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Global Commodities

Cobalt: Solving for a Supply-Constrained Market

Bottom Line: Cobalt looks set to be the main constraint on battery market growth. Even without a rise in electric vehicle demand we foresee a tight market, while overreliance on the Democratic Republic of Congo on the supply side cannot be avoided. We expect aggressive substitution and scrap recovery over the coming years, but not before further price gains. A doubling of the cobalt spot price over the coming couple of years is not out the question, while we raise our long term price to $22.5/lb.

Key Points

Battery-powered growth. While other commodities are growing their share of consumption through batteries, cobalt has been down this path already. Around 55% of cobalt is already going into rechargeable batteries, compared to lithium's ~40% and nickel's ~5%, which has resulted in industry-leading trend demand growth of 6.1% CAGR since 2010.

Even without EV demand, cobalt is a tight market. Add the expected EV demand into the mix, where we model 10% penetration in 2025, and we have a major problem. Without demand adjustment through substitution and thrifting, we would foresee a 60% rise in cobalt demand to 2025. However, there is simply not enough supply potential to match this. Moreover, cobalt cannot escape the overreliance on the Democratic Republic of Congo (DRC), which accounts for 60% of mined cobalt units currently and ~85% of industry supply growth over the coming five years. Indeed, around half of the cobalt produced globally is mined in the DRC and refined in China. The DRC-China Chemical-Battery power axis has become increasingly dominant over recent years.

More aggressive substitution and scrap recovery are needed. We have seen some estimations of significant deficits in the cobalt market in the 2020s. That's simply not the way commodity markets work; they will naturally self-solve to bring supply and demand closer to balance. In the near term, there is some new cobalt supply coming towards commission in the DRC, plus Glencore's restart of its copperbelt operations. Moreover, we believe existing assets can squeeze out more supply at current prices. Beyond this, to solve the market balance we assume secondary cobalt recovery grows strongly, more than doubling in volume by 2025. We also have to model ongoing substitution in those sectors where there is less inertia to change, notably prosthetics and hard facing products, plus aggressive shifting to lower cobalt cathodes in EVs.

In all scenarios we can envision, the cobalt price goes higher. To be clear, we have had to make very aggressive assumptions to bring the cobalt market anywhere near balance. To maximise supply and substitute demand in such a way need a simple catalyst – price. Whether this happens sooner or later, in our view the cobalt price will have to move from the current level of ~$30/lb back towards the 2007 peak of ~$50/lb in order to initiate the processes needed to address the looming market deficits. We have the annual average cobalt price peaking at $40.5/lb in 2019.

BMO Capital Markets

Global Commodities

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Summary

- We view cobalt as a supply-constrained market into the medium term.
- To put the cobalt market in simple terms, it is the power axis of DRC mining - China refining - battery demand.
- In order to make space for EV demand, we have to substitute aggressively in other cobalt end uses.
- Battery recycling must increase dramatically in the coming years to permit enhanced cobalt recovery.
- In all scenarios we can envision, the cobalt price goes higher.

Recent BMO Commodity-Related Research

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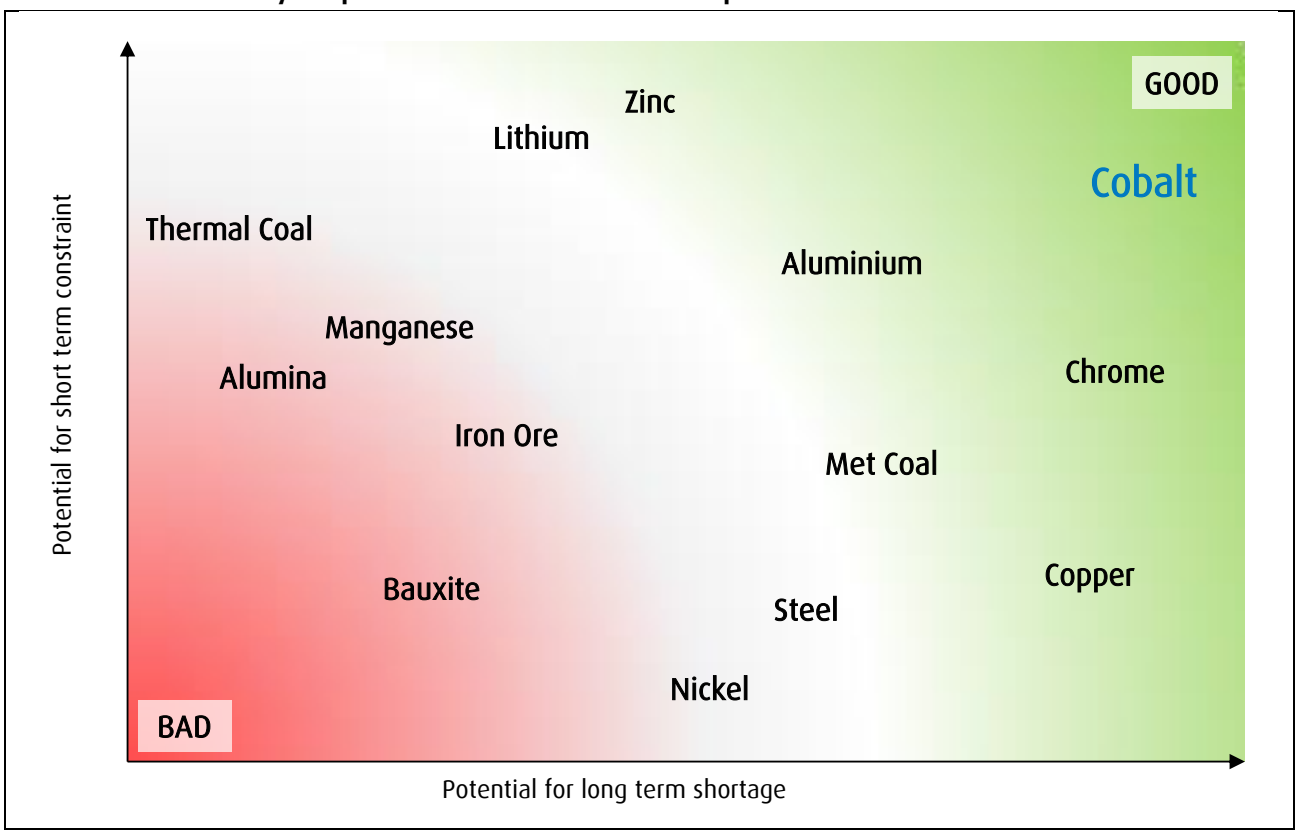
Key Points to Know About the Cobalt Market

Cobalt Fact	Implication
Cobalt has been the best performing metal we cover over the past 12 months	We have started to draw inventory quickly following supply problems
The cobalt market is currently around 100kt in annual market size	At current spot prices, this makes cobalt a $6.6bn market
Almost all cobalt is extracted as a by-product or co-product stream	Cobalt will rarely justify development of a project on its own, making supply more reliant on other metal prices
Cobalt is traded on the London Metal Exchange	This gives an easily accessible reference price to investors; however, the Metal Bulletin 99.8% price is still considered the industry reference
The largest single use of cobalt is in smartphones (not EVs)	Cobalt makes up 50-60% of the cathode in the average smartphone, and there is a natural reluctance to substitute this for safety and performance reasons
Only 10% of cobalt is currently consumed in electric vehicle batteries	In order to make space for EV demand, we have to substitute aggressively in other cobalt end uses
We currently have a tight cobalt market without EV demand	Automakers and battery manufacturers will invest heavily to thrift cobalt in battery chemistry, moving to more nickel-rich compounds
We see cobalt as the biggest potential constraint to EV penetration	Even though gaining direct cobalt exposure is difficult, it is crucial to understand this market given the wider implications
China has next to no domestic cobalt resource ...	There are no active Chinese private sector miners to help alleviate supply issues
... but is ~80% of cobalt chemical production globally	We expect Chinese companies to look to secure supply through mining asset purchases, similar to those seen recently
Around 50% of global cobalt units are mined in the DRC then refined in China	To put the cobalt market in simple terms, it is the power axis of DRC mining - China refining - battery demand
Cobalt supply from the DRC is China's greatest reliance on a single country for commodity raw material	Any disruption to this link would cause major dislocations in the cobalt market
Only 10% of cobalt is currently recycled	This must increase dramatically in the coming years, and will perhaps be the biggest growth area for cobalt
Consumer pressure is increasing to ensure traceability of cobalt amid child labour concerns	We would expect to see a 'non-DRC premium' develop for cobalt, both for current quotes and for new projects
We expect a rising cobalt metal surplus over the coming years, but also a rising cobalt chemical deficit	Metal conversion into chemicals will have to grow, either at refineries or (more likely) in China, permitting a cobalt sulphate premium.
We have to make very aggressive assumptions on both supply and demand to bring near-balance to this market in future years	In all scenarios we can envision, the cobalt price goes higher

For further detail on the electric vehicle market and battery trends, we recommend reading Lithium Recharge: Driving to Multi-Decade Thematic published October 24, 2017, by Joel Jackson.

Exhibit 1: BMO Commodity Comparison Chart – Cobalt Is in a Good Spot



Source: BMO Capital Markets

Why Did Cobalt Rally This Year?

There has been a combination of factors that has aided cobalt's outperformance over 2017, but in our view three in particular have acted as catalysts:

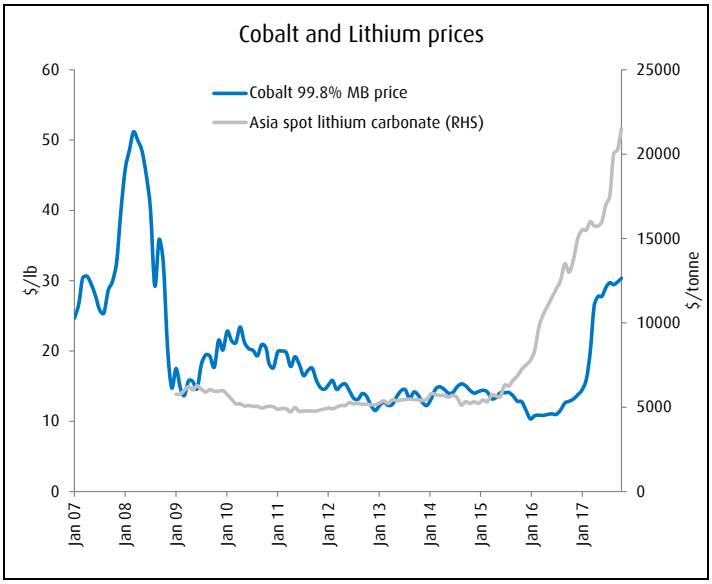
1. Continued growth in smartphone sales. Smartphone batteries are still the main end use market for cobalt, and after a weak H1 2016 demand growth recovered in H2 and has continued through 2017.

2. Global cobalt mine supply is down 2.7% YoY in 2017 on our estimates, with weakness at Glencore operations and disputes at GTL's Big Hill primary cobalt tailings operation seeing DRC output fall by ~5kt cobalt contained.

3. Most importantly, on December 30 last year, China announced a revised E-bus battery subsidy policy. Essentially, this prioritised the higher battery quality technologies, penalising LFP (lithium-iron-phosphate) and benefitting NMC (nickel-manganese-cobalt). Chinese battery manufacturers have scrambled to add cobalt-containing NMC capacity, and also raw materials to fill this given expectations that equivalent quality-driven subsidies will be put in place for car batteries.

