Acting to meet criticality challenges

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Selected elements

	60 REE Rare Earths	26 Cu Copper	28 Ni Nickel	27 Co Cobalt
				
Criticality Score and change	14	9	10	13
Action identified:	Recycling	Capital investment	New technology / more reserves	Substitution
Reduce usage of metal	⊘			⊘
Increased supply		$↑	$↑	

Challenges for consumers

SUPPLY

Public Policies

Technology

Financing

Social acceptability

DEMAND

Sustainability	Supply	Substitution
Meaningful recycling rates hard to achieve for new and complex applications	Lead time for new capacity should not be underestimated Producer ingenuity important to maintain cost advantages	Many factors drive focus on substitution
Encouragement needed for circular economy to work	**Positive supply changes**	**R&D to reduce dependency on primary production**

Profitability along the supply chain needed for a stable market

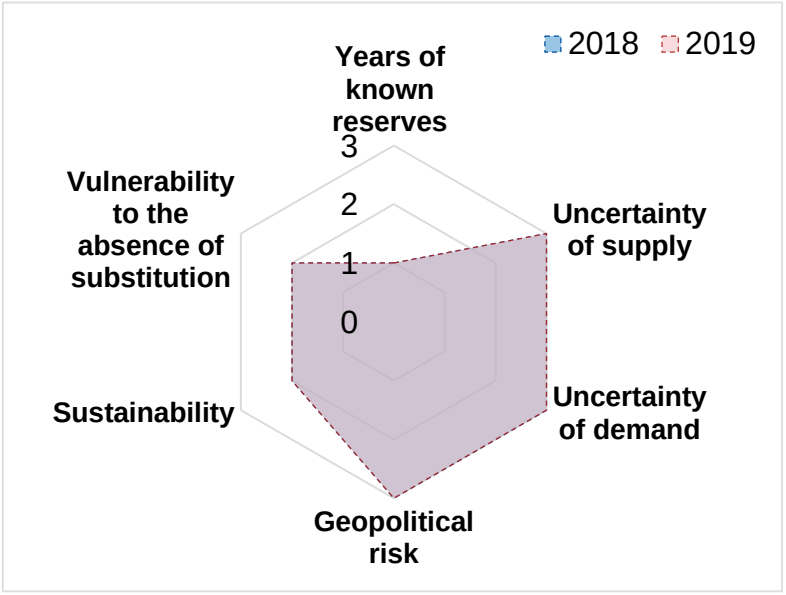
REE – Recycling an economic challenge, Substitution a technical one

60

REE

Rare Earths

Criticality Score



Uncertainty of supply

Forecast supply deficit for 2027 is greater than 50%

Sustainability

High recycling rate needed to maintain supply / demand balance and geopolitical supply risk, but technology lacking

Vulnerability to the absence of substitution

Little real alternative to rare earth magnets in many small motors

Main Challenges

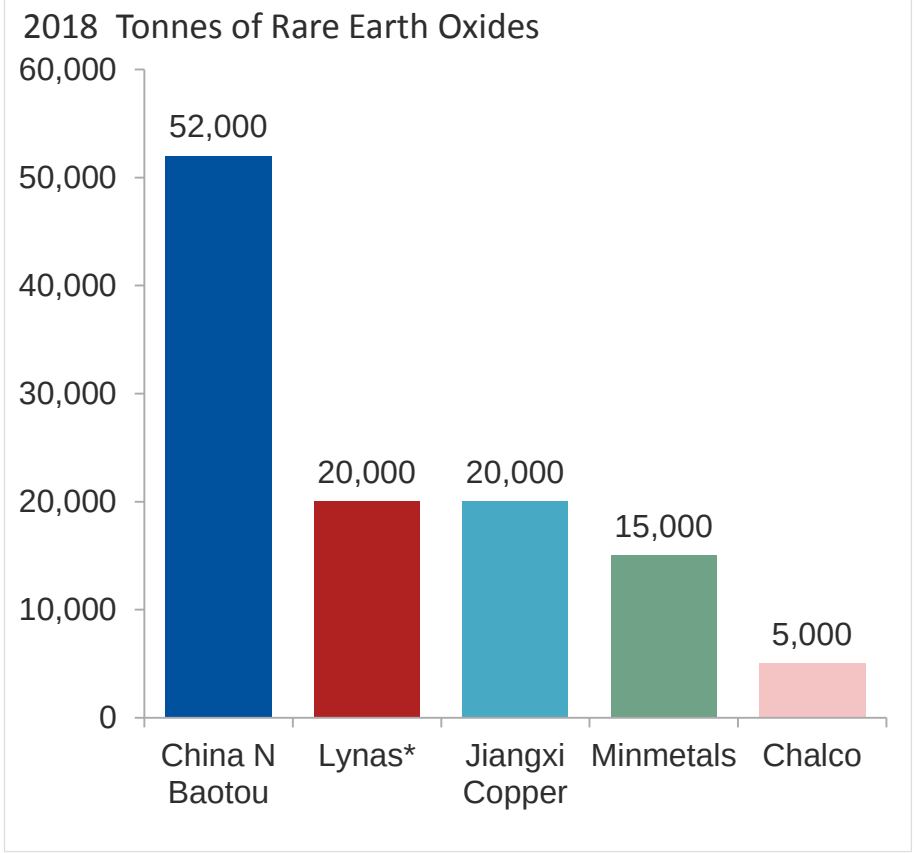
- Very expensive dismantling process and non-standardized manufacturing makes it difficult to recycle magnets, especially NdFeB
- No industry accepted standards for collecting used magnets or for manufacture of recyclable magnets

