Financing the development of mineral material flows
Deep-dive on zinc, rare-earth and graphite

World Materials Forum

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FINANCING

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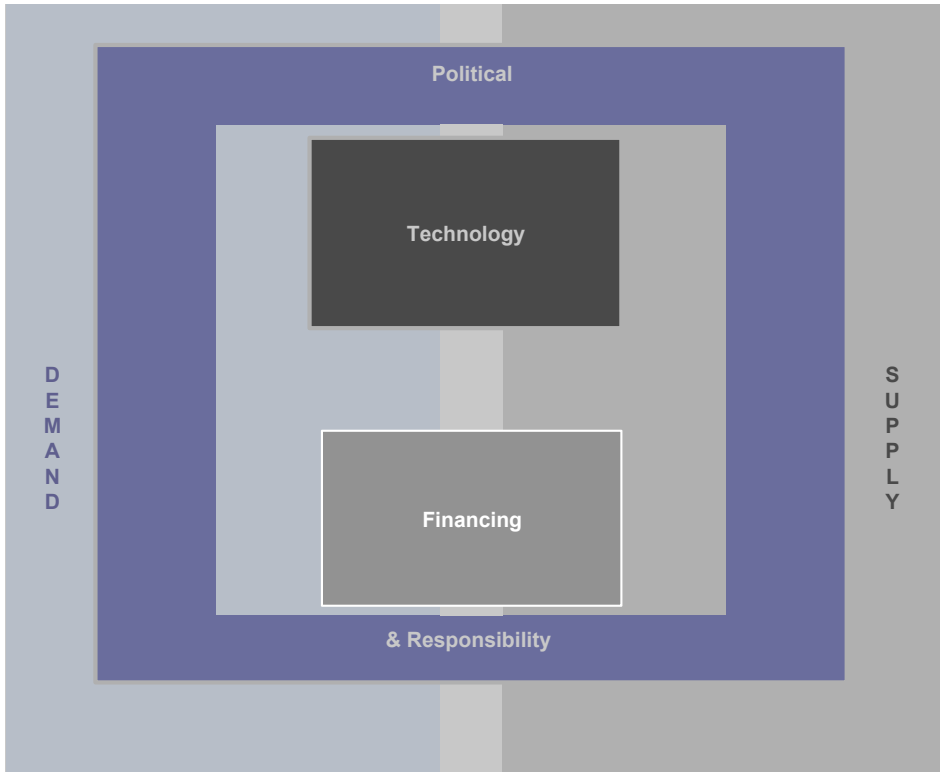
Sustainable Mineral raw material flows depend on many financing decisions



- **Public financing:** to develop national/ regional geoscientific data and knowledge, to guide investors towards high-potential areas, to regulate the mining sector ensuring sustainability is at the optimal level.
- **Exploration funding:** to explore the high-potential areas, identify ore deposits (or extensions of known ones), undertake as economically justified all necessary studies (maiden resource estimate, scoping, preliminary economic assessments, prefeasibility and feasibility) up to the decision to invest into commissioning a new mine or scale up an existing one. **This may require over 50 million dollars, in the case of very large projects.**
- **Mine investment:** in view of the results of a feasibility study, invest the funds to commission a new mine (or an extension of an existing one) +/- a processing plant +/- a smelter and all the needed auxiliary facilities/ infrastructure