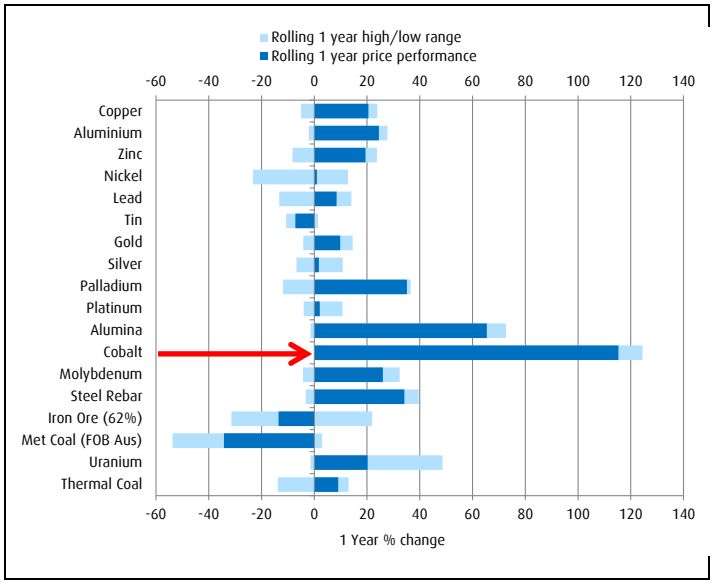
Until this, cobalt was the perennial underperformer in metals markets. While all others were gaining in 2010 as QE-led reflation took hold, cobalt was already starting to move lower, a trend that persisted until 2013. However, prices have now risen by over threefold from the December 2015 low to levels last seen just before the GFC, at ~$31/lb. This makes cobalt the best performer of the commodities we cover over the past year in terms of price gains, and at current spot market pricing a market worth $6.6bn per annum.

Exhibit 2: Recent Cobalt Price History



Source: Metal Bulletin, BMO Capital Markets

Exhibit 3: Cobalt Has Outperformed Over the Past Year

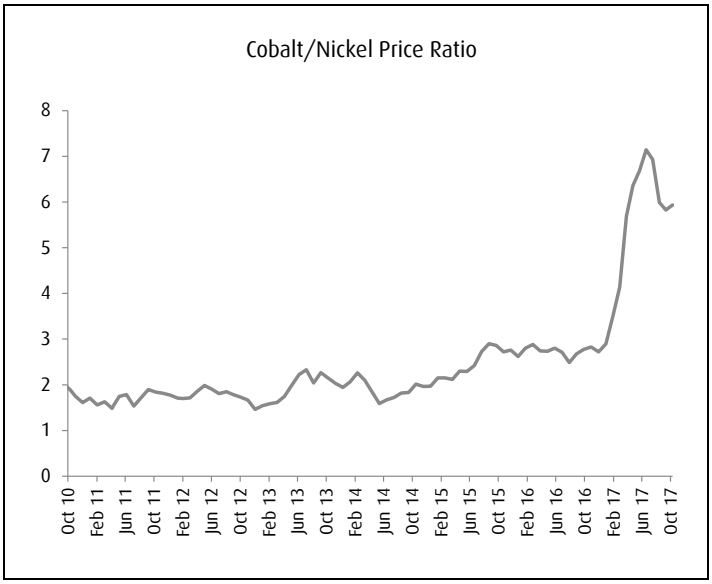


Source: LME, Bloomberg, BMO Capital Markets

On a longer-term view, current prices have moved back above the longer-term inflation-adjusted average of $22/lb. Cobalt has a history of spikes higher following a period of underperformance, which is mainly related to the structure of the supply side. Without a primary mine supply side to speak of, cobalt has less of an elastic supply buffer than peers.

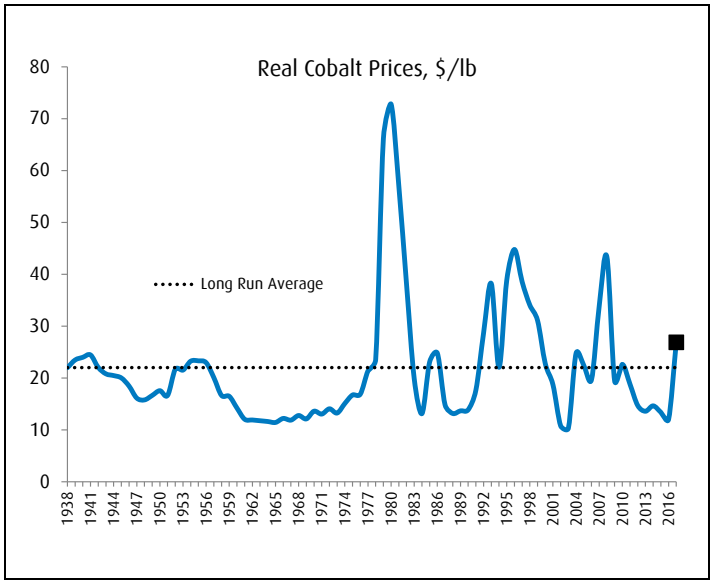
Interestingly, cobalt's ratio to its largest potential direct substitute, nickel, has also jumped. Having been around 2:1 for many years, this ratio jumped to over 7:1 in June, a level last reached in 1999. Given the extent of substitution we believe will be needed in this market, this is an important development.

Exhibit 4: Cobalt to Nickel Ratio Has Risen Dramatically in 2017



Source: LME, Metal Bulletin, BMO Capital Markets

Exhibit 5: Long-Term Cobalt Price History (in Today's Money)



Source: Metal Bulletin, BMO Capital Markets

DRC Dependence – The Inherent Risk in Cobalt Supply

Cobalt's supply side is unique among peers. It has heavy reliance on a single supply country (DRC), a complex value chain, and next to no primary supply, coming as a by-product of nickel and copper operations. What sets it aside, however, is that China has next to no domestic resource, and thus is beholden to international markets for supply. Buffers against raw material constraint are thus limited.

Similar to peers, established assets are generally in decline. Combined output from key supply countries Australia, Russia, and Zambia is 28% lower than seen a decade ago. Moreover, given the ongoing underperformance in price, not just for cobalt but also for nickel and, until recently, copper, very few new projects are coming through the pipeline in short order.

Cobalt occurs in the earth's crust to an average concentration of less than half of that of copper and nickel. Ore-forming geological processes accumulate cobalt into minable concentrations almost exclusively alongside copper and nickel – there are, therefore, no sizeable primary sources of cobalt. The major deposit types that contain cobalt as a by-product metal are sediment hosted, such as those found in the African copperbelt, hydrothermal; magmatic, and lateritic.

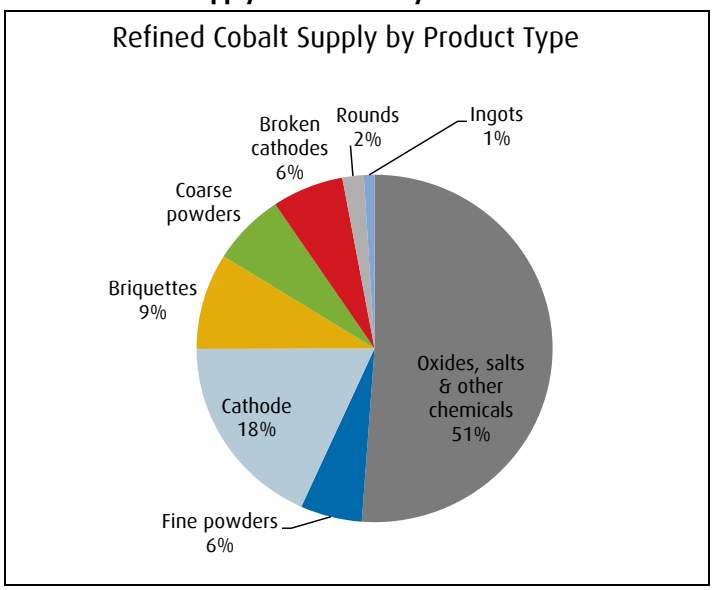
The process chain for cobalt normally involves mining and separation of ore, with subsequent upgrade to a 6-8% cobalt concentrate and/or partially refined into an intermediate product (20-40% Co). This is then further refined into cobalt metal or chemical products. Currently, <20% of cobalt is refined in the same country in which it is mined, leading to a strong trade in concentrates (often on long-term contracts). As an example, with the temporary closure of the Katanga facility, only state-owned miner Gecamines is refining cobalt in the DRC at present, with the remainder of cobalt units exported.

Exhibit 6 shows the varied forms in which cobalt is supplied to global markets, all with slightly different discounts or premia to the widely quoted 99.8% high-grade cobalt index. The LME price is also used as a reference, though that contract is still struggling for liquidity. Cobalt is generally a trader-driven market given the level of merchant material, and can be considered relatively opaque in terms of hard data.

To keep up with demand growth, refined cobalt supply has doubled since 2004, a CAGR of 5.5%. Historically, production of cobalt metal dominated, but since the portable electronics revolution took hold supply of chemicals has been driving supply growth, accounting for ~60% over the past decade. Supply of cobalt in chemical form overtook that in metal in 2012, and is now over 40% higher.

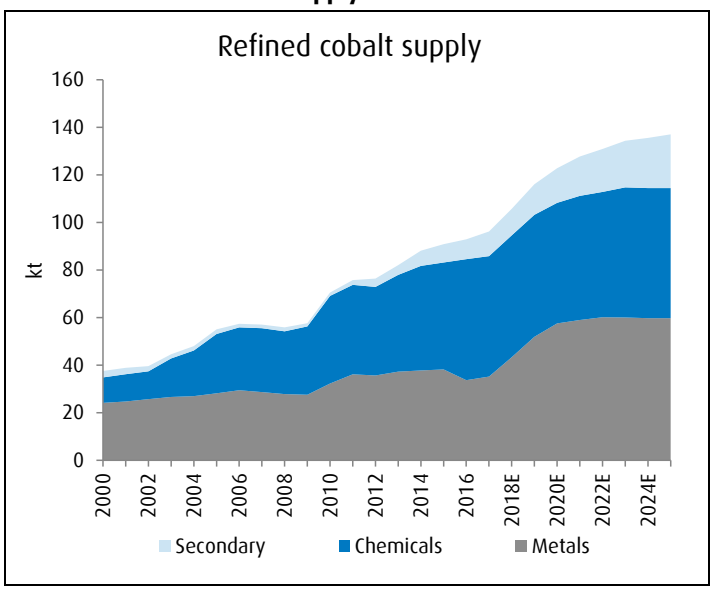
One area where cobalt has struggled has been scrap recovery for secondary supply. The fact that cobalt is used in alloy form in most of its main metal uses makes recovery closed loop (i.e., back into the same process) at best, while for chemicals the difficulty in cathode separation and recovery has been widely discussed. Even with acceleration in recent years, only ~10% of refined cobalt comes from secondary sources. In our view, given the supply-constrained nature of the cobalt market this has to change. We model the recovery ratio rising to 16% by 2025, doubling cobalt supply from secondary sources.

Exhibit 6: Cobalt Supply Comes in Many Forms



Source: Darton, BMO Capital Markets

Exhibit 7: Cobalt Chemical Supply Now Exceeds That of Metal



Source: CDI, BMO Capital Markets

The level of DRC risk in cobalt supply cannot be underplayed. In our view, the wider market has become sanguine to the geopolitical risk in that country, and while the majority of cobalt is mined in Katanga Province, a long way from the capital Kinshasa, turbulence has caused issues in the past. This country was of course subject to the deadliest conflict in modern African history less than 20 years ago. Protests against long-standing president Joseph Kabila have intensified in recent times. Presidential elections are now overdue, and unrest is growing. We do not assume any major issues in our modelling, but the concentrated nature of the cobalt supply side means the potential for a supply shock remains high.

In the past, the DRC has made efforts to force greater processing of cobalt ore within the country, occasionally banning shipments on a temporary basis. This has seen a push towards more intermediate products, but given the lack of consistent power in the country, in our view full refining is impractical and thus unlikely.

Currently, the DRC is responsible for 60% of mined cobalt units. Given this is one of the few supply regions across the world where existing mines can creep capacity, DRC dependence is only going to grow. We see the DRC representing 65% of mined cobalt units in 2025.

One area we would hope supply declines in the DRC is from artisanal mining. The use of child labour in cobalt extraction rightly received very bad press, and to date the industry has not taken adequate measures to ensure traceability of cobalt units. With the LME launching a probe into their listed cobalt brands and Amnesty International cranking up the pressure on China's Zhejiang Huayou to review their supply chain after reports they were sourcing child-mined material, we anticipate this supply will fall to be partially offset by legitimate mining of affected areas. In our view, the consumer will increasingly push, via the electronics companies, to ensure cobalt used in products has come from bona fide mining operations. This situation will provide another impetus to potential cobalt substitution in batteries.

Growth in the cobalt market is dominated by certain areas. The power axis from DRC mine supply to Chinese chemicals into batteries becomes ever-more dominant every year. Over the decade from 2010 to 2020, we expect 5.0% CAGR in DRC mine output growth, which will permit a 5.9% CAGR in Chinese chemical output growth (we do not expect the recent clampdown on battery production plants to move upstream to cobalt chemicals).

