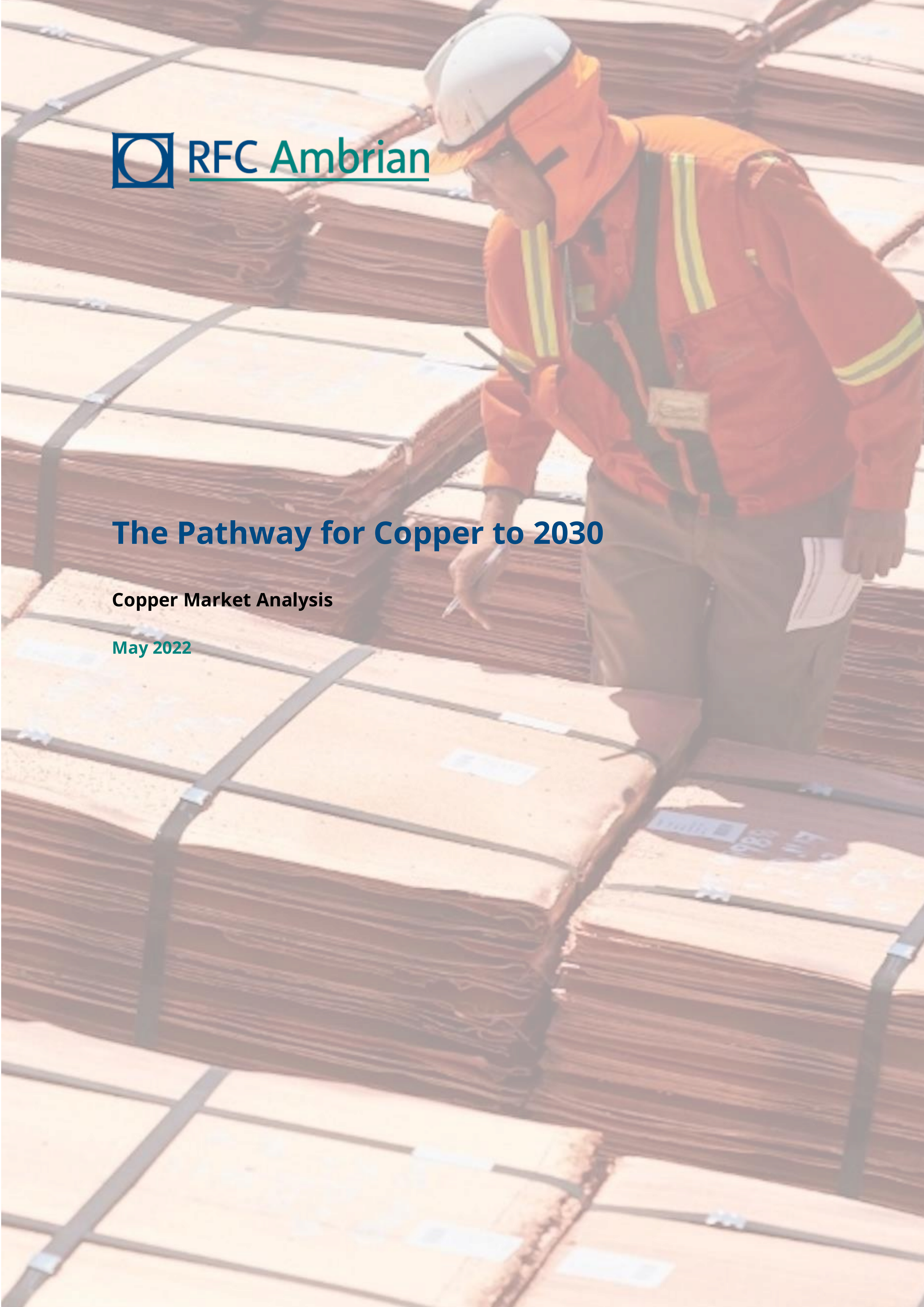

The Pathway for Copper to 2030

Copper Market Analysis

May 2022

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Front picture: Los Bayas, Glencore

Executive Summary picture: International Copper Association

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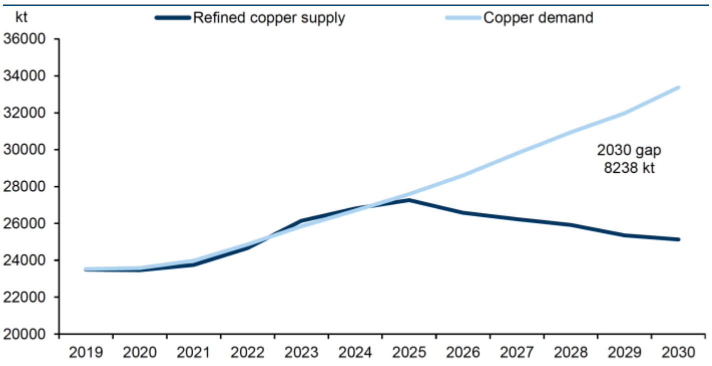
Executive Summary

It appears to be an accepted fact that over the coming decade there will be insufficient copper supply to balance the demand for copper. The view is solidified with research from commodity market specialists such as Wood Mackenzie and reputable research houses such as Goldman Sachs and Citigroup, and investors are used to seeing charts such as Figure 1 showing very large copper deficits by 2030 (Goldman Sachs - Copper is the New Oil, 13 April 2021).

However, this is not the view of everyone in the market. For example, Norilsk Nickel (also a significant copper producer) gave an outlook that the copper market would be in balance by 2030 at its Capital Markets Day in November 2021. This has prompted us to take a closer look at the copper market to see how these views can be so different. This report considers the current supply and demand assumptions and examines the outlook for copper to 2030.

Figure 1. Copper Supply Gap Projection



Source: Goldman Sachs.

RFC Ambrian are experienced natural resources corporate financiers and investors but do not purport to be specialists in commodity market detail; however, we keep a close watch on the pipeline of new resource projects, producers, and developers, as demonstrated in our previous reports, and make our own projections of supply. So, this report analyses existing copper market forecasts and discusses some of the many assumptions and sensitivities that need to be considered when analysing the potential copper market supply and demand dynamics in 2030.

Supply Challenges

The copper mining industry faces a range of challenges over the next decade, some of them applicable to the whole industry and others more project specific. We see four broad issues facing the copper industry: grade decline and the depletion of reserves, climate change impacts, ESG pressures, and political and regulatory issues. Many of these were discussed at depth in our report "Copper Projects Review 2021" – December 2021, and so will not be repeated in this report.

However, it is worth highlighting the ongoing political risks in many of the major copper producing countries and resultant civil unrest, as well as permitting, water, power, and tailings issues. Furthermore, in today's environment of climate change awareness, it has become essential for copper companies to focus on ESG issues and to minimise their carbon footprint.

Much of this reduction in carbon footprint will only be achieved through the implementation of best practice in mine design, which means incorporating new technology and innovative practices into existing mines where possible but particularly into new mine developments. This includes the digitalisation of operations, the use of renewable energy, the electrification of haulage, minimising the mine footprint, ore sorting and beneficiation, and dry tailings stacking. These measures will also increase safety and reduce operating costs.

Renewables to Boost Copper Demand

The demand for renewable energy and for electric vehicles (EVs) is changing the demand pattern for many commodities. Copper is one that appears to be a major beneficiary of decarbonisation and is central to the delivery of the energy transition as well as being a critical element in the generation, transmission, storage, and consumption of low carbon electricity.

Copper used in EVs, solar, wind, storage, and charging infrastructure is expected to experience strong growth rates going forward, although there will be some offset of copper consumption lost in other forms of energy supply and conventional vehicles.

Recent Market Events

This report does not consider the short-term outlook for copper, but it is worth noting that the copper market has recently been significantly impacted by the COVID-19 pandemic and on-going supply chain disruptions and these impacts may have lasting effects. Furthermore, this report has been written less than three months after the start of the Russian invasion of Ukraine, and the full effects of this event are still unfolding.

The impact of the war in Ukraine is rippling out across the world and apart from the human catastrophe, economically it is causing sanctions, disrupted supply chains, surging energy costs, and uncertainties about the flow of commodities and goods in and out of Russia and other markets. Russia was the fourth largest producer of refined copper in 2020, accounting for 5% of global production. Much of it is under contract, although sanctions could lead to a disruption in Russian copper supply. This report has not been able to fully consider the possible consequences of these events in the longer-term analysis.

Copper Market Analysis

On the supply side, the report takes two approaches to calculating future copper production. The first is based on analysis of the production expansion plans of 15 top copper producers, whose existing operations account for 57% of 2020 production.

The second is based on our database of greenfield and brownfield copper projects and takes a close look at copper projects currently coming on-stream, as well as projects at late-stage development, feasibility, and pre-feasibility level. The report also considers potential copper scrap supply levels used in the smelting and refining of copper.

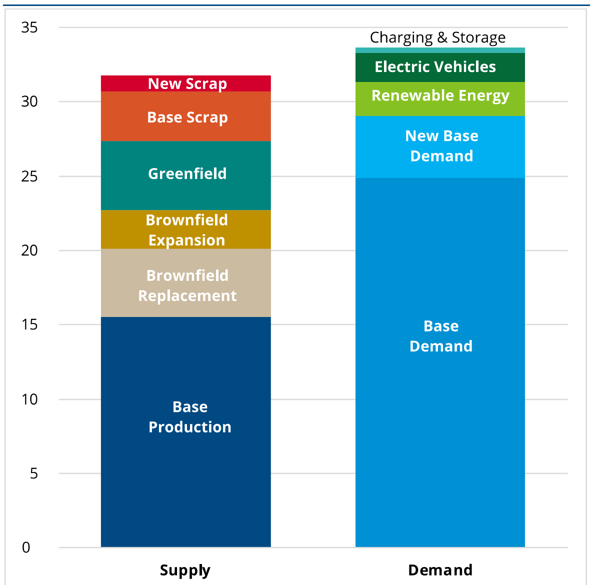
On the demand side, the report looks at existing market demand forecasts, as well as focusing on a recent report from the International Copper Association (ICA) which highlights a lower ratio of the copper used in battery electric vehicles (BEVs), relative to existing internal combustion engine (ICE) vehicles. This has a negative impact on the current projections of additional copper demand from renewables.

Copper Market Balance

Finally, we use these number to present a forecast of how the copper market balance may look in 2030 as well as looking at the sensitivity analysis of the assumptions used.

Important factors influencing the supply-demand balance are the number and size of new projects expected to come on-stream, the level of new copper demand created from global investment in the decarbonisation of energy, as well as expectations for growth for the balance of global copper consumption.

Figure 2. Copper Market Balance 2030F



Source: RFC Ambrian. NB. Base Production after closures.

We forecast an overall increase in refined copper supply of 7.0 Mt of refined copper, a 2.5% CAGR from 2020 to 2030. This is produced from new copper concentrate and SX-EW production, as well as from increased copper scrap supply. The refined copper supply under is forecast to total 31.7 Mt in 2030, compared with 24.7 Mt in 2020.

For renewable energy demand we have used an increase of 4.6 Mt from 2020 to 2030, largely based on the market consensus data, and have not made any changes for reduced BEV copper intensity. We have also assumed demand of 2.0% for ongoing non-renewable copper consumption, compared with an historic average of 2.5%. This results in total refined copper demand of 33.6 Mt in 2030, equivalent to a CAGR of 3.1%.

The result is a market deficit of about 1.9 Mt. While the assumptions used are open to debate, they are not unreasonable, and the forecast shows a materially smaller deficit to that assumed by the general market consensus.

More Investment and More M&A and More Innovation

Nevertheless, this still suggests that copper supply is likely to struggle to match demand forecasts and more investment is required in greenfield and brownfield production, which will likely require higher copper prices (relative to history).

Based on industry-wide capital intensity data, we calculate that some US$196 bn of investment will be required to achieve the 6.8 Mt production (before disruption allowance) in our supply forecast. Of this, US$80 bn is for greenfield projects and US$116 bn is for brownfield projects, of which US$71 bn is simply for replacement capacity. A further US$35 bn of investment will be required to close the supply gap (if it can be achieved from increased supply).

Of the top 15 producers analysed in the report, five companies will achieve little or no growth in copper production by 2030, and a further five will achieve a CAGR of less than 5% over the period, based on their current project pipeline and announcements. Although this will not necessarily increase supply, this raises the prospect of M&A activity if these companies wish to enhance their growth prospects.