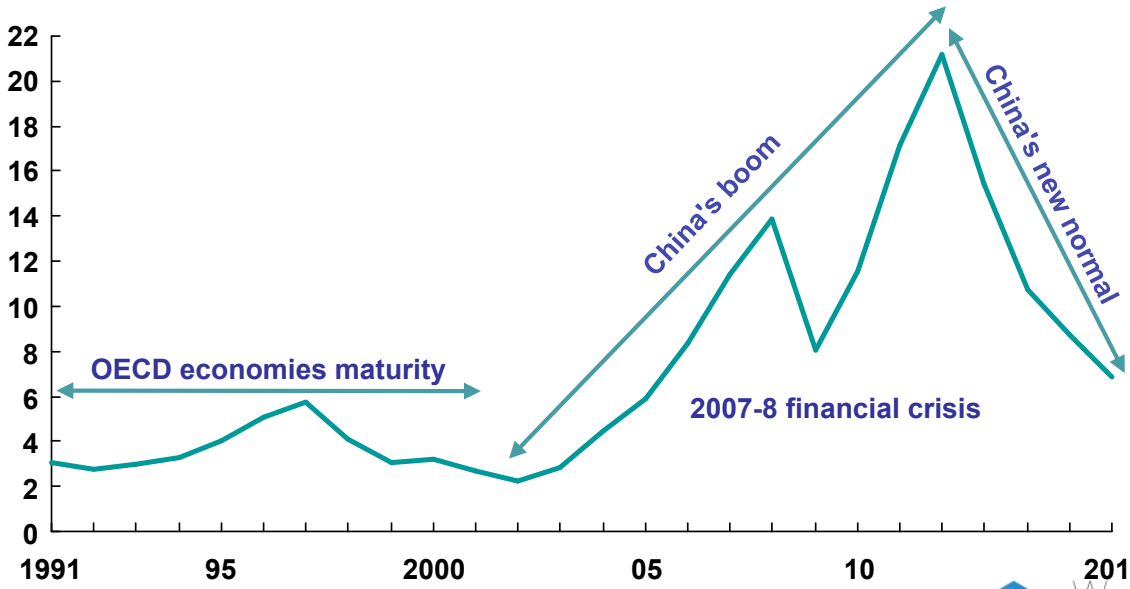
Impact of project financing

- Decline of public efforts in geological database development
- Sharp and continuous decline of investments in exploration and in new mine investment going on since 2012 (-56 % from 2012 to 2016)
- Overemphasis on exploration for gold
- Difficult operational environments (declining ore grades, harder to find deep-seated concealed ore deposits; conflicts, political or regulatory instability; energy/ water issues)

This paves the ground for extended supply deficits in the coming years and price increases. Zinc is the first metal concerned, copper is positioned to follow up.

Global annual investments in mineral exploration, in constant billion $ US (2014 value), over the 1991-2016 period

World non-ferrous metals annual exploration budgets 1991-2016 (excludes energy sources, iron ore and industrial minerals) in constant 2014 US$



- Financing should be a stabilising factor, but it is not as investments tend to be counter-cyclical.
- Since 2012, investments in mineral exploration fell by 53%

Data sources: Metals Economic Group, SNL, US Bureau of Labour Statistics

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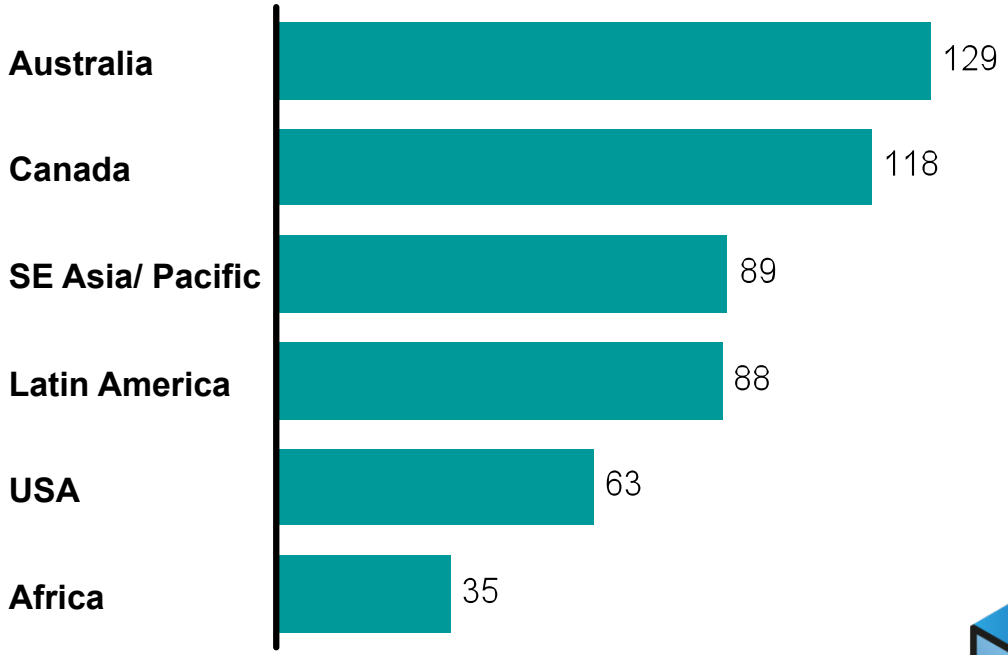
Exploration investments are highly variable from region to region…

Average investment in mineral exploration over the 1991-2016 period, in constant 2014 $US/ km2



Data sources: Metals Economic Group, SNL

- The variability of investments does not reflect geological factors (Africa's geology is comparable to Australia's or Canada's).
- It rather reflects other factors co-determining attractiveness: governance, security of tenure; available infrastructure, energy and water supplies.

