Note: The following is a redacted version of the original report published April 28, 2022 [28 pgs].

Green Metals

Nickel's class divide

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Where ESG and energy security collide. At the beginning of the year, nickel's place within green metals was as a key competitor in the race for mineral dominance of energy storage. Now, it sits at the intersection of Europe's push for decarbonisation and energy independence. At the heart of Europe's strategy lies its desire to rapidly electrify its transportation sector - a source of 20% of its emissions and c.2mb/d of Russian oil imports. With Europe's domestic EV sector already favouring nickel-based batteries, nickel is set to benefit the most from politically motivated demand accelerating already rapid growth in nickel battery use.

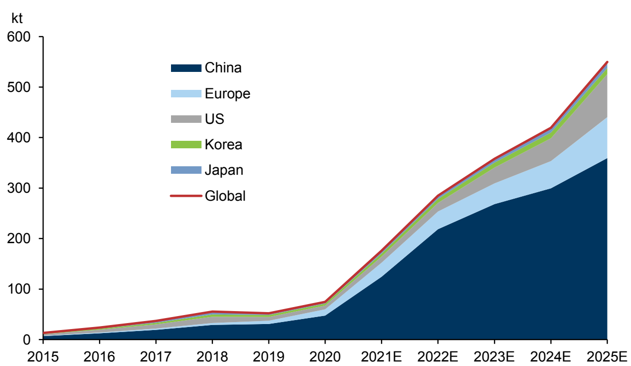
Nickel's bull market is already here. Unlike copper and aluminium – both of which face green demand driven super cycles in coming years – extreme tightness and rapidly rising prices in the nickel market are already here. Even with the most expedient short cycle supply solution, the battery grade nickel market will continue to face extreme tightness this year (196kt deficit), on our estimates. Accelerated by Russia supply risk and some positioning extremes, prices moved rapidly higher early in the year. However, with inventories already at low levels, the time frame for resolution suggests that a near depletion in class 1 stock is likely to occur over the next 2-3 quarters before an eventual softening turn. We see further substantial upside to the LME nickel price over the next 12 months, and upgrade our 12m price forecast to $42,000/t (vs. $24,000/t previously) implying 25% upside.

No short-cuts from scarcity. Some market participants expect nickel's tightness to be solved using a chemical short-cut and pre-existing supply capacity, converting low-purity class 2 nickel – used in stainless steel – to the high-purity class 1 nickel required for batteries. While it is possible to produce class 1 nickel from class 2, we believe it is insufficient to meet the long-run demand for battery grade metal and will not be fast enough to resolve the state of extreme depletion in the nickel market today. Even if conversion capabilities were expanded, the very high carbon intensity of this production path limits its sustained role as a supply solution for green conscious consumers. Should prices rise to our 12m target, there would likely be higher demand destruction and supply substitution in the stainless steel sector. Accordingly, we do not believe nickel can sustain prices at such levels in the long run. However, given the persistent tightness in the forward balances and lack of class 1 supply in the pipeline to resolve this, even after a fade from peak we see a higher sustained price environment for nickel through the next 2-3 years.

Nickel still faces raw material competition. Unlike copper's key role in the green transition, nickel's long-run battery-metal dominance is far from assured. While the next two years of expected demand growth is effectively locked in given prior investments, beyond that a shift in technology, policy or first-mover advantage in battery adoption by EV OEMs leaves nickel facing a riskier demand path. Indeed, there is already momentum behind nickel-free lithium iron phosphate batteries (LFP). China has led the way in this preference but now some Western auto manufacturers such as Tesla are also showing increased appetite for non-nickel technology. With lower cost, no cobalt-related ESG risks and an improving energy density, LPF batteries could continue to extend their market share. This would radically transform the shape of forward balances. Under our base case, the nickel market will be in a substantial 833kt deficit by 2030. However, the sufficient long-term supply options and demand substitutes leave the range of outcomes wide at this point.

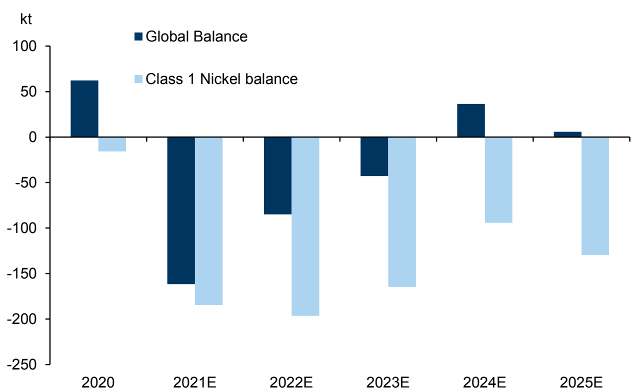
Nickel's class divide in 12 charts

Exhibit 1: Demand for battery grade nickel is surging
EV nickel battery demand, by country of battery production



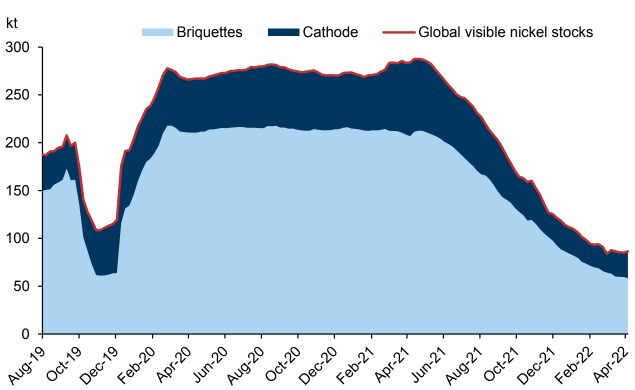
Source: Goldman Sachs Global Investment Research, BNEF, ANL

Exhibit 2: Deficit in class 1 battery grade nickel is set to continue on an open ended basis



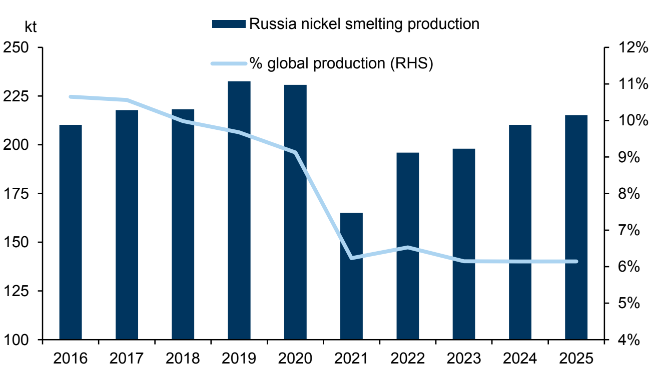
Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 3: There isn't enough visible stock left to solve class 1 shortfall even this year



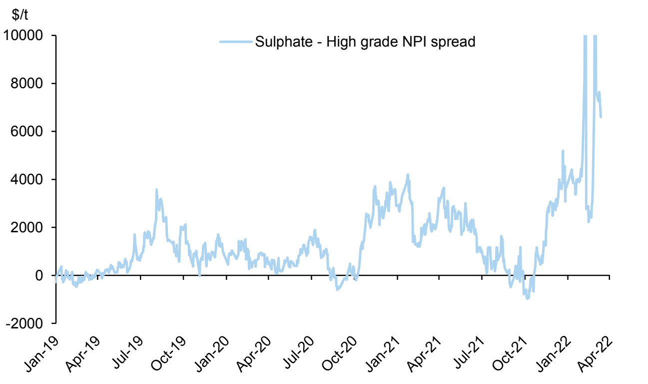
Source: Bloomberg, Goldman Sachs Global Investment Research

Exhibit 4: Russian supply risk is also substantial at this point



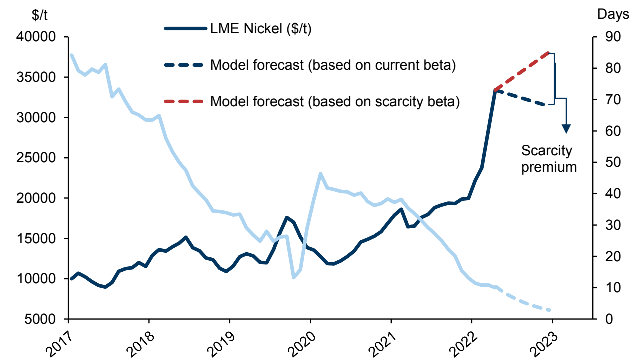
Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 5: Widening in NPI-sulphate price spread needs to be sustained to support conversion investments



Source: SMM, Goldman Sachs Global Investment Research

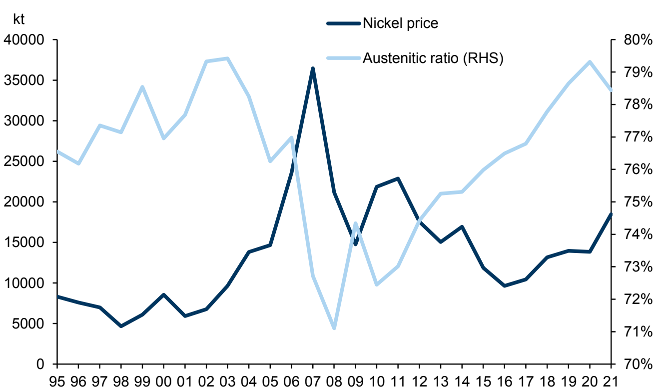
Exhibit 6: As the market faces a complete stock-out, price should rally over the remainder of this year



We exclude the monthly average from month of Mar-22 when the LME contract was temporarily suspended.

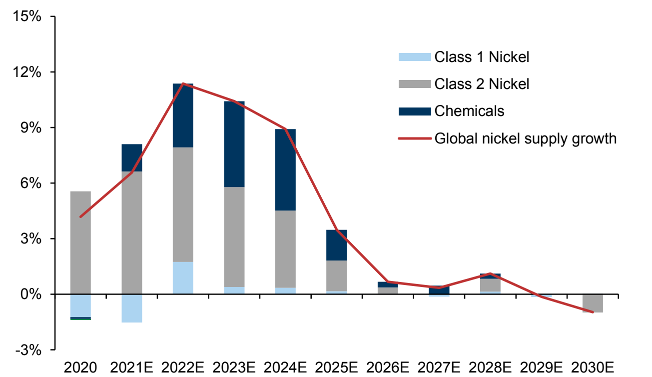
Source: Wind, CRU, Goldman Sachs Global Investment Research

Exhibit 7: Some stainless steel demand destruction will result from rising prices



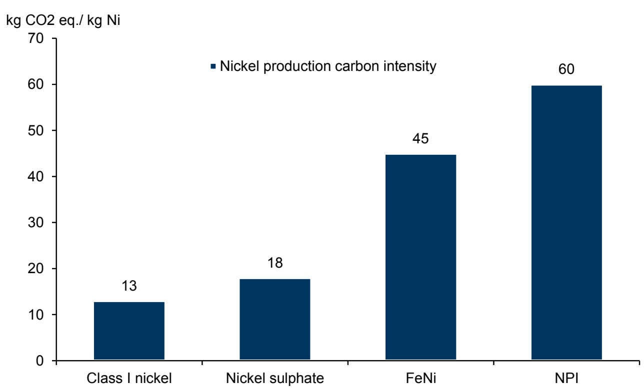
Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 8: Supply responses are in the pipeline for 2022-24 but not much after



