BERNSTEIN

14 September 2020

North American Oil & Gas Exploration/Production

Global Metals & Mining: King Copper once and future

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What makes for a good commodity stew? A dollop of demand strength. A sprinkle of supply concerns. A rising cost curve. Minimal threats from alternatives.

We see all these ingredients and more for the copper sector and are thus **more bullish than both consensus commodity forecasts and the forward curve** (Exhibit 81).

How do we arrive at these conclusions?

We provide **10 reasons why copper demand is robust** (Exhibit 3-Exhibit 34): A 100-year trend supports growth, Per capita consumption modest but critical, Infrastructure spending too low, Stimulus programs benefit copper demand, The EV revolution needs copper, Substitution and minaturization has plateaued, A circular economy for copper is impossible in the near term, Greening of electricity means copper wins, Copper serves a variety of endmarkets, and Copper least sensitive to carbon price of the metals.

We provide **11 reasons why copper supply may disappoint** (Exhibits 35-Exhibit 65): Copper is geologically relatively scarce, Ore grades of copper fall over time, Productivity gains have been stagnant for years, Wage deflation can't offsite productivity, We are finding less and less copper, We aren't spending enough to find more, We aren't spending enough to develop more, Ever higher environmental standards are lengthening time needed to approve, finance and execute mine construction, Consensus supply forecasts over-promise and under-deliver, Disruptions to supply are significant and inevitable, and Metals & Mining companies have remained disciplined and have not been paid for growth.

Analyst Page | Bernstein Events | Industry Page

BERNSTEIN TICKER TABLE

Ticker	Rating		11 Sep 2020 Closing Price	Target Price	TTM Rel. Perf.		EPS Adjusted 2019A	EPS Adjusted 2020E	EPS Adjusted 2021E	P/E Adjusted 2019A	P/E Adjusted 2020E	P/E Adjusted 2021E
APA	O	USD	11.89	20.00	(61.8)%	USD	(1.69)	(2.72)	(1.42)	(7.05)	(4.37)	(8.36)
SPX			3,340.97				159.39	128.05	162.10	20.96	26.09	20.61

O - Outperform, M - Market-Perform, U - Underperform, N – Not Rated

INVESTMENT IMPLICATIONS

We currently do not cover metals & mining equities.

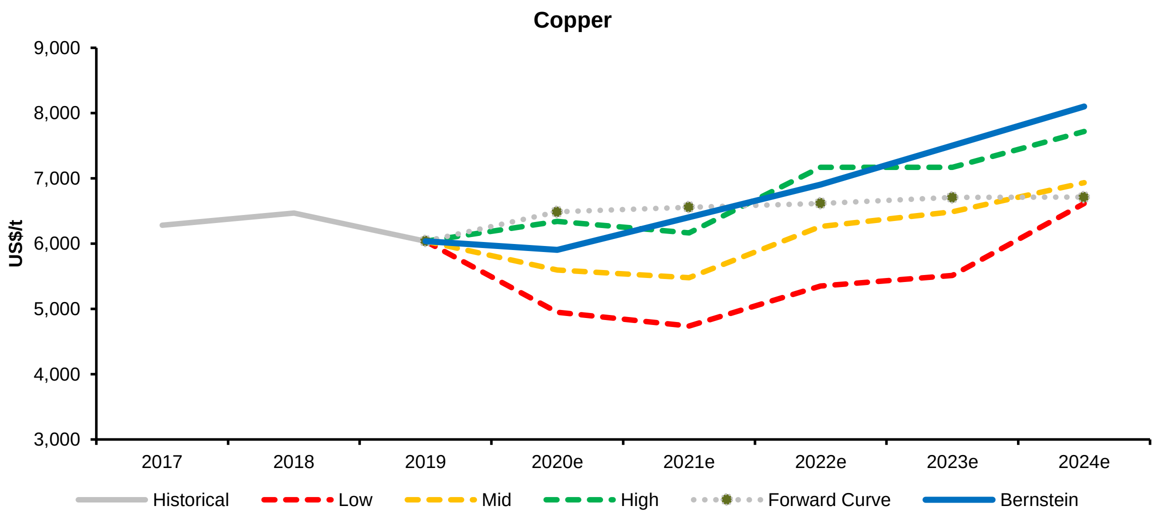
DETAILS

OUR THEMES AND CONVICTIONS AT A GLANCE

The full details of our copper price deck (Exhibit 1) are discussed below, but we start with it here. It is underlain by two assumptions: first that the 35-year trend between marginal cash cost of copper (90th percentile of C1) and price holds (at ~135%) and second that the rise in cash costs over the next 5 years will average second quartile versus history (8.1% CAGR nominal).

EXHIBIT 1: **Bernstein copper deck vs consensus**

Copper								
	2017	2018	2019	2020e	2021e	2022e	2023e	2024e
Historical	6,280	6,468	6,035					
Low			6,035	4,948	4,735	5,350	5,512	6,614
Mid			6,035	5,592	5,478	6,261	6,484	6,934
High			6,035	6,338	6,160	7,165	7,165	7,716
Forward Curve			6,035	6,485	6,556	6,615	6,705	6,710
Bernstein			6,035	5,900	6,400	6,900	7,500	8,100



Source: SNL Financial, CME, Bloomberg and Bernstein Estimates and Analysis

Our conviction in our price deck is underlain by the various arguments laid out below. We summarize those arguments here (Exhibit 2). We are happy to engage in a debate around any of these items and highlight areas of high importance and lower conviction as places to attack us.

EXHIBIT 2: **Table of importance and conviction**

Topic	Importance (more blue = higher)	Conviction
Demand 1: Stimulus programs benefit copper demand		++
Demand 2: Greening of electricity means copper wins		++
Demand 3: The EV revolution needs copper		++
Demand 4: Copper least sensitive to the carbon price		++
Demand 5: Substitution and minaturization has plateaued		+
Demand 6: A completely circular economy for copper is impossible in the near term		+
Demand 7: Copper serves a variety of endmarkets		+
Demand 8: Per capita consumption modest but critical		++
Demand 9: Infrastructure spending too low		?
Demand 10: A 100-year trend supports growth		++
Supply 1: Historical cash flow discipline should theoretically lead to copper volume growth, but options are poor and few		?
Supply 2: We aren't spending enough to find more copper		+
Supply 3: Current expansionary capex spend is too low to grow copper production		+
Supply 4: Rising environmental standards – a headwind for current mines and potential projects		+
Supply 5: Copper is geologically relatively scarce		++
Supply 6: Ore grades of copper fall over time		++
Supply 7: We are finding less and less copper		+
Supply 8: Consensus supply forecasts over-promise and under-deliver		?
Supply 9: Disruptions to supply are significant and inevitable		+
Supply 10: Productivity gains have been stagnant for years		+
Supply 11: Wage deflation can't offset productivity		++

Conviction: ++ = strong, + = medium, ? = lowest
Source: Bernstein analysis

10 REASONS COPPER DEMAND IS ROBUST

Although clearly both supply and demand dynamics are important for commodity market fundamentals (and are interrelated); we begin with a demand deep dive. It is our view that demand dynamics are likely to change over a shorter timeframe and be a source of broader market debate compared to supply dynamics. As such, changes in (views on future) demand have the capacity to influence prices in a shorter time period and often to a greater magnitude than supply dynamics.

We begin with demand dynamics which are related to ESG (Demand 1-4); move on to drivers which explore the health of demand mix (Demand 5-7), and finish with longer term trends (Demand 8-10). We believe copper demand is likely to remain robust for many years to come.

DEMAND 1: STIMULUS PROGRAMS BENEFIT COPPER DEMAND

Infrastructure spending is well below required levels in both developing and developed countries. Emerging markets continue their march towards the creation of wealthier societies; infrastructure is a critical enabler of this. The trend of urbanization doesn't show signs of slowing, and again this requires substantial infrastructure spending. Developed markets, on the other hand, are waking up to the fact that their infrastructure needs repair.

DEMAND 2: GREENING OF ELECTRICITY MEANS COPPER WINS

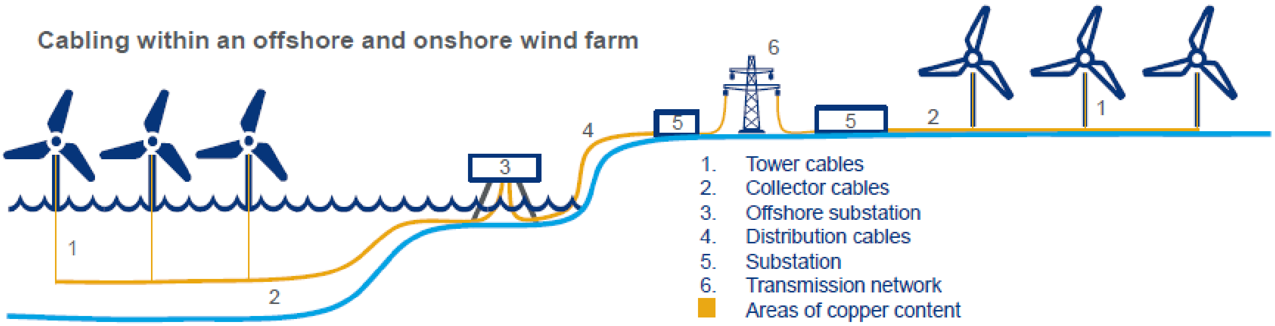
Copper is an irreplaceable metal to meet the goals of a greener economy. Fundamentally, copper is unmatched in its electrical and thermal conductivity, which are only surpassed by some precious metals such as gold. At the very highest level, the construction of the "green economy", represents the move to an increasing share of electricity in the world's primary energy mix and then increasing the efficiency with which this electricity is converted into economic utility. Any change that reflects this overarching narrative (whether EVs, renewable energy, or the efficiency of anything from electric motors to electrical transformers) is going to require more copper than its "conventional" counterpart.

It is not enough to simply state that copper is important for a greener economy. To analyse the impact of various emission targets, we need to quantify the amount of copper we will need, and the first step in this is to estimate the **"copper effectiveness"** of the metal in reducing CO_2 emissions—i.e. the tonnes of CO_2 emissions reduced per year for each additional tonne of copper embedded in the economy for this purpose. The European Copper Institute's estimate that adding one tonne of copper can reduce 100-7,500 tonnes of CO_2 emissions per year. This range of copper effectiveness spans almost two orders of magnitude, which shouldn't be too surprising given the vast range of applications. What we need to understand is the distribution of this effectiveness and thus the average or representative level of copper effectiveness in aggregate. This in turn will allow us to approximate the amount of copper demand to meet various CO_2 emission targets.

One of the clearest instances of the role played by copper in reducing CO_2 emissions is in the energy mix and the copper intensity of low-emission fuel sources. Renewable energy assets require 3-15 times as much copper as conventional power generation per unit of installed capacity. If we examine wind and solar energy facilities (these tend to use the most copper per unit power capacity), a large amount of cabling is needed to connect the many wind turbines, solar cells, and energy storage systems over a large area. Moreover, many of the major electrical components which these assets require are copper-intensive (such as generators, inverters and transformers). Offshore wind, for instance, is far more copper-intense than onshore, primarily due to the greater need for cabling to transfer power, but also due to the copper content of generators and transformers (Exhibits 3 to 5).

Importantly, these copper-intensive industries are growing rapidly, Today's wind capacity of ~600GW is set to almost triple over the next decade and a growing (but still minority) share of this will be coming from offshore farms. We estimate that the current growth trajectory of wind capacity equates to a ~330kt of copper demand this year, growing at an 9% CAGR over the next 10 years. In other words, we should be expecting almost 1 million tonnes per annum of incremental copper demand coming from wind power alone in 2029 (Exhibit 7). Solar power is similarly continuing its capacity build out globally, requiring yet further increases in copper production.

EXHIBIT 3: **The move to renewable energy generation will require a considerable amount of copper**



Source: Wood Mackenzie

EXHIBIT 4: **The draw from wind energy is considerable, as seen below for onshore farms...**

Copper Intensity in Wind Farms	
	Onshore
Component	tonnes Cu / MW
Generator	0.4
Transformer	1.0
Tower cables	0.3
Gearbox	0.1
Collector cables	2.6
Substation	0.5
Distribution cables	0.5
Total	**5.4**

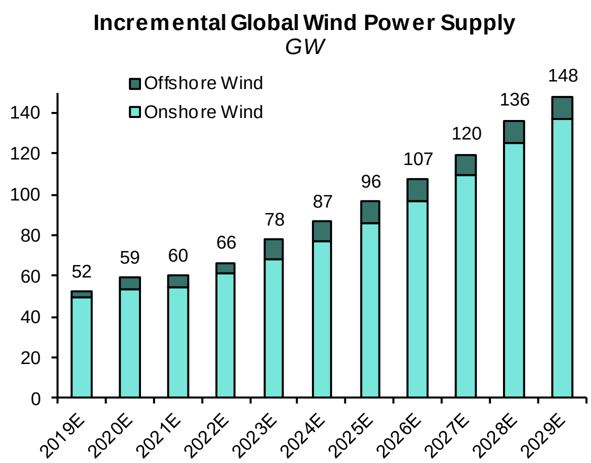
Source: Wood Mackenzie

EXHIBIT 5: **...though offshore farms require even more copper per unit of energy**

Copper Intensity in Wind Farms	
	Offshore
Component	tonnes Cu / MW
Generator	3.2
Transformer	1.4
Tower cables	0.6
Gearbox	-
Collector cables	5.1
Substation	1.1
Distribution cables	3.9
Total	**15.3**

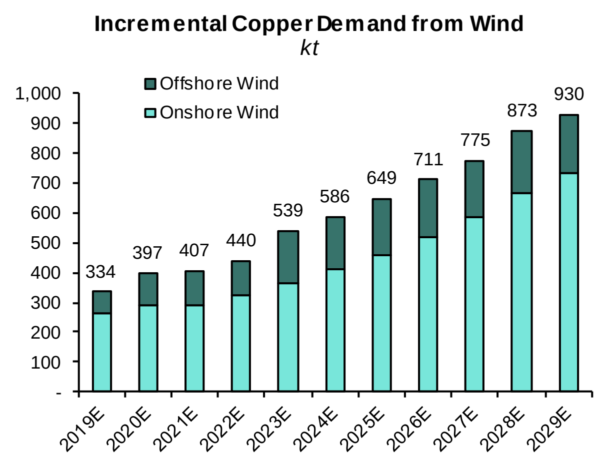
Source: Wood Mackenzie

EXHIBIT 6: **Rapid growth of wind power...**



Source: Bernstein estimates and analysis

EXHIBIT 7: **...and commensurate copper demand growth**



Source: Wood Mackenzie, Bernstein estimates and analysis

Of course, cars are not the only polluters in today's world. The energy generation industry would have to addressed in decarbonisation scenarios, which is most likely to encompass a shift towards zero-impact solar and wind technologies. The question becomes how copper intensive these technologies are. We break these down as follows:

+ **Electricity generation.** We estimated the copper effectiveness of electricity generation on the assumption that low-emission energy sources will be split evenly between solar, onshore wind and offshore wind. We know the incremental amount of copper required per MW of installed capacity vs. conventional power generation. We also know that coal power, for example, emits around 5000 tCO_2/MW. Based on this we can estimate copper effectiveness.
+ **Residential, commercial and other.** The estimates for this category are less precise, given the range of applications. We have assumed the logarithmic average of the European Copper Institute's range of 100-7,500, which would round to 1000 tCO_2/tCu. We used the logarithmic average since we are likely to see an exponential distribution of copper effectiveness, in which very few applications yield 7,500 tCO_2/tCu, and a longer tail of less effective applications. If the distribution is exponential, the logarithmic average will be the appropriate one to use.
+ **Industrials.** The estimates for industrial applications are similarly vague given the range of industrial processes. We have assumed that copper effectiveness for industrial applications would be significantly lower than that of residential and commercial applications. This is because many industrial processes have been optimized over decades, so the scope for "quick fix" improvements would be lower. Also, big changes in CO_2 emission would need to come from electrification of existing thermal processes, which is likely to be copper intensive.
+ **Land use and biomass.** Copper effectiveness is zero for this segment. The use of copper does not reduce CO_2 emissions from burning or rotting trees or from farming.

EXHIBIT 8: **Though the demand pull for copper in other avenues of decarbonisation is much lower (i.e. the copper effectiveness is much *higher*), these factors make up the majority of eventual copper demand**

Copper Intensity of Decarbonisation

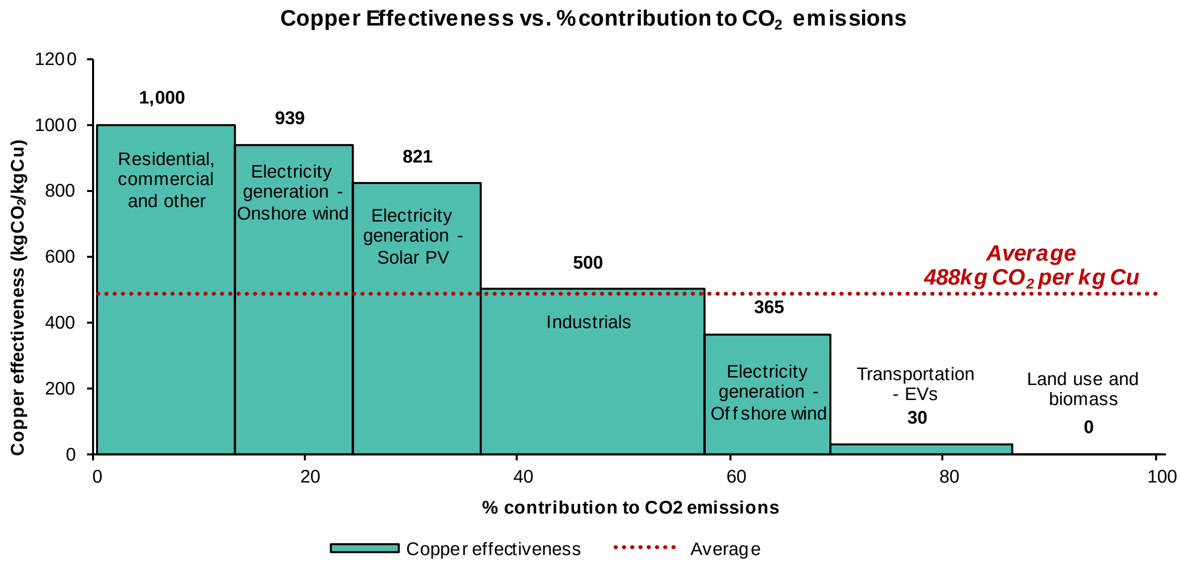
Residential / Commercial Energy Consumption	Power Generation - Onshore Wind	Power Generation - Solar	Power Generation - Offshore Wind	Land Use / Biomass
1,000kg CO_2 per kg copper	939kg CO_2 per kg copper	821kg CO_2 per kg copper	365kg CO_2 per kg copper	none

Source: Bernstein analysis

In Exhibit 8 we summarise copper effectiveness by application and provide approximate weighting for their contribution to overall decarbonisation. We estimate **the average to be ~500 tCO_2/tCu – i.e. every tonne of copper embedded in the global economy has the potential to remove ~500t of CO_2 per annum**. A key point to note is that EVs are far more copper intensive[1] than the other major applications. This means that the amount of copper used per tonne of CO_2 reduction would commensurately vary depending on how aggressively EVs are pursued versus other measures.

[1] Copper intensity in this context refers to the number of tonnes of copper, embedded in the physical capital stock of an economy, required to reduce CO_2 emissions by one tonne per year (i.e.: the reciprocal of copper effectiveness)

EXHIBIT 9: **We estimate the rough distribution of decarbonising technologies to be as shown below, meaning that the implied average copper effectiveness is ~500kgCO₂/kgCu**



Source: European Commission Joint Research Centre EDGAR, International Energy Agency (IEA), US Department of Energy, Bernstein analysis

Estimate range

With these estimates of effectiveness, we are not aiming to be final or give exact precision. There are a lot of moving variables here: the technology mix could be different, the copper consumption could be different, the estimates of current emissions have some margin of error, etc. As such, we show an upper and lower bound scenario to go along with our base case, with a brief summary of the logic defined in the below exhibit:

EXHIBIT 10: **Our three scenarios for copper demand can be broken down as below**

Scenarios - Copper Use in Decarbonisation			
	Copper Effectiveness *t CO_2 / t Cu*	**Impact on Copper Demand**	**Logic**
Upper Bound *(Cu least effective)*	*150*	Highest	*Copper is employed in highly copper-intensive decarbonising applications (e.g. a large ramp-up of offshore wind capacity). This scenario is also in line with rapid uptake of EVs, which draw the most demand copper demand relative to their contribution to emissions.*
Mid Level	*500*	-	*Copper use is akin to our base case modelling, shown in Exhibit 9. The largest and most copper-intensive demand pull comes from EVs, though there is also a considerable amount of copper required by on/offshore wind and solar energy.*
Lower Bound *(Cu most effective)*	*1,000*	Lowest	*Copper is highly effective in decarbonising the environment. The highest-impact applications and least-copper-intensive applications (e.g. onshore wind and solar) are used in a higher quantity.*

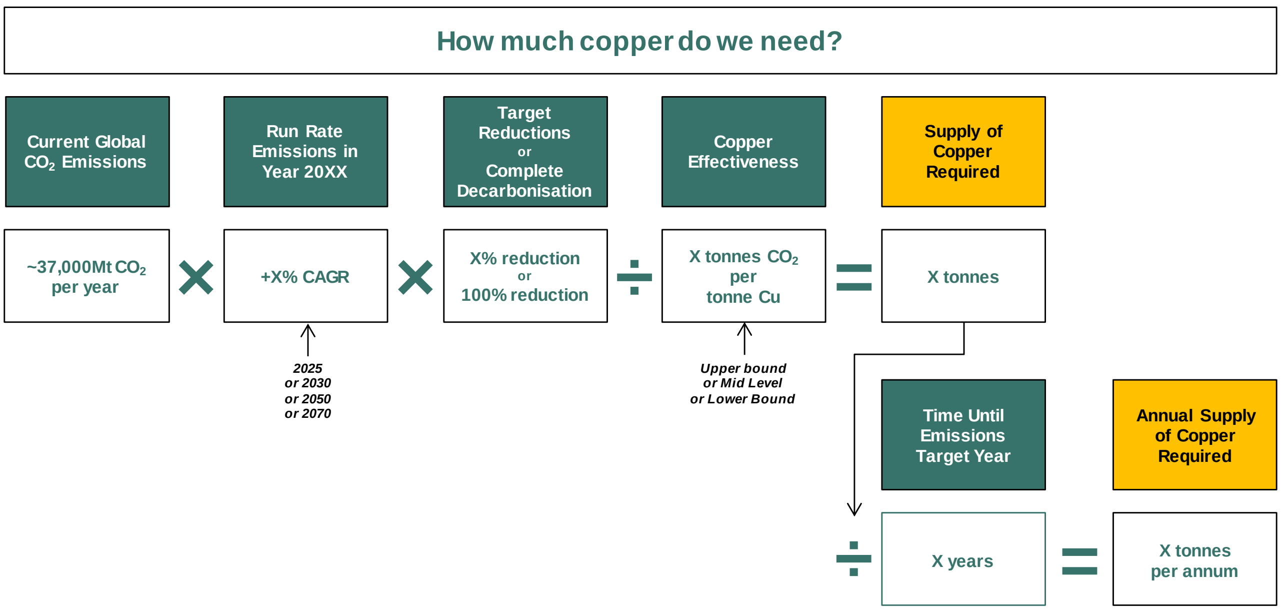
Source: Bernstein analysis

How quickly does copper supply need to grow?

Further to the effectiveness of copper, we also need to model several pathways towards decarbonisation (i.e. the importance that global development goals will attach to it). The most straightforward way to do this is to set a date in the future – say the year 2050 – and to assume that the target of zero emissions can be achieved at this point in time. We lay out various scenarios which show the timing of decarbonisation – from a rapidly accelerated "Greta" scenario, aiming to be net zero by 2025, to a more conservative target of 2070. Of course, we could also see a scenario where complete decarbonisation is not implemented, but rather a gradual reduction in emissions is the primary focus of policies. This is essentially what has been put in place to date, so we use this as our base case "Government Targets" scenario, showing it alongside the more drastic decarbonisation options.

Our calculation method is exactly the same across each scenario, as laid out in Exhibit 11.