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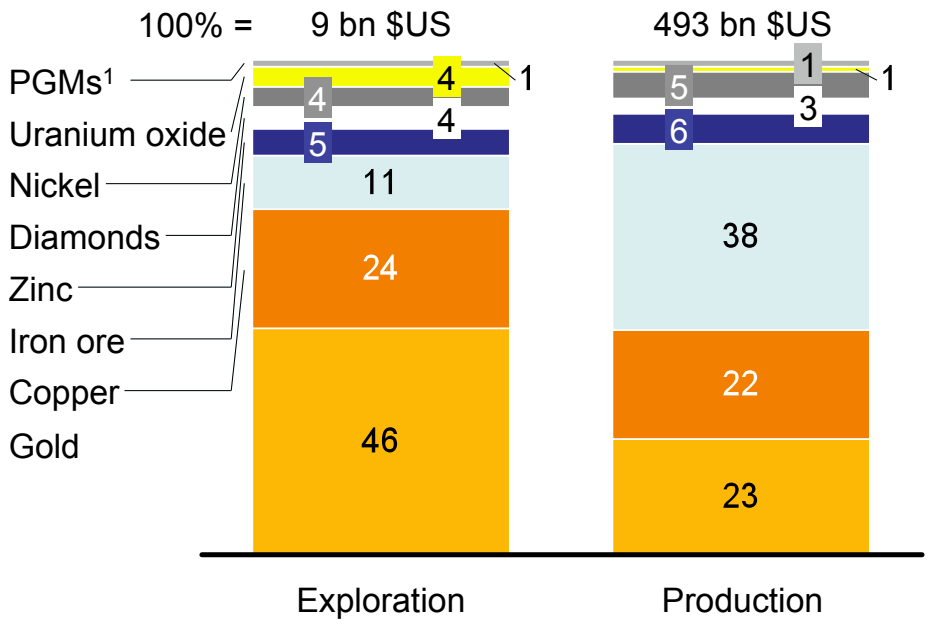
Exploration investments are also very uneven on a commodity basis, with most investment $ going to gold

Respective 2015 production value and exploration budget shares of selected minerals and metals.



1 Platinum Group Metals

- Exploration investments appear uncorrelated with the production value of the different minerals and metals.
- Investments tend to be driven by profitability perspectives, rarely by industrial strategy considerations.
- Gold is historically a favourite with exploration investors, as projects are generally smaller, offering shorter pay-back periods
- Base metals deposits require more investment as deep seated, hidden deposits will need to be found to replace depleted high-grade outcropping deposits

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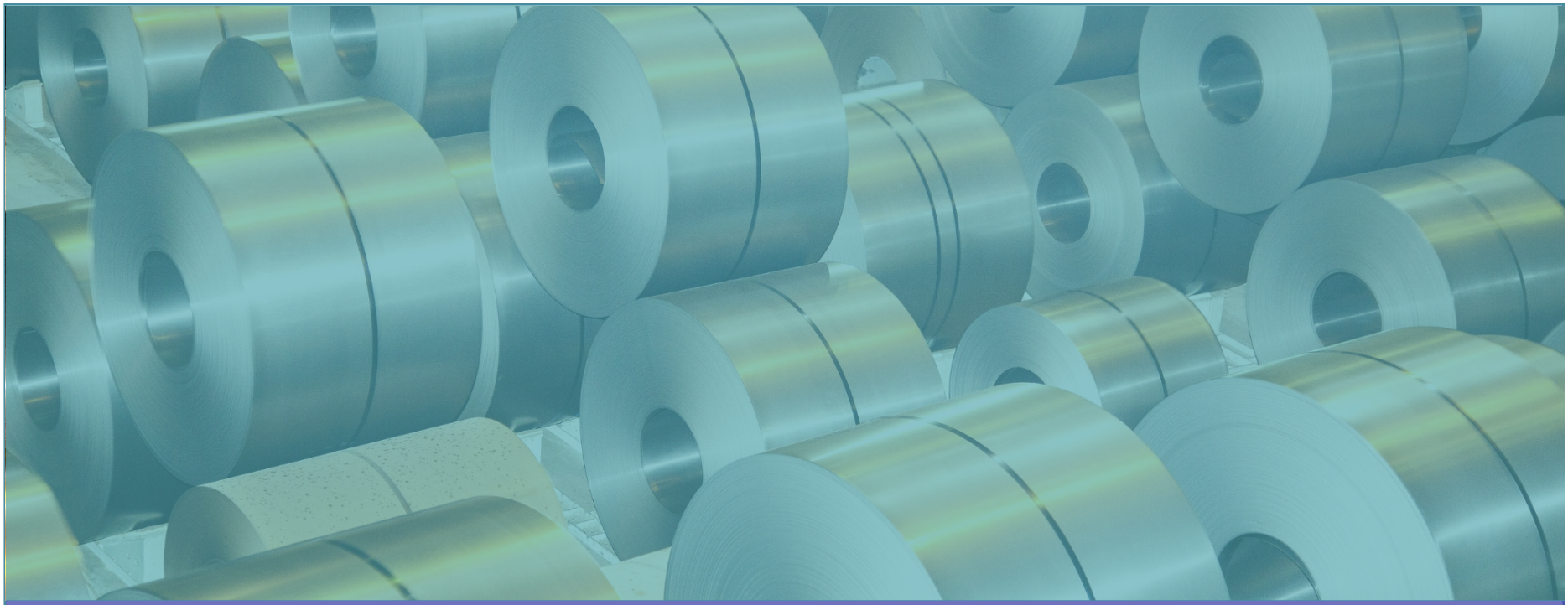

