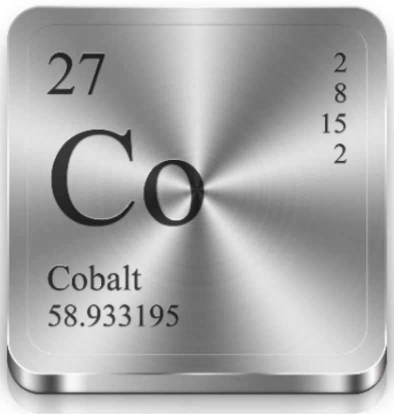
RFC Ambrian

The Alchemist



Issue 31:

Cobalt

Cobalt has had a meteoric rise in 2017. In this issue of The Alchemist *we delve into the cobalt market and try to piece together the demand story for this mischievous metal.* The Alchemist *would like to thank the Cobalt Development Institute (www.thecdi.com) for its assistance with this report*

Cobalt — An Intense Blue Flash in the Pan?

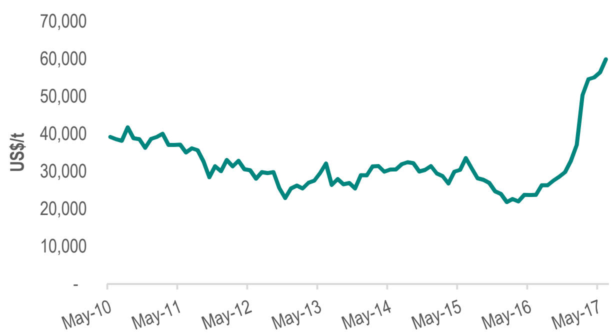
INTRODUCTION

Cobalt has been one of the star metals of 2017, with a 70% price rise since January. It is now trading at almost US$60,000/t (~US$27/lb). The market is in slight oversupply; in 2015 global demand for refined cobalt of ~87,000t was met by refined production of ~98,000t, with this oversupply likely narrowing in 2016. The impressive price ascent and increased investor interest have prompted *The Alchemist* to take a close look at the cobalt market. Our findings lead us to believe that, despite the healthy prospects for rechargeable battery demand, continued strong demand growth for cobalt cannot be taken for granted.

- Forecasting future cobalt demand is fraught with difficulty due to the recent advances in battery technology. These advances are almost certainly negatively affecting the demand for cobalt in its main growth area — lithium-ion battery cathodes.
- Still, our modelled scenarios suggest that there may be a deficit in cobalt in the short-medium term. A ramp-up in production from a number of Democratic Republic of Congo-based developments should heavily reduce (or totally eliminate) that deficit, but the DRC remains an intensely volatile country in which to do business.
- Outside the DRC, other near-term supply avenues are not immediately obvious, as, regardless of the cobalt price:
    - Traditional copper and nickel mines that produce a significant supply of cobalt as a by-product are still subject to copper and nickel market dynamics, which are currently unfavourable for new investment on the scale necessary.
    - Pure-play cobalt production, lacking the economies of scale of traditional copper-cobalt and nickel-cobalt production and subject to obstacles in processing technology, may be prohibitively expensive to develop and operate.
- A longer-term shortfall in supply is likely to lead to demand destruction rather than a supply increase:
    - A supply shock (eg, due to the outbreak of any conflict in the DRC) will in all likelihood push cobalt prices up substantially in the short term, but will consequently hasten demand destruction as battery producers further reduce the need for cobalt in cathode.

Investors can gain exposure to cobalt through a number of avenues outside traditional mining stocks and several junior mining stocks listed on the ASX and TSX offer investors exposure to cobalt development potential. Nevertheless, equity investors should be very cautious during a period of price volatility and technology-driven changes in demand.

Figure 1: LME Cobalt 99.3% 2010 to 2017



Source: Bloomberg

WHAT IS COBALT?

Cobalt is a shiny, grey, brittle metal. It is very hard and can take a high polish. It's ferromagnetic, and thus capable of being magnetised. It is a transition group metal, with a close packed hexagonal (CPH) crystal structure at room temperature, but which changes at 421°C to a face-centred cubic form. The metal is rarely used as a structural material in its pure form, and is almost always found as an alloy or component of another system due to its favourable alloying properties and ability to maintain its magnetic properties at high temperatures (up to 1121°C). Cobalt is vital for the health of many organisms and is an important constituent of Vitamin B12.

There are approximately 30 principal cobalt-bearing minerals, and over 100 more that contain minor amounts of the metal.

Table 1: Common Cobalt-bearing Minerals

Name	Formula
Erythrite	$Co_3(AsO_4)_2.8H_2O$
Skutterudite	$(Co,Ni)As_3$
Cobaltite	$CoAsS$
Carollite	$Cu(Co,Ni)_2S_4$
Linnaeite	$Co^{2+}Co_2^{3+}S_4$
Asbolite	$(Ni,Co)_{2-x}Mn^{4+}(O,OH)_4.nH_2O$

Source: The Alchemist

Cobalt is considered a 'technology enabler' as it is a critical element of many of the most important innovations in the energy and industrial sectors. It also forms the basis of many advanced biomedical applications. The importance — and potential criticality — of cobalt has led the US Government to label it a strategic metal and the EU to include it on a list of critical metals.

THE MISCHIEVOUS MINE SPRITE

The name cobalt apparently originates from the Erzgebirge ('Ore Mountains') region of Saxony, an area straddling the German and Czech border near Dresden, a major historic silver mining centre. At a loss to explain the numerous health and mineral processing issues caused by the arsenical cobalt in the minerals cobaltite (CoAsS) and smaltite ($CoAs_2$), Medieval miners surmised that they must be the work of a malignant sprite that frequented the mines — a 'kobold'. In the 1730s, Swedish chemist Georg Brandt isolated a substance from the ore and named it *cobalt regulus*. Further scientific work in the 1780s showed that this was in fact a new element, which was then named cobalt.