EXHIBIT 11: **How we use our effectiveness estimates to come to a total global copper demand figure**



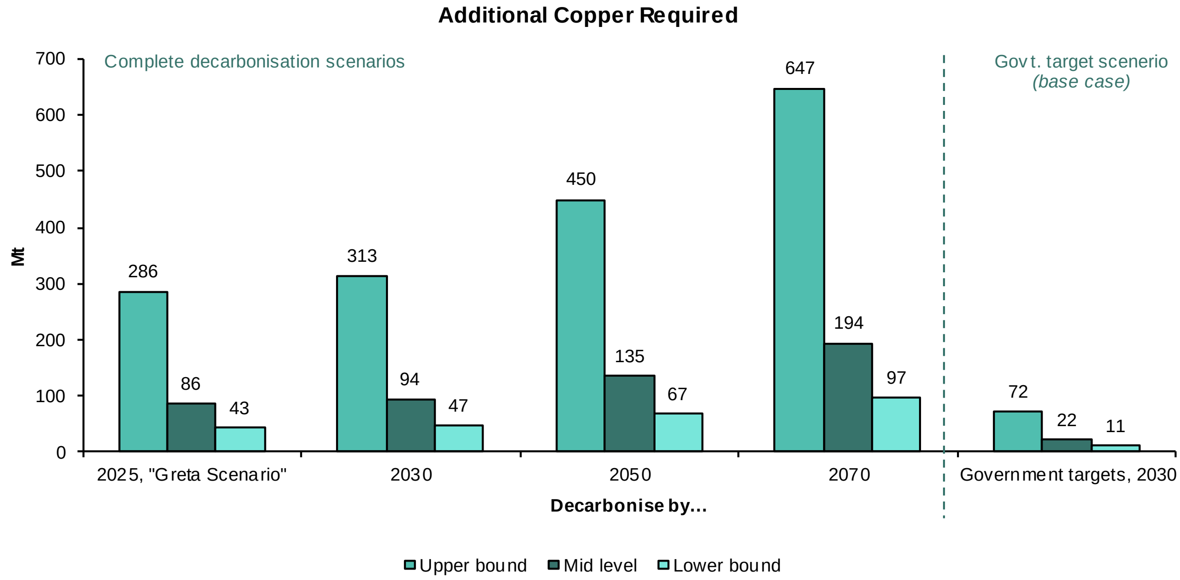
Source: Bernstein analysis

Our estimates show that we need between 10-70Mt of total additional copper to meet the 2030 global CO_2 emission targets (Exhibit 11). This equivalent to 2-13Mt of incremental annual copper demand each year until 2030 (Exhibit 13). Unsurprisingly, the amount of copper required is far larger to meet decarbonisation targets. The most aggressive decarbonisation scenario with a less-efficient use of copper would require ~95Mt of annual incremental copper production.

Importantly, from these figures we can calculate the implied growth rates of copper production to meet the demands (Exhibit 14). In short, **copper production needs to grow by between 3% and 6% per year between now and 2030 in order to meet the government targets. More rapid decarbonisation scenarios than envisioned under the 2015 Paris Agreement require growth rates of copper that are completely divorced from what we have seen historically.**

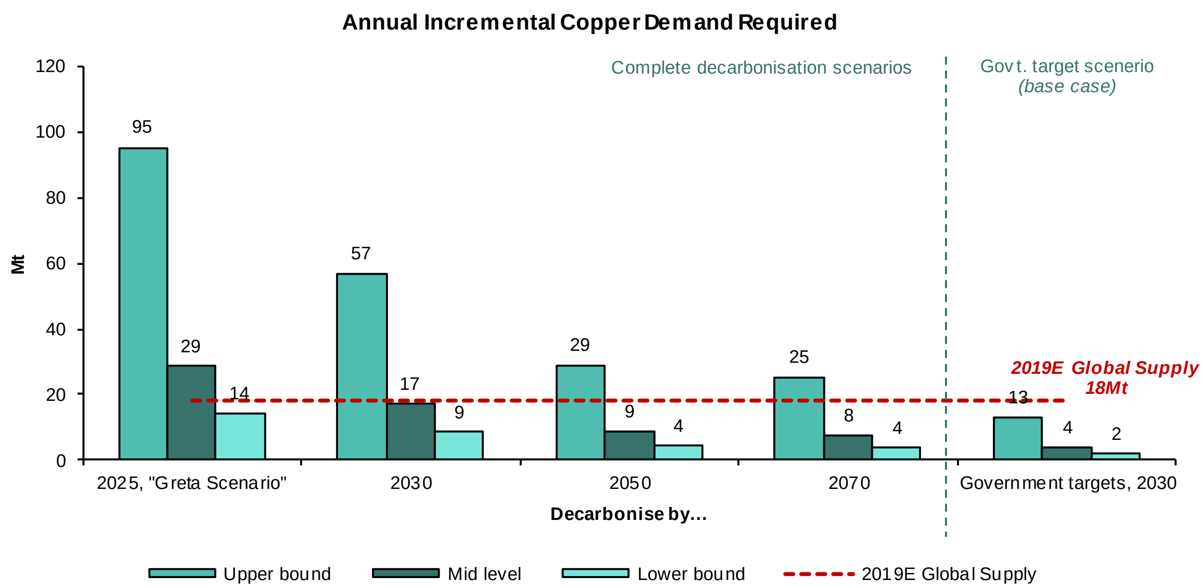
+ The "Greta Scenario" of decarbonisation by 2025 would require copper production growth of between 10% and 31% per year until 2025 (depending on the copper intensity of decarbonisation), which would be impossible without an unprecedented reorientation of the global economy.
+ A complete decarbonisation by 2070 would require growth rates of copper that are, of course, much more in line with the historical trend. However, the flip side of this is that leaving the issue until 2070 means that the magnitude of the problem grows larger over time. Under one possible scenario, leaving the decarbonisation of the world till 2070 would then require an investment in copper intensive technologies roughly equal to the total known reserve base of copper (i.e. 647Mt of copper required versus total identified reserves of 830Mt)!

EXHIBIT 12: **Unsurprisingly, any complete decarbonisation scenario would require substantially more copper than the government targets**



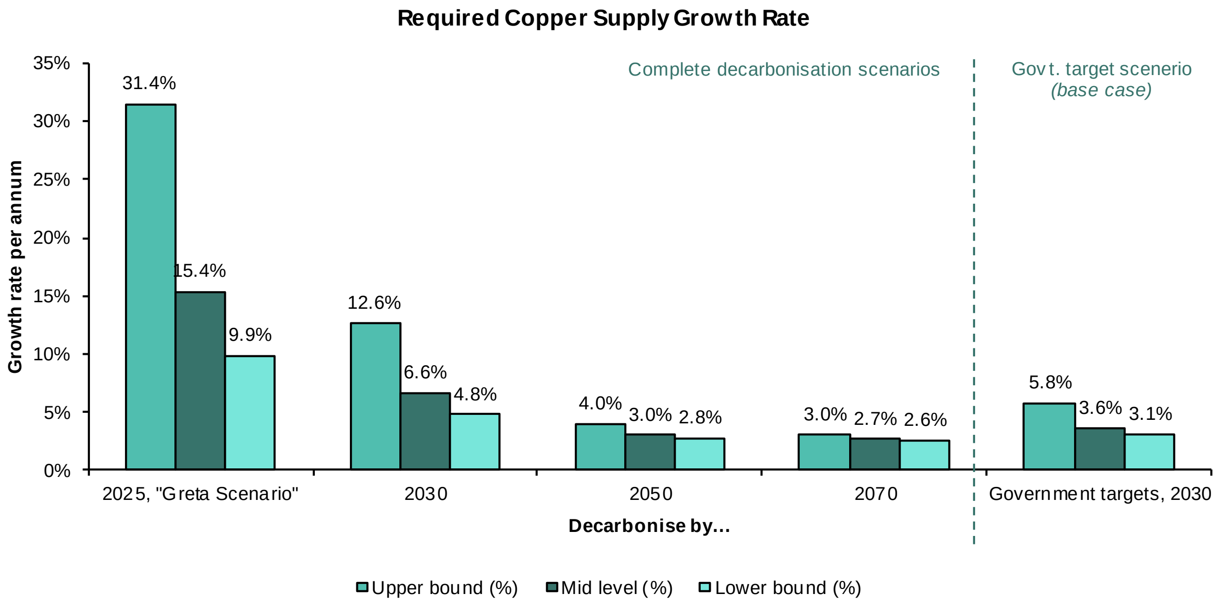
Source: European Commission Joint Research Centre EDGAR, International Energy Agency (IEA), US Department of Energy, Bernstein analysis

EXHIBIT 13: **The draw on copper is considerable, especially when you put this in the context of the current global supply (and we don't see much by way of growth coming over the horizon)**



Source: European Commission Joint Research Centre EDGAR, International Energy Agency (IEA), US Department of Energy, Bernstein analysis

EXHIBIT 14: **The supply growth required to keep pace with decarbonising demand is ~4% in our base case**



Source: European Commission Joint Research Centre EDGAR, International Energy Agency (IEA), US Department of Energy, Bernstein analysis

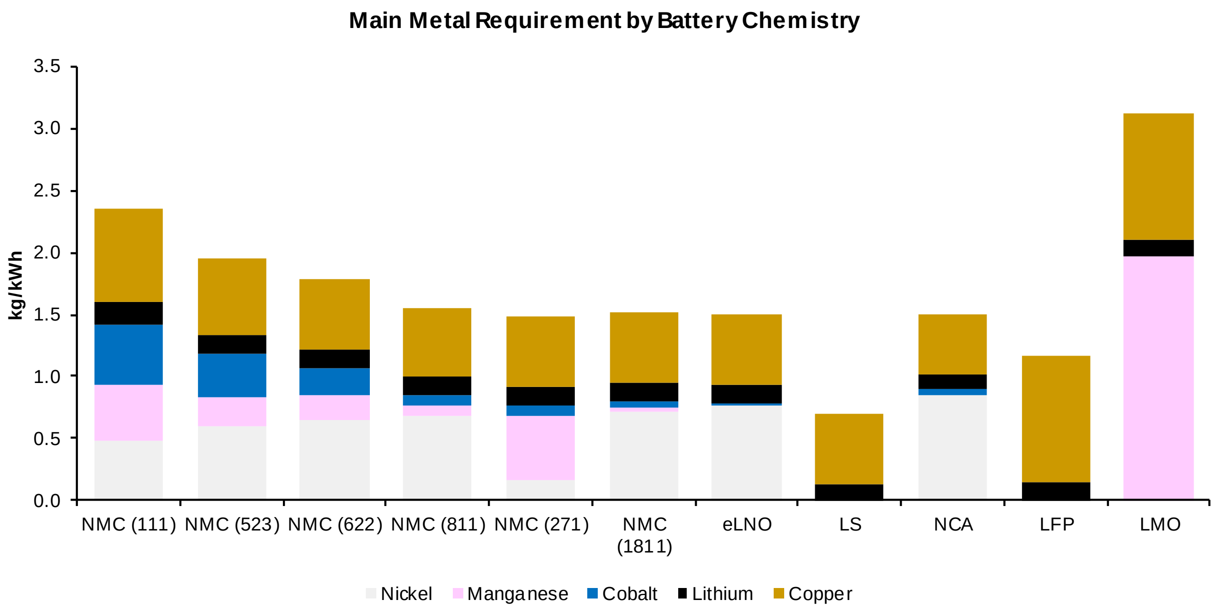
DEMAND 3: THE EV REVOLUTION NEEDS COPPER

Exhibit 15 color codes the metals roughly by their native state (nice touch no?) and shows requirements by chemistry. Note the difference between the red line on the previous exhibit and the metal requirements below include the other materials needed for battery construction.

Note that copper is present in all batteries (and in the stator, inverter, charger as well). Other metals trade off in terms of dominance by chemistry type.

Said another way, I can find a battery chemistry without cobalt, or without manganese, or without nickel, or with variable amounts of lithium and copper (but will always need some). Of course not all batteries are created equally in terms of commerciality, performance, safety, etc. But to the extent that batteries are substitutable, the cost of raw materials will influence decisions. For a primer on battery technology, click *EV Revolution Blackbook 2019.*

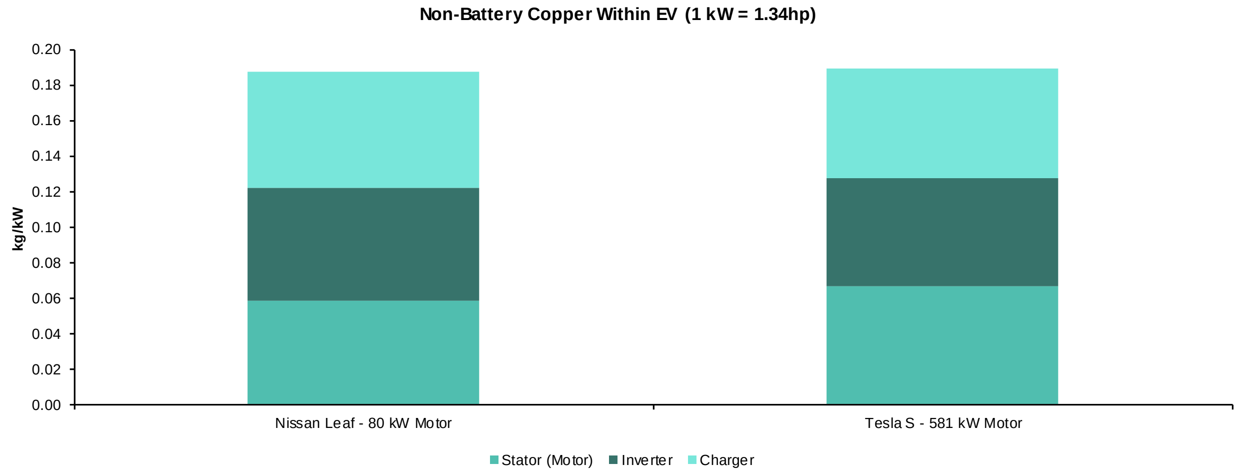
EXHIBIT 15: **if we concentrate on the "metal" mass requirements, we see variation in mass needed and in composition depending on which chemistry technology wins. A 50 kWh battery for a single EV requires from <50 kg to 150 kg of these materials**



Source: Bernstein analysis & estimates

A final point on forecasting metals demand – Exhibit 16 shows that copper is required for more than just the battery…stator, inverter, and charger all have need as well.

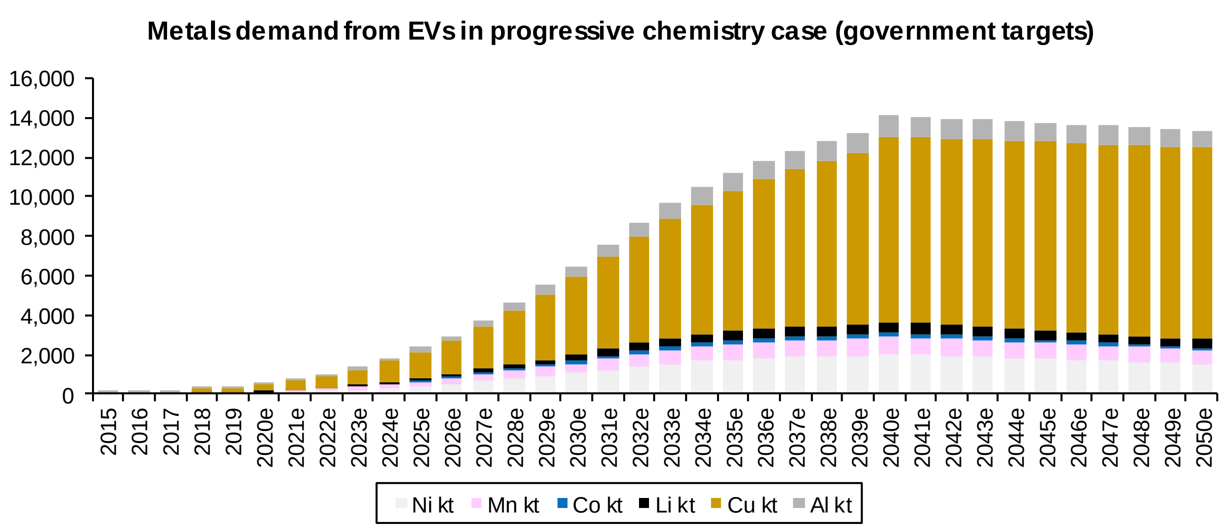
EXHIBIT 16: **However, for copper, there is more to the EV transition than just the battery, there is also the motor, the inverter/converter and internal charging requirement. There is also the copper associated with the external charging of EVs as well as investment in the grid, all of which require copper**



Source: Bernstein analysis

Exhibit 17 shows an annual demand by product by combining our EV forecast with our battery chemistry forecast. Note that annual demand peaks in 2040 when government targets are hit. In subsequent years, changes in the battery chemistry create modest declines in some metals. Copper dominates by volume.

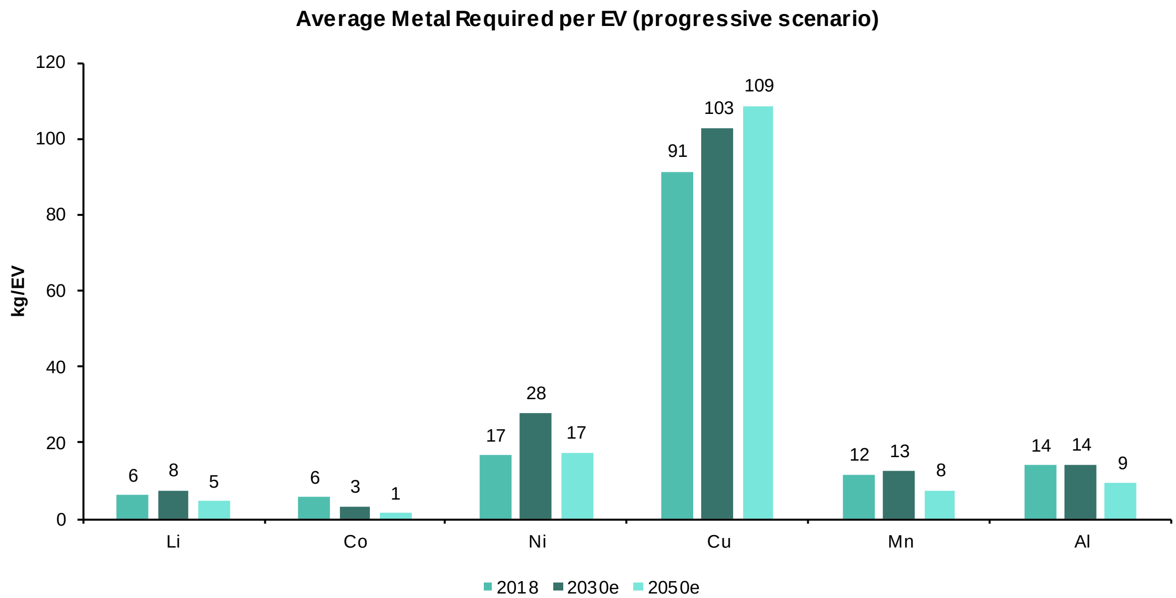
EXHIBIT 17: **Annual metal demand for EVs…a plateau and gradual fall as chemistry innovation wins**



Source: Bernstein analysis & estimates

On a per vehicle basis (**Exhibit 18**), note that transitions in battery chemistry to lower metal requirements means that the absolute mass of metals per EV falls in the very out years (except for copper).

EXHIBIT 18: **Demand for metals per EV to rise in mid term but in out years battery chemistry efficiencies reduce the demand**

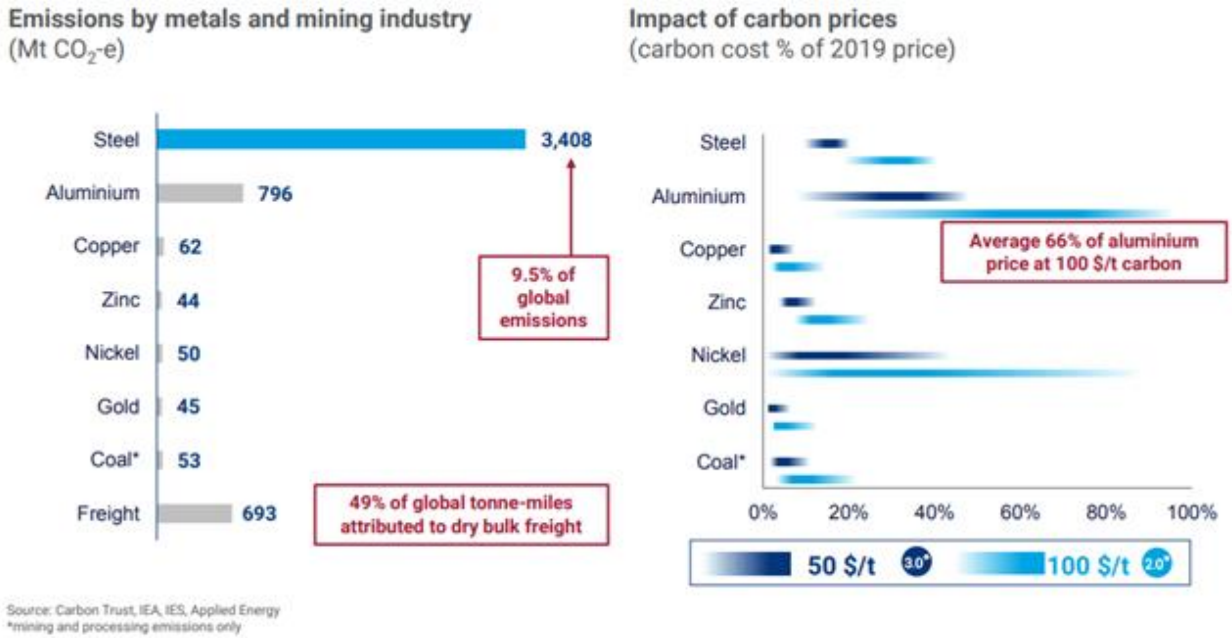


Source: Bernstein analysis & estimates

DEMAND 4: COPPER LEAST SENSITIVE TO THE CARBON PRICE

We note that copper is less exposed to carbon price versus other non-precious metals, especially steel and aluminum.

EXHIBIT 19: **The copper industry emits much less carbon dioxide and is thus much less exposed to carbon taxes**



Source: WoodMac; Bernstein analysis

We discuss substitution more broadly below (in Demand 5). Historically, substitution of copper for aluminum has accelerated once copper prices reach three times the aluminum price. We flag here the possibility of reverse substitution of aluminum for copper given aluminum's exposure to emissions. Making two simple assumptions of a $50/t carbon price and a 3 for 1 substitution based on weight (and ignoring other attendant practicalities including the wire rod premia); the CO_2 cost differential alone is enough to offset the current price differential, i.e. theoretically driving reverse substitution.

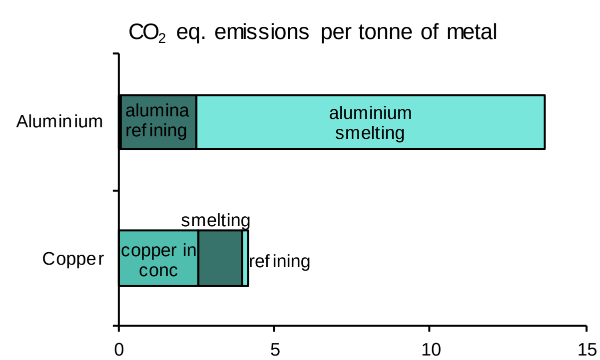
Additionally, the global and cross-sector imperative toward lowering CO_2 emissions may by itself prove a powerful driver for increased consumption of metals with a lower emissions profile, like copper.

EXHIBIT 20: **CO2 costs could drive reverse substitution...**

		Copper	Aluminium	3x Al.
LME price	USD/t	6,668	1,789	5,367
US Premium	USD/t	145	336	1,008
Price	USD/t	6,813	2,125	6,375
Price diff.	USD/t			-438
CO_2 emissions (eq.)	mt (industry)	62	796	
CO_2 emissions (eq.)	per t metal	4.2	13.7	41.0
Assumed CO_2 cost	USD/t	50	50	150
CO_2 cost	USD/t metal	209	684	2,051
CO_2 cost differential	USD/t metal			1,842

Source: Bernstein analysis, Wood Mackenzie

EXHIBIT 21: **...given aluminum's higher emissions vs copper**



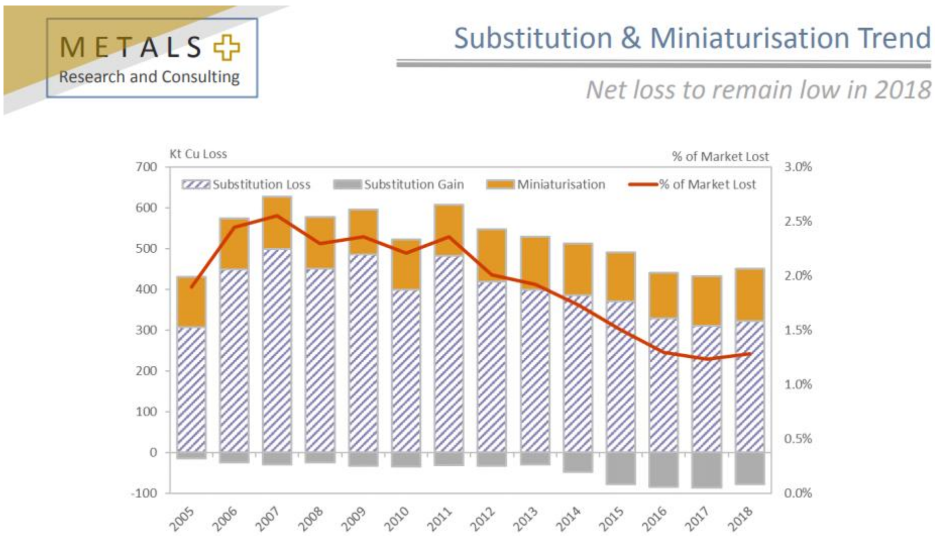
Source: Wood Mackenzie. Bauxite mining is unlabelled given it's a neglible 0.04t of CO2 eq per tonne of aluminum produced

DEMAND 5: SUBSTITUTION AND MINATURIZATION HAS PLATEAUED

It is possible to substitute other commodities (particularly aluminum) for copper. It is also possible to miniaturize copper-bearing equipment. The impact of both of these trends have played out. In any case, the impact of substitution is embedded in the copper intensity shown previously.

