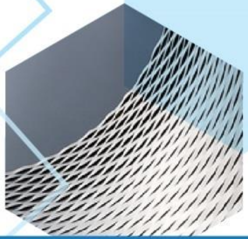
WORLD MATERIALS FORUM



Raw materials: Unlikely return of the 2003-2013 supercycle

Understanding the macroeconomic context and impact on raw materials

9th June 2016

McKinsey&Company

Geoscience for a sustainable Earth
brgm

Context and scope

Summary of WMF 2015

- Increasing pressure on the materials industry to meet the expected booming global demand
  - Need to cope with middle class growth, urbanization, connection to the internet and general push for green behaviors
  - Need to produce more quantities at lower cost and with less damage to the environment
  - Need to anticipate future balance of supply and demand
- Need to design a new path to seize the resulting business opportunity
  - Improved processes to extract and transform resources
  - Increased efficiency of circular economy
  - Alternative materials to substitute or complement existing offering
- New management approaches necessary to succeed
  - Integrated approach combining materials composition and sourcing, part design and manufacturing processes
  - Partnership among different actors, competitors and customers to leverage new skills
  - Innovation on governance of public / private schemes at an international level

Contents

Overview of future macroeconomic context

1

A supercycle like the one seen in the 2003-2013 period is not expected to return in the foreseeable future, the Chinese development profile was unique, and it coincided with significant deterioration of geological conditions

2

Physical **availability of supply is not likely to be an issue,** but practical availability may be impeded by cost, exploration, accessibility, environmental or geopolitical limitations

3

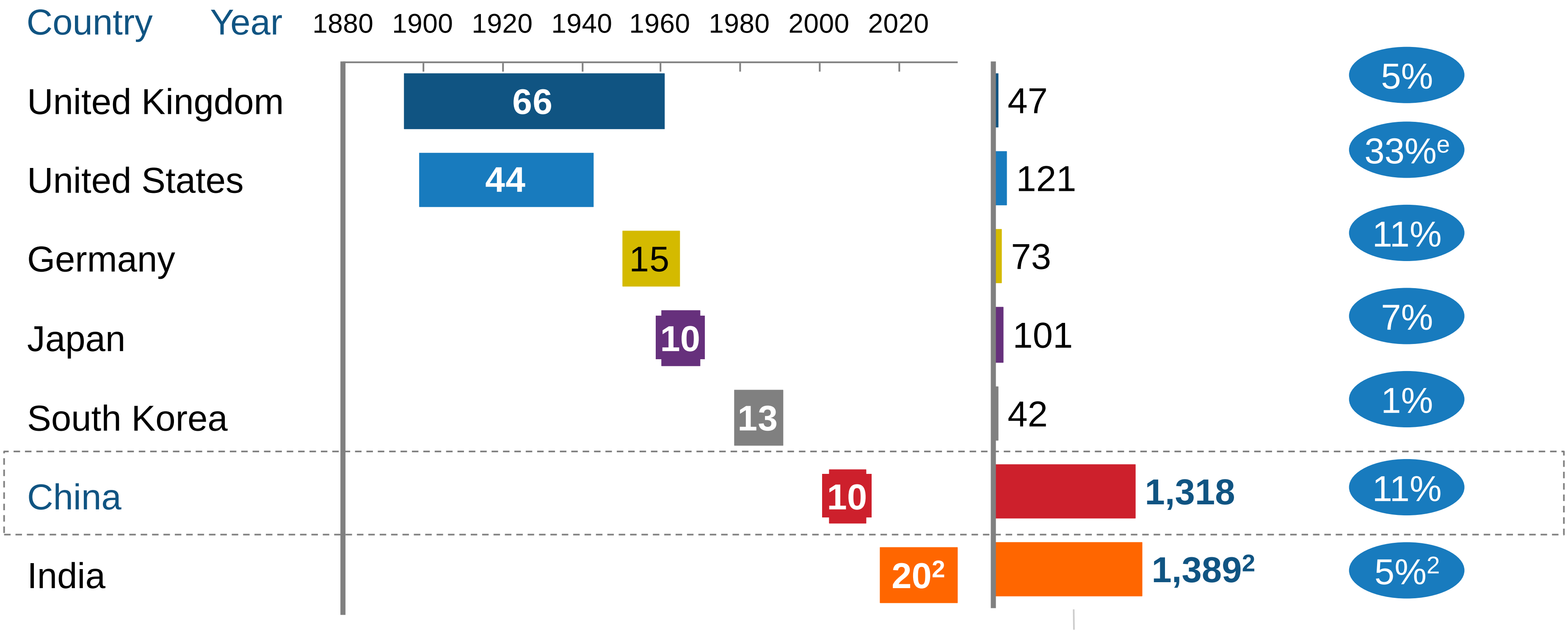
Price corrections are expected to occur, at least for select materials, due to **temporary or perceived imbalances in supply and demand**