Source: Woodmac, Goldman Sachs Global Investment Research

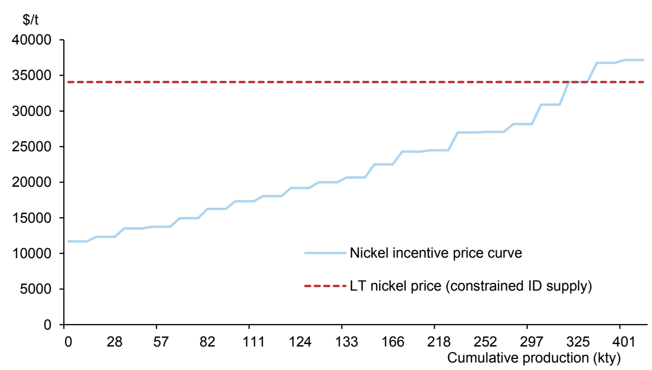
Exhibit 9: Carbon intensity may limit Indonesian conversion as LT supply solution



Source: Nickel Institute, Goldman Sachs Global Investment Research

Exhibit 10: A high incentive price is needed to support non Indonesian projects

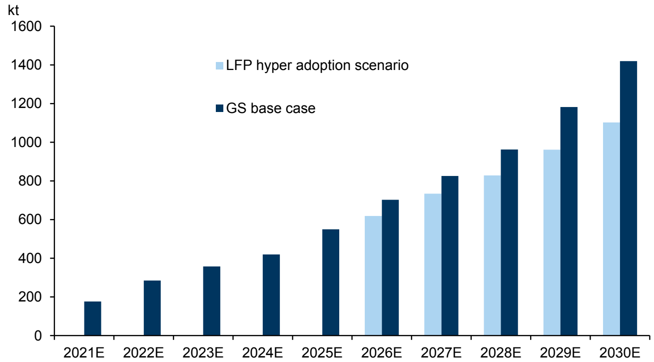
Nickel incentive price curve



IRR = 15% and Cobalt price = $20/t

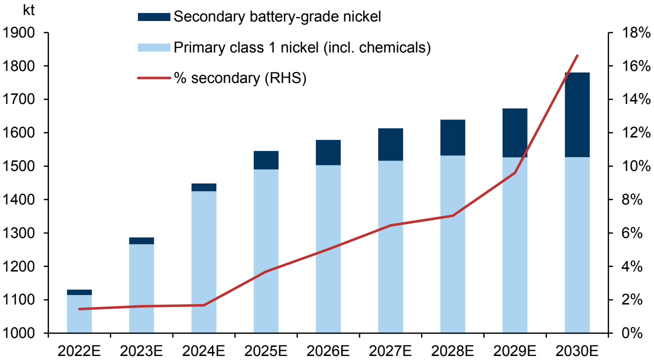
Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 11: Evolving battery chemistry provides a higher degree of uncertainty in the medium to long term



Source: Goldman Sachs Global Investment Research

Exhibit 12: Battery recycling part of solution but not enough
Class 1 nickel supply



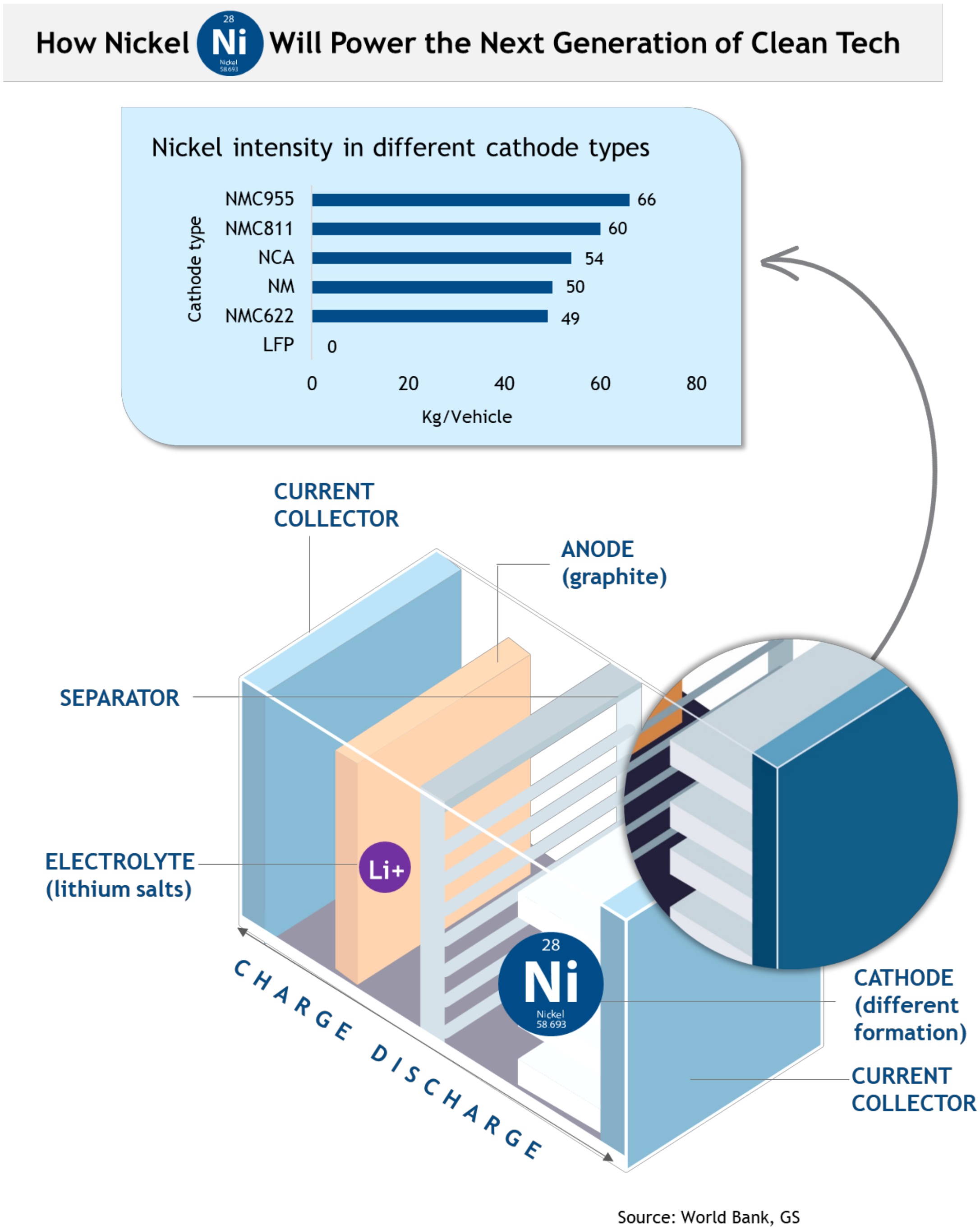
Source: Woodmac, BNEF, INSG, Goldman Sachs Global Investment Research

Quantifying nickel's role in the EV revolution

The electrification of the global road transportation is generating a series of positive demand shocks across raw material markets. Among the base metals, nickel sits as the key beneficiary of the demand uplift from the green transition. The impact on nickel demand from autos in the ICE era was negligible, representing just 1-2% of global nickel demand. However, nickel is a key raw material in the cathode component of batteries, making it central to the expansion of electric vehicles. Cathode chemistry has the key on a battery's voltage and conductivity profile and nickel's relative high energy density means less weight and greater range in the EV. With an average 55kg of nickel per EV battery and a rapid expansion path projected in EV sales, we see nickel demand from EV batteries rising from just 194kt in 2021 (7% of global demand) to 313kt in 2022, and reaching 566kt in 2025. By 2030 we estimate EV batteries will generate up to 1.5Mty of nickel demand, representing 32% of global nickel demand.

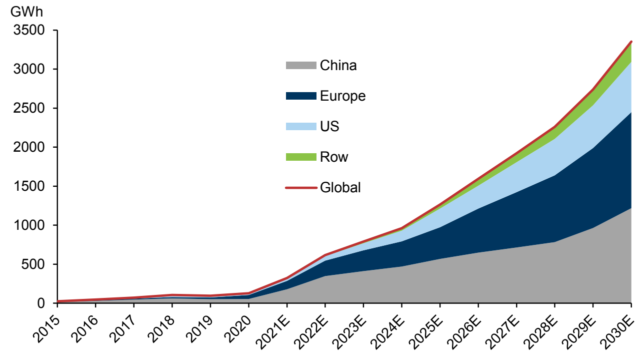
It is important to note that nickel's EV battery demand effect has already started to gather momentum. Due to a combination of policy incentives and improving EV economics, electric vehicle penetration has sharply increased over the last two years, with EV units sold rising sharply from 2.1mn in 2019, to 6.2mn in 2021. This accelerating trend is expected to continue, with our autos analysts forecasting a doubling of sales by 2023 (14mn units), and a more than tripling by 2025 (20.2mn units). We estimate battery demand will increase from 323 GWh in 2021 to 1,263 GWh in 2025, and reaching 3,300 GWh in 2030. This near ten fold increase in battery capacity for EVs lies at the core of the green demand boom for this metal. We would note though that there are additional green demand channels. We estimate c.47kty of demand from wind installations, where nickel is used to improve the toughness of alloy steels, decrease weight and increase the reliability of the turbine gearbox and c.20kty from stationary energy storage installations, where non nickel-intensive batteries account for ~70% of the whole market.

Exhibit 13: How Nickel Will Power the Next Generation of Clean Tech



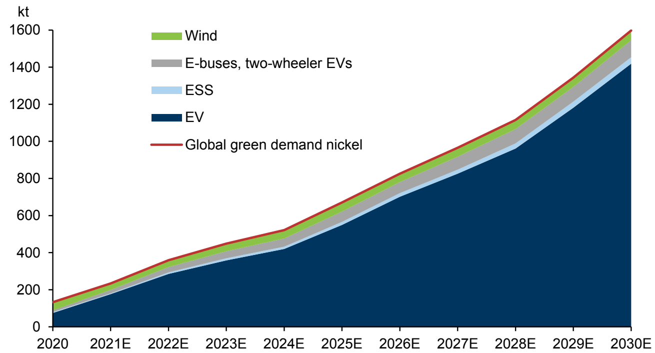
Source: Goldman Sachs Global Investment Research, World Bank

Exhibit 14: The battery capacity demand from EVs increases ten-fold by 2030
Battery capacity demand from electric vehicles, by country, 2015-30E



Source: Goldman Sachs Global Investment Research

Exhibit 15: Electric vehicles are the main drivers of green nickel demand
Global green nickel demand (2020-2030E)