We highlight charts presented previously at a Bernstein breakfast by Metalsplus with focus and expertise on this topic.

EXHIBIT 22: **Substitution has undoubtedly been happening, at ~2.0-2.8% of the copper market per year since 2005. We note this substitution is explicitly included in our intensity-based forecast**

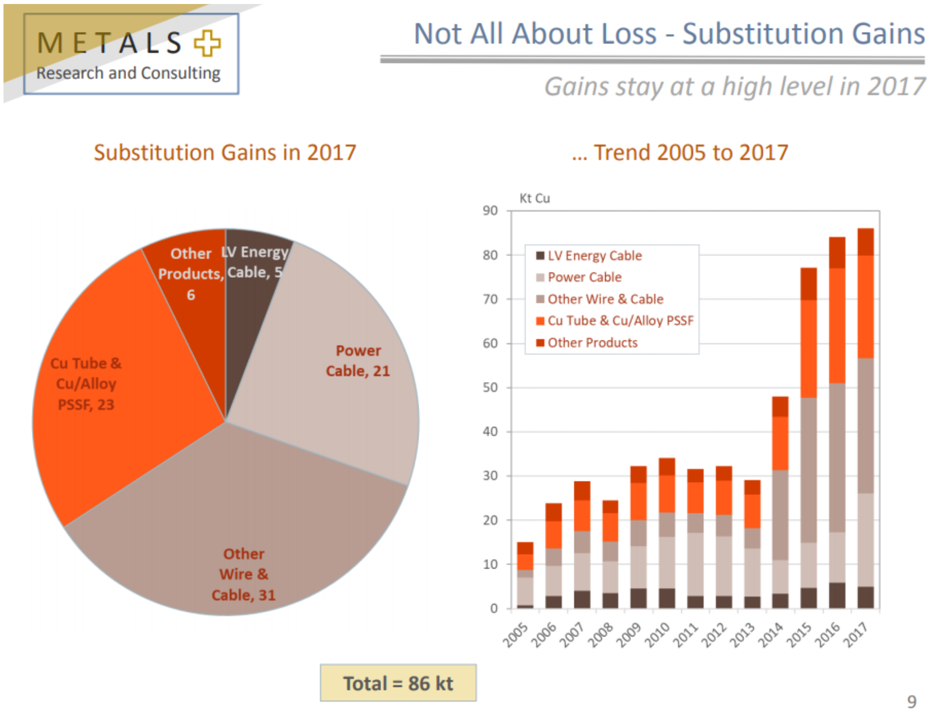


	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Substitution Loss	306	448	499	450	485	399	482	420	398	385	371	329	311	322
Substitution Gain	-15	-24	-29	-25	-32	-34	-32	-32	-29	-48	-77	-84	-86	-78
Miniaturisation	124	125	127	127	111	123	125	127	130	127	120	112	121	128
Total Net Loss	415	550	597	552	563	488	576	514	499	464	414	357	346	372
% of Market Lost	1.9%	2.4%	2.6%	2.3%	2.4%	2.2%	2.4%	2.0%	1.9%	1.7%	1.5%	1.3%	1.2%	1.3%

4

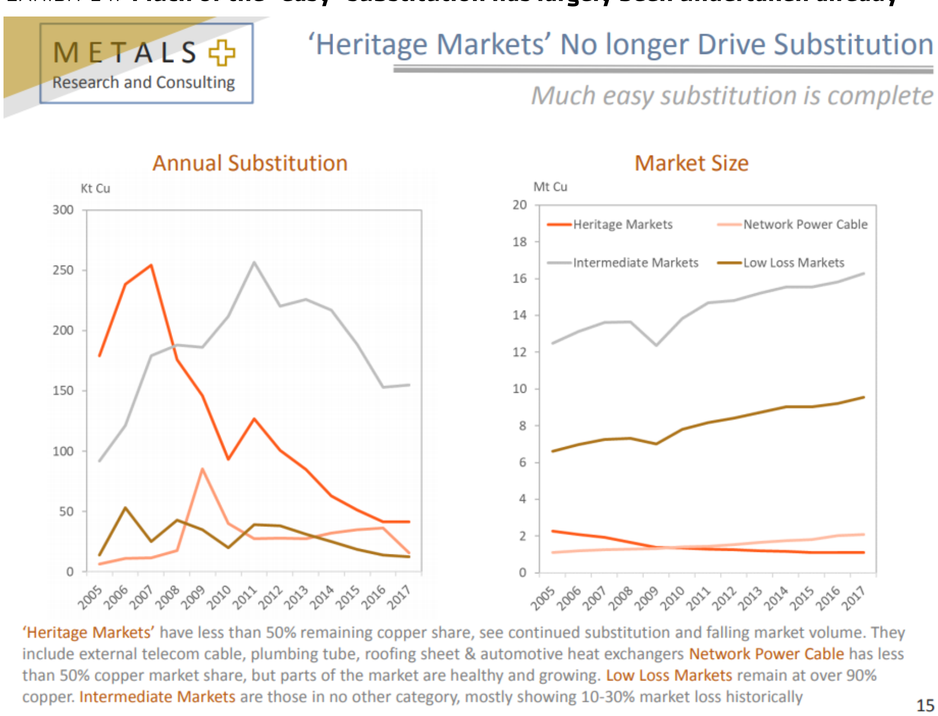
Source: MetalsPlus as presented to Bernstein breakfast seminar

EXHIBIT 23: **...in fact, gross copper substitution gains have become larger in recent years**



Source: MetalsPlus as presented to Bernstein breakfast seminar

EXHIBIT 24: **Much of the "easy" substitution has largely been undertaken already**



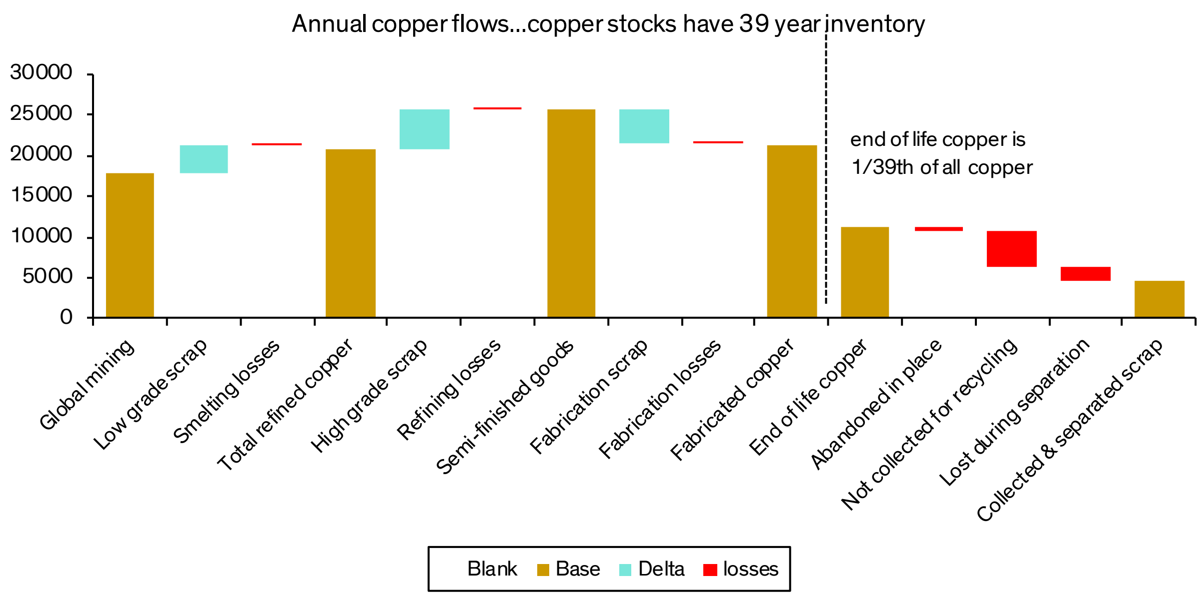
Source: MetalsPlus as presented to Bernstein breakfast seminar

DEMAND 6: A COMPLETELY CIRCULAR ECONOMY FOR COPPER IS IMPOSSIBLE IN THE NEAR TERM

Clearly significant amounts of copper get recycled. Exhibit 25 shows that roughly 1/6th of total refined copper is provided by scrap 1/5th of semi-finished copper is provided by scrap (of course around 1/6th of semi-finished stocks returns to fabrication scrap). Can recycling supplant mining? Only under three conditions: (1) if demand for copper falls so low as to be met by scrap (which for reasons above we deem unlikely) or (2) we rapidly increase the supply of end of life copper (a typical piece of copper survives 39 years "in the wild" which is to say in use) or (3) the efficiency of recycling end-of-life copper is increased.

In terms of item (2), the idea of more rapidly moving copper out of service runs against the notions of the circular economy (which would prefer its use to last even longer). In terms of 3, we note that roughly 40% of end-of-life copper becomes recycled. We also note that the most cost effective recycling already occurs and to capture the remaining 60% of recycling would require either recycling innovations or government mandates. In either case, with perfect recycling, we could displace 25% of current copper demand at a time when we expect demand to double so some substitution will doubtless occur, but not whole substitution.

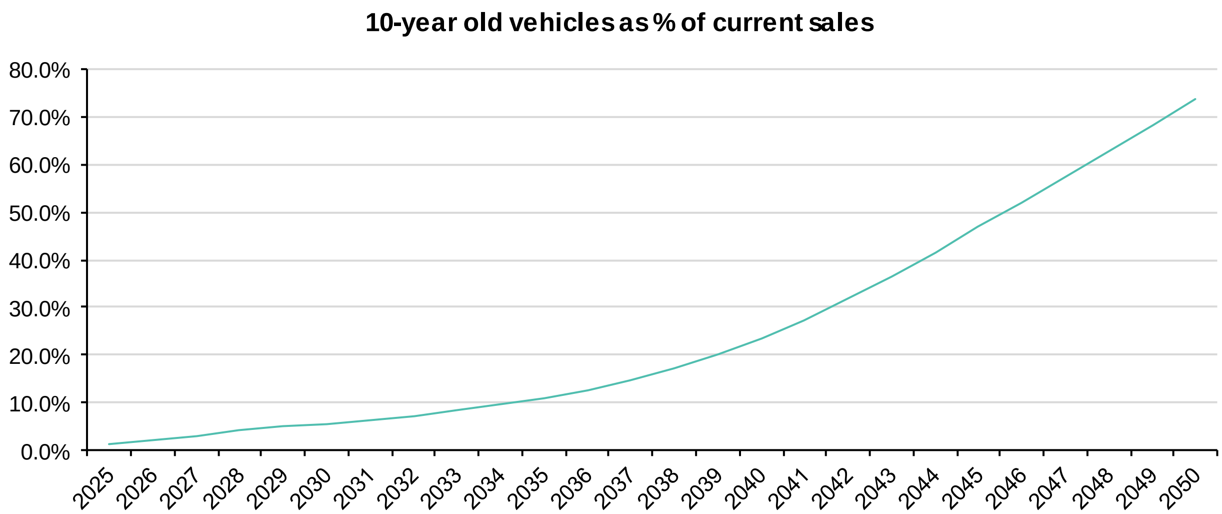
EXHIBIT 25: **Flow of copper supply, demand, and recycling**



Source: Fraunhofer Institute for Systems and Innovation Research ISI for ICA; Bernstein analysis

Another quick note on recycling of EVs (the fastest growing source of demand and thus potential recycling supply). In theory, the call on 'reserves' could be offset by recycling. For comparison, in 2030, cobalt demand would be ~125 kt per annum while recycling estimates from Circular Energy Storage Research & Consulting estimate ~34 kt per annum available (call is a quarter of demand). Our EV demand is a function of the fleet sales times cobalt per vehicle. Our fleet model includes a 10-year vehicle life and assumes those vehicles exit the stock. If 100% perfect recycling of such material occurred, they could supply only a fraction of the required material (5% by 2030 and half by the late 2040s). In theory the recycling of non-EV metals could offset the 'call on reserves', but given the exponential growth in the EV fleet, it cannot mathematically be the source of its own recyclable material.

EXHIBIT 26: **10-year old vehicles (i.e., a source of recycling) as a % of current sales (starting in 2025)...you can't recycle copper that hasn't served its useful life**



Source: Bernstein analysis and estimates

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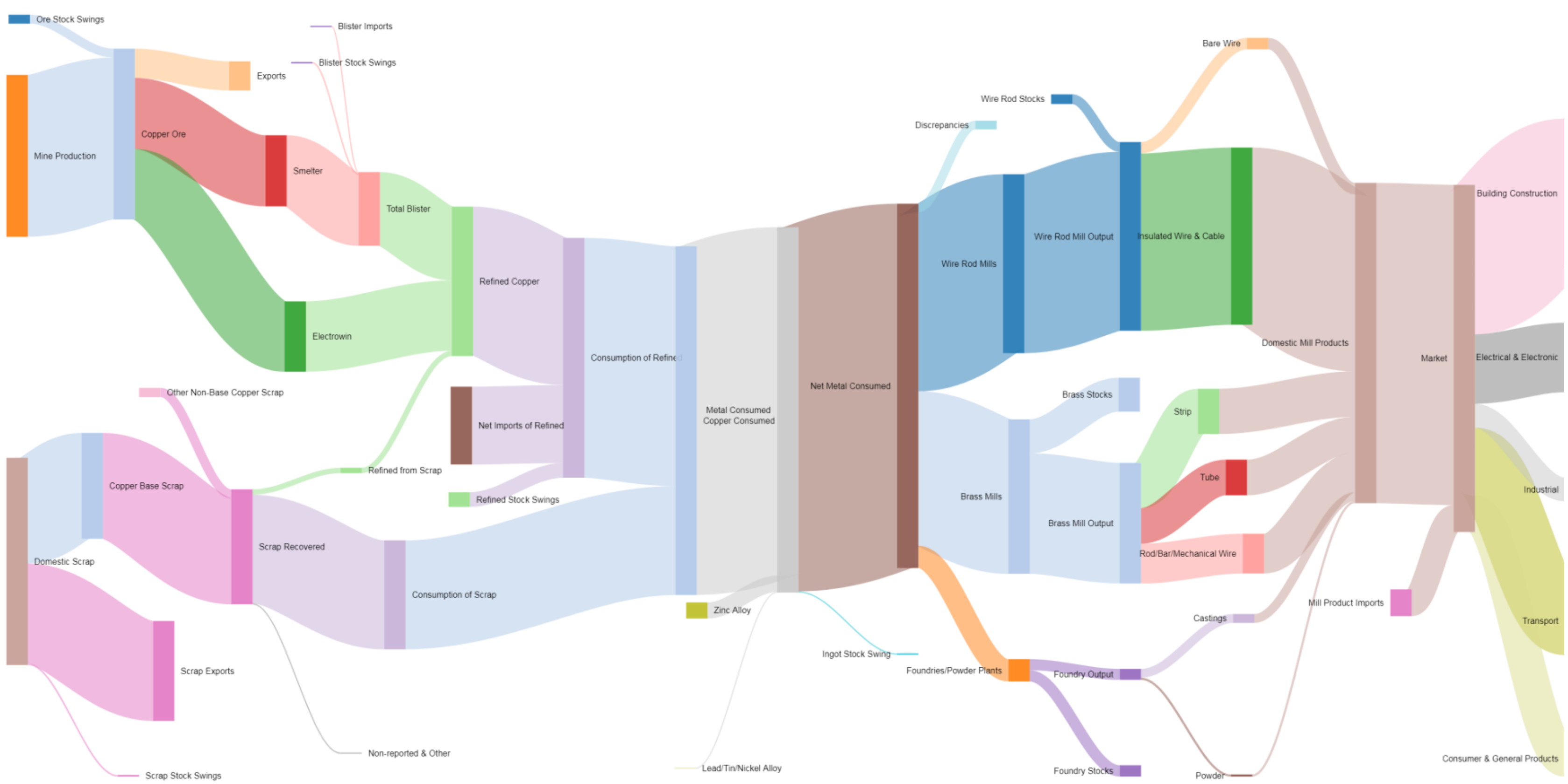
DEMAND 7: COPPER SERVES A VARIETY OF ENDMARKETS

Although we have talked in detail about two new sources of copper demand (EVs and decarbonization), it is important to keep in mind that copper use today is significant and flows into a number of sectors. It is thus difficult for a single disruption to damage copper demand (Exhibit 27).

EXHIBIT 27: **Copper serves construction, electrical & electronic, industrial, transport, and consumer products**

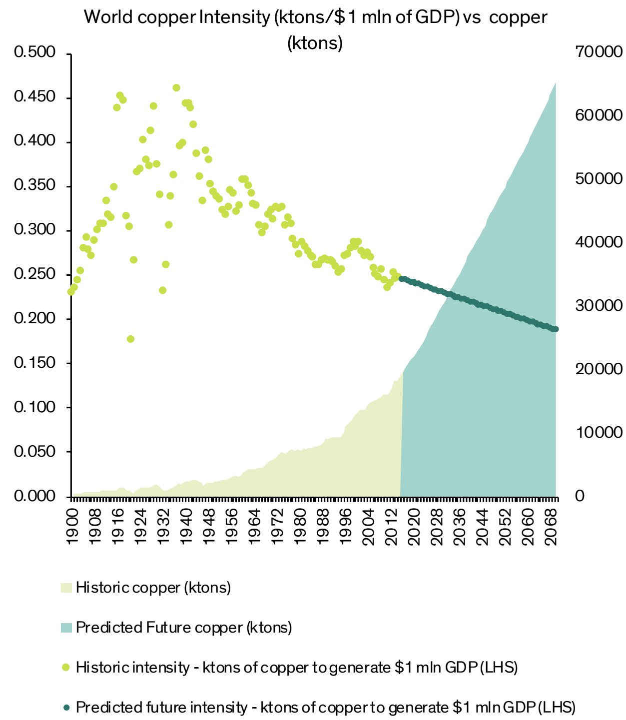


Source: ICSG; Bernstein analysis

DEMAND 8: PER CAPITA CONSUMPTION MODEST BUT CRITICAL

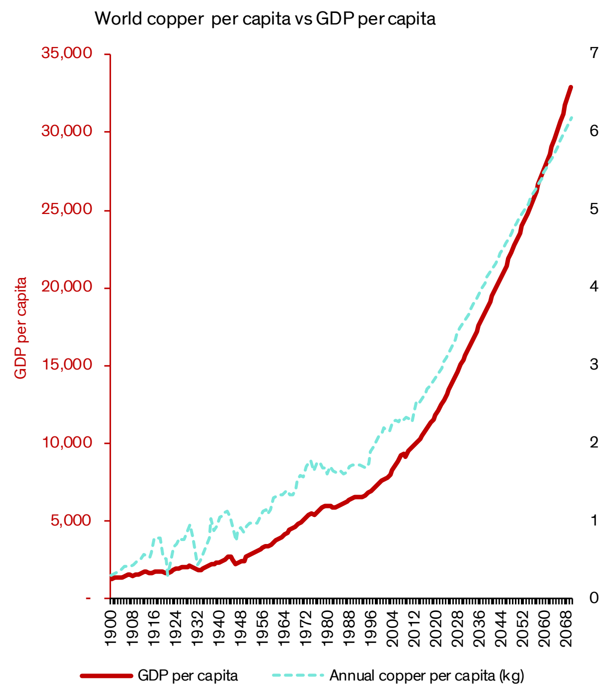
In Exhibit 28, shaded green shows historic copper consumption while green dots show how many ktons of copper were needed to generate $1 mln of GDP. By extrapolating that intensity trend (blue dots/line) and multiplying that intensity by forecast GDP (we use data from OECD, World Bank, and IMF), we arrive at a copper demand forecast (shaded blue). Exhibit 29 compares GDP per capita against copper demand per capita – a tripling of copper demand implies only ~6-7 kg per capita consumption.

EXHIBIT 28: **Copper demand and intensity**



Source: USGS, OECD; World Bank, IMF; Bernstein estimates & analysis

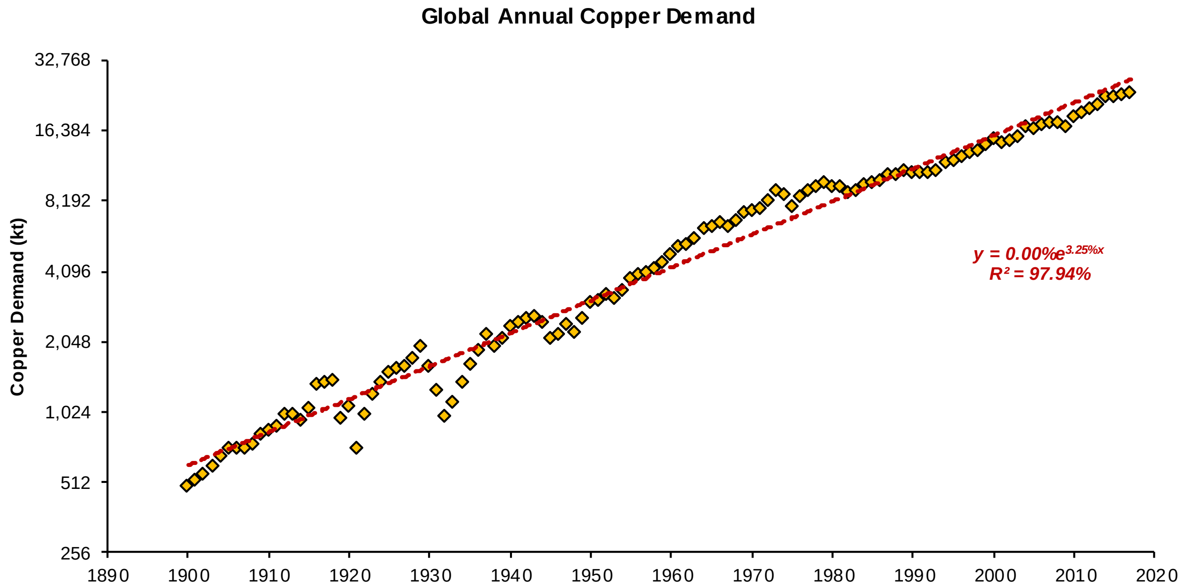
EXHIBIT 29: **Predicted copper demand forecast per capita compared to overall world GDP per capita**



Source: USGS, OECD; World Bank, IMF; Bernstein estimates & analysis

Copper demand growth is strongly dependable…

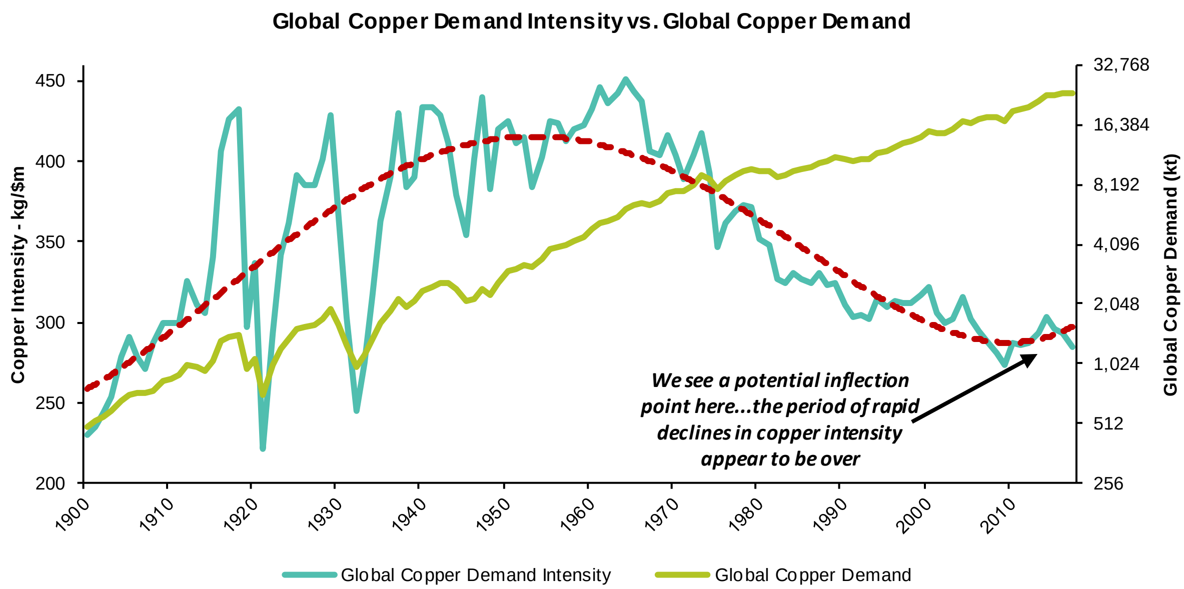
EXHIBIT 30: **Remarkably consistent trend global copper growth over the last 120 years**



Source: Mitchell, Maddison, USGS, Wood Mackenzie, Bernstein analysis

Note that the conservative "extension of linear trend" is arguably too conservative with the potential of an inflection even before the impacts of new demand sources are included.