2017 has seen some disruption to this chain. The 5.3ktpa Big Hill cobalt mine in the DRC has seen a blockade since March as minority owner Gecamines seeks to bring in a different partner. This tailings

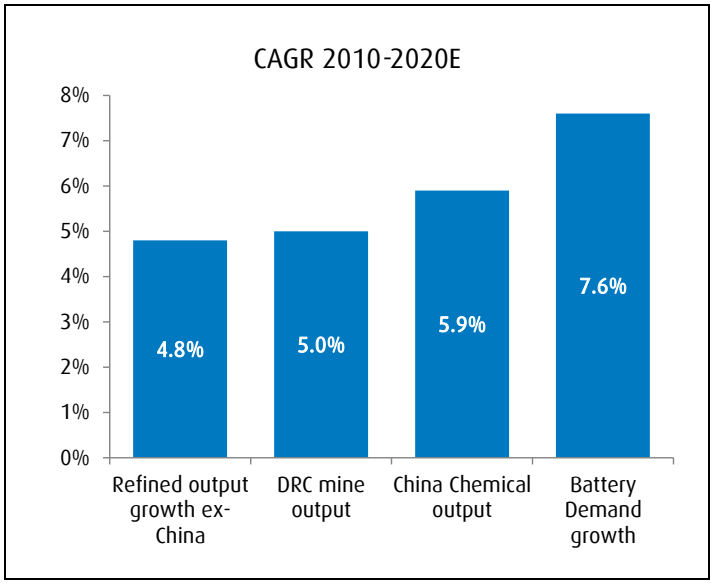
operation is the DRC's fourth-largest cobalt mine, the only major operation where cobalt is the primary material, and is responsible for ~4.5% of global supply. According to Bloomberg reports, the court schedule means no more cobalt is likely to be produced until 2020 unless there is a settlement to this dispute. This, coupled with the temporary closures at Glencore's copper-based operations in the country, means DRC mined output has fallen YoY for the first time since 2012. Even with draws on concentrate stocks, China's chemical output will grow by less than 1,000t this year since 2012 – this is not a coincidence.

We expect the 2017 DRC output to be a blip, and with the Roan Tailings project for ERG set to ramp up from 2018 and a restart at Glencore's Katanga facility (where cobalt output will rise towards 20ktpa), we anticipate the DRC to be the major driver of 6% and 15% YoY growth in global mined cobalt output over 2018 and 2019, respectively.

There are many commodity markets where Chinese refined output has come to dominate, but perhaps none more pertinent than cobalt chemicals (including battery cathode precursor chemicals). China is currently responsible for 80% of all refined cobalt content in chemicals globally. Indeed, were there to be a Chinese purchaser of the 8.5ktpa Freeport Cobalt refinery in Finland, this figure would jump to 97% overnight. Given the potential importance of this market to consumers, and the concerns over China's share of production in industries such as steel and aluminium, that this hasn't garnered more attention is perhaps somewhat of a surprise.

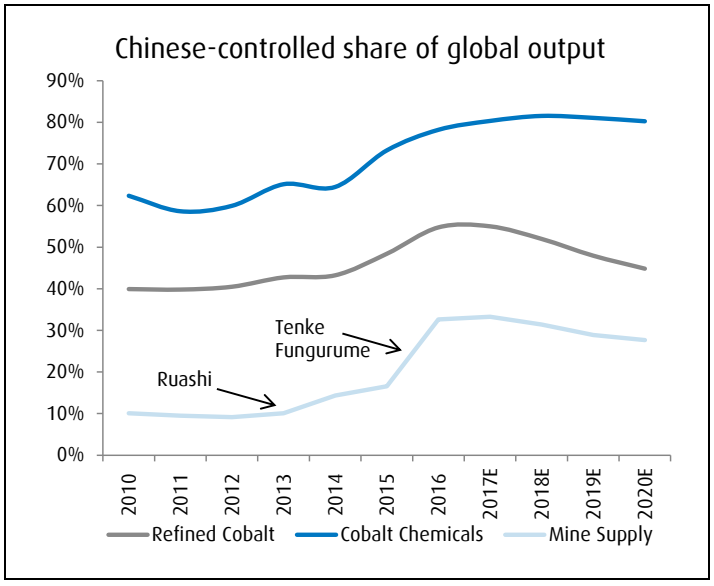
The bigger issue for China's cobalt chemicals industry is securing the mine supply needed to fill this capacity. The share of global mine output owned by Chinese producers is only 34%, and before the purchase of Tenke Fungurume by China Molybdenum from Freeport and Lundin in 2016 this figure was only 17%. We would not be surprised to see further Chinese purchases of cobalt assets to boost security of supply to chemical facilities in future years.

Exhibit 8: The DRC-China Chemical-Battery Power Axis Has Become Increasingly Dominant Over Recent Years



Source: CRU, CDI, BMO Capital Markets

Exhibit 9: China Has Been Trying to Secure Mine Supply to Close the Gap to Its Refined Market Share



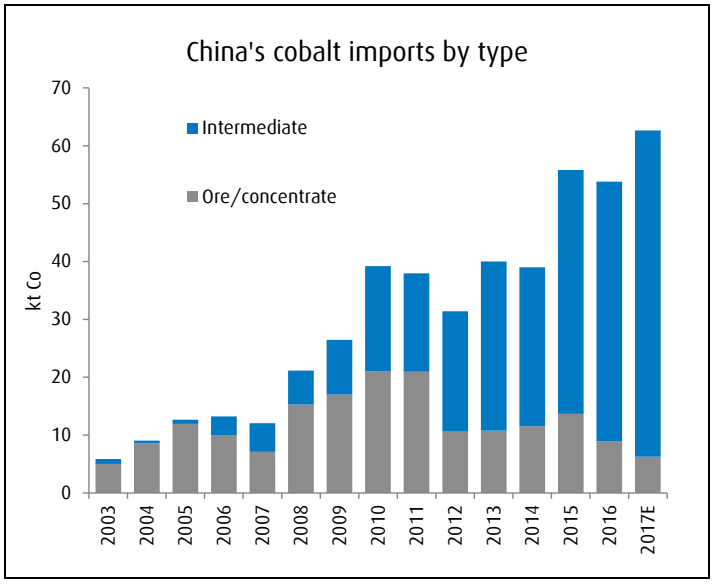
Source: CRU, CDI, BMO Capital Markets

In other markets, certainly until the recent environmental clampdown, China's private sector mining of domestic resource would help solve the balance. However, without domestic resource, this is impossible in cobalt. Cobalt units mined domestically account for just 3% of China's cobalt consumption.

To fuel cobalt chemicals growth, China has thus had to import increasing volumes of cobalt ores and intermediates to fuel gains in chemicals output. Currently, over 50% of ore mined globally goes to China. However, that doesn't tell the full story. Only 7% of this material is from the 40% of cobalt units

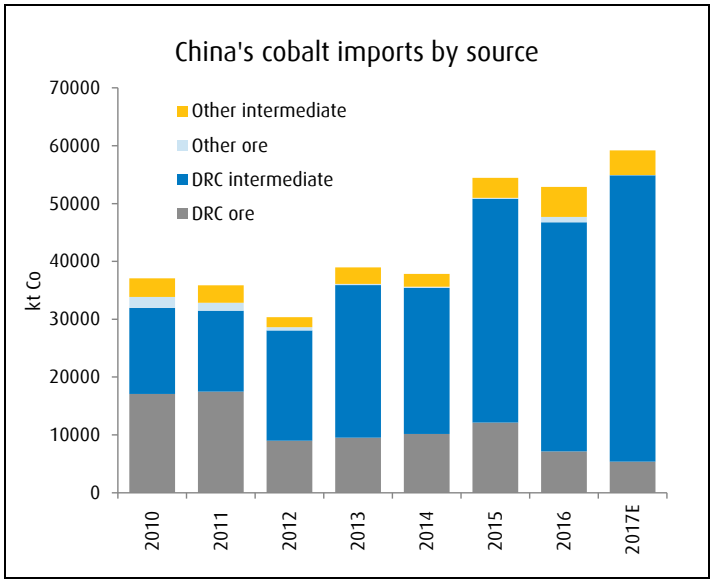
mined outside the DRC. Ninety-three percent comes from the DRC, mainly in intermediate form. Or put another way, **around half of the cobalt produced globally is mined in the DRC and refined in China**. This makes cobalt supply from the DRC China's greatest reliance on a single country for commodity raw material – more than chrome from South Africa, tin from Myanmar and iron ore from Australia.

Exhibit 10: Chinese Cobalt Imports Continue to Rise ...



Source: China Customs, BMO Capital Markets

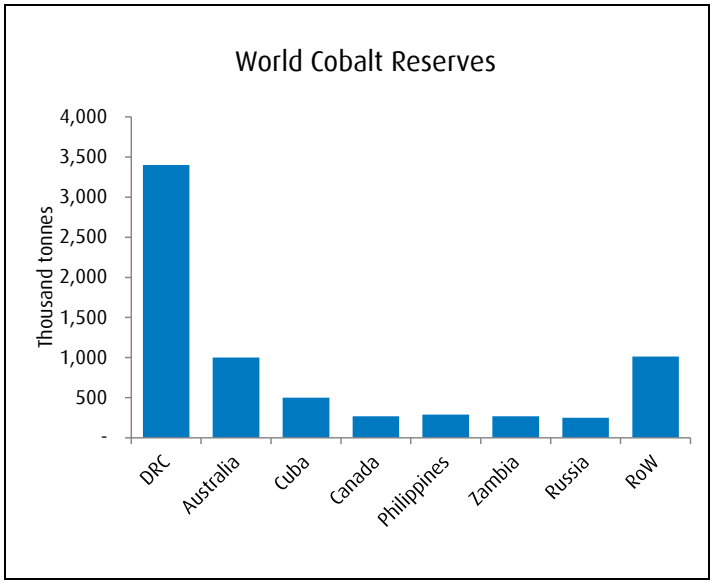
Exhibit 11: ... but Are Dominated by DRC-Sourced Material



Source: China Customs, BMO Capital Markets

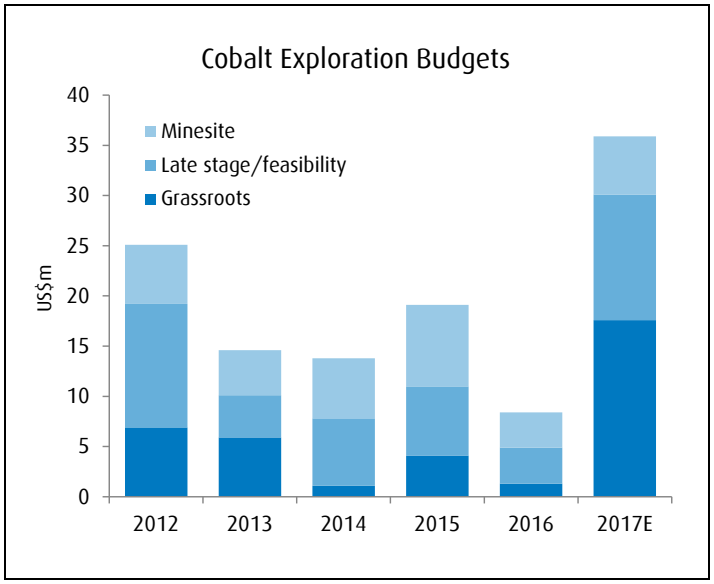
Naturally, the cobalt price gain over 2017 has seen a push to identify and develop new projects. Spend on cobalt-related exploration has more than tripled this year to seek potential resource additions though no sizeable resources have been identified to date. However, just under half of global reserves are also in the DRC, and unsurprisingly much of the focus has been on safer mining jurisdictions such as Australia and Canada, which combined hold around 15% of global reserves. And with funding both from traditional mining funds and technology-related funds available given the strength of the EV story, we expect further developments in 2018. However, just as with other metals, getting such projects to market will take a long time.