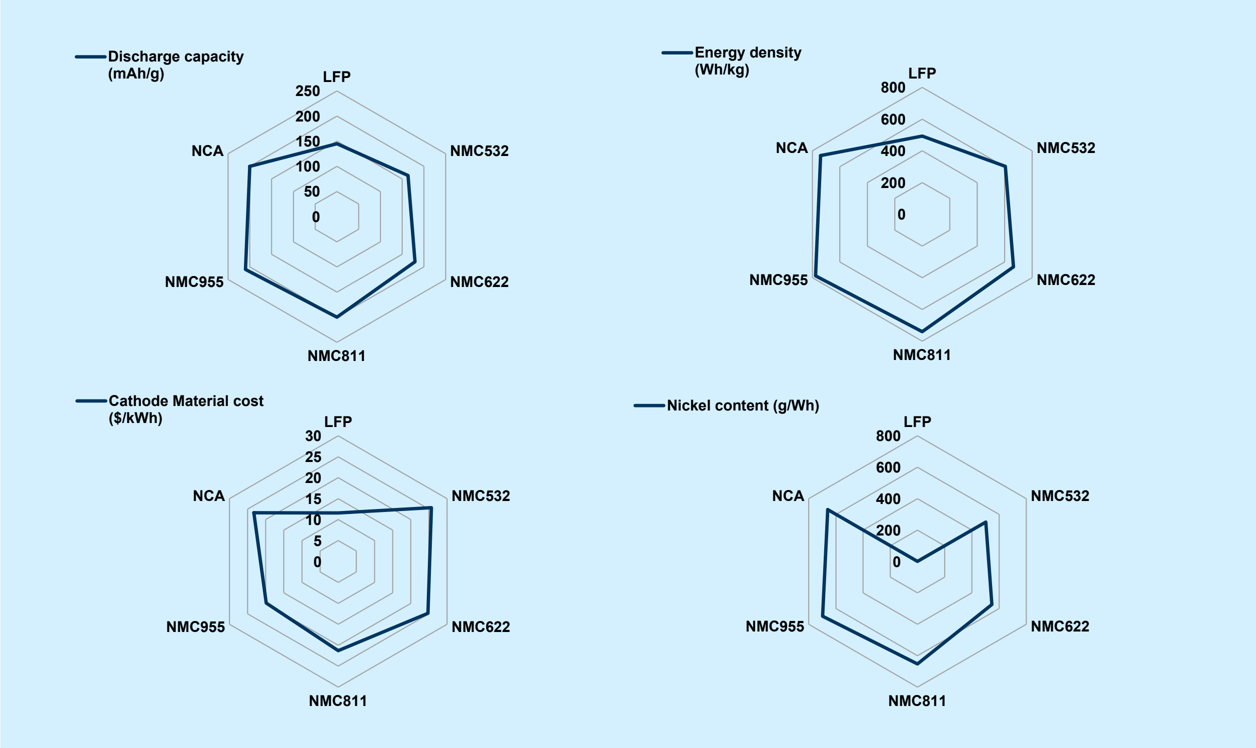
Source: BNEF, IRENA, ANL, Goldman Sachs Global Investment Research

EV Battery based nickel demand is a function of technology

Nickel's role in the battery revolution is likely to face a volatile path of adoption rates among different competing chemistries, in our view. Ultimately, the demand for different battery chemistries will depend upon the technological innovation being pursued to increase the safety of the battery pack, reduce its cobalt content, and decrease its cost. However, the current chemistry mix favours nickel-based Li-ion batteries. Nickel is used in the cathode of Li-ion EV batteries, with the amount of nickel used dependent on battery chemistry and the capacity of the battery (see Exhibit 13). However, not all nickel is created equal when it comes to Li-ion batteries. Refined nickel can be broadly categorised into class 1, class 2 and chemicals based on metal content. Nickel rich batteries require high purity nickel which can be produced using class 1 metal dissolution or chemicals. The nickel-based chemistries (i.e., nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminium (NCA)), contain 500-700 g/kWh of nickel. The battery capacity varies by the type and size of the EV – a battery EV or BEV (80 kWh/vehicle) that runs fully on its battery has four times the capacity of a plug-in hybrid EV or PHEV (20 kwh/vehicle). The nickel content of a BEV with 80kWh battery capacity ranges between 40kg/vehicle for an NMC 532 cathode, to 66kg/vehicle for an NMC 955 cathode.

Exhibit 16: Nickel-based batteries are lighter and last longer

A higher energy density implies lighter batteries whereas low cathode material costs imply cheaper batteries.



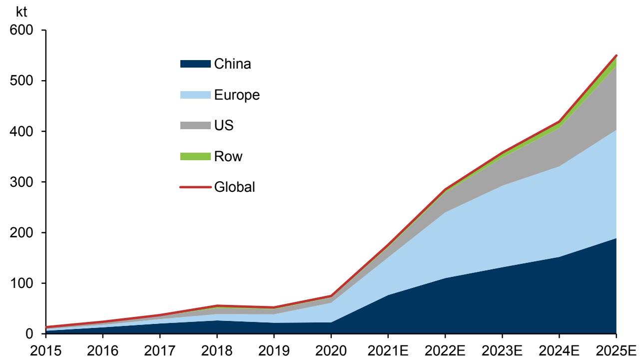
Source: Goldman Sachs Global Investment Research, IEA

Aggregating nickel demand from EV batteries

To forecast nickel demand from EV batteries, we use the EV sales forecasts of our global autos analysts, and the chemistry mix of Li-ion batteries. In addition to our equity analysts' EV estimates, we also include nickel demand from EV batteries for buses and two-wheeler vehicles. The chemistry mix, a determining factor of demand, is the share of the cathode chemistries (the nickel -based NMC or NCA batteries) and the non-nickel-based LFP batteries. Our EV sales based model estimates nickel demand from EV batteries amounting to 313kt in 2022, and growing on average by 23% pa through 2023-25, reaching 566kt in 2025. There are significant geographical variations in battery chemistry preference. Presently, LFP batteries are favoured in China, whereas the nickel-based NMC batteries are more popular in the developed markets. China has a higher share of LFP batteries (50%) as they are cheaper and more stable at high temperatures, relative to NMC batteries, though they provide lower energy density. The popularity of LFP in China can also be attributed to the Chinese battery manufacturers' claim to key LFP patents, which restricts the production of LFP exclusively to China. The lack of LFP production outside China, along with a preference for higher density, has led to a higher share of NMC batteries in the DMs (60% in the EU and the US presently, decreasing to 55% by 2025).

Exhibit 17: Most developed market EV sales are nickel based chemistries

Nickel battery demand, by country of EV sales

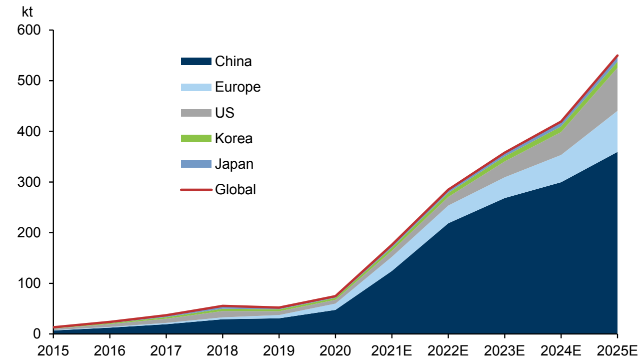


*sales exclude buses and two-wheelers

Source: BNEF, ANL, Goldman Sachs Global Investment Research

Exhibit 18: Majority of nickel based batteries are produced in China

Nickel battery demand, by country of battery production



Source: Goldman Sachs Global Investment Research, BNEF, ANL

Exhibit 19: Green nickel demand is dominated by the electrification of road transportation

Demand based on country of production

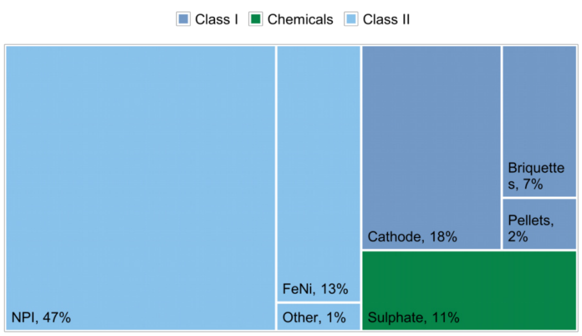
Green Demand (kt)		2021E	2022E	2023E	2024E	2025E	2026E	2027E	2028E	2029E	2030E
Electrical vehicles	EU	28	35	41	54	75	121	152	182	226	274
	US	12	17	31	45	79	136	153	175	211	253
	China	124	218	268	300	334	415	478	549	665	789
	RoW	12	14	17	21	22	30	42	57	80	103
	Global	**176**	**285**	**358**	**419**	**511**	**702**	**825**	**962**	**1182**	**1419**
	y/y growth		*62%*	*26%*	*17%*	*22%*	*37%*	*18%*	*17%*	*23%*	*20%*
Stationary energy storage	EU	1	1	1	2	2	3	4	5	6	7
	US	0	1	1	1	2	4	4	5	6	6
	China	3	7	9	9	10	11	13	15	18	19
	RoW	0	0	1	1	1	1	1	2	2	2
	Global	**5**	**9**	**12**	**13**	**16**	**19**	**22**	**27**	**32**	**34**
	y/y growth		*87%*	*30%*	*11%*	*21%*	*22%*	*15%*	*25%*	*19%*	*7%*
Wind	EU	6	7	7	7	8	10	13	15	15	16
	US	6	3	3	3	4	3	3	3	3	3
	China	15	20	24	27	30	24	24	24	24	24
	RoW	8	7	9	8	8	8	8	8	8	10
	Global	**35**	**37**	**41**	**45**	**50**	**46**	**48**	**50**	**50**	**53**
	y/y growth		*7%*	*12%*	*9%*	*11%*	*-9%*	*5%*	*4%*	*1%*	*5%*
E-buses, two-wheeler EVs	**Global**	**18**	**28**	**38**	**44**	**55**	**59**	**70**	**77**	**80**	**92**
	y/y growth		*52%*	*36%*	*17%*	*25%*	*7%*	*18%*	*10%*	*4%*	*15%*
Global nickel green demand	**Total**	**234**	**359**	**449**	**522**	**632**	**826**	**965**	**1116**	**1344**	**1598**
	y/y growth		*54%*	*25%*	*16%*	*21%*	*31%*	*17%*	*16%*	*20%*	*19%*
	% total nickel demand	*8%*	*12%*	*14%*	*15%*	*17%*	*21%*	*24%*	*26%*	*30%*	*34%*

Source: BNEF, ANL, Goldman Sachs Global Investment Research

An unresolved shortage in battery grade nickel

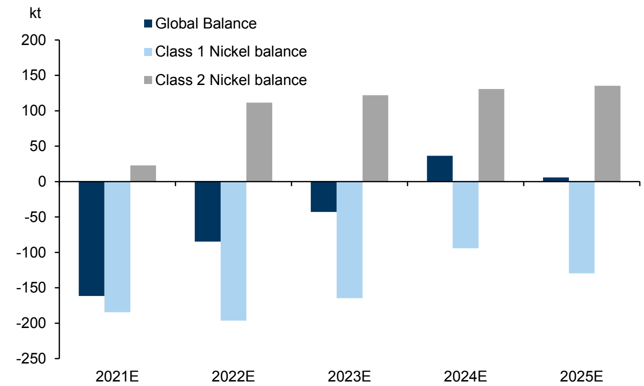
The nickel market in its current form is not equipped to meet this rapid growth in EV battery related demand. We estimate that the refined nickel market experienced a record sized deficit of 162kt in 2021 and forecast an extension of deficit in the class 1 market on an open-ended basis thereafter (see Exhibit 22). Absent significant fundamental adjustment, the nickel market will not be able to supply the units required for the electrification of the global road transport sector. The severity in fundamental imbalance is set to continue in stark terms in 2022. We project a 196kt deficit in class 1 nickel this year. Given already very low class 1 inventories and additional risks around Russia supply, this year is likely to see an extreme scarcity episode in this market. We forecast supply to grow by 8% to 3Mt, with supply growth concentrated in NPI production, we forecast the class II nickel market to be in 112kt surplus and the primary nickel market in a 196kt deficit. Whilst more significant surpluses in class 2 nickel in 2023-24 could potentially offset continued shortfalls in class 1 (via additional as yet unannounced NPI to sulphate conversion capacity), after that point we currently see a reversion to significant class 1 and aggregate nickel deficits (see Exhibit 22). In its current fundamental gearing, the nickel market is woefully unprepared for the green demand acceleration that lies ahead.