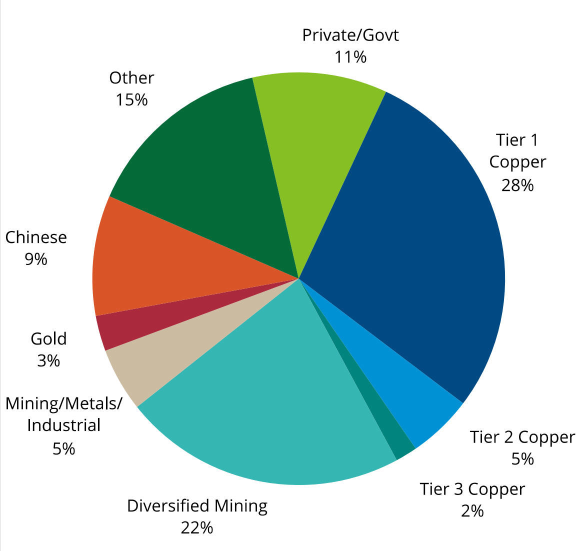
Finally, increasing ESG concerns and the resulting implications for the industry’s social license to operate, particularly in areas experiencing climate-related and operationally-derived water stresses, will, in our opinion, be a significant driver of innovation in the copper mining industry. Innovation, step changes in operational practices and new disruptive technologies will likely play an underappreciated but important role in the security of copper supply in the years ahead.

1. Copper Supply Analysis

In 2020, mined copper production totalled 21.0 Mt, supplied by a large number of producers. S&P Global Intelligence lists 307 individual companies or groups producing copper, accounting for 85% of the total production. This production was sourced about 80% from producers of copper concentrate and 20% from producers of copper using SX-EW extraction methods.

However, copper production is not just about mine supply, it is further complicated by the fact that copper concentrates need to be smelted and the product (blister or anode copper), along with copper produced from SX-EW operations, need to be refined. These processes also involve the inclusion of copper scrap, and it is the ultimate refined copper production (cathode copper) that it consumed by the manufacturing industry (along with further copper scrap).

Figure 3. Mined Copper Producers by Type



Source: S&P Global Market Intelligence, company data.

1.1 The Copper Miners

Figure 3 shows a breakdown of the top 100 mined copper producers by type, with 'Other' representing the balance which were not classified as many of them produce copper as a by-product of other mining operations. The top 100 account for 85% of the production covered and are companies or groups that produced more than 20 kt/y of copper in 2020. In this breakdown we have classified Codelco (the world's largest copper producer) as a Tier 1 copper producer, even though it is owned by the government of Chile.

Figure 3 shows that the copper market is both broad and diverse in terms of producers and gives an indication of the difficulty in tracking and measuring annual copper production. However, by tracking the production from diversified miners; Tier 1, Tier 2, and Tier 3 copper producers; and gold producers, some 60% of the copper production from this group (equivalent to some 51% of total mined copper production) can be analysed.

1.2 Recent Trends in Copper Supply

Table 1 shows the ten-year mined copper production from 2010 to 2020, with data from the International Copper Study Group (ICSG). Mine production has increased by a CAGR of 2.7%. The historical data shows that the average utilisation has been 71% and includes a number of factors including unforecastable annual disruptions. 2020 was a slightly more difficult year for producers due to the COVID-19 pandemic and utilisation was lower than the few previous years but was still in-line with the decade's average.

It is unclear how the ISGC capacity figure is derived, but the market focuses on mine production additions, and as part of that calculation we apply a 10% disruption allowance to our production numbers for unexpected production losses. Wood Mackenzie uses a disruption allowance of 5%.

Production growth was stronger in the first half of the decade than the second half and **since 2015 production CAGR has been just 1.4%.** This is attributed to continued price declines from 2011 to 2016 which led to lower investment in exploration and project development, increasingly stringent ESG requirements, a shortage of new high quality large-scale copper projects available to be developed, and a range of social and political issues in a number of countries which are large producers of copper.

Table 1. Copper Mine Production 2010-2020 (kt)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR 2010-2020
Mine Capacity	19,283	19,476	20,011	20,793	21,580	22,360	23,474	24,003	24,063	24,163	24,762	2.5%
Mine Conc. Prodn	12,727	12,627	13,345	14,543	14,875	15,709	16,401	16,543	17,120	17,195	17,252	3.1%
Utilization (%)	0.66	0.65	0.67	0.70	0.69	0.70	0.70	0.69	0.71	0.71	0.70	
SX-EW Capacity	4,345	4,416	4,468	4,580	4,651	4,622	4,704	4,709	4,729	4,818	4,901	1.2%
SX-EW Production	3,324	3,458	3,645	3,794	3,906	3,915	3,912	3,776	3,890	3,769	3,792	1.3%
Utilization (%)	0.77	0.78	0.82	0.83	0.84	0.85	0.83	0.80	0.82	0.78	0.77	
Total Capacity	23,628	23,892	24,479	25,372	26,231	26,982	28,178	28,712	28,792	28,981	29,663	2.3%
Total Production	16,051	16,085	16,990	18,337	18,781	19,624	20,313	20,319	21,010	20,964	21,044	2.7%
Utilization (%)	0.68	0.67	0.69	0.72	0.72	0.73	0.72	0.71	0.73	0.72	0.71	

Source: S&P Global Market Intelligence, ICSG, company data.

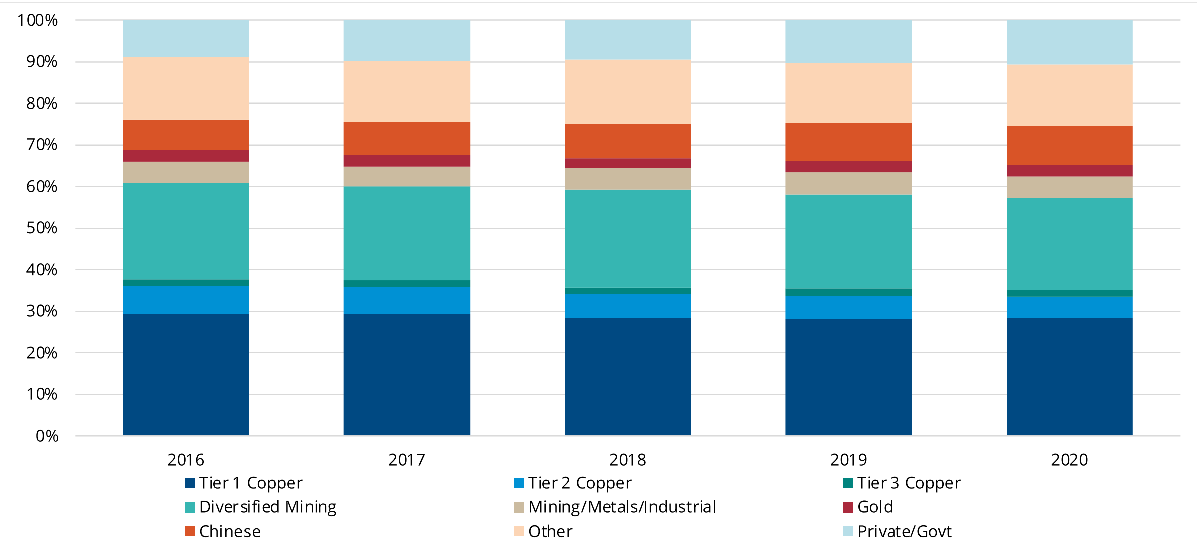
Figure 4 shows the contribution to production from 2016 to 2020 by each of the different groups of producers. It shows little change in the overall structure of the industry. Growth of about 5% came from the private and government groups and growth of nearly 8% came from the Chinese companies. Production growth from the other groups was only modestly positive aside from the diversified miners which was slightly negative.

In absolute terms, the largest additions to production over this period came from Zijin Mining (+251 kt), First Quantum (+221 kt), Kaz Minerals (+159 kt), Southern Copper (+101 kt), Norilsk Mining (+101 kt), and Gécamines (+94 kt).

In absolute terms, the largest decreases in production over this period came from Freeport-McMoRan (-410 kt), Glencore (-158 kt), Codelco (-126 kt), MMG (-104 kt), Hudbay Minerals (-79 kt), and Vale SA (-76 kt). These include three of the world's four largest copper producers.

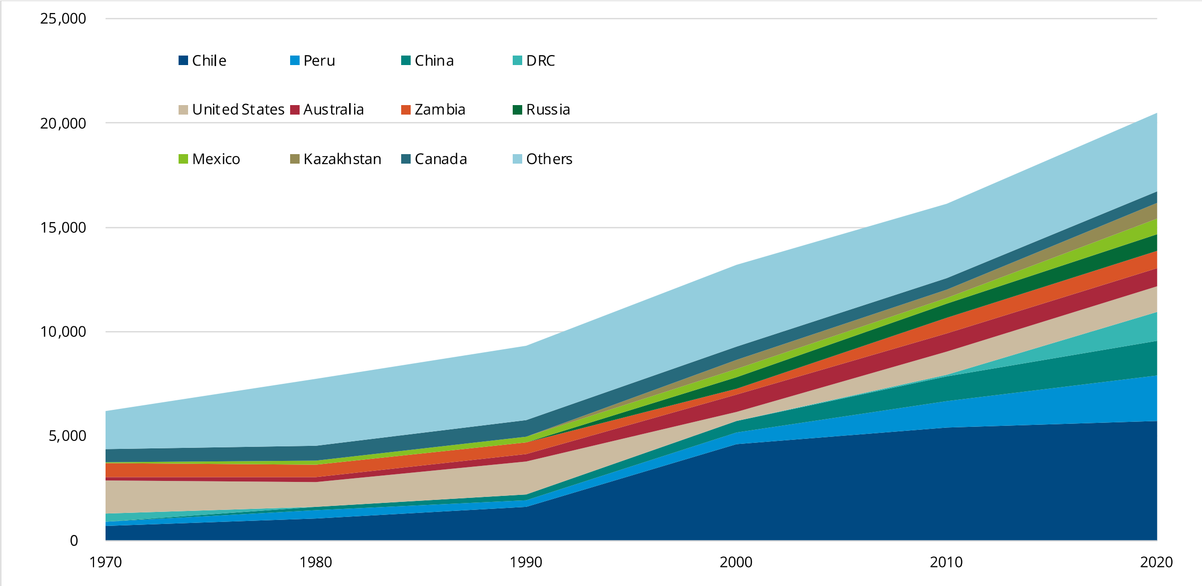
The consequence of this recent period of relatively low production growth is that it appears to have helped set the market's expectations of low-capacity growth going forward. While some of the negative or restrictive aspects to industry growth persist, it is necessary, however, to examine future production growth on its own merits with detailed analysis of current development projects.

Figure 4. Top 100 Copper Producers 2016-2020



Source: S&P Global Market Intelligence, company data.

Figure 5. Copper Mine Production by Country 1970-2020



Source: World Bank, Oct 2021.

1.3 The Broad Outlook for Future Supply

As a longer-term benchmark, Figure 5 shows mined copper production growth from 1970 to 2020 by country. This period includes a significant step-up in output from Chile and Peru, coinciding with the expansion of the Chinese economy.

Chile is currently the largest producer accounting for 28% of production in 2020, followed by Peru (10%), China (8%), DRC (7%), and the United States (6%). **The overall CAGR for copper mine production from 1970 to 2020 was 2.4%.**

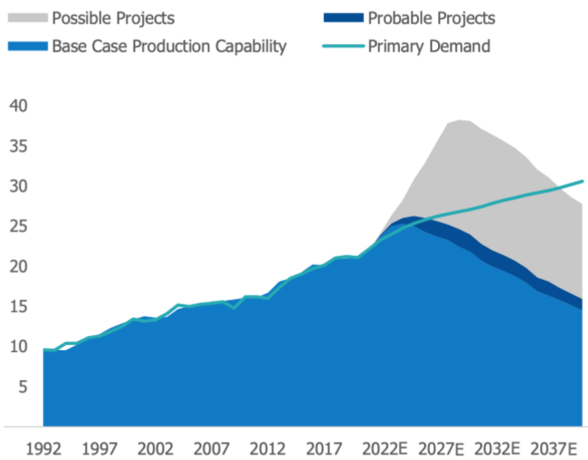
The outlook for future copper production largely depends on:

- the longevity of existing mining operations and mine closures.
- the fall in production from grade declines over time.
- brownfield increases from capacity expansions and/or reserve extensions.
- the number and size of new greenfield projects coming on-stream.

