Metals Monthly: Innovation in Battery-Grade Nickel

April 2019

This is the BloombergNEF Metals Monthly, covering key developments that affect emerging metals impacted by the transition to low-carbon technologies. We profile miners and investors developing new strategies and products, and curate datasets to drive transparency in the pricing of new metal commodities. We welcome your feedback on this report: bnefminmet@bloomberg.net.

Nickel demand and EV batteries

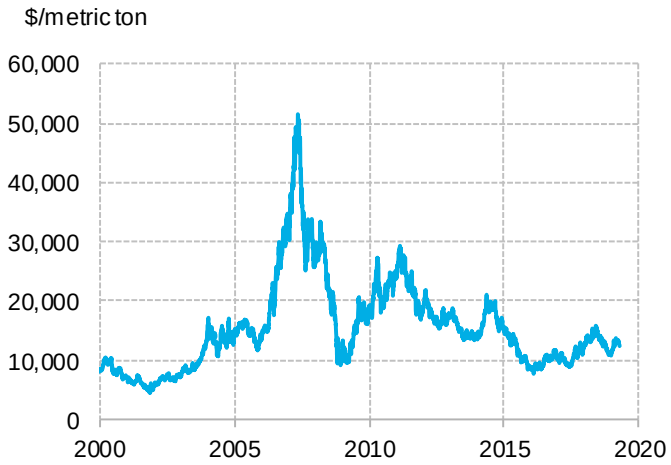
"Lithium ion batteries should be called Nickel-Graphite because primarily the cathode is nickel."[1] Three years after Elon Musk's attempt to rename the lithium-ion battery in 2016, nickel prices have risen at a compounded annual growth rate (CAGR) of 15%. A technology shift is happening in the EV battery industry, where in order to increase range and battery density, companies like Tesla, LG Chem, and BMW are shifting to high-nickel cathode chemistries like NMC 811 and NCA+. While it will take some time for the market to make a full transition, there are already plans to expand the utilization of high-nickel cathodes deployed in EVs in the next five years.

BNEF forecasts battery demand for nickel may increase ninefold by 2030, versus the sixfold increase in demand for lithium.[2]

Read more about battery technology: *Lithium-Ion Batteries: A 101 Guide*

Since 2016, global annual production of nickel has increased by 200,000 metric tons. Yet, analysts and producers alike remain bearish about the ability of the industry to meet future demand. This is partly because the industry experienced a "Minsky moment" in 2007-2009, when companies committed to mega projects on the back of soaring nickel prices driven by increased demand from China's stainless steel industry until Tsingshan's discovery of low-cost nickel pig iron using novel processing technology caused a price crash. This development led to a sudden drop in prices from a high of $51,000 per metric ton in May 2007 to $10,000 per metric ton by January 2009. A decade later, producers remain gun-shy toward expanding capacity and allocating capital.

Figure 1: LME Nickel Spot Price, 2000-2019



Source: Bloomberg Terminal, LME

Class 1 nickel faces deficit by 2024

Nickel is mined from two types of deposits, sulphide and laterite ores. Sulphide ore is more easily refined to a higher purity (> 99% Ni), and accounts for 40% of

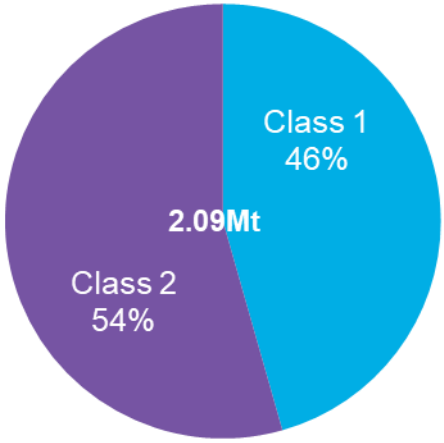
[1] https://www.mining-journal.com/events-coverage/opinion/1173190/lithium-ion-batteries-called-nickel-graphite

[2] BNEF is updating our EV battery cathode chemistry mix in the upcoming Electric Vehicle Outlook

global resources. Laterite ore, often contains iron, and is more commonly processed to obtain a lesser nickel purity (< 99% Ni). The high purity nickel is Class 1 nickel, suitable for batteries. Lower purity nickel is referred to as Class 2 and is primarily used for production of stainless steel.