Cobalt use goes back to at least 2000BC. Cobalt compounds, although not identified as such, gave a rich, blue colour to glazes, ceramics and glass across the world. Examples of this include pottery from ancient Persia, Egypt, Pompeii and the Tang dynasty in China. The main use of cobalt remained as a colouring agent right up to the early 20th Century. From the 1920s to the 1990s, advances in materials technology led to the increasing use of cobalt in alloys, catalysts and magnets, and in the early 1990s the first lithium-ion battery was commercialised by Sony. This heralded the beginning of cobalt as a battery material.

GEOLOGY OF COBALT DEPOSITS

Like many niche metals, cobalt is relatively common in the Earth's crust; it is the 33rd most abundant element. However, it is not found in its 'native' form in nature, and it is relatively rare to find in economically exploitable concentrations. In seeking to understand the supply and demand dynamics of cobalt, it is important to understand the geological constraints that underpin its production:

- Cobalt is found economically in four main deposit types, with one of these making up the vast bulk of mined supply.
- Geological conditions of cobalt formation also influence to a large degree how cobalt is processed from cobalt-containing ore.

Figure 2: Cobaltite in Matrix

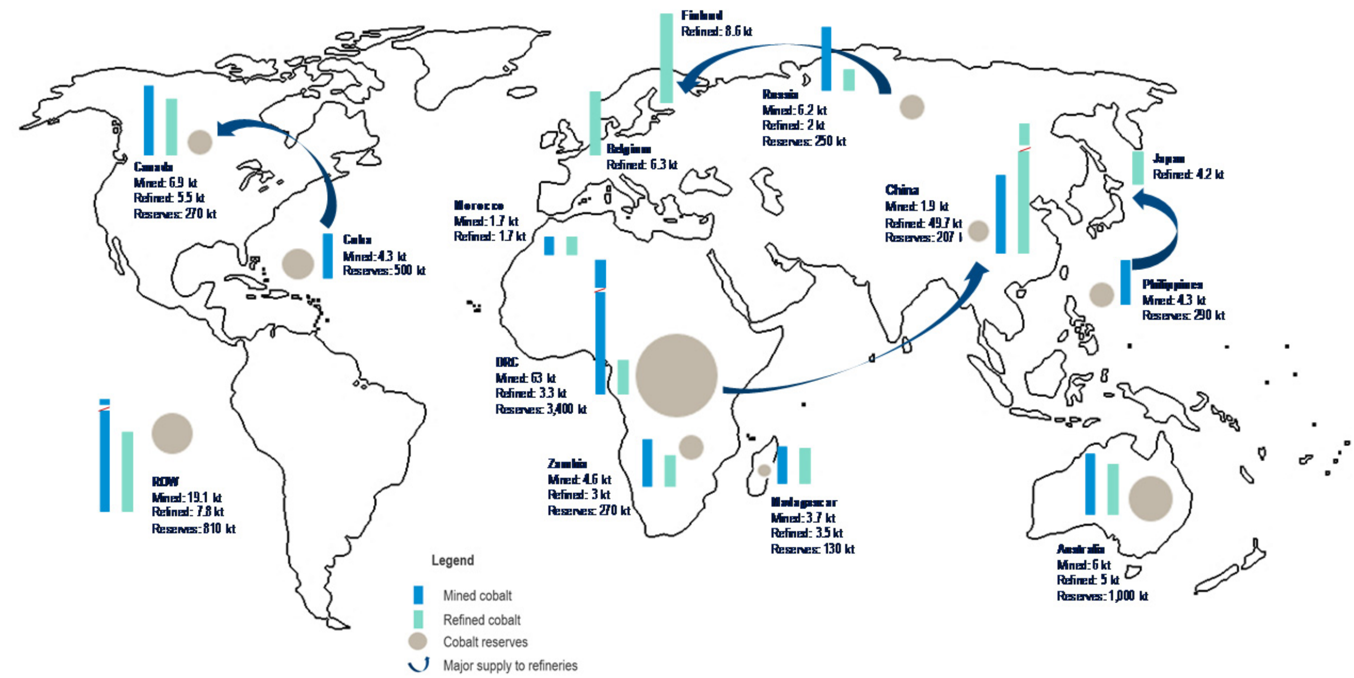
Source: The Alchemist

Table 2: Major Cobalt Deposit Types

Deposit type	Formation	Major examples	Prod
Sediment-hosted	Diagenetic processes in a near-shore or saline lagoon environment convert sea water sulphates to sulphides and concentrate metallic elements sourced from sediments	Tenke Fungurume, Democratic Republic of Congo	~63%
Hydrothermal volcanogenic	Precipitation of minerals from hydrothermal fluids passing through the host rock	Bou-Azzer, Morocco	~2%
Magmatic sulphide	Liquid sulphide phase is concentrated in magmas. This phase preferentially collects and concentrates metallic elements such as cobalt	Noril'sk, Russia; Sudbury, Ontario, Canada; Kambalda, Australia	~10%
Laterite	Tropical weathering causes the breakdown of cobalt silicates and sulphides in ultramafic bodies, enriching weathered rocks	Moa, Cuba; Ambatovy, Madagascar	~25%

Source: The Alchemist

Figure 3: World Cobalt Production 2016



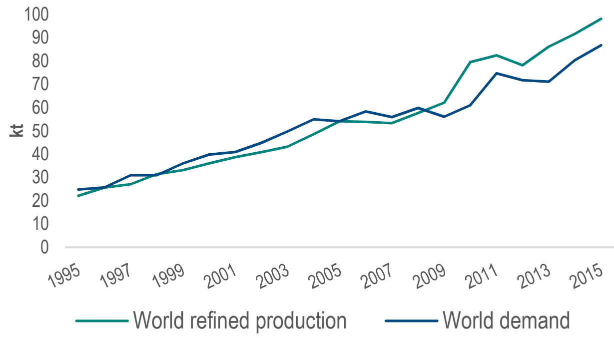
Source: USGS, CDI, SNL

SUPPLY

Over 95% of the world's mined cobalt is produced as a by-product of copper and nickel. The DRC supplies over 50% of the world's mined supply and China produces over 40% of the world's refined cobalt material.