Understanding and forecasting each of these factors is important in determining the mine production going forward. The way to do this is to have a database of every single operating copper mine (and mines producing copper as a by-product) and every copper project.

Very few organisations compile and maintain this data because it is difficult to gather, requires significant resources, and some data is unavailable. S&P Global Intelligence can provide a starting point with listings of 419 operating mines, expansion projects, and satellite deposits, as well as 1,205 development and exploration projects, but is not a complete data set and further analysis is required.

Figure 6. Copper Supply Projection



Source: Norilsk Nickel.

Even Wood Mackenzie adds an additional 15% to its supply projections over a ten-year period (where there is an acceleration of demand and elevated prices) to cover 'off-radar projects' that it has not been able to account for. It notes that in the ten years of the last super-cycle, off-radar projects accounted for 14% of the supply by 2014[1].

Generally, it is hard to find the assumptions and a breakdown of supply growth given by commodity specialists in the copper market. Also, future supply is often divided into probable and possible projects (see Figure 6) and how these are risk-adjusted and added to the base production can have a material impact on the final outlook for future supply.

Table 2. Indicative Copper Mine Supply Forecasts

Forecast (Mt)	2020	2030	Chng	CAGR
Goldman Sachs[1]	20.8	21.5	0.7	0.7%
Citigroup[2]	20.2	24.4	4.2	1.9%
Norilsk Nickel[4]	-	-	-	3.0%
S&P Global[5]	21.0	-	-	3.3%

Source: Company reports. 1. Copper is the New Oil April 2021. 2. Copper Book, Oct 2021. 3. Based on 20-year reported CAGR, Mar 2021. 4. Capital Markets Day, Nov 2021. 5. CAGR for forecast to 2026, Mar 2022.

Table 2 shows projections for copper mine supply growth from 2020 to 2030 from a number of commodity specialists. These are not all on the same basis (some based on different periods) but gives an indication of the broad range of forecasts for copper mine supply growth currently in the market.

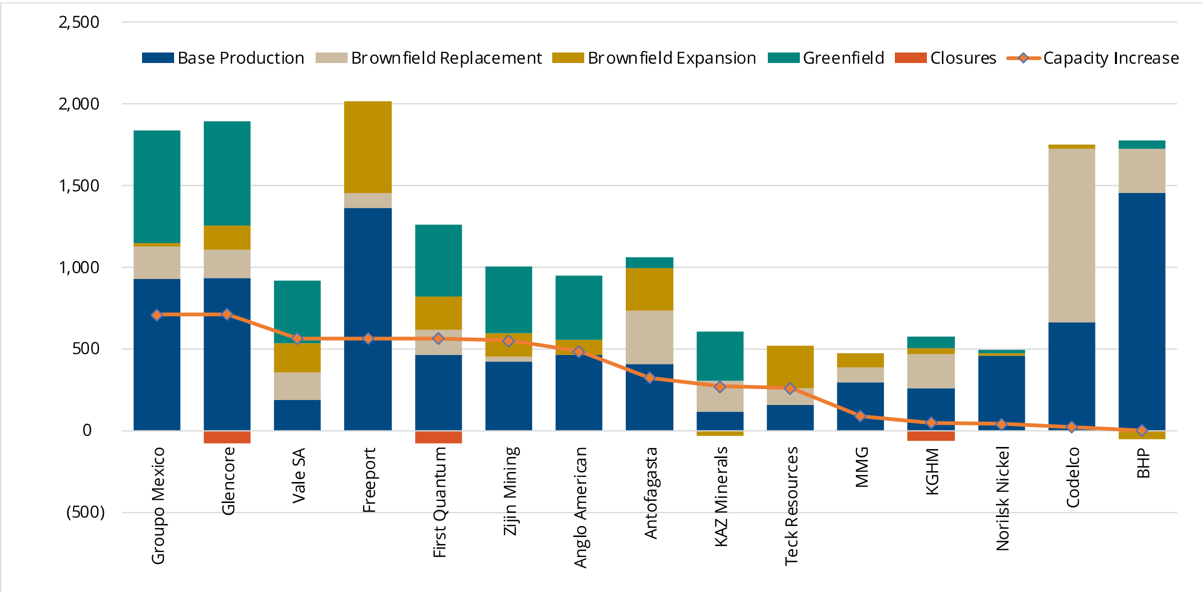
1.4 New Production from Major Producers

To better understand some of the trends and issues in forecasting future production, we have carefully analysed 15 of the top copper producers. These companies accounted for about 57% of total mined copper production in 2020.

We analysed company reports and presentations to establish forecast production growth from 2020 to 2030. The data was based off the attributable production for 2020 and we have identified the brownfield expansions, greenfield projects, and closures for each copper producer. The hardest figure to identify in some cases was the actual capacity of brownfield projects (replacement and expansion). Some estimates were made as some companies only give the incremental increase in production of brownfield projects.

Figure 7 shows the results for the 15 companies, ordered by the level of expected production increase from 2020-2030. While the results may not be representative of the whole industry, it does give an indication of the mine supply outlook.

Figure 7. Major Copper Producers 2020-2030F Production

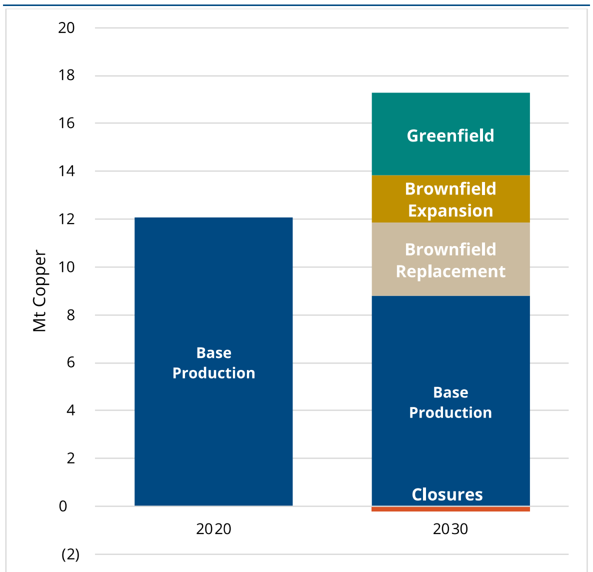


Source: Company reports, RFC Ambrian estimates.

[1] Wood Mackenzie – Will a lack of supply growth come back to bite the copper industry, Mar 2021.

Brownfield and greenfield projects included in the data did include some 'probable' projects, and a few expansion options where decisions had not yet been made, but our view is that there is a high probability that these projects will proceed. The size and experience of these companies suggests that they would not talk about them in their project pipelines if they did not understand the risks and expect them to go ahead. These companies are also unlikely to have any significant financing issues.

Figure 8. Capacity Projection of 15 producers



Source: Company reports, RFC Ambrian estimates.

Figure 8 shows the combined results of the 15 companies and the data suggests an increase of 5.2 Mt in mine production from 2020 to 2030. Using a disruption factor of 10% this is equivalent to **net new mine production of 4.7 Mt and a CAGR of 3.3% for the 15 companies.** In terms of the underlying decline in the base capacity the data suggest an overall decline of about 27%, equivalent to a decline rate of about 3.0% per annum. Data presented by Wood Mackenzie suggests a base capacity decline rate of about 2.8% per annum.

The mine closure rate is about 1.8% of the 2020 capacity. This appears quite low but likely reflects the quality of the orebodies held by the top producers. We would anticipate this rate to be higher from the other copper producers (accounting for 43% of total production) as they are likely to have a higher percentage of smaller, shorter-life orebodies. We would also expect the brownfield and greenfield expansions of this group to carry higher risk of development and financing.

These factors would reduce the effective supply growth of this group. For our scenario, we eliminated 30% of the pro-rata brownfield and greenfield projects for this group and applied it after a 7.2% mine closure rate (4x) and used a 10% disruption factor. This results in **net production growth of the remaining producers of 1.8 Mt** by 2030 equivalent to a CAGR of 1.8%.

Combining both groups gives a forecast of an overall net mine production increase of 6.5 Mt and CAGR of 2.7% from 2020 to 2030.

1.5 A Focus on New Copper Projects

Our second approach to looking at potential new production is to examine all copper projects in the market. RFC Ambrian maintains a database of copper projects which we believe is reasonably comprehensive, although recognise that it is not exhaustive, particularly at the smaller end of the market and where projects are held by governments or private companies. Chinese producers can also be somewhat opaque.

Our project database is divided into three categories: under development, probable, and possible. These contain both greenfield and brownfield projects, and we further sub-divide the possible projects into lower- and higher-risk. For this exercise the higher-risk possible list contains projects that have higher development risks but also may be longer dated than the 2030 timeframe.

Table 3 summarises the potential capacity additions from our project database. For this exercise, the brownfield production is only the net new production and not the whole project capacity. The table shows projected production increases for each of our project categories. The greenfield projects for each of the categories are listed in Appendix 1.

In order to calculate how much actual production might come on-stream, we have assumed what we believe to be a suitable risk adjustment factor to each category's total, as well as a mine disruption factor to calculate an overall potential net addition to production.

Table 3. Copper Mine Projects Potential (Mt)

Project Type	Projects Prodn	Risk Factor	Supply Prodn
Greenfield Under Development	1.69	100%	1.69
Brownfield Under Development	2.42	100%	2.42
Probable Greenfield	1.57	70%	1.10
Probable Brownfield	1.30	70%	0.91
Possible Lower-risk Greenfield	2.15	50%	1.07
Possible Lower-risk Brownfield	0.99	50%	0.50
Possible Higher-risk Greenfield	2.90	0%	-
Mine Closures	(0.86)	100%	(0.86)
Total	**12.16**		**6.83**

Source: RFC Ambrian.

The risk adjustment factors in Table 3 reflect a range of broad political and industry related circumstances as well as individual project risks based on a review of individual project IRRs and capital efficiencies (NPV/CAPEX) within each group. Both are discussed in more detail in the next section (2 – Copper Project Risks). However, we recognise that the risk factors have an element of subjectivity and can only ever be a best estimate. This is a key area in the diversity of views on the outlook for copper over the next decade, but interestingly is not the most sensitive assumption to the overall market balance in 2030 within our scenario (see 4 – Copper Market Balance).

For mine closures we have assumed the same combined rate as we calculated in the company-focused approach, which is effectively to subtract 4.1% of 2020 production.

The scenario suggests a potential to increase net new mine production by 6.8 Mt from 2020 to 2030. However, using a disruption factor of 10% this is equivalent to net new mine production of 6.3 Mt and a CAGR of 2.7% from 2020 to 2030. Some 3.7 Mt (4.1 Mt x 0.9) of this production coming on-stream is already operating, being commissioned, or under construction.

1.6 Copper Scrap Supply

The increase in mine production is not the only expected addition to supply. New supply also comes from copper scrap. Copper scrap, or secondary copper, contributes significantly to the copper market supply and plays an important role in balancing the copper market. Consequently, it needs to be considered in the overall supply equation. It is usually divided into two main categories: new and old scrap.

Old scrap generally refers to post-consumer products and includes copper wire, copper tubing, roofing copper, and copper pipe and is usually converted to refined metal and alloys. New scrap is copper metal discarded in fabrication and manufacturing processes and is typically considered higher-grade material than old scrap. The majority of this new scrap material is recycled and used directly in semi-finished goods production.

