

## European Metals & Mining

# Metals & Mining: HeyPAL...got any nickel? Spotlight on the global nickel market and supplying the electric vehicle industry

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At the start of this month, we attended the Metal Bulletin International Nickel Conference in Toronto and visited Vale's nickel operations. This report outlines our thoughts on the nickel market, issues for current and future supply, the potential for electric vehicle demand and implications for higher future nickel prices.

**The great debate – where will battery-grade nickel come from? The solution – High Pressure Acid Leaching (HPAL) – has a history of dramatic cost overruns.** Sulphide ore sources are running out, and lateritic ore sources are currently mostly geared towards stainless steel production. So where do we get nickel for EVs? More nickel sulphide mines? HPAL? Conversion of Nickel Pig Iron (NPI)/ferronickel? We think it will likely be through more HPAL in places like Indonesia that we will get our nickel battery feed (purity, cobalt content and ore availability are key positives).

**General optimism on prices.** In the near term, underlying stainless steel demand (70%+ of nickel demand currently) has rebounded strongly from its 2015 blip. We have seen exchange stocks of nickel fall very quickly since the start of 2018, indicating that the market is tightening, and there is a general consensus that the market is in deficit.

Structurally, nickel industry grades are declining (similar to copper). Environmental issues in China (that we highlighted in our iron ore work) are beginning to have an impact in the nickel market too: we have seen shutdowns in Chinese NPI production over the past month or two. Finally, we have seen nickel growth capex decline significantly in recent years, raising the prospect of production declines in 4-5 years.

**Indonesia back in the game.** The ore export ban was lifted last year, and Indonesia is back in the game. During the ban period, Indonesia has become a much bigger player in Nickel Pig Iron production, and has also developed its first stainless steel capacity.

To what extent will Indonesian stainless capacity continue to grow, and to what extent will Indonesia grow in High Pressure Acid Leach for the battery market? Environmental issues regarding the disposal of leach process tailings will be significant. We have seen the government take on Grasberg over its river tailings disposal system, and whilst this was a politically-motivated move, it shows the government's willingness to use environmental issues as leverage over producers. As the world's largest nickel producer, Indonesia's geopolitical risk will remain a critical issue for the global nickel market.

**Geological pressures + lack of investment + geopolitical risk + EV demand pull = higher required prices.** Our base case nickel price of US\$18,500/t in 2021 is well above consensus at US\$14,735/t, and we still see further upside from higher electric vehicle demand.



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Bernstein Events



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## TICKER TABLE

Ticker	Rating		12 Jun 2018	Target Price	TTM Rel. Perf.		EPS Adjusted			EV/EBITDA		
			Closing Price				2017A	2018E	2019E	2017A	2018E	2019E
AAL.LN	O	GBP	1,873.20	1,800.00	66.6%	USD	1.72	2.57	2.71	6.86	4.72	4.76
ANTO.LN	O	GBP	1,092.50	1,000.00	31.7%	USD	0.76	0.87	1.08	6.38	5.89	5.31
BHP	M	USD	51.83	47.19	33.2%	USD	4.06	5.17	5.48	7.55	6.88	6.75
BHP.AU	M	AUD	33.69	29.53	28.7%	USD	2.03	2.59	2.74	7.50	6.84	6.71
BLT.LN	M	GBP	1,768.80	1,500.00	44.2%	USD	1.23	1.56	1.65	7.50	6.84	6.71
BBL	M	USD	47.34	41.53	41.4%	USD	6.19	7.87	8.34	7.53	6.87	6.74
FM.CN	O	CAD	21.31	26.00	64.4%	USD	(0.16)	1.18	1.69	14.68	7.92	5.68
GLEN.LN	O	GBP	389.00	500.00	33.5%	USD	0.39	0.52	0.81	7.18	5.71	4.56
IVN.CN	O	CAD	3.35	15.00	(33.0)%	USD	0.22	(0.13)	(0.09)	9.06	(22.58)	28.47
RIO.LN	O	GBP	4,419.00	4,500.00	34.0%	USD	4.85	4.84	4.72	5.84	6.22	6.37
RIO	O	USD	59.10	64.46	29.5%	USD	4.85	4.84	4.72	5.87	6.25	6.40
S32.LN	M	GBP	218.60	170.00	33.4%	USD	0.22	0.20	0.20	5.55	6.21	6.18
S32.AU	M	AUD	3.79	2.79	29.2%	AUD	0.28	0.26	0.26			
S32.SJ	M	ZAR	3,810.00	2,701.54	44.6%	ZAR	2.83	2.60	2.57			
VALE3.BZ	O	BRL	50.85	50.00	76.5%	USD	1.23	1.62	1.80	5.66	5.23	4.91
VALE	O	USD	13.69	14.61	53.9%	USD	1.23	1.62	1.80	5.66	5.23	4.91
MSDLE15			1,606.40				101.31	109.65	118.48	15.86	14.65	13.56
MXAPJ			573.43				42.01	46.28	50.89	13.65	12.39	11.27
MXEF			1,139.46				93.07	103.24	114.52	12.24	11.04	9.95
SPX			2,782.00				129.72	157.87	173.14	21.45	17.62	16.07

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

AAL.LN,ANTO.LN,BHP,BLT.LN,BBL,FM.CN,GLEN.LN,IVN.CN,RIO.LN,RIO,S32.LN,S32.SJ,VALE3.BZ,VALE close date is 06/11/2018:

## INVESTMENT IMPLICATIONS

We came away from the recent International Nickel Conference with increased confidence in our views around the nickel market. We see nickel prices as needing to move higher purely based on expected continued growth in stainless steel alone, and when any kind of assumption on electric vehicle demand is layered on top of that, our view of what would constitute a "required" or "equilibrium" nickel price would move even higher still.

Within our coverage, we see Glencore as the preferred exposure to the electric vehicle theme, being the only company within our coverage providing meaningful exposure to all three of our preferred electric vehicle theme metals: copper, nickel and cobalt. Indeed, Glencore is one of the few mining stocks globally where meaningful exposure to mined cobalt production can be found, the company providing as it does c.40% of the world's cobalt at present (and this set to increase over the coming years). On top of this, Glencore is the world's third-largest nickel producer (after Vale and Nor Nickel), is investing in new nickel projects (Onaping Deeps in the Sudbury Basin) as well as ramping up Koniambo, and we expect nickel to be >10% of EBITDA generated by 2023 on our current base case price deck, up from just 4% in 2017.

We also like Vale for their nickel exposure, being the largest producer of nickel in the world, with some high-quality nickel product offerings that command significant market premia, and with optionality in the nickel portfolio to pivot production towards battery-suitable materials in order to capture any incremental market premiums for those products. We expect the nickel operations to be >18% of EBITDA generated by 2023 on our current base case price deck, up from 6% in 2017.

Given that our base case nickel prices incorporate little to no demand growth from the electric vehicle battery segment, we see the potential for incremental upside to our base case price forecasts if indeed significant electric vehicle penetration rates do materialise.

## DETAILS

### FOCUS ON NICKEL

At the start of this month, we visited Vale at their Totten nickel mine in the Sudbury Basin and attended the Metal Bulletin International Nickel Conference in Toronto. The former will be the subject of a later note, but this report lays out our thoughts on nickel market, issues for current and future supply, the potential for electric vehicle demand and implications for higher future prices using insights from the Toronto conference to both corroborate and augment our previous analysis.

We came away from the conference with increased confidence in our views around the nickel market with regards the supply side challenges that we see in supplying the burgeoning electric vehicle battery demand segment.

We see nickel prices as needing to move higher purely based on expected continued growth in stainless steel alone, and when any kind of assumption on electric vehicle demand is layered on top of that, our view of what would constitute a "required" or "equilibrium" nickel price would move even higher still (as we showed in our recent note [Electric Revolution 2018: The Resistance, Part 3 - Raw material bottlenecks in the EV supply chain](#)) see Exhibit 1.

#### The great debate – where will we get incremental battery-grade nickel from?

- + Sulphide ore sources – traditionally the mainstay of the nickel industry as a whole – are running out, and lateritic ore sources are currently largely geared towards production of nickel units for use in the stainless steel industry. It seems clear that if we are to deliver electric vehicles in the future, change is needed. But what? More nickel sulphide mines? High Pressure Acid Leach? Conversion of NPI/ferronickel? We explain why we think it will probably be through more HPAL in places like Indonesia that we will feed EV battery demand. . .but that this will require much higher nickel prices. We see HPAL as the solution, but the history of HPAL projects is one of dramatic cost overruns and ramp-up delays.

#### General optimism on prices

- + Underlying stainless steel demand has rebounded strongly from its 2015 blip. As we have cautioned before, simply looking at monthly, or even yearly, growth rates can lead to much confusion and over-interpretation of the production data series! It is not surprising to us that stainless steel demand has rebounded to the c.5% level.
- + We have seen exchange stocks of nickel fall very quickly since the start of 2018, indicating that the market is tightening; there is a consensus from within the industry, nickel trade bodies and industry consultants, that the market is in deficit.
- + As a more structural feature, nickel industry grades are declining. We have previously made this point with regards the copper industry, and indeed the phenomenon forms one part (of many) of our positive thesis regarding copper prices. However, the same is just as true of the nickel industry.
- + Environmental issues are also starting to affect the nickel industry. We have discussed Chinese environmental issues in our recent iron ore work, and it seems that these are also starting to bite in nickel. For instance, we have seen shutdowns in Chinese NPI production over the past month or two.
- + Finally, we note that (like copper) we have seen a significant reduction in growth capex over the past six years. When investment dries up, the natural depletion rate of the industry comes to the fore several years down the line. The output of the current production base, plus highly probably projects (i.e. broadly those projects already commenced/sanctioned) will peak in 2020 and then decline at c.2.4% CAGR to 2030. Given the significant time lags involved in mining project investment and development, we need to start sanctioning investment now to avoid these impending declines in output.

#### Indonesia back in the games

- + In 2014, Indonesia implemented a ban on the export of nickel ores from the country in a bid to encourage investment in value-added processes within Indonesia itself. In anticipation of the ore export ban coming into place, China imported massive amounts of ore and stockpiled it, as well as pivoting towards imports from the Philippines. However, with the conditional relaxation of the ore ban in 2017, and limited export licences issued to various companies, Indonesian nickel ore exports are expected to increase once more.