Exhibit 20: Only Class 1 and chemicals (nickel sulphate) are suitable for batteries



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 21: Deficit in class 1 battery grade nickel is set to keep global balance tight



Source: INSG, Goldman Sachs Global Investment Research

Exhibit 22: GS nickel class 1 and 2 fundamental projections to 2025

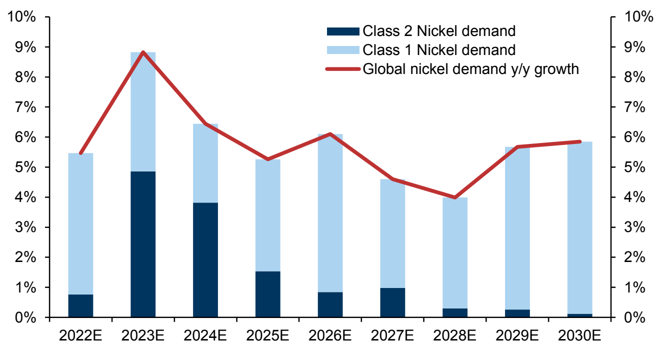
('000 tonnes)	2021E	2022E	2023E	2024E	2025E
Class 1 Nickel demand	1158	1293	1413	1500	1630
% change y/y	17%	12%	9%	6%	9%
Green	234	359	449	522	632
Stainless Steel	257	245	244	241	234
Other	668	690	721	737	764
Class 2 Nickel demand	1712	1734	1881	2007	2061
% change y/y	15%	1%	8%	7%	3%
Stainless Steel	1712	1734	1881	2007	2061
Production					
Class 1 Nickel	791	838	847	857	860
Class 2 Nickel	1735	1901	2047	2176	2222
Chemicals	183	276	416	563	623
Others	0	0	0	0	0
Probable projects	0	1	20	32	49
-Class 1	0	0	3	5	7
-Class 2	0	1	18	28	42
World output	2709	3017	3331	3628	3754
World output (adj. for disruption)	2709	2926	3231	3519	3642
Battery Scrap Supply		16	20	24	55
Global Balance	-162	-85	-43	37	6
Class 1 Nickel balance	-185	-196	-165	-94	-130
Class 2 Nickel balance	23	112	122	131	135

Source: Woodmac, INSG, ISSF, Goldman Sachs Global Investment Research

Battery demand set to drive open-ended class 1 deficits

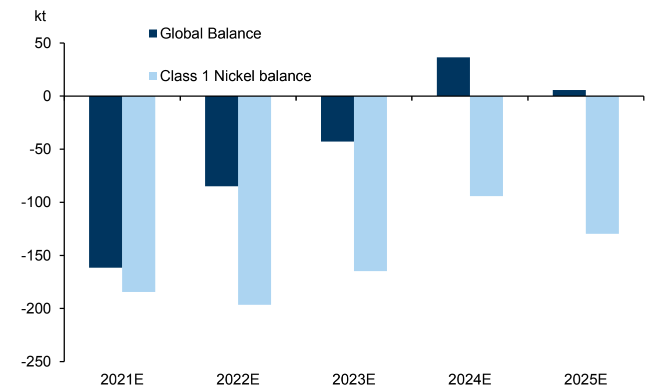
The battery related nickel demand rose sharply to c.200kt, surging 131% y/y as EV sales accelerated in 2021. We expect the class 1 nickel demand from EVs to grow sharply to 313kt bringing the class 1 demand to 1.3Mt (+12% y/y) in 2022. The significant increase in demand would push the class 1 market into a deficit of 196kt. The continued acceleration of EV battery demand through 2023-24, would lead the class 1 demand growth, persistently keeping the class 1 market in a deficit of 165kt (2023E) and 94kt (2024E). We expect class 1 nickel demand to grow rapidly as countries near their ICE vehicle phase-outs and the emphasis of green transition gathers steam in the EMs. For 2026-2030E, we forecast additional green demand volume (193kty) to be double compared to 2021-25E (100kty). As a result, we expect the class 1 deficit to increase sharply to from 291kt in 2026E to 871kt by 2030E.

Exhibit 23: Green transition will drive class 1 demand
Global nickel demand growth, by class



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 24: Balance is very tight now (and in future) for class 1

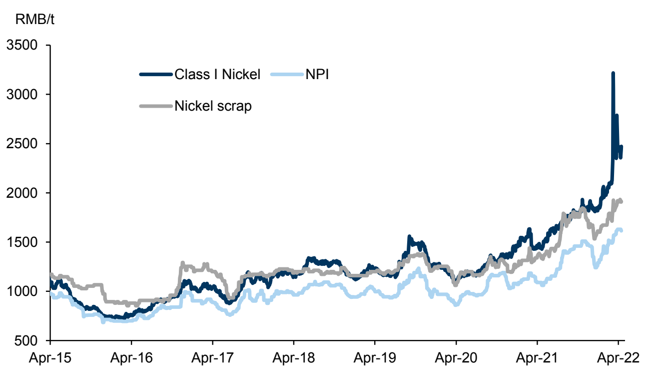


Source: Woodmac, Goldman Sachs Global Investment Research

Stainless steel demand momentum set to limit class 2 oversupply

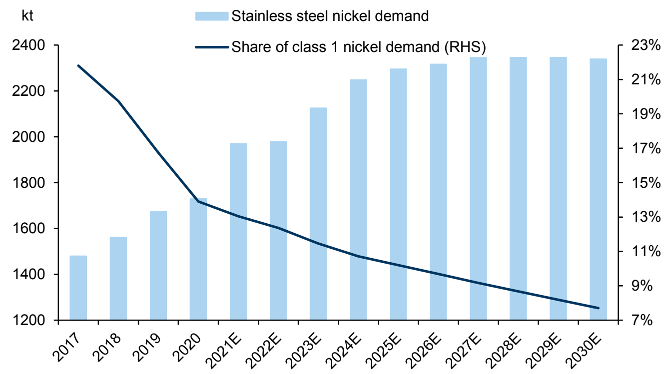
While green nickel demand will undoubtedly be the accelerator of nickel demand in our view, representing 21% of global demand in 2025E and 34% in 2030E, nickel demand should remain a function of stainless steel. We expect stainless steel-based nickel demand to grow to 1.978Mt (+0.49% y/y) in 2022. Around 85% of future stainless steel output growth, in our forecasts, will come from China and Indonesia, which use mostly class 2 nickel (high grade NPI) as it is around 20% cheaper than using refined nickel or scrap (see Exhibit 25). We forecast an increase in stainless steel demand (+1% y/y) to imply a +112kt surplus in the class 2, in 2022. The strength in stainless steel-based nickel demand would continue through 2023-24 however we expect increasing use of non-nickel based stainless steel due to high nickel prices. As a result, the class 2 market surplus will face a surplus c.130kt in 2023-24 even as class 2 supply grows strongly over the same period. Furthermore, based on the western preference and the technical requirement for class 1 nickel to produce the 300 series (c.5%-10%), we expect class 1 demand to remain on average at 10% (240kty) of total stainless steel nickel demand. Finally, in case of shortage of NPI, we see an increase in nickel scrap usage in China similar to 2021, when the nickel scrap ratio for stainless steel jumped from 16% to around 22%.

Exhibit 25: NPI remains the preferred choice by Chinese stainless steel producers



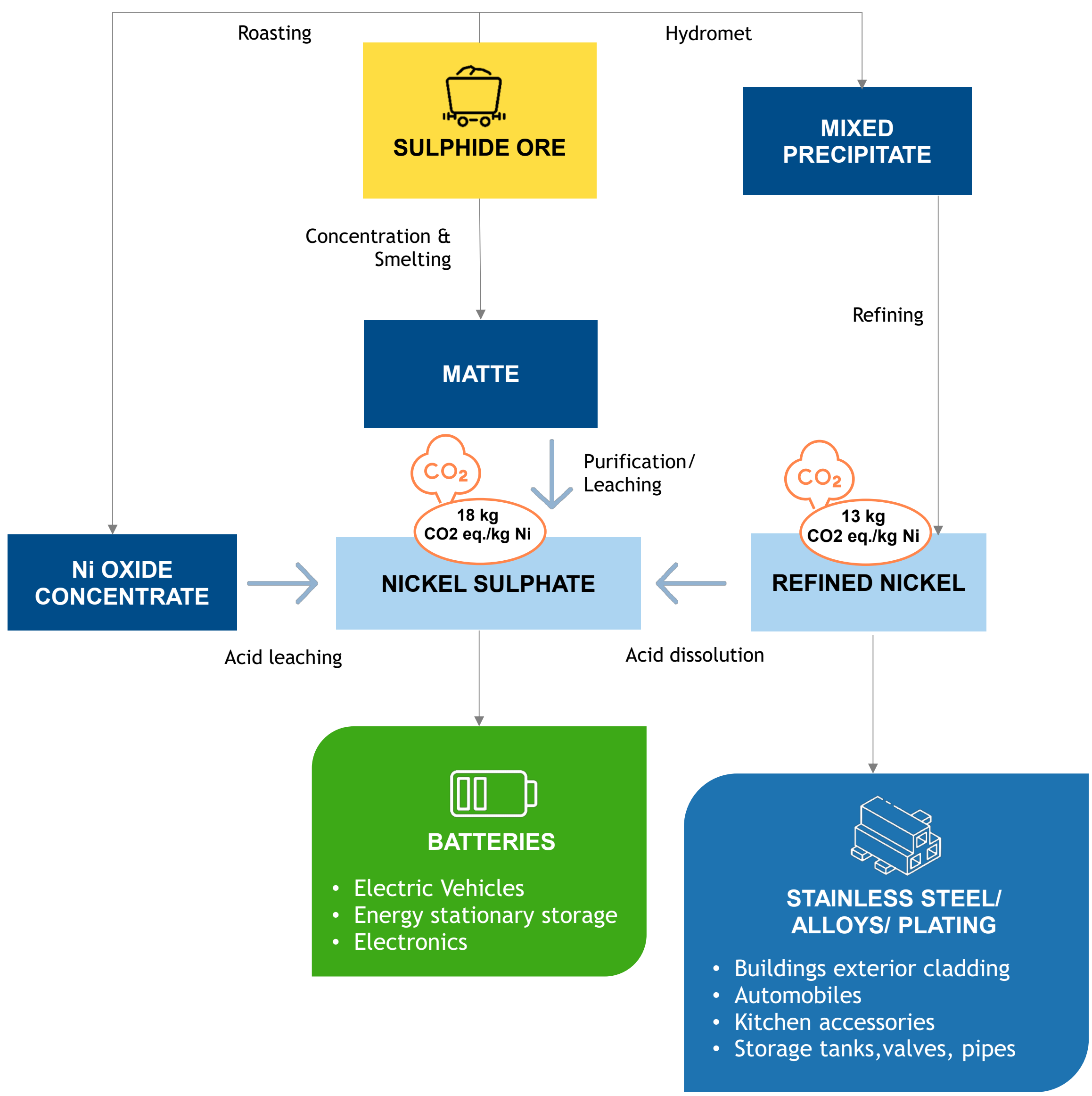
Source: Wind, Goldman Sachs Global Investment Research