It should be noted that the DRC and Zambia have substantial informal mining industries that mine and process raw materials across the entire spectrum. Many NGOs have raised serious concerns about the potential for cobalt sourced from child and enforced labour to enter the supply chain, and have placed pressure on cobalt purchasers to ensure the transparency and legality of their cobalt supply. An analysis of the USGS estimates of total DRC cobalt production vs. publicly-reported production from SNL suggests that the informal sector could account for between 8-10,000tpa of mined cobalt production.

Figure 4: World Cobalt Supply and Demand, 1995-2015



Source: USGS

Over 90% of cobalt is produced as by-product of copper and nickel mining. Historically, given that the cobalt market has been in near constant oversupply (when adding stockpiles and mined metal), supply has been driven by copper and nickel supply-demand dynamics — a prime example being the copper price-driven idling of the Katanga copper-cobalt mine complex in the DRC in late 2015, which removed ~3% of the world's cobalt supply. With the recent acceleration in demand for cobalt, it appears that the market is seeing a decoupling of the cobalt price from copper and nickel dynamics, and cobalt (at least in the short term) may be overtaking these two as the key value driver in some of the mines where it is produced. This may have the effect of increasing mine life or keeping open copper and nickel mines when they previously may have been uneconomic.

FROM MINE TO MARKET

The market in refined cobalt production is dominated by China, which accounts for 40% of refined cobalt production. Most of China's unrefined cobalt comes from the DRC (recent statistics suggest the figure is around 60%).

The overall worldwide production of refined cobalt is split roughly 60:40 between cobalt produced at vertically-integrated nickel or copper mine and refinery sites and standalone metal refineries.

Table 3: Major Cobalt-Producing and Refining Countries

Country	Mine	Refine	Approximate surplus (Mined-Refined) (t)	Supply chain	Major facilities
Australia	✓	✓	1,000	Surplus exported to Japan	Murrin Murrin
Belgium		✓	(6,300)	Imported from DRC, Australia, and recycling	Umicore facilities
Canada	✓	✓	1,400	Surplus exported to Norway, USA, ROW	Saskatchewan
China	✓	✓	(42,000)	Imported from DRC	Various
Cuba	✓		4,300	Exported to Canada	Moa
DRC	✓	✓	59,700	Surplus exported to China, Belgium, ROW	Various
Finland		✓	(8,600)	Imported from Russia, ROW	Kokkola, Harjavalta
Japan		✓	(4,250)	Imported from Australia and Philippines	Niihama
Madagascar	✓	✓	Negligible	Mine/refine in balance	Ambatovy
Morocco	✓	✓	Negligible	Mine/refine in balance	Bou-Azzer
Philippines	✓		4,300	Exported to Japan	Taganito
Russia	✓	✓	4,200	Surplus exported to Finland	Norilsk Polar Division
Zambia	✓	✓	1,600	Surplus exported to China, ROW	Chambishi

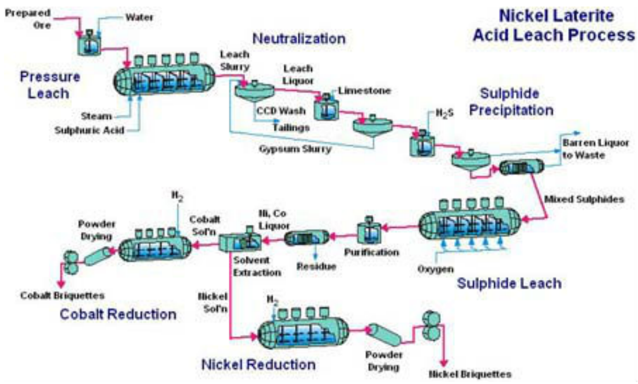
Source: CDI, SNL, USGS

Within China, the largest producers of refined cobalt are Huayu Cobalt Co, Jinchuan and the GEM Group. Outside China, large, integrated operations such as Ambatovy, Madagascar (operated by Sherritt International), Murrin Murrin, Western Australia, and Bou-Azzer, Morocco, mine and refine cobalt. Standalone copper and nickel refineries, such as Kokkola and Harjavalta in Finland, Niihama in Japan and Chambishi in Zambia, process concentrates and semi-refined cobalt from sources across the world.

Cobalt processing generally begins only after the primary metal (usually copper or nickel) has been concentrated and extracted. The processes are often unique to the mineralogy of the ore exploited. There are three basic processes used for cobalt extraction: hydrometallurgy (including solvent extraction; electrolysis and electro-winning), pyrometallurgy and vapometallurgy.

In hydrometallurgy, metals are separated using differences in solubility and electrochemical properties while in the solution. One of the most common hydrometallurgical processes is pressure acid leaching (PAL). PAL involves pre-heating slurried ore and mixing it with concentrated sulphuric acid at high temperature and pressure to convert nickel and cobalt to soluble sulphate salts. These are then fed into a counter-current decantation circuit where the enriched slurry is washed to produce a clear solution of nickel and cobalt and a solid residue. Nickel, cobalt and other sulphides are then precipitated through a reaction with injected hydrogen sulphide. The mixed metal sulphide is refined through re-leaching with oxygen at high pressure. This coverts the sulphide to a metal sulphate phase. Iron and copper are then removed using chemical reactions and the cobalt is separated from the nickel using an organic reagent.

Figure 5: Generic Acid Leach Process for Nickel-Cobalt Laterite Ores



Source: metalpedia.asianmetal.com

Cobalt-containing nickel sulphide ores are treated using a modified PAL process known as the Sherritt Process, named after Sherritt International. In this, sulphide concentrate containing less than 1% cobalt is pressure leached at high temperatures in an ammonia solution. Both copper and nickel are removed in a series of chemical reduction processes, leaving only nickel and cobalt sulphides. Pressure leaching with air, sulphuric acid and ammonia recovers more nickel before cobalt powder is added as seed to precipitate cobalt in a hydrogen gas atmosphere.