Currently, global supply is split evenly between Class 1 and Class 2 nickel. (Figure 2) Miners' confirmed investment plans indicate nickel supply may grow 17%, but the majority of this growth in supply will be from Class 2 nickel as a result of Nickel Pig Iron (NPI) producing mines in the Philippines and Indonesia coming on stream.

Figure 2: Global Nickel Global Supply, 2018



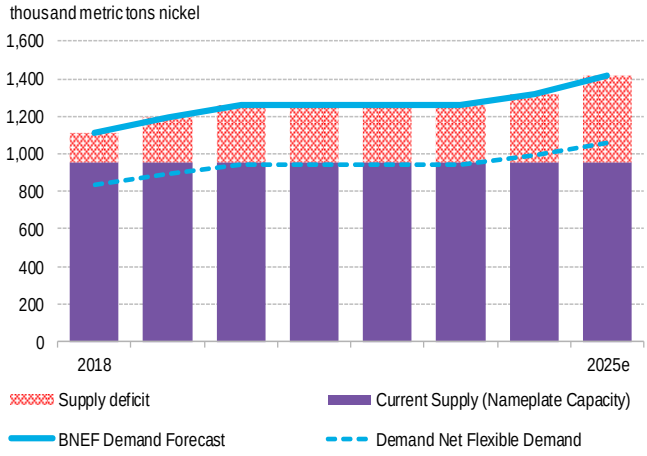
Source: BloombergNEF, company reports

With EV cars to reach 500 million by 2040, BNEF estimates that battery demand for Class 1 nickel may reach over 500,000 metric tons by 2025.

Read more about EV: *Global Summit 2018: The Future of Electric Vehicles*

To meet future demand, Class 1 nickel supply must increase at a CAGR of 5.86% over the next 7 years. There is also a portion of Class 1 nickel (used in production of stainless steel) that can be technically shifted over to Class 2 if needed. Assuming this flexible capacity responds, the global Class 1 nickel market will not face a deficit until 2024. (Figure 3)

Figure 3: Class 1 Nickel Supply and Demand Forecast



Source: BloombergNEF. Note: Assuming about 25% of Class 1 demand is flexible (able to switch to Class 2).

Nickel's dominant producers set to expand existing capacity

The nickel market is mature compared to other battery metal markets such as lithium. It is consolidated and comprise of large and financially stable companies. Global production of Class 1 nickel is controlled by the top 10 producers who collectively account for over 90% of annual output. These producers are likely to maintain their market lead beyond 2025 due to current spare capacity and continuous investment in expansion and technology.

The mining industry needs about 10 years of lead time for new nickel mines, encompassing scoping studies, feasibility studies, permits, capital raising, FID, engineering, commissioning and ramping-up. We hold the view that focusing solely on the building of new mines and refineries to meet forecasted demand will be inadequate in the medium term. However, optimization of existing capacity and investment in next-generation (next-gen) technology will contribute significantly toward the increase in supply to meet forecasted demand in the short to medium term.

Investment in next-gen HPAL technology will guarantee nickel supply for batteries

The cost of converting low-grade nickel ore into Class 1 nickel sulphate for battery production has proven to be capitally intensive. High Pressure Acid Leaching (HPAL) plants comprise one of the technologies producers are developing to change this. HPAL has been around since 1959. First introduced at the MOA joint venture in Cuba, its adoption has been relatively slow with mixed results. This slow take-up has been primarily attributed to poor performance, cost overruns and substandard recoveries.