Exhibit 12: The DRC Contains Roughly Half of Global Cobalt Reserves



Source: USGS, BMO Capital Markets

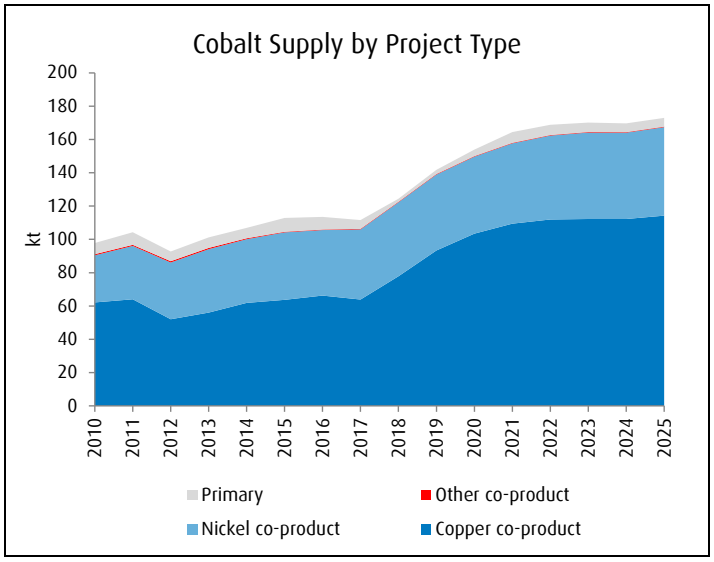
Exhibit 13: Cobalt Exploration Has Surged With Price Gains



Source: S&P Global, BMO Capital Markets

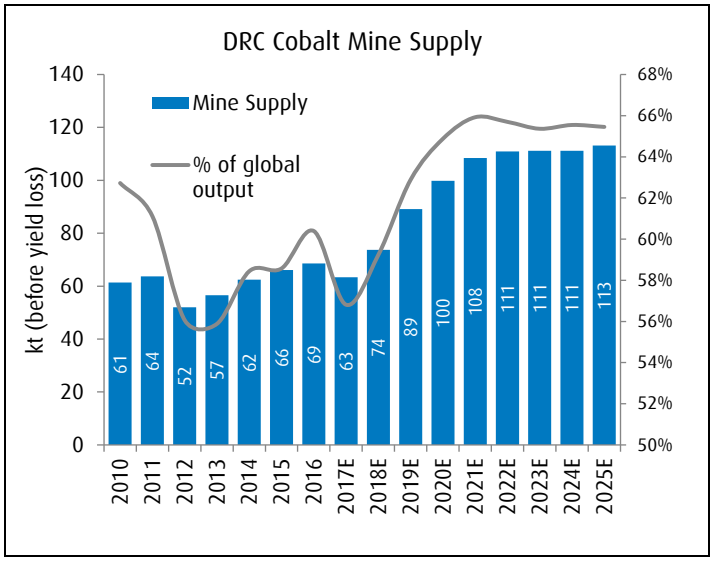
Cobalt's main challenge is that it very, very rarely will justify its own project. The vast majority of cobalt supply globally is either from a primary copper or primary nickel operation as a by or co-product stream. The cobalt price, while potentially helping with overall mining costs through credits, will rarely justify development of a project on its own. For example, for most nickel-based projects even a fivefold increase in cobalt price barely moves project IRR. Thus, unlike its battery peer lithium, there are next to no projects that could come to market in short order. Even with funding in place the process plant needed for cobalt is many times more complex than that for spodumene (lithium in rock), where the Australian miners have been able to react quickly to pricing.

Exhibit 14: The Majority of Cobalt Comes as a Copper Co-Product



Source: CDI, BMO Capital Markets

Exhibit 15: We Need to See Accelerated Growth in DRC Supply



Source: CDI, Darton, BMO Capital Markets

In the short term, potential cobalt growth is all about the DRC. The Roan Tailings Reclamation (RTR) project is still on track for 2018 shipments at present, and when fully ramped to 14kt Co content this will be the fourth-largest operation in the world. Independence Group's Nova Bollinger also shipped first material this year, though at 1.7kt Co it is much less impactful.

We also expect restarts at currently idled operations, partly to recover cobalt but also as the nickel market moves back towards needing additional Class I supply in future years. This would include the 1.2kt Tocantins operation for Votorantim in Brazil, plus the Glencore copperbelt restarts. We also expect creep from existing operations as producers seek to benefit from the higher cobalt price through optimising recovery circuits.

Beyond that, cobalt has a problem. There are very few potential projects coming through the chain, with most still being at exploration phase. The most likely looks to be the Sunrise project in Australia for CleanTeq, but even then first production would not be until 2021 at best. Cobalt simply cannot rely on non-DRC mine output to solve any near-term constraints, and will need what are currently early-stage projects to come to market by the middle of the next decade.

Exhibit 16: Potential Cobalt Projects

Project	Location	Ownership	Output
In construction stage			
Roan Tailings	DRC	ERG	14,000 tpy Co over next 3-5 years.
In pre-construction phase			
Idaho Cobalt Project	USA	eCobalt	1,100 tpy cobalt sulphate equivalent, mine life 12.5 years.
Dumont	Canada	RNC/Waterton	Up to 1,000 tpy cobalt, highly dependent on Ni price
NICO	Canada	Fortune Minerals	1,600 tpy battery grade cobalt sulphate.
Sunrise	Australia	Clean Teq	Potential for up to 3-5,000 plus tpy of cobalt from 2021 onwards
In exploration phase			
Thakaringa	Australia	Broken Hill Prospecting	3 primary Co deposits - Pyrite Hill, Big Hill and Railway.
Tabac Project	Australia	Dragon Energy	Yet to be determined.
Mt. Gilmore	Australia	Corazon Mining	Yet to be determined.
Mt. Thirsty	Australia	Barra Resources	Base case 1,900 tpy for the first five years. Plans for open pit mine and hydrometallurgical processing plant.
Various Co assets	Canada/USA	Cruz Capital Corp.	Total of 8 separate cobalt prospects (7 in Canada, 1 in the US). Output yet to be determined.
Werner Lake Cobalt Project	Canada	Global Energy Metals Corp.	Yet to be determined.
Teledyne Co Project	Canada	LiCo Energy Metals Inc.	Yet to be determined.
Copper Prince	Canada	Green Swan Capital Corp.	Yet to be determined.
Smith Cobalt Property	Canada	Cobalt PowerGroup Inc.	Yet to be determined.

Source: Darton, BMO Capital Markets

The lack of potential supply growth plus the overreliance on the DRC make cobalt a supply-constrained market prone to supply shocks. We assume refined cobalt supply grows strongly (10%) over 2018 on a further draw in above-ground mined inventory, with further steady gains over future years. Even assuming a perfect DRC (without any disruption above the usual 4% allowance), project restarts, and strong growth in secondary supply for 2025, we can only get to 137kt from 96kt in 2016. Given that a supply-constrained market has to solve for available material, this is the starting point around which demand projections have to solve for.

Below, we provide a list of companies with exposure to cobalt supply. This is certainly not exhaustive and, particularly for the producers, cobalt is generally a small part of valuation. Among major companies, Glencore has the largest exposure to cobalt, while Cobalt27 is the closest to a cobalt pure play. Meanwhile, with its technology and expertise, Umicore is highly exposed to the growth in secondary supply needed to balance the cobalt market.

Exhibit 17: Companies With Exposure to Cobalt Supply

Producers	Main Listing	Market Cap (US$ Mn)*
African Rainbow Minerals Ltd	S Africa	1,792
Anglo American Platinum Ltd	S Africa	7,320
China Molybdenum Co. Ltd	China (HK)	18,427
Cobalt 27 Capital Corp.	Canada	146
First Quantum Minerals Ltd	Canada	8,068
Freeport McMoran	US	19,992
GEM Co Ltd	China	4,210
Glencore Plc	UK	67,042
Jinchuan Group Int. Resources Co. Ltd	China (HK)	678
Lundin Mining	Canada	5,250
Metallurgical Corp. of China (MCC)	China (HK)	14,468
Nornickel	Russia	41,197
Sherritt International Corp.	Canada	315
Sumitomo Metal Mining Co. Ltd	Japan	11,430
Umicore	Belgium	10,323
Vale SA	Brazil	52,833
Vedanta Resources	UK	2,741
Zhejiang Huayou Cobalt	China	6,814

*As of Mid-November 2017

Source: Bloomberg, BMO Capital Markets

Exhibit 18: Selected Cobalt Development Companies

Development Companies	Main Listing	Market Cap (US$ Mn)*
Ardea Resources Ltd	Australia	99
Berkut Minerals Ltd	Australia	14
Broken Hill Prospecting (Cobalt Blue)	Australia	5
Castle Silver Resources Inc.	Canada	9
Cblt Inc.	Canada	3
Clean TeQ	Australia	656
Cobalt Blue Holdings Ltd	Australia	17
Corazon Mining Ltd	Australia	16
Cruz Cobalt Corp.	Canada	10
Ecobalt	Canada	86
First Cobalt	Canada	65
Fortune Minerals Ltd	Canada	44
Global Energy Metals	Canada	3
Kings Bay Resources Corp.	Canada	4
LiCo Energy Metals	Canada	10

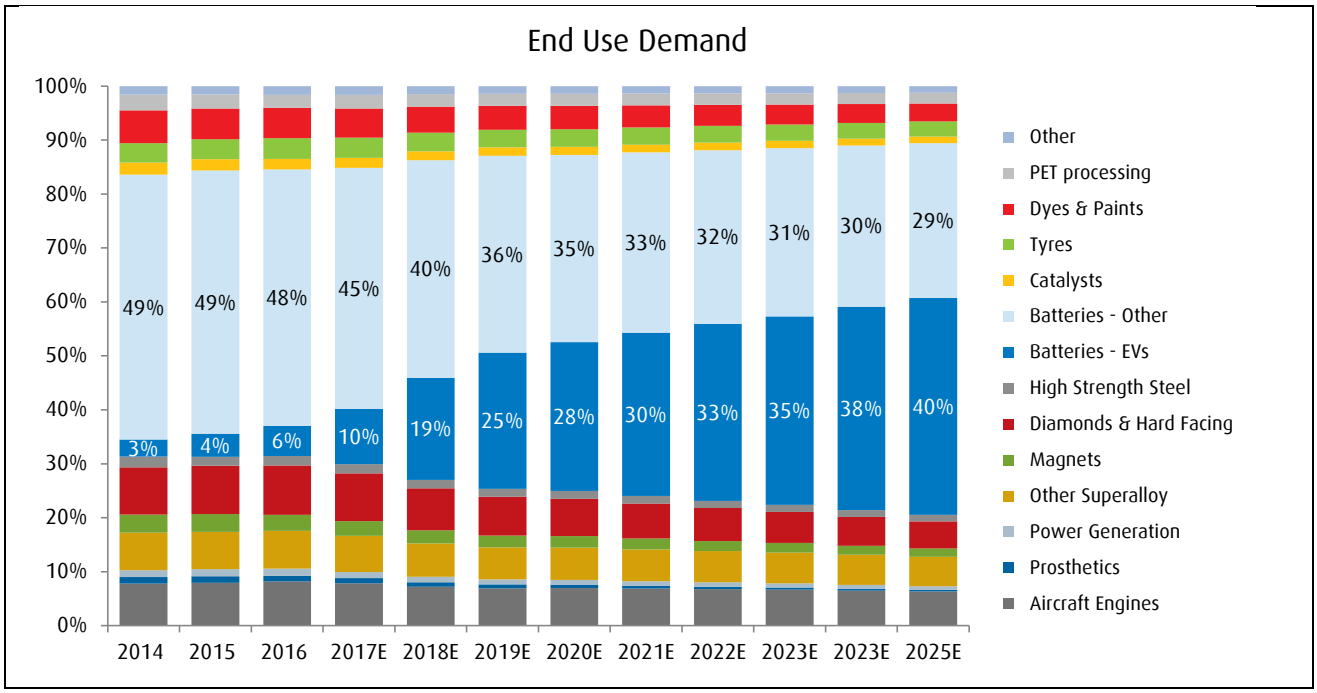
*As of Mid-November 2017

Source: Bloomberg, BMO Capital Markets

Strong Substitution Needed to Make Space for EV Demand

With long-term annual demand growth averaging 6%, cobalt demand has grown from ~40kt in 2000 to exceed 100kt for the first time on our estimates this year. End uses are varied, with cobalt metal used in superalloys for turbine blades and prosthetic implants, magnets, and high strength steel, and cobalt chemicals used as catalysts in various processes plus in dyes and paints. However, it is fair to say that these markets have not been the main driver of cobalt growth. **For demand, think cobalt, think batteries.**

Exhibit 19: Cobalt Demand Breakdown Over Time – EVs Overtake Conventional LCO From 2022



Source: CDI, BMO Capital Markets

Back in 2000, batteries accounted for just 16% of total cobalt consumption. With the rapid commercialisation of lithium-ion rechargeable technology and the shift towards lithium-cobalt oxide (LCO) batteries for portable electronics, batteries now account for 55% of total cobalt consumption on our estimates. This compares to lithium at ~40% going into batteries, and nickel at ~5% currently.