China's past growth was exceptionally fast – especially when put in a historical context

Time to replicate China's per capita GDP[1] growth between 2002 and 2011
GDP per capita PPP Int. $,Years

Population in the middle of growth period
Million

End of period share of global GDP
USD Real, %



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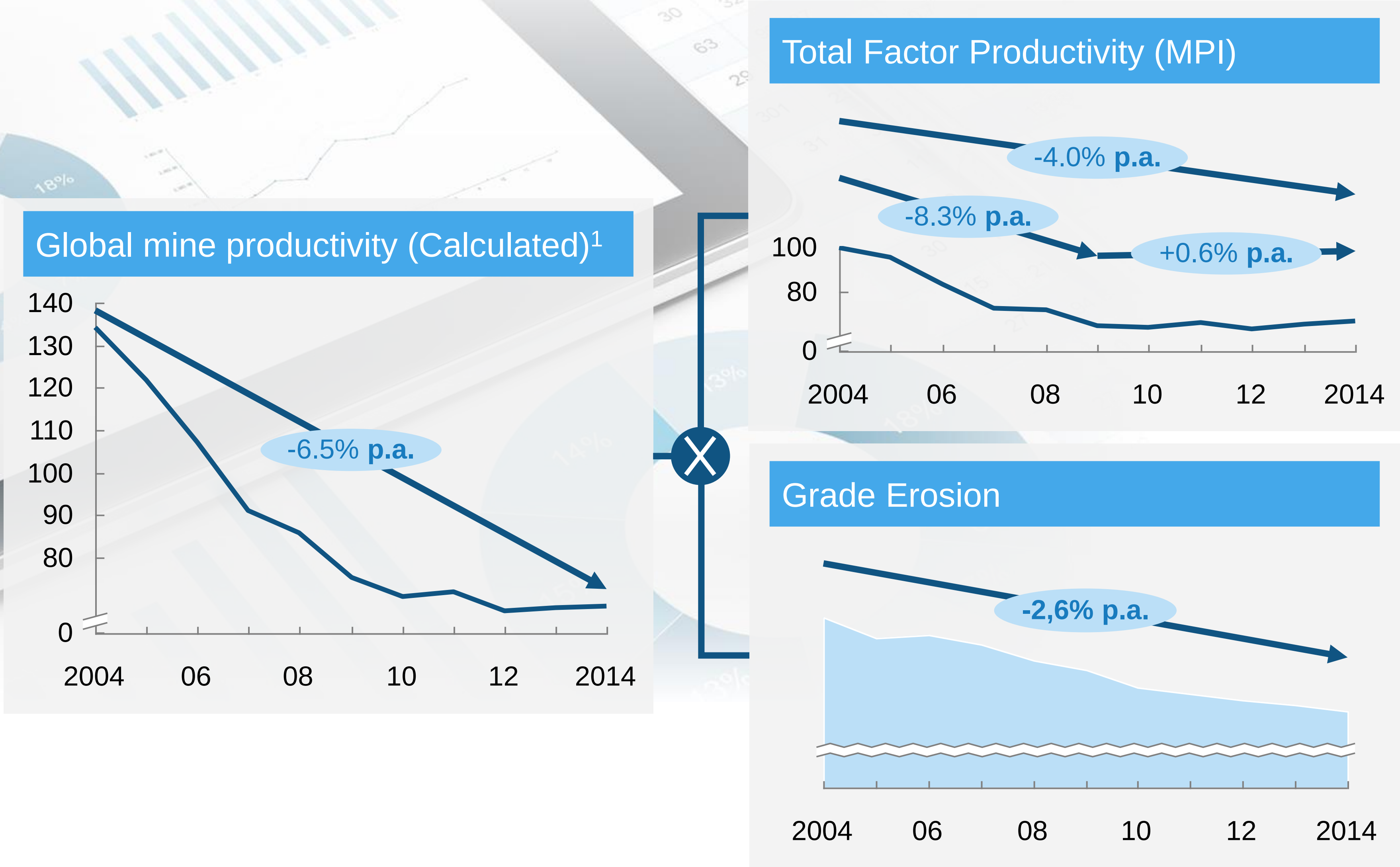
1 Historical time required to replicate Chinese per capita GDP (in PPP terms, International Dollars) growth between 2002 ($ 4 100) and 2011 ($ 8 700)