Exhibit 26: Scrap consumption to increase as competition for class 1 nickel increases



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 27: Nickel production from sulphide ore



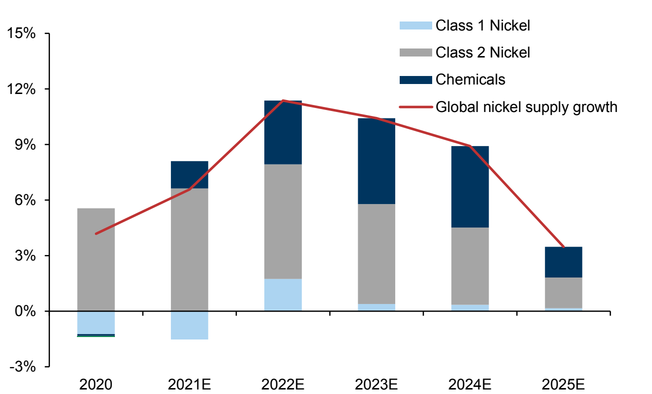
Source: Woodmac, Nickel Institute, Goldman Sachs Global Investment Research

Strong but insufficient battery grade supply response

Nickel-based battery cathode requires metal salts which are produced from nickel sulphate, in turn derived via nickel chemicals or class 1 nickel. The lack of this battery grade nickel supply in 2021 to meet the EV battery demand, prompted refined nickel producers to come up with another solution. The oversupply of NPI in the class 2 market, and the ease with which NPI can be converted into matte (which can be further processed by refineries into battery-grade sulphate) has been recognized as the most immediate solution for solving the battery grade shortage. Unless associated with additional NPI lines, this represents a debottlenecking between NPI surplus and battery grade deficit rather than additions to aggregate supply. Despite this recognition as potential deficit solution, the current NPI-to-matte supply capacity, along with other sulphate supply routes such as high pressure acid leaching (HPAL), are insufficient to meet the current demand coming from batteries. Even with the strong growth projected in battery grade nickel supply through 2022-24 (Exhibit 8), the rapid expansion in EV battery demand means continued deficits in class 1 remain.

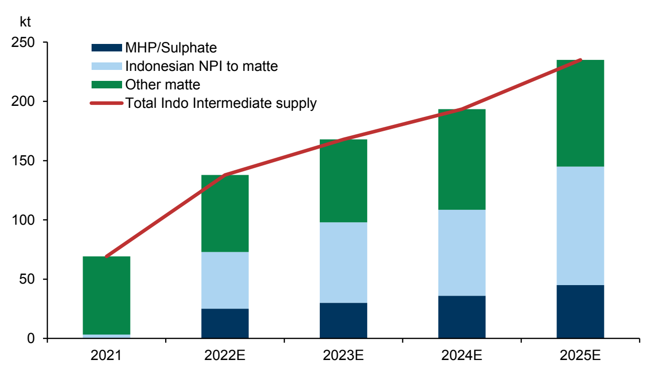
China and Indonesia are set to generate the majority of this current base case supply. After very strong growth in Indonesian NPI output in 2021 (+268kt, 42% y/y), production will remain strong in 2022 (+264kt,+29%) and modestly decelerated into 2023 (+139kt, 12% y/y). Indonesian NPI-to-matte conversion volumes will increase from representing 5% of total Indonesian intermediate supply in 2021, to 35% in 2022E (48kt), and stabilizing at 40% thereafter. There remains some risk on these conversion volumes given the production could deviate on the differential in NPI and NPI to matte margins, in our view. In turn, the majority of growth in chemicals supply for battery production will focus on China, with our projected 34% increase in 2022E as a number of battery related players ramp up capacity. These projects rely on Indonesian matte or MHP refining making Indonesian intermediates a critical feedstock for chemicals production.

Exhibit 28: Battery grade nickel supply growth peaks in 2022



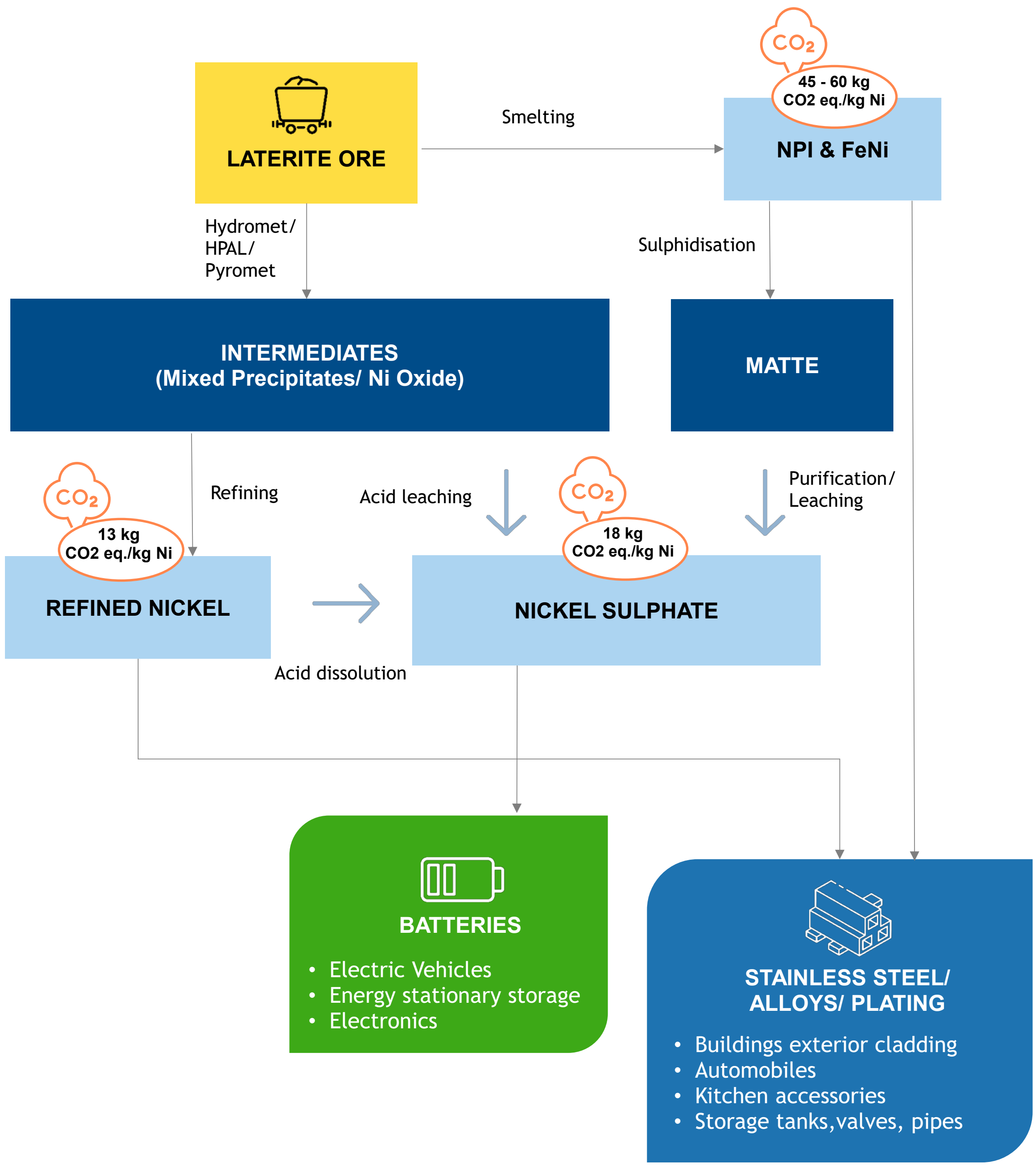
Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 29: NPI-to-matte conversion is becoming the crucial Indonesian intermediate



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 30: Battery grade sulphate production from NPI-to-Matte route is carbon intensive



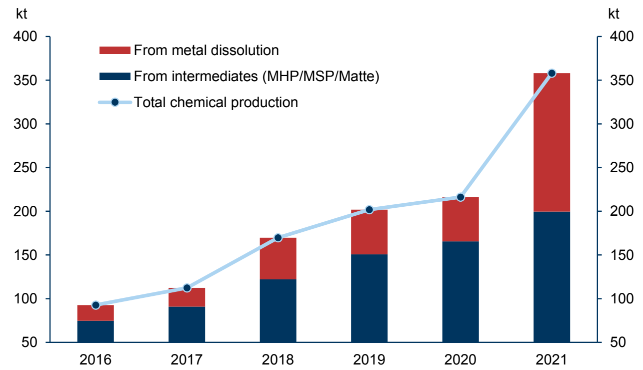
Source: Woodmac, Nickel Institute, Goldman Sachs Global Investment Research

Class 1 inventories are already at critical low levels

Supply side disruptions in sulphate and NPI production amid strong demand environment in the battery and stainless steel sector led to a significant draw of class 1 inventories last year. The proportion of battery-grade nickel sulphate production from metal dissolution increased to 44% from 24% in the previous years (see Exhibit 31). As a result, the global visible class 1 stocks decreased sharply and are just 93kt presently (see Exhibit 34). Furthermore, the exchange stocks have fallen to 10 days of stock on a consumption adjusted basis - the lowest they have been in 12 years. Moreover, the LME off-warrant stock data shows inventories falling from a peak of 44kt in Feb-21 to just

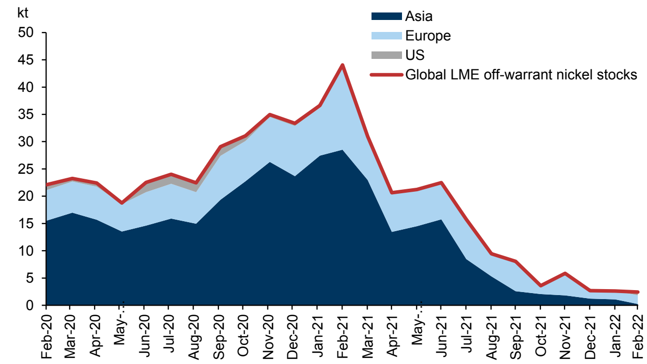
2.4kt by Feb-22 according to the latest data. With our projected 196kt deficit in the class I market, the global visible stocks are not sufficient to tackle the demand coming from batteries. We believe non-visible units would have to be delivered to the exchange in response to high prices amid strong demand. As a result of the inventory draw, we expect extremely high prices until a clear solution is established.