ZINC

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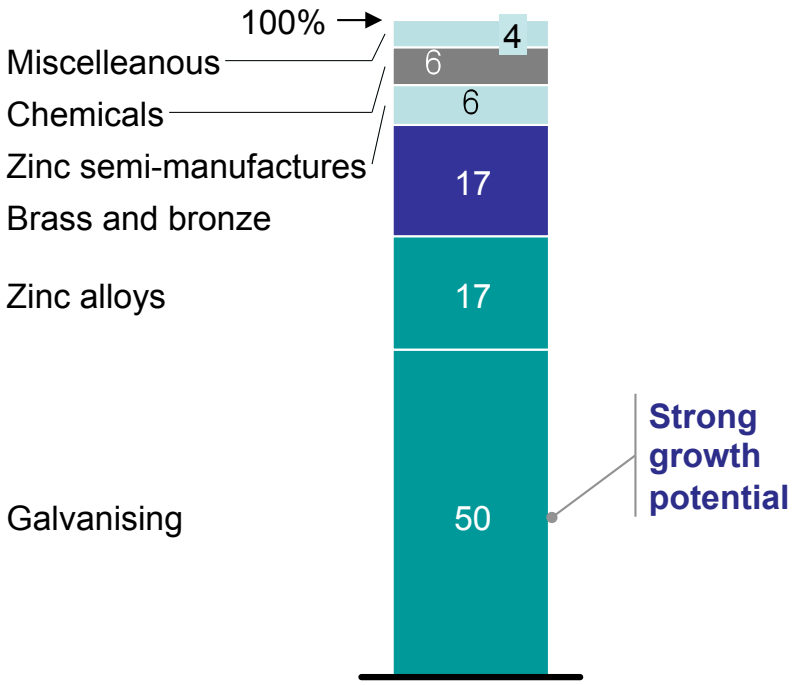
Zinc demand to grow by 4%/ year in the coming years

Not substitutable
Substitution at moderate cost and/or loss of performance
Substitution at low cost

Zinc uses in 2016, %



- Steel protection by galvanisation is the main application of zinc
- Over the 2005-2015 period cars in use grew by an AAGR of 20% in China (2015 sales: 21 M cars) and 11% in India (2015 sales: 3.4 M cars).
- Motorisation rates in China (118 vehicles per 1 000 persons) and India (22) are still well below the EU-28 level (579).
- Local brands produced for the local market have low galvanisation rates, but this is going to change
- Aluminium or plastics may partly substitute galvanised steel in cars
- Zn traces in soils is an important factor of agricultural productivity. But India and China suffer from low Zn level in their soils creating an opportunity for Zn addition to fertilisers

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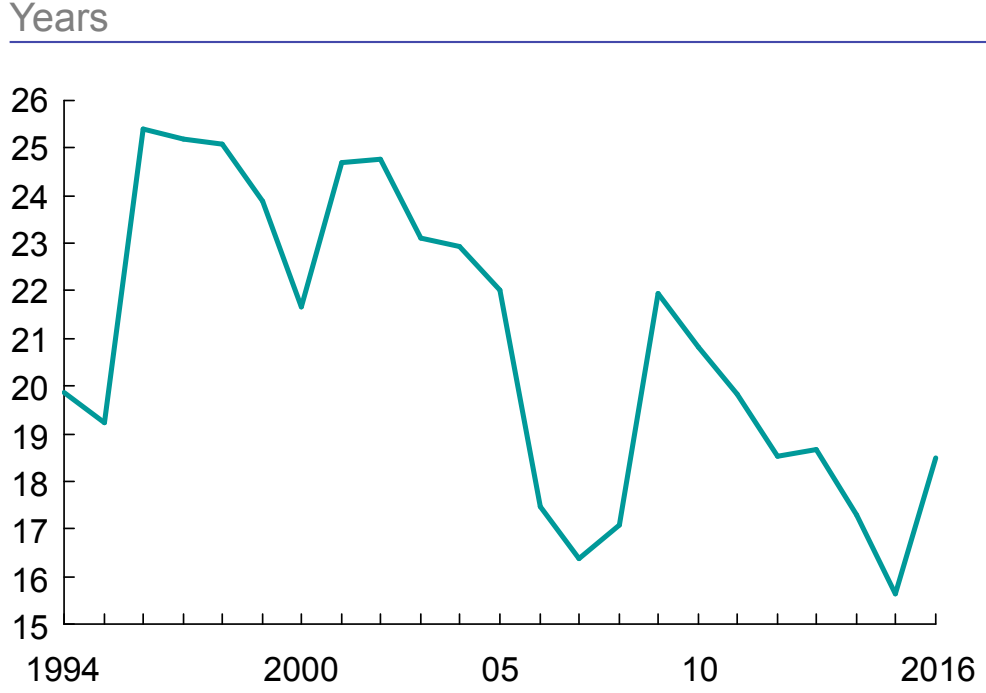
Zinc reserves reported by USGS are very low (18 years) and on a declining trend. The discovery of top tier deposits becomes urgent.