Innovations/Industry Approach

- Goldwind currently recycles its own magnets
- Lab scale research (TU Delft University) on combining pyro / hydrometallurgy to extract REEs from permanent magnets
- Use of induction motors in Electric Vehicles

REE – Malaysian and Chinese supply struggle to meet demand

REO production - China dominates supply

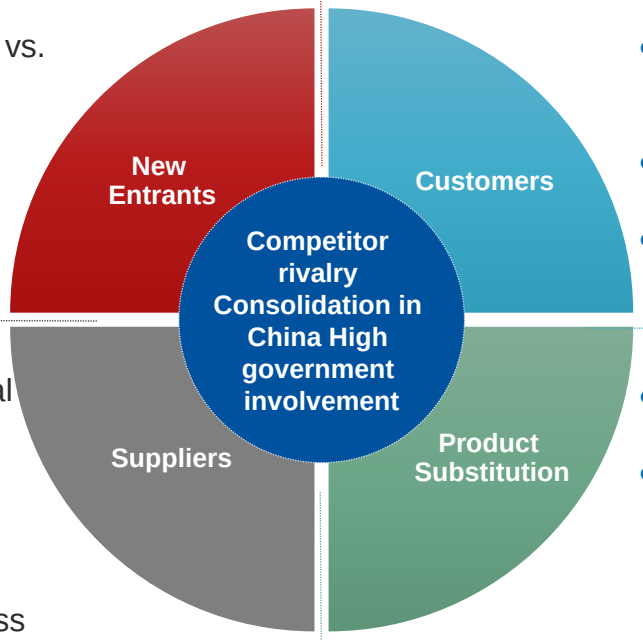


* Australia and Malaysia

Porter Analysis

Entry Barriers: High
- Economic REE deposits are rare
- Lack of available capital vs. high upfront cost of separation facilities
- Little focus from mining majors
- Lack of quality deposits

Supplier Power: Medium
- Mineral rights and "social license to operate" difficulties
- Beneficiation and processing using readily available reagents
- Environmental awareness driving greater government intervention



Customer Power: High
- Concentrated customer base
- Majority of downstream production (i.e. magnets) in China
- Significant value-add occurs downstream
- Strong market support for stable non-China supply

Substitution Risk: medium
- Cost of REE as % of total product cost
- Some availability of competing technologies (i.e. induction motor in cars) for certain applications
- But, significant trade-off in performance / efficiency

Further standards and industry development required

Copper – deficit deferred as producers react

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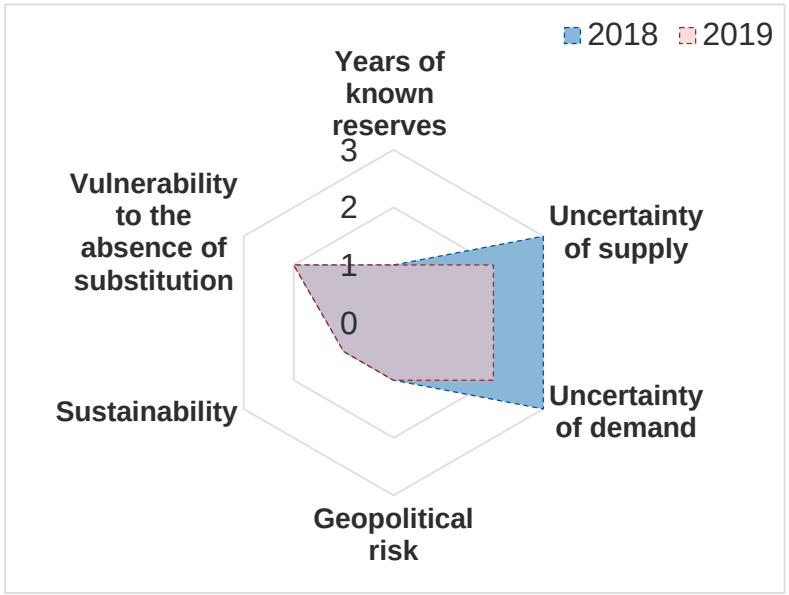
Cu