In pyrometallurgical processes, heat is used to separate metals based on differences in physical and chemical characteristics. These methods are mainly used for magmatic sulphide ores. Flash smelting is commonly used, where dry concentrates are fed into the furnace with a pre-heated air or oxygen mixture. Nickel and cobalt are recovered as a sulphide matte, while iron is recovered in slag and sulphur in sulphur dioxide gas. Smelting can produce a variety of nickel/cobalt products, such as carbonates and oxides.

Cobalt is usually extracted from these smelting products using electrolytic processes where a cobalt anode dissolves in an electrolytic cell and deposits cobalt ions onto a cathode.

Vapometallurgy is a modern process that is effective for processing lateritic ores. Nickel and cobalt metal can be recovered and refined directly from the ore, matte or concentrate. The metal in the ore is vaporised using carbon monoxide and other gases. This vapour then passes to a separate chamber where metal is deposited. This is a streamlined process that mainly operates at atmospheric pressure.

Cobalt is produced as powders, briquettes, cathodes, rounds and ingots depending on its end-use. Most speciality manufacturers of cobalt worldwide can supply cobalt to numerous specifications. The most common forms of cobalt product are outlined below.

Table 4: Cobalt End-products

Product	Use
Battery Grade Cobalt Oxide	Used as precursors for the battery cathode materials for lithium-ion and lithium-polymer batteries
Mixed Metal Hydroxide	Specially made to individual customer specification as precursors to lithium mixed metal oxides that serve as cathode materials for lithium-ion and lithium-polymer batteries
Fine Cobalt Powder	Used as an additive in rechargeable alkaline nickel cathode-based batteries
Cobalt Hydroxide	Used as a conductive additive in the cathode of rechargeable alkaline nickel cathode-based batteries
Cobalt Sulphate	Used as a raw material to produce cobalt precursors and cobalt-based cathode materials for lithium-ion and lithium-polymer batteries

Source: The Alchemist

Figure 6: Cobalt Sulphate Powder

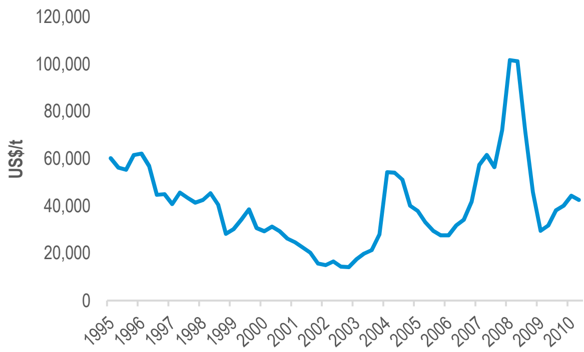
Source: The Alchemist

PRICING AND TRADING

Over the years numerous attempts have been made to determine a cobalt price discovery mechanism. In 1999 Western Mining Corporation (now owned by BHP) began selling cobalt on its website through a system known as COSS (the Cobalt Open Sales System). It was joined in 2000 by OMG (now Freeport Cobalt), but by 2008 BHP had suspended the system.

Since 1997 *Metal Bulletin* has published an online log of the deals, bids, offers and assessments that are reported to it, as well as detailed specifications for its cobalt prices. It has played a key role in providing a reference price for low-grade, 99.3% min cobalt and high-grade, 99.8% min cobalt metal. Prices have been published twice a week and have been used by sellers and buyers as a basis for the pricing of long-term contracts between producers, traders and consumers.

Figure 7: Metal Bulletin 99.3% Cobalt Price, 1995-2010



Source: CDI

Since 2010 the LME has been trading cobalt and the main price reference has been the *London Metal Bulletin* free-market quotation. Average volume has generally been low, but in the latter half of 2016 and early 2017 trading volumes increased substantially, with a rising number of market participants trading and stockpiling cobalt metal and tracking prices. However, cobalt buyers are still largely resistant to exchange-basis pricing.

Concerns have been raised about using the LME as a pricing reference, with some industry participants arguing that that the cobalt metal business was too small to justify an effective terminal exchange contract and that such small markets are best left to industry participants to monitor and determine viable pricing. There is some concern that low liquidity levels can result in increases in price volatility and spread levels.

Table 5: LME Physical Specifications for Cobalt

Spec	Detail
Quality	Cobalt with a minimum of 99.3% purity
Shape	Cathodes (broken or cut), ingots, briquettes, rounds and coarse grain powder
Lot Size	1 tonne
Warrant	1 tonne (with a tolerance of +/- 2%)

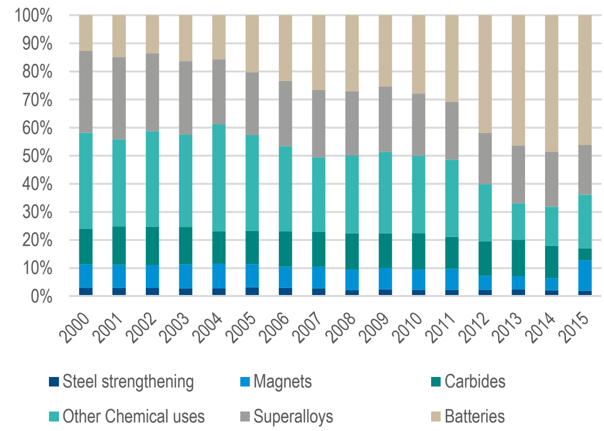
Source: London Metals Exchange

COBALT END-USE

Historically, superalloy construction was the main end-use for cobalt. Superalloys are defined as “alloys developed for elevated temperature service, where relatively severe mechanical stressing is encountered and high surface stability is frequently required”. The driving force behind their development was the jet engine, which has required ever higher operating temperatures. The use of the alloys has, however, extended into many other fields, such as of turbines, space vehicles, rocket motors, nuclear reactors and power plants.

Since the early 2000s there have been two major shifts in cobalt demand patterns. First, a significant shift in demand from the US and Western Europe to Asia, due mainly to the strength of the Chinese manufacturing sector. This coincided with the second: the rise of cobalt demand from the battery sector. Today over 45% of all cobalt produced is used in the manufacture of rechargeable batteries.