- + From the Indonesian government point of view, the ore ban has worked in one sense, and value-added processes have indeed been brought into the country. As such, Indonesian nickel pig iron exports have emerged and grown since 2013 onwards, and are expected to continue to grow. At the moment, the export ban relaxation officially lasts until 11<sup>th</sup> January 2022, so without further changes, all ore exports must stop by that date. The key question is whether that will remain the case.
- + In addition to smelting capacity, Chinese companies have recently started to go one step further and build stainless steel capacity within Indonesia. A key question is the extent to which Indonesian stainless capacity will continue to grow.
- + Another key question is the extent to which Indonesia will grow in HPAL...both Tsingshan and Jinchuan are reportedly looking at the potential for HPAL plants to produce Mixed Hydroxide Precipitate products containing nickel and cobalt that could then be processed for batteries in China. However, time lags (Tsingshan looked at making stainless in Indonesia for 10 years before it became a reality) and price expectations – as well as expectations around capital costs and the realities of environmental permitting – will all need to be considered here.
  - o Environmental issues regarding the disposal of leach process tailings will be significant. We have seen the government take on Grasberg over its river tailings disposal system, and whilst this was a politically-motivated move, it shows the government's willingness to use environmental issues as leverage over producers.
- + As the world's largest producer of nickel, Indonesia's geopolitical risk will remain a critical issue for nickel globally. We have already seen significant government intervention in the industry with divestment requirements, increased royalties, export bans etc., and this could potentially have a significant impact on the global nickel industry in the future.

**EXHIBIT 1: Summary of estimated price scenarios by electric vehicle scenarios, and relative to current prices**

Price by Scenario	Cu	Ni	Co	Li
Spot	7,261	15,472	82,750	18,500
ex EV	8,746	19,084	-21,975	5,370
Govt. Targets	10,750	58,296	132,922	12,072
Rapid Adoption	11,620	74,560	192,523	13,845
Slow Adoption	9,549	35,383	43,431	8,986

Govt Scenarios	Cu	Ni	Co	Li
Spot	7,261	15,472	82,750	18,500
Govt Targets Avg.	10,750	58,296	132,922	12,072
Upside/(Downside)	48.0%	276.8%	60.6%	(34.7%)

Slow Adoption	Cu	Ni	Co	Li
Spot	7,261	15,472	82,750	18,500
Slow Adoption	9,549	35,383	43,431	8,986
Upside/(Downside)	31.5%	128.7%	(47.5%)	(51.4%)

Source: Bloomberg, SNE, SNL, Cobalt Development Institute, Wood Mackenzie, Bernstein estimates and analysis

## THE GREAT DEBATE - WHERE WILL BATTERY-GRADE NICKEL COME FROM?

### ELECTRIC VEHICLES CREATE POTENTIAL INCREMENTAL DEMAND PULL FOR NICKEL

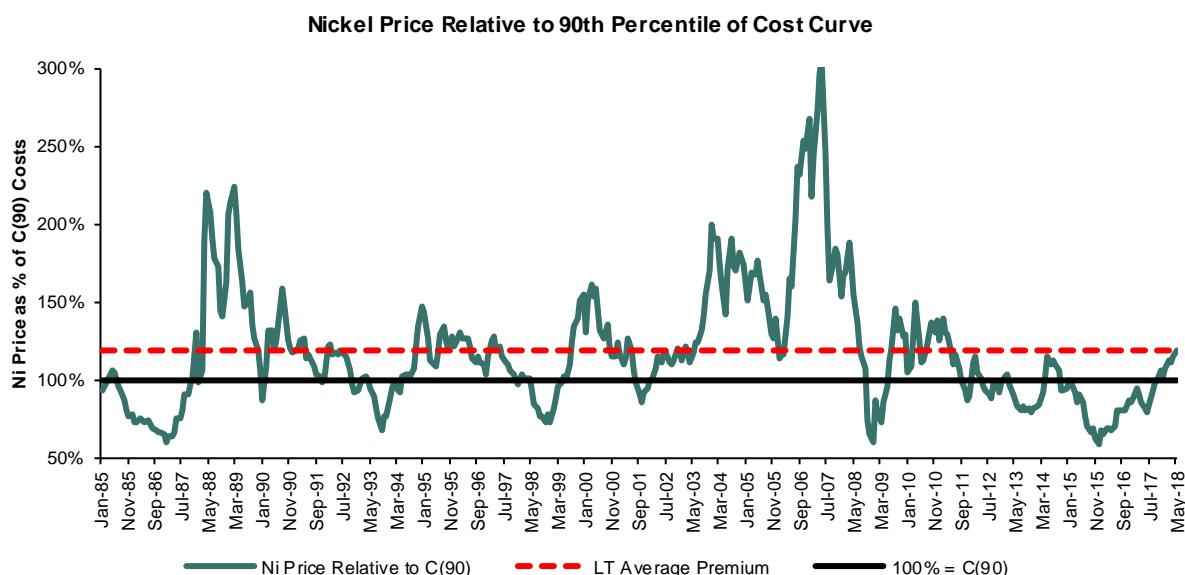
It was joked in Toronto that this was a battery conference masquerading as a nickel conference. That is perhaps unsurprising, given the increasing fervour in the market regarding electric vehicles, and the potential impact that any significant electrification of global transport would have on the nickel market.

Judging by this conference and our interactions with numerous sources, it seems largely consensual that NMC, and to a lesser extent NCA, lithium-ion battery chemistries will form the cathode materials of choice for at least the medium term. Indeed, our own work over the past few years has highlighted just how significant the impact of vehicle electrification could be on the nickel market ([Metals & Mining: Lithium, nickel or cobalt? Where does the electric vehicle bottleneck sit?](#), [Electric Revolution 2018: The Resistance, Part 3 - Raw material bottlenecks in the EV supply chain](#)).

When you combine the potential demand-pull from electric vehicle batteries with the fact that the "traditional" nickel market has itself been relatively depressed for many years now, with prices at times cutting deep into the cost curve (more so than even for other commodities towards which we have been positively predisposed over the years such as copper – see Exhibit 2), the price upside potential becomes clear.

We would note that much of the recent press coverage in terms of electric vehicles, and indeed the communications coming directly from the vehicle manufacturers themselves, has been about reducing cobalt loadings in the battery cathode – and indeed a move towards lower cobalt loadings has been factored into all our previous analysis of the electric vehicle theme. But what this press coverage and auto-maker statements ignore is that the direct corollary of reducing cobalt loadings is an increase in nickel loadings. This sounds great with cobalt over US\$80,000/t, concerns prevalent regarding the situation in the DRC, and nickel having until very recently only been at c.US\$12-13,000/t. However, it does gloss over the major issues we face to deliver the kinds of incremental battery-suitable nickel units that will be required if we are to significantly electrify our global vehicle fleet.

**EXHIBIT 2: Nickel prices cut deep into the cost curve for many years, and have only recently recovered to any appreciable extent...some of this has been helped by the higher cobalt price driving higher by-product credits for nickel producers**



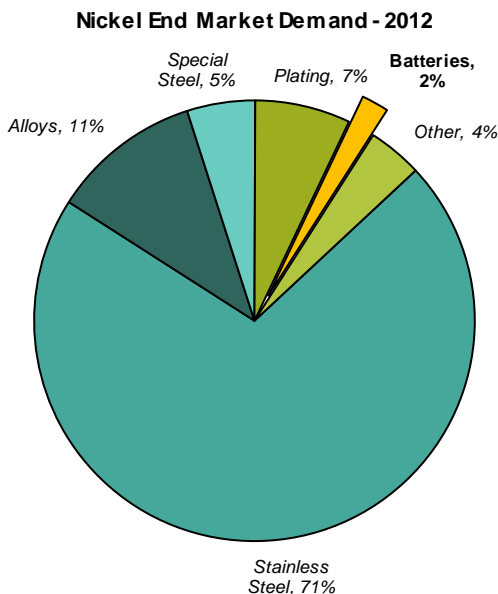
Source: Wood Mackenzie, Bloomberg, Bernstein analysis

Whilst the excitement regarding electric vehicles as a nickel demand source is growing, it is important to remember that actual physical demand for battery nickel is still very small indeed. Estimates of exact size differ, but all are within the low single digit

range – Nornickel (formerly Norilsk), for example, estimated 5% for 2017 (Exhibits 3 & 4). It is, however, the fastest growing segment, and of course the extent to which one expects that to continue to grow depends on one's assumptions regarding the speed, extent and exact form of electric vehicle adoption. The fact that nickel prices have strengthened so promisingly, then, is in fact more indicative of underlying strength in stainless steel demand, but more on that later. What is interesting, however, is that, since the start of this year, it is inventory stocks of a certain form of nickel, briquettes, that have declined most significantly. Given their suitability for dissolving into a nickel sulphate product, the nickel-containing material required in electric vehicle battery manufacturing, this is perhaps indicative that battery demand is indeed starting to have a differentiated impact on the nickel supply side.

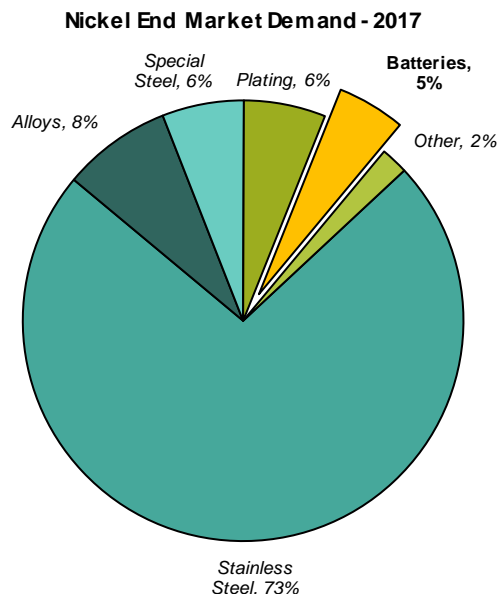
As we've said, however, one's view on the growth of the battery demand segment for nickel depends on one's view of how vehicle electrification plays out. Our own estimates, under the three different electric vehicle scenarios that we described in our recent *Blackbook* on the EV theme ([Electric Revolution 2018: The Resistance](#)), are shown in Exhibit 5, where we can see a range of EV nickel demand in 2025 of 221-445kt. At the conference, Nornickel mentioned a potential EV nickel demand by 2025 of 440kt. That is versus a current nickel market size of c.2,200kt.