Exhibit 31: Increase in production of metal dissolution based sulphate led to big class stock draws
China nickel sulphate production, by feedstock



Source: SMM, Goldman Sachs Global Investment Research

Exhibit 32: Off-warrant stocks are almost exhausted

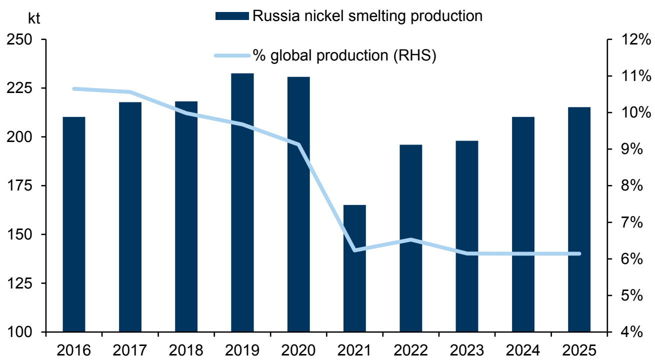


Source: LME, Goldman Sachs Global Investment Research

Potential Russia supply losses would accelerate depletion path

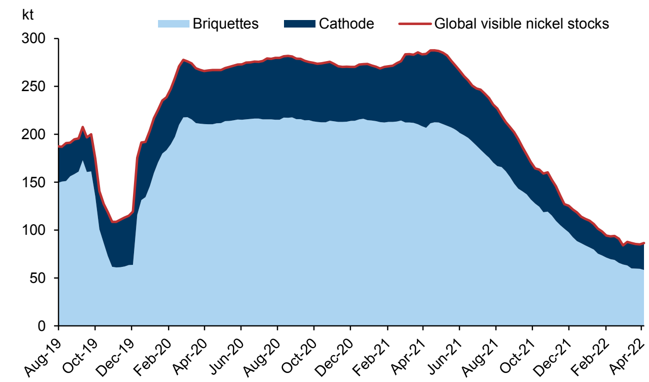
The acute tightness in the nickel market is also at risk from possible disruption of Russia's class 1 and intermediate supply. Russia is set to produce 133kt of class 1 supply in 2022 (GSe), 16% of global supply, as well as supplying intermediate nickel product to other refineries in Europe which account for 60kt refined output there. As reported in the media, the uncertainty around sanctions has made it difficult to ship commodities out of Russia whether due to reduced freight capacity or limitations on obtaining insurance. Import data shows that Russia also accounted for c.40% of Chinese refined nickel imports last year. It is possible that China could import a higher proportion of nickel from Russia, if both sanction risk and logistical hurdles are resolved. For now, there is no evidence that Russia's exports of nickel to developed markets has been impacted by consumer self-sanctioning. That risk will however grow the longer the conflict in Ukraine lasts and consumers negotiate new contracts focussed on 2023. Any supply losses in this context would only serve to further accelerate the path to stock depletion.

Exhibit 33: Around 6% of global nickel supply is at risk from Russian supply disruption



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 34: There isn't enough visible stock left to solve class 1 shortfall even this year



Source: SMM, Goldman Sachs Global Investment Research

The path to solving nickel's scarcity

The current fundamental outlook for nickel points to a persistent and substantive shortfall in class 1 supply. In this section we consider the implications and necessary adjustments from that starting point. The first and most immediate regards the prospect of a scarcity spike in price in the near term as stocks approach depletion levels over the next 3-4 quarters. In that setting, we see the potential for the nickel price to peak close to $42,000/t on a 12-month timeframe (vs $24,000/t previously). This path reflects a growing risk of stock out as well as a price level which will generate sizeable enough demand destruction to defer that eventuality. Beyond this immediate price spike scenario, the fastest supply response channel (from 2023 onwards) is from the addition of NPI to sulphate conversion capacity in Indonesia. The incentive for expanding this path will be less tied to the nickel price, than the premium of the spread of nickel sulphate-NPI over conversion cost (which we estimate $4000-5000/t Ni). Currently that incentive exists though announcements of capacity addition has been slow, likely because margins on output NPI production remain very strong. Over the medium term, we estimate that the nickel price will need to trade on average close to $30,000/t as a necessary incentive on supply investment to solve the forwards shortfalls. In this context, we forecast nickel to average $34,650/t in 2022, $37,500/t in 2023, $32,500/t in 2024 and $30,000/t in 2025 (vs. $22,000/t in 2022 and $25,000/t in 2023).

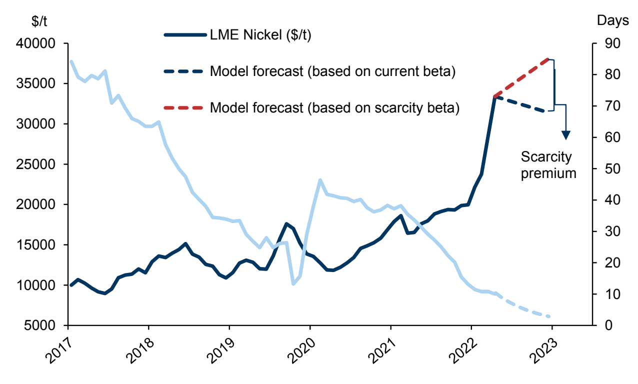
Scarcity path leads to continued upside price pressures near term

The class 1 nickel market is in an environment of acute tightness, in our view, and we believe this will persist at least until the year-end and possibly into 2023H1. To model the nickel prices in this setting, it is important to capture the relationship between inventories and prices. This relationship depends on the state of market – we believe that the beta of price to inventories is a function of the level of inventories. The lower the inventories, the higher the impact of change in inventories on prices. When inventories fall (or rise) to extremes: 1) either the market prices scarcity when stocks are extremely low and depleting 2) or prices a massive demand slowdown and possible oversupply when stocks are high and rising.

We model this dynamic using a monthly break-adjusted least square model of LME nickel price, exchange stocks adjusted for consumption and Chinese stainless steel production. To project the 1-year ahead price, we estimate two price paths – one is based on the current beta of stocks to prices and the other based on a scarcity beta. In an environment of scarcity, our model suggests the monthly price could average c.$38,000/t by year-end. However, it is possible that the beta evolves faster as we are already at critically low levels of inventory (see Exhibit 35). Moreover, the Russian invasion of Ukraine has added uncertainty to the supply of c.200kt of refined metal supply. In such a fundamentally tight set-up, we expect a depletion of inventories to scarcity levels and the beta of stock to be high and volatile. In this context, we see prices moving close to historical highs and raise our 12m target to $42,000/t (vs $24,000/t previously) (see Exhibit 36).

Exhibit 35: The scarcity based price model suggests prices to reach a monthly average of $38,000/t

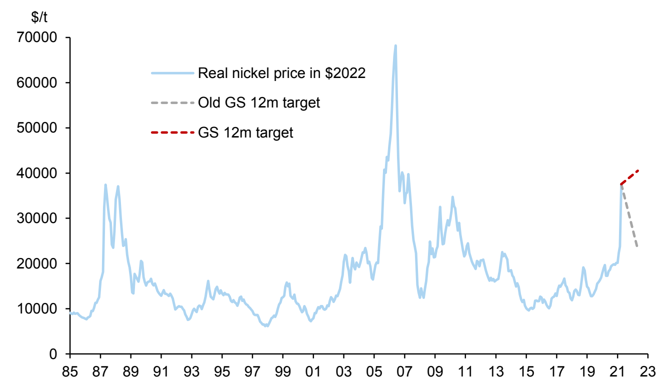
Model of monthly average LME nickel prices ($/t)



We exclude the monthly average from month of Mar-22 when the LME contract was temporarily suspended.

Source: Wind, CRU, Goldman Sachs Global Investment Research

Exhibit 36: We expect the 12m prices to reach $42,000/t



Source: Haver Analytics, Goldman Sachs Global Investment Research

A break-adjusted price model for short-term nickel prices

We identify Chinese stainless steel production and consumption adjusted exchange inventories to be the best set of explanatory variables for nickel prices over the last 5 years. To conduct variable selection, we run rolling OLS for all viable combinations from a set of variables: global manufacturing PMI, global stainless steel production, nickel production, Chinese nickel inventories adjusted for consumption and our selected variables. We choose the model with the highest explanatory power and sound economic logic. We regress exchange inventories adjusted for consumption against nickel prices controlling for stainless steel production. However, in the last 5 years, supply side project announcements, the COVID crisis, the recovery and energy crisis has induced structural breaks in the markets. To account for these structural change in regression model, we use the Bai and Perron (1998) method which identifies breaks based on persistence in errors. Furthermore, to tackle the issue of the non-stationary and reduce the noise, we take annual growth rates of monthly stainless steel production, monthly averages for prices and consumption adjusted inventories.

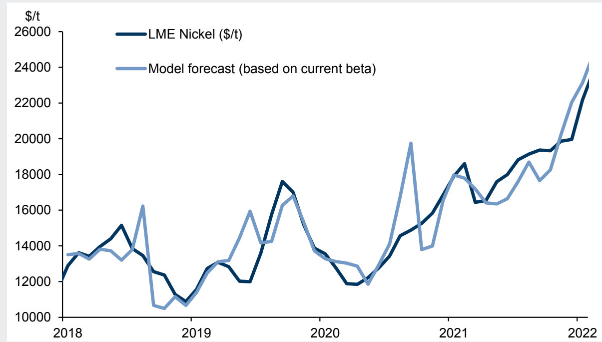
Exhibit 37: The beta of nickel prices to inventories is state-dependent, increases in periods of scarcity pricing

Break-adjusted Least Square Regression Model of Nickel Prices

Regimes	Beta of exchange stocks adj. for consumption to nickel prices	t-Statistic
Jan'18 - Aug'18	-0.651297***	-5.27
Sep'18 - Aug'18	0.580988***	7.23
Sep'19 - Now	-0.261749***	-7.72
Fixed variable	**Coefficient**	**t-Statistic**
Constant	0.174633***	8.41
China stainless steel output	0.479415***	4.31
Model Parameters		
R-squared	0.78	
Standard error	0.11	

Source: Goldman Sachs Global Investment Research

Exhibit 38: Overall the model has a good in-sample fit



Source: London Metal Exchange, Goldman Sachs Global Investment Research

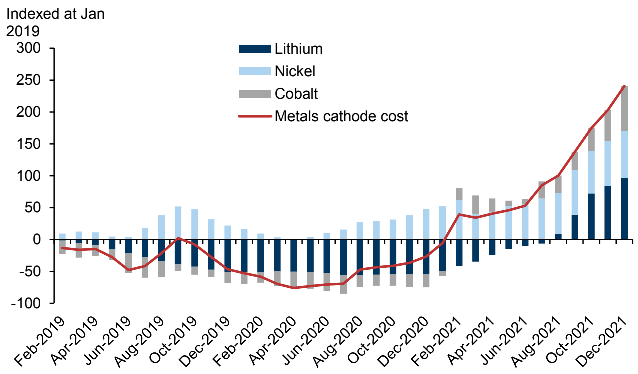
Our model identifies 3 regimes (see Exhibit 37) – we identify the break in 2018Q3 a result of the Indonesian HPAL project announcement and the one in 2019Q3 as a mixed effect from stocks taken off-exchange as a result of the Indo export ban in July 2019, the COVID crisis and the recovery. Additionally, we avoid over-fitting by rejecting the model with 5 breaks that would include two above mentioned breaks and additional breaks which mark the start and end of COVID outbreaks and the power crisis. The model results in a good in-sample fit and with a R^2 = 0.78 and standard error = 0.11 (see Exhibit 38).