Copper

Criticality Score

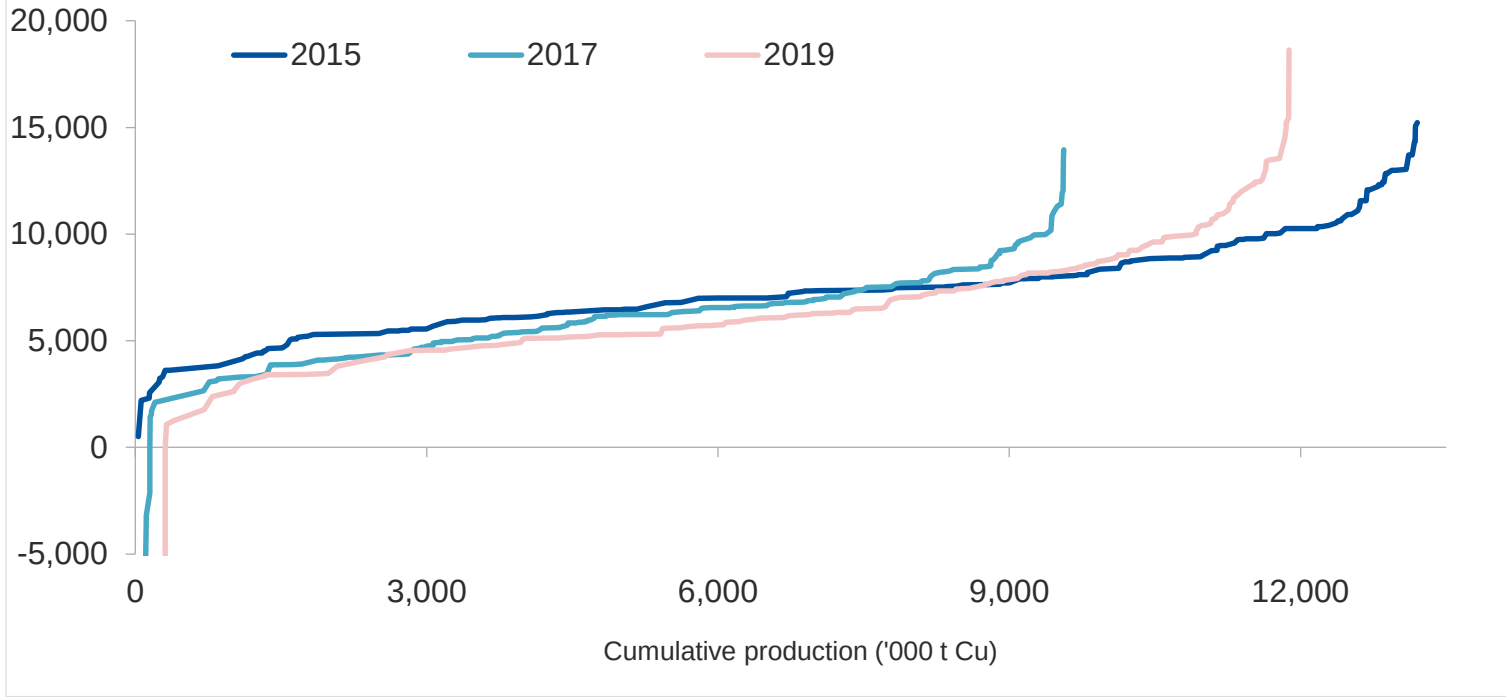


Uncertainty of supply

Has reduced as shelved mining projects have been fast-tracked to financing. Ten Tier 1 (>100ktpa) “Firm Projects” in January 2019 vs six in Jan 2018 and five in Jan 2017

Significantly larger pipeline of projects in the 2019 database compared with 2017, but not back to 2015 levels