EXHIBIT 3: **Nickel demand for batteries has grown...**



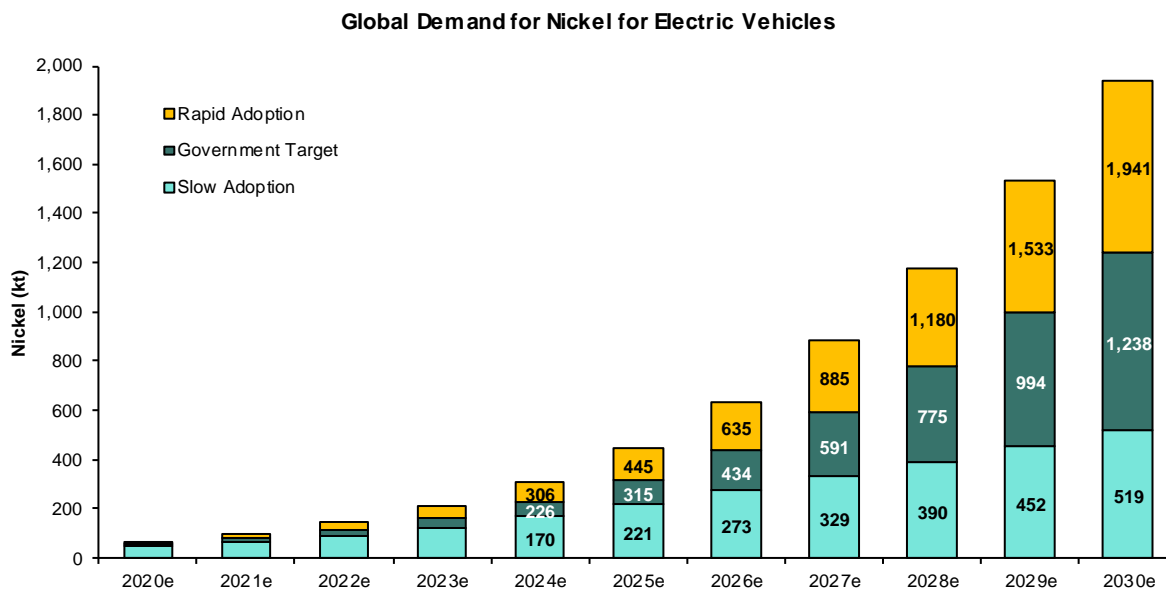
Source: Corporate reports, Bernstein analysis

EXHIBIT 4: **...but at present remains a very small part of the overall demand picture**



Source: Corporate reports, Bernstein analysis

**EXHIBIT 5: The Bernstein scenarios for electric vehicle adoption and the requirements they would imply for nickel: potentially very significant incremental demand versus a current nickel market size of c.2,200kt**



Source: Bernstein estimates and analysis

### NOT ALL NICKEL IS EQUAL WHEN IT COMES TO ELECTRIC VEHICLES

We think the key when it comes to nickel, however, is the supply side. Not all nickel is equal, and particularly when it comes to batteries. Nickel sulphate is what battery makers need, and whilst in theory nickel sulphate can be made from almost any nickel product, the ease, cost and effectiveness of doing so varies widely by ore/processing/product type.

As we have noted before, there are broadly two types of nickel ore bodies, the nickel sulphides and the nickel laterites. Sulphides were the mainstay of the nickel industry for many years, and are mined (both open pit and underground), concentrated, smelted (to make an intermediate product known as a matte) and then refined in a broadly similar processing route to the typical route for the primary copper industry today. This produces what is known as a Class 1 nickel, with a nickel content of at least 99.8%, which can take different physical forms (depending on the refining route), including powders, briquettes, pellets and cathode. These can then be used to make nickel sulphate, in essence by dissolving the nickel metal product in a sulphuric acid and introducing oxygen-containing gas. Some forms dissolve more easily/cost-effectively than others (powders and briquettes, for example, dissolve well).

We can then split the laterite (oxide) ores into two groups: the limonite ores and the saprolite ores. Typically, both ore types will be present in a laterite orebody (Exhibit 6), which are almost exclusively exploited via open pit operations given that they are generally large in area and relatively shallow. These tend to be found in tropical locations, particularly Indonesia and the Philippines, and are formed by the progressive weathering of bedrock.

Rain water, made slightly acidic through interaction with the atmosphere and decaying vegetation, leaches the rock as it passes downwards. More soluble components, such as magnesium, are leached from the profile, while the least soluble elements, like iron and aluminium, are preferentially concentrated towards the top of the profile. Elements with moderate solubility like nickel are initially leached, but then reprecipitated further down the profile as the acidity of the water changes as it interacts with less weathered, more alkaline rocks. The rate of weathering is controlled by the amount of rainfall and the permeability of the bedrock.

As a result of this process, and as we can see from Exhibit 4, the chemical composition of the laterite ore bodies changes as one gets deeper, with the limonite generally consisting of a layer above the saprolite, with a lower nickel content, higher iron and cobalt content, and lower magnesia content (the fact that the saprolite ores have higher magnesia content is what makes them

unsuitable for the High Pressure Acid Leach processes that we discuss later given the high levels of acid that the magnesia consumes in the HPAL process).

### **DIFFERENT ORE TYPES → DIFFERENT PROCESSING ROUTES → DIFFERENT NICKEL PRODUCTS**

The differing characteristics of these ore types leads to them being processed in different ways, thus generating different nickel products – a rough schematic of these processing routes is shown in Exhibit 6. As we can see, the saprolite zone of the lateritic ore bodies is generally processed by either the blast furnace or the Rotary Kiln Electric Furnace (RKEF) route, typically to generate a Ferronickel or Nickel Pig Iron product, which is then used in stainless steel making – as we can see, the unit nickel content of these products is relatively low, but one also gets the "bonus" iron units in your stainless melt shop feed.

However, the big issue facing the nickel industry supply side, at the same time as this potential demand-pull from electric vehicles is looming on the horizon, is the exhaustion of the sulphide nickel deposits (Exhibit 8). Of the world's undeveloped resources, only 20% are sulphide deposits, and only 4% are *high grade* sulphide deposits. It is for this reason that many at the conference were in agreement with our view that, if widespread EV adoption is going to become a reality, we will need to begin to source nickel units for the battery market from the lateritic ore bodies that are largely currently used (largely) to produce ferronickel and NPI, and which currently end up in the stainless steel industry.

There is some flexibility in the short term, given that at the moment there is a portion of global nickel output that would currently be feasible, in theory, for battery materials, but which is currently flowing into the stainless steel industry. Whilst we believe that there is some Class 1 nickel that will always be required for the stainless steel industry to ensure an adequate supply of nickel units (ferronickel and NPI having much lower nickel content, as we have seen), there is clearly some scope to switch some of the battery-suitable material currently going to stainless into the battery market (Exhibit 9).

### **CHINA IMPORTING MORE BATTERY-SUITABLE NICKEL PRODUCT**

This substitution will likely come from easily-dissolvable products such as briquettes, and indeed we have seen LME briquette stocks fall this year from 290kt to 230kt, a decline of over 20% in the space of five months (Exhibit 10), whilst the estimated Chinese imports of briquette (China, of course, being the predominant location of battery material manufacture), have risen significantly in recent quarters (Exhibit 11).

With remaining LME briquette stocks of c.230kt, this can likely tide the battery industry over for a few years (depending, of course, on your EV demand outlook), but beyond this, to supply the EV battery market on a sustainable basis, we are clearly going to need to generate nickel units for the battery market from laterite deposits. Indeed, anecdotal evidence recounted at the conference indicated that some battery precursor material manufacturers are currently unsure of exactly where they are going to get their nickel feed from on an ongoing basis! Some point to briquette stocks, but clearly these will only last so long.

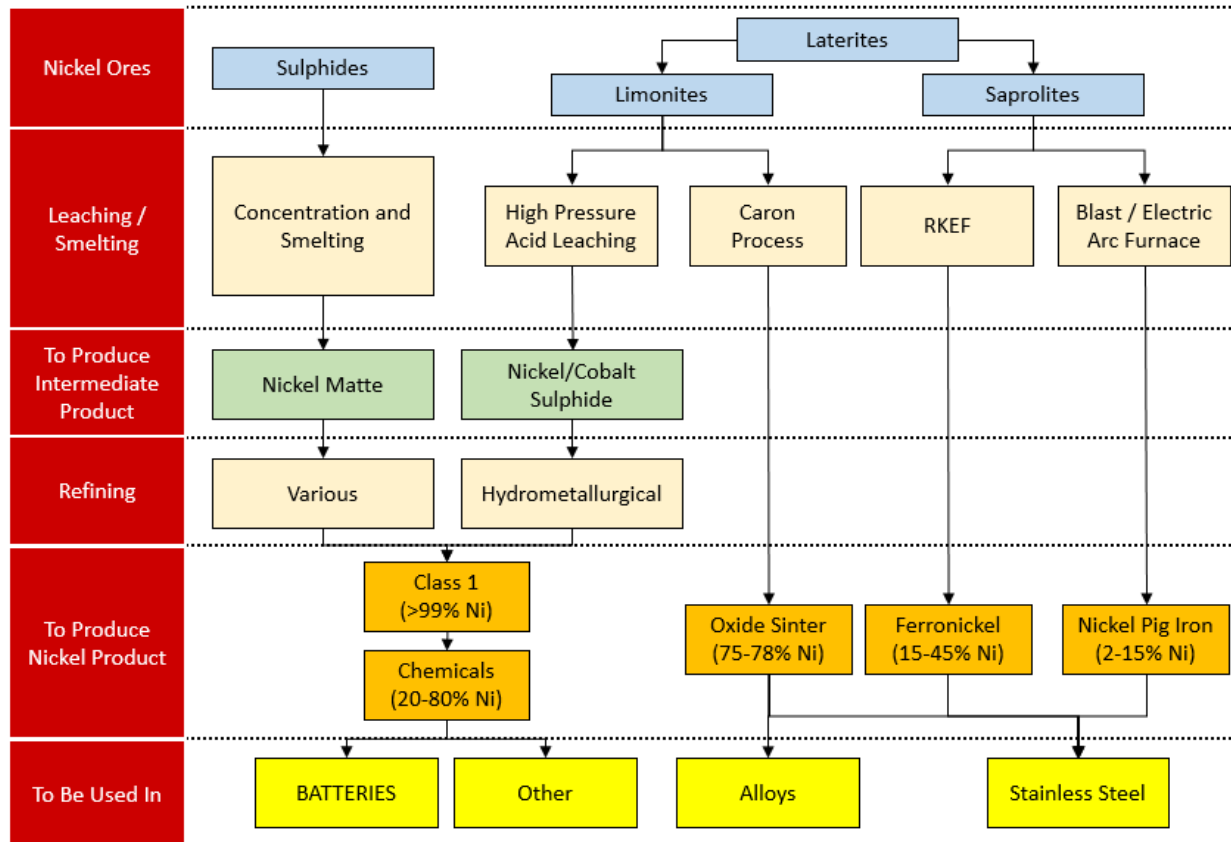


EXHIBIT 6: Schematic of "typical" lateritic nickel deposit (e.g. found in Indonesia or the Philippines)

LATERITE ORE BODY	Ni%	Fe%	Co%	MgO%
Red Limonite	<0.7%	>50%	<0.1%	>0.5%
Yellow Limonite	0.7-1.1%	>45%	<0.1%	>2%
	1.1-1.6%	30-45%	0.1-0.2%	<5%
Transition	1.5-1.8%	20-30%	0.1%	5-15%
Saprolite	1.5-1.8%	15-25%	<0.1%	15-25%
	>1.8%	10-20%	<0.05%	15-25%
Non-Ore	>0.3%	5%	0.01%	35-45%