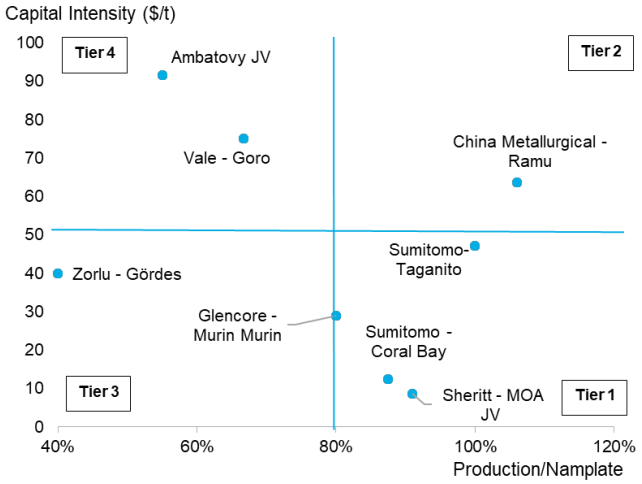
BNEF analysed the capital intensity and recovery rates of eight HPAL plants currently in operation. (Figure 4) Three out of the eight HPAL plants satisfied our criteria to be classified as Tier 1 assets, meaning they were able to achieve their designed recovery rate at relatively low per unit capital costs. Out of these three, two of the projects are operated by Sumitomo (Coral Bay and Tanganito). This highlights the importance of expertise and experience in delivering successful HPAL projects. Sumitomo is planning on partnering with Vale in Indonesia to develop a project at Pomalaa, Southeast Sulawesi.

With Sumitomo successfully delivering HPAL projects, interest has been renewed in HPAL. Leading this group is Tsingshan and its partners, with an optimistic target of producing 131,000 metric tons of nickel sulphate crystals from laterite in Indonesia through HPAL technology with an anticipated 50,000 metric tons coming on stream by the end of 2019.

Not all HPAL projects have been successfully ramped up. Projects like Glencore's Murin Murin (previously called Minara) and First Quantum's Ravensthorpe (currently furloughed) in Australia have experienced various technical difficulties and delays.

Of upcoming HPAL projects, we estimate about 300,000 metric tons of battery-grade nickel per year of new capacity may be added by the mid-2020s. This is from a combination of development of new assets as well as expansion of existing assets. (Figure 5)

Figure 4: Performance of existing HPAL operations



Source: BloombergNEF, company reports and announcements. Note: Based on MOA's construction over 50 years ago, its capex was assumed to be $0.3 billion same as that for Coral Bay since it has the next lowest capital cost of construction among the companies investigated.

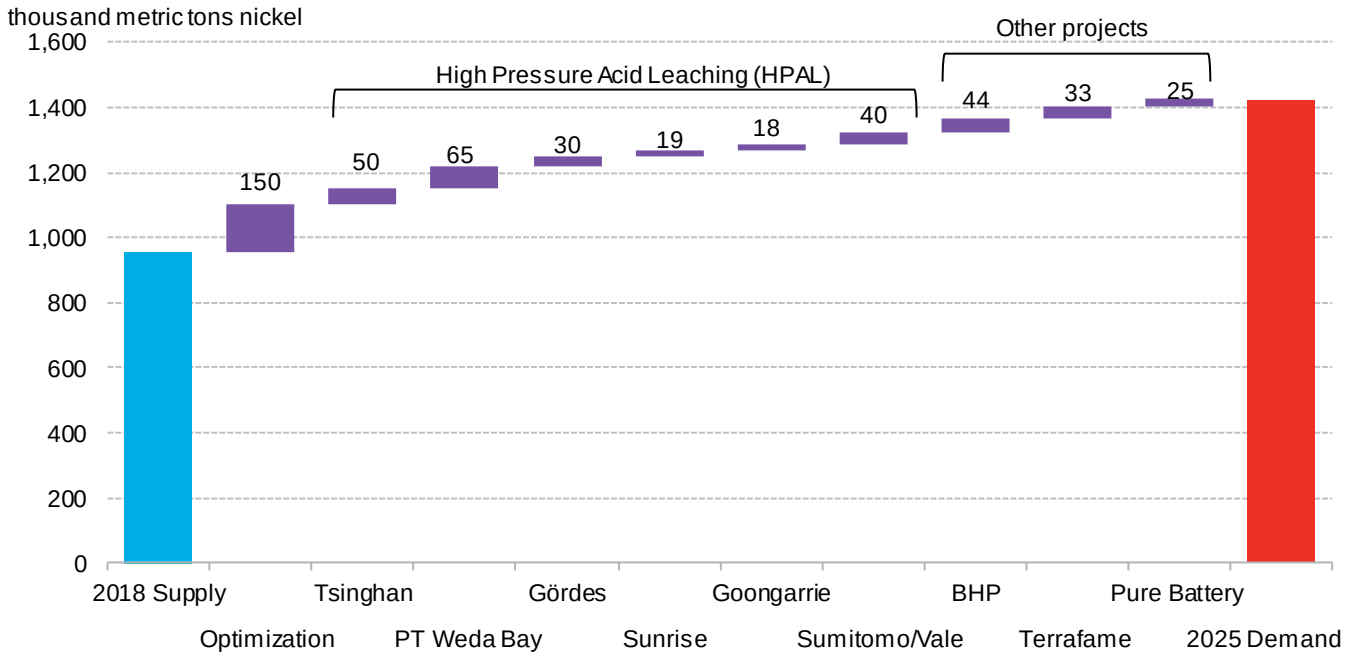
A couple of smaller projects like Cleanteq's Sunrise and Ardea Resource's Goongarie are less likely to be delivered on schedule. However, Cleanteq's selection of China Metallurgical Group (CMG) as the key delivery partner offers the project CMGs experience from the development of the Ramu HPAL asset. Ardea is also searching for a strategic partner to improve their capability in attaining full production by mid 2020s, depending on the investment climate.