Long run year project cost curves, real (2018$) full economic costs, $/t

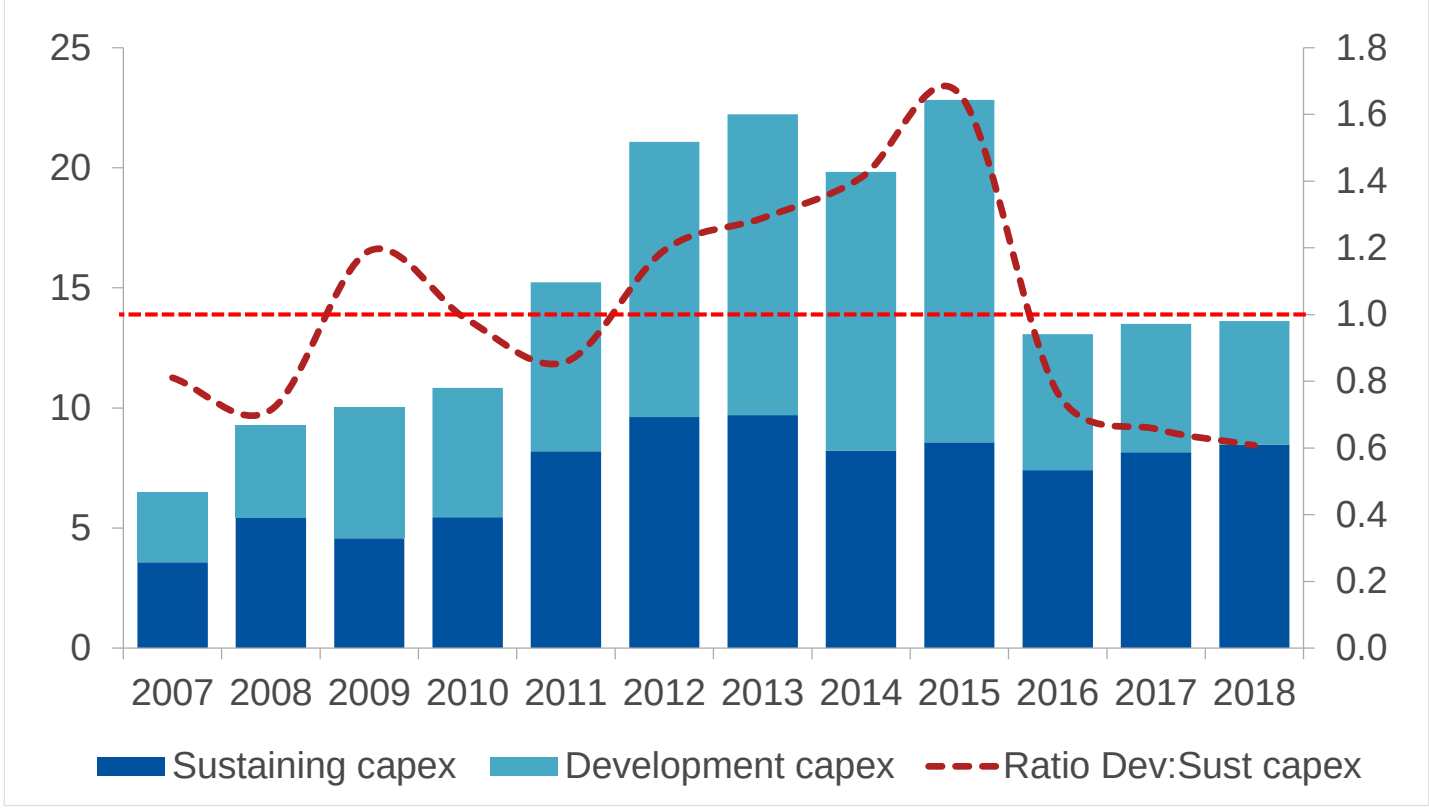


Copper – investment in development had been “banked” in prior years

Period	Operator	Mine	Typical Cu kt/a	Initial Capex $bn
2010-16	MMG/Glencore	Las Bambas	400	9.65
2010-13	Rio Tinto	Oyu Tolgoi I	150	6.20
2012-19	First Quantum’	Cobre Panama	285	5.87
2012-16	Freeport McMoRan	Cerro Verde II	270	4.60
2013-18	KGHM	Sierra Gorda	150	4.20
2012-15	BHP	Escondida OGP I	150	4.20
2011-21	CODELCO	Chuquicamata block cave	320	3.64
2011-23	Freeport McMoRan	Grasberg block cave	328	3.03
2013-17	BHP	Escondida desalination	-	3.43

Source: Company Reports

Copper capital expenditure from major companies representing ~75% of market between 2007-2018 - $bn



Big projects need better visibility of market movements to attract funding even in largest diversified miners

Source: CRU Analysis, Company Reports

Nickel – successful production technology change needed

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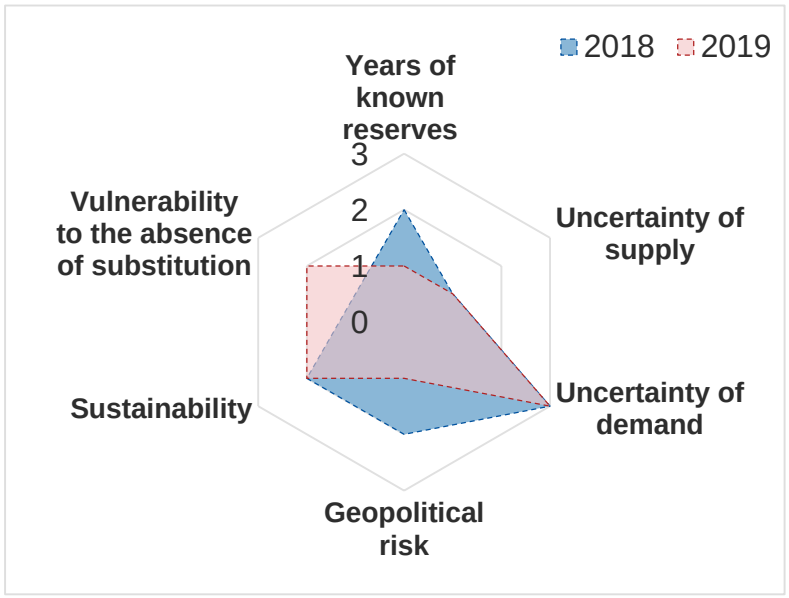
Ni