Figure 8: Cobalt End-use, 2000-2015



Source: CDI, The Alchemist

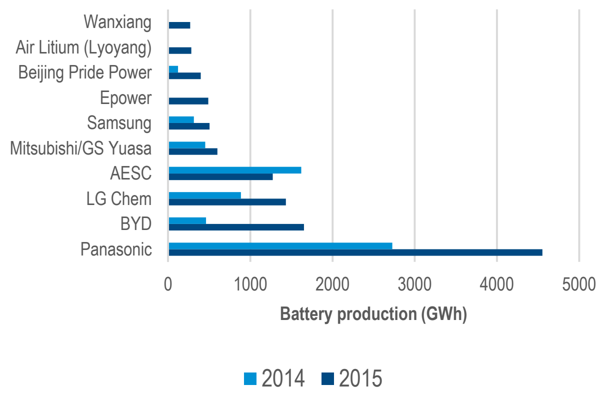
LITHIUM-ION BATTERIES

With cobalt demand from superalloys and other lesser end users forecast to grow at a slow rate (anywhere from 1-3% YoY), future demand growth will likely be dominated by the lithium-ion rechargeable battery sector.

Compared with the older nickel-cadmium and nickel metal hydride rechargeable batteries, lithium-ion batteries are preferable as they have a greater specific energy density (energy stored per unit volume), a much lower self-discharge rate and they lack the characteristics that required the older types of battery to go through complete charge cycles in order to avoid 'memory effect' (where shallow discharges would prevent the cells from being unable to discharge properly in the future).

Cobalt is a critical raw material for lithium-ion batteries, where it is required to be supplied in specific chemical form for production of precursor material.

Figure 9: Electric Vehicle Lithium-ion Battery Producers

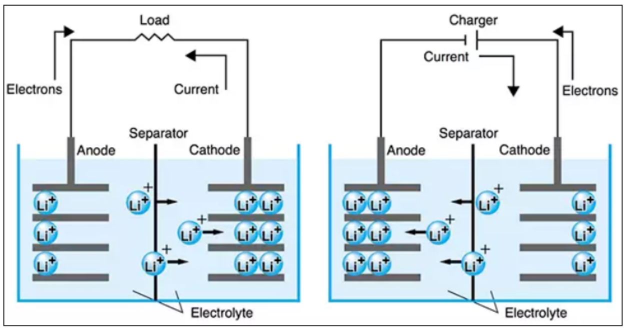


Source: evobsession.com

Lithium-ion uses a cathode (positive electrode), an anode (negative electrode) and electrolyte as conductor. During discharge, the ions flow from the anode to the cathode through the electrolyte and separator; charge reverses the direction and the ions flow from the cathode to the anode.

When the cell charges and discharges, ions shuttle between cathode (positive electrode) and anode (negative electrode). On discharge, the anode undergoes oxidation, or loss of electrons, and the cathode sees a reduction, or a gain of electrons. Charge reverses the movement.

Figure 10: Basic Architecture of a Lithium-ion Battery



Source: Battery University

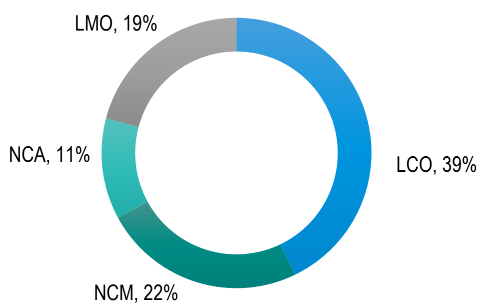
Lithium-ion is named for its active materials; the words are either written in full or shortened by their chemical symbols. There are five main types of lithium-ion batteries in use today, which are outlined in the table below.

Table 6: Common Lithium-ion Batteries

Type	Co in cathode (%)	Comments	Main uses
LCO	60-100	Lithium cobalt oxide batteries consist of a cobalt oxide cathode and a graphite carbon anode. Drawbacks include a relatively short lifespan, low thermal stability and limited load capabilities	*Apple IPhone*, laptops, cameras
NMC	33.3	One of the most successful Li-ion systems. Combining nickel and manganese in the cathode enhances the inherent strength of each element; nickel is known for its high specific energy but poor stability, whereas manganese can achieve low internal resistance but offers a low specific energy	*Tesla Powerwall*
NCA	15	The lithium nickel cobalt aluminium oxide battery, shares similarities with NMC by offering high specific energy, reasonably good specific power and a long life span	*Tesla Model S*
LMO	-	Used for power tools, medical instruments, as well as hybrid and electric vehicles. Most Li-manganese batteries blend with lithium nickel manganese cobalt oxide (NMC) to improve the specific energy. LMO NMC is chosen for most electric vehicles	*Nissan Leaf, Chevy Volt, BMW i3*
LFP	-	The LFP battery offers good electrochemical performance with low resistance. The key benefits are high current rating and long cycle life, besides good thermal stability, enhanced safety and tolerance if abused	Power tools

Source: The Alchemist

Figure 11: Lithium-ion Battery Production by Type (2015)



Source: The Alchemist

THE FUTURE FOR COBALT

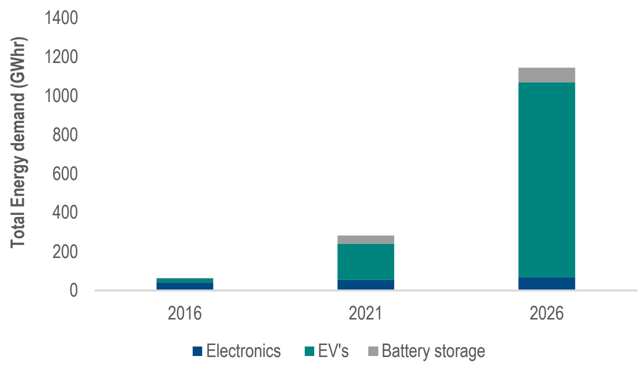
Any analysis of future demand for cobalt must be framed by three very important points:

1. *Growth in traditional industries that use cobalt (ceramics, health, superalloys, etc) is expected to be low.* Thus, rechargeable batteries will provide a substantial portion of forecast demand growth for the foreseeable future.

