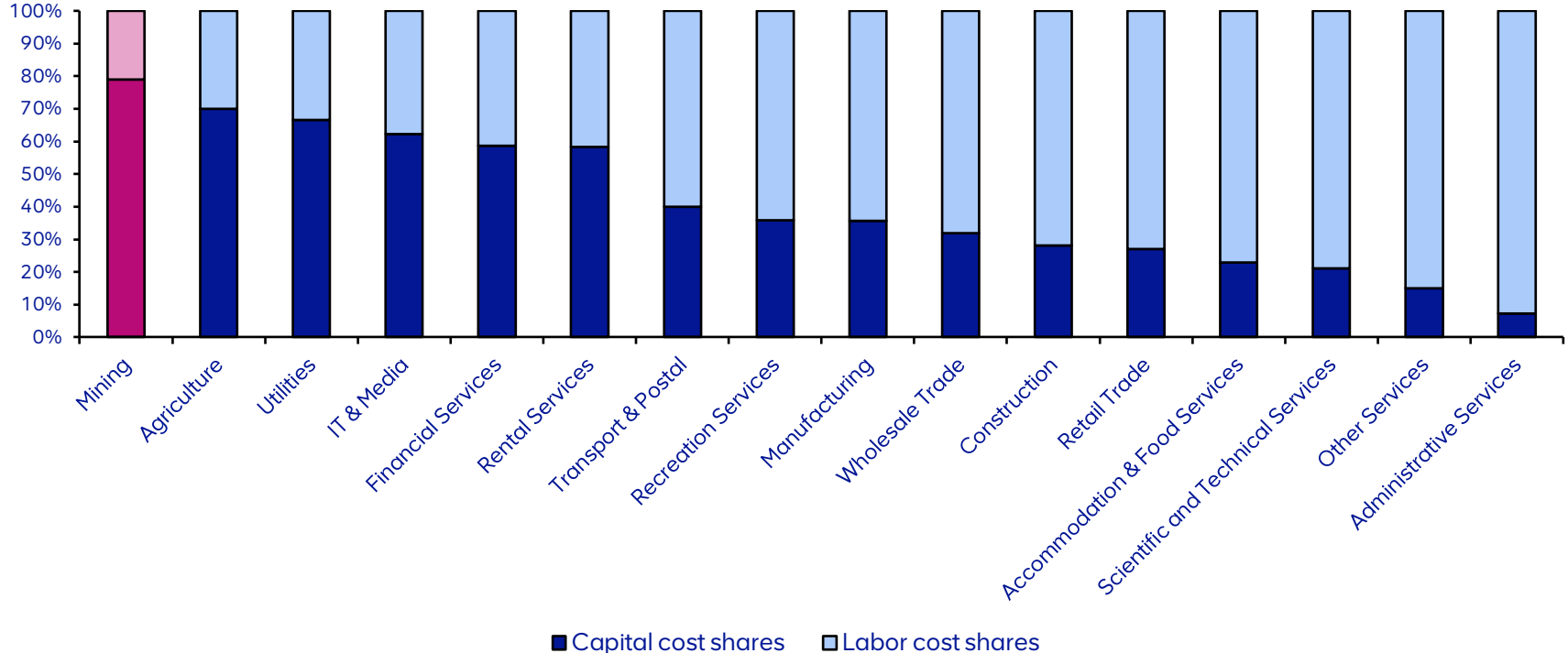
The most recent step change in mining productivity was driven by scale...from 40t to 400t haul trucks...it is this "order of magnitude" change that is required to offset grade declines.