Zinc production years in the reserves



Data sources: USGS

- Zinc reserves are on a declining trend and now represent only 18 years of production, while Zn demand is likely to grow at 4%/ year.
- As it takes in average about 15 years from discovery to mine, there is a need to have new Zn deposits discovered
- A significant Zn price increase could alleviate problems for a while through conversion of part of the known resources into reserves
- Significantly underexplored regions such as Iran, hold important discovery potential

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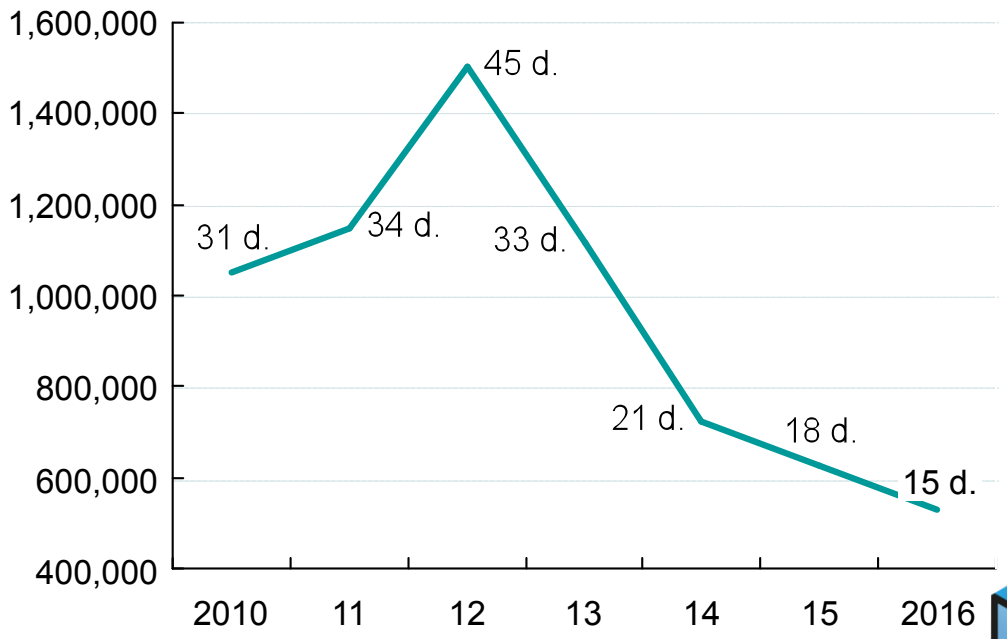
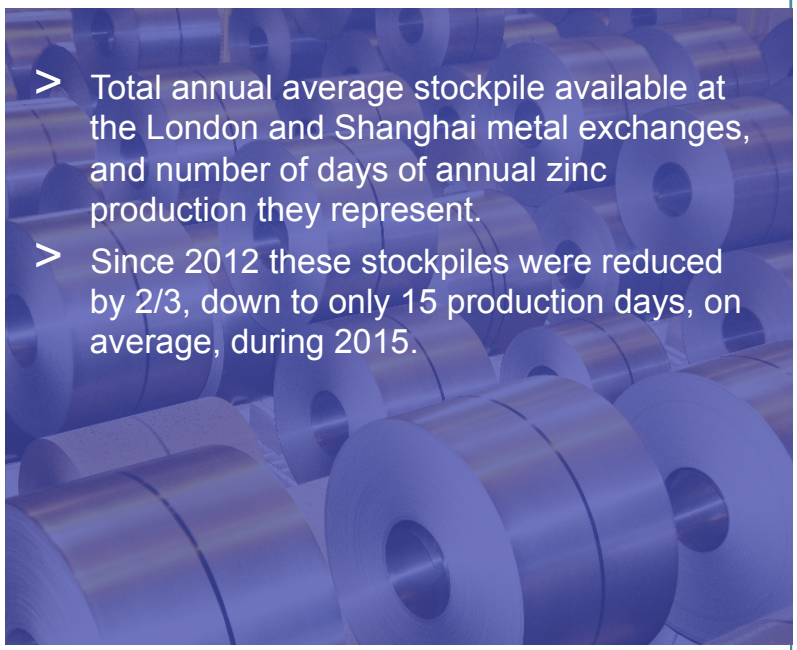
… and stockpiles at major stockmarkets are dwindling

Zinc stockpiles

Metric tonnes of Zn in London and Shanghai stocks





- Total annual average stockpile available at the London and Shanghai metal exchanges, and number of days of annual zinc production they represent.
- Since 2012 these stockpiles were reduced by 2/3, down to only 15 production days, on average, during 2015.