Nickel

Criticality Score



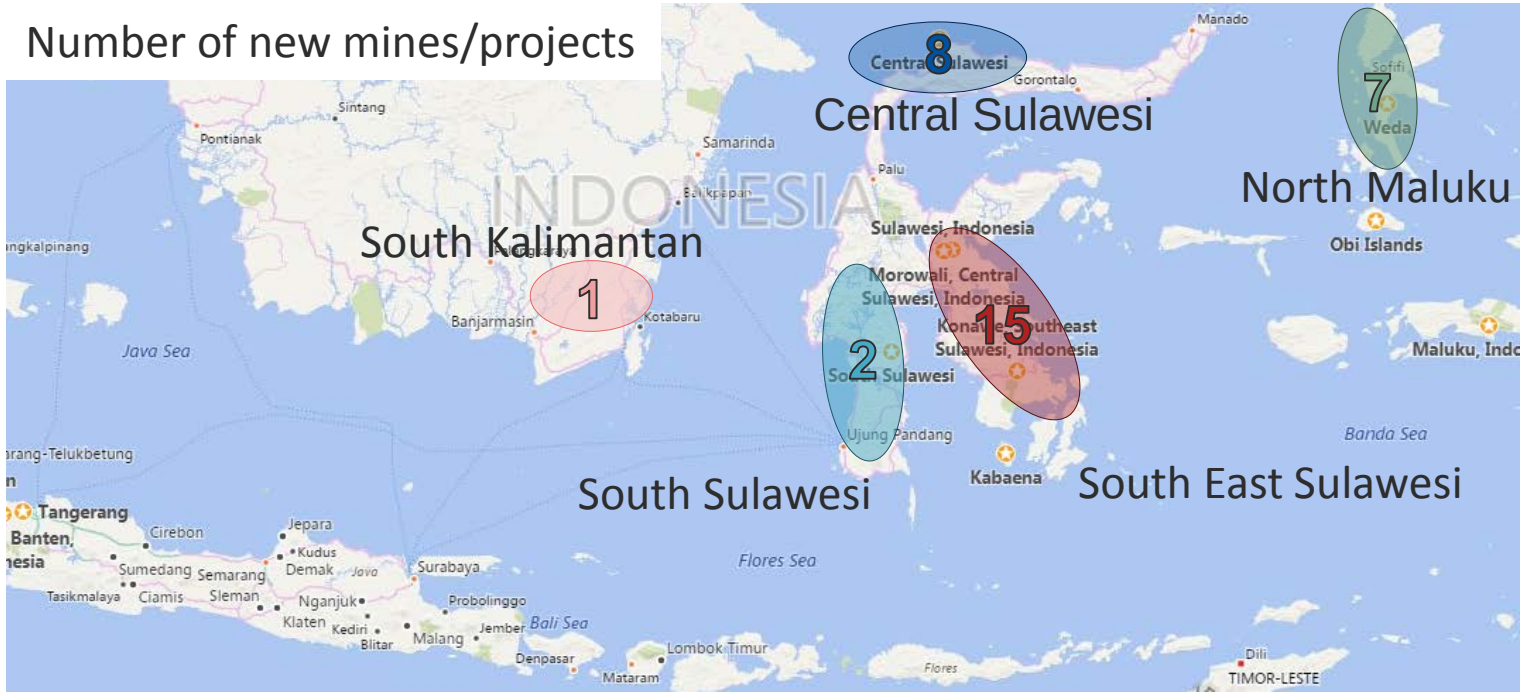
Years of known reserves

Known reserves increased dramatically in Indonesia more than replacing losses elsewhere

Geopolitical risk

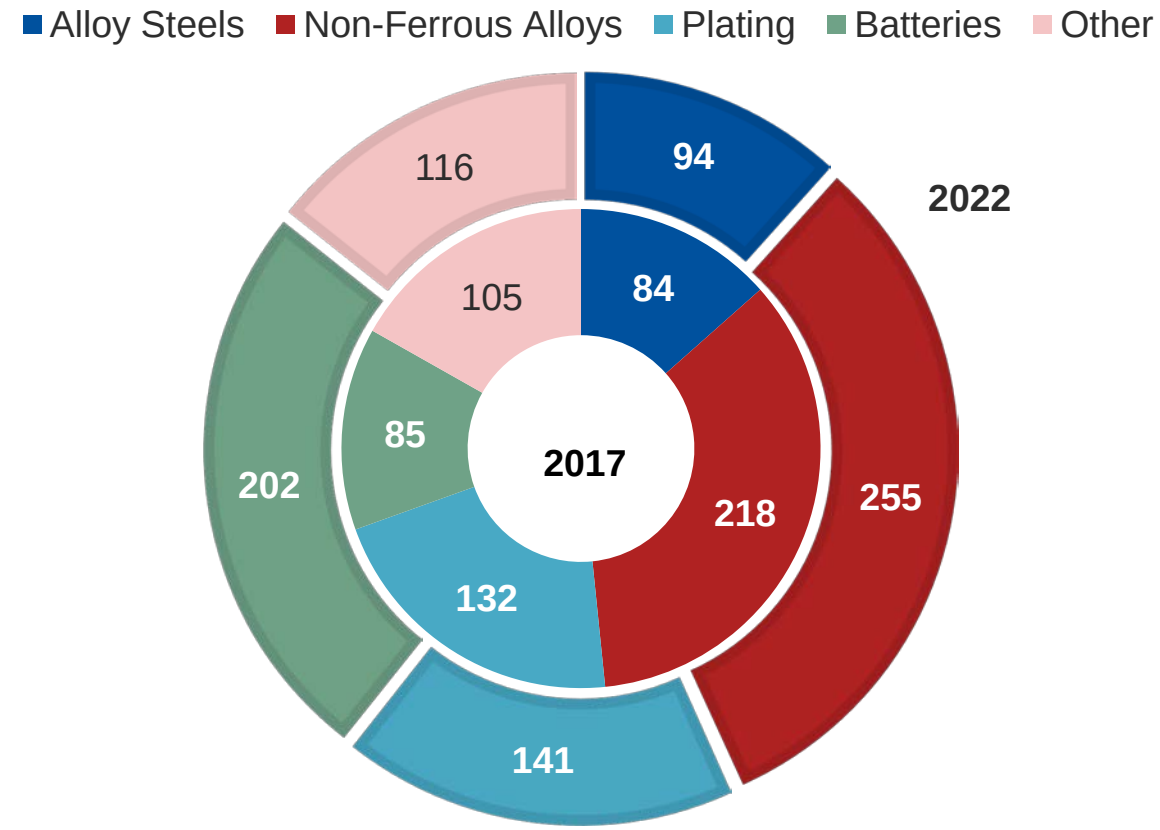
Supply outlook maintained through new project identification, but heavy concentration on Indonesia