Cobalt-containing lithium-ion-based batteries have high charge density and power-to-weight ratios (they can store more energy in a smaller area) versus lead-acid and nickel-metal hydride battery cells. They also have short recharge times and high cycling ability (i.e., they can traverse charge-discharge cycles for a long time). The low atomic weight renders lithium-ion batteries relatively lightweight because of lithium's low atomic mass, while cobalt is crucial in conserving battery strength and lifespan. These properties, together with high specific energy are why LCO batteries became the staple for smartphones, tablets and power tools.

The key properties of the major lithium-ion battery cathode chemistries are shown in Exhibit 20, below. While all contain lithium, not all contain cobalt, and cobalt proportion can vary significantly. Notably, ~60% of the weight in a LCO cathode is cobalt.

Exhibit 20: Battery Cathode Chemistries – NMC Favoured for EVs, LCO for Portable Electronics

Cathode Types	NMC[1]	NCA	LFP	LMO	LCO
Raw Materials	Lithium Nickel Cobalt Manganese	Lithium Nickel Cobalt Aluminum	Lithium Iron Phosphate	Lithium Manganese Oxide	Lithium Cobalt Oxide
Chemical Formula	$Li(NiMnCo)O_2$	$LiNiCoAlO_2$	$LiFePO_4$	$LiMn_2O_4$	$LiCoO_2$
Energy Density (Wh/kg)	NMC111: 199 NMC532: 205 NMC622: 225 NMC811: 270 More nickel content increases energy density	200-260	90-120	100-150	150-200
Thermal Runaway (Celsius)	210 (Stable)	150 (Least Stable)	270 (Most Stable)	250 (Most Stable)	150 (Least Stable)
Lifespan[2] (# of Cycles)	1500-4500 (High)	500-1000 (Low)	1000-2000 (Medium)	500-1000 (Low)	500-1000 (Low)
Primary Applications	EVs	EVs	EVs	Power tools, medical devices	Portable electronics
Cobalt as % of cathode (by weight)	~19% (NMC111) ~12% (NMC622) ~6% (NMC811)	~9%	Zero	Zero	~60%
Notes	Shift towards more nickel content for higher energy density, and less cobalt/manganese (stabilizers) without compromising battery safety	High energy density, but high cost due to more expensive cobalt, and marginal safety due to relatively lower thermal runaway	Lower energy density relative to nickel cathodes is forcing OEMs to switch from LFP to NMC. Remains ideal for commercial vehicles due to high safety and lower cost	Relatively low energy density and lifespan, but absence of cobalt allows for better affordability	Excels on high specific energy, but limited safety. Most OEM (Samsung, Apple, etc.) confirm that LCO will be first choice for the future

[1]NMC cathode types vary by ratios of nickel/manganese/cobalt per Li content, e.g. per one atom of Li, NMC622 contains one atom formulated with 60% Ni, 20% Mn, 20% Co

[2]Represents the number of complete charges a battery can perform before capacity falls to 80%

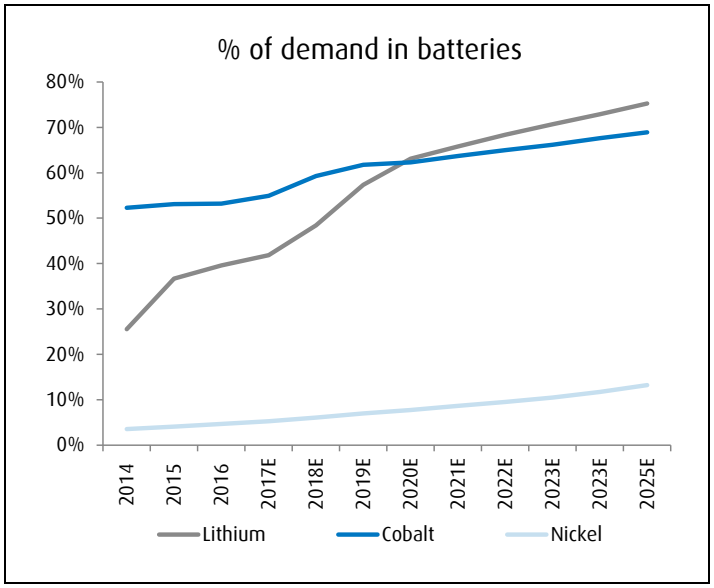
Source: Battery University, BMO Capital Markets

Currently, smartphones are the largest single end-use for cobalt, representing around a quarter of total demand. From ~300m units in 2010, global shipments are now ~1,500m units, with average cobalt content ~16 grams each. This alone has added over 20kt to annual cobalt demand over the same period – battery size may be small but volume is large. YoY growth rates for smartphone shipments slowed to around zero in H1 2016, but have since recovered strongly as global economic growth has improved. In our view, this was one of the key catalysts for 2017's cobalt price gains.

Other segments of the portable electronics markets, such as tablets (~35g/unit) and laptops (~40g/unit), are no longer drivers of growth. After adding 8ktpa to cobalt demand in short order, global tablet sales are now ~24% below their 2014 peak, while laptop sales have been in steady decline over time. Energy storage (ESS) is a growing market for cobalt, but is coming off a low base, and while more e-bikes now use Li-ion technology, cobalt use in this area remains below 1ktpa. Power tools are a growing area for cobalt demand, and in our estimates account for ~2ktpa at present.

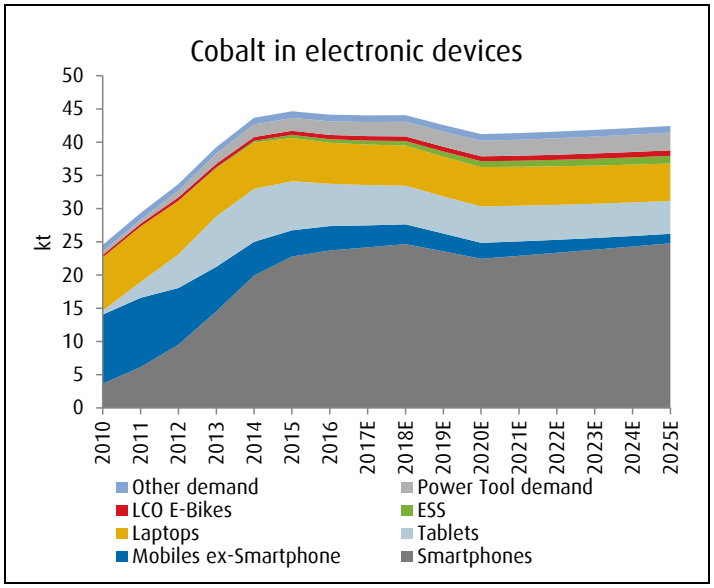
Overall, portable electronics remain central to cobalt demand, and will do into the future. However, we view demand as being on a slight downtrend in this area, as market penetration plateaus and cobalt per unit is minimised in certain cases. Partly, this is down to the need for thrifting, as discussed in more detail in the following pages. Without this, we would see demand moderately higher from portable electronics in 2025 compared to today's levels. With the potential exception of LMO gaining share in power tools, we do not expect mass substitution of LCO in portable electronics given the natural inertia to change, particularly after Samsung's widely reported problems with the Galaxy Note 7. This is even with the two main cathode raw materials having tripled in price over the past two years.

Exhibit 21: Cobalt Already Has Over 50% of Demand in Batteries, With Peers Only Now Starting to Catch Up



Source: CRU, CDI, BMO Capital Markets

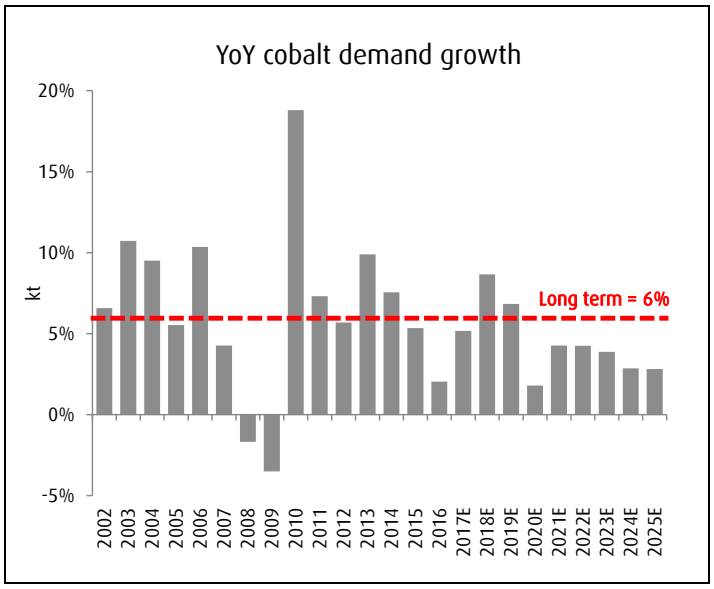
Exhibit 22: Portable Electronics, Particularly Smartphones, Have Driven Growth in Demand – We Now Expect a Plateau



Source: IDC, Darton, BMO Capital Markets

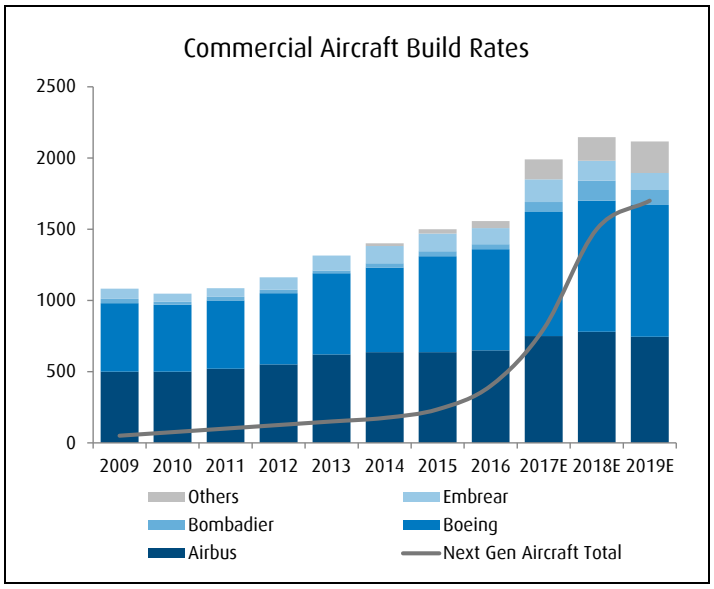
Cobalt demand growth has not just been smartphones, however. The second-largest end use in recent years has been in turbine blades for aircraft engines, where cobalt's resistance to creep at high temperatures and pressures makes it a core element of superalloys used for critical components. Aircraft build rates are rising and order backlogs at Airbus and Boeing combined currently represent ~8 years of production. Importantly, the share of "next generation" engines continues to grow. Given these operate at higher temperature than their predecessors, this promotes further cobalt use.