2 India is yet to surpass the Chinese 2011 level, expected to surpass the $ 8 700 per capita level in 2030, midpoint = 2022

Source: Angus Maddison; World Bank; McKinsey analysis; McKinsey Global Institute

An unprecedented fall in grade was seen across the mining spectrum, and coupled with China's boom, this led to sharp productivity declines



Global mine productivity (Calculated)[1]

Total Factor Productivity (MPI)

Grade Erosion

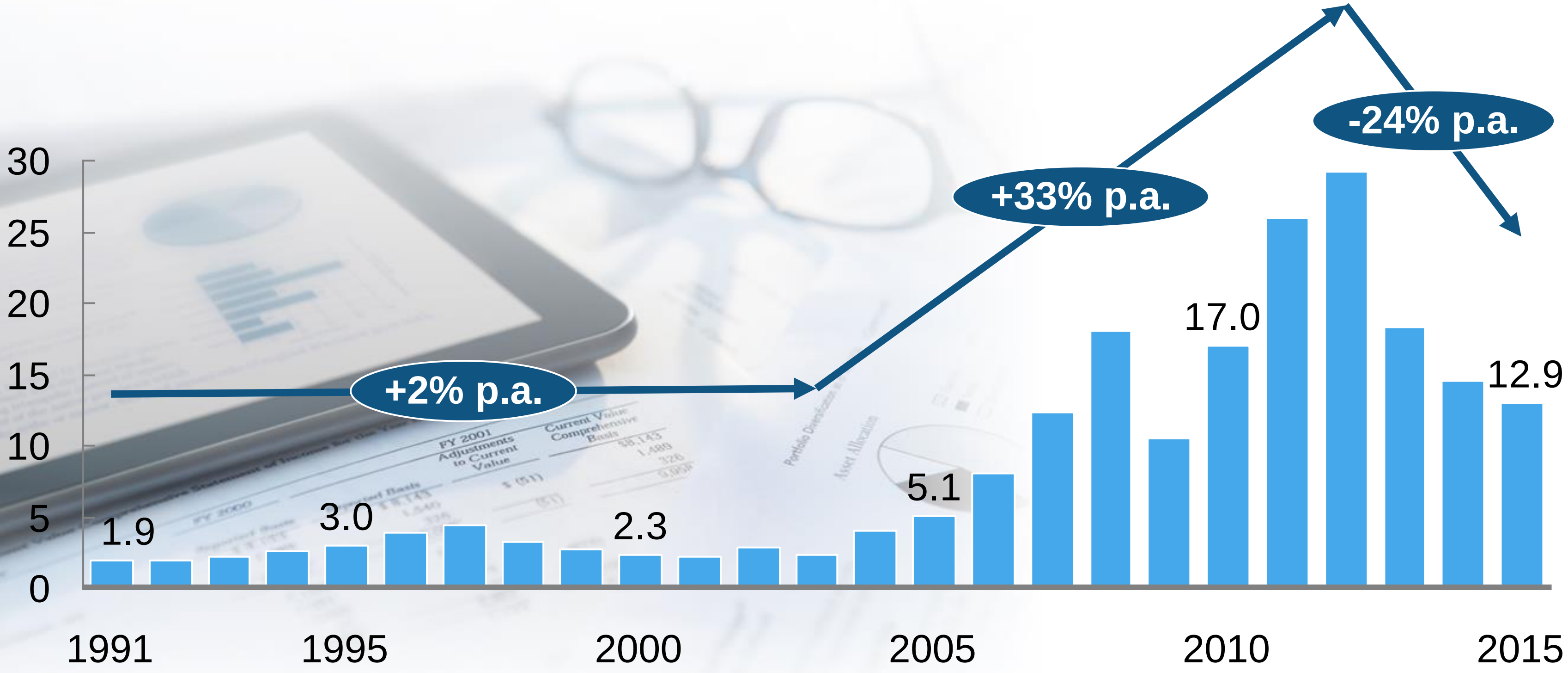
[1] 2002 value assumed to be 100

Source: McKinsey Basic Materials Institute (BMI Mining Model); MPI study 2015

1 NO RETURN OF THE SUPERCYCLE

Exploration spending has reduced in the last few years, potentially reducing discoveries in the future