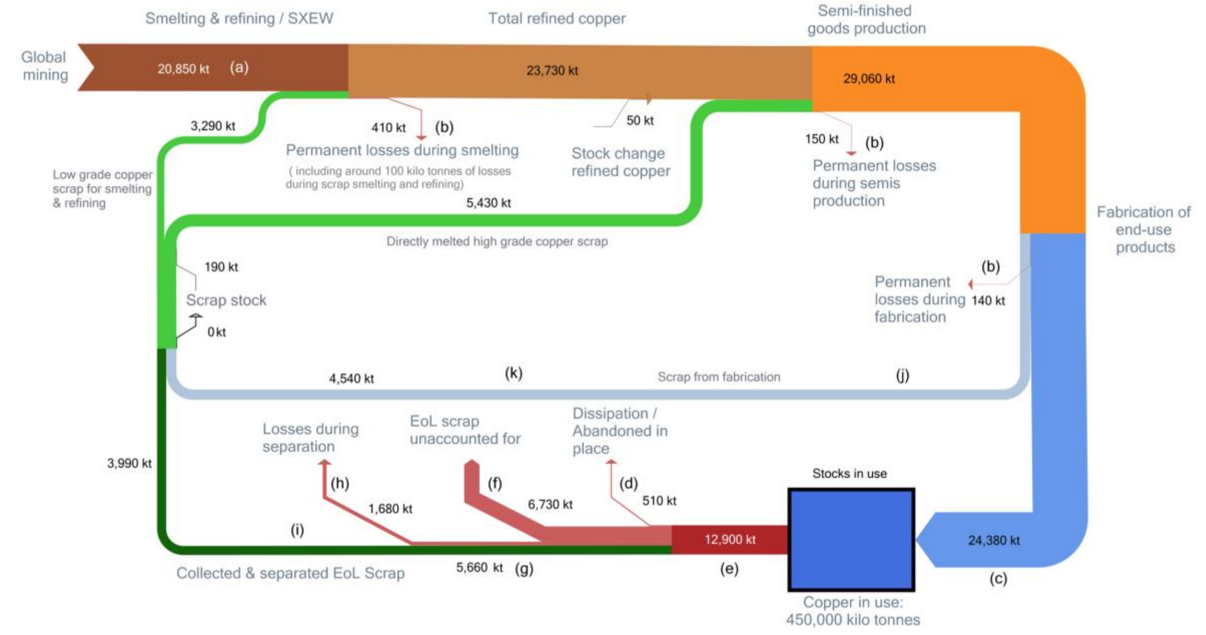
Table 4. Old Scrap Sensitivity Table (kt)

	Mine Production increase & CAGR				
	3,378	4,609	5,894	7,237	8,641
	1.5%	2.0%	2.5%	3.0%	3.5%
Scrap Ratio					
15%	359	543	736	938	1,148
16%	603	800	1,006	1,220	1,445
17%	847	1,056	1,275	1,503	1,742
18%	1,091	1,313	1,544	1,786	2,039

Source: RFC Ambrian.

Figure 9 shows the flow of copper material and scrap. Copper scrap used up to the refined production level in 2020 totalled 3.3 Mt and over the past 10 years has been around 14.5% to 18.7% of mined production. Industrial production growth increases copper demand as well as increasing the pool of available scrap. In addition, higher prices encourage more scrap to flow into the market. This means that the level of scrap will rise out to 2030, along with increases in mine production, smelter production, and refined production.

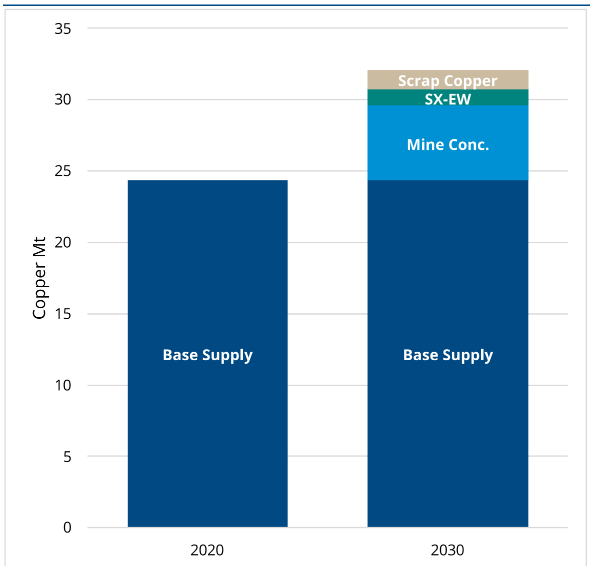
Figure 9. Copper Stocks and Industry Flows of Material and Scrap (2018)



Source: International Copper Association Jan 2020

We are unable to track smelter and refinery capacity but must assume that they increase in step with mine capacity as they have generally done in the past. Table 4 gives an indication of the potential increase in old copper scrap supply for different levels of mine production and different scrap rates.

Figure 10. Net Change in Cu Supply 2020-2030



Source: Company reports, RFC Ambrian estimates.

The two approaches used in this report to calculate net new mine production suggested an increase of 2.7% from 2020 to 2030. Using this and based on a scrap ratio of 16% (which is in line with the ten-year average over the prior period), we calculate that by 2030 there is likely to be an additional 1.07 Mt of copper scrap within the system, a CAGR of 2.8% for copper scrap growth from 2020 to 2030.

1.7 Refined Copper Supply

In conclusion, Table 5 shows copper production from mined production, through smelter production, to refined production from 2010 to 2020 and the forecast to 2030. The refined copper production is the supply that is ultimately used to manufacture semi-fabricated copper products. **The historic figures show a CAGR of 2.7% for refined copper supply from 2010 to 2020.**

The refined copper supply from this scenario is forecast to be 31.7 Mt in 2030. This is an overall increase in refined copper supply of 6.98 Mt, a 2.5% CAGR from 2020 to 2030.

This is based on a 2.7% CAGR for mine production growth, derived from the copper project analysis, resulting in a 6.31 Mt increase from 2020 to 2030. This comprises 5.18 Mt of copper concentrate production and 1.13 Mt of SX-EW copper production. In addition, there is a further 1.07 Mt of new copper scrap within the system.

Table 5. Copper Production from Mine Through to Refinery (kt) - 2030 scenario 16% scrap ratio

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2030F	CAGR 2010-2020	CAGR 2020-2030
Concentrates														
Mine Capacity	19,283	19,476	20,011	20,793	21,580	22,360	23,474	24,003	24,063	24,163	24,762	32,207	2.5%	2.7%
Mine Conc. Production	12,727	12,627	13,345	14,543	14,875	15,709	16,401	16,543	17,120	17,195	17,252	22,439	3.1%	2.7%
Utilization (%)	*0.66*	*0.65*	*0.67*	*0.70*	*0.69*	*0.70*	*0.70*	*0.69*	*0.71*	*0.71*	*0.70*	*0.70*		
Consumption	12,787	12,948	13,560	14,197	15,005	15,560	16,285	16,482	17,119	17,303	17,774	22,439		
Balance	-60	-321	-215	346	-130	149	116	60	2	-107	-521	0		
Stocks	2,243	1,922	1,707	2,053	1,923	2,072	2,188	2,248	2,250	2,143	1,621			
Blister Copper														
Smelter capacity	18,530	18,579	19,584	20,553	21,900	22,906	23,768	24,173	24,150	24,428	24,935	32,230	3.0%	2.6%
Mine copper	12,787	12,948	13,560	14,197	15,005	15,560	16,285	16,482	17,119	17,303	17,774	22,439	3.3%	2.4%
Scrap copper	2,466	2,195	2,702	2,985	3,054	2,921	2,967	2,828	3,049	3,044	3,255	4,312	2.8%	2.9%
Smelter Production	15,253	15,144	16,263	17,182	18,059	18,481	19,252	19,311	20,167	20,347	21,028	26,751	3.3%	2.4%
Utilization (%)	*0.82*	*0.82*	*0.83*	*0.84*	*0.82*	*0.81*	*0.81*	*0.80*	*0.84*	*0.83*	*0.84*	*0.83*		
Consumption	15,050	15,437	16,541	17,380	18,375	18,874	19,514	19,547	20,421	20,584	20,910	26,751		
Balance	203	-293	-279	-198	-316	-393	-262	-236	-253	-237	119	0		
Stocks	3,345	3,052	2,773	2,575	2,260	1,866	1,605	1,368	1,115	878	997			
Refined Copper														
Refinery capacity	23,310	23,919	25,035	26,599	28,403	28,854	29,395	30,217	30,506	31,110	31,809	40,958	3.2%	2.6%
Smelter copper	15,050	15,437	16,541	17,380	18,375	18,874	19,514	19,547	20,421	20,584	20,910	26,751	3.3%	2.5%
SX-EW Production	3,324	3,458	3,645	3,794	3,906	3,915	3,912	3,776	3,890	3,769	3,792	4,926	1.3%	2.6%
Other scrap copper	528	502	395	272	237	163	51	121	14	55	50	66		
Refined Production	18,902	19,397	20,581	21,446	22,518	22,952	23,477	23,444	24,325	24,408	24,752	31,743	2.7%	2.5%
Utilization (%)	*0.81*	*0.81*	*0.82*	*0.81*	*0.79*	*0.80*	*0.80*	*0.78*	*0.80*	*0.78*	*0.78*	*0.78*		

Source: ICSG, RFC Ambrian estimates.

The three areas of increased supply in 2030 do not equal the sum, due to stock changes included in the 2020 balance.

The sensitivity of these supply number is examined further in section 4 – Copper Market Balance.

1.8 New Copper Scrap Supply

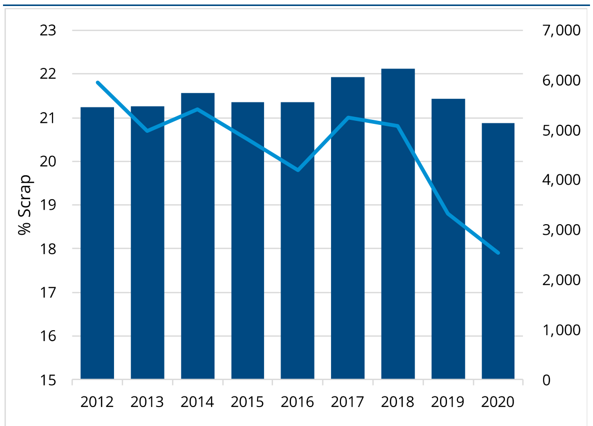
The copper supply picture is further slightly complicated by some companies reporting the copper used in copper and copper alloys semis production as global consumption of copper, rather than reporting refined consumption or fabricated end-use products.

The difference is around 5-6 Mt of copper scrap (about 20% of refined copper production) used directly in semi-finished goods production. In 2020, this was 5.1 Mt.

This is new scrap; copper metal discarded in fabrication and manufacturing processes, which largely remains in an internal loop within the manufacturing process. **This source of scrap only grows with fabrication levels and is relatively insensitive to copper prices.**

The volume of scrap produced from copper products fabrication is slightly lower than the volume of scrap input and so overall the new scrap usually adds around 0.5 to 1.0 Mt of copper to the supply equation at the fabrication end-use level. However, this data is largely opaque and difficult to analyse, and most market analysis focuses on the refined consumption.

Figure 11. New Scrap Used in Fabrication (kt)



Source: ICSG.

Figure 11 shows that the global trend over the past decade has been for consumption of more refined copper and less recycled copper use directly in fabrication of end-use products, particularly in China.

2. Copper Project Risks

The copper mining industry faces a range of challenges over the next decade, some of them applicable to the industry as a whole and others more project specific. Many of these were discussed at depth in our report "Copper Projects Review 2021" – December 2021, and so will not be repeated in this report, but it is worth highlighting the main challenges in relation to assessing the overall risk factors applied to projected new capacity in the previous section.

2.1 The Broader Challenge

We see four broad issues facing the copper industry: grade decline and the depletion of reserves, climate change impacts, ESG pressures, and political and regulatory issues.

Grade Decline and Depletions

The first challenge to copper supply is the effect of grade decline and depletions on existing capacity. By increasing throughput, many existing mines can mitigate this effect to some degree and new mines are able operate economically at lower grades through scale and the implementation of new technology. However, these measures require continued investment in new brownfield and greenfield capacity.

Based on industry-wide capital intensity data[2], the cost of a brownfield expansion for an existing mine and plant is about US$13,600 per t/y of copper capacity and for greenfield we calculate an average of about US$18,250 per t/y of copper capacity. **Based on the 6.8 Mt/y of new capacity we forecast by 2030 in Table 3, we calculate that some US$196 bn of investment will be required. Of this, US$80 bn is for greenfield projects and US$116 bn is for brownfield projects, of which US$71 bn is simply for replacement capacity.**

This is not an insignificant investment and is only likely to be achieved if copper prices remain at sufficient levels to achieve strong returns for investors. We believe that high copper prices (relative to history) will be required to attract additional capacity. Otherwise, despite new investment in brownfield and greenfield production, copper supply is likely to struggle to match demand forecasts.