Exhibit 23: Cobalt's Long-Term Demand Growth Has Exceeded Peers; We Assume a Slowdown Owing to Lack of Available Supply



Source: CRU, CDI, BMO Capital Markets

Exhibit 24: It's Not Just Batteries – Superalloy Demand for Jet Engines Is Also on the Rise



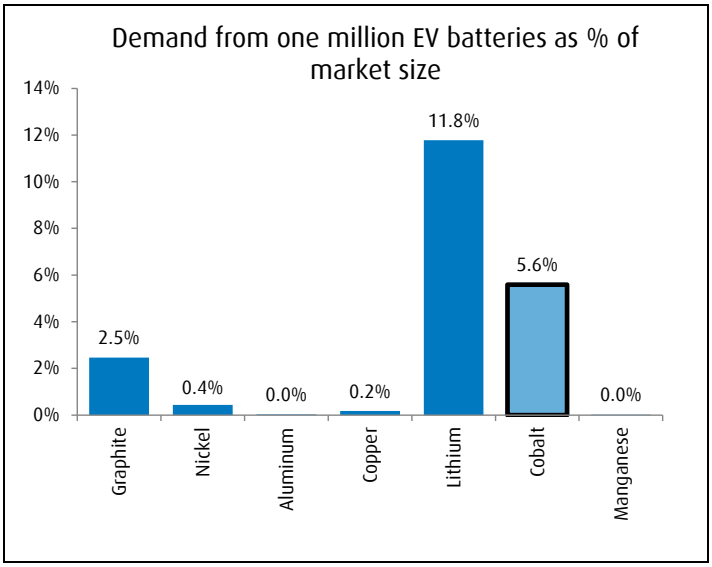
Source: ATI, BMO Capital Markets

Given the relative demand strength in electronics and superalloys, we would foresee a relatively tight cobalt market on these alone given the challenges in supply growth. But of course, demand in electric vehicles is coming, and will be the fastest growing part of the cobalt market.

As per our recent lithium report, the transition towards higher EV penetration now seems inevitable. The key driver for us is regulatory and legislation pushes in Europe and China to reduce air emissions, pressuring automobile OEMs to redesign model lineups. The ability to push for this has been boosted by better battery range/technology, and recent EV designs with better driving experiences, emboldening governments that car makers can produce EV cars consumers will want.

We believe base case 10% EV penetration by 2025 (6% battery electric vehicles / BEV as well as 4% plug-in hybrids / PHEV) is reasonable. This will be too high for some, and too low for others, but 10% seems good middle ground between realistic battery supply chain capabilities and OEM/regulatory targets and proclamations. A variety of cathodes are used for EVs, and traditionally Chinese manufacturers have favoured cobalt-free lithium-iron-phosphate (LFP) batteries given their lower cost (and thus increased cost-competitiveness against internal combustion engines). However, the Chinese government is in the process of prioritising the higher battery quality technologies, and penalising LFP. As a result, the general market expectation is that Chinese battery producers will shift to the NMC (nickel-manganese-cobalt) EV battery chemistry favoured in the rest of the world due to high energy density capabilities allowing for extended range. Meanwhile, Tesla continues to drive its own path with nickel-cobalt-aluminium (NCA) technology, with cathodes of around 9% cobalt by weight.

Exhibit 25: Relative to Market Size, Cobalt Is Highly Exposed to EV Demand



Source: INSG, Bloomberg, BMO Capital Markets

Exhibit 26: Flexing Global EV Penetration and Battery Size Can Have a Large Influence on Potential Cobalt Demand

2025 EV demand scenarios (2024 cobalt demand)

Cobalt per Battery (kg/kWh)	EV Market Penetration Rate (%)						
	2.5%	5.0%	7.5%	10%	12.5%	15.0%	17.5%
0.26	20	40	60	**80**	100	120	140
0.23	18	35	53	**71**	88	106	124
0.20	15	31	46	**62**	77	92	108
0.17	**13**	**27**	**40**	**53**	**66**	**80**	**93**
0.15	12	23	35	**46**	58	69	81
0.13	10	20	30	**40**	50	60	70
0.11	8	17	25	**34**	42	51	59

Source: Industry Reports, Bloomberg, BMO Capital Markets

The potential cobalt constraint on EV growth is clear, and is gaining wider acceptance. This process has been accelerated by Volkswagen's notable failure to secure long-term cobalt supply via tender. And as a result, we expect car companies to lean on battery makers to spend more R&D dollars to accelerate reductions in cobalt content.

In our view, this is a process that would have happened anyway given cobalt's DRC exposure. No purchasing manager wants to be so reliant on supply of a critical raw material from a single supply source, particularly one with a poor human rights track record and the threat of political instability.

Unlike lithium, where the cathode chemistry has relatively little impact on overall demand, for cobalt altering cathode market share assumptions can have a large impact. Currently, the vast majority of cathodes for EVs are either NMC111 or LFP, with small amounts being NCA or LMO (usually in a blend).

We model an aggressive shift away from NMC111 towards NMC622 chemistry from 2020 onwards, which amounts to a halving of contained cobalt on a like for like basis. By 2025, NMC622 has 60% overall market share and becomes the standard EV cathode chemistry of choice. We also assume that,

after a decline in market share over the coming years, some Chinese manufacturers choose to sustain LFP cathode use in EVs in light of tight cobalt supply, keeping the overall market share at 20%. Meanwhile, Tesla's NCA maintains market share more or less in line with the overall market.

Exhibit 27 shows our calculation for cobalt demand. To allow for the time gap between battery manufacture and EV demand, we have assumed raw materials are purchased one year in advance of EV sales (i.e., 2018's EV sales translate to cobalt demand in 2017). Given rising EV sales and the reduction in LFP cathode use, cobalt demand rises from 5kt last year and 10kt in 2017 to 33kt by 2020 and 59kt by 2022, even assuming the shift to NMC622. As a result, EVs overtake portable electronics' as in terms of cobalt demand by 2022, and will account for 40% of total demand by 2025.

Of course, there are many potential scenarios for both cobalt cathode content and EV penetration. Exhibit 26 presents the impact of these in a table for 2025 EV demand (and thus 2024 cobalt demand). As an example, should average cobalt content in kg per kWh stay at today's level of 0.20, and EV penetration reach 15% compared to the 10% we model, cobalt into EVs would be 92kg, not much below today's total market size. Alternatively, should the cobalt used in EV battery cathodes drop by a quarter to 0.15kg per kWh, and EV penetration only reach 2.5%, only 2ktpa of cobalt demand would be added compared to 2017 levels.

Between 2016 and 2025 we see cobalt demand in batteries growing by 53kt, which breaks down into 54kt of EV demand growth, a 2kt net decline in portable electronics and 1kt of growth in energy storage.

Exhibit 27: Our Base Case Calculation for EV Cobalt Demand

	2014	2015	2016	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Key EV Assumptions:												
Global light vehicle sales (millions)	86	89	92	94	95	98	100	102	104	106	108	110
EV Market Penetration Rate (BEV/PHEV of total car sales)	0.5%	0.6%	0.8%	1.0%	1.8%	3.6%	5.1%	6.0%	6.8%	7.7%	8.7%	10.0%
EV Car Sales (millions)	0.4	0.5	0.8	0.9	1.8	3.5	5.1	6.1	7.1	8.2	9.3	11.0
NCA share	*9%*	*10%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*10%*	*10%*	*10%*	*10%*
LFP share	*30%*	*35%*	*35%*	*31%*	*27%*	*25%*	*22%*	*20%*	*20%*	*20%*	*20%*	*20%*
LMO share	*5%*	*5%*	*5%*	*5%*	*4%*	*4%*	*3%*	*3%*	*2%*	*2%*	*1%*	*1%*
NMC 111 share	*56%*	*50%*	*49%*	*53%*	*50%*	*49%*	*39%*	*27%*	*23%*	*18%*	*13%*	*7%*
NMC 622 share	*0%*	*0%*	*0%*	*1%*	*8%*	*12%*	*25%*	*40%*	*45%*	*50%*	*55%*	*60%*
NMC 811 share	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*1%*	*2%*
EV Car Co Content (kg per kWh)	0.20	0.18	0.18	0.19	0.20	0.20	0.19	0.18	0.17	0.17	0.16	0.15
Average pack size across BEV + PHEV (kWh)	26.7	28.5	29.3	28.7	29.0	29.4	29.7	30.0	30.4	30.7	31.1	31.4
Cobalt Demand* (kt):												
EVs	**3**	**4**	**5**	**10**	**21**	**29**	**33**	**38**	**42**	**47**	**53**	**59**

*assumes purchase 1 year in advance of demand

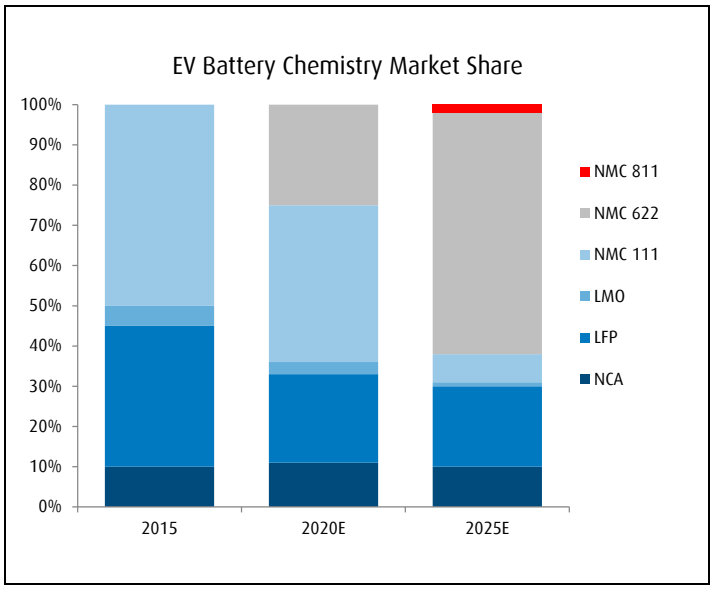
Source: Industry Reports, Bloomberg, BMO Capital Markets

In our view, part of the uncertainly around EV penetration comes from the fact that automakers have been rushed into setting targets following the bad press around emission tests, and are only now backfilling these with strategy. In our view, they will quickly realise that EV sales targets can generally be met by targeting urban areas. Cities have the greatest pollution problem, ability to build charging infrastructure and potential to incentivise use through tax structures. Moreover, the typical range anxiety that comes with driving an EV will be less acute in an urban area where charging stations and support are likely to be closer at hand should there be any issues.

This doesn't change the total EV sales number, but does mean that expectations of EV battery sizes rising aggressively into the future on the back of range expansion are less likely. This in turn will help ease the weight burden EVs currently face. We do have average pack sizes rising over time, but by less than 10% in total over the forecast period.

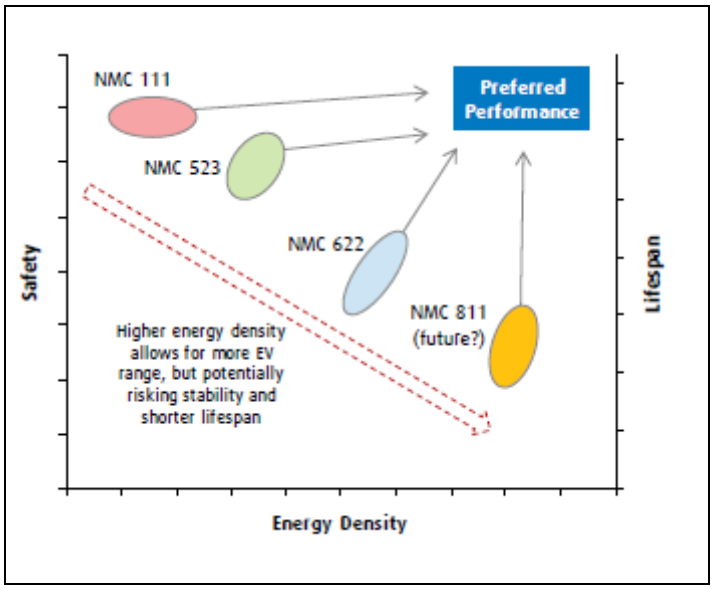
In terms of cobalt, the implication is that one of the major reasons to push for NMC811, highly nickel-rich cathode chemistry is alleviated. This doesn't mean that the push for greater energy density won't continue or that automakers and battery manufacturers won't keep pushing towards it, but given the safety and lifespan concerns that come hand in hand with such a shift there is less pressure to rush towards this technically difficult transition. We only model 2% of EVs as NMC811 in 2025.

Exhibit 28: We Assume Increasing Use of Nickel-Rich Cathodes for Electric Vehicles ...



Source: Avicenne, BMO Capital Markets

Exhibit 29: ... as the Industry Seeks Higher Energy Density and Lower Cost – Provided Safety Concerns Can Be Addressed



Source: ACS, BMO Capital Markets

We have seen forecasts of over 160kt cobalt demand by 2025 by some reputable research houses. And there is nothing wrong with those, as our bottom-up modelling in an unconstrained environment would yield a similar figure. However, as we noted earlier, the maximum available supply we can muster is 137kt. The cobalt market must solve for this through demand thrifting and substitution.