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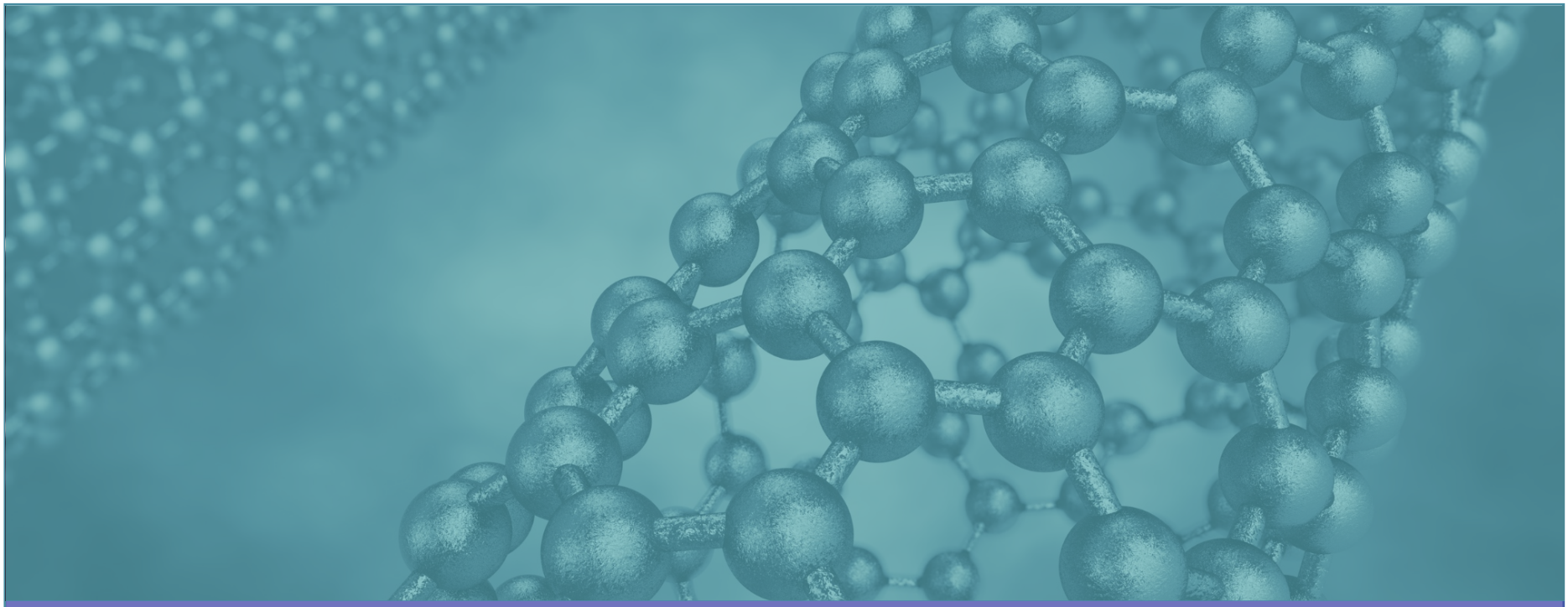

NATURAL GRAPHITE

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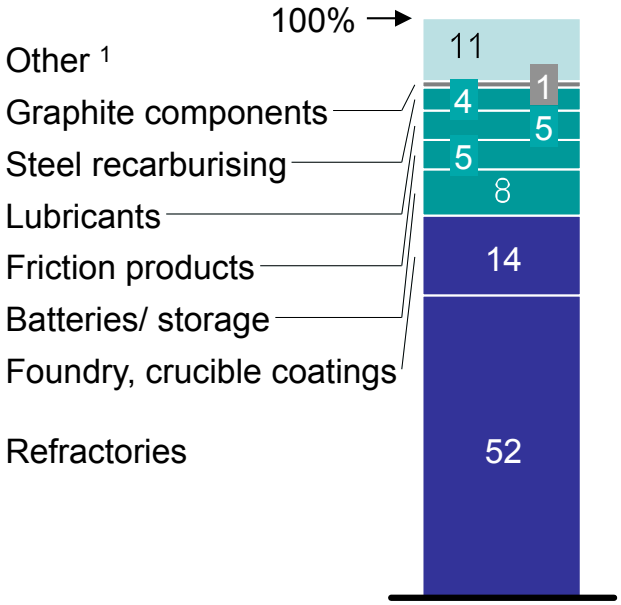
Natural graphite demand to grow at a whopping 13%/ year in the coming years, with graphite demand for Li-ion batteries to even grow at 21%/ year.