Mining Productivity and Scale of Capital Equipment - Caterpillar Trucks

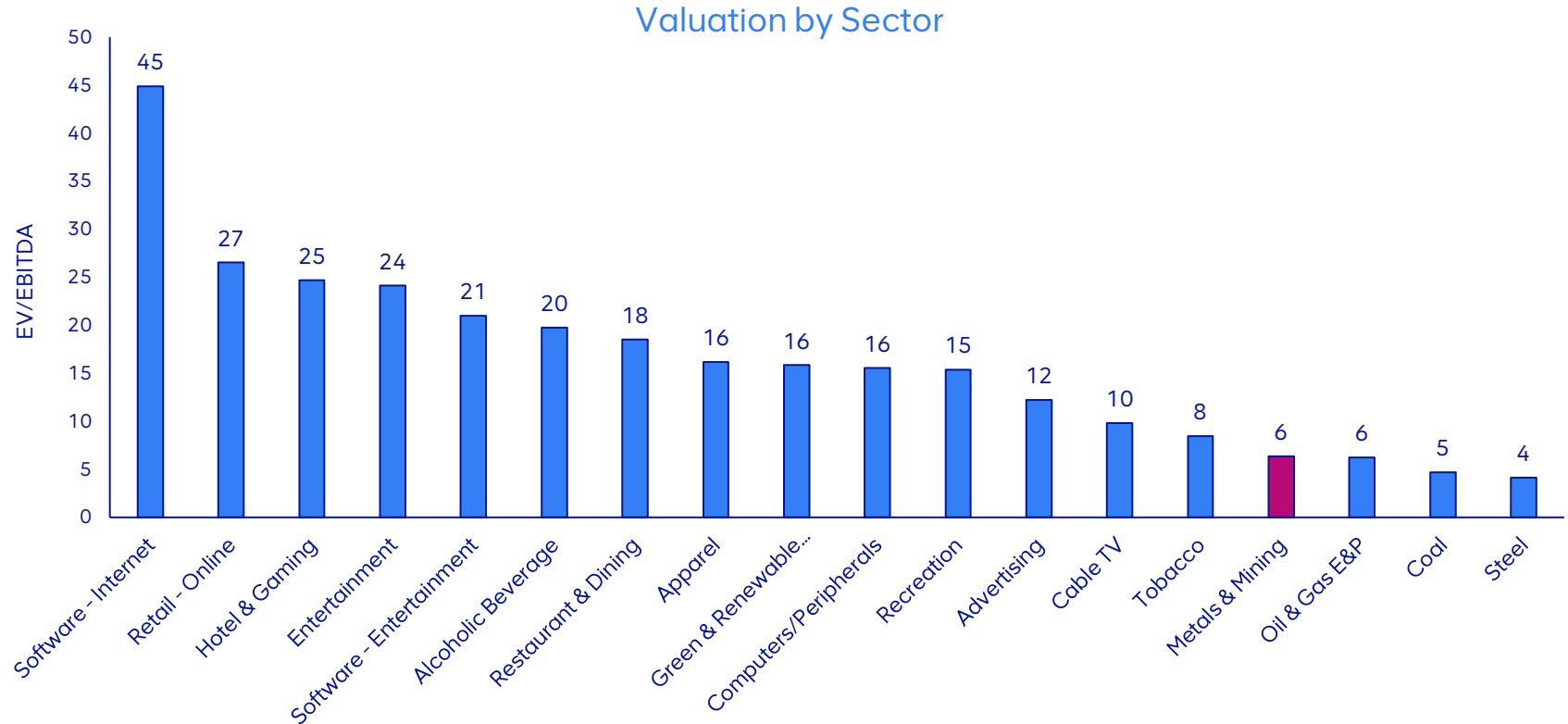


Mining is the most productive use of labour in the modern economy... productivity in the supply of raw materials underpins the productivity of every other activity.