Figure 7 showing the production forecast for 15 top copper producers highlights that five companies will achieve little or no growth in copper production by 2030, and a further five will achieve a CAGR of less than 5% over the period, based on their current project pipeline and announcements. This raises the prospect of M&A activity if they wish to enhance their growth prospects.

Climate Change

As with most other commodities, the second major challenge is climate change. Despite the clear requirement for more copper to meet the world's climate change targets, it could become more challenging to produce refined metal as restrictions on industrial activity tighten.

However, the emissions profile of copper is attractive when benchmarked against other non-ferrous metals, including its closest substitute, aluminium, and may encourage governments to prioritise its development as is happening with many other critical minerals.

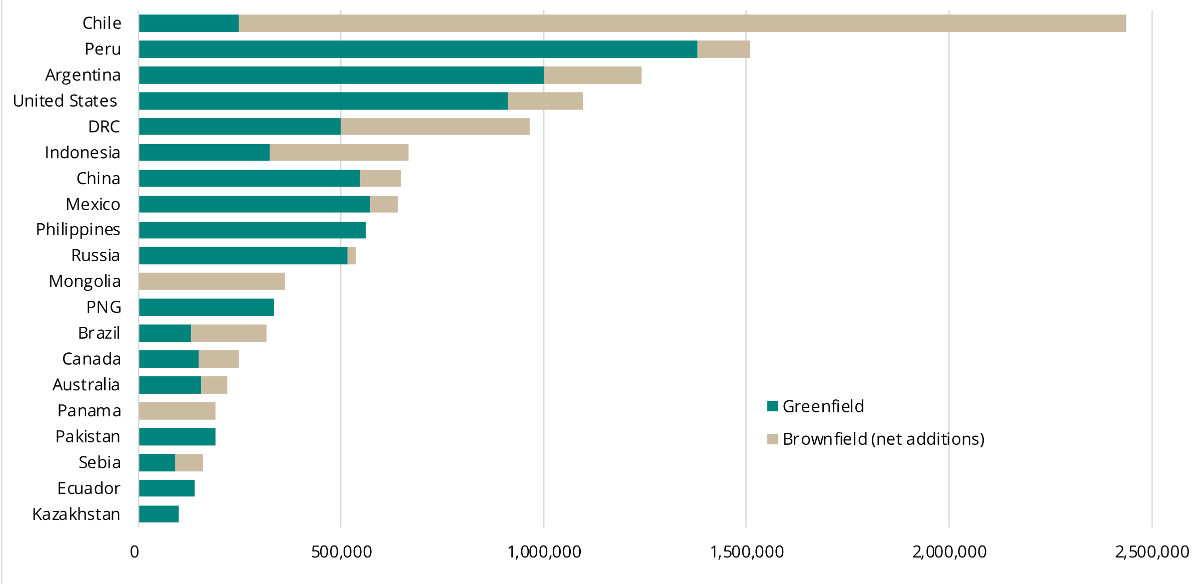
ESG and Political & Regulatory

The final challenges comprise a range of ESG and political issues. These include political and civil unrest, permitting challenges, and power, tailings, and water issues. While these issues relate to the broader industry, they tend to be geographically focused and can also be project specific.

Figure 12 shows the country breakdown of all the projects combined (unadjusted for risk), with a breakdown of greenfield and brownfield capacity increases. The chart highlights the dominance of new capacity coming from South America, while the US and DRC are also potentially large producers.

[2] Southern Copper Feb 2022.

Figure 12. Copper Project Capacity Expansions 2020-2030 (t) by Country



Source: Company reports, RFC Ambrian estimates.

Table 6 shows the Control Risk country ratings for a number of these countries, all with medium to high political, operational and security ratings, except Chile. However, Chile's political risk was recently raised from low to medium with civil protests experienced throughout the country. In addition, the government of Chile is passing a bill for royalty and tax changes that would increase the tax burden specifically for copper producers.

Both Chile and Peru have seen significant civil unrest and labour disruptions in the country due to people seeking social reform. Ecuador and Argentina have also experienced demonstrations, creating an uncertain or unpredictable political and economic environment in Argentina, especially as there is social opposition to mining operations in certain parts of the country.

Over the past few years, political protests in Peru have blocked access to the shipping ports and main transportation routes and has forced the Peruvian government into contentious negotiations over indigenous land rights and environmental concerns.

This unrest has negatively impacted copper production in these countries, and there have been several high-profile protests and blockades aimed against a number of specific mining and exploration projects by local communities. These are having a negative impact on investment sentiment in these regions.

Table 6. Control Risk Country Ratings

Country	Political	Operational	Security	Terrorism
Chile	Medium	Low	Low	Low
Peru	Medium	Medium	Medium	Low
Argentina	Medium	Medium	Low	Low
DRC	High	High	Medium	Low
Indonesia	Medium	Medium	Medium	Medium
Mexico	Medium	Medium	Medium	Low
Philippines	Medium	Medium	Medium	Medium
Mongolia	Medium	Medium	Medium	Nil
PNG	High	High	High	Nil
Brazil	Medium	Medium	Medium	Low

Source: S&P Global Market Intelligence, Control Risk

Figure 13 shows the results of scores for indices that cover issues central to mining companies' social licence to operate calculated by Verisk Maplecroft. The analysis focuses on the nine countries that have witnessed a spike in socio-environmental protests in response to extractive projects in the last 15 years. Indigenous rights are 'high' or 'extreme risk' in every jurisdiction. The combined score reveals that 8 out 9 of the countries are high risk, although as we have highlighted conditions in Chile have since deteriorated.

Figure 13. Issues Central to Mining Companies' Social Licence to Operate

Industry	Aggregate	Corruption	Indigenous Peoples' Rights	Civil Unrest	Security Forces and Human Rights	Labour Rights	Water stress
Peru	High 4.57	High	High	High	Medium	High	Low
Argentina	High 4.41	High	High	High	High	Medium	Medium
Chile	Medium 5.66	Low	High	Medium	Medium	High	Medium
Colombia	High 4.87	High	High	High	High	High	Low
Ecuador	High 3.66	High	High	High	High	High	High
Brazil	High 4.91	High	Extreme	High	High	Medium	Low
Bolivia	High 4.41	High	High	High	High	High	Low
Venezuela	High 3.29	Extreme	High	Extreme	Extreme	High	Low
Mexico	High 3.44	Extreme	High	High	High	High	High

Legend: Extreme risk 0-2.5 High risk >2.5-5 Medium risk >5-7.5 Low risk >7.5-10

Source: Verisk Maplecroft 2019.

Meanwhile, mining companies continue to face increasing levels of regulation and scrutiny to get key mining permits granted. This includes glacier protection legislation which has been enacted and applied in Argentina and is advancing through Congress in Chile.

Water shortages are also a serious problem in many countries. This includes Chile where water is an issue and important to the copper mining industry and where water shortages are already impacting production. Some mining companies in Chile are responding to the social concerns, possible legislative change, and the reality of shrinking freshwater reserves by investing in alternative water sources and efficient water management technologies, principally through desalination.

The combination of these issues suggests that the development of the copper pipeline with 44% of potential copper production coming from South America will not be straightforward, and why there is a lot of scepticism about future copper production in these countries.

Nevertheless, despite the increased risks, delivering new copper capacity in South America is not impossible. In Peru, Anglo American is constructing the large Quellaveco mine and Minsur is commissioning Mina Justa, Oz Minerals and Appian Capital have projects under construction in Brazil, and there are 11 brownfield projects in Chile, with others in Peru and Brazil.

2.2 The Project Specific Challenges

Developing a mining asset, is not straightforward. In addition to the broader risks, it entails multiple industry specific risks. It can take up to 15 years for a company to take a project from first discovery to production; depending on the size, rate of expenditure, and ease of permitting. This would typically be 2-4 years for initial exploration, 2-4 years advanced exploration including drilling and defining reserves, 2-3 years for economic evaluation and obtaining approvals and finance, and 2-4 years for construction.

All the projects in our probable and possible (low risk) categories are at the feasibility or final investment decision (FID) stage, indicating that they could be in production from 2 to 7 years' time, based on the timescale outlined. This means that with eight years remaining until 2030, all these projects have the potential to come on-stream within that timeframe. However, the mining industry has a history of delays for various reasons, and it is inevitable that some projects will fall short of this timescale or not succeed at all.

In today's environment of climate change awareness, it has become essential for copper companies to focus on ESG issues and to minimise their carbon footprint. Much of this reduction in carbon footprint will only be achieved through the implementation of best practice in mine design, which means incorporating new technology and innovative practices into existing mines where possible but particularly into new mine developments. This includes the digitalisation of operations, the use of renewable energy, the electrification of haulage, minimising the mine footprint, ore sorting and beneficiation, and dry tailings stacking. These measures will also increase safety and reduce operating costs.

Table 7. Project IRR and Capital Efficiency

Greenfield Projects	Weighted IRR %	Capital Efficiency
Under Development	41.4	1.20
Probable	26.8	0.47
Possible Lower-Risk	23.8	0.50
Possible Higher-Risk	19.3	0.41
Total	**25.4†**	**0.48**

Source: RFC Ambrian. †Unweighted median IRR = 20.7%.

2.3 Copper Mine Project Returns

Some 68% of the projects in our database have project financial data based on various types of feasibility studies and economic assessments. This data is summarised in Table 7 and helps give an initial benchmark for returns and the potential for development. The numbers are not wholly comparable as the publication dates for the reports span up to nine years and have different price assumptions. Also, returns are likely to be significantly higher at current copper prices.

2.4 Copper Mine Project Risks

Based on these broad range of risks, and project returns data, we have used a 70% risk factor for probable projects and a 50% risk factor for possible projects as shown in Table 3. Wood Mackenzie also uses a 50% discount on its possible projects and assumes a delay in production. For identified probable projects, Wood Mackenzie does not appear to apply a risk factor to the production.

Our scenario excludes all higher-risk possible projects in the calculation (for risk and timing reasons) and we have not added any production for unidentified production (as we noted earlier Wood Mackenzie adds an additional 15% to its numbers).

Source: Andina Division, Codelco

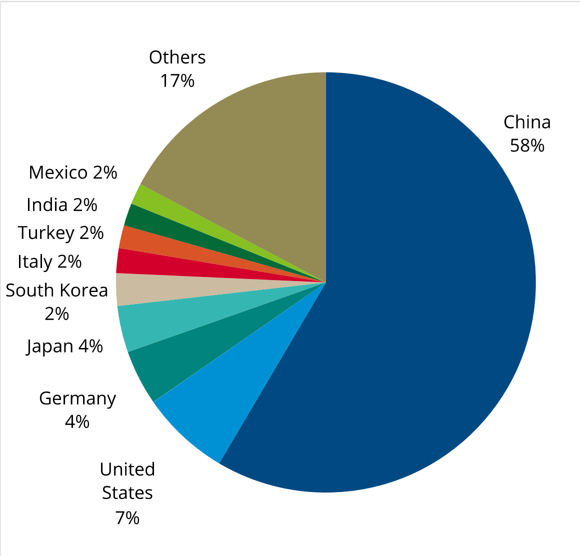
3. Copper Demand Analysis

Copper is used widely in a broad range of industries due to its high electrical and thermal conductivity, ductility, and corrosion resistance. Key copper-consuming industries include construction, electrical and electronic equipment manufacturing, power industry, transport, mechanical engineering, various equipment, and consumer goods production. Over 60% of refined copper produced globally is used in electrical conductors, including various types of cable and wire.

3.1 Copper Consumption by Region

Refined copper consumption totalled 24.8 Mt in 2020, an annual increase of 3.5%. The largest copper consumer globally is China, accounting for 14.5 Mt in 2020, equivalent to 59% of the total. Figure 14 shows the top copper consumers in 2020.