Need for demand destruction set to further fuel price spike

With limited supply flex in the short run (i.e. over the next 2-3 quarters), we see a necessity for demand destruction through high prices. For nickel, we expect that effect to be most pronounced in the stainless sector whilst far more limited on the battery side in the short term. Nickel in stainless steel can be substituted either with different metals, where nickel is not critical, or by increasing the use of nickel scrap. Given the already high scrap ration in the West and low EOL stainless steel pool in China, shifting to other types of stainless steel has been the approach during past bull cycles. Historical analysis suggests that a 10% increase in the price leads to a decrease of ~15kt of nickel demand in stainless steel. Nevertheless, this is likely to impact mostly class 2 demand, with limited impact on class 1 nickel, thus ultimately not softening the market. On the battery side, we view short term demand from EVs as relatively inelastic given long-term contracts drive the raw material requirements over a 2-3 year horizon. In the medium term, it is possible that OEMs which bear the cathode costs could then switch faster to LFP (an adjustment risk subsequently discussed).

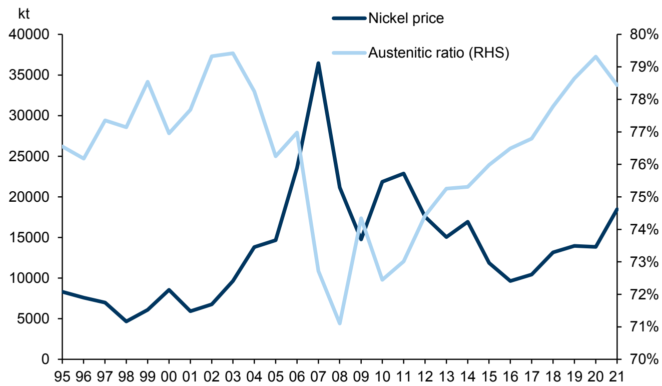
Exhibit 39: Lithium, not nickel, is the main cause of increasing costs in 2021

Cumulative change in metals cathode cost, by metal



Source: Wind, Goldman Sachs Global Investment Research

Exhibit 40: Extreme prices lead to demand destruction in stainless steel, not EVs

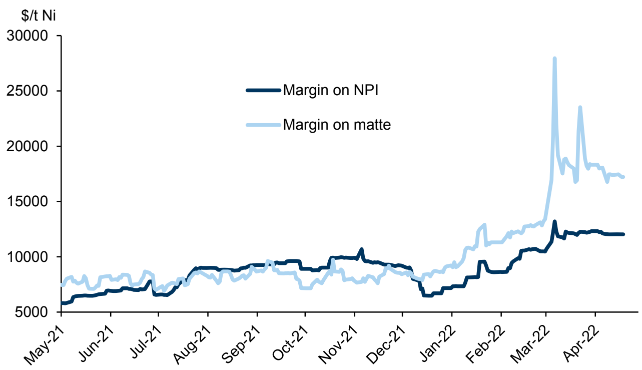


Source: Woodmac, Goldman Sachs Global Investment Research

NPI-to-matte based solution to battery grade sulphate has its challenges

The fastest supply response channel that can solve the class 1 tightness – NPI to sulphate conversion in Indonesia – relies on the economics of cost and margin. The new NPI-to-matte process entails simply the addition of sulphur to high grade NPI obtained from the laterite ore, thus creating a relatively elastic path which can respond to high prices. However, until now, we have not seen evidence of matte supply from Indonesia to China in export data. This could be due to sustained NPI prices, which makes matte conversion less preferable by NPI producers (see Exhibit 41). Another reason could be the lack of integrated supply chains which are more profitable and allow the NPI producer to directly convert the high grade matte to sulphate (see Exhibit 42). Nevertheless, given the high Class 1 prices, NPI producers in Indonesia will be likely incentivized to start converting NPI to sulphate in the near future, as this process becomes more profitable than selling NPI to stainless steel producers (see Exhibit 42). Hence, we expect this softening force to become available only in at least 6-8 months' time, the time required to build the matte-to-sulphate production lines. We would also note that a decrease in the class 1 prices would give little incentive to pursue NPI-to-matte projects and potentially make the route of class 1 dissolution more preferable as a short-term solution.

Exhibit 41: The recent rally in class 1 nickel prices has improved margins on matte



Source: SMM, Wind, Goldman Sachs Global Investment Research

Exhibit 42: Integrated supply chains are more profitable

$/t	NPI	Matte	Sulphate	
			Non integrated	Integrated
Cost	10423	11423	23724	15423
Selling price	22182	19724	26957	26957
Margin	**11759**	**8301**	**3233**	**11534**

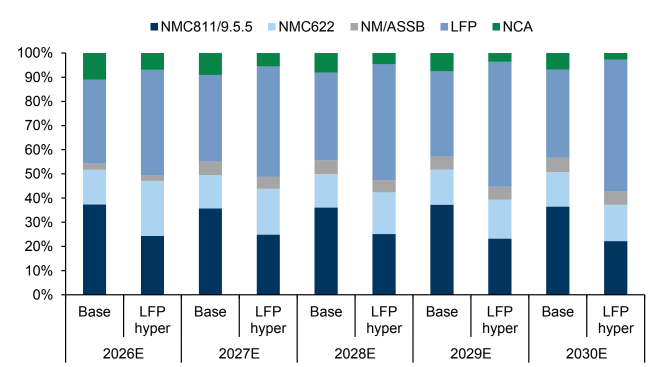
*Non integrated producers are producers that buy matte from a third party
** NPI cost is based off PT Indonesia Morowali Industrial Park data

Source: SMM, Company data, Goldman Sachs Global Investment Research

A scenario of less nickel-intensive EV battery demand

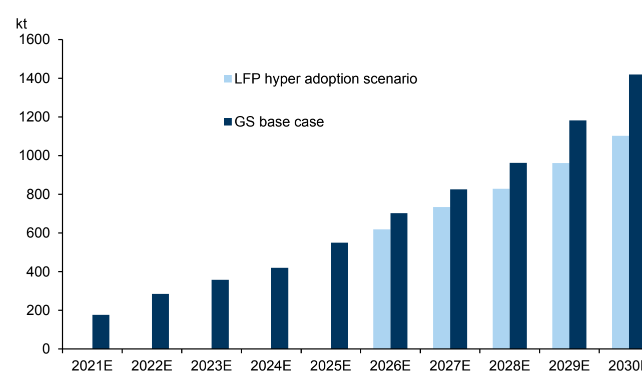
While keeping our base case for EV nickel demand, we see a growing tilt towards LFP batteries outside China and incorporate this as under a 'LFP hyperadoption' scenario, starting 2026. In this scenario, we find nickel battery demand to moderate, and grow at 15% pa on average (vs. 21% in our base case) over 2026-30E. The case for LFP batteries is becoming stronger, as car manufactures plan to shift the more price-sensitive car segments to LFP-based batteries. This move by car manufacturers globally coincides with the expiry of LFP patents, which would allow producers outside China to manufacture and innovate LFP batteries. In a less-nickel intensive battery world, we model LFP share in the global chemistry mix evolving to 55% vs. 36% in our base case, by 2030. The reason to consider LFP batteries is two-fold - first, they do not contain cobalt, a metal which faces a very challenging path to sustainable supply; and second, advances in cell-to-pack (CTP) battery technology have helped reduce concerns around low energy density. However, LFP adoption could face challenges from rising lithium prices and lack of ex-China production expertise.

Exhibit 43: DMs would need to move away from nickel-based batteries for a LFP hyperadoption scenario
Cathode chemistry mix under base case and LFP hyperadoption scenario



Source: Goldman Sachs Global Investment Research

Exhibit 44: A LFP battery hyperadoption would generate a drag in nickel battery demand of as much 300kt by 2030 (vs our base case)

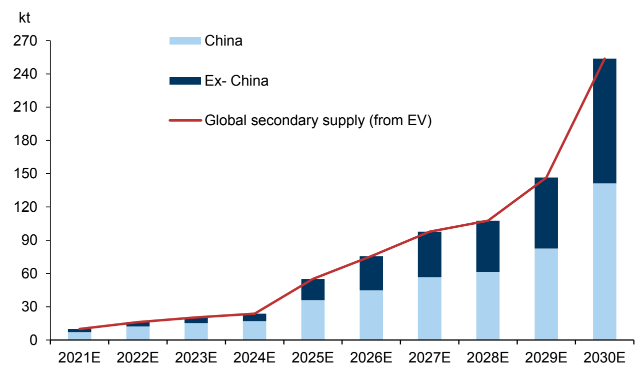


Source: Goldman Sachs Global Investment Research

The recycling revolution can help narrow the supply gap, but cannot solve deficits

In our view, the fast-growing EV sector and policy-makers' increased focus on the circular economy will almost certainly lead to the development of the battery recycling sector, something that could ultimately provide a cheaper and cleaner solution to nickel tightness. However, we do not expect battery recycling to have any material impact until at least 2028, when sufficient EOL EV batteries will come online. Nickel recycling from batteries is a function of the life span of the battery, replacement options, and the collection rate of batteries and materials. We incorporate these factors in our battery recycling model and estimate c.70GWh of batteries becoming available in 2026E, rising to c.356 GWh in 2030E. Nevertheless, not all of this is a potential source of nickel: we estimate 19% of it will be LFP. We assume nearly 100% is recycled and 90% nickel is recovered, as governments make OEMs responsible for managing the recycling stage and current rates are already above 90%. This translates into secondary nickel supply of 76kt in 2026E, more than tripling by 2030 to 254kt (7% of supply).

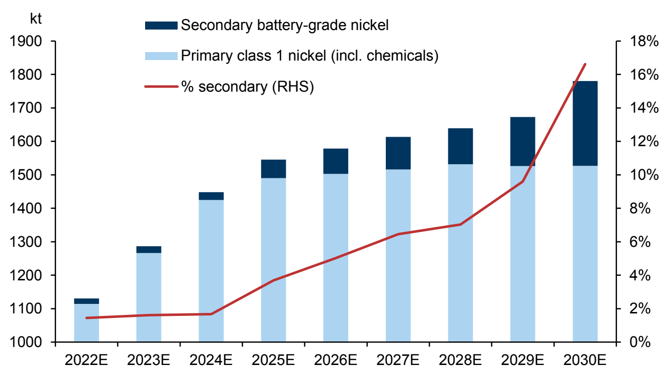
Exhibit 45: Battery scrap nickel to grow materially from 2028



Source: Woodmac, BNEF, Goldman Sachs Global Investment Research

Exhibit 46: Recycling and scrap to become part of the solution in an increasingly circular economy

Class I nickel supply

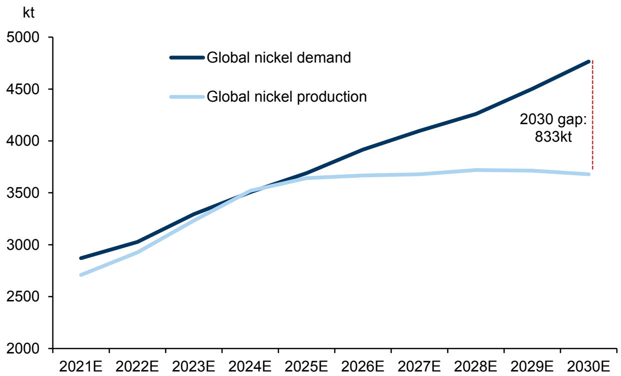


Source: Woodmac, BNEF, INSG, Goldman Sachs Global Investment Research

Incentive price now above $30,000/t to solve deficits

As with copper and aluminium, the green transition should translate into record level long-term deficits for nickel. We expect the nickel market to move into an 833kt deficit in 2030 reflecting strong demand growth (6% y/y pa) as opposed to stagnating supply which is expected in the latter half of the decade to grow only at 1% compared to 8% average growth in 2021-25. The LT supply gap will be partially resolved by Indonesian projects, independently of the future nickel price, given their lower cost compared to the rest of the world, in our view. Based on consultant data, we estimate 850kt of possible projects in Indonesia are set to come online post 2025 which could alone close the LT gap. However, we do not expect all of Indonesian supply to come online as environmental concerns gather momentum post 2025. Indonesia is among the most polluting countries and while we do not see any material threat to nickel supply in the form of environmental policies in the next 3-4 years as the world's focus shifts to energy security, it is likely that in the long term the push for stricter environmental policies will increase, threatening the development of nickel supply. We estimate that ~320kt would be at risk, leaving a LT gap of 300kt to be solved by greener ex-Indonesia projects. Consultant data show that there are 22 costed possible ex-Indo projects (416kt) and based on those we estimate the incentive price would need to be close to $34000/t (in real terms) to stimulate sufficient ex-Indonesia projects.