EXHIBIT 31: **We see potential inflection point in copper demand intensity…we have seen trend decline since the early 1960s but economic development has perhaps never looked so copper intensive as it does now**

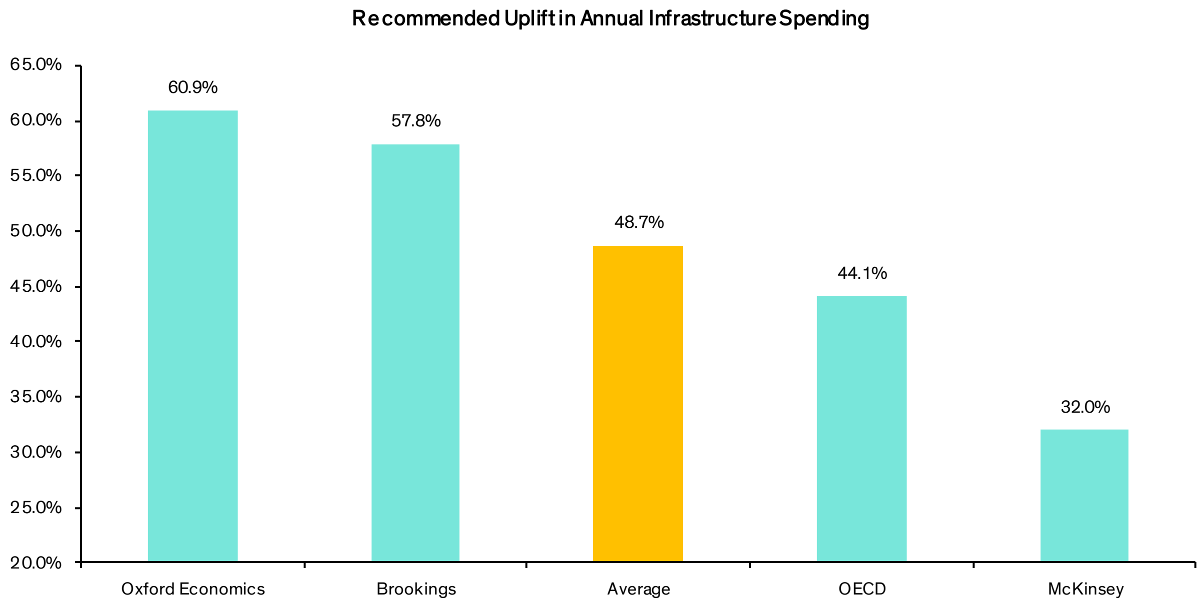


Source: Mitchell, Maddison, USGS, Wood Mackenzie, World Bank, Bernstein analysis

DEMAND 9: INFRASTRUCTURE SPENDING TOO LOW

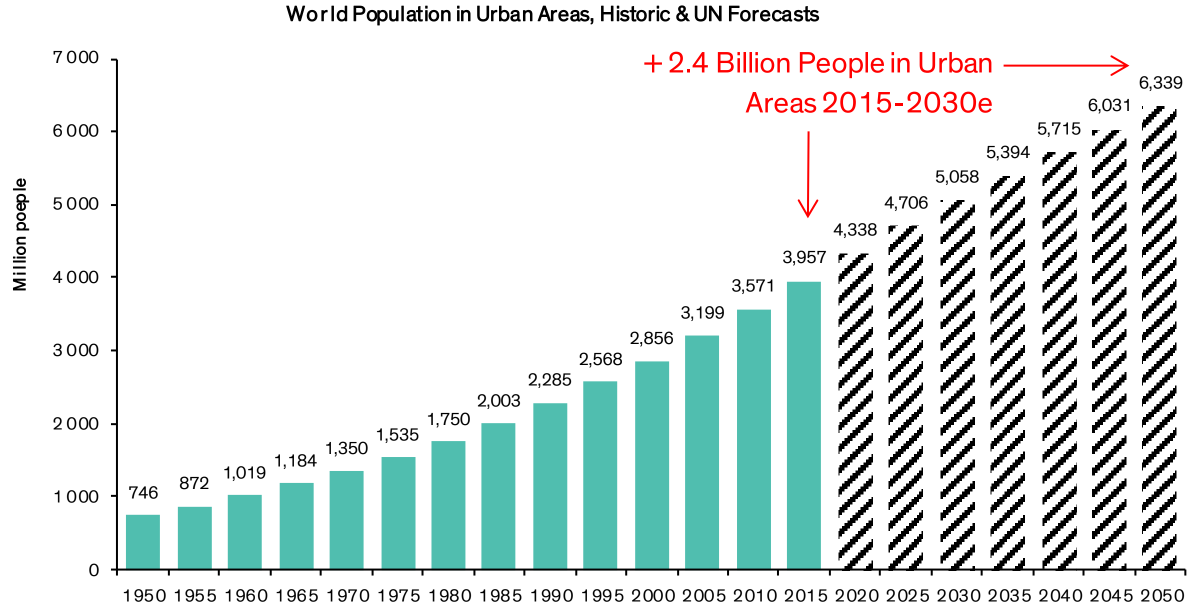
Infrastructure spending is well below required levels in both developing and developed countries. Emerging markets continue their march towards the creation of wealthier societies; infrastructure is a critical enabler of this. The trend of urbanization doesn't show signs of slowing, and again this requires substantial infrastructure spending. Developed markets, on the other hand, are waking up to the fact that their infrastructure needs repair.

EXHIBIT 32: **Major studies recommend an average of ~50% uplift in infrastructure investment over the next 15 years will be required (excluding investment in the "green" economy).**



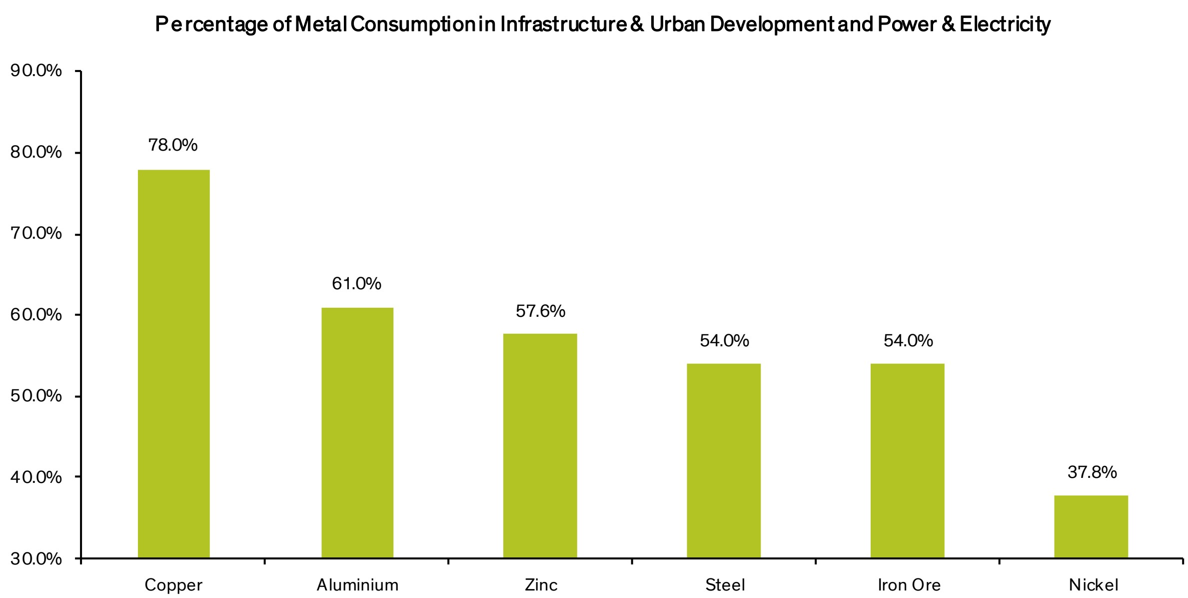
Source: Bernstein, Brookings: "Delivering on Sustainable Infrastructure for Better Development and Better Climate", OECD: "Investing in Climate, Investing in Growth", Oxford Economics for the Global Infrastructure Hub: "Global Infrastructure Outlook", McKinsey: "Bridging Global Infrastructure Gaps"

EXHIBIT 33: **The world is urbanizing...**



Source: UN, Bernstein analysis

EXHIBIT 34: **...and more than any other metal, copper benefits substantially from the development of infrastructure**



Source: UN, Bernstein analysis

DEMAND 10: A 100-YEAR TREND SUPPORTS GROWTH

See Exhibits 28-29.

11 REASONS THAT COPPER SUPPLY IS STRETCHED

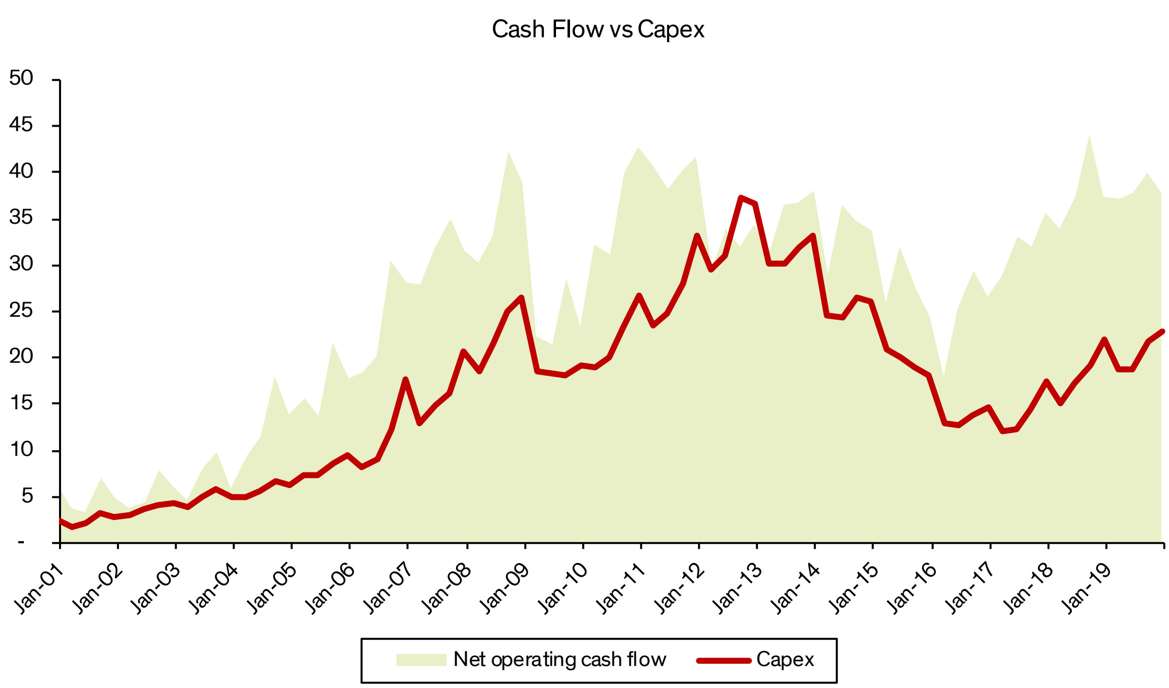
Turning to the supply side, we explore a number of arguments for why future supply will be more difficult. First we address how miners' corporate decision-making may choke significant additional copper supply (Supply 1-4); outline how copper's geology offers a natural insurance against a supply wave (Supply 5-7) and illustrate how historical supply dynamics can give us comfort (Supply 8-11). This suggests a higher incentive price is needed for supply growth.

SUPPLY 1: HISTORICAL CASH FLOW DISCIPLINE SHOULD THEORETICALLY LEAD TO COPPER VOLUME GROWTH, BUT OPTIONS ARE POOR AND FEW

From 2009 to 2016 the sector outspent cash flow…a trend that has since reversed as shown in Exhibit 35.Companies are not currently being rewarded for volume growth but rather for returning cash to shareholders, and although it has recovered from the 2016 lows, sector capex spend is still at relatively moderate levels relative to cash flows.

Current corporate messaging indicates a desire to balance investment and cash returns, and a theoretical desire to grow in copper. Given a significant reduction in the sector's financial leverage in the past three years and an enduringly positive fundamental view on copper, we suspect that investor sentiment has already changed enough to allow investment in high quality, low jurisdictional risk, high returning copper projects – the problem is that precious few of these exist (also see Supply 5-7). Therefore, we suspect that mining companies either a) continue to spend at moderate growth capex in copper, but deliver precious little additional copper supply, or b) mining companies with less financial disciple could invest in lower quality copper project, which by their very nature are likely to be more expensive and take longer to deliver – clearly a positive for copper market fundamentals.

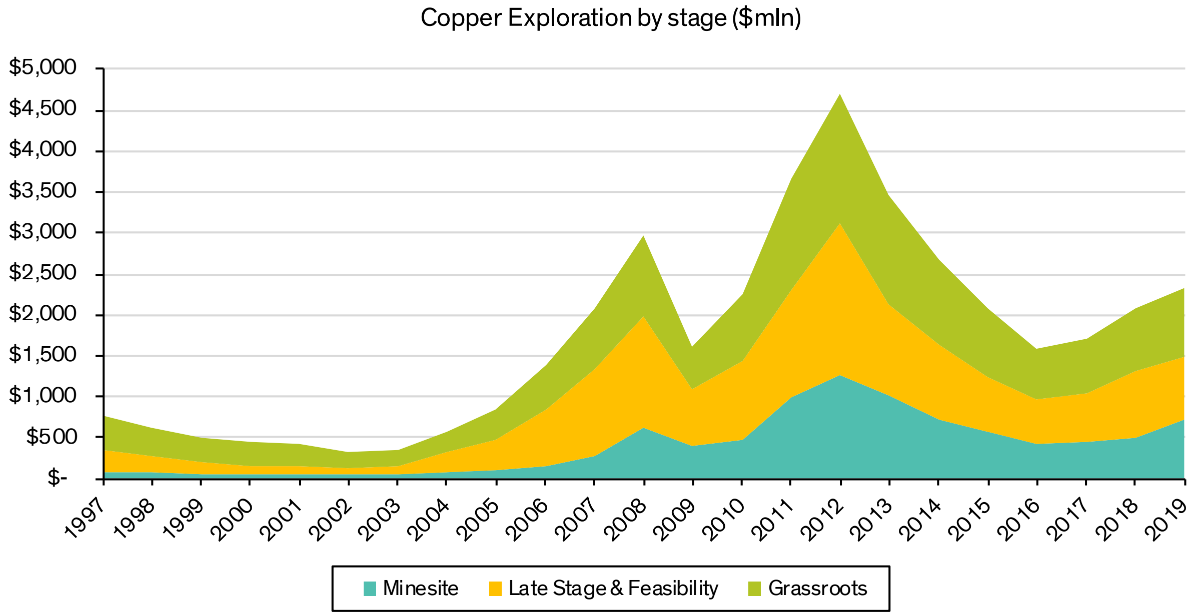
EXHIBIT 35: **Cash flow in excess of capex…a 2016 lesson learnt**



Source: Company reports, Bernstein analysis, Bloomberg

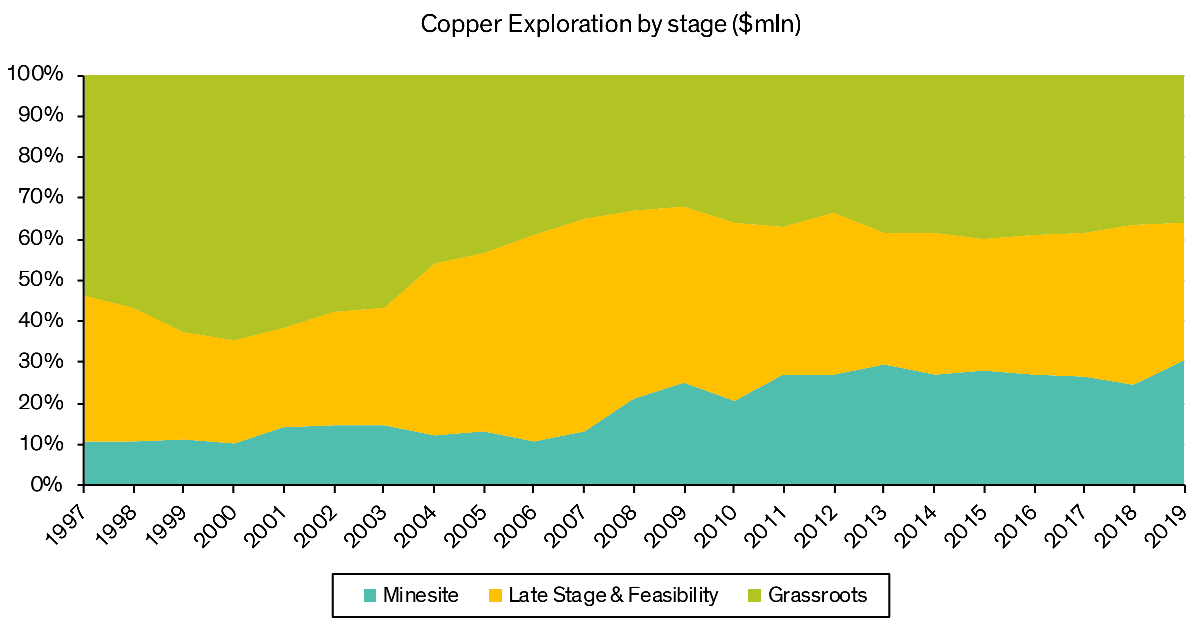
SUPPLY 2: WE AREN'T SPENDING ENOUGH TO FIND MORE COPPER

EXHIBIT 36: **Copper exploration budgets a fraction of a decade ago...**



Source: SNL; Bernstein analysis

EXHIBIT 37: **....and exploration has moved away from grassroots**



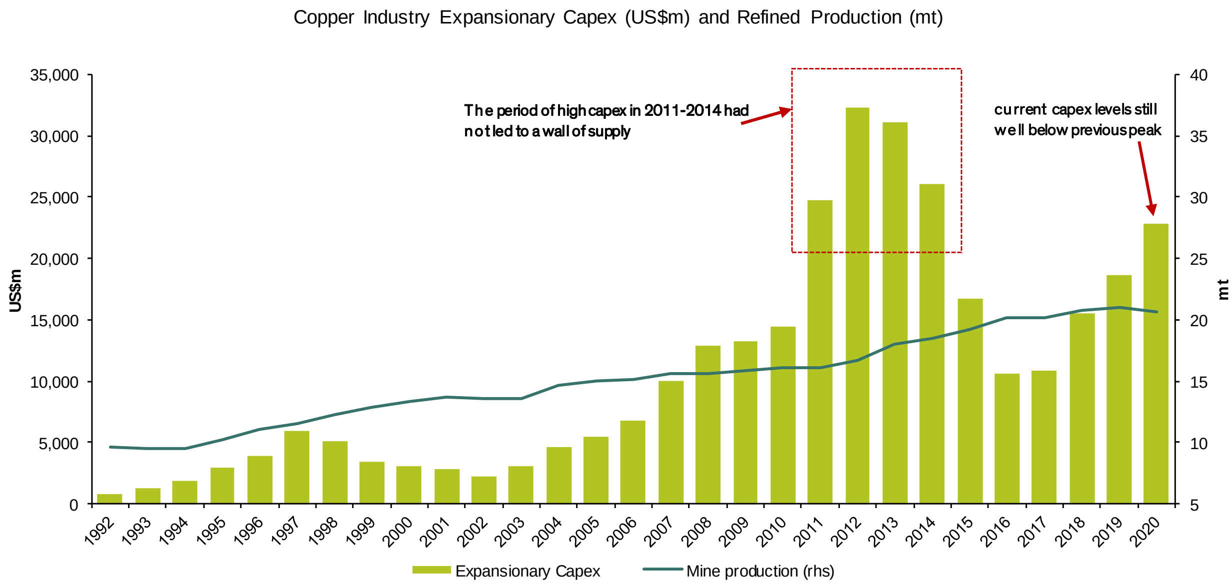
Source: SNL; Bernstein analysis

SUPPLY 3: CURRENT EXPANSIONARY CAPEX SPEND IS TOO LOW TO GROW COPPER PRODUCTION

Copper growth capex spend has proved pretty cyclical (much like the rest of mining capex). As we show in Exhibit 38, the last growth capex cycle (2011-14) apparently didn't yield an increase in copper production. This implies that each $ of copper growth capex spend seems to be yielding less additional copper produced.

Therefore, although copper growth capex is currently trending upwards; we remain relatively sanguine on the potential for this to drive meaningful additional copper supply. The current spend is still below previous peak, and much of copper "expansionary" spend is increasingly being allocated to environmental improvements (see Supply 4) and offset the production drag from copper grade decline (see Supply 6).

EXHIBIT 38: **Expansionary capex while high is well below previous peaks**



Source: Wood Mackenzie, Bernstein analysis

SUPPLY 4: RISING ENVIRONMENTAL STANDARDS – A HEADWIND FOR CURRENT MINES AND POTENTIAL PROJECTS

The ability for mining companies to sustainably and profitably operate is dependent in large part on the ability to comply with the regulatory regimes of the communities in which they operate. Though partly reactionary, we are seeing rising environmental standards for mining operations across the board in most countries. We highlight some of the issues below:

+ **Water** – industrial use of potable water has been in increasing focus given climate change-driven drought in some mining regions e.g. Chile. As an example, Antofagasta recently indicated in August 2020 that it could spend c$1bn on desalination facilities at its flagship Los Pelambres mine, to enable it to run on 100% desalinated water by 2025.
+ **Tailings** – the Brumhadinho dam tragedy in Brazil in January 2019 brought the risk profile of miners' tailings operations into much sharper focus. The mining industry has made a concerted effort to respond, with the ICMM releasing the Global Industry Standard on Tailings Management in August 2020. The use of cheaper upstream tailings dams (i.e. the kind which failed and led to the Brumhadinho tragedy) is likely to become all but extinct; leading to increased project, mine operating, and mine rehabilitation costs, all else being equal.
+ **Local community relationships** – mining companies generally actively engage with local communities and have established consultation processes (including for new mine projects). The destruction of the heritage site Juukan Gorge in Australia by Rio Tinto which, though legal, caused widespread public outcry and cuts in bonuses for Rio Tinto management. A likely fallout will be increased input from local communities, longer timelines for project approvals and the potential for higher costs. We see potential for this trend to extend beyond Australia's iron ore industry.

These environmental trends are likely to lengthen the regulatory approval for new copper projects, and environmental pressure on new and current copper operations and also likely to make each $ of copper exploration and growth capex spend less efficient. This trend is also exacerbated by copper's falling grade profile; as more resources have to be used, and more tailings produced, to yield the same amount of copper.

This is not a new phenomenon, in fact, 20 years ago in 1996, Rio Tinto's Bob Adams was highlighting this issue in his AGM shareholder address! And things have only got harder over those ensuing 20 years…

"…the average time between initiating a new project and commencement of construction has lengthened considerably. In some instances this is a consequence of environmental permitting procedures. In others it reflects protracted negotiations with local communities and sometimes, of course, these two processes become intertwined.

The group's Marandoo iron ore mine in Australia is a good illustration of this point. In the 1960s Hamersley obtained permits and subsequently constructed a new mine together with two new towns, a 180 mile railway and a port in less than two years. All of this in a remote location. In the 1990s it took longer just to obtain the permits to construct a further medium sized mine in the same area.

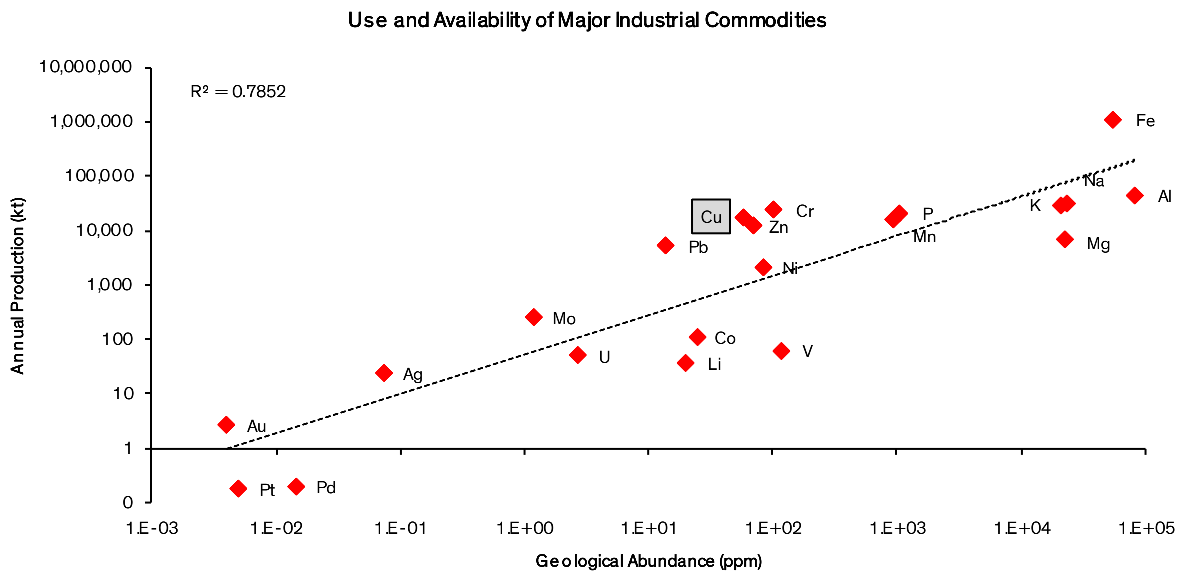
Delays in gaining project approval demand more resources from developers – financial resources, technical resources and human resources."