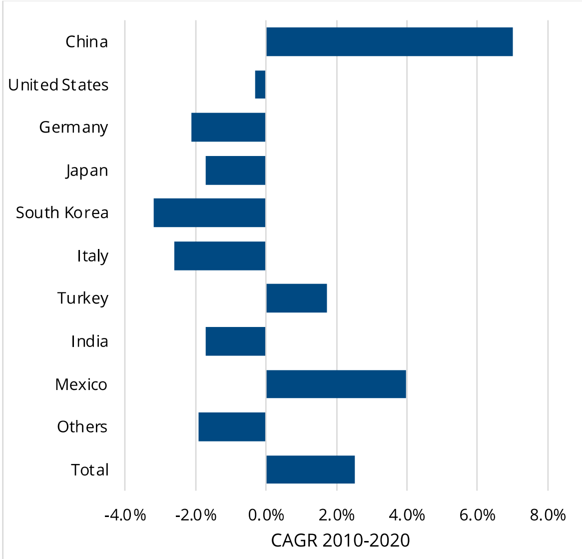
Figure 14. Refined Copper Consumption 2020



Source: World Bank Oct 21.

Copper consumption in China has risen by a CAGR of 7.0% from 2010 to 2020. Copper consumption also increased in some other developing countries such as Mexico (+4.0% CAGR) and Turkey (+1.7%), however, copper consumption in most other major economies has been falling as shown in Figure 15. Over the period 2010 to 2020, consumption in the Unites States declined by a CAGR of 0.3%, Germany by 2.1%, Japan by 1.7% and South Korea by 3.2%. However, the stagnation and decline of copper intensity has been apparent for decades.

Figure 15. Refined Demand CAGR 2010-2020



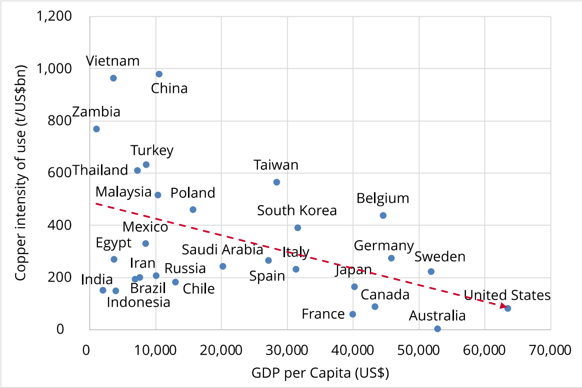
Source: World Bank Oct 21.

Copper consumption has been declining in mature economies mainly due to declining investment in infrastructure, reduced intensity of use, and substitution. Other factors include manufacturing offshoring (to China), a slowing in real estate construction, and trends of dematerialization.

A recent paper looking at forecasting US copper demand[3] concluded that US copper demand would gradually drop from the baseline level of 240 kg/person to its minimum value of 227 kg around 2032 before peaking at 243 kg in 2070 because of growth in some end-use sectors and shrinkage in the others. This 1.0% increase from 2015 to 2070 is small compared to an expected per capita GDP growth of about 100% during the same time span.

[3] Forecast of the U.S. Copper Demand: A Framework Based on Scenario Analysis and Stock Dynamics, Rui He and Mitchell J. Small, Jan 2022

Figure 16. Refined Copper Intensity of Use 2020



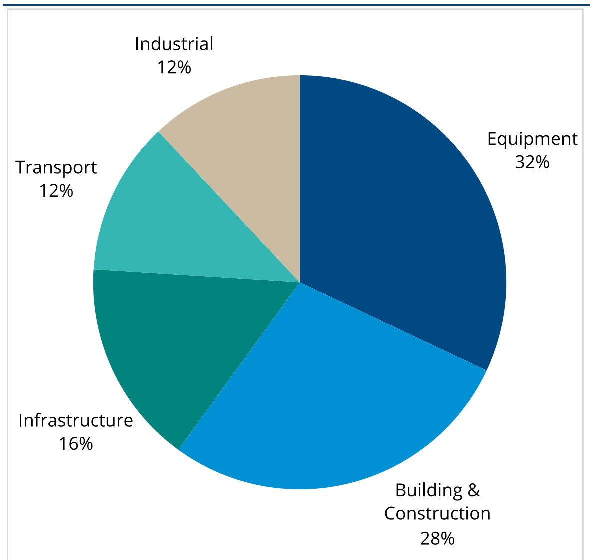
Source: ICSG, IMF

The intensity of refined copper use per US dollar of GDP in Figure 16 illustrates how intensity of use declines as economies mature.

Substitution is a relatively significant issue in terms of reducing overall consumption. In 2021 it was 1.3% of global use, according to the latest research by the International Copper Association (ICA) and is driven by relative material cost.

Most copper substitution over the recent years has been centred on power cables, winding wires in transformers, and alloys and involves substitution with aluminium. Copper is expected to continue experiencing substitution pressures, particularly at higher prices (absolute and relative to aluminium).

Figure 17. Copper Consumption by Industry

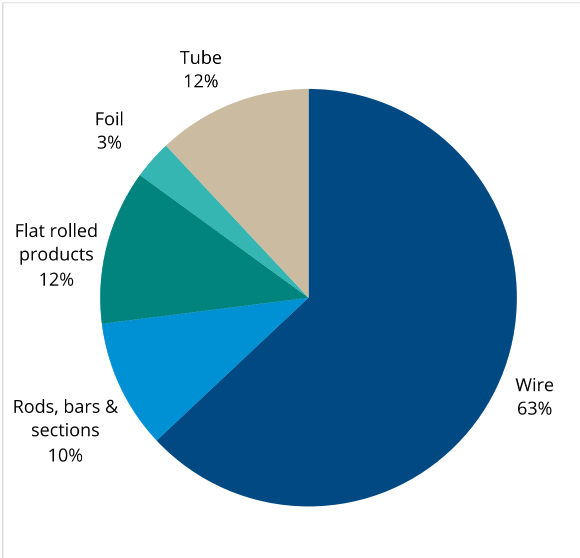


Source: ICSG.

3.2 Copper Consumption by Use

Analysing copper and copper alloys semis consumption by use is difficult due to the lack of detail available. The main two breakdowns available are consumption by industry, shown in Figure 17, and consumption by product, shown in Figure 18. There is limited further information about the composition of each industry which makes detailed analysis difficult.

Figure 18. Copper Consumption by Product



Source: ICSG.

3.3 The Broad Outlook for Future Demand

As a longer-term benchmark, Figure 19 shows refined copper consumption growth from 1970 to 2020 by country. This period includes a significant increase in consumption from China due to the expansion of the Chinese economy. **The overall demand CAGR from 2070 to 2020 was 2.5% and over the past decade has also been 2.5%**.

Generally, it is hard to find the assumptions and a breakdown of demand growth given by commodity specialists in the copper market. Table 8 shows projections for copper demand growth from 2020 to 2030 from a number of commodity specialists. These are not all on the same basis (some based on different periods) but give an indication of the broad range of forecasts for copper demand growth currently in the market.

Table 8. Indicative Copper Demand Forecasts

Forecast (Mt)	2020	2030	Chng	CAGR
Goldman Sachs[1]	23.5	33.7	10.2	3.7%
Citigroup[2]	23.9	32.5	8.6	3.1%
Wood Mackenzie[3]	-	-	-	2.0%
IEA (SDS)[4]	24.0	30.4	6.35	2.4%
S&P Global[5]	24.7	-	-	3.4%

Source: Company reports. 1. Copper is the New Oil April 2021. 2. Copper Book, Oct 2021. 3. Base case on 20-year reported CAGR, Mar 2021. 4. The Role of Critical Minerals in Clean Energy Transitions, May 2021. 5. CAGR for forecast to 2026, Mar 2022.

There are five key market drivers for copper demand:

- Population growth and consumer trends.
- Industrial production.
- Fiscal and monetary stimulus.
- Technology innovation and adoption.
- Decarbonisation of the global economy.

China's copper consumption growth in the coming decade will continue to be a major determinant of overall global copper consumption, but an area of significant growth for copper over the next decade will be increased demand for the decarbonisation of energy. Copper plays a central role across every stage of this by enabling renewable energy generation technologies, implementation of EV battery technology, and connection to grid infrastructure. Furthermore, renewable power generation sources and cleaner transportation vehicles are more copper intensive compared to their conventional counterparts.

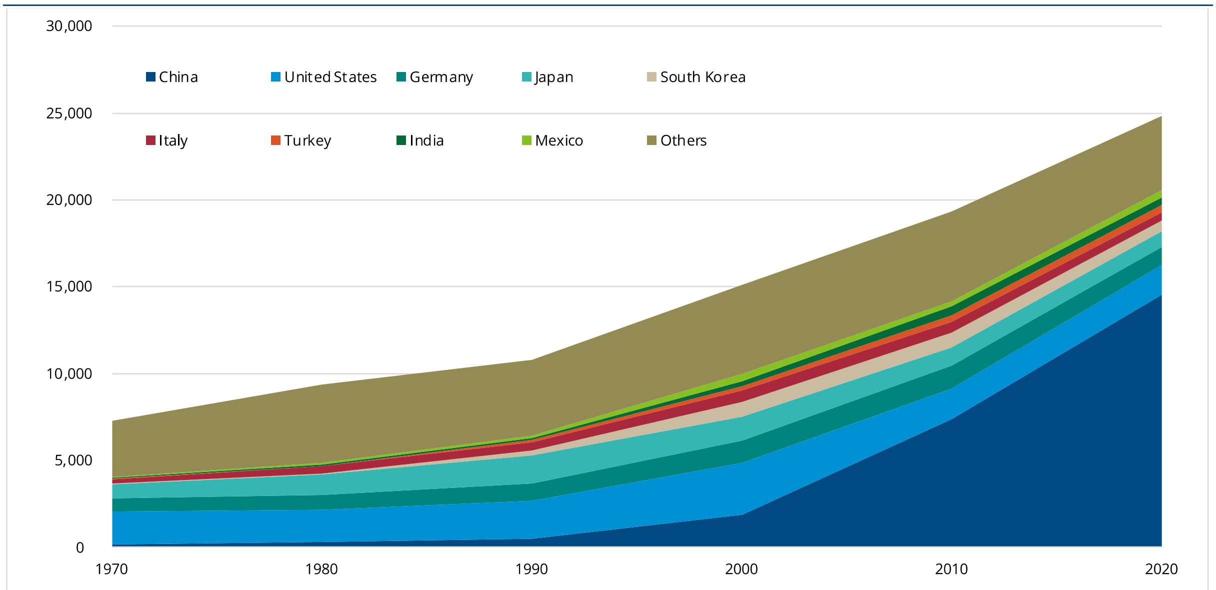
3.4 Electric Vehicle Copper Consumption

The largest opportunity for demand increases for copper comes from increased energy efficiency in the transportation sector, driven by the growth in the growth in use of lithium-ion batteries in electric vehicles (EVs).

In today's internal combustion engine (ICE) autos most of the contained copper is in the wiring loom. The starter and alternator are the next largest contributors as shown in Figure 20. The standard assumption has been that a passenger battery electric vehicle (BEV) is nearly four times more copper intensive than an ICE auto. This is based on a report commissioned in 2017 by the International Copper Association (ICA) with the results shown in Table 9. Calculations in the market are based largely off this assumption.

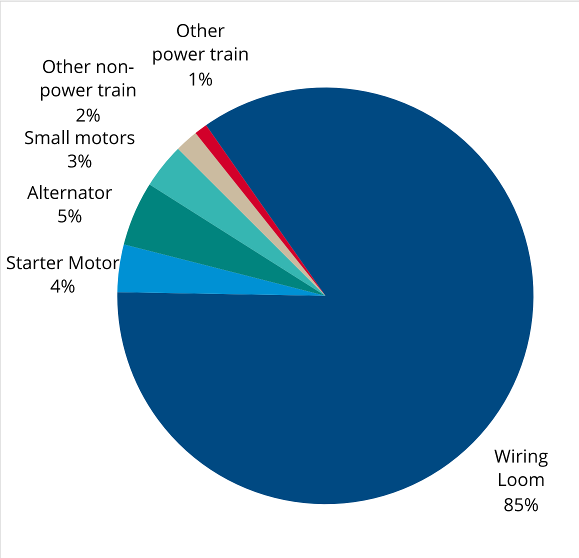
However, in March 2022, the ICA released a new report it commissioned on automotive copper demand, carried out by IDTechEx. The report primarily focused on the outlook to 2040, but the conclusions should lead analysts to reduce their EV copper demand outlook somewhat.

Figure 19. Refined Copper Consumption 2010-2020



Source: World Bank.