2. *Battery technologies are advancing at a rapid pace.* For this reason, most battery metal demand forecasts will not be projected past 2021, and what is true today may not necessarily be true next year (or even next month!).

3. *Cobalt as a constituent of cathodes in today's lithium-ion batteries is substitutable.* This is to varying degrees by nickel and manganese.

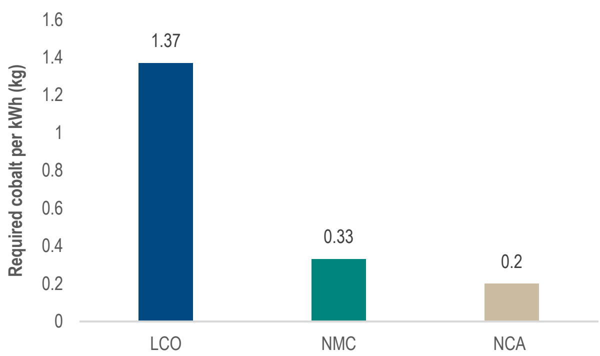
Figure 12: Lithium-ion Battery Demand by Sector, 2016 to 2026



Source: The Alchemist

Future demand growth for cobalt is heavily tied to demand for rechargeable batteries. There is little doubt that the demand for these batteries will continue to grow, with the mass take-up of electric vehicles, advances in home and grid storage and the continued popularity of hand-held mobile devices. However, what the demand for cobalt as a constituent of future batteries will be is open to question.

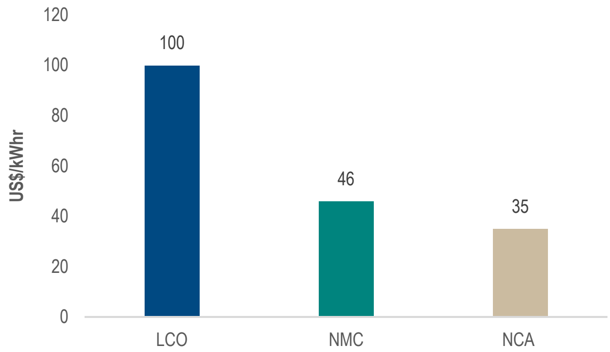
Figure 13: Cobalt Content of Lithium-ion Batteries per kWh



Source: The Alchemist

In order for any new technology to be embraced fully, it must make economic sense when held up against its competitors. The three main factors driving battery adoption across the world are: regulations for emissions control; rising renewables energy generation; and falling battery costs. Battery power costs are falling YoY as manufacturing scale rises. However, recent cobalt price rises and scarcity of supply have the potential to arrest the fall in prices, particularly in the more cobalt-intensive LCO and NMC batteries. The chart below shows the assumed cost per kWh for the main battery types at June 2017 commodity prices.

Figure 14: Lithium-ion Batteries Metal Cost per kWh, June 2017



Source: The Alchemist

Of these, the one most popular for mobile phones and other hand-held devices is LCO, while electric vehicles prefer NCA and LMO. Recent market analysis suggests that supply-side concerns are prompting battery producers to transition away rapidly from intensive cobalt use in the cathode of NMC and NCA batteries.

Currently, the cathode combination of an NMC is typically one-third nickel, one-third manganese and one-third cobalt, also known as 1:1:1. Current Li-ion research gravitates heavily towards rebalancing the ratio of ni:co:mg in NMC batteries from the current 1:1:1 towards a ratio of 8:1:1.

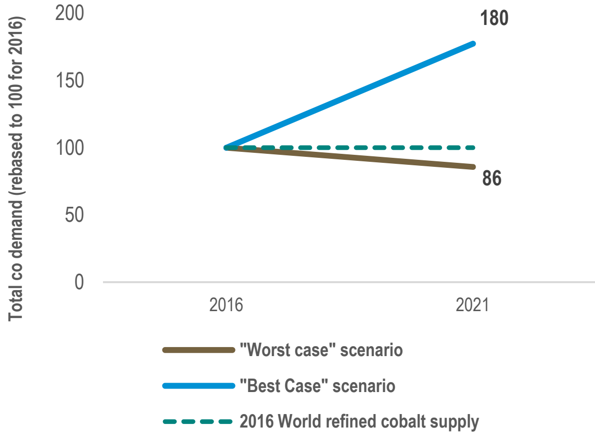
Furthermore, in a development that may be significantly negative for cobalt demand, NMC batteries are thought by some to be on the cusp of replacing LCO batteries almost entirely within the next few years.

Using the demand analysis for various battery uses (electronics, EVs and battery storage), the appropriate batteries for those uses and their relative cobalt content, *The Alchemist* has plotted the potential demand for cobalt based on a 'worst case' and a 'best case' scenario.

- The 'worst case' scenario for cobalt assumes that all lithium-ion battery demand in 2021 is met by NMC batteries using an 8:1:1: ratio in the cathode (ie, NMC has replaced all LCO in portable electronics).
- The 'best case' scenario for cobalt assumes that all portable electronic demand will continue to be met by LCO batteries (100% Co in cathode), while all electric vehicle batteries use NCA 15 (15% Co in cathode) and all static storage uses NMC 1:1:1. The results are shown below.

Note: The cobalt demand figures shown in the graph assume that all current non-battery demand for cobalt grows at a rate of 2% YoY from 2016-2021.

Figure 15: Cobalt Demand Scenarios 2016-2021



Source: CDI, The Alchemist

What our analysis shows is that, in the 'worst case' scenario, refined cobalt demand in 2021 may be marginally lower than in 2016. In the 'best case' scenario, cobalt demand may be ~80% higher than today. Clearly it is likely that the results will be somewhere in the middle, although it is our view that they will be skewed towards the 'worst case' scenario.

New Supply Sources

Assuming the cobalt demand picture in 2021 is somewhere between the scenarios, it is likely that new supply sources will be needed to service the demand.

A number of DRC projects are in the development phase, which we think could help to meet or eliminate any potential short-medium term cobalt deficit.