Not substitutable
Substitution at moderate cost and/or loss of performance
Substitution at low cost

- Natural and synthetic graphite compete for the production of Li batteries anodes, crucibles and refractories.
- High purity natural graphite with large flakes (+/- 180 µm) has cost advantages over synthetic graphite
- Although graphite for Li-ion batteries anodes only represented 8% of the 2014 demand, this is a fast growing end-use (+ 21%/ year, up to +/- 2025?)
- The development of vertically integrated supply chains by OECD countries based industries, from mine to spherical coated graphite (SCG) for Li-batteries anodes production, appears vital to the development of a Western electrical cars industry.

1 Includes glass making, paint and nuclear power plants

Data sources: Roskill 2015

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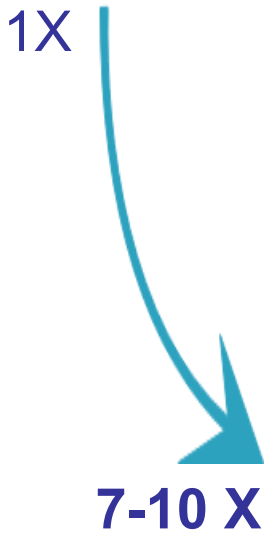
Simplified Process Route For The Production Of CSG And Indicative Pricing Of Natural Graphite Products – Value Addition Happens Essentially In The Final Stages (Spheroidisation And Coating) Of Anode Material. This Requires Advanced Proprietary Know-how And Technology



Value addition


Mining of graphite ore: a few percent of graphite


Crushing and grinding

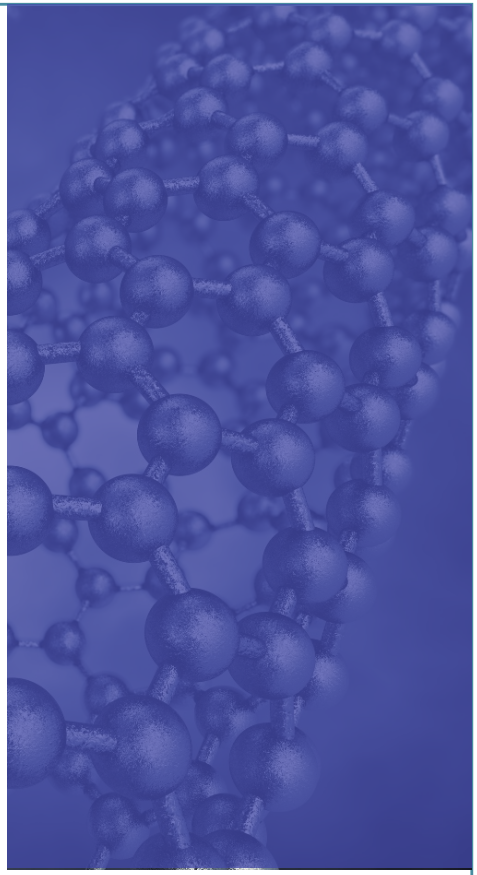

Flotation: separation of the graphite flakes- Unit price of graphite concentrate, 95% Total Content in Graphite: 700 - 1000 $US/ t (2016 pricing)


Micronising - 800 - 1200 $US/ t (2016 pricing)


Spherical graphite production - 10-25 µm - 3 to 4 000 $US/ t (2016 pricing)


Purification to 99.5% carbon content - 4 to 6 000 $US/ t (2016 pricing)


Coating spherical graphite pellets for Li battery anodes - 7 to 10 000 $US/ t (2016 pricing) - The processing multiplied the initial value of graphite by a factor of 10.



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RARE EARTH

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A family of 14 – 16 elements, needed by different rapidly evolving markets for high-technology applications.

Market share 2015, in %		
79%	Permanent magnets	Nd Pr Dy Gd Tb
7%	Phosphors for lighting	Ce La Eu Tb Gd
4%	Glass production	Ce La Nd Pr Y
3%	Automotive catalysis (exhaust gas cleaning)	Ce La Nd Pr
3%	Fuel cracking catalysts	La Ce
3%	High resistance ceramics and dielectrics	Y La Ce Nd Pr
3%	NiMh batteries alloys	La Ce Nd Pr Sm
2%	Polishing powders	Ce La Pr