Exploration estimates for global mining
USD Bn



- Across all major regions, world-class discoveries cost over 1 billion USD
- Global discoveries over the most recent 15 year period covered only two thirds of reserve replacement needs, this shortfall is expected to increase

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Source: McKinsey Basic Materials Institute, Minex, Press

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① NO RETURN OF THE SUPERCYCLE

Boom time investments have led to current overcapacities in many materials, like steel or aluminium, particularly in China

ILLUSTRATIVE

Expected capacity utilisation vs. expected demand to 2020 for select commodities

Source: Word Steel Association, World Aluminium, BMI Steel Vision, BMI Aluminium Vision

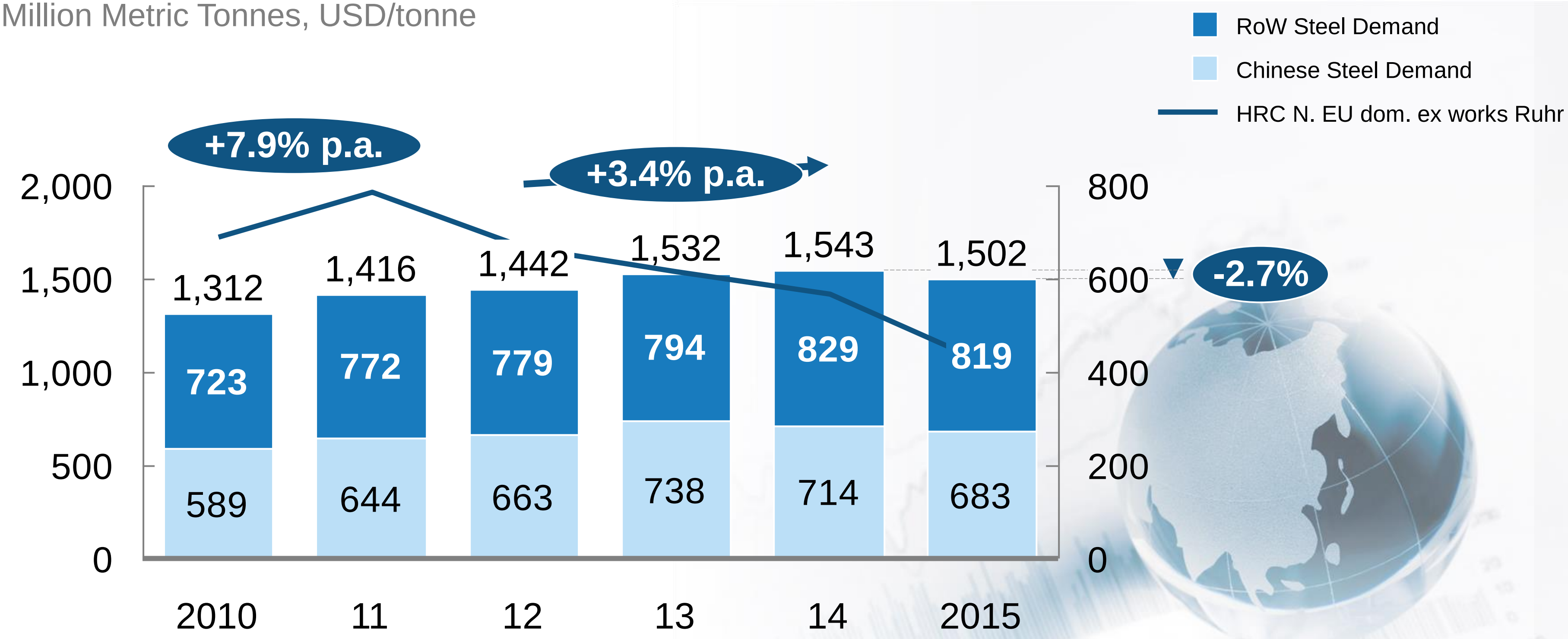
① NO RETURN OF THE SUPERCYCLE

The collapse of steel prices was driven by increasing oversupply that will dampen future price growth