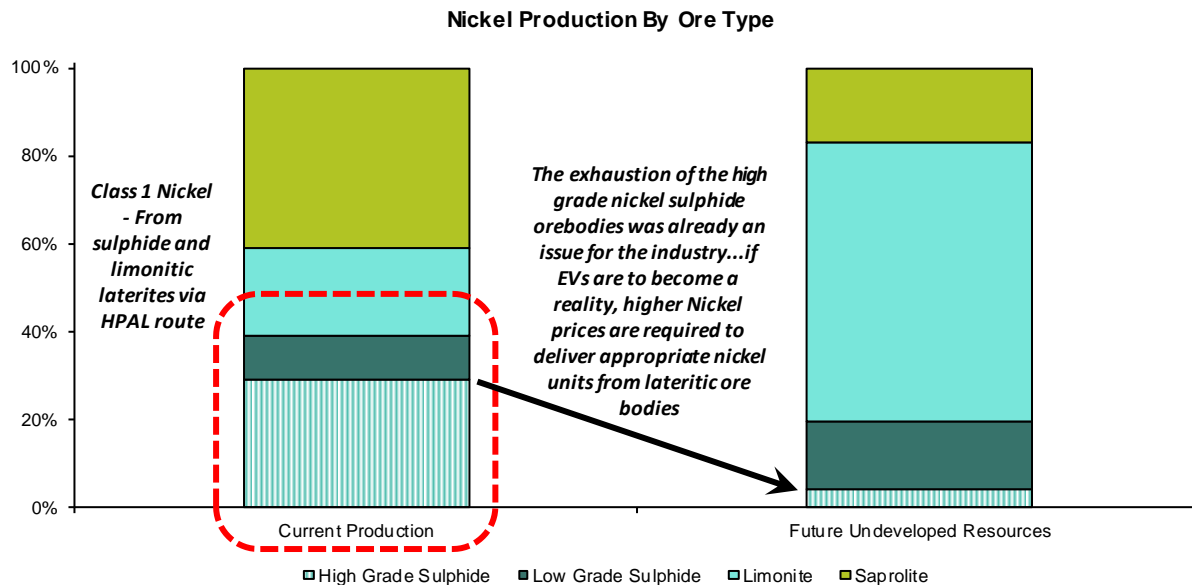
Source: AME, Bernstein analysis

EXHIBIT 7: Major processing routes for nickel ores and their applications



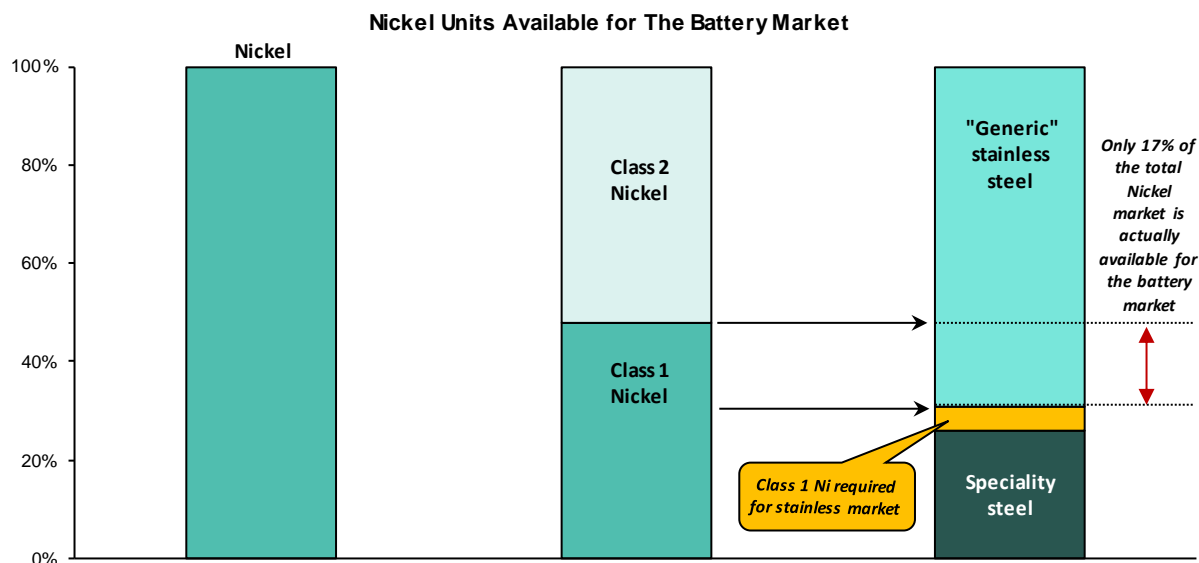
Source: Schmidt et al., Bernstein analysis

**EXHIBIT 8: As we have shown before, there is very little nickel sulphide left to be developed, and the majority of future resources are limonites...**



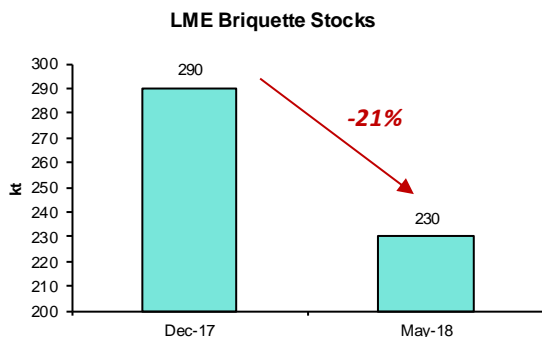
Source: Vale, Bernstein analysis

**EXHIBIT 9: ...there is some scope for substitution of Class 1 nickel out of the stainless steel industry, but beyond that we will need to develop more sources of battery-suitable nickel units**



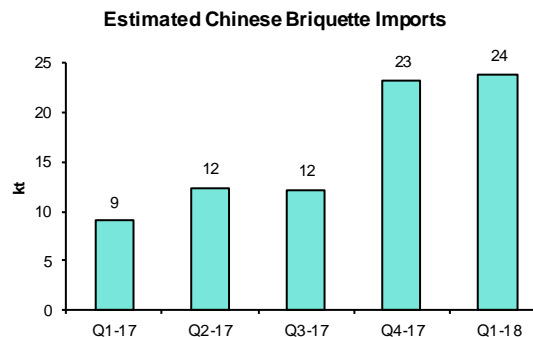
Source: Vale, Bernstein analysis

EXHIBIT 10: **Briquette stocks have come down significantly this year...**



Source: Nornickel, Bernstein analysis

EXHIBIT 11: **...whilst China is importing more briquette**



Source: Nornickel, Bernstein analysis

**SO, WHERE DO WE GET OUR EV BATTERY NICKEL FROM?**

This is where the first part of the big debate really starts: where will we get these electric vehicle battery nickel units from exactly? There are four options to generate battery-suitable nickel units:

1. Build more sulphide capacity
2. Build more High Pressure Acid Leaching capacity
3. Dissolution of NPI product directly
4. Build additional processing steps into ferronickel/NPI streams i.e. add a conversion facility after the blast furnace to remove the iron, which would produce a nickel matte which could then be refined in a similar way to the intermediate matte product produced via the sulphide deposit route

**Option 1:** The issue with option one is that there simply isn't the nickel sulphide resource base available to satiate any reasonable degree of EV battery nickel demand. In the near term, the fact that persistently low nickel prices over many years has stifled any investment in such capacity means that, if anything, production from these sources is falling.

The two largest producers globally, Vale and Nornickel, have little to no upside in their production expectations over the next 3-5 years. Whilst Glencore is adding volume over this period through the Koniombo ramp-up (which is itself, of course, a ferronickel project in any event) and subsequent development of Onaping Deeps (a new mine in Sudbury, Ontario), in the context of the global nickel market this is small.

So, whilst Vale is once more investing in its nickel operations within the mine sites themselves (i.e. not just investment in sulphur emission technology to comply with environmental regulations), this is largely to improve the profitability of those operations rather than grow production. Indeed, the production footprint of these operations has recently been *reduced* for the next five years compared with previous plans.

In addition to this, we would see the "incentive" price for sulphide projects as comfortably higher than recent nickel prices in any event – figures of US\$18,000/t were regularly discussed in this regard in Toronto, and if we (probably quite generously) believe that the capital intensity of greenfield sulphide deposits is somewhere in the US\$30-40,000/t, with construction and ramp-up period somewhere between 4-6 years, we would estimate a nickel price of something in the US\$18-22,000/t range in order to generate a 15% IRR.

**Option 2:** This brings us to options two, three and four, all of which entail generating battery-suitable feed from lateritic ore, and all of which present their own challenges and uncertainties. Whilst the HPAL route, option one, utilises limonitic ore, the other two options would utilise saprolite ore.

HPAL appears as an attractive solution given the relative availability of limonitic compared with other types of nickel ore (refer back to Exhibit 8), and Indonesia in particular, with its large limonite nickel reserves looks a solid candidate to potentially be a significant player. However, HPAL certainly has its drawbacks! The HPAL process involves leaching laterite ore in sulphuric acid within titanium-lined autoclaves at up to 270°C, and pressures of up to 45 atmospheres. So, ore is mined and crushed to create a fine material, and these fines are mixed with water to create a slurry which is then preheated. This hot slurry is pumped into an autoclave (a giant pressure cooker of sorts) where acid is added. The slurry and acid then react as they flow through several compartments within the autoclave. Solvent extraction is used to separate nickel (and cobalt) from solution as metal, or the nickel is precipitated as an intermediate product (oxide, hydroxide or sulphide concentrate).

One drawback of this route is that the capital requirements are high, and this means that projects must be quite large in order to be economic. This is an extremely challenging technical process given the pressures and temperatures involved, and we have seen numerous recent projects get into financial and operating difficulties which has seen capital intensities rise dramatically vs. expectations, construction and ramp-up schedules lengthen, and nameplate planned capacities never even achieved. The experience of the HPAL projects highlighted in Exhibit 12, as well as the difficulties that BHP Billiton had with Ravensthorpe – now owned by First Quantum and currently on care and maintenance – are testament to that fact.

### How much is HPAL going to cost, and what does it mean for prices?

Given the history of HPAL projects, the question for this processing route turns on the capital intensity of new projects – will companies have learned the lessons from the past, and avoid the huge capex blow-outs and production difficulties we have witnessed? Or will they be dogged with the same issues of a fundamentally difficult processing route?

If it's the latter, then these hypothetical projects would need far, far higher nickel prices, above US\$30,000/t in order to generate value, whilst even if they can get their capital intensity of investment down to US\$40,000/t, we would still need higher nickel prices than currently prevailing in the market (US\$15,000/t) unless cobalt moves another leg higher still. This *"if they can get their capital intensity of investment down to US\$40,000/t"* however, is a big if, in our view. Whilst some conference delegates claimed that the Chinese nickel producers believe that they can do HPAL at US\$40,000/t or less, and hence have an "incentive price" of maybe even just US\$15,000/t nickel, we feel this is a very optimistic view.