Factor Share of Value Add by Sector

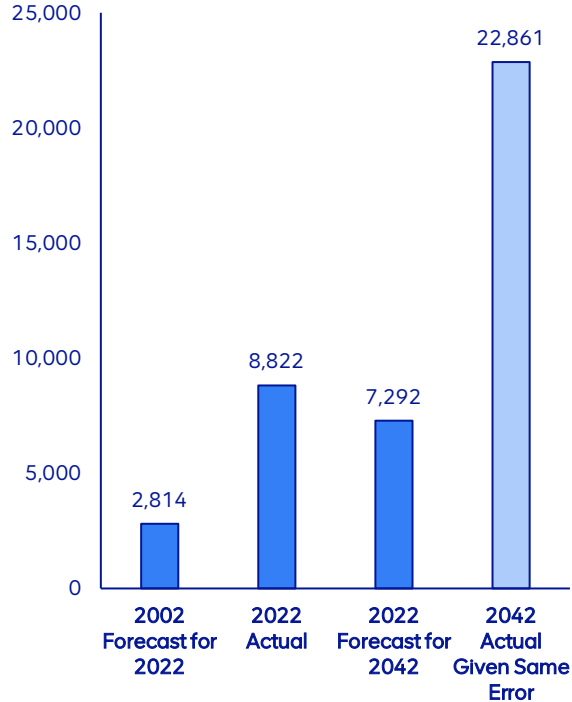


However, while our stated preference is for a just transition to a sustainable future...our revealed preference tells a markedly different story.

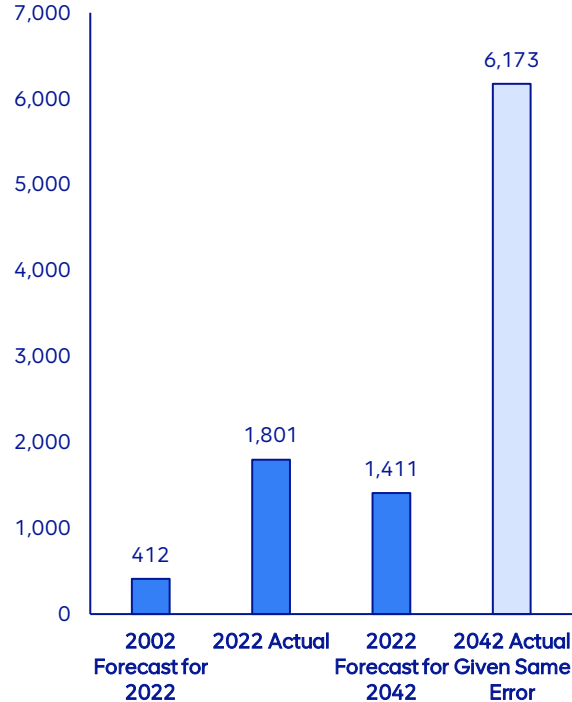


So what does this all mean...higher real commodity prices.

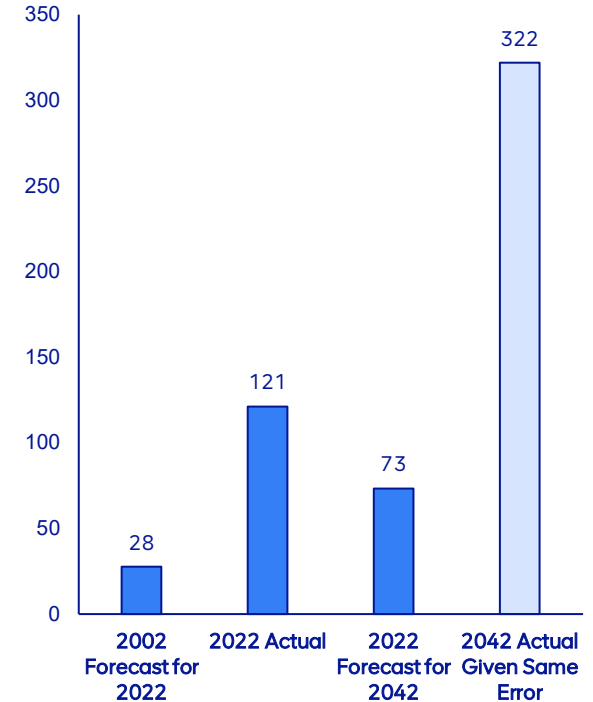
Copper - Real 2022\$



Gold - Real 2022\$



Iron Ore - Real 2022\$





Thank you