Figure 20. ICE Copper Content (29.4 kg)



Source: ICSG, IDTechEx

Table 9 shows that ICE autos now have an average of 29.4 kg per vehicle, an increase of 31%. However, while appearing positive, this is now the base to use for comparison going forward and does not alter historic demand numbers. This means that the increase in copper content for a BEV is now only 2.8x (using 83 kg for a BEV). However, the BEV copper content number is also likely too high because battery and EV construction are improving and increasing the efficiency of copper use.

Table 9. Copper Used in Autos (Cu/vehicle)

Vehicle	2017 Report		2022 Report‡	
	lbs	kg	lbs	kg
ICE autos	18-49	8.2-22.2	65	29.4
HEV	85	38.6	-	-
PHEV	132	59.9	-	-
BEV	183	83.0	149	67.7

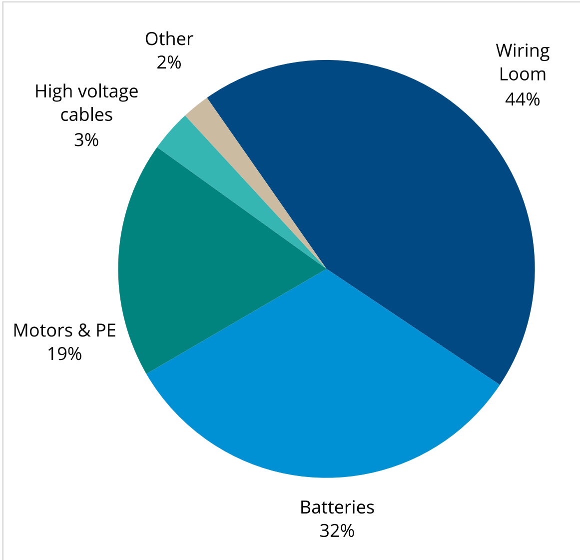
Source: IDA, ICA, IDTechEx. ‡ Excludes copper for autonomous use.

No figure was reported for 2030 in the latest report, but a figure of 72 kg was given for 2040, although this includes 4.3 kg of copper use for autonomous systems which are unlikely to be widely implemented before 2030. This still suggests a likely steady decline in copper consumption per vehicle for BEVs over the period. Citigroup expects the copper content for BEVs to decline to 60 kg/vehicle by 2030.

Using a value of 29.4 kg for an ICE in 2020 and about 68 kg for a BEV in 2030 would mean that a passenger BEV is only just over twice as copper intensive than an existing ICE auto.

Figure 21 shows the forecast copper content for a BEV by 2040 (excluding autonomous equipment), according to the latest report by the ICA. After the wire loom, a large part of the copper within a passenger BEV is used within the battery in the form of copper foil.

Figure 21. Forecast BEV Copper Content (67.7 kg)



Source: ICSG, IDTechEx

Table 10 shows the forecasts for the increase in copper consumption in EVs from 2020 to 2030 by a number of commodity specialists. These forecasts include assumptions about the penetration of EVs by 2030, the decline in ICE autos, and the ongoing growth of auto demand over that period. Citigroup notes that a 1% change in the gross passenger vehicle market matters more than a 10% change in EV penetration.

Table 10. Indicative EV Demand Forecasts (Mt)

Forecast (Mt)	2020	2030	Chng	CAGR
Goldman Sachs	0.210	3.044	2.834	30.7%
Citigroup	0.222	2.304	2.080	26.3%
IEA (SDS)	0.114	1.263	1.149	27.2%

Source: Company reports.

3.5 Solar PV Copper Consumption

Worldwide solar PV capacity has increased by almost 20 times over the past decade, spurred by declining costs and strong policy support in key regions. The IEA reports that with sharp cost reductions over the past decade, solar PV now offers some of the lowest electricity costs in most countries, cheaper than new coal- or gas-fired power plants. Copper is used in interconnectors, wiring and inverters.

With continued growth in construction of solar PV, copper consumption in solar PV is expected to be strong. Table 11 shows the forecasts for the increase in copper consumption in solar PV from 2020 to 2030 by a number of commodity specialists. These forecasts are based on assumptions about the growth and efficiency of solar PV out to 2030.

3.6 Wind Energy Copper Consumption

Global installed capacity of wind power has nearly quadrupled over the past decade, spurred by falling costs, which have declined by about 40% on average globally, and policy support in more than 130 countries according to the IEA.

Wind power is expected to continue growing strongly, with the offshore wind industry maturing and adding to developments in onshore wind on the back of technology improvements and low-cost financing, with particularly strong growth in Southeast Asia, India, Latin America, and the Middle East.

3.7 Other Renewable Copper Consumption

In addition, to copper demand coming from Solar PV and Wind, demand is also expected from other renewable areas including charging infrastructure, storage, and other expansions of the electricity grid.

3.8 Total Renewable Energy Demand

Table 11 shows that despite slightly different assumptions for renewable energy demand for copper, the overall increase is similar. **For this scenario, we have used an increase of 4.55 Mt from 2020 to 2030 for renewable energy demand, based on the average from Table 11 and have not made any changes for reduced BEV copper intensity. However, given the risks to copper intensity in BEVs, we believe there are downside risks to this number going forward.**

3.9 Non-renewable Copper Demand

The new demand for renewable energy can be estimated from assumptions about volumes and copper intensity, however, the demand growth for the balance of copper demand is more difficult to calculate. The decline in ICE autos can be forecast under given assumptions but is included in the EV calculations of the commodity specialists, however, the offsetting negative demand effect on conventional energy from renewables is more difficult to forecast. The three commodity specialists have a range of 0.9% to 2.4% for demand growth of the balance of non-renewable demand. For this scenario, we have used 2.0%, compared with an historic average of 2.5%.

Table 11. Indicative Renewable Energy Contributions to Copper Demand 2020-2030 (Mt)

Renewable Energy	IEA (SDS scenario)				Goldman Sachs				Citigroup			
	2020	2030	Chng	CAGR	2020	2030	Chng	CAGR	2020	2030	Chng	CAGR
EVs	0.11	1.26	1.14	27.2%	0.21	3.04	2.83	30.7%	0.22	2.30	2.08	26.3%
Solar PV	0.34	0.93	0.59	10.6%	0.38	1.09	0.72	11.2%				
Wind Energy	0.22	0.57	0.35	10.0%	0.40	0.81	0.41	7.4%	1.26	3.47	2.21	10.6%
Power Grid	4.92	7.37	2.45	4.1%	-	-	-	-				
Charging Infrastructure	-	-	-	-	0.01	0.18	0.17	29.1%	0.01	0.16	0.16	41.4%
Storage	0.01	0.09	0.09	32.5%	0.01	0.08	0.07	22.3%	0.02	0.42	0.39	33.6%
Renewable Demand	5.60	10.22	4.62	6.2%	1.01	5.20	4.20	17.8%	1.51	6.35	4.84	15.4%
Other Copper Demand	18.40	20.13	1.72	0.9%	22.53	28.50	5.97	2.4%	22.40	26.17	3.77	1.6%
Total Copper Demand	24.00	30.35	6.35	2.4%	23.54	33.70	10.17	3.7%	23.92	32.53	8.61	3.1%

Source: Company Reports.

3.10 Total Forecast Demand in 2030

The sensitivity of the CAGR of the non-renewable copper demand, also depends on the assumption of the base level (2020) of renewable demand within the total demand. The three commodity specialists in Table 11 have a wide range of assumptions, but we have used 1.0 Mt for this scenario.

The sensitivity of the total demand is shown in Table 12, varying the increase in renewable demand and the growth CAGR of the non-renewable demand from 2020-2030.

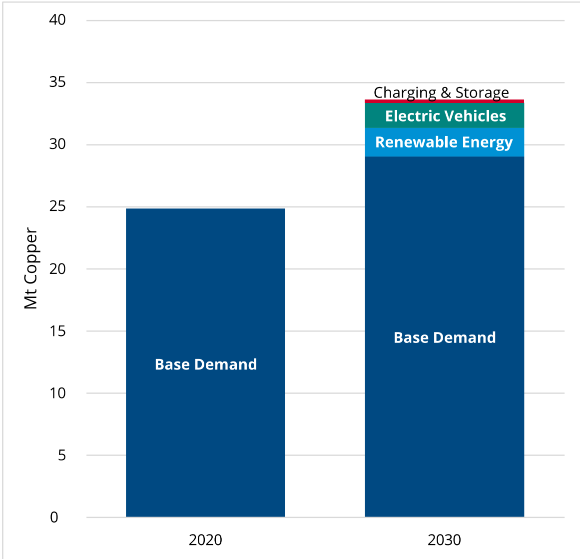
Table 12. Overall Demand Sensitivity (Mt)

	Renewable Demand Increase Mt				
	3.50	4.00	4.55	5.00	5.50
Other CAGR					
1.0%	29.8	30.3	30.9	31.3	31.8
1.5%	31.2	31.7	32.4	32.7	33.2
2.0%	32.6	33.1	33.6	34.1	34.6
2.5%	34.0	34.5	35.1	35.5	36.0
3.0%	35.5	36.0	36.6	37.0	37.5

Source: RFC Ambrian.

Based on our scenario, the increased demand for renewables combined with the increase in demand for ongoing copper consumption, suggests **total refined copper demand of about 33.6 Mt in 2030, equivalent to a CAGR of 3.1%.** Figure 22 shows the change in forecast copper demand from 2020 to 2030 based on these assumptions.

Figure 22. Change in Copper Demand 2020-2030



Source: Company reports, RFC Ambrian.

Source: International Copper Association.

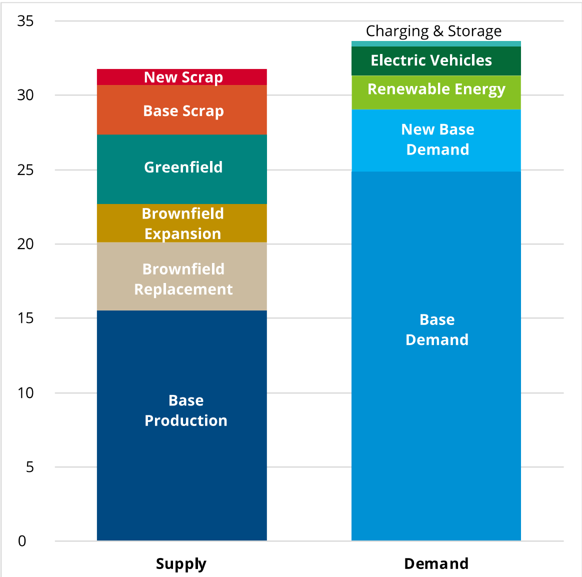
4. Copper Market Balance

4.1 Overall Market Balance

Refined copper production is forecast to be 31.7Mt in 2030, under the copper supply scenario calculated in this report. Refined copper consumption, largely using consensus market demand forecasts, is expected to be about 33.6 Mt in 2030.

This suggests a market deficit of about 1.9 Mt in 2030. While the assumptions in this report are open to debate, we believe they are not unreasonable, however, the resultant deficit is materially different to that assumed by general market consensus.

Figure 23. Copper Market Balance 2030F



Source: RFC Ambrian. NB. Base Production after closures.

The overall balance comprises a large number of assumptions and so it is worth analysing some of the sensitivities within the scenario. Table 12 shows how a 10% positive change for a range of assumptions would reduce the market deficit. A move in the opposite direction would have a negative effect on the balance. If all the factors moved in the same direction by 10% to positively improve the deficit, the change would total 2.3 Mt. Similarly, moving in the same direction negatively would increase the deficit by 2.3 Mt.

Of these sensitivity factors, Table 13 shows that the scrap ratio, the increase in demand from renewable energy, and the non-renewable demand CAGR from 2020-2030 are the most sensitive factors on the overall scenario we have presented. The risk factors used for new mine production are important but are less sensitive to a 10% change.