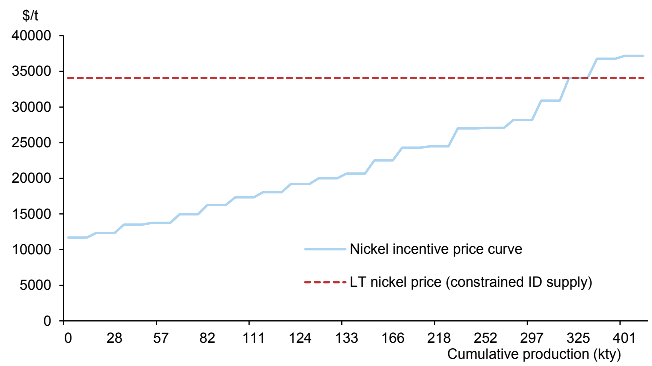
Exhibit 47: We are approaching record level LT supply gap



Source: Woodmac, Goldman Sachs Global Investment Research

Exhibit 48: A green premium can push the incentive price higher

Nickel incentive price curve



IRR = 15% and Cobalt price = 20$/t

Source: Woodmac, Goldman Sachs Global Investment Research

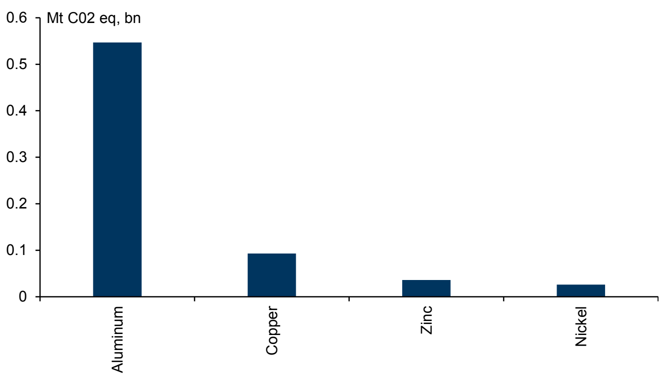
Nickel's ESG challenge

The great paradox of decarbonisation is its reliance on carbon-intensive commodities. Similar to aluminium, nickel is a key green transition enabler with a polluting production process. Although, nickel accounts just for 0.1% of global emissions (vs 2% for aluminium sector), it's decarbonisation is important in making EVs carbon neutral. Despite emitting overall lower carbon emissions than ICEs, EVs have higher emissions at the beginning of their lives, given the higher material intensity. OEMs' focus on reducing emissions in the EV supply chain puts focus on nickel sulphate's environmental impact. The emissions attached to sulphate production vary according to the process (see Exhibit 50), from as low as 18-23 tCO2/t Ni for sulphate produced from matte (from sulphide ore) or from the dissolution of Class I nickel to 15-30 tCO2/t Ni and 50-70 t CO2/t Ni for sulphate obtained from MHP and NPI to matte conversion respectively. This compares to emission intensity of 13 t CO2/t Ni for refined nickel and 45-60 t CO2/t Ni for FeNi and NPI.

Nickel's battery utility limits chemistry dilution

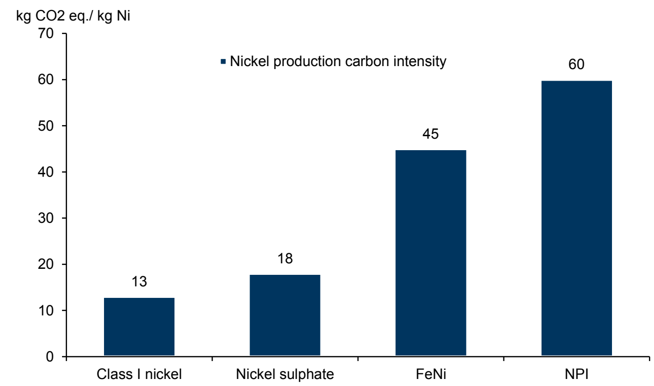
The different pressures for decarbonisation between aluminium and nickel show themselves in their potential solutions. While we expect aluminium supply decarbonisation to be ultimately policy-driven, through the introduction of a carbon tax (see European CBAM), nickel would not be considered at risk of carbon leakage, at least in the next years, in our view. Indeed, OEMs will drive nickel supply decarbonisation to comply with emissions targets and to satisfy increasing sensitivity of consumers to ESG-related issues, as has happened with cobalt. However, the approach used with cobalt is not applicable to nickel given its importance in creating lighter long range batteries. Nickel helps increase energy density in lithium ion batteries, thus making it key for a smaller battery, lighter vehicles and ultimately carbon neutral EVs. There is some risk of a greater shift to LFP batteries, which would solve both cobalt and nickel supply chain ESG issues. However, LFP chemistry is not favoured by all car segments.

Exhibit 49: Nickel contribution to global emissions is small



Source: OpenLCA, Goldman Sachs Global Investment Research

Exhibit 50: Future growth will come from carbon intensive processes



Source: Nickel Institute, Goldman Sachs Global Investment Research

Indonesia's decarbonisation challenge

The longer-term challenge is focused on decarbonising nickel's supply chain. Currently more than 50% of nickel is produced using coal-fuelled energy, with renewable sources being less than 20%, with Indonesia being the country relying the most on fossil fuel sources. Given Indonesia already represents 39% of total supply, any decarbonisation of this supply segment will not be a simple undertaking. Some producers there have signalled a move towards greener sources, with Tsingshan planning to build 2 GW of renewables sources to power its operations in Indonesia. Nevertheless, coal-fired electricity is expected to continue to growth until 2027, accounting for 64% of electricity generation by 2030. If this is untenable, perhaps due to Western consumer green preference, then there are two potential outcomes. First, Indonesian producers accelerate investments in decarbonisation, which will come at a cost and likely restrain the pace at which supply is added to solve the LT supply gap. Second, Indonesia is incapable of decarbonising and green units have to be sourced from other locations with higher cost. It is unclear at the current juncture which path will dominate, and likely depends on prospective pressures from consumers, autos and OEM demand. Nevertheless, both these scenarios picture a path for nickel prices towards higher levels, to solve the LT supply gap in one case, and to incorporate a potential green premium in the other.

GS Nickel supply-demand balance

Exhibit 51: GS Global Nickel Supply-Demand Balance

('000 tonnes)	2017	2018	2019	2020	2021	2022E	2023E	2024E	2025E
Consumption - DM									
US	155	162	153	133	128	138	163	184	229
% change y/y	14%	5%	-6%	-13%	-4%	8%	18%	13%	24%
Europe	334	333	305	278	334	370	375	398	429
% change y/y	-1%	0%	-8%	-9%	20%	11%	1%	6%	8%
Japan	153	166	149	141	163	183	204	209	222
% change y/y	6%	8%	-10%	-6%	15%	13%	11%	2%	7%
Other DM	9	8	8	7	8	9	9	9	9
% change y/y	3%	-8%	-1%	-11%	7%	8%	2%	2%	2%
Sub- DM	651	669	616	560	633	700	751	800	890
% change y/y	4%	3%	-8%	-9%	13%	11%	7%	6%	11%
Consumption - EM									
China	1197	1176	1342	1449	1557	1661	1815	1925	2010
Indonesia	55	170	164	206	383	402	450	493	496
China & Indonesia	1252	1346	1506	1655	1939	2063	2265	2418	2506
% change y/y	6%	8%	12%	10%	17%	6%	10%	7%	4%
Other EM	332	337	325	265	298	265	279	289	295
% change y/y	2%	1%	-3%	-18%	12%	-11%	5%	4%	2%
Sub- EM	1584	1683	1831	1920	2237	2327	2543	2707	2801
% change y/y	5%	6%	9%	5%	17%	4%	9%	6%	3%
Global Consumption	**2235**	**2352**	**2447**	**2479**	**2870**	**3027**	**3294**	**3507**	**3691**
% change y/y	5%	5%	4%	1%	16%	5%	9%	6%	5%
World ex-China & Indonesia	983	1006	941	825	931	965	1030	1089	1185
% change y/y	3%	2%	-6%	-12%	13%	4%	7%	6%	9%
Global Production									
Global Primary Production	2042	2186	2372	2542	2709	2926	3231	3519	3642
% change y/y	*4%*	*6%*	*10%*	*4%*	*7%*	*9%*	*10%*	*9%*	*4%*
China	**655**	**713**	**857**	**783**	**746**	**665**	**759**	**875**	**920**
% change y/y	*10%*	*9%*	*20%*	*-9%*	*-5%*	*-11%*	*14%*	*15%*	*5%*
Indonesia	**203**	**289**	**396**	**638**	**905**	**1158**	**1334**	**1453**	**1526**
% change y/y	*70%*	*43%*	*37%*	*61%*	*42%*	*28%*	*15%*	*9%*	*5%*
ex-China & Indonesia	**1239**	**1218**	**1186**	**1121**	**1057**	**1118**	**1150**	**1200**	**1216**
% change y/y	*-5%*	*-2%*	*-3%*	*-5%*	*-6%*	*6%*	*3%*	*4%*	*1%*
Global Battery Scrap Supply						16	20	24	55
Global Balance	**-193**	**-166**	**-75**	**62**	**-162**	**-85**	**-43**	**37**	**6**
Cash Prices (annual average)									
Current dollars ($/t)	10414	13118	13944	13803	18474	34650	37500	32500	30000
Current dollars (c/lb)	472	595	632	626	838	1572	1701	1474	1361

Disclosure Appendix

Reg AC

We, Nicholas Snowdon, Aditi Rai, Annalisa Schiavon, Daniel Sharp and Jeffrey Currie, hereby certify that all of the views expressed in this report accurately reflect our personal views, which have not been influenced by considerations of the firm's business or client relationships.

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