"Other than Oyu Tolgoi and Los Pelambres, Grasberg is the most recent discovery, in 1988. Many of these mines were discovered back in the 1800s. And here, or at Grasberg, completing mining of the open pit this year. ***So the point is mining world-class mines is extremely rare,*** *and now we're in a period of time where -- and this is where we've gone through, over the last 15 years, extensive exploration when prices were high and companies were investing. So even with all this investment, finding big new mines is really tough. And having these kinds of mines in our portfolio is going to prove very valuable…* ***we haven't had any big technology revolution in the copper mining business.*** *We've made progress with technology and so forth. But copper, as a commodity, is very tough to replace. We haven't seen any shale oil-type developments in our business.* ***In fact, we're seeing SxEw opportunities dry up; new opportunities are low grade, sulphide opportunities which require lots of infrastructure and development and mining a lot of material to get a copper like we're getting at Cerro Verde.****"*

SUPPLY 5: COPPER IS GEOLOGICALLY RELATIVELY SCARCE

We observe that the consumption of commodities correlates with their geologic abundance (Exhibit 39).

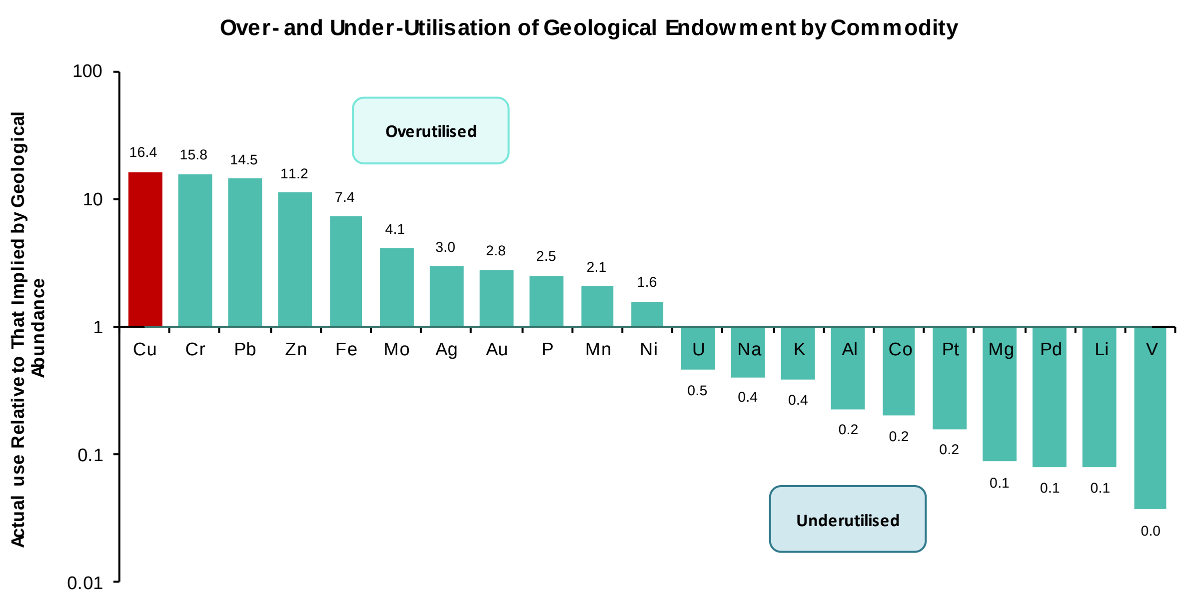
EXHIBIT 39: **Consumption of commodities correlate with geological abundance...**



Source: USGS, Bernstein analysis and estimates

And relative to its consumption, copper is over-utilized (Exhibit 40). That puts pressure on supply.

EXHIBIT 40: **Copper amongst most over-used for its endowment**

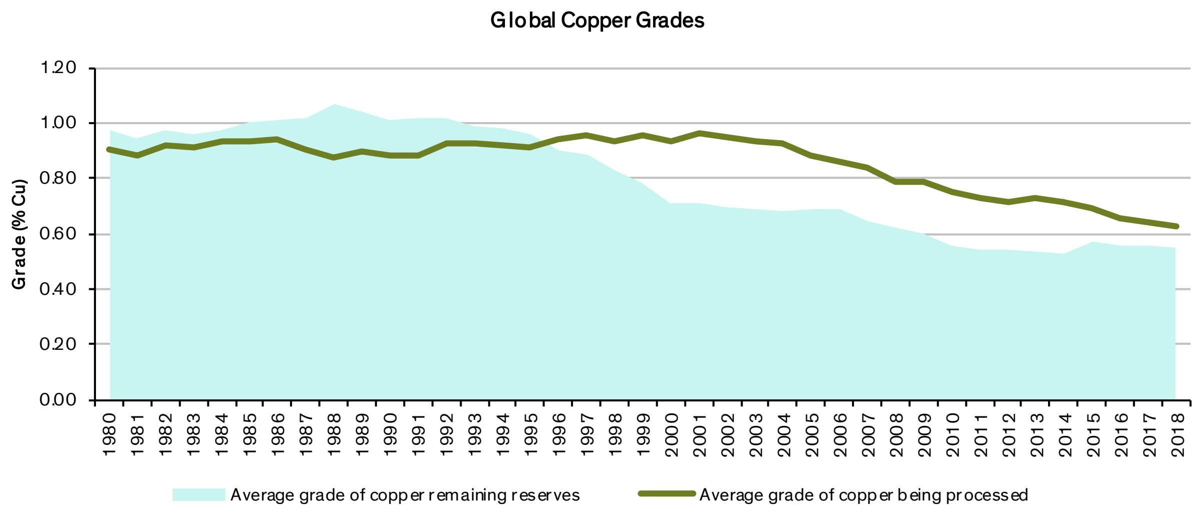


Source: USGS, Bernstein analysis and estimates

SUPPLY 6: ORE GRADES OF COPPER FALL OVER TIME

Exhibit 41 shows two things. First, that the average grade of copper reserves (the source of future production) is falling over time. Importantly, if ore falls from 1% copper grade to 0.5% copper grade, then twice as much ore must be mined and milled – a doubling of effort. Second, in the late 1990s a cross-over point was reached from an era in which the copper to come was higher grade than the copper of the day to the opposite.

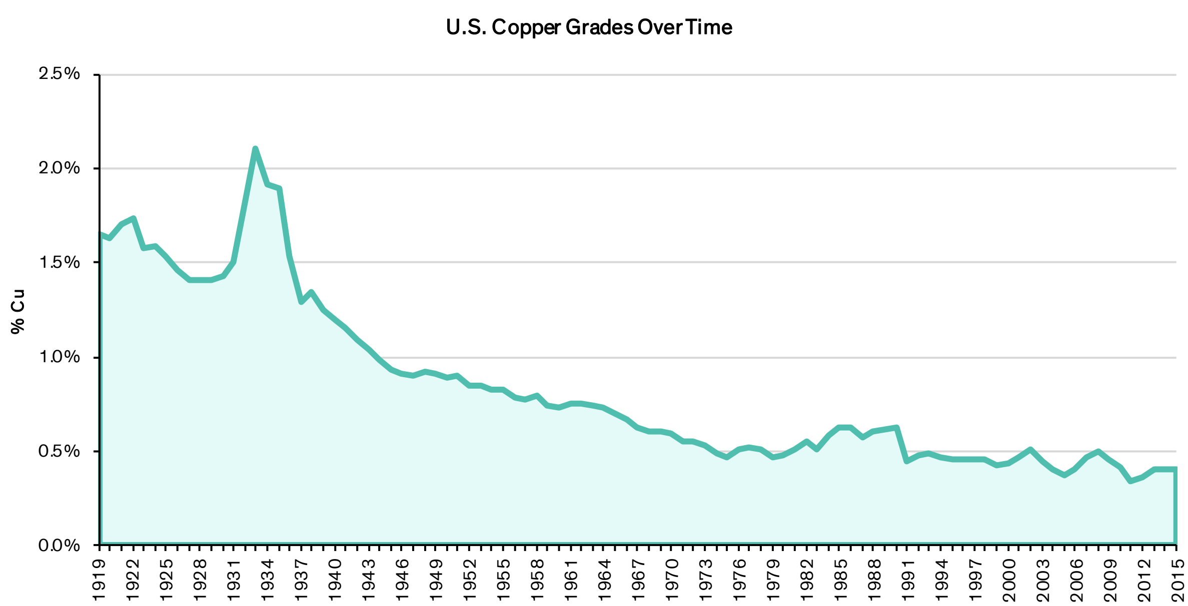
EXHIBIT 41: **Global copper grades have been falling sharply since the mid-1990s…**



Source: Wood Mackenzie, Bernstein Analysis

Where we have a longer record (the US), the trend is clear (Exhibit 42).

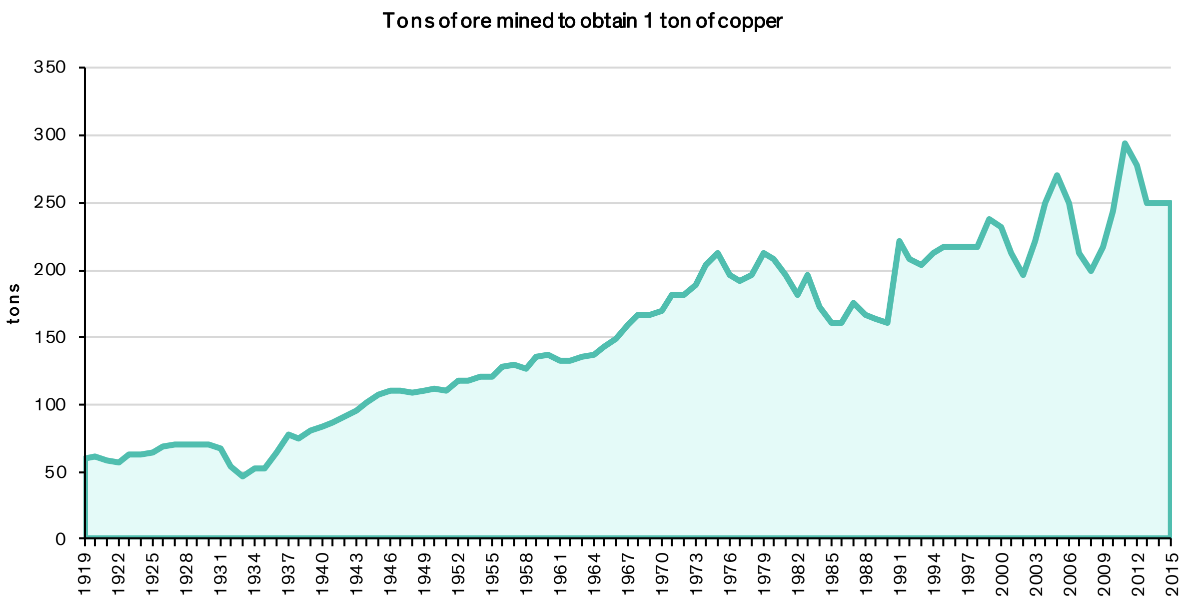
EXHIBIT 42: **…and where we have a long time series (the US), we can see the trend**



Source: USGS, and Bernstein estimates and analysis.

And re-casting the data in terms of tons of ore mined to obtain a ton of copper shows the trend more drastically (Exhibit 43). Note of course that operating costs of mining are strongly variable against ore mined…

EXHIBIT 43: **Shown another way, tons of ore mined to obtain a ton of copper is up 6x in a century**

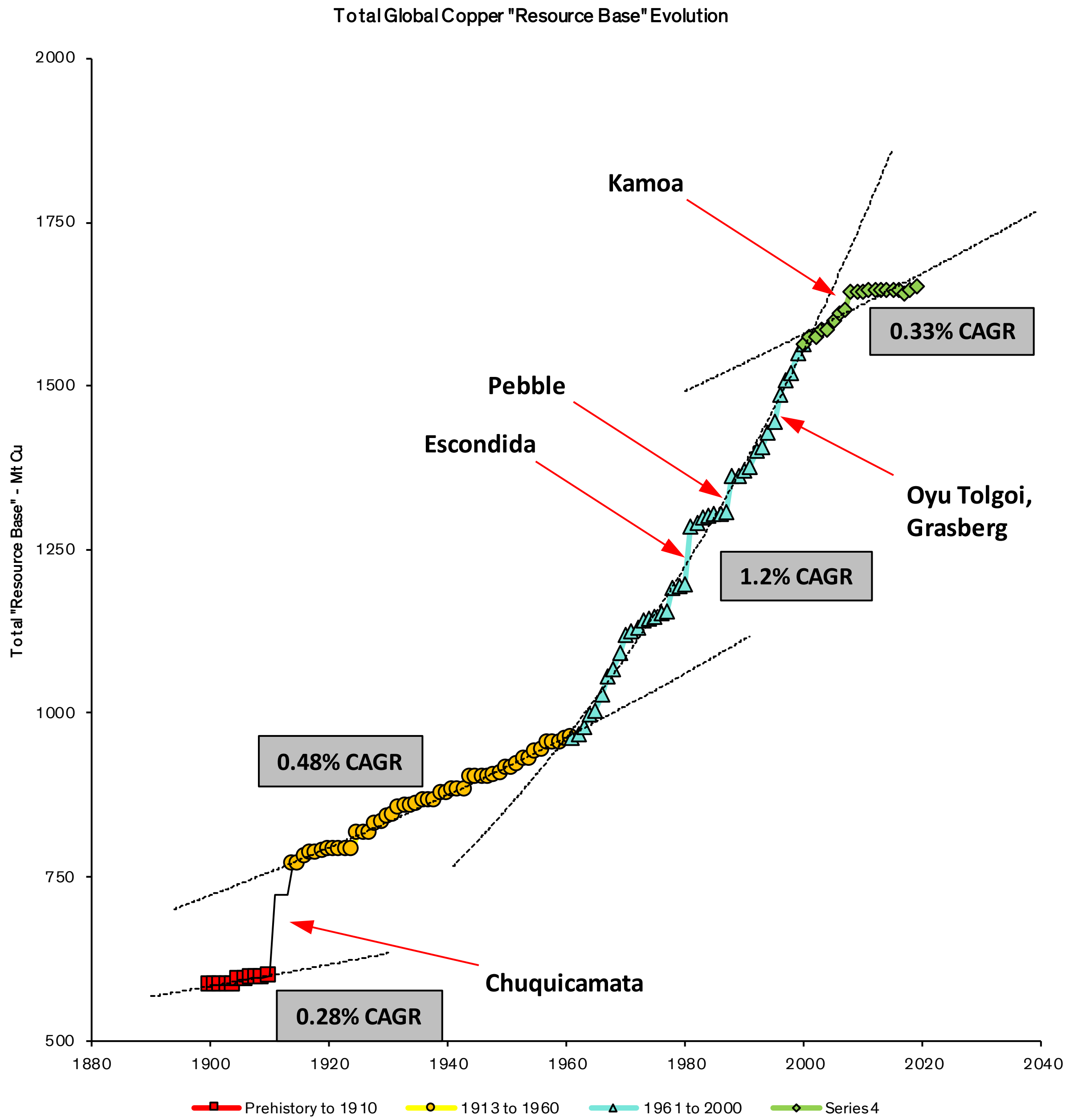


Source: USGS, and Bernstein estimates and analysis.

SUPPLY 7: WE ARE FINDING LESS AND LESS COPPER

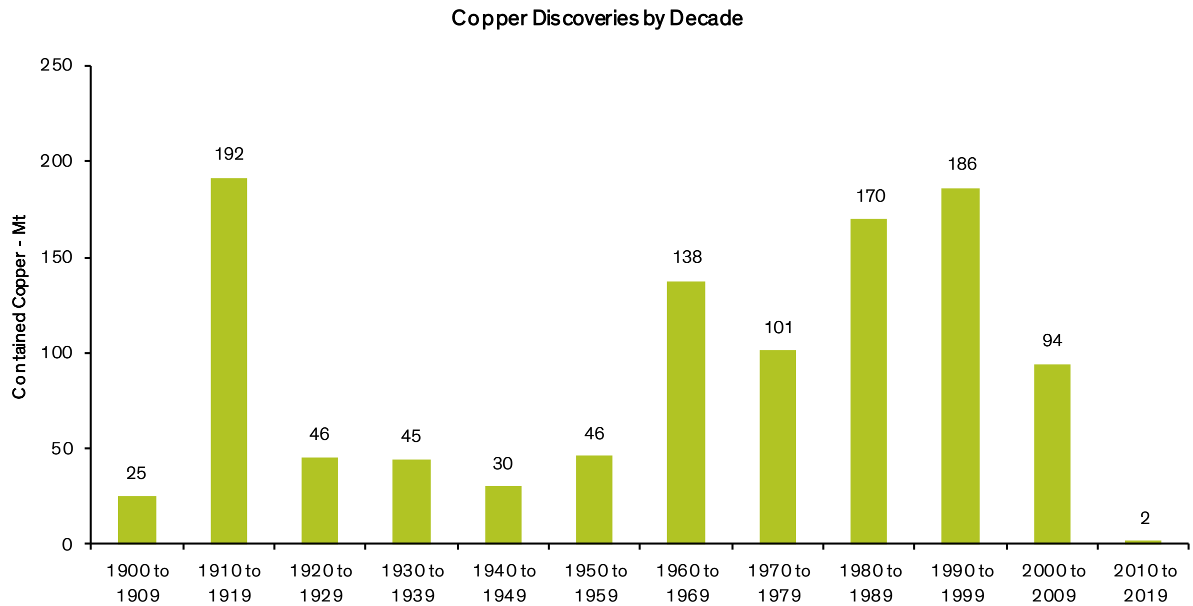
The copper resource base grows when discovered volumes exceed extractions. Exhibit 11 shows that the current era has trivial growth in the resource base (certainly compared to past eras). The most recent notable significant discovery, for one example, of the Winu deposit by Rio Tinto was 503 Mt copper equivalent at a 0.45% ore grade.

EXHIBIT 44: **The world is not growing the copper resource base**



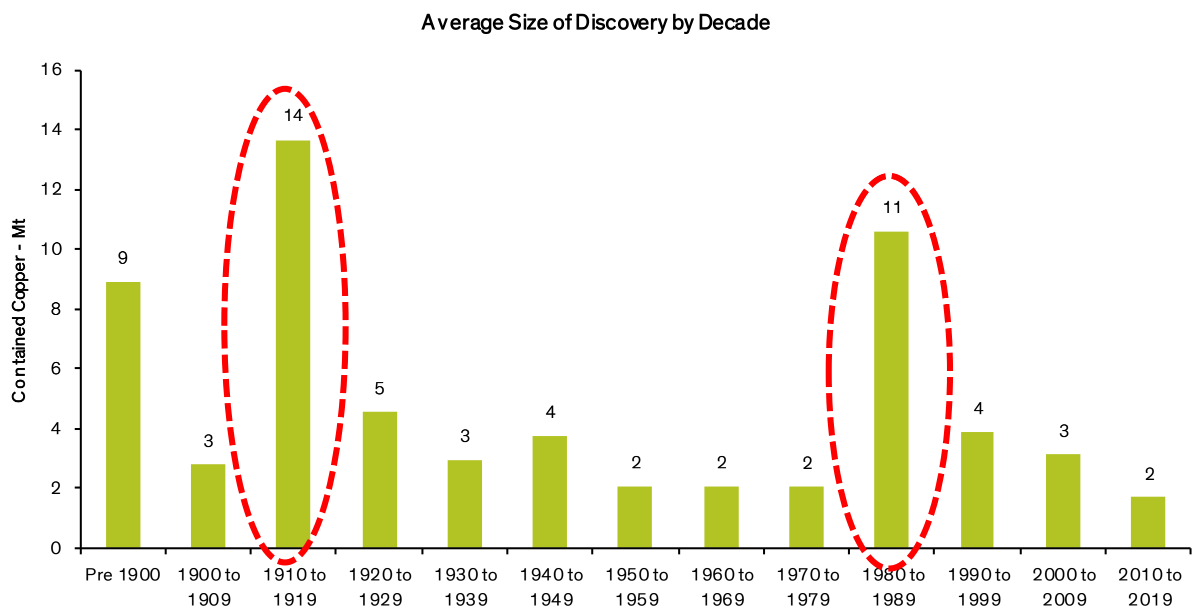
Source: USGS, Wood Mackenzie, corporate reports, and Bernstein estimates and analysis.

EXHIBIT 45: **This is driven by both a decline in the number of discoveries...**



Source: USGS, Wood Mackenzie, Schmitz, corporate reports, and Bernstein estimates (2016-19) and analysis.

EXHIBIT 46: **...and just as importantly for the economics of copper mining, by the scale of those deposits**

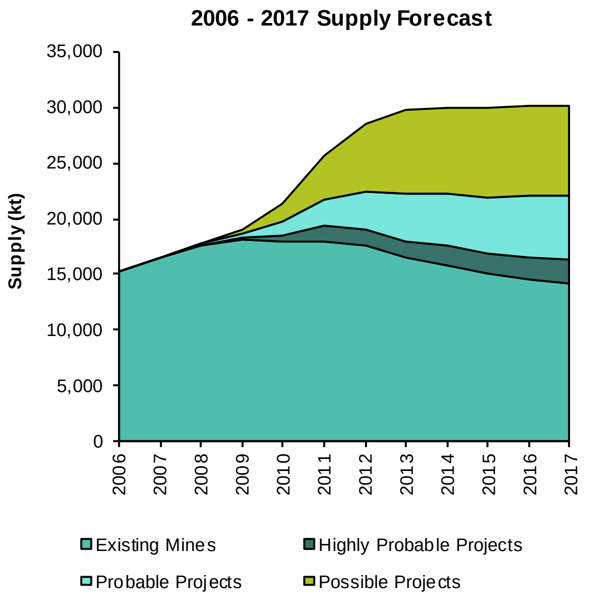


Source: USGS, Wood Mackenzie, Schmitz, corporate reports, and Bernstein estimates (2016-19) and analysis

SUPPLY 8: CONSENSUS SUPPLY FORECASTS OVER-PROMISE AND UNDER-DELIVER

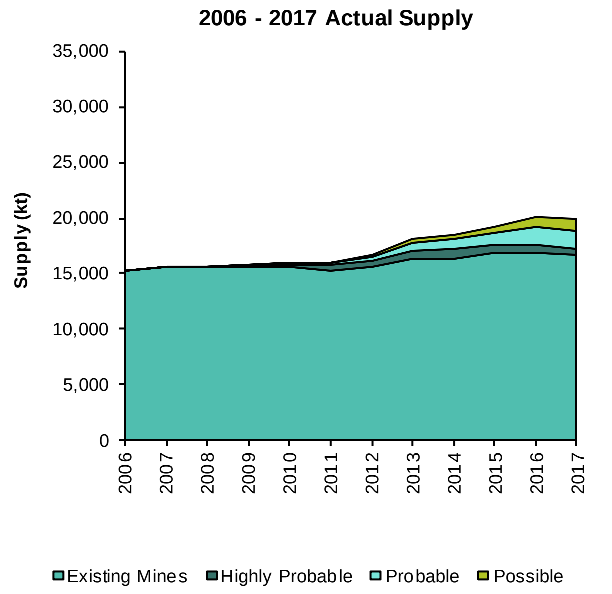
We can use historical forecasts of copper supply to back-test true deliverability. The reality is disappointing…with a forecast of nearly doubling (99% growth) emerging as less than a third of supply expansion.