Number of new mines/projects

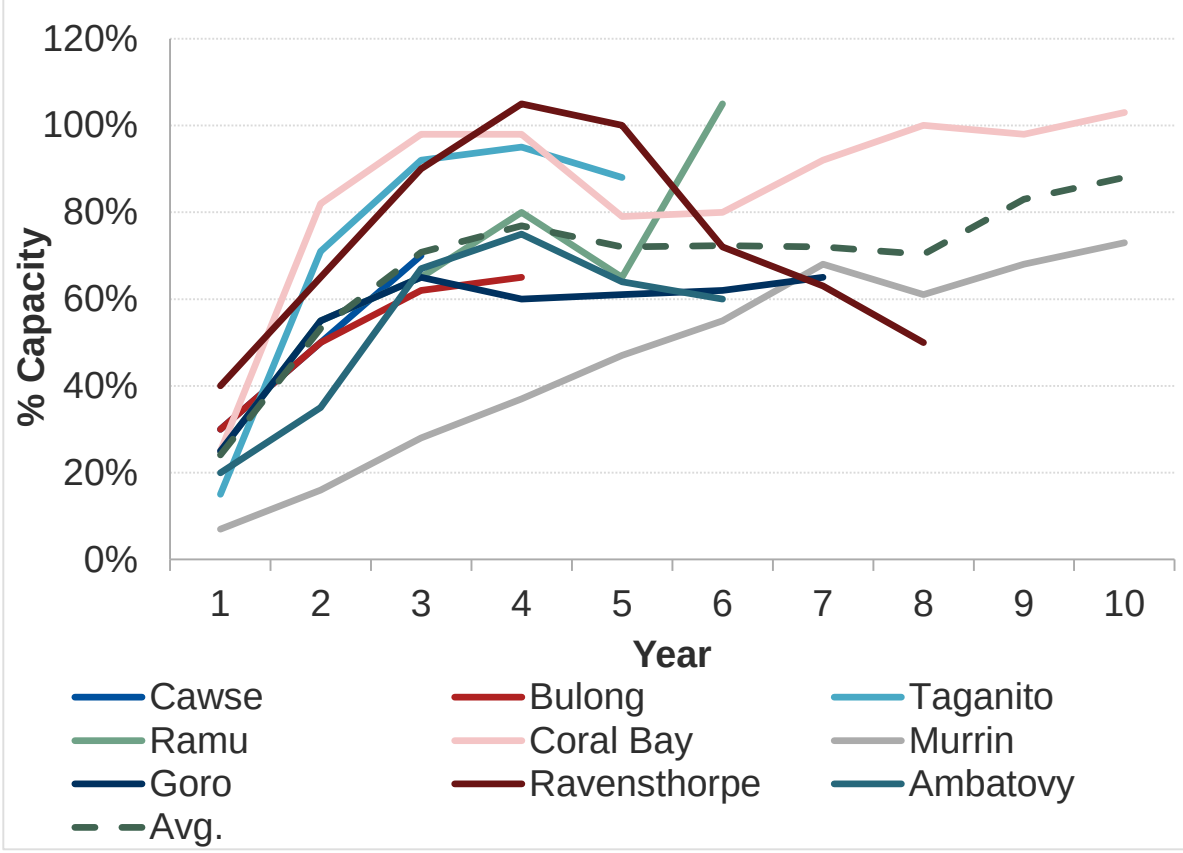


New projects need aggressive ramp-up schedules to meet demand

Non-stainless nickel demand, 2017 and 2022, '000 tonnes



Ramp up schedule at HPAL plants (actual achieved by asset from start up year)



Growth in all areas of nickel demand make optimal allocation of iron free nickel units between end uses critical while new supply ramps up