Table 7: DRC Near-term Cobalt Production

Owners	Project	Status
Eurasian Resources/ Zijin Mining	RTR (tailings and open pit)	Expected to ramp up to full production by late 2017/early 2018 with production of ~14,000tpa cobalt
Glencore	Katanga restart and ramp-up	Previously produced >2,500tpa, but Glencore understood to be reworking mine plan to deliver significantly more production, potentially up to 25,000tpa
Sicomines	Project Miniere	Details and development timeline unclear, but USGS forecasts production of >19,000tpa by 2018
Total potential new Co supply		**35-60,000tpa**

Source: Company reports, SNL

These figures suggest that the cobalt deficit is likely to be met by 2021. However, this still leaves the world reliant on the DRC as the main source of cobalt.

As part of our investigation into potential new sources of world cobalt supply outside the DRC, *The Alchemist* delved into the USGS' 'Minerals Yearbooks' for cobalt from 2010 to 2014. In the books, the USGS publishes a quite comprehensive list of all projects at the feasibility stage that are slated for production in the future.

Of the ~40,000t of ex-DRC new mine development capacity slated by the USGS to come into production by 2016, ~33,000t was forecast by-product production from copper or nickel production, and of this a little over 5,000t was actually produced in 2016, as outlined in Table 8.

The Alchemist has not individually checked the status of each potential development in the list and makes no comment on the merit or possibility for each development to come to fruition. While many might have stalled for technical or corporate reasons, the evidence suggests that most simply don't stack up economically as nickel-cobalt or copper-cobalt developments.

Hence, outside the DRC cobalt supply is still largely constrained by copper and nickel market dynamics. Absent a sustained upswing in the prices of both copper and nickel, it is hard to see where substantial new supply will come from.

A Brief Note on the DRC

The causes and historic issues fuelling conflict in the DRC are manifold and very complex. Suffice to say the country is in an extremely dysfunctional state and has been for some time, which is unsurprising given its horrific legacy of colonialism and conflict by proxy.

The people of the DRC live in some of the poorest conditions on earth: infrastructure in many places is non-existent, corruption is rampant across all walks of life and armed conflict is an ever-present threat, especially in the restive east of the country near the borders with Uganda, Rwanda and Burundi. Unsurprisingly, the country ranks 184th of 189 in the World Bank ease of doing business index. Many observers are reporting recent increases in civil unrest; there have been attacks on police and the armed forces, large jail breaks and massive demonstrations in the capital Kinshasa. Under these circumstances, many, including the ex-head of the UN, Kofi Annan, are making dire warnings about the potential for the recommencement of war, which also has the potential to draw in a large number of external actors and provoke wide-scale disruption to Central and West Africa.

Table 8: Forecast Cobalt Production ex-DRC vs. Actual Supply

Forecast first production	Country	Project	Main commodity	Ore type	Forecast prod (tpa)	Actual prod 2016 (t)
2014	Cameroon	Nkamouna	Cobalt	Nickel-cobalt laterite	6,100	0
2012	Madagascar	Ambatovy	Copper	Nickel-cobalt laterite	5,600	3,273
2011	Australia	Gladstone Nickel	Nickel	Nickel-cobalt laterite	5,000	0
2014	Philippines	Mindoro Nickel	Nickel	Nickel-cobalt laterite	3,300	0
2011	Papua New	Ramu	Nickel	Nickel-cobalt laterite	3,300	1,600
2013	Australia	Wingellina Nickel	Nickel	Nickel-cobalt laterite	3,000	0
2014	Zambia	Ichimpe	Copper	Copper-cobalt ore	2,000	0
2013	Canada	NICO	Gold	Gold-cobalt-bismuth-	1,860	0
2015	Mexico	El Boleo	Copper	Copper-cobalt-zinc-	1,700	420
2013	Zambia	Muliashi	Copper	Copper-cobalt oxide	1,500	0
2011	Australia	Niwest	Nickel	Nickel-cobalt laterite	1,400	0
2011	Australia	Ravensthorpe	Nickel	Nickel-cobalt laterite	1,400	0
2012	United States	Idaho Cobalt	Cobalt	Cobalt-copper-gold	1,260	0
2012	Finland	Outokumpu	Copper	Copper-zinc-cobalt	940	0
2014	Philippines	Acoje	Nickel	Nickel-cobalt laterite	930	0
2016	Turkey	Caldag	Nickel	Nickel-cobalt laterite	900	0
2016	Australia	Nova Nickel	Nickel	Nickel sulphide	850	0

Source: USGS, SNL

OTHER POTENTIAL "NEW" SUPPLY SOURCES

Stockpiles

An analysis of the USGS supply and demand figures outlined in the graph on page 3 suggests a cumulative oversupply of ~75,000t of refined cobalt in the world market between 2010-15. Stockpile figures for refined cobalt are notoriously hard to come by (most is probably in China), but the figures suggest that there may be a significant overhang of unused refined material to be worked through that could meet some of the demand in the years ahead.

Recycling

Recycled cobalt is recovered from the production processes of manufacturers of applications like hard metal and cemented carbide tools or rechargeable batteries, petrochemical catalysts and alloys used in aerospace applications. Cobalt recycling from applications in pigments, glass, paints, etc, is not possible as these are dissipative. Accurate figures on rates of recycling and 'new' cobalt supply derived from it are hard to come by, but growth in the worldwide recycling rate is unlikely to add significant new supply in the near term.

Sea-floor Mining

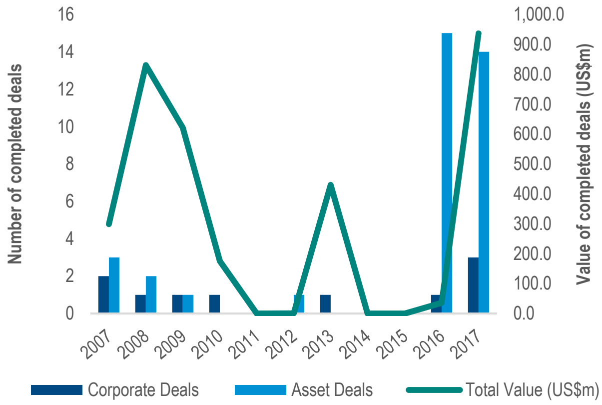
Significant metalliferous resources exist in various sea-floor deposits around the world. In the case of cobalt, these occur as ferromanganese oxide concretions on the sea-floor that have been enriched in cobalt by extraction from sea water and pore fluids from muds.