EXHIBIT 47: **In 2007, the maximum 2017 run-rate supply was estimated at 30.2Mt, +99% growth (+6.4% CAGR) generating fears about a possible "wall of supply"...**



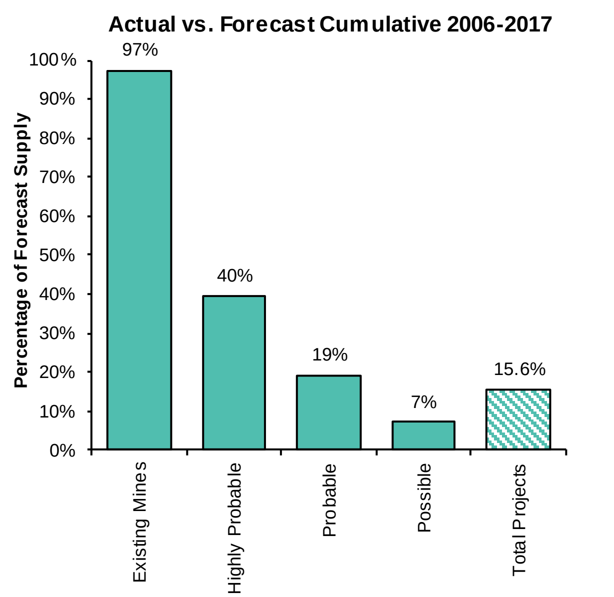
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 48: **... when in reality, despite the copper price hitting US$10,000/t in 2011, supply actually grew just +31% (+2.5% CAGR).**



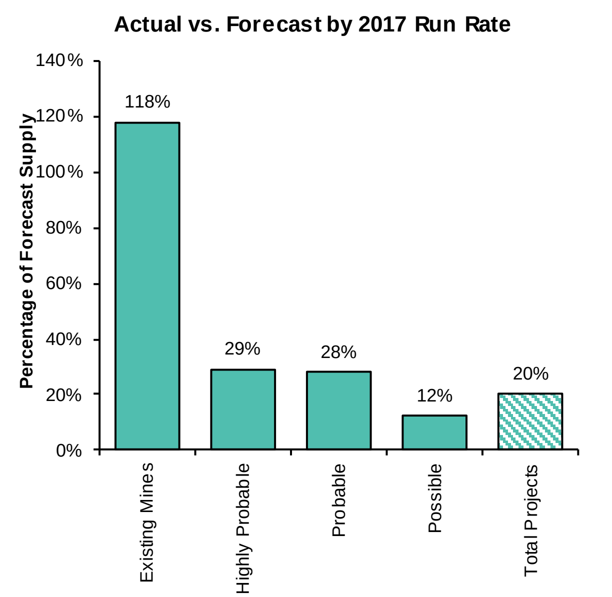
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 49: **... actual vs. forecast was 97% for existing mines, but dropped down for new projects...**



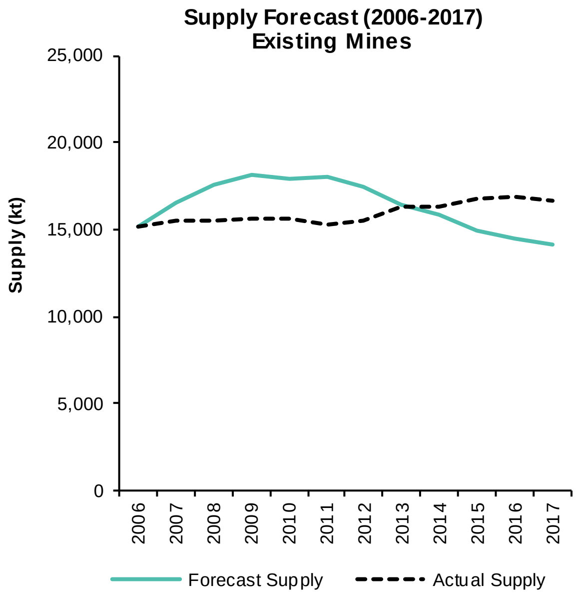
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 50: **... to ~20% of forecast projects coming on-line**



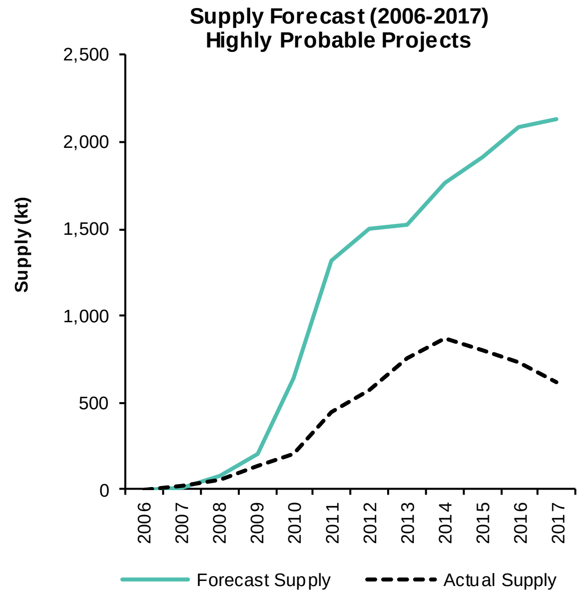
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 51: **Actual supply from existing mines surpassed the 2006 forecast in 2013.**



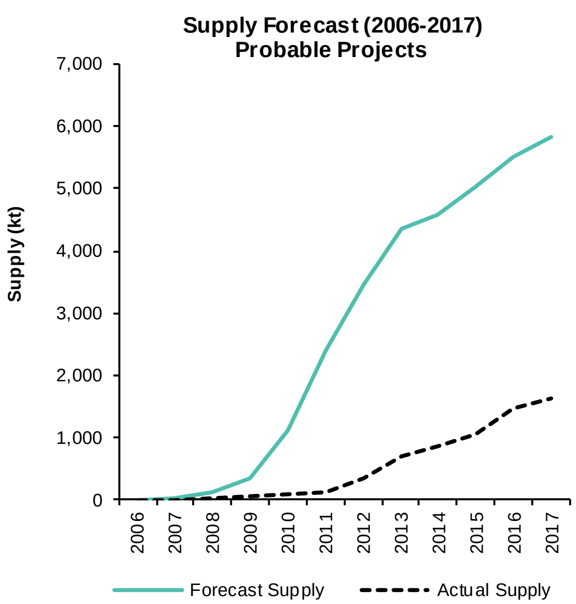
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 52: **Supply from highly probable projects lagged expectations.**



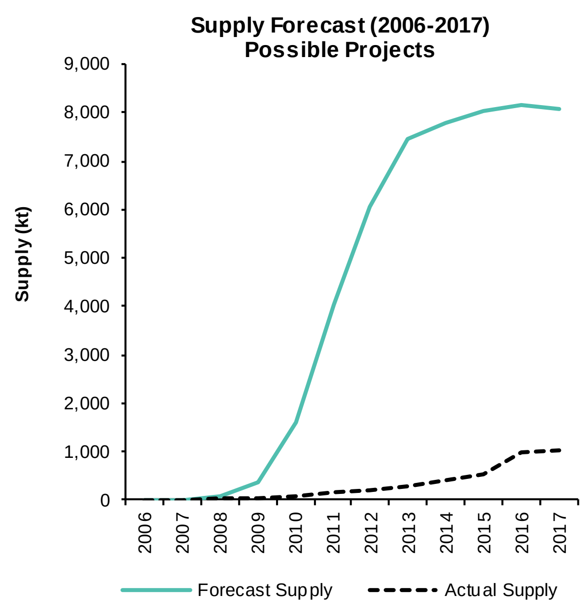
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 53: **Supply from probable projects also fell below the potential…**



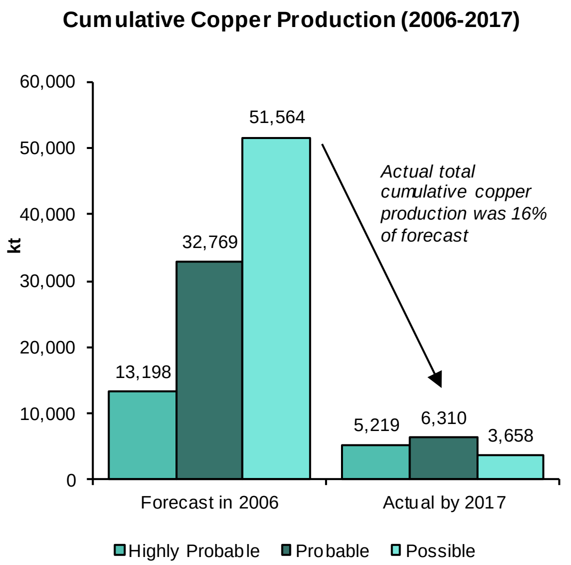
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 54: **… as did supply from possible projects**



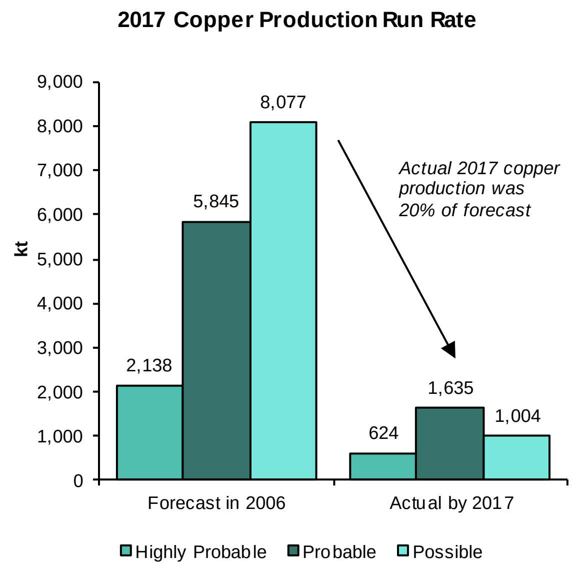
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 55: **Of the potential new projects, only 16% of the cumulative total came on-line...**



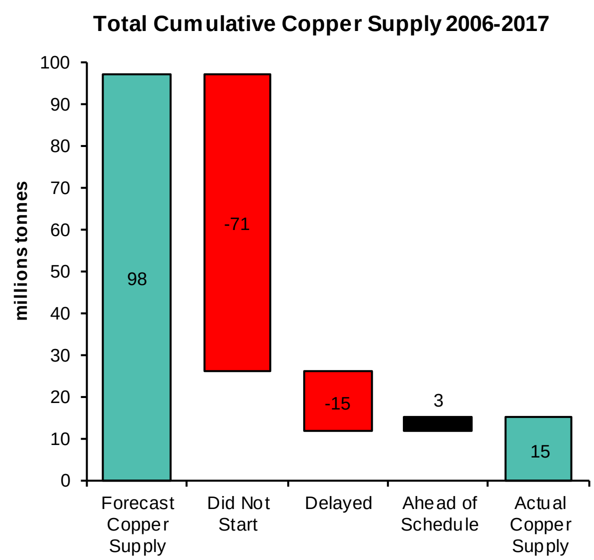
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 56: **... or 20% of the expected 2017 run rate**



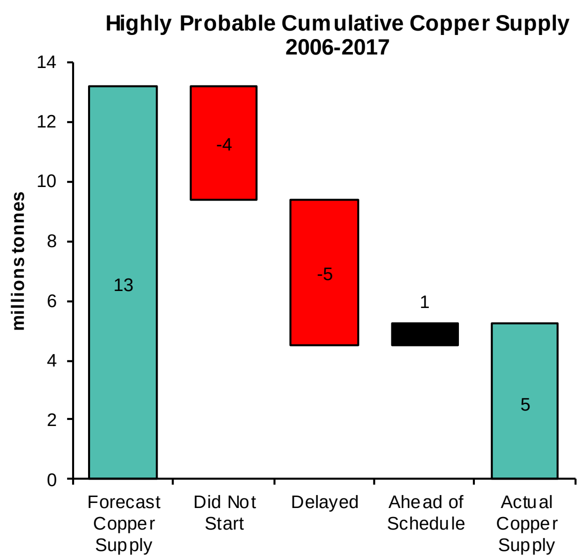
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 57: **So what happened to these potential new projects? Overall, most of them just did not start**



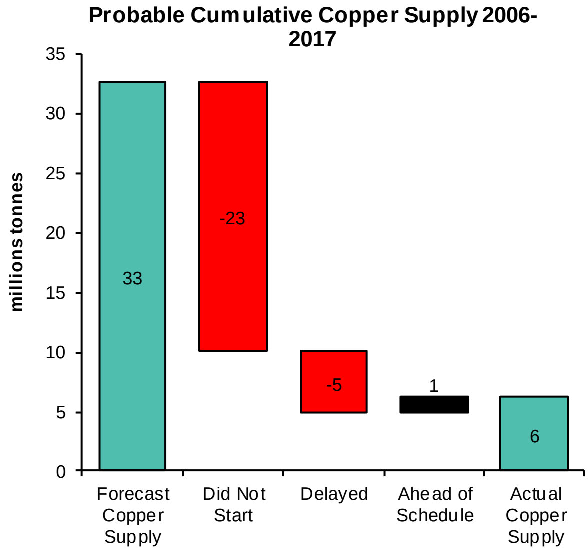
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 58: **For highly probable projects, of the difference in supply, about half was from projects not starting and the rest from delays**



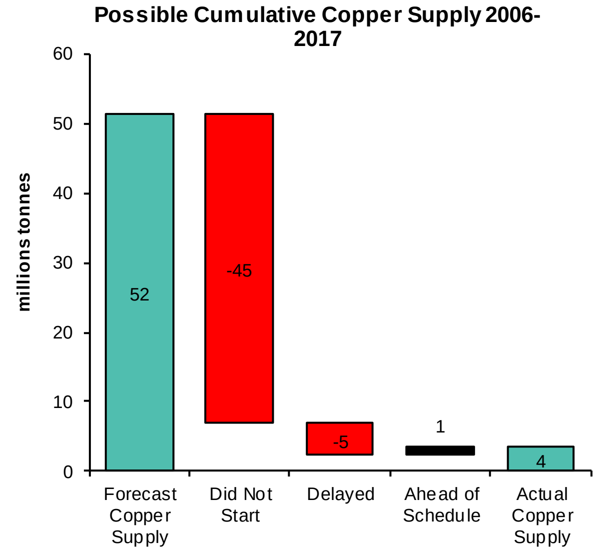
Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 59: **For probable projects, the split was more in favour of projects not starting...**



Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

EXHIBIT 60: **...which was more evident for possible projects**

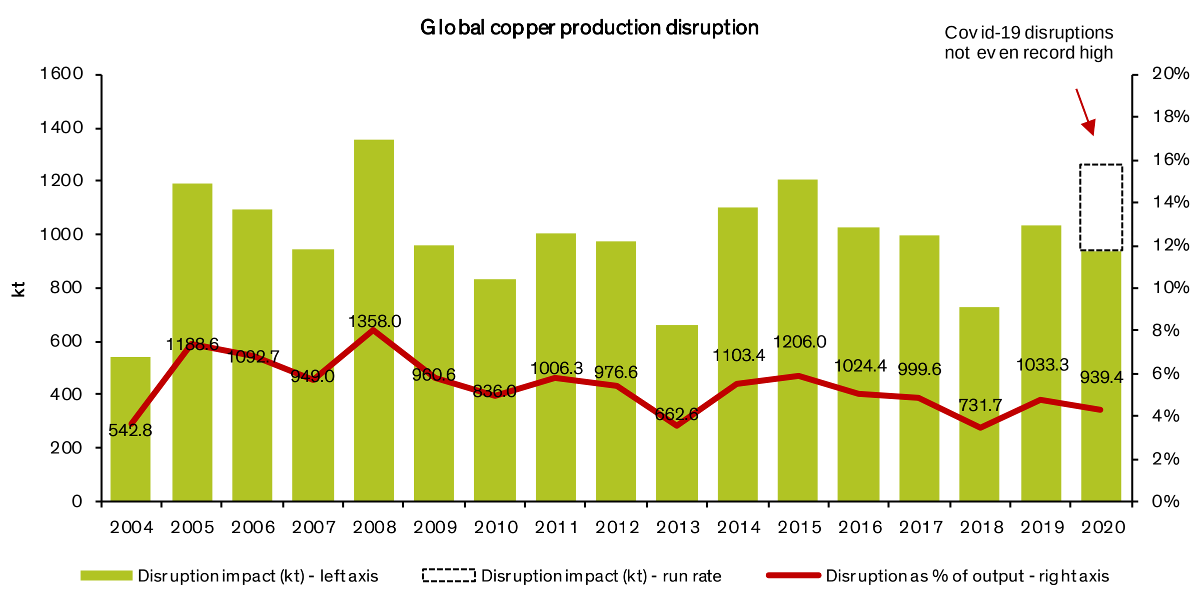


Source: Brook Hunt, Wood Mackenzie, Bernstein analysis

SUPPLY 9: DISRUPTIONS TO SUPPLY ARE SIGNIFICANT AND INEVITABLE

One challenge to supply demand balances is that while demand disruptions are rare (and typically GDP driven), supply disruptions are hard to forecast, common, and potentially significant (Exhibit 61). A single example – despite the covid-19 disruptions of 2.8%, 2020 disruptions are in fact in line and not extreme versus other disruptions, taking 4.3% of supply off the market.

EXHIBIT 61: **Expect several percent of supply to be typically disrupted...with potential spikes**

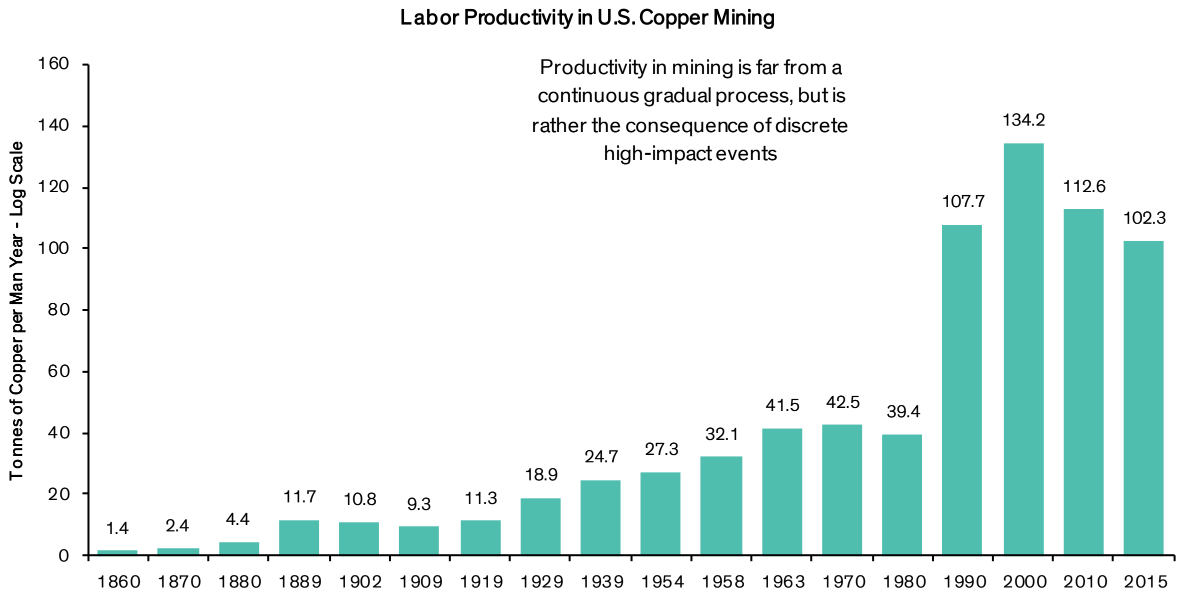


Source: Wood Mackenzie, Bernstein analysis

SUPPLY 10: PRODUCTIVITY GAINS HAVE BEEN STAGNANT FOR YEARS

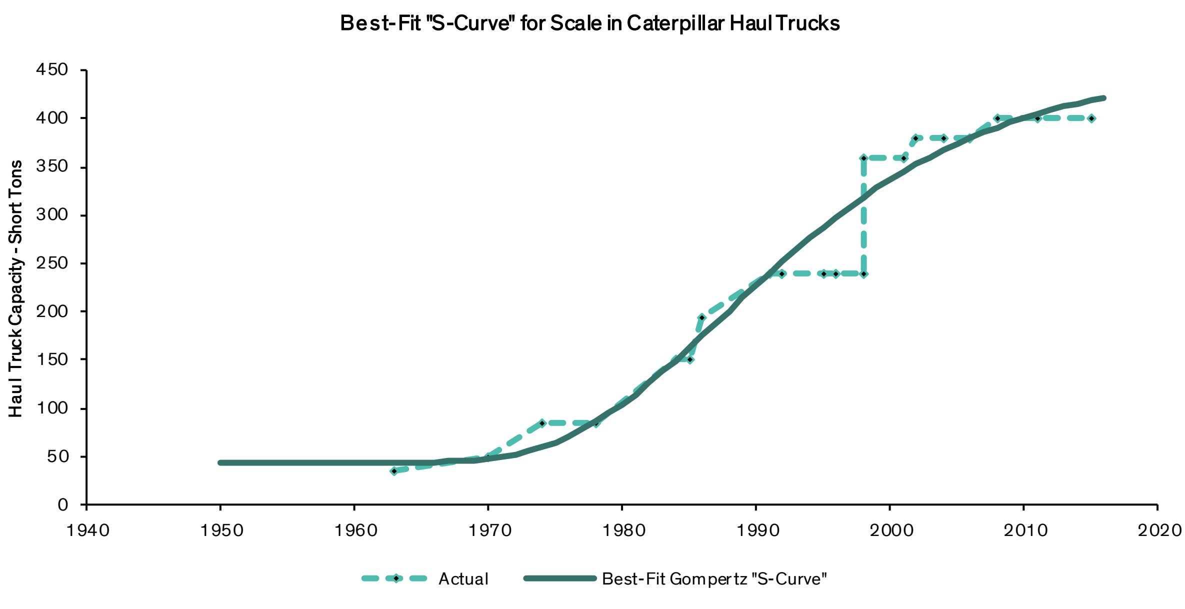
We can use the US (again where the time series is longest) to show tonnes of copper per man year trends (Exhibit 62). While a revolution occurred from 1860 to 1890 (10x improvement) and another revolution in the 1990s, productivity has been around 100 tons for decades.

EXHIBIT 62: **Labor productivity has peaked...**



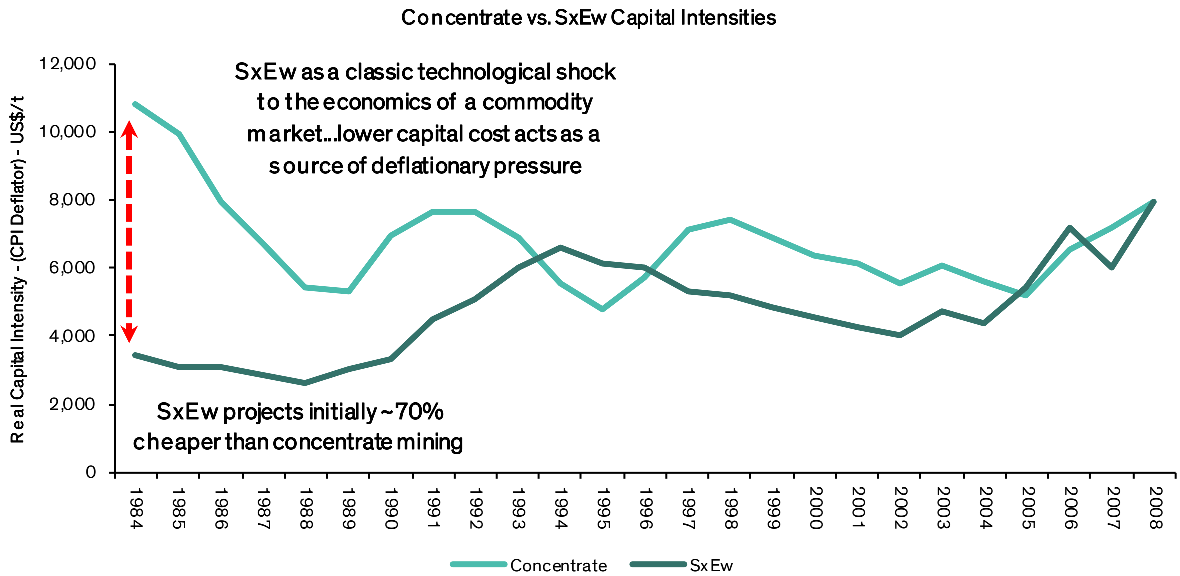
Source: U.S. Census, BLS, Schmitz, Wood Mackenzie, and Bernstein estimates and analysis.

EXHIBIT 63: **...with plateauing truck size an obvious cause**



Source: Corporate reports, U.S. Census, BLS, Schmitz, Wood Mackenzie, and Bernstein estimates and analysis.