From a Chinese point of view, the choice would then become whether to import the ore and build the plant in China or Indonesia (for example). China has the advantage of access to sulphuric acid – required, of course, in the HPAL process – but the cost of transporting bulk ore. In Indonesia, sulphuric acid itself would either need to be purchased from the market – bumping up operating costs – or would need to be generated from a constructed acid plant – bumping up initial capital costs.

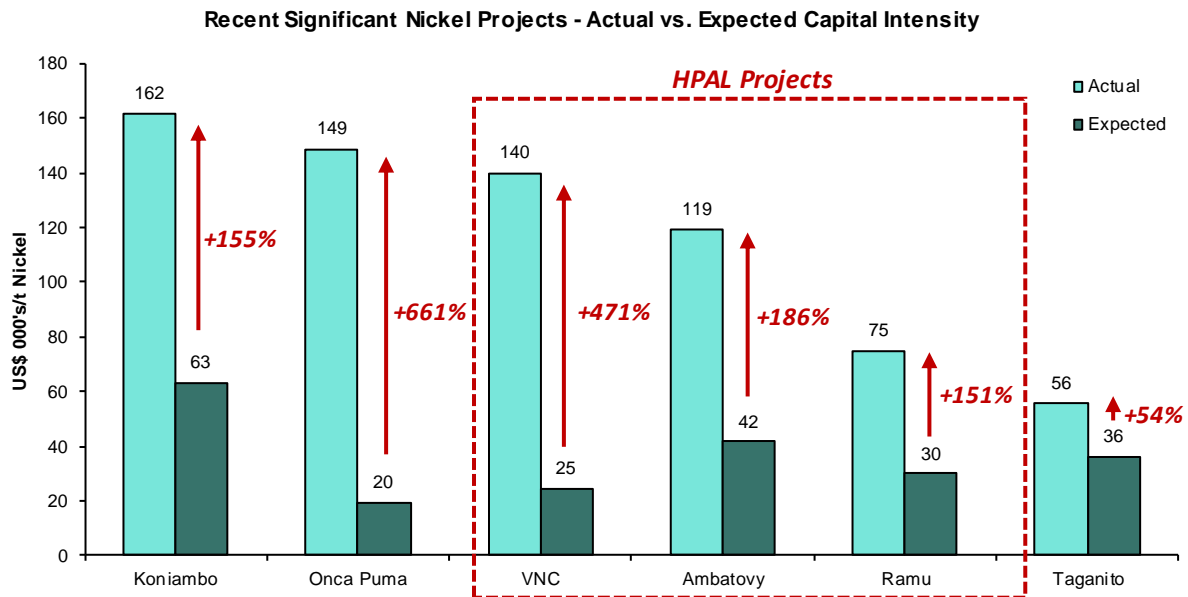
The other issue, particularly for any HPAL constructed in Indonesia or the Philippines, is the need to dispose of the residual tailings from the acid leach process. Given the events in the Philippines, where environmental issues have blown-up significantly over recent years, this would clearly be a significant problem, whilst in Indonesia we have recently seen the government take on Grasberg over its river tailings disposal system. Whilst this was largely a politically-motivated, rather than environmentally-motivated, move, at the very least it highlights the government's willingness to use environmental issues as leverage over producers in the country. It was noted at the conference that one potential option for HPAL tailings in Indonesia was seabed disposal. One would question whether considering the use of this kind of disposal method is one of the reasons why the Chinese companies might think they can build HPAL at lower capital intensities than previous projects. In our view, however, the solution to the high capital intensity of production of a required commodity is simply not to externalise the costs of the production process; a desire for cheap nickel units cannot justify cutting costs by adopting a less costly method of tailings disposal that happens instead to be pollutive of the environment.

Given the technical complexities of HPAL as a process, the so-called "Bermuda Triangle of HPAL" (Exhibit 13), the history of project difficulties and dramatic capex escalation, and the very significant issues regarding disposal of residual tailings from the process, we believe that one should be cautious regarding any estimate of capital intensity of future HPAL projects. In Exhibit 14 we estimate the nickel price that would be required to generate a 15% IRR for an HPAL nickel project at various capital intensity and cobalt price assumptions. However, we believe that the appropriate range is likely given in Exhibit 15 – at a capital intensity of ~US\$60,000/t – of c.US\$22-27,000/t. Of course, we show the sensitivity up to a capital intensity of US\$100/t Ni, and as we have seen in Exhibit 12, previous HPAL projects have even topped this.

We believe it is unlikely that anyone would build another HPAL project now if they thought it was going to cost them US\$100,000/t of nickel output. As we have noted, some companies appear to believe that they can do it much cheaper than

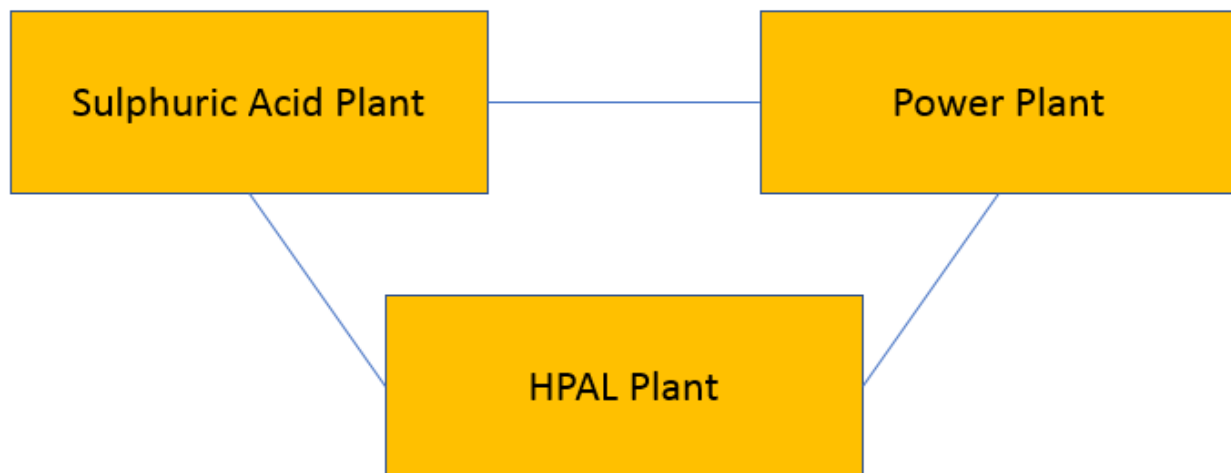
previous projects. If this is true, there is perhaps a minor downside risk that some capacity comes online in the belief that it can be achieved at a lower capital intensity than in the past, even if that turns out not to be true. However, one would hope at the very least that companies now, having witnessed the history of HPAL, would at least build-in greater *capital contingencies* into their economic assessments, thus raising the *effective* capital intensity of those investments. Even if this is not the case, it would only take the example of another project blowing up in terms of capex/opex/delays in Indonesia for people to rapidly re-assess their idea of how much these investments will cost in practice.

**EXHIBIT 12: The recent history of large-scale nickel project development contains some absolute disasters...several of them HPAL projects seeking to exploit laterite ore bodies**



Source: Corporate reports, Wood Mackenzie, Bernstein analysis

**EXHIBIT 13: The so-called "Bermuda Triangle of HPAL". When producing under high pressure, any change in the chemical composition of the ore feed can severely impact the production capability, and a problem at any one of the three plants shown here leads to a production stoppage...**



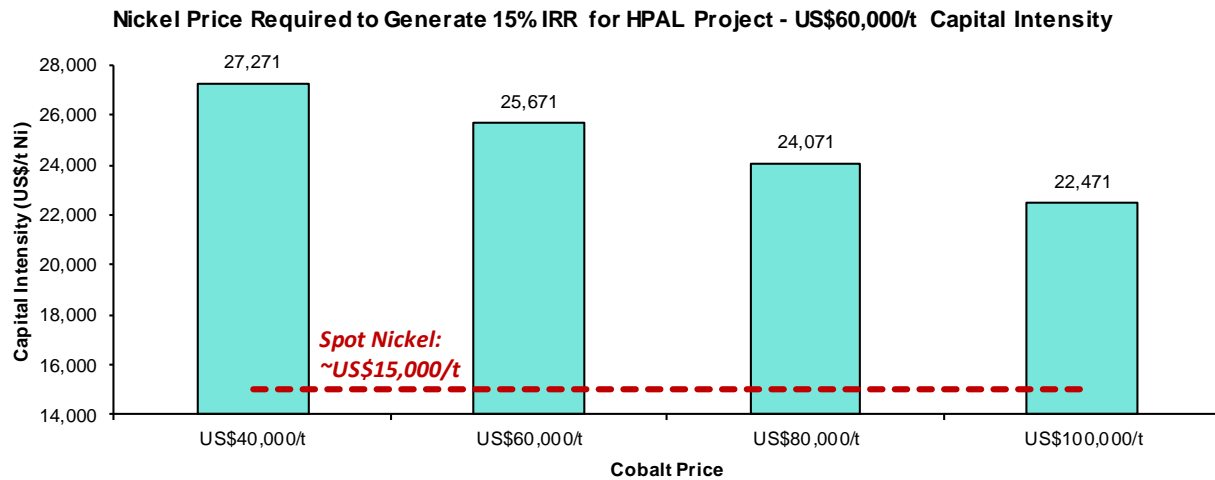
Source: Bernstein

EXHIBIT 14: **Sensitivity of nickel price required to generate 15% IRR on HPAL project at various capital intensity and cobalt price assumptions**

		HPAL Capital Intensity (US\$/t Ni)			
		40,000	60,000	80,000	100,000
Cobalt Price (US\$/t)	40,000	20,782	27,271	33,759	40,247
	60,000	19,182	25,671	32,159	38,647
	80,000	17,582	24,071	30,559	37,047
	100,000	15,982	22,471	28,959	35,447

Source: Wood Mackenzie, Corporate reports, Bernstein analysis

EXHIBIT 15: **We believe that this gives an idea of the kind of range of nickel price required to generate a 15% IRR for an HPAL project**



Source: Wood Mackenzie, Corporate reports, Bernstein analysis

**Option 3:** So HPAL is difficult and expensive, what about just dissolving nickel products from the saprolite ore sources? This, though technically possible, would be extremely expensive: one estimate from the conference put the estimate of an "incentive price" for dissolving NPI to generate a battery-suitable nickel product at over US\$30,000/t, and operating costs of doing so were discussed at around the same levels as our own calculations – i.e. c.US\$10,000/t of contained nickel in nickel sulphate to dissolve NPI.

**Option 4:** The other alternative we mentioned was to take an NPI or Ferronickel process and add extra processing steps...this would in essence involve adding a converter after the initial pyrometallurgy processing to remove the iron and produce a nickel matte which could then be refined in a 'traditional' nickel refinery.