Cobalt – risk mitigation through substitution to nickel…

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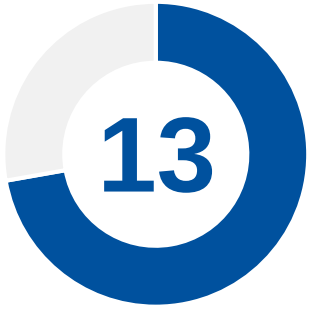
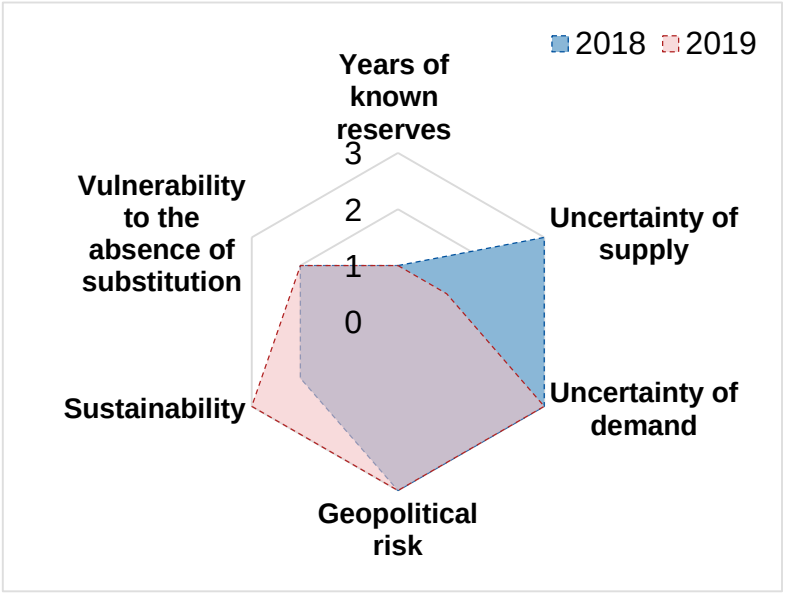
Co

Cobalt

Criticality Score





Vulnerability to the absence of substitution

Efforts continue being made to minimise use of cobalt in battery applications

Uncertainty of supply

Reaction of artisanal and informal mining sector to increase production has exceeded expectations. As regulation and hence acceptance of this sector increases, its ability to provide swing capacity will remain

Main Challenges

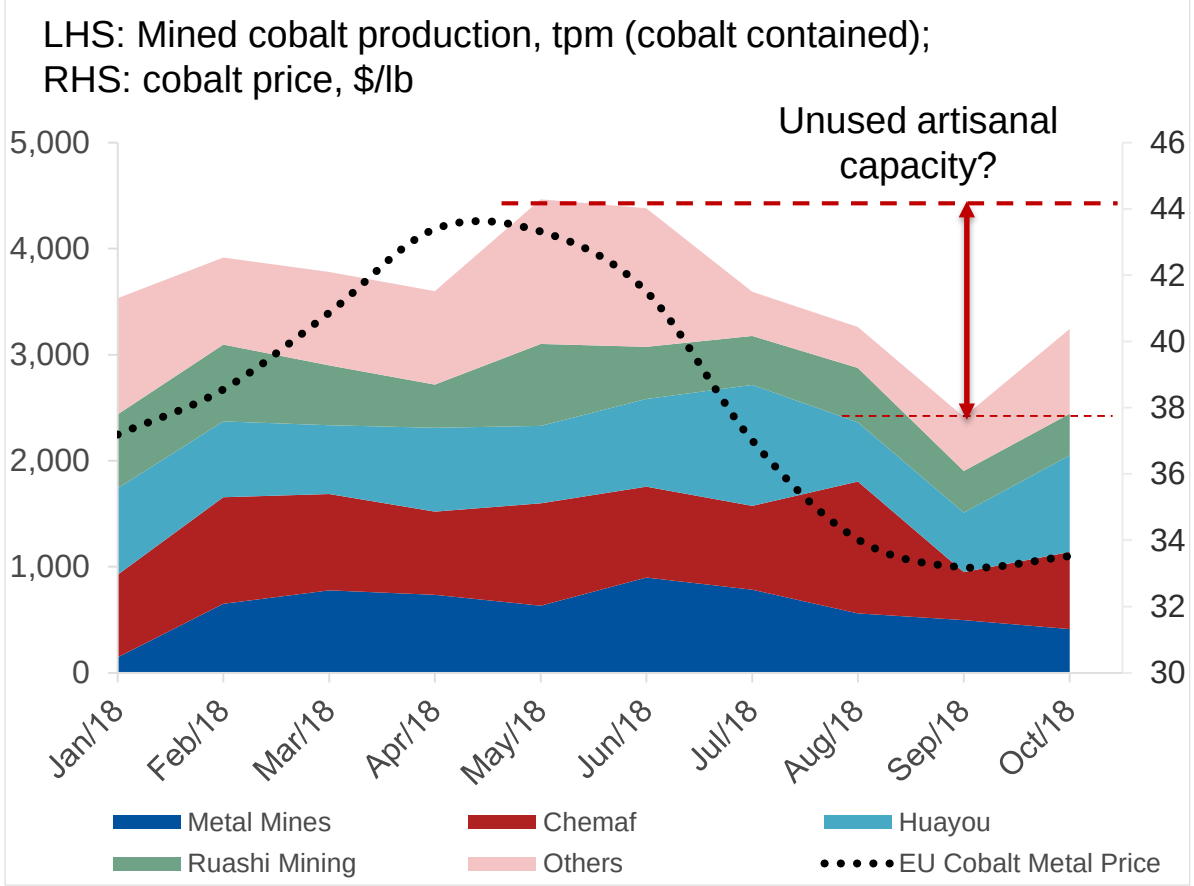
- Cobalt free batteries are less stable than those with a small amount of cobalt sustaining demand growth for cobalt chemicals at least in mid-term
- Increased demand for cobalt metal in super-alloys and hard alloys needs to be met