EXHIBIT 64: **The revolution around milling 'shock' (from concentrate to SxEw) has played out**

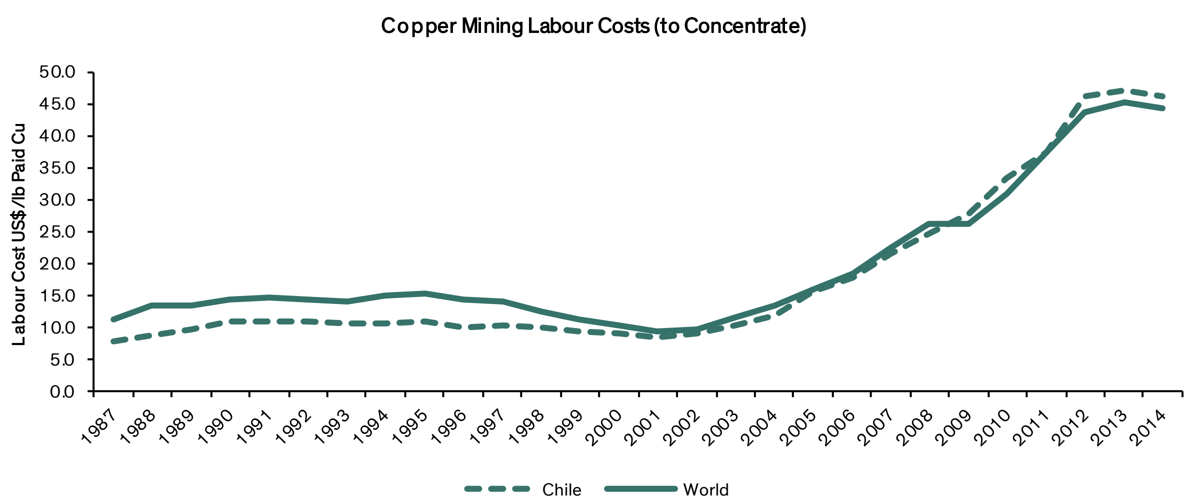


Source: Wood Mackenzie, and Bernstein estimates and analysis.

SUPPLY 11: WAGE DEFLATION CAN'T OFFSET PRODUCTIVITY

Labor costs for copper mining (Exhibit 10) have stagnated and deflation on labor costs (with the risk of strikes from unionized workers in relation to new wage negotiations and disruption of mining operations) seem unlikely.

EXHIBIT 65: **Mining wage rates have increased dramatically as a consequence of the cessation of productivity gains, and persistent labour unrest/strikes across the industry continue to lend upward pressure to production costs**



Source: Wood Mackenzie, Bernstein Analysis

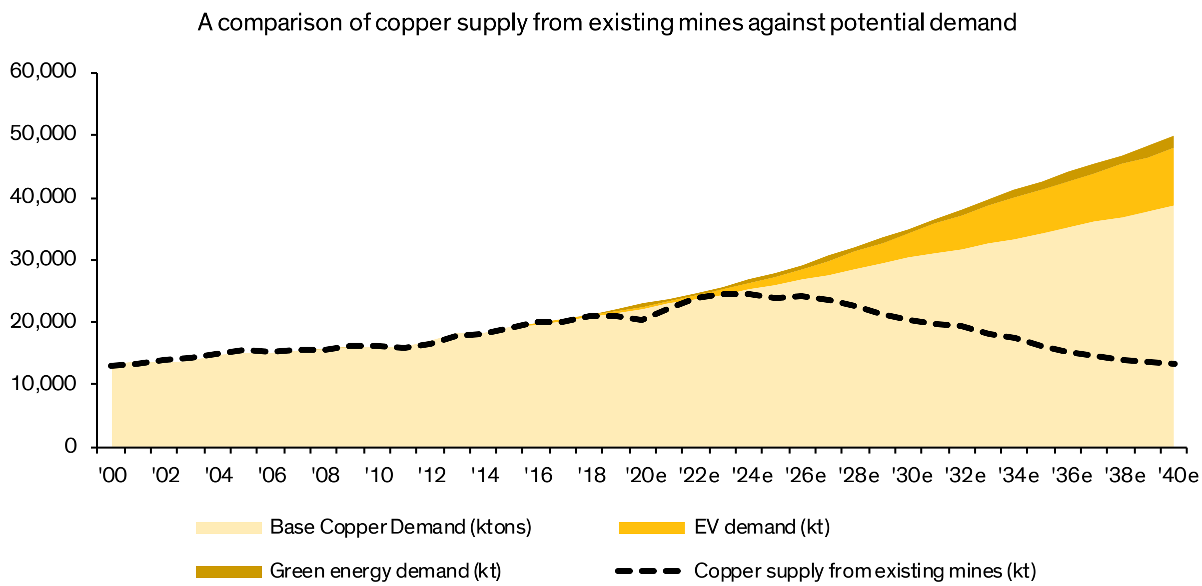
THE PRICE OF COPPER IS SET BY THE MARGINAL PRODUCER

PRICE 1: DEMAND TO OUTSTRIP SUPPLY

Having considered a number of reasons to be worried about supply and confident about demand, we try to tie the two together into how to think about a price framework.

We start (Exhibit 66) but simply contrasting copper supply from existing mines (i.e., pre new development capital) against our base copper demand layering in a potential EV demand forecast and a windpower ("green energy") forecast. The gap by 2040 (~14,000 ktons per year) is comparably to the entire copper supply in 2005.

EXHIBIT 66: **So, the long-term outlook for copper is clear. We cannot meet global demand without making major investments into supply, the question is whether these positive fundamentals translate into the copper price?**

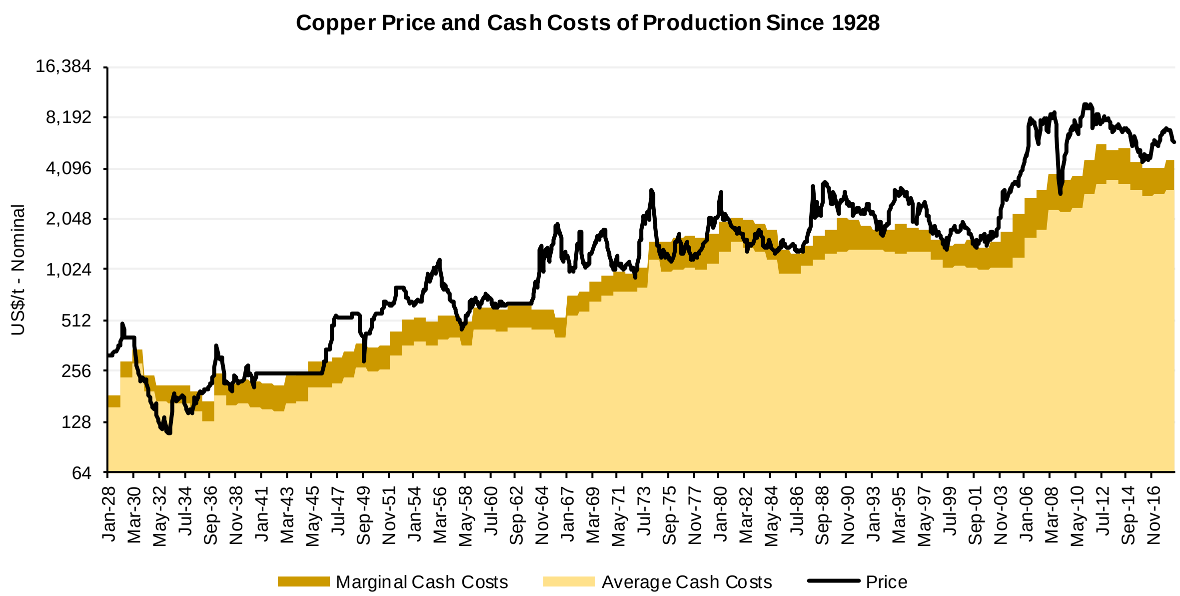


Source: Wood Mackenzie, Bloomberg, SNL, Bernstein analysis

PRICE: 2. HISTORY SHOWS PRICE RESPONDS TO SUPPLY COST

What incentive price will be needed to provide that copper? One hundred years of history (Exhibit 67) shows us that the price of copper must exceed the cash cost of copper except for short periods of times during the bottom of cycles.

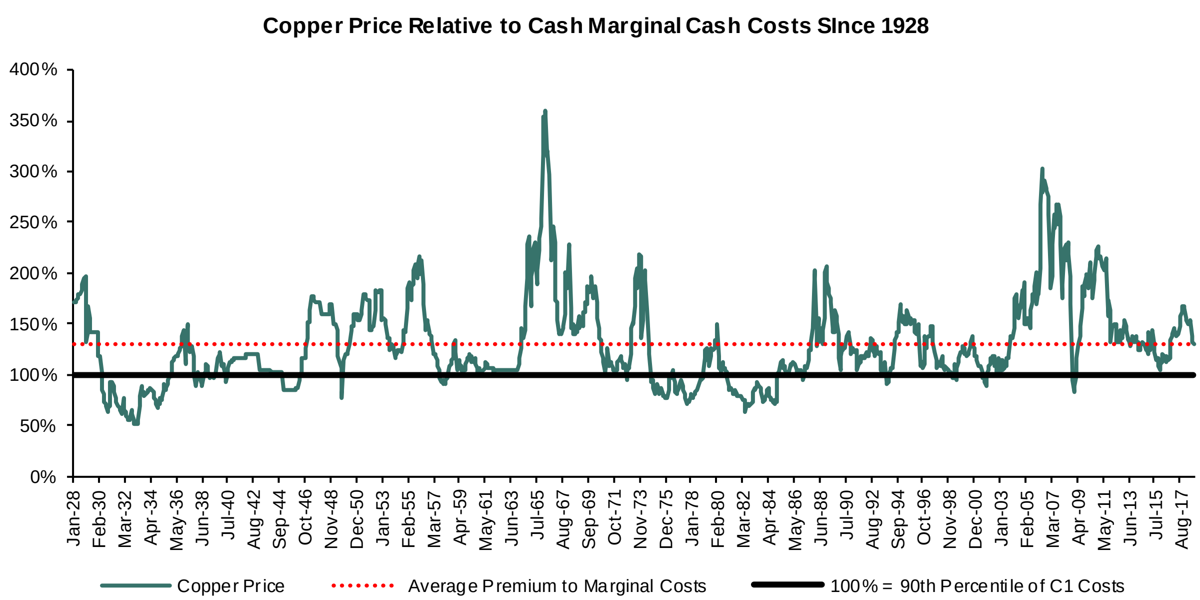
EXHIBIT 67: **For 100 years, the cash cost of copper controls the price of copper...**



Source: USGS, LME, World Bank, CRU, Wood Mackenzie, Corporate reports, Bernstein analysis & estimates

And in fact, the long run average premium of copper price to marginal cash cost is 130% (Exhibit 68).

EXHIBIT 68: **For 100 years, the copper price reverts to an average of 130% of the marginal cash cost...**

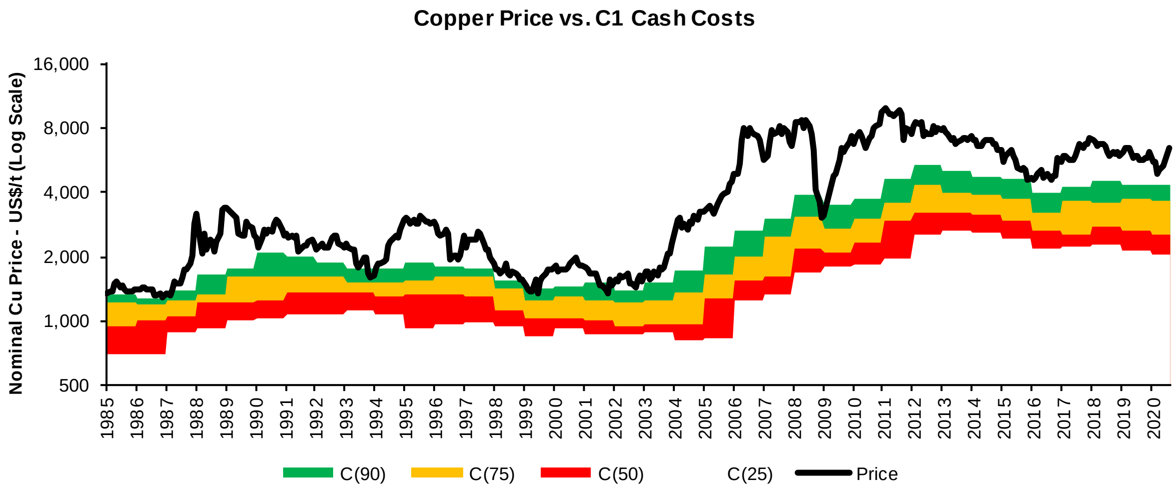


Source: USGS, LME, World Bank, CRU, Wood Mackenzie, Corporate reports, Bernstein analysis & estimates

PRICE 3: CURRENT MARGINS ARE NOT ENTICING ENOUGH TO SPOIL PARTY

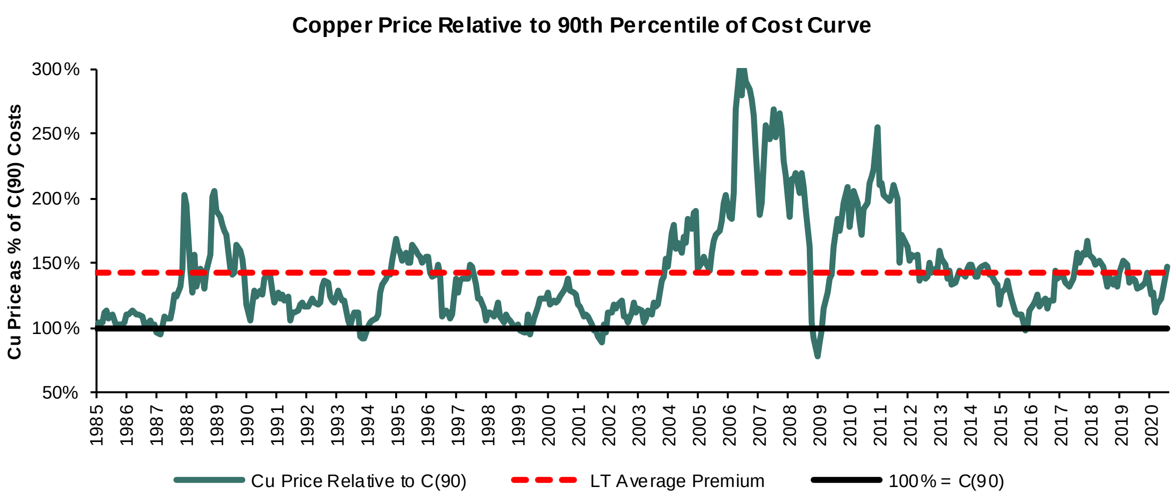
The following exhibits show that while absolute copper price is high, it is not the absolute price that determines margins or incents capital. In fact, current margins are reasonable but not near top cycle.

EXHIBIT 69: **Copper price vs. C1 cash costs...not elevated versus history (compare to 2006 or 2010)**



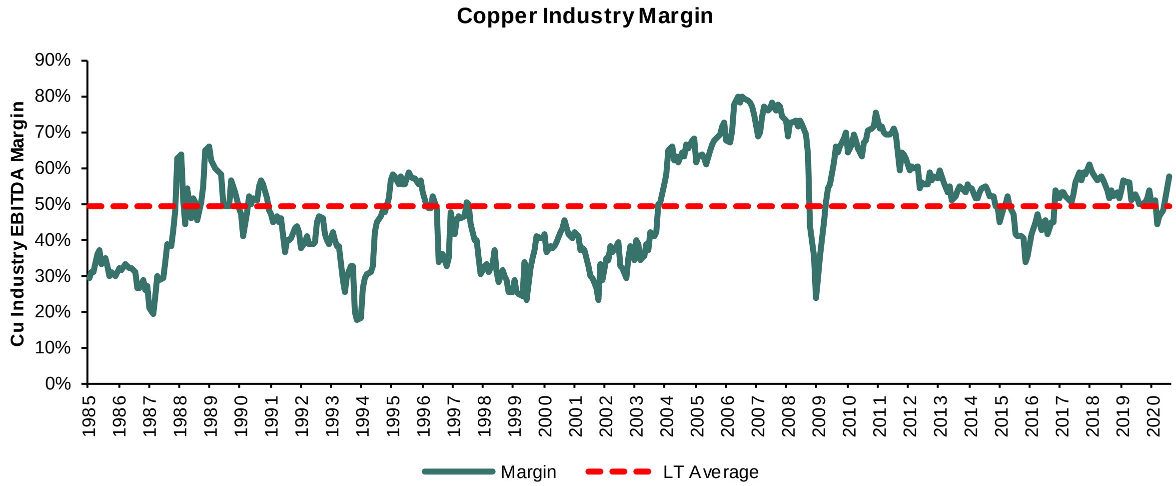
Source: Wood Mackenzie, Bloomberg, Bernstein analysis:

EXHIBIT 70: **The last 35 years has averaged price of 135% of cash cost...around where we are today**



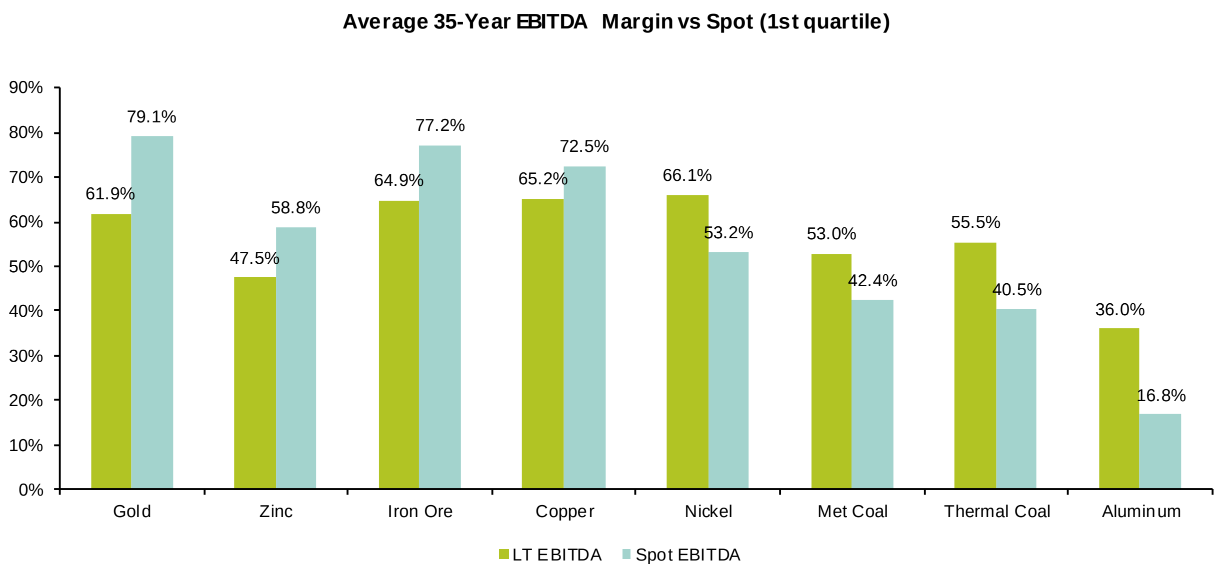
Source: Wood Mackenzie, Bloomberg, Bernstein analysis

EXHIBIT 71: **Copper EBITDA margins only modestly elevated...not the "grow signal" of early 2000s**



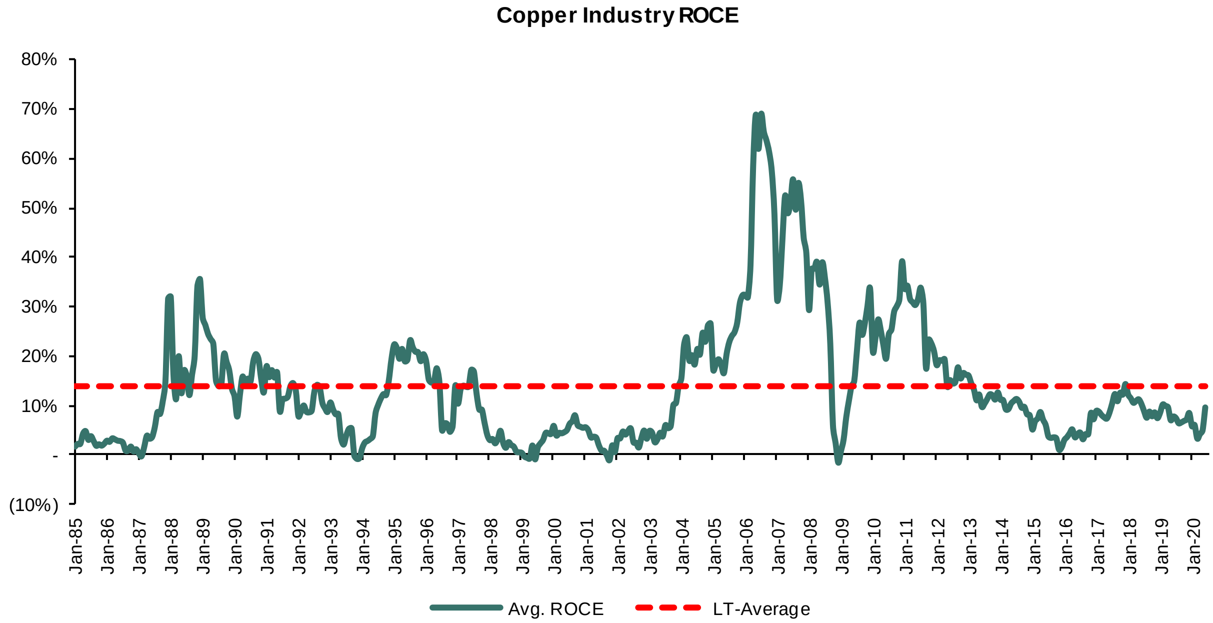
Source: Wood Mackenzie, Bloomberg, Bernstein analysis

EXHIBIT 72: **While copper margins above long term average, gold, zinc, and iron ore more pronounced (and compete for capital)**



Source: Wood Mackenzie, AME; CRU; SNL; Bloomberg, Bernstein analysis

EXHIBIT 73: **Returns on capital employed (which embed 'past sins') not strong enough to entice massive overinvestment**



Source: Wood Mackenzie, AME; CRU; SNL; Bloomberg, Bernstein analysis

PRICE 4: INFLATIONARY PRESSURE GOOD FOR COMMODITIES IN GENERAL

Exhibit 74 shows the average return of a range of assets/factors since 1970 conditioned on the level of inflation in a given year (the factor strategies are shown here long-short). The key conclusions from this are that equities are one of the most effective assets to hold as inflation rises, at least until inflation reaches a 5% level. Within equities value factors do well as inflation rises, and within value it is the more "mean reversion" type of value factor such as price/book that is key and not the more income-type factors such as dividend yield.

Within fixed income it is FX carry strategies that most clearly do progressively better as inflation rises. On average these strategies have been loss-making at inflation rates less than 1% but have been significantly more profitable at inflation rates over 2%. Commodities and gold also score well on this basis, both outright commodity holdings and also the equity of the commodity sectors. Real assets are also good inflation hedges in theory. We show below that real estate indices are positively exposed to inflation, and more importantly from an investability perspective so are REITS. However, this time we would be much more cautious on near-term exposure to real estate given the scale of the current recession and the exposure of the sector to the structural problems of the retail and leisure sectors.

EXHIBIT 74: **Factor and asset performance in different inflation regimes**

Since 1970	US Equities Total Return, yoy	US Bonds Total Return, yoy	Equity: PBK, yoy	Equity: Dividend Yield, yoy	Equity: Momentum, yoy	Equity: Variance, yoy	Equity: Residual Variance, yoy	FI Momentum, yoy	FI Carry, yoy	FX Carry, yoy
<-1	-23.12	7.63	-2.53	-4.97	-46.11	-8.43	-10.79	-4.72	1.46	-7.10
-1 to 0	-8.75	10.63	-6.46	-3.17	-2.95	25.66	23.77	4.48	2.64	-5.31
0 to 1	2.54	4.39	-9.18	-0.57	12.61	16.44	13.97	0.90	1.85	-5.43
1 to 2	14.68	8.98	0.96	1.66	5.68	5.72	7.15	1.12	3.02	1.90
2 to 3	17.94	5.97	4.32	-0.59	4.27	-2.01	-1.61	-0.25	0.54	4.63
3 to 4	12.86	11.19	3.75	2.44	11.51	4.92	6.30	0.31	2.04	3.59
4 to 5	10.98	8.75	4.66	1.71	5.89	10.69	12.53	0.12	0.41	4.98
>5	5.19	5.29	8.51	4.45	12.86	6.60	6.41	0.31	4.66	2.01

Since 1970	US REITS, yoy	Real Estate Index, yoy	GSCI Commodity Index, yoy	Brent Oil, yoy	Gold, yoy	US Energy relative, yoy	US Metals & Mining relative, yoy	Silver, yoy	High Yield Bonds, yoy
<-1	-37.47	-9.25	-53.16	-42.59	7.86	-11.56	-15.63	-1.98	-0.17
-1 to 0	-11.10	-4.34	-42.22	-42.91	2.40	-8.41	-19.51	-11.55	-4.72
0 to 1	3.67	3.95	-34.74	-39.21	-5.11	-20.19	-27.82	-13.80	-2.31
1 to 2	17.71	5.37	-8.32	-11.06	4.35	-8.73	-9.11	2.75	8.66
2 to 3	22.50	4.26	9.31	15.37	7.00	-1.72	6.03	11.04	12.85
3 to 4	21.90	4.68	18.98	19.68	10.58	4.54	1.41	11.78	8.82
4 to 5	4.20	4.04	21.51	17.57	5.74	6.69	6.73	-2.32	5.92
>5	9.41	8.00	20.10	39.07	21.39	5.70	1.57	22.90	1.48

Note: Returns for Energy, REITS and Metals & Mining are from 1974, returns for FX Carry are from 1975 and returns for GSCI Commodity index and Oil are from 1971 and High Yield Bond returns are from 1987
Equity PBK, Dividend Yield, Momentum, Variance, Residual Variance and FI Momentum, FI Carry and FX Carry factor strategy returns are Long/Short
Energy and Metals & Mining sector returns are relative to broader US equity market
Real Estate Index returns are from Robert Shiller's Real Estate return database
Source: Bernstein Portfolio Strategy team; Ken French database, AQR, Robert Shiller's database, Factset, FRED, Datastream, Bernstein analysis

The conclusion from the above exhibit is that equities become a core holding. So how does one diversify equity risk if inflation rises ? Exhibit 75 shows the correlation of assets and strategies with equities predicated on inflation levels. Government bonds become a less useful diversifier as inflation rises. The most striking result to us is that value, income and low volatility strategies within the equity market become better diversifiers from a passive long-only equity position as inflation rises. The importance of value as a diversifier does not seem to be constrained to equities as Carry strategies with fixed income markets (between short and long dated debt) and FX carry strategies (between the debt of countries with differing levels of yields) also tend to have lower correlation with equities at higher levels of inflation. Gold retains a low correlation with equities as inflation rises, but investable real estate in the form of REITS and also high yield bonds have a correlation with equities that increases with inflation and hence become less attractive.