In terms of the main end uses, as discussed above we already assume relatively aggressive thrifting in EV batteries as cathode chemistries move to more nickel-rich compounds, which helps. Meanwhile, the natural safety inertia in portable electronics mean mass substitution is improbable in our view. The other big consumer in terms of aircraft engines also has long qualification periods for new alloys and the ability to pass through price gains to end users; hence, we see major barriers to switching here.

Thus, we have to look at some of the smaller end uses for substitution. We believe the prosthetics segment (knee and hip implants) is an area with viable alternatives already, and will be a natural area of switching; however, this yields less than 1kt of lower demand. We also consider that the use of cobalt as a binder in diamond and cemented carbide tool applications for metal cutting (currently ~9% of demand) can be reduced through chemistry redesign, while use in magnets (3%) will see a natural decline over the coming years. Meanwhile, cobalt use in non-high temperature superalloys for creep prevention may also come under some pressure from composite materials. Exhibit 30 shows our assessment of substitution risk across the various end use segments.

As a result, we have 2025 demand at 148kt, much closer to the supply we have available at the same time. The substitution impact really starts to kick in from 2020.

Exhibit 30: Cobalt Substitution Risk by End-Demand Segment

End use	Estimated proportion of 2017 demand	Substitution Risk	Alternative material
Metals			
Aircraft Engines	8%	Low	Silicon carbide (SiC) materials used to manufacture ceramic matrix composites (CMCs)
Prosthetics	1%	**High**	Titanium-based alloys
Power Generation	1%	Low-Med	Nickel based alloys or ceramic-matric composities.
Other Superalloy	6%	Low	Fibre-reinforced metal matrix composites (MMCs), reinforced carbon-carbon composites, nickel-based and iron-based superalloys.
Magnets	3%	Med	Barium/strontium ferrites, neodymium-iron-boron magnets and nickel-iron alloy magnets.
Diamonds & Hard Facing	9%	Med-High	Reduction of intensity through cobalt-iron-copper and iron-copper compounds.
High Strength Steel	2%	Low-Med	Iron-nickel alloys, cements, and ceramics.
Chemicals			
Batteries - EVs	12%	**High**	Reducing cobalt per unit in NCA and NMC batteries. Elimination of liquid electrolytes and development of solid-state electrodes.
Batteries - Other	43%	Low	Vanadium flow, zinc bromide redox flow batteries
Catalysts	2%	Low-Med	Rhodium can be used as a hydroformylation catalyst. Ruthenium, molybdenum, nickel and tungten can be used for hydrodesulphurisation.
Tyres	4%	Low	
Dyes & Paints	5%	Med	Cerium, iron, lead, manganese and vanadium.
PET processing	2%	Low	
Other	2%	Low-Med	

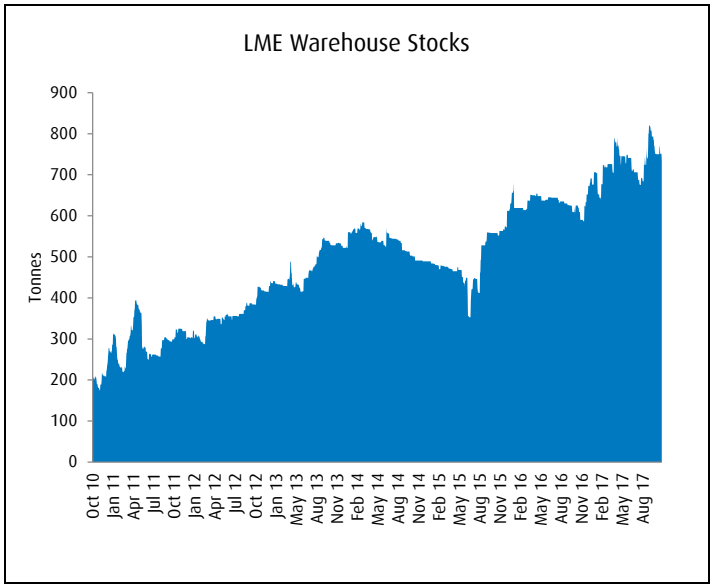
Source: CDI, BMO Capital Markets

Of course, there is one other source of supply/demand in the cobalt market, being strategic purchases. Traditionally, these have come from government reserves, with the US DLA being net sellers of 12kt of cobalt over the 2000-08 period. More recently, the DLA, Japanese government, and China's SRB have been purchasing cobalt sulphate as a strategic resource, effectively adding to demand. We anticipate that, with a tighter market and higher prices, this will not continue in 2018.

Meanwhile, as the battery story has gained traction we have also seen the emergence of institutional investors looking for direct cobalt exposure via physical metal positions. While this can amplify price moves in tight markets (i.e., investors bidding against consumers for the same material), in general we would view this behaviour as a market buffer, in other words, releasing material when the market is tight and soaking it up when there is ready availability. To this end, we assume stockpiles (strategic and institutional) are released over the 2024-25 period to ease the deficit in the market.

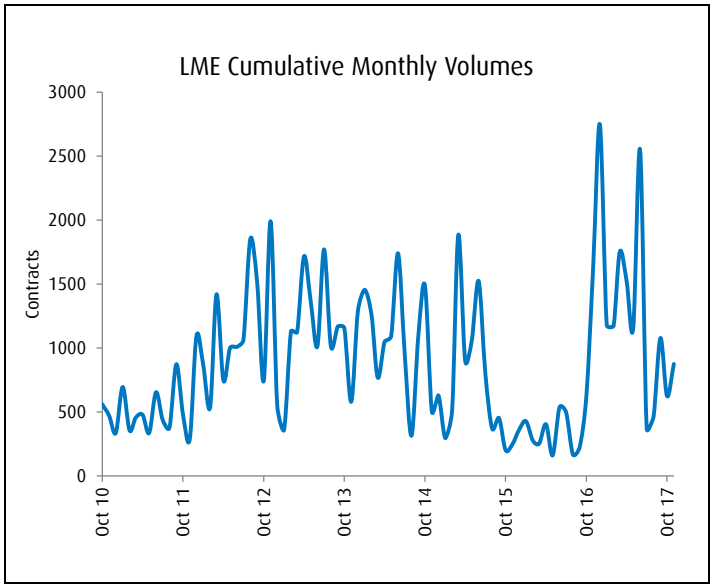
Of course, the London Metal Exchange does have a cobalt futures contract. However, despite some pick-up in these volumes as the price rallied earlier this year, overall liquidity is still low. Moreover, only cobalt metal can be used for physical delivery against positions, which, as we have discussed, is a diminishing part of the overall market, while any liquid cobalt sulphate contract is still years away. Thus, while the LME price is generally a decent market reference, the contract itself cannot be considered central to the cobalt market.

Exhibit 31: LME Stocks Have Been Rising, but These Are Small as a Proportion of the Market



Source: LME, BMO Capital Markets

Exhibit 32: Trading Volumes on the LME Contract Are Growing Following the Rapid Price Move



Source: LME, BMO Capital Markets

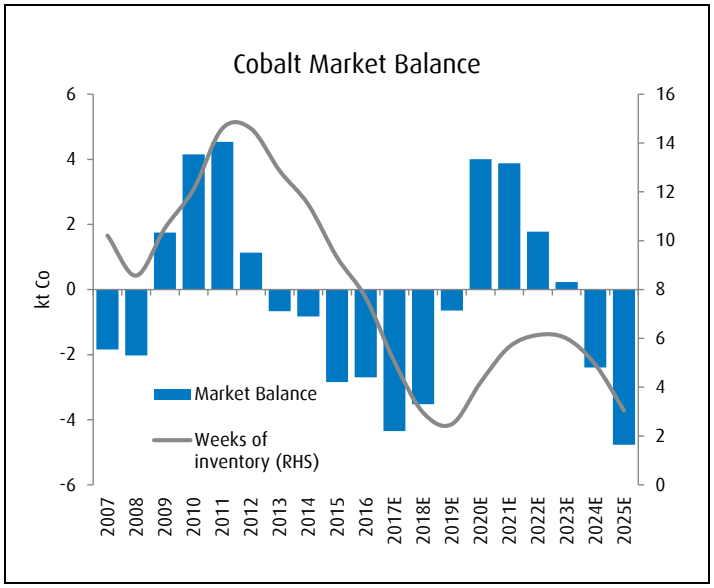
All Roads Lead to Further Price Gains, With a Substitution Level Event Needed

Putting everything together, and incorporating our aggressive assumptions to maximise supply and substitute demand, our base case balance is shown in Exhibit 33. After a strong surplus post-GFC, we see the refined cobalt market as having been in deficit since 2013, but 2017's 4.3kt as the largest yet. As such, even with strong growth in refined supply over the next couple of years, this only serves to reduce the deficit. Only in 2020-22 do we return to surplus after more aggressive substitution kicks in. Beyond this we again foresee a deficit even assuming almost complete release of industry stockpiles.

Notably, we see end-2017 inventory as just five weeks of consumption – lower than they were during the 2007-08 price spike. And with deficits in the coming years, this drops to two and a half weeks by end-2019 – a critically low level. Even with our aggressive assumptions, the level of inventory cover doesn't recover to end 2016 levels through our forecast period. Without doubt, cobalt is set to be a very tight market in future years.

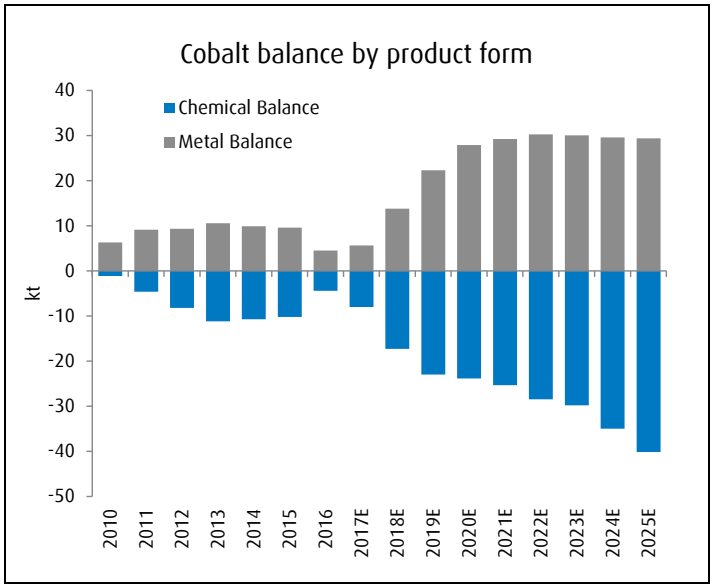
One notable sub-plot we would highlight is the growing dichotomy between metal and chemical balances in cobalt. With restarts at metal producing operations and overall demand stagnant following substitution, all other things being equal, cobalt metal could end up in a 30kt surplus. Conversely, direct cobalt chemical output is set to underperform the growth in battery demand, leading to a rising deficit in this segment of the market. We do not view this as a problem per se, as metal can be dissolved in acid to form cobalt sulphate (or other chemicals), but as there is a cost involved with this operation battery-grade cobalt sulphate would likely realise a premium over and above cobalt content. Meanwhile, subject to capex costs we would anticipate some current metal producers might alter their process to focus on the chemical market growth.

Exhibit 33: After a Period of Heavy Stocking Post-GFC, We Have Strong Deficits Over 2015-2019



Source: CRU, CDI, BMO Capital Markets

Exhibit 34: The Metal Surplus and Chemical Deficit Are Set to Grow, Unless Established Processing Capacities Change

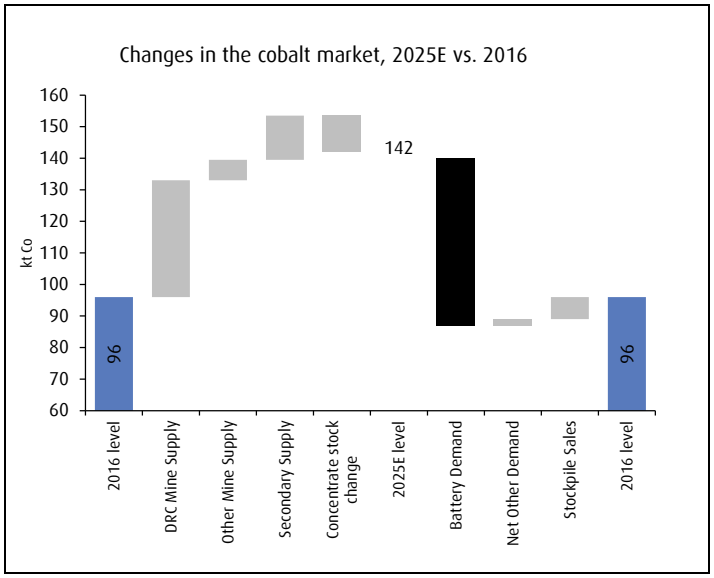


Source: CDI, BMO Capital Markets

From 96kt in 2016, we see the cobalt market size growing to 142kt in 2025, a 4.5% CAGR. The majority of the supply bridge to this level will come from DRC supply, with just over a quarter coming from increased secondary supply. For demand, essentially all the growth is from batteries, with net other demand showing a slight fall.