Innovations/Industry Approach

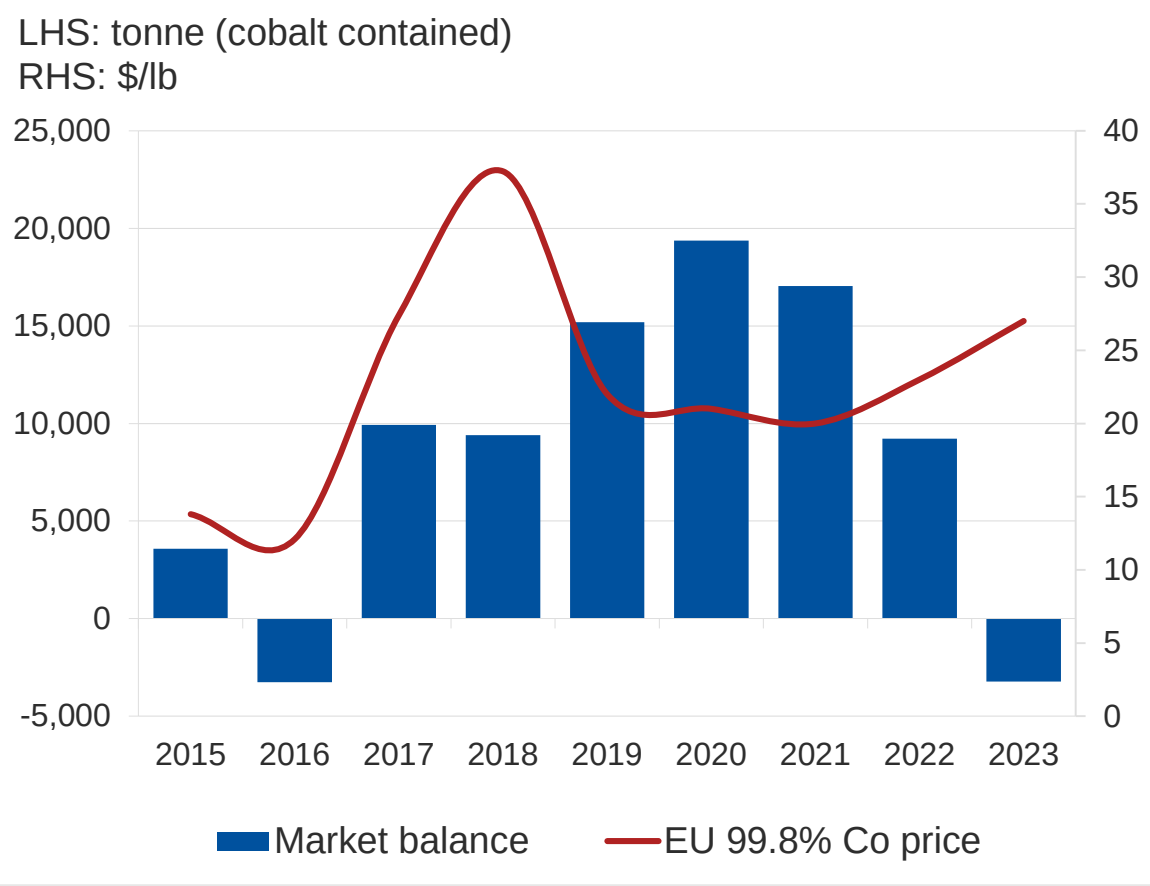
- Early stage R&D of cobalt free batteries e.g. Samsung using graphene as cathode and car makers (BMW, Toyota etc)
- Recycling – Pyrometallurgy (Umicore) and Hydrometallurgy in China, Australia and N America.
- Option for new HPAL plants to reprocess waste streams provides flexibility

Unused artisanal capacity exists but cobalt is still heading for deficit

Latent DRC artisanal capacity potential exists and can respond to price increases



Prices to remain depressed in the mid-term, but deficits are on the horizon



In the absence of extensive substitution options, cobalt recycling needs to be ramped up and artisanal mining regularised to meet increasing demand

Criticality Assessment 2019: the key takeaways

1. Market reactions to criticality were expected in 2018 and were seen strongly in Copper, Nickel and Cobalt, validating criticality assessment approach and its predictive capability

2. In an era of rapidly changing demand specifically in the automotive and energy generation sectors, consumers should identify key situations where options over future consumption are valuable

3. Consumers need to engage earlier with producers for longer term stability of supply and demand and hence prices

   - Nickel and Cobalt: need optimised allocation of units between consuming sectors and flexibility on material sources
   - Copper: better signalling of changes in demand will support financing efforts for largest new assets
   - Rare Earth Elements: development and adherence to new standards will ensure recycling supports demand growth

4. Suppliers are behind many of the changes in criticality assessments, but for full circular economy to be realised, more changes from Consumers are needed to increase the ease of recycling and competitiveness of secondary materials

5. Responsibility for managing the risk is predominantly lying with producers but this shifts as secondary materials become a more significant share of supply

THANK YOU

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