Whilst this option sounds relatively attractive, the incentive is not there at present for any NPI producer to do it at present given that they can sell their NPI to the market at only a ~US\$1,000/t discount to the LME price, whereas the additional operating costs of conversion to nickel sulphate from NPI/ferronickel were estimated by one conference delegate to be in the region of US\$4,000 (we think this is likely optimistic).

One of the key issues with this option is that it is likely to be much more difficult than the HPAL route to control the level of contaminants in the final product. This is of crucial importance when it comes to battery applications for nickel products; as we heard Sankar Das Gupta, CEO of NMC battery maker ElectroVaya, say at the conference: for the battery makers, managing impurities is easily one of the biggest challenges that they face – very small impurities in the product can cause subtle changes in things like the pH level within the battery, and this can dramatically affect battery performance. It is for this reason, according to Das Gupta, that companies have often struggled to replicate performance even when just switching between nickel sulphate products that have originated from different ore sources.

As another conference delegate noted, the levels of impurity we are talking about here are the equivalent of one drop out of all the water going over Niagara Falls in a 24hr period...this is a very low parts per million issue that we are talking about here. In addition, this route, utilising as it would saprolite ore bodies, would give much lower cobalt returns than the HPAL route utilising limonite ore bodies.

We must remember, as well, that the saprolite ore bodies will also continue to be needed to supply a stainless steel market that still exhibits relatively high trend demand growth!

### **Conclusion: We need HPAL, and for that we need higher nickel prices**

We conclude that, particularly if we are to adequately supply a rapidly growing electric vehicle battery market, we are going to need whatever incremental nickel sulphide production that we can muster, plus a significant amount of investment in lateritic options, most likely via the HPAL route given the ability to recover the cobalt in the limonitic ore bodies and the greater ability to ensure purity of product relative to potential processing of the saprolite ore bodies.

For this, we expect significantly higher nickel prices will be needed. We would always caution, however, on focusing just on the "magic number" – we are likely, particularly given the underperformance of nickel prices in the last 6-7 years, to need several years of elevated prices to get companies comfortable to commit to investing the large sums required for incremental nickel projects.



## GENERAL OPTIMISM ON PRICES (IN ADDITION TO EV STORY)

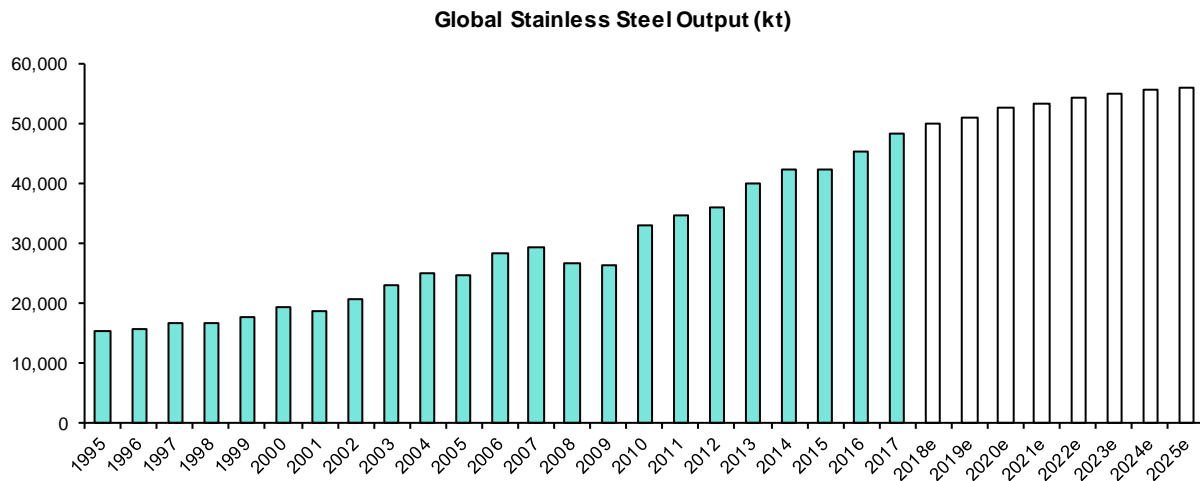
Several nickel industry delegates were optimistic on nickel prices, in line with our view, and for many of the reasons that we have previously discussed:

**1. Underlying demand has rebounded strongly.** Just as we have argued it would for several years, underlying stainless steel demand has, like for most commodities, rebounded strongly from its 2015 blip. As we have cautioned before – see, for example, [Metals & Mining: On the role of mined commodities in economic growth](#) – simply looking at monthly, or even yearly, growth rates can lead to much confusion and over-interpretation of the production data series...compare, for example, the YoY growth rates shown in Exhibit 17, which shows a fairly chaotic picture, with the annual global stainless steel output series and trend growth line shown in Exhibit 21, which shows a clear picture of trend 5.4% annual growth with a 98% r-squared statistic!

Both are based on exactly the same underlying data, but one allows us to see through the noise of single period, temporary moves away from trend. Little wonder, then, that conference speakers noted that stainless steel demand has rebounded to the c.5% level. As we have shown previously, the long-term growth rate of nickel demand and supply is c.4.7% (Exhibit 19), and thus it is unsurprising that this growth rate is very close to that of stainless steel.

On top of this, the recovery in oil & gas prices appears as if it could be a marginal demand benefit from the specialty steels and high-nickel alloys end demand segment.

### EXHIBIT 16: Global stainless steel output and forecast



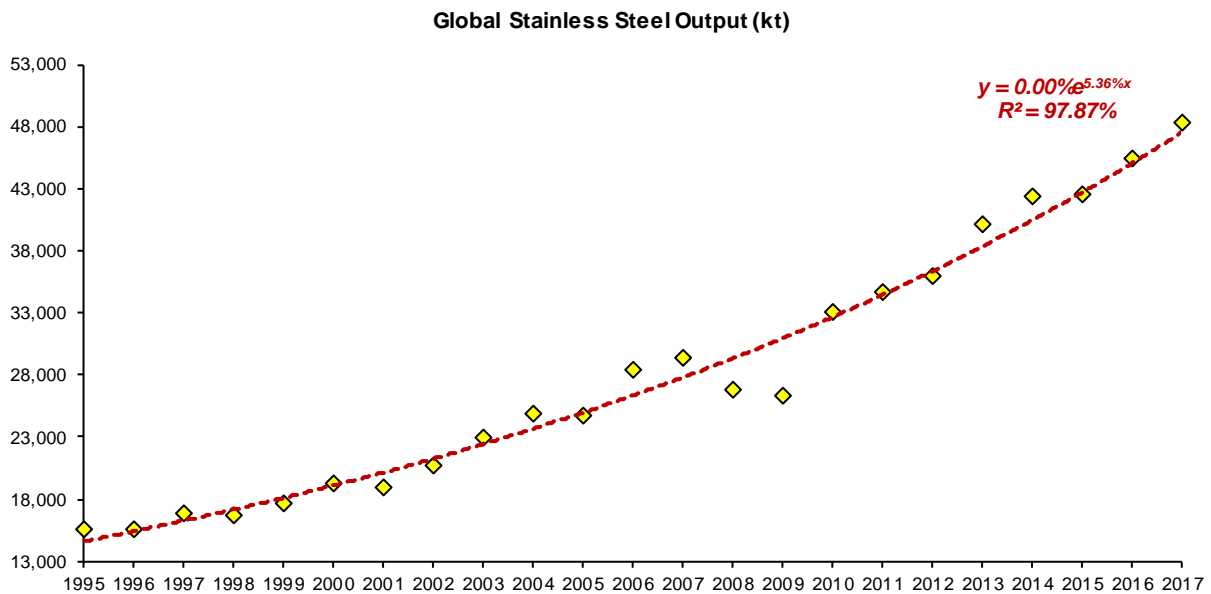
Source: Wood Mackenzie estimates, Bernstein analysis

EXHIBIT 17: **Just looking at annual percentage changes can paint a confused picture of the real underlying trend...**



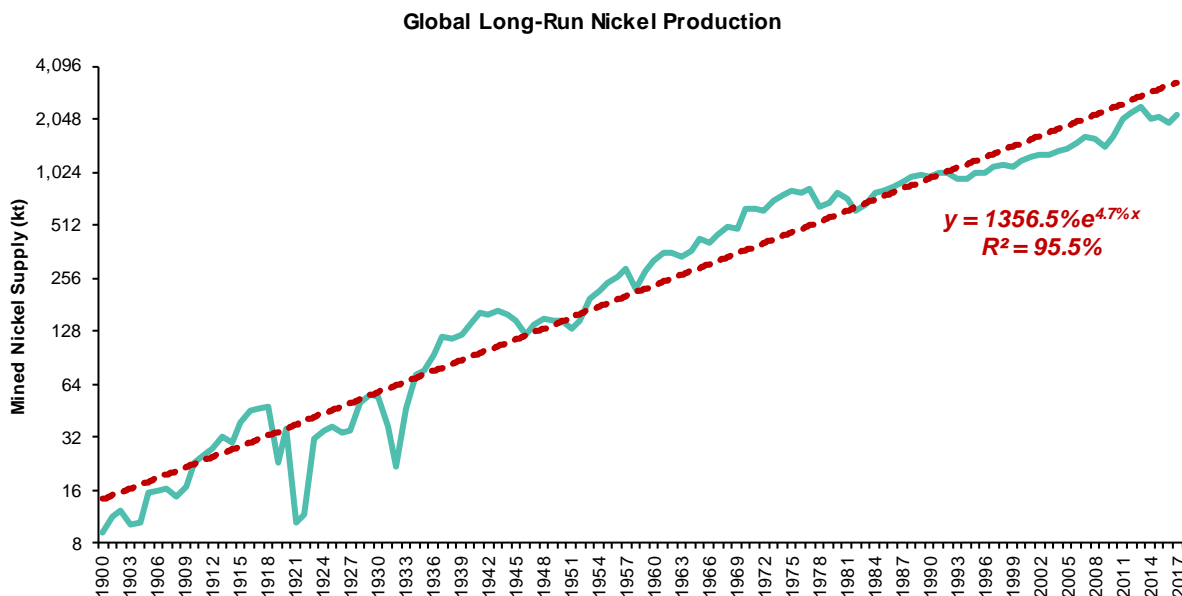
Source: Wood Mackenzie, Bernstein analysis

EXHIBIT 18: **...whereas here we can see that underlying trend much more clearly: stainless steel output 5.4% trend annual growth rate over the last 20+ years**