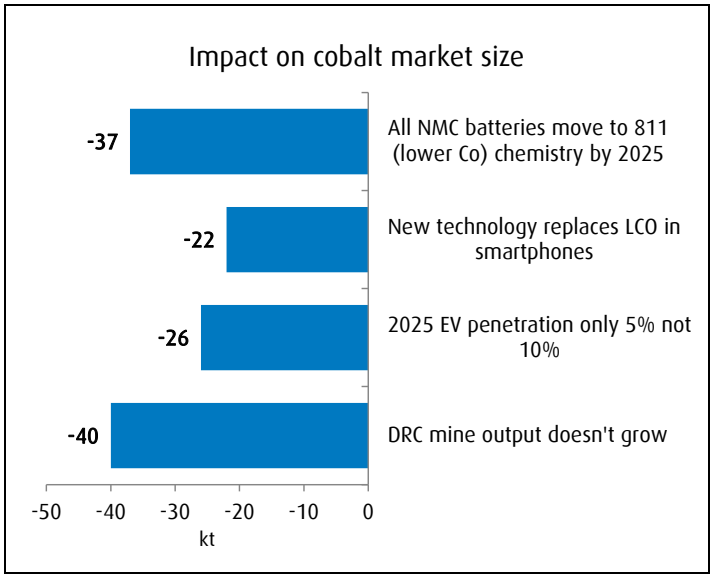
In terms of key risks to this forecast, all the major ones would drive downside to market size. If DRC supply were to be flat on today's levels, the 2025 market size would essentially still be ~100kt. This reinforces the importance of the DRC to cobalt market growth – without it EV penetration simply has to slow. Exhibit 36 also considers potential demand side scenarios that would reduce market size. Were EV penetration to only be 5% in 2025 (at the low end of industry expectations) rather than our 10% assumption, keeping the relative cathode shares the same this would see a 26kt drop in cobalt demand. If NMC811 technology were to become the mainstream this could reduce demand by 37kt. Finally, if the lack of material were to drive cobalt out of smartphones this would see a 22kt drop in market size. All these scenarios would result in less substitution needed in other areas, but we would also note that while they affect 2025 demand, they would not avoid the imbalance problems we are facing before the end of the decade.

Exhibit 35: Our Base Case for Changes in Cobalt to 2025 – We Have to Assume Substitution in Other Areas to Make Way for EVs



Source: CRU, CDI, BMO Capital Markets

Exhibit 36: Potential Impacts on Cobalt Market Size in 2025 From Various Scenarios



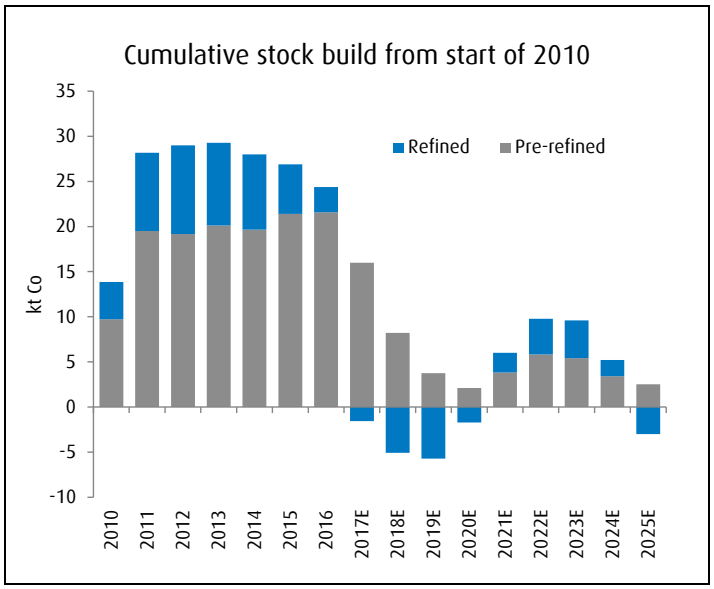
Source: CDI, BMO Capital Markets

For cobalt, there are no published inventory figures such as those widely available for the base metals. However, we can imply changes to these from the balances in the market. Exhibit 37, using the start of 2010 as a base, shows our expectations of the cumulative changes in stocks. Pre-refined (mined but not refined) cobalt unit inventory rose strongly over 2010-11, and continued to rise through 2016. However, with the problems in mine output we see a destock in 2017, and another next, reflecting a raw material constraint passing through the process chain and tying in well with price action to date. Meanwhile, refined inventory is now lower than levels seen at the start of 2010 following five consecutive years of deficit. And by 2019-2020 on our base case, total cobalt units across the chain will be lower than at the start of 2010, while global demand is ~60% higher.

The impact of inventory draws through the chain plays into our price outlook. While pre-refined inventory was high (with most of this sitting in China) the cobalt price underperformed. Now, this overhang is gone and available supply is set to get increasingly tight. We expect the gains in DRC output will keep 2018's average at or around current spot levels of ~$31/lb. However, to kick-start the processes needed to solve for the supply constraint, we forecast a rise to >$40/lb on average in 2019 with potential for a spike above 2007's ~$50/lb peak – this is the Substitution Level Event needed. With a shift back to surplus, we forecast $30/lb for 2021. Essentially, we have on average doubled our price forecast over the coming years.

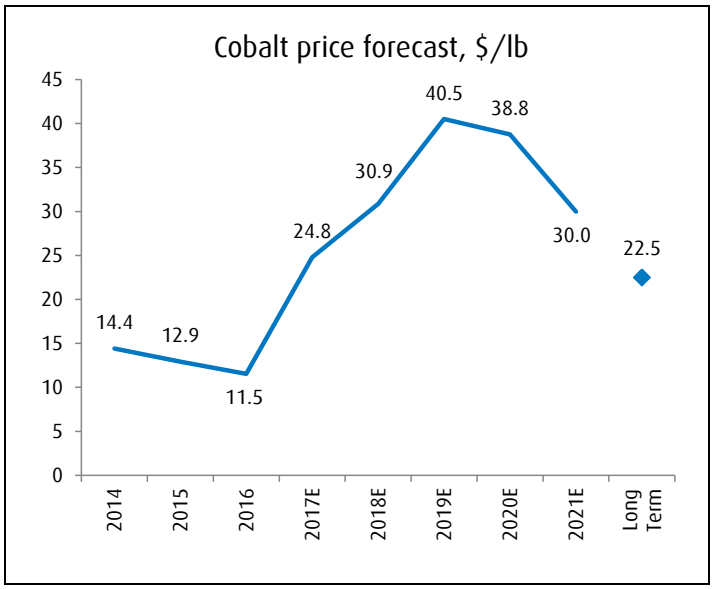
Assessing a long-term price is more challenging for cobalt than for other commodities, given standard incentive price models don't work for co-products. Instead, we look towards what might be a sustainable through the cycle price for cobalt. As we noted before, taking a guide from history the average price in real terms is just over $22/lb. We thus raise our long-term price to $22.5/lb (from $15/lb previously), though given the tight market ahead it may be many years before we see this level.

Exhibit 37: This Year Has Seen a Significant Draw in Cobalt Units Contained in Both Refined and Upstream Material, as Will 2018



Source: CRU, CDI, BMO Capital Markets

Exhibit 38: We See the Cobalt Price Gaining Further in 2019-20 to Encourage Market Solutions, and Raise LT to $22.50/lb



Source: Metal Bulletin, BMO Capital Markets

Putting everything together, we see the following implications related to the cobalt market:

- Further strong price gains over the coming two to three years
- EV demand for cobalt forcing substitution in other end uses
- A shift in EV cathode chemistry away from cobalt towards nickel
- Li-ion battery recycling seeing accelerated growth
- A discount emerging for material from the DRC where traceability cannot be proven
- A cobalt sulphate premium over metal to reflect the deficit in the chemical market
- A need to see new cobalt projects to balance the books by the middle of the next decade

Exhibit 39: BMO Cobalt Supply-Demand Balance

		2015	2016	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
SUPPLY												
Mine Supply												
Primary	kt	8.3	7.6	5.3	1.8	2.5	3.9	6.5	6.2	5.7	5.3	5.3
Nickel co-product	kt	40.5	39.3	42.1	44.4	45.6	46.2	48.2	50.4	51.9	51.8	53.1
Copper co-product	kt	63.7	66.3	63.9	77.9	93.4	103.5	109.5	112.0	112.3	112.3	114.3
Other co-product	kt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	**kt**	**112.9**	**113.5**	**110.5**	**119.4**	**136.1**	**147.7**	**157.9**	**162.1**	**163.3**	**162.9**	**166.0**
YoY change	*%*	*6%*	*1%*	*-3%*	*8%*	*14%*	*9%*	*7%*	*3%*	*1%*	*0%*	*2%*
Process Losses		-20	-20	-20	-21	-24	-27	-28	-29	-29	-29	-30
Recoverable Cobalt		**92.6**	**93.1**	**90.6**	**97.9**	**111.6**	**121.2**	**129.4**	**132.9**	**133.9**	**133.5**	**136.1**
Refined Supply												
Metals	kt	38.2	33.7	35.2	43.3	51.9	57.5	59.0	60.1	60.0	59.7	59.7
Chemicals	kt	45.0	50.9	50.7	51.3	51.3	50.7	52.2	52.7	54.7	54.7	54.7
Secondary	kt	7.7	8.4	10.4	11.2	12.9	14.6	16.6	18.1	19.6	21.1	22.6
Total	**kt**	**90.8**	**92.9**	**96.2**	**105.7**	**116.1**	**122.8**	**127.7**	**130.9**	**134.3**	**135.5**	**137.0**
YoY change	*%*	*3%*	*2%*	*4%*	*10%*	*10%*	*6%*	*4%*	*2%*	*3%*	*1%*	*1%*
CONSUMPTION												
Metals	kt	28.6	29.2	29.5	29.5	29.6	29.7	29.7	29.9	30.0	30.2	30.3
Chemicals	kt	62.9	63.6	69.0	79.7	87.1	89.1	94.1	99.2	104.1	110.8	117.5
Stockpiles	kt	2.2	2.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.0	-6.0
Total	**kt**	**93.7**	**95.6**	**100.5**	**109.2**	**116.7**	**118.8**	**123.8**	**129.1**	**134.1**	**137.9**	**141.8**
YoY change	*%*	*5%*	*2%*	*5%*	*9%*	*7%*	*2%*	*4%*	*4%*	*4%*	*3%*	*3%*
Surplus (Deficit)	**kt**	**-2.8**	**-2.7**	**-4.3**	**-3.5**	**-0.6**	**4.0**	**3.9**	**1.8**	**0.2**	**-2.4**	**-4.8**
Inventory	**kt**	**16.8**	**14.1**	**9.7**	**6.2**	**5.6**	**9.6**	**13.5**	**15.2**	**15.5**	**13.1**	**8.3**
Weeks of Consumption		*9*	*8*	*5*	*3*	*2*	*4*	*6*	*6*	*6*	*5*	*3*

Source: CDI, BMO Capital Markets

BMO Capital Markets

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Hold	Market Perform	49.5%	15.4%	39.1%	47.7%	39.4%	41.1%
Sell	Underperform	3.4%	10.0%	1.7%	3.2%	1.5%	5.0%

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http://researchglobal.bmocapitalmarkets.com/documents/2013/rating_key_2013_to_2016.pdf

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