EXHIBIT 75: **Correlation of assets to equities as inflation rises**

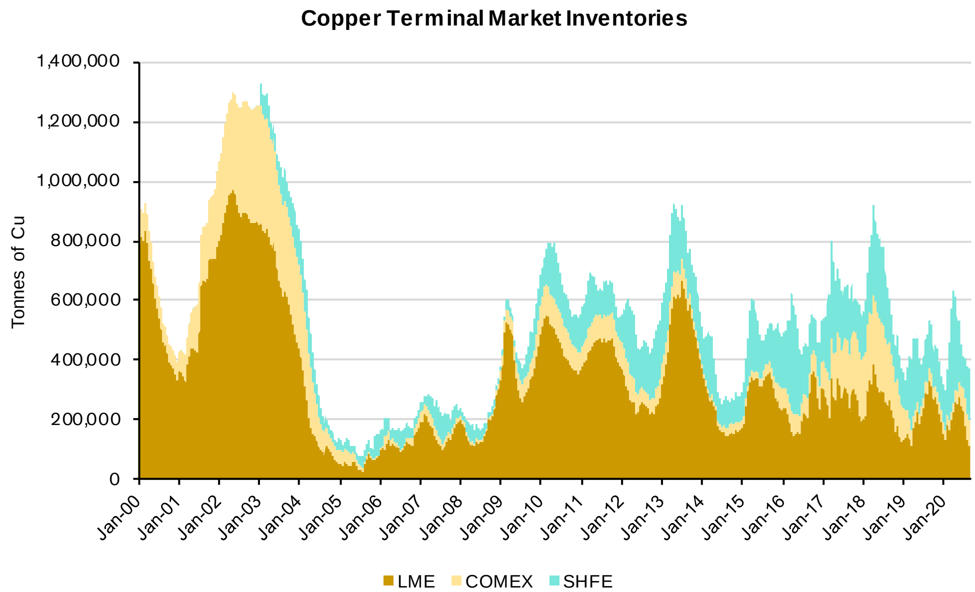
Since 1970	US 10y Bonds	Equity: Price to Book	Equity: Dividend Yield	Equity: Momentum	Equity: Variance	Equity: Residual Variance	FI Mom	FI Carry	FX Carry
<1	-0.09	0.19	-0.18	-0.27	-0.21	-0.24	0.09	0.26	0.27
1-2	-0.22	0.26	-0.36	-0.24	-0.32	-0.30	0.15	0.05	0.33
2-3	0.00	0.10	-0.13	-0.09	-0.30	-0.31	0.06	-0.07	0.15
3-4	0.00	-0.02	-0.41	0.04	-0.51	-0.51	0.12	-0.06	0.12
4-5	0.24	-0.10	-0.40	-0.05	-0.50	-0.48	0.00	-0.12	-0.04
>5	0.31	-0.05	-0.50	0.05	-0.63	-0.58	-0.22	-0.16	0.03

Since 1970	GSCI Commodity Index	Oil	Gold	Silver	Energy Stocks relative	Mining Stocks relative	REITS	Real Estate Index	High Yield Bonds
<1	0.15	0.17	0.13	0.17	-0.16	0.27	0.32	0.22	0.51
1-2	0.13	0.21	-0.11	-0.04	0.02	0.11	0.39	-0.03	0.56
2-3	0.07	0.08	0.05	0.12	-0.11	0.02	0.33	-0.08	0.57
3-4	0.20	0.23	0.03	0.22	0.12	0.18	0.44	-0.10	0.64
4-5	-0.04	-0.02	-0.14	0.16	-0.09	0.17	0.49	0.02	0.51
>5	0.09	0.03	-0.02	0.01	-0.01	0.15	0.62	0.00	0.62

Note: Returns for Energy, REITS and Metals & Mining are from 1974, returns for FX Carry are from 1975 and returns for GSCI Commodity index and Oil are from 1971 and High Yield Bond returns are from 1987
Equity PBK, Dividend Yield, Momentum, Variance, Residual Variance and FI Momentum, FI Carry and FX Carry factor strategy returns are Long/Short
Energy and Metals & Mining sector returns are relative to broader US equity market
Real Estate Index returns are from Robert Shiller's Real Estate return database
Source: Bernstein Portfolio Strategy team; Ken French database, AQR, Robert Shiller's database, Factset, FRED, Datastream, Bernstein analysis

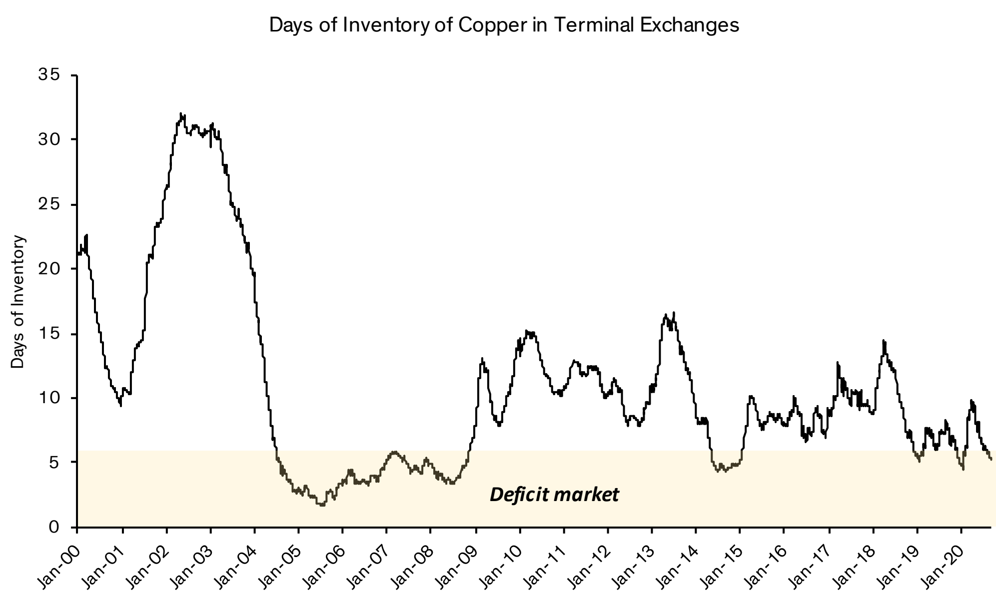
PRICE 5: CURRENT STATE OF COPPER MARKET

EXHIBIT 76: **Copper inventories are at reasonable levels (and certainly well below pre "super cycle" level, despite billions of dollars of investment in new capacity).**



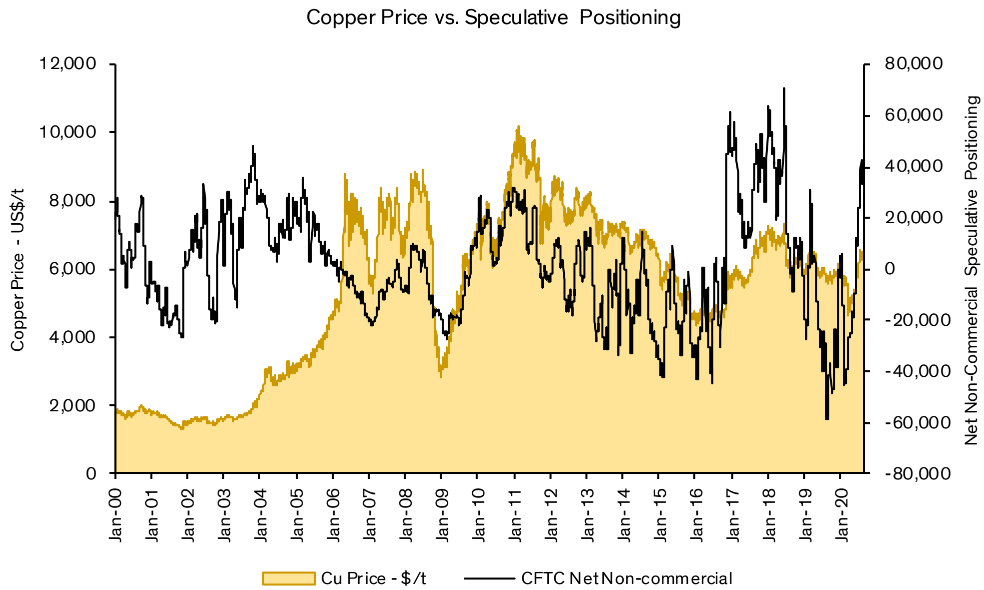
Source: Bloomberg, Wood Mackenzie, Haver, Bernstein analysis & estimates

EXHIBIT 77: **Days of inventory remain low**



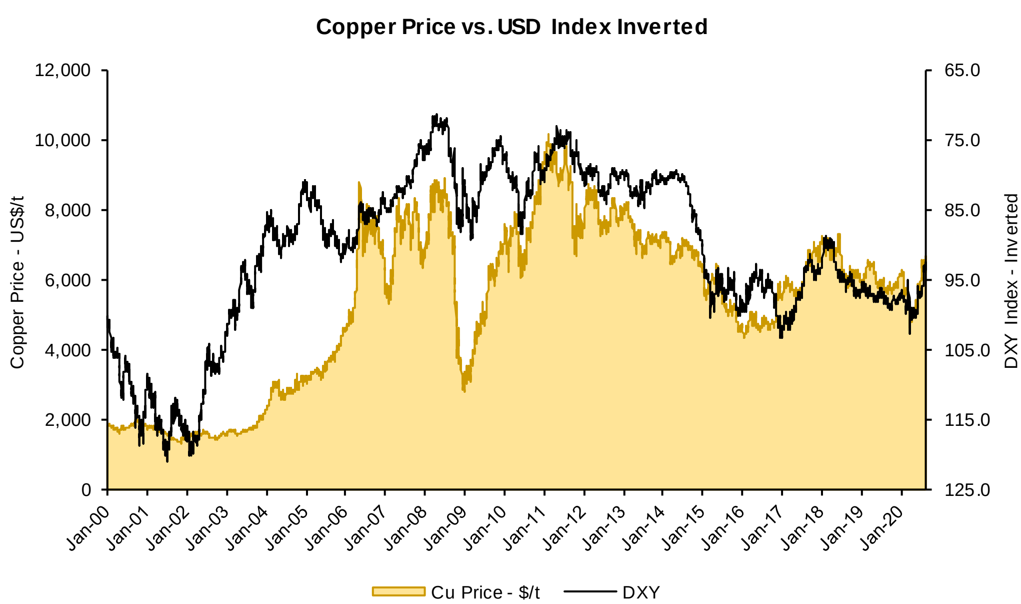
Source: Bloomberg, Wood Mackenzie, Haver, Bernstein analysis & estimates

EXHIBIT 78: **Non-commercials are net long copper (but below 2017 and 2018 levels)**



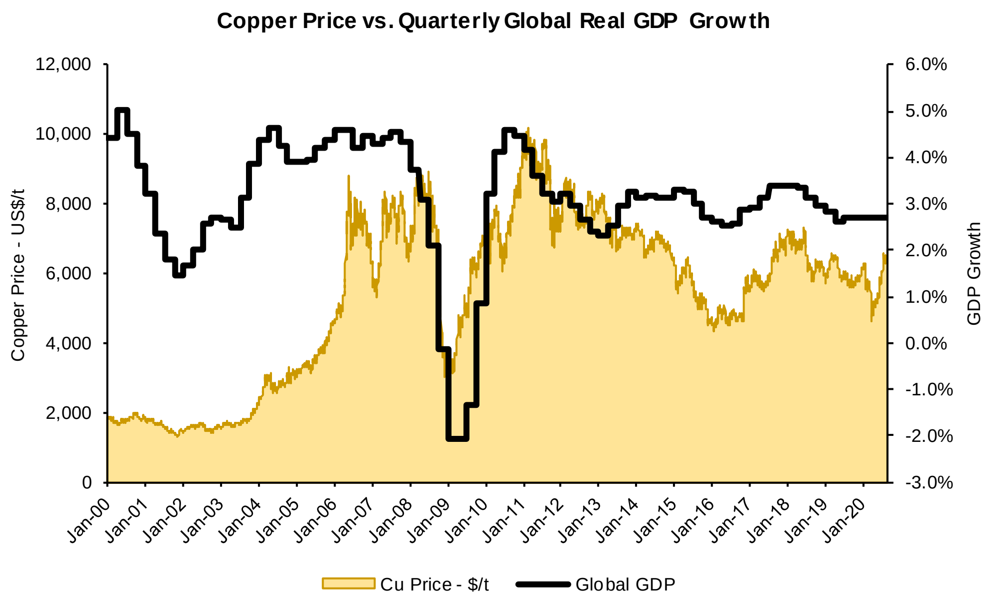
Source: Bloomberg; Bernstein analysis

EXHIBIT 79: **Copper / dollar trend has been consistent last 2 years**



Source: Bloomberg, Wood Mackenzie, Bernstein analysis & estimates

EXHIBIT 80: **Dr. Copper not responding to GDP signal to same degree as global financial crisis (given rapid inflationary policy response) xxx need to update haver data pull**



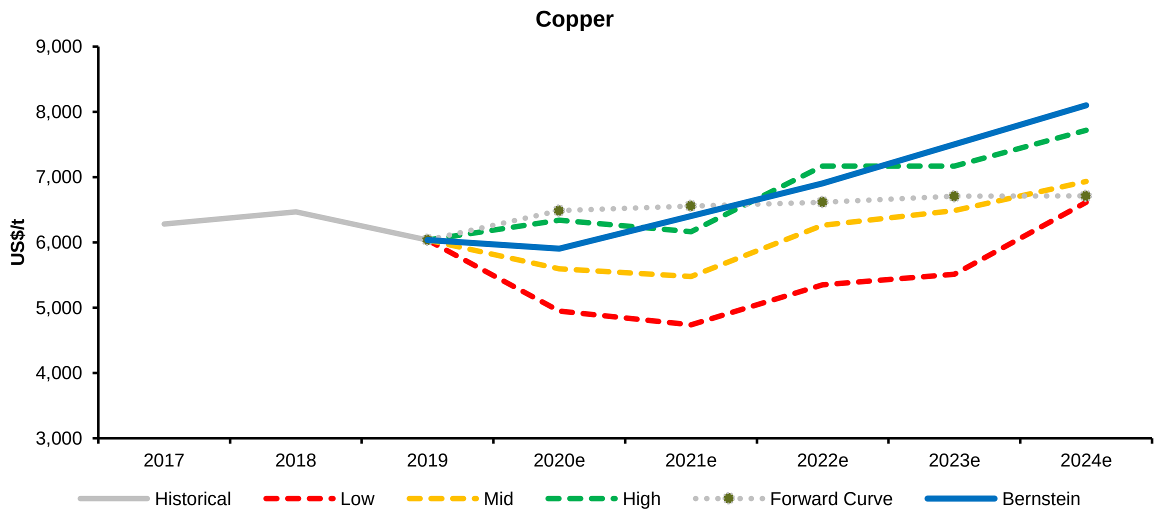
Source: Bloomberg, Wood Mackenzie, Haver, Bernstein analysis & estimates

PRICE 6: OUR COPPER COMMODITY DECK

To arrive at our copper price deck (Exhibit 81), we make two assumptions: first that the 35-year trend between marginal cash cost of copper (90th percentile of C1) and price holds (at ~135%) and second that the rise in cash costs over the next 5 years will average second quartile versus history (8.1% CAGR nominal).

EXHIBIT 81: **Bernstein copper deck vs consensus**

Copper								
	2017	2018	2019	2020e	2021e	2022e	2023e	2024e
Historical	6,280	6,468	6,035					
Low			6,035	4,948	4,735	5,350	5,512	6,614
Mid			6,035	5,592	5,478	6,261	6,484	6,934
High			6,035	6,338	6,160	7,165	7,165	7,716
Forward Curve			6,035	6,485	6,556	6,615	6,705	6,710
Bernstein			6,035	5,900	6,400	6,900	7,500	8,100



Source: SNL Financial, CME, Bloomberg and Bernstein Estimates and Analysis

DISCLOSURE APPENDIX

VALUATION METHODOLOGY

North American Oil & Gas Exploration/Production

Our valuation framework for our coverage of North American E&P oil & gas stocks varies by company but is driven by a measure of delivered cash flow (EBITDA) against the appropriate multiple (EV/EBITDA). We support the valuation with deep dive NAVs where appropriate. We adjust our target multiples to include the effects of growth, capitalization, capital efficiency, FCF yield, and risk.

Apache Corp

We arrive at our Target Price by applying a multiple of 7.0x to our 2021E EBITDA estimate of $2.1 billion.

RISKS

North American Oil & Gas Exploration/Production

The primary risk to our target prices for the North American E&Ps is lower than expected commodity prices over the next few years. For instance, oil prices could be negatively affected by slower than expected economic growth, higher global supply, or faster switching to alternative fuel sources, which could depress product demand and drive oil prices below the marginal cost of supply. For natural gas, prices could be negatively affected by warm weather, continued healthy supply growth, lower coal-to-gas power switching, or lower than expected LNG/pipeline net exports. Additionally, government policy and administration, including but not limited to changes to various countries' tax rates/fiscal terms, have the potential to positively or negatively affect the commodities and companies.

Apache Corp

We rate APA Outperform. Key risks to the downside include (1) balance sheet risks in a low commodity environment, (2) execution mis-steps in Suriname, and (3) lower commodity prices.

REQUIRED REGULATORY DISCLOSURES

- References to "Bernstein" relate to Sanford C. Bernstein & Co., LLC, Sanford C. Bernstein Limited, Sanford C. Bernstein (Hong Kong) Limited 盛博香港有限公司, Sanford C. Bernstein (Canada) Limited, Sanford C. Bernstein (India) Private Limited (SEBI registration no. INH000006378) and Sanford C. Bernstein (business registration number 53193989L), a unit of AllianceBernstein (Singapore) Ltd. which is a licensed entity under the Securities and Futures Act and registered with Company Registration No. 199703364C, collectively. On and as of April 1, 2019, AllianceBernstein L.P. acquired Autonomous Research. As a result of the acquisition, the research activities formerly conducted by Autonomous Research US LP have been assumed by Sanford C. Bernstein & Co., LLC, which will continue to publish research under the Autonomous Research US brand and the research activities formerly conducted by Autonomous Research Asia Limited have been assumed by Sanford C. Bernstein (Hong Kong) Limited 盛博香港有限公司, which will continue to publish research under the Autonomous Research Asia brand.
- References to "Autonomous" in these disclosures relate to Autonomous Research LLP and, with reference to dates prior to April 1, 2019, to Autonomous Research US LP and Autonomous Research Asia Limited, and, with reference to April 1, 2019 onwards, the Autonomous Research US unit and separate brand of Sanford C. Bernstein & Co., LLC and the Autonomous Research Asia unit and separate brand of Sanford C. Bernstein (Hong Kong) Limited 盛博香港有限公司, collectively.
- References to "Bernstein" or the "Firm" in these disclosures relate to Sanford C. Bernstein & Co., LLC, Sanford C. Bernstein Limited, Sanford C. Bernstein (Hong Kong) Limited 盛博香港有限公司, Sanford C. Bernstein (Canada) Limited, Sanford C. Bernstein (India) Private Limited (SEBI registration no. INH000006378), Sanford C. Bernstein (business registration number 53193989L), a unit of AllianceBernstein (Singapore) Ltd. which is a licensed entity under the Securities and Futures Act and registered with Company Registration No. 199703364C and, with reference to April 1, 2019 onwards, Autonomous Research LLP, collectively.
- Bernstein and Autonomous analysts are compensated based on aggregate contributions to the research franchise as measured by account penetration, productivity and proactivity of investment ideas. No analysts are compensated based on performance in, or contributions to, generating investment banking revenues.
- Bernstein rates stocks based on forecasts of relative performance for the next 6-12 months versus the S&P 500 for stocks listed on the U.S. and Canadian exchanges, versus the MSCI Pan Europe Index for stocks listed on the European exchanges (except for Russian companies), versus the MSCI Emerging Markets Index for Russian companies and stocks listed on emerging markets exchanges outside of the Asia Pacific region, and versus the MSCI Asia Pacific ex-Japan Index for stocks listed on the Asian (ex-Japan) exchanges - unless otherwise specified. We have three categories of ratings:

  Outperform: Stock will outpace the market index by more than 15 pp in the year ahead.

  Market-Perform: Stock will perform in line with the market index to within +/-15 pp in the year ahead.

  Underperform: Stock will trail the performance of the market index by more than 15 pp in the year ahead.

  Not Rated: The stock Rating, Target Price and/or estimates (if any) have been suspended temporarily.
- For purposes of the Market Abuse Regulation (MAR) and the FINRA Rule 2241, 'Outperform' is classified as a Buy, 'Market-Perform' is classified as a Hold, and 'Underperform' is classified as a Sell
- As of 09/11/2020, Bernstein's ratings were distributed as follows: 277 Outperform - 47.4% (0.0% banking clients) ; 249 Market-Perform - 42.6% (0.0% banking clients); 59 Underperform - 10.1% (0.0% banking clients); 0 Not Rated - 0.0% (0.0% banking clients). The numbers in parentheses represent the percentage of companies in each category to whom Bernstein provided investment banking services. All figures are updated quarterly and represent the cumulative ratings over the previous 12 months. These ratings relate solely to the investment research ratings for companies covered under the Bernstein brand and do not include the investment research ratings for companies covered under the Autonomous brand. This information is provided in order to comply with Article 6 of the Commission Delegated Regulation (EU) 2016/958.

12-Month Bernstein Rating History as of 09/10/2020

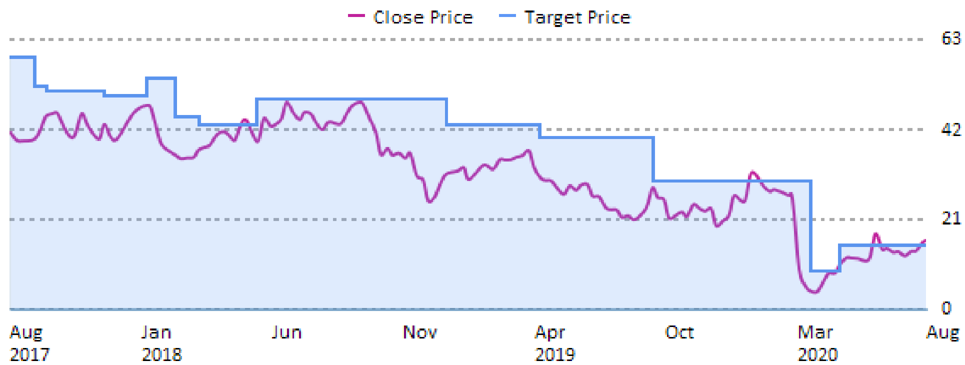
Ticker	Rating Changes
APA	O (IC) 05/13/11

Rating Guide: O - Outperform, M - Market-Perform, U - Underperform, N - Not Rated

Rating Actions: IC - Initiated Coverage, DC - Dropped Coverage, RC - Rating Change

APA / Apache Corp (USD)

Date	Rating	Target
05-Jul-2017	O	59.00
29-Aug-2017	O	52.00
20-Sep-2017	O	51.00
01-Dec-2017	O	50.00
17-Jan-2018	O	54.00
23-Feb-2018	O	45.00
26-Mar-2018	O	43.00
04-Jun-2018	O	49.00
09-Jan-2019	O	43.00
03-May-2019	O	40.00
11-Sep-2019	O	30.00
16-Sep-2019	O	30.00
17-Mar-2020	O	9.00
24-Apr-2020	O	15.00
13-Aug-2020	O	20.00



Source: Bernstein - As of 13-Aug-2020

O - Outperform
M - Market-Perform
U - Underperform
N - Not Rated

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