Data sources: BRGM, IMCOA

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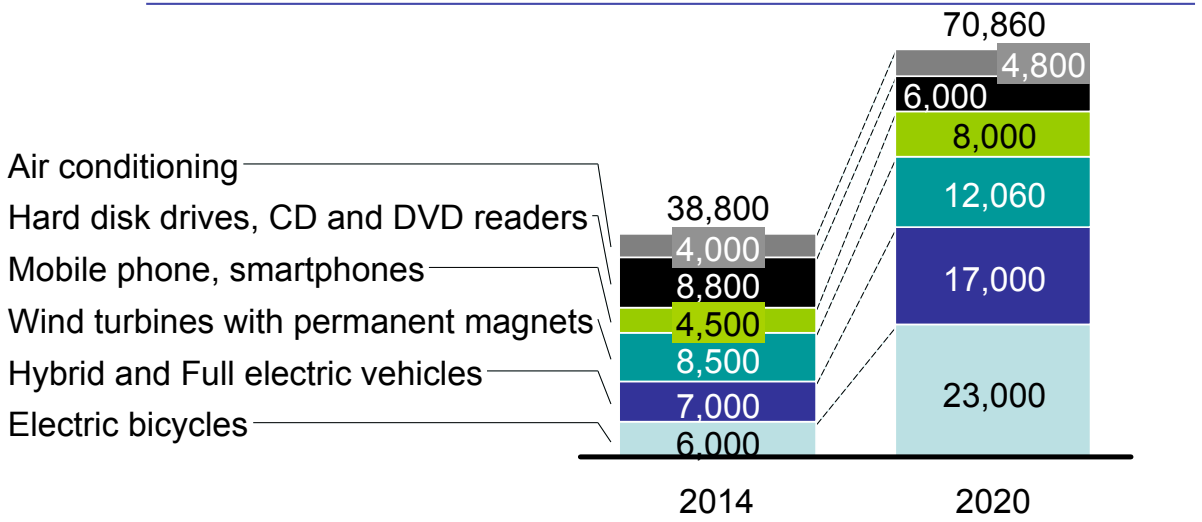
Nd-Fe-B Permanent magnet demand scenario 2014-2020: +83% demand growth in just 6 years. This end-use could grow at a 7.4% CAGR from 2016-2025

Demand of magnetic material

Metric tonnes Nd-Fe-B magnetic material



Data sources: Arnold Magnetics, IEA, IHS Markit, Adamas Market Intelligence

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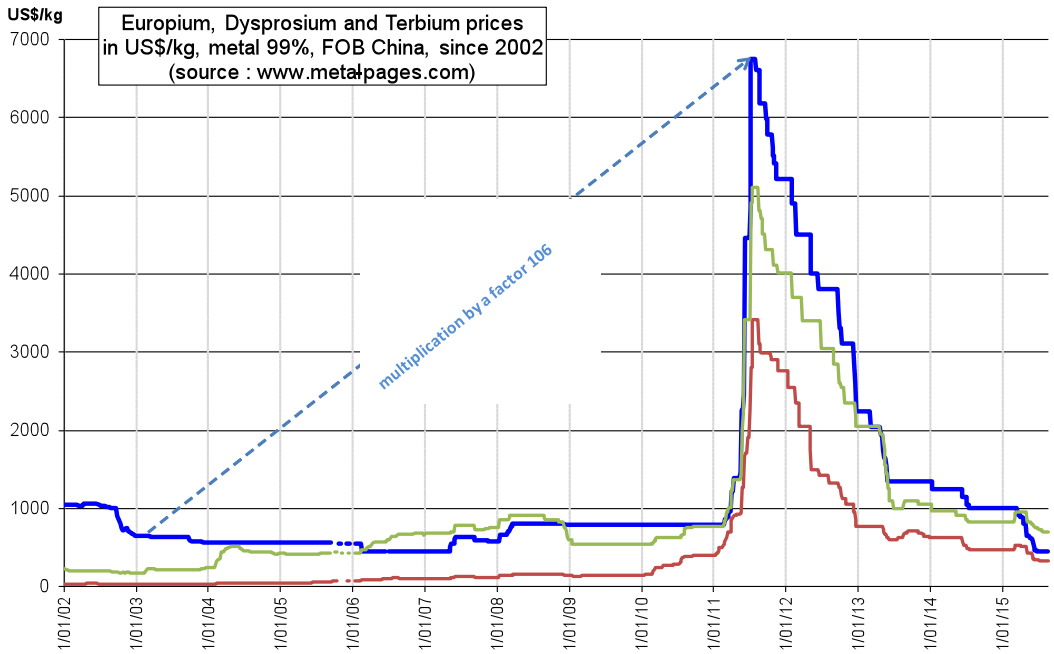
The risk of rare earth price fly-ups



- The extreme concentration of rare earth mining/ metallurgy and, to a slightly lesser degree, of permanent magnets production in China, on one hand, and the related dependence of many OECD industries on permanent magnet imports from China and Japan can cause extreme price fly ups in case of geopolitical tensions.
- This already happened in 2011… but several projects out of China could start within a few years if there is a price fly-up. 6 have already completed feasibility studies.

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