Additionally, other emerging technologies such as Selective Acid Leaching (SAL) aim to combine the leaching and selection process using mild acid and strong oxidation process to reduce exposure time and cost of recoveries. This process, currently on trial by Pure Battery Technologies in Australia, will use mixed hydroxide precipitate as raw materials to produce nickel sulphates. If SAL is successfully implemented on a mass scale, this can bring another 25,000tpa of battery-grade nickel production capacity to the market. Notably, BHP is developing the largest nickel sulphate plant at the Nickel West Kwinana refinery which will

process about 40,000tpa of nickel powder for nickel sulphate production. Additionally, Terrafame has also announced its plans to develop a 33,000tpa plant using the pressure leaching technology to be constructed by Outotec. These three projects, if successful, will bring over 100,000tpa of battery grade nickel to the market by 2025.

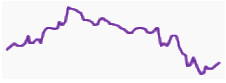
Together, innovations in HPAL and SAL nickel refining have the potential ability to meet Class 1 nickel demand from batteries, by the mid-2020s. The question that remains is how successful these companies will be at delivering on their capacity announcements and if a crash in nickel prices may delay plans.

Figure 5: Upcoming nickel projects and their announced capacities



Source: BloombergNEF, company reports and announcements

Key Pricing Data for Battery Metals

Metal		Starting Price	Ending Price	MOM	YOY	Sparklines
		$/t	$/t	% change	% change	Daily
		03/29/2019	04/29/2019		04/29/2019	2019 YTD
Lithium	Hydroxide *Source: AMTL China Lithium 56.5% DEL*	$14,228	$13,958	-2%	-43%	
	Carbonate *Source: AMTL China 99.5% DEL*	$11,379	$11,360	-0.2%	-50%	
Cobalt	Oxide 72% *Source: AMTL China DEL*	$25,774	$29,773	16%	-61%	
	Sulphate 20.5% *Source: AMTL China DEL*	$6,853	$7,796	14%	-65%	
Nickel	Sulphate *Source: AMTL China Ni 22% Co 0.05% EXW*	$4,432	$4,269	-4%	-6%	
Manganese	Electrolytic Flake 99.7% *Source: Antaike China Changjiang Spot Price*	$2,078	$2,088	0.5%	-0.1%	
Graphite	Fine Flake *Source: AMTL China Flake-194*	$574	$560	-2%	-17%	
Aluminum Alloy	LME 3-month	$1,455	$1,385	-5%	-28%	
Copper	LME 3-month	$6,483	$6,400	-1%	-6%	

Source: Bloomberg Terminal Metal Prices Dashboard MB<GO>

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