However, to date, no sea-floor metalliferous mining has ever been carried out and most attempts to commercialise ocean-floor mining to date have been stymied by technological, political, environmental and funding issues. It is therefore highly unlikely that sea-floor mining can provide sufficient new cobalt supply in the short-medium term.

PUBLIC MARKETS

After a moribund period between 2009 and 2015, M&A activity in cobalt projects and companies has seen a major upswing, both in terms of number of deals and total deal value. (Deal value for 2017 is heavily skewed by Glencore's purchase of 31% of the Mutanda property for US$922m.)

Figure 16: Cobalt M&A 2007-2017

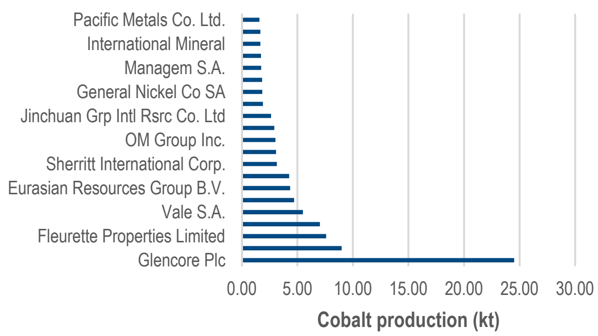


Source: SNL

Exposure to Cobalt

Unfortunately, exposure to pure-play cobalt production for mining investors today is near-impossible. The top 20 producers of the metal are dominated by large diversifieds, Chinese diversifieds, private groups and nickel producers.

Figure 17: Attributable Cobalt Production by Company, 2016



Source: SNL

However, there are a few companies that give investors exposure to both cobalt metal and cobalt end products.

Cobalt 27 Capital (TSX:KBLT)

Started trading on the TSX Venture Exchange on 23 June after a C$200m IPO. The company aims to offer investors access to physical cobalt and owns over 2,000t of cobalt metal, which will be stored in secure warehouses in Europe and North America but must be further refined to be used in lithium-ion batteries. The company's holdings come from a group of investors, including Pala Investments. Cobalt 27 also plans to make streaming deals with cobalt-producing companies, and has already acquired royalties on eight exploration-stage properties containing cobalt.

Umicore (BRU:UMI)

Umicore is a global materials technology and recycling group, with about 10,000 employees and a turnover of €11.1bn. Umicore generates the majority of its revenues from (and dedicates most of its R&D efforts to) clean technologies, such as emission control catalysts, materials for rechargeable batteries and recycling; as such, it has a significant market share in cobalt end products.

Furthermore, there are a number of publicly-listed juniors that are developing projects in stable jurisdictions, wherein cobalt is a key value-driver in the potential product mix. The more advanced are summarised below. *The Alchemist* cautions that a cursory analysis of the differentials between market caps and potential capital costs of the projects points to the likely difficulties of many of the projects being brought to production.

CONCLUSION

We began our investigation into the cobalt market in order to try and understand what is driving demand and whether existing or likely supply could match it. There has been a lot of attention paid to the role of cobalt in the near-medium-term rise in lithium-ion batteries for electric vehicles and stationary storage.

Our investigations have led us to temper our excitement about the medium-longer-term demand outlook for cobalt. Non-battery uses of cobalt will continue to demand a significant market share and are forecast to grow at a slow, but steady, rate. Indications are that supply-side worries are driving battery producers to reduce their reliance on cobalt significantly through technological advances.

Major projects coming on stream in DRC in the near-medium term may wipe out most of the potential deficit in cobalt supply, but will continue to leave the world over-reliant on the DRC as a supply source. *The Alchemist* suggests that any coming supply shock from DRC will, counter-intuitively, seriously dent the long-term prospects for new cobalt development.

Table 9: Junior Cobalt Development Companies

Project name	Main Owner	Market Cap (US$m)	Exchange	Project location	Development stage	Co Resource (000t)	Potential Capital Cost (US$m)	Potential cobalt production (tpa)	Potential product mix
Idaho	eCobalt Solutions Inc.	113	TSX	USA	Feasibility Started	25	147	1,257	Cobalt, Copper
Kalgoorlie	Ardea Resources Limited	27	ASX	Australia	Scoping study	386	613	900	Cobalt, Nickel
Mt Thirsty	Barra Resources Limited	18	ASX	Australia	Scoping study	20	400	NA	Cobalt, Nickel
Niwest	GME Resources Limited	22	ASX	Australia	Scoping study	52	345	NA	Nickel, Cobalt
Sconi	Australian Mines Limited	24.5	ASX	Australia	Feasibility Started	54	597	675	Scandium, Cobalt
Syerston	Clean TeQ Holdings Limited	309.6	ASX	Australia	Feasibility Started	114	705	3,222	Scandium, Cobalt, Nickel
Thackaringa	Cobalt Blue Holdings Limited	13	ASX	Australia	Scoping study	49	NA	NA	Cobalt
Werner Lake	Global Energy Metals Corp	3.9	TSX-V	Canada	Scoping study	NR	NA	NA	Cobalt, Copper

Source: SNL

RFC Ambrian Limited

www.rfcambrian.com

Level 12, Gateway
1 Macquarie Place
Sydney NSW 2000

telephone +61 2 9250 0000
facsimile +61 2 9250 0001

Level 28, QV1 Building
250 St Georges Terrace
Perth WA 6000

telephone +61 8 9480 2500
facsimile +61 8 9480 2511

Condor House
10 St Paul's Churchyard
London EC4M 8AL

telephone +44 (0)20 3440 6800
facsimile +44 (0)20 3440 6801