Source: Wood Mackenzie, Bernstein analysis

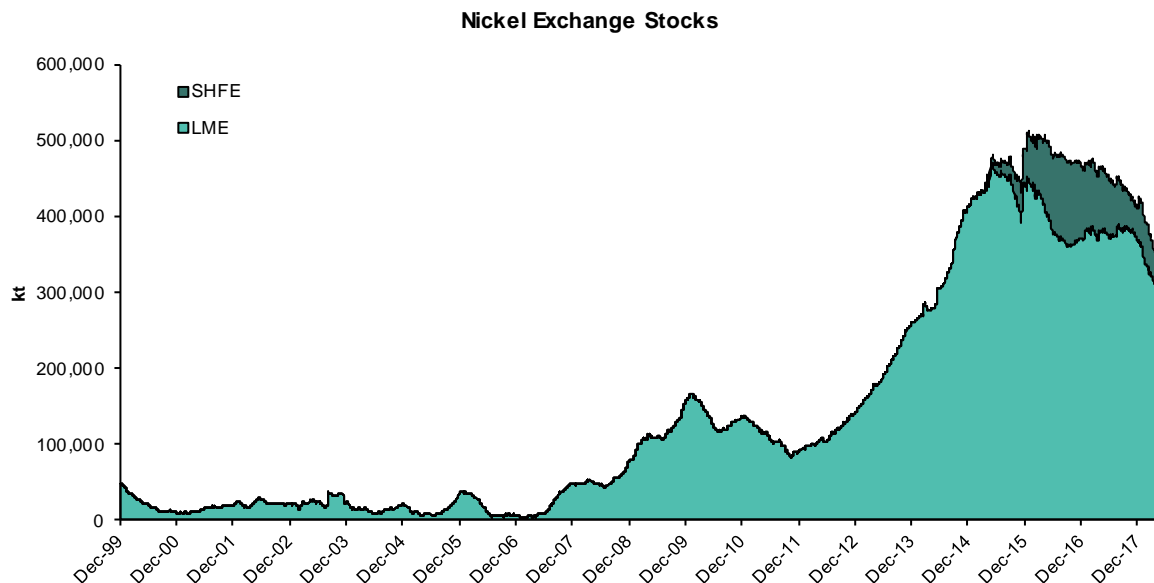
EXHIBIT 19: **We have seen trend long-run nickel production grow at 4.7% CAGR over the last ~120 years**



Source: USGS, Wood Mackenzie, Bernstein analysis

**2. Market has tightened as global deficit reached and stocks falling.** Whilst estimates differ, there is a general consensus that the nickel market is "in deficit", and nickel exchange stocks are now falling rapidly. Both industry players, industry trade bodies and independent consultants all agree that the market is now in deficit, and the draw-down in exchange inventories is clear to see (Exhibit 20). As we mentioned previously, the fact that we have seen draw-downs in briquette products may well be indicative that the underlying fundamentals of the market are starting to be affected by burgeoning demand for battery-suitable nickel units.

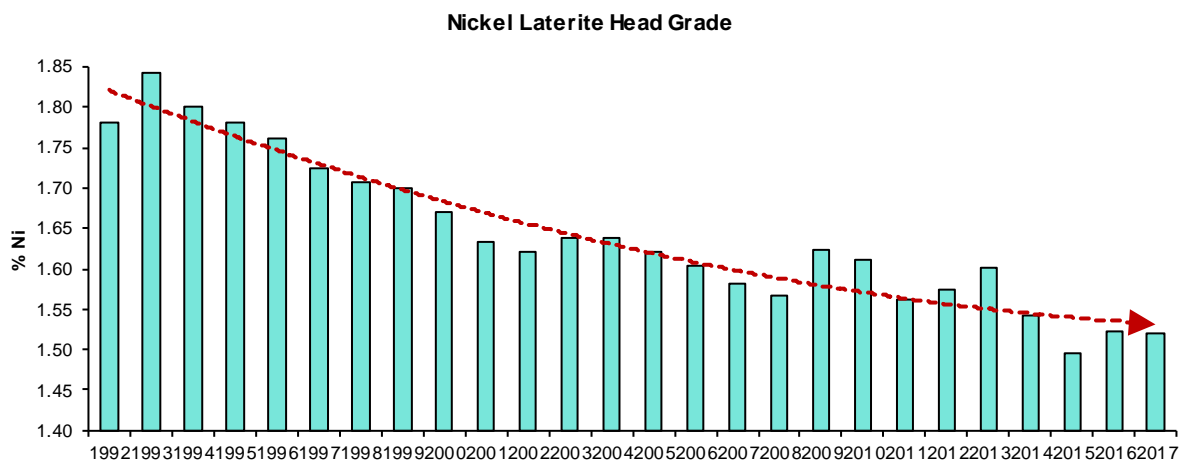
EXHIBIT 20: **Nickel exchange stocks have started to decline much more rapidly over the course of 2018**



Source: Bloomberg, Bernstein analysis

**3. Grades are declining.** We have previously made this point in the copper industry, and indeed the phenomenon forms one part (of many) of our thesis regarding the structural challenges facing the copper supply side and its implications for copper prices – see, for example, our *Blackbook Global Metals & Mining: The End of a Golden Century of Growth*. However, the same is just as true of the nickel industry (Exhibit 21).

EXHIBIT 21: **Just like in the copper industry, nickel grades are falling**



Source: Wood Mackenzie, Bernstein analysis

**4. Environmental issues beginning to bite in China.** According to conference delegates, environmental issues in China (that we discussed to a significant extent with regards to our recent iron ore work), are also starting to bite in the nickel industry.

Indeed, according to Wood Mackenzie, the Shanghai Cooperation Organisation summit, which is planned to be held in Qingdao, Shandong province this month, is likely to lead to reduced provincial nickel output as environmental restrictions are put in place that will limit production.

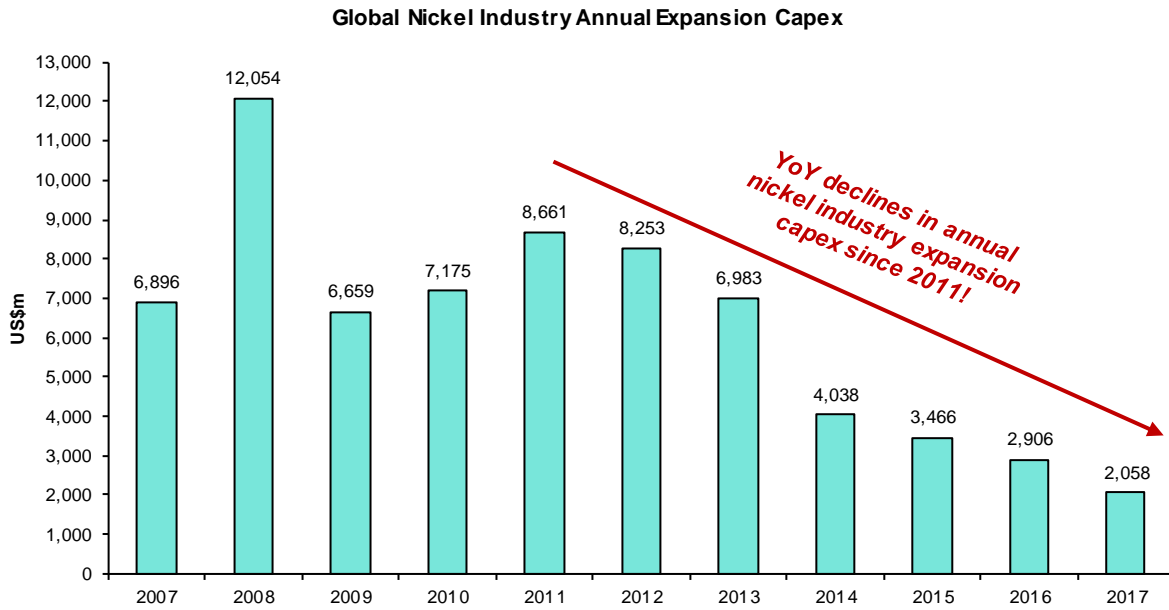
For example, Shandong Xinhai (the largest NPI producer in China) suspended six of its 30 production lines on 25<sup>th</sup> May, whilst Shandong Jinhaihui is also to suspend one of its three lines. The other operating plant, Shandong Shenyang, will also reduce output, though to what extent is not known.

**5. Investment in new capacity has dried up.** Similar to the copper industry (for example, see our note [Metals & Mining: Copper & Gold - Not a production wall...it's a production cliff! \(in 2 charts\)](#)), investment in the global nickel industry has been declining for many years now. In fact, in aggregate (see Exhibit 22), we have seen year-on-year declines in the amount of expansion capex since 2011 – six straight years! This has particularly been the case with the laterite deposits (Exhibit 24).

As we have stressed many times before, when investment dries up, the natural depletion rate of the industry begins to come to the fore of the supply-side several years down the line. In fact, according to Wood Mackenzie estimates, the output of the current production base, plus highly probable projects (i.e. broadly those projects already commenced/sanctioned) will peak in 2020 and decline at c.2.4% CAGR to 2030.

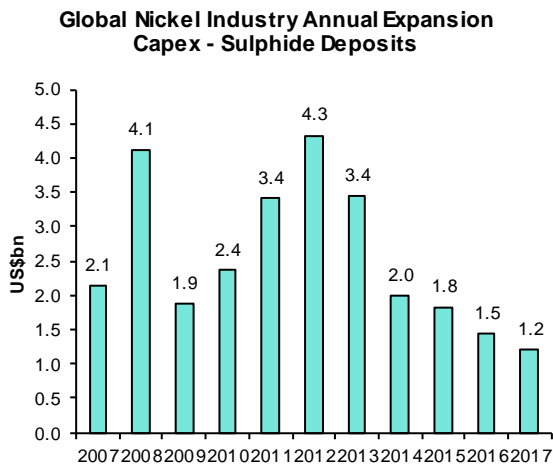
Given the significant time lags involved in mining project investment, we really need to start sanctioning investment right now in order to overcome these impending declines in output. If we take the example of Koniambo, for instance, pre-feasibility work and engineering studies started in 2000, a feasibility study started in 2003 and was finished in 2005, the project was approved in 2007 (targeting first ore in 2011), the first ferronickel was produced during 2013 on Line 1, and Glencore began *reconstruction* of Line 2 in 2017. Full capacity is now expected to be reached in 2020. Granted this was a particularly problematic project, but it could end up being 20 years from pre-feasibility work commencing to reaching full production!

EXHIBIT 22: **Similar to the copper industry, we have seen year on year declines in industry investment in future production growth since 2011...**



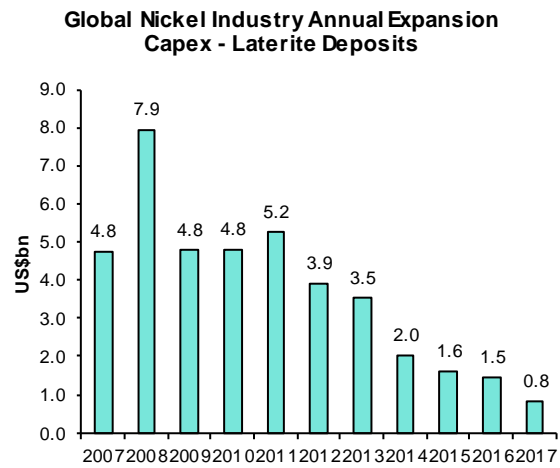
Source: Wood Mackenzie, Bernstein analysis

EXHIBIT 23: **...whilst evident for the sulphide deposits...**



Source: Wood Mackenzie, Bernstein analysis

EXHIBIT 24: **...lack of investment it is perhaps most acute in the laterite portion of the industry**



Source: Wood Mackenzie, Bernstein analysis

## INDONESIA BACK IN THE GAME...FOR NOW

Back in 2014, Indonesia implemented a ban on the export of nickel ores from the country in a bid to encourage investment in value-added processes within Indonesia itself. At the time, Indonesian ore was the main feedstock for the production of Nickel Pig Iron (NPI) in China. In anticipation of the ore export ban coming into place, China imported massive amounts of ore and stockpiled it, as well as pivoting towards imports from the Philippines.