Table 13. Supply/Demand Sensitivity (10% chng)

Assumption 2020-2030	Original Value	Revised Value	Impact Mt
Probable risk	70.0%	77.0%	0.181
Possible risk	50.0%	55.0%	0.141
Non-T15 new capacity of T15	70.0%	77.0%	0.236
Non-T15 closure rate	7.2%	6.5%	0.074
Disruption allowance	10.0%	9.0%	0.070
Scrap ratio	16.0%	17.6%	0.438
Renewable energy 2020	1.0 Mt	1.10 Mt	0.117
Renewable energy demand	4.55 Mt	4.10 Mt	0.450
Non-renewable demand CAGR	2.0%	1.8%	0.565

Source: RFC Ambrian. T15 = 15 top companies

4.2 Conclusion

This report highlights the many uncertainties and risks surrounding the outlook for copper in 2030, however, the scenario analysis suggests that the market deficit may not be as large as the current perception in the market. Nevertheless, the deficit still looks to be significant at this stage.

The implications are that high copper prices (relative to history) are likely to continue and will need to be high enough to encourage additional new greenfield capacity or brownfield expansions to come on stream.

It also appears that some major copper producers currently have limited growth opportunities and may need to turn to M&A to grow their copper businesses.

Source: Zaldivar, Antofagasta.

Appendix 1 – Greenfield Copper Projects

The production figures in the following tables represents the expected greenfield additions to supply over the period 2020 to 2030. This is particularly relevant in Table 14 where some of the projects had already started production in 2020.

Table 14. Copper Projects Under Development 2020-2030

	Project	Country	Owner/Operating Company	Project Stage	Prodn kt/y	Resource Cu Mt	Grade % Cu
1	Quellaveco	Peru	Anglo American	Constr. Started	300,000	13.61	0.46%
2	Kamoa-Kakula	DRC	Ivanhoe Mines	Operating	284,000	11.34	4.63%
3	Qulong	China	Zijin Mining Group	Operating	160,000	4.21	0.39%
4	Udokan	Russia	Metalloinvest	Constr. Started	135,000	26.70	0.97%
5	Mina Justa	Peru	Minsur SA	Commissioning	92,000	3.25	0.75%
6	Timok (Čukaru Peki)	Serbia	Zijin Mining Group	Operating	91,000	0.89	3.28%
7	Tominskoye	Russia	Russian Copper	Preproduction	81,000	1.58	0.37%
8	Khoemacau	Botswana	Cupric Canyon Capital	Operating	62,596	6.30	1.66%
9	Gunnison	USA	Excelsior Mining	Operating	56,700	2.90	0.28%
10	Xietongmen	China	Jinchuan Group	Constr. Started	50,000	2.91	0.34%
11	Pumpi	DRC	Wanboa Mining	Operating	45,000	1.24	-
12	Pumpkin Hollow	USA	Nevada Copper	Operating	40,000	3.33	0.55%
13	Florence	USA	Taseko Mines	Limited Prodn	38,555	1.42	0.32%
14	Pilares	Mexico	Southern Copper	Constr. Started	35,000	0.32	0.70%
15	Musonoi	DRC	Jinchuan Group	Constr. Started	34,500	1.09	2.40%
16	Dar Alou	Iran	National Iranian Copper	Constr. Started	32,500	0.67	0.36%
17	Aljustrel	Portugal	I'M SGPS SA	Operating	32,000	-	-
18	Tshukudu/Motheo	Botswana	Sandfire Resources	Constr. Started	30,000	0.75	1.25%
19	Kambove	DRC	China Nonferrous	Constr. Started	28,000	0.40	2.63%
20	Pedra Branca	Brazil	OZ Minerals	Commissioning	24,000	0.30	1.58%
21	Serrote	Brazil	Appian Capital	Constr. Started	20,000	0.31	0.59%
22	Kombat	Namibia	Trigon Metals	Operating	14,500	0.28	1.98%
23	Al Hadeetha	Oman	Alara Resources	Constr. Started	7,699	0.14	0.86%
	Total				**1,694,050**		

Source: RFC Ambrian, S&P Global Market Intelligence, company data.

Table 15. Probable Copper Projects 2020-2030

	Project	Country	Owner/Operating Company	Project Stage	Prodn kt/y	Resource Cu Mt	Grade % Cu
1	Michiquillay	Peru	Southern Copper	Feasibility	225,000	7.25	0.63%
2	El Arco	Mexico	Southern Copper	Feas. Complete	190,000	10.73	0.40%
3	Los Chancas	Peru	Southern Copper	Feasibility	150,000	3.86	0.53%
4	Josemaria	Argentina	Josemaria Resources	Feas. Complete	131,000	4.67	0.25%
5	Tia Maria	Peru	Southern Copper	Constr. Planned	120,000	2.62	0.35%
6	Resolution	USA	Rio Tinto	Preproduction	120,000	27.30	1.53%
7	Zafranal	Peru	Teck Resources	Feas. Complete	75,000	1.83	0.36%
8	Upper Kobuk	USA	Trilogy Metals	Feas. Complete	70,300	4.01	1.79%
9	Costa Fuego	Chile	Hot Chili	Commissioning	66,000	2.88	0.40%
10	Santo Domingo	Chile	Capstone Mining	Constr. Planned	63,500	1.72	0.29%
11	Alemao	Brazil	Vale SA	Prefeas./Scoping	60,000	2.09	1.30%
12	Eva	Australia	Copper Mountain	Constr. Planned	45,000	1.45	0.43%
13	Magistral	Peru	Nexa Resources	Feas. Started	40,500	0.95	0.47%
14	Tizert	Morocco	Managem SA	Feas. Started	40,000	0.73	-
15	El Pilar	Mexico	Southern Copper	Constr. Planned	35,000	0.85	0.30%
16	Kambove	DRC	China Nonferrous	Constr. Started	28,000	0.40	2.63%
17	NorthMet	USA	PolyMet Mining	Constr. Planned	24,853	2.81	0.25%
18	Black Butte	USA	Sandfire Resources	Feas. Complete	23,000	0.59	2.69%
19	Buenavista	Mexico	Southern Copper	Preproduction	20,000	0.48	0.47%
20	Victoria	Canada	KGHM International	Constr. Planned	18,000	0.35	2.60%
21	Silangan	Philippines	Philex Mining	Feas. Complete	15,000	3.24	0.48%
22	Horne 5	Canada	Falco Resources	Constr. Planned	8,000	0.22	0.17%
23	Platreef	South Africa	Ivanhoe Mines	Feas. Complete.	5,900	1.36	0.16%
	Total				**1,574,053**		

Source: RFC Ambrian, S&P Global Market Intelligence, company data.

Table 16. Possible Lower-Risk Copper Projects 2020-2030

	Project	Country	Owner/Operating Company	Project Stage	Prodn kt/y	Resource Cu Mt	Grade % Cu
1	El Pachon	Argentina	Glencore	Feasibility	400,000	15.46	0.47%
2	Hu'u	Indonesia	Vale SA	Pre-feasibility	325,000	-	-
3	Baimskaya	Russia	Nova Resources	Feas. Complete	300,000	9.80	0.39%
4	NuevaUnion	Chile	Teck Resources	Feasibility Started	190,000	16.60	0.37%
5	Wafi-Golpu	PNG	Newcrest Mining	Feas. Complete	160,000	8.65	0.86%
6	Cascabel	Ecuador	SolGold	Prefeas/Scoping	139,000	12.25	0.34%
7	Vizcachitas	Chile	Los Andes Copper	Prefeas/Scoping	111,000	7.74	0.37%
8	Rosemont	USA	Hudbay Minerals	Feas. Complete	101,605	5.62	0.36%
9	Casino	Canada	Western Copper	Constr. Planned	77,000	4.92	0.13%
10	Quebradona	Colombia	AngloGold Ashanti	Feasibility	61,235	4.41	0.73%
11	Marimaca	Chile	Marimaca Copper	Feas. Complete	36,000	0.64	0.57%
12	Hillside	Australia	Rex Minerals	Feas. Complete	35,000	1.97	0.58%
13	Kalongwe	DRC	Chengtun Mining	Feas. Complete	30,000	0.30	2.70%
14	Viscaria	Sweden	Copperstone Res.	Feasibility Started	30,000	0.73	0.98%
15	Copperwood	USA	Highland Copper	Constr. Planned	28,000	1.36	1.35%
16	Boa Esperanza	Brazil	Ero Copper	Constr. Planned	27,200	0.50	0.85%
17	Prieska	South Africa	Orion Minerals	Feas. Complete	22,000	0.36	1.18%
18	Antilla	Peru	Heeney Capital	Prefeas/Scoping	20,865	1.23	0.32%
19	Angangueo	Mexico	Southern Copper	Constr. Planned	19,500	0.09	1.44%
20	Mabilo	Philippines	Mt Labo Expl. & Dev.	Constr. Planned	18,000	0.23	1.78%
21	Sulphur Springs	Australia	Develop Global	Feas. Complete	14,000	0.23	1.32%
22	Cerro del Gallo	Mexico	Argonaut Gold	Constr. Planned	2,250	0.19	0.09%
	Total				**2,147,655**		

Source: RFC Ambrian, S&P Global Market Intelligence, company data.

Table 17. **Possible Higher-Risk/Longer Dated Copper Projects**

	Project	Country	Owner/Operating Company	Project Stage	Prodn kt/y	Resource Cu Mt	Grade % Cu
1	Tampakan	Philippines	Indophil Resources	Feasibility	375,000	15.25	0.52%
2	Taca Taca	Argentina	First Quantum	Feasibility	250,000	11.66	0.40%
3	Haquira	Peru	First Quantum	Prefeas/Scoping	193,000	6.30	0.45%
4	Reko Diq	Pakistan	Tethyan Copper	Feas. Complete	190,000	24.35	0.41%
5	Frieda River	PNG	PanAust	Feas. Complete	175,000	12.60	0.46%
6	Los Azules	Argentina	McEwen Mining	Prefeas/Scoping	153,000	13.39	0.37%
7	Pebble	USA	Northern Dynasty	Prefeas/Scoping	145,000	36.95	0.34%
8	Santo Tomas	Mexico	Oroco Resource	Target Outline	125,000	-	-
9	Canariaco Norte	Peru	Candente Copper	Feasibility Started	119,000	6.43	0.34%
10	Mason Valley	USA	Hudbay Minerals	Target Outline	112,000	-	-
11	Koksay	Kazakhstan	Nova Resources	Feasibility Started	100,000	3.82	0.43%
12	La Verde	Mexico	Solaris Resources	Prefeas/Scoping	92,000	2.91	0.39%
13	Mankayan	Philippines	Mining and Minerals	Prefeas/Scoping	90,000	1.03	0.46%
14	Sakatti	Finland	Anglo American	Reserves Dev.	90,000	0.85	1.90%
15	Filo del Sol	Argentina	Filo Mining	Prefeas/Scoping	67,000	1.89	0.31%
16	Maturi	USA	Antofagasta	Prefeas/Scoping	65,000	11.68	0.53%
17	Kingking	Philippines	St. Augustine Gold	Feasibility Started	64,000	2.89	0.24%
18	Caravel	Australia	Caravel Minerals	Feasibility Started	61,000	2.84	0.24%
19	San Nicolas	Mexico	Teck Resources	Feasibility Started	52,920	1.32	1.13%
20	Escalones	Chile	World Copper	Prefeas/Scoping	52,089	1.56	0.37%
21	Mutoshi	DRC	Chemaf SPRL	Constr. Started	50,000	-	-
22	Cotabambas	Peru	Panoro Minerals	Prefeas/Scoping	44,000	2.38	0.33%
23	White Pine	USA	Highland Copper	Prefeas/Scoping	40,000	2.43	1.06%
24	Tovaku	Chile	Soc. Punta del Cobre	Prefeas/Scoping	40,000	1.29	0.19%
25	Haib	Namibia	Deep-South Res.	Prefeas/Scoping	35,000	2.41	0.30%
26	Morrison	Canada	Pacific Booker Min.	Feas. Complete	29,600	1.76	0.63%
27	El Espino-Venus	Chile	Soc. Punta del Cobre	Prefeas/Scoping	26,000	0.71	0.53%
28	Copper Flat	USA	THEMAC Resources	Feas. Complete	25,000	0.69	0.23%
29	Zonia	USA	World Copper	Prefeas/Scoping	22,200	0.30	0.32%
30	McIlvenna Bay	Canada	Foran Mining	Feas. Complete	17,690	0.52	1.17%
31	Skouries	Greece	Eldorado Gold	Constr. Started	3,200	1.40	0.45%
	Total				**2,903,699**		

Source: RFC Ambrian, S&P Global Market Intelligence, company data.

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