However, with the conditional relaxation of the ore ban in 2017, and limited export licences issued to various companies (contingent on certain provisions such as at least 30% of smelting capacity being dedicated to ore below 1.7% nickel, and provided that they can show progress towards further smelter development) Indonesia nickel exports are expected to increase once more. However, the government has recently announced stricter rules regarding new export licence applications: only smelters already in construction phase will get licences from now on, smelters must have sufficient ore reserves to last the "lifetime of the smelter" and fines of 20% of revenue will be imposed on exporters who do not hit six-month targets for smelter construction (both for existing and new permits).

From the Indonesian government point of view, the ore ban has worked in one sense, and value-added processes have indeed been brought into the country. There were 13 operating smelters in the country in 2017, and according to the government this could grow to 31 by 2021 (though power plant construction remains a bottleneck to the full realisation of this potential capacity). As such, Indonesian nickel pig iron exports have emerged and grown since 2013 onwards, and are expected to continue to grow. Whilst we have called this "Indonesian nickel pig iron", in reality it is just Chinese nickel pig iron relocated to Indonesia.

At the moment, the export ban relaxation officially lasts until 11<sup>th</sup> January 2022, so without further changes, all ore exports must stop by that date. The key question becomes whether that will remain the case. In addition to smelting capacity, Chinese companies have recently started to go one step further and build stainless steel capacity within Indonesia. This is based on an integrated NPI-ferrochrome-stainless steel model, and at present this is giving Tsingshan, the Chinese stainless steel manufacturer currently operating a 2Mtpa facility at Morowali in July 2017 (and with plans to open another 1Mtpa in H2 2018), a significant cost advantage over other Chinese stainless producers in China that rely on purchasing NPI: the cost of NPI production in Indonesia is c.US\$8,000/t, the cost of nickel in NPI is only ~US\$1,000/t less than the LME nickel prices (so perhaps c.US\$12,000-12,500/t YTD) and on top of that they are able to reap the energy benefit of providing a hot NPI stream into the stainless melt. A key question is the extent to which Indonesian stainless capacity will continue to grow.

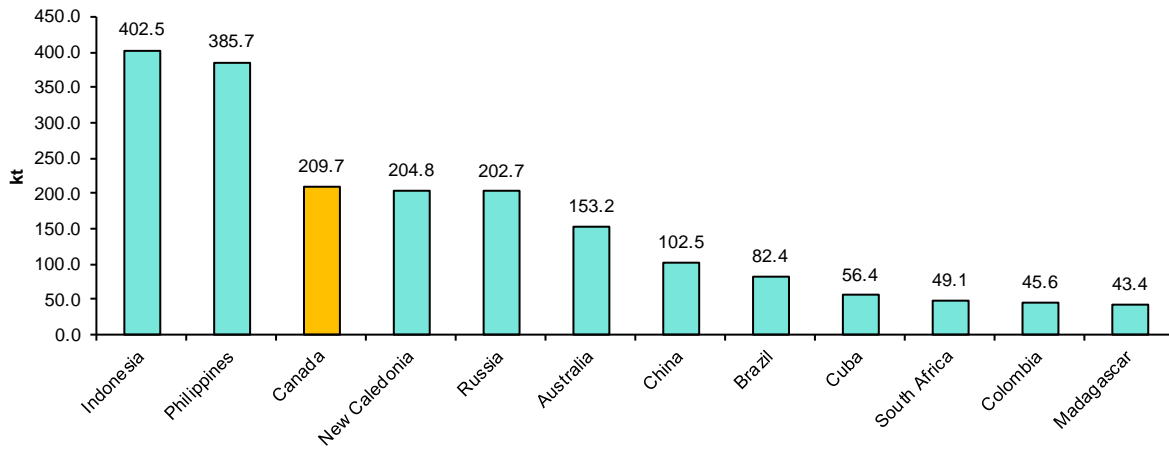
Another key question is the extent to which Indonesia will grow in HPAL...both Tsingshan and Jinchuan are reportedly looking at the potential for HPAL plants to produce Mixed Hydroxide Precipitate products containing nickel and cobalt that could then be processed for batteries in China. However, time lags (Tsingshan looked at making stainless in Indonesia for 10 years before it became a reality) and price expectations – as well as expectations around capital costs and the realities of environmental permitting – will all need to be considered here.

As we have noted, environmental issues regarding disposal of leach process tailings will be significant, and we have recently seen the government take on Grasberg over its river tailings disposal system – whilst this is largely a politically-motivated, rather than environmentally-motivated, move, at the very least it highlights the government's willingness to use this kind of issue as leverage over producers in the country.

As the world's largest producer of nickel (Exhibit 25) and the location for a significant portion of the world's nickel reserves (Exhibit 26 and Exhibit 27), Indonesian geopolitical risk will also remain an issue; we have already seen significant government intervention in the industry with divestment requirements, increased royalties, export bans etc., and this could also potentially have a significant impact on the global nickel industry particularly with much future nickel growth seemingly coming from Indonesia, and with the country potentially playing a significant role in the provision of future battery-suitable nickel units.

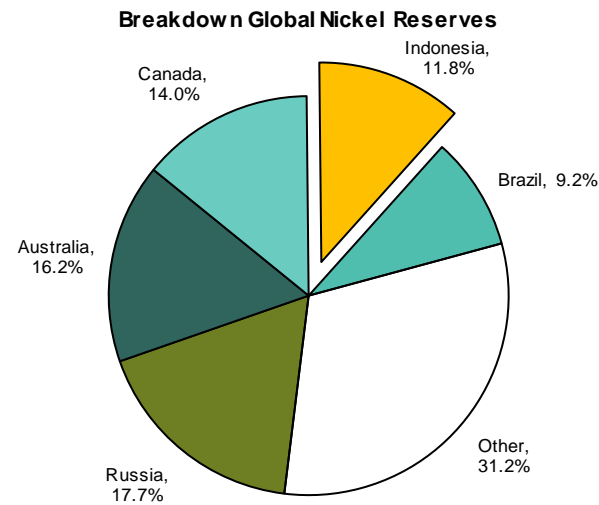
**EXHIBIT 25: Indonesia and the Philippines are now comfortably the biggest nickel producers in the world, with Canada, New Caledonia and Russia in the "next group" behind**

**Global Mined Nickel Production by Country 2017**



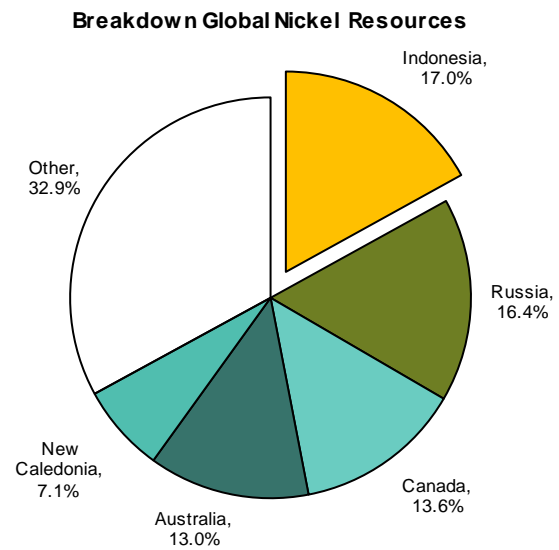
Source: Wood Mackenzie, Bernstein analysis

**EXHIBIT 26: Indonesia has c.12% of global nickel reserves...**



Source: Wood Mackenzie, Bernstein analysis

**EXHIBIT 27: ...and 33% of global nickel resources**



Source: Wood Mackenzie, Bernstein analysis

## DISCLOSURE APPENDIX

**VALUATION METHODOLOGY****European Metals & Mining**

Our price targets are based on a sum of the parts and DCF analysis. We forecast FCF per business unit for each company in our coverage, using our own commodity price forecasts, and aggregate the numbers into a DCF.

**RISKS****European Metals & Mining**

The four most significant risks facing the major mining houses are lack of capital discipline, operating cost inflation, a sustained downturn in the Chinese economy and resource nationalism.

- + Capital discipline. Capital discipline is perhaps the most important mechanism by which the mining industry can create value. We have seen lapses in capital discipline before, and a return of such periods would lend downward pressure to prices.
- + Operating cost inflation. Following 10 years of double-digit US dollar-denominated cost inflation in the industry, unit costs have come down in recent years as commodity prices have fallen. We expect to see a return of cost inflation, but should this be stronger than we expect, then it has the capacity to erode value.
- + Chinese economic risks. China is important in commodities as both the major source of demand growth and as the location of the marginal units of supply. The market has become extremely sensitive to sentiment regarding the Chinese economy, with the level of leverage of particular concern.
- + Resource nationalism. Finally, we note with concern the trend toward global fragmentation and the ever greater desire to extract value from the mining sector. We believe that this is ultimately a self-defeating strategy by host governments, but it is one with an impressively long pedigree. Persistent macroeconomic headwinds will make this an ever more attractive option.



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  - Market-Perform: Stock will perform in line with the market index to within +/- 15 pp in the year ahead.
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### 12-Month Rating History as of 06/11/2018

Ticker	Rating Changes
AAL.LN	O (IC) 09/05/12
ANTO.LN	O (RC) 11/26/14
BBL	M (RC) 01/22/18 O (RC) 07/05/17 M (RC) 05/08/14
BHP	M (RC) 01/22/18 O (RC) 07/05/17 M (RC) 05/08/14
BHP.AU	M (RC) 01/22/18 O (RC) 07/05/17 M (RC) 05/08/14
BLT.LN	M (RC) 01/22/18 O (RC) 07/05/17 M (RC) 05/08/14
FM.CN	O (IC) 06/02/15
GLEN.LN	O (RC) 02/13/13
IVN.CN	O (IC) 12/09/16
RIO	O (IC) 09/05/12
RIO.LN	O (IC) 09/05/12
S32.AU	M (RC) 08/20/15
S32.LN	M (RC) 08/20/15
S32.SJ	M (RC) 08/20/15
VALE	O (RC) 01/25/17
VALE3.BZ	O (RC) 01/25/17

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

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

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