STEEL EXAMPLE

Global steel demand in 2015 experienced its first drop since 2009

Million Metric Tonnes, USD/tonne



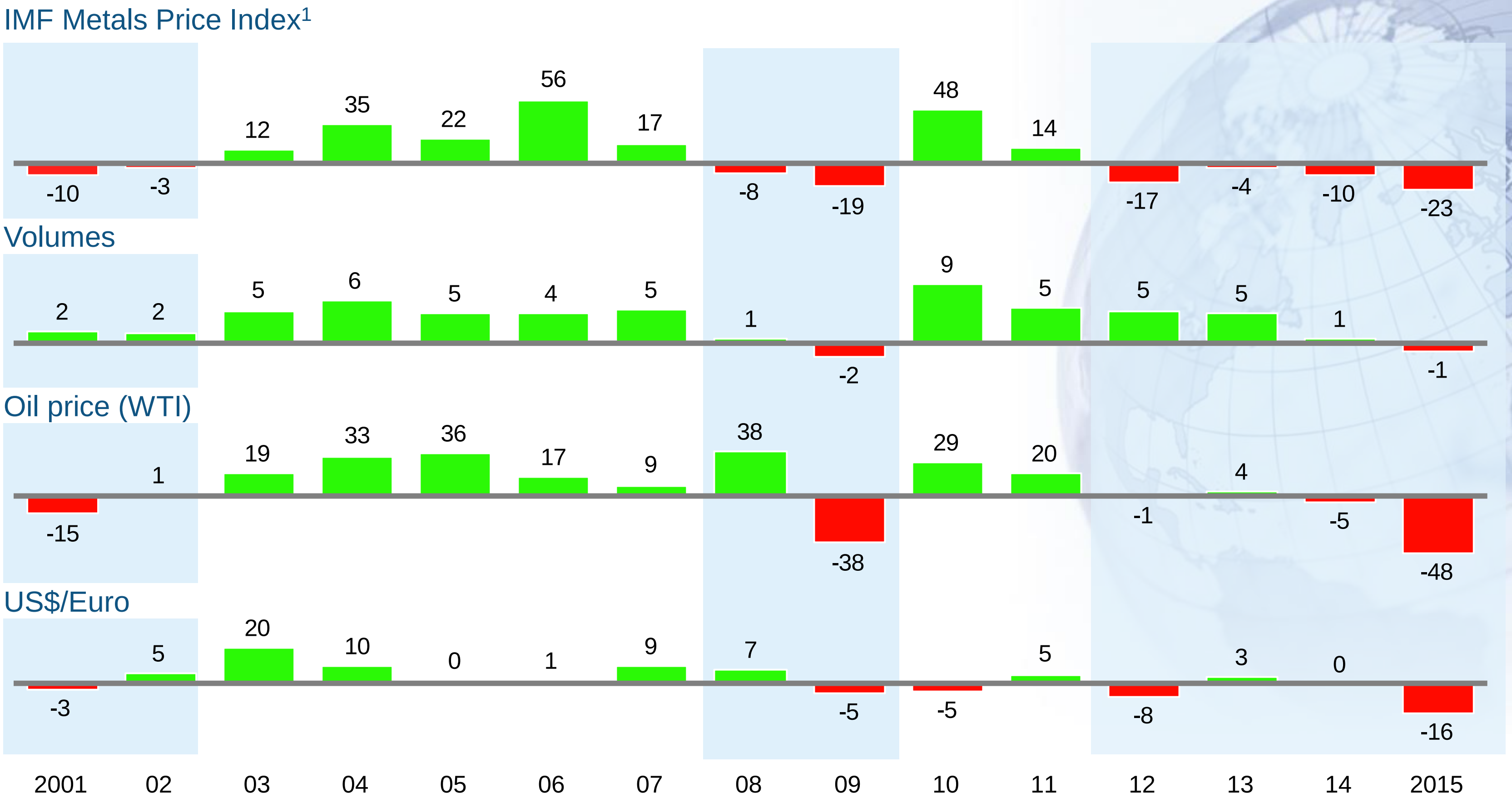
71	80	83	74	70	65	**Average RoW capacity util.** Percent
85	80	73	80	79	76	**Average CHN capacity util.** Percent

Source: Steel Business Briefing, McKinsey Integrated Steel Demand Model

Global commodity markets suffered a bearish year in 2015. The main causes were the stronger dollar, falling oil prices and growing oversupply

Comparison of price drivers

Year on year change, percentage



1 Includes copper, aluminium, iron ore, tin, nickel, zinc, lead, and uranium price indices

Source: IMF, MGI, McKinsey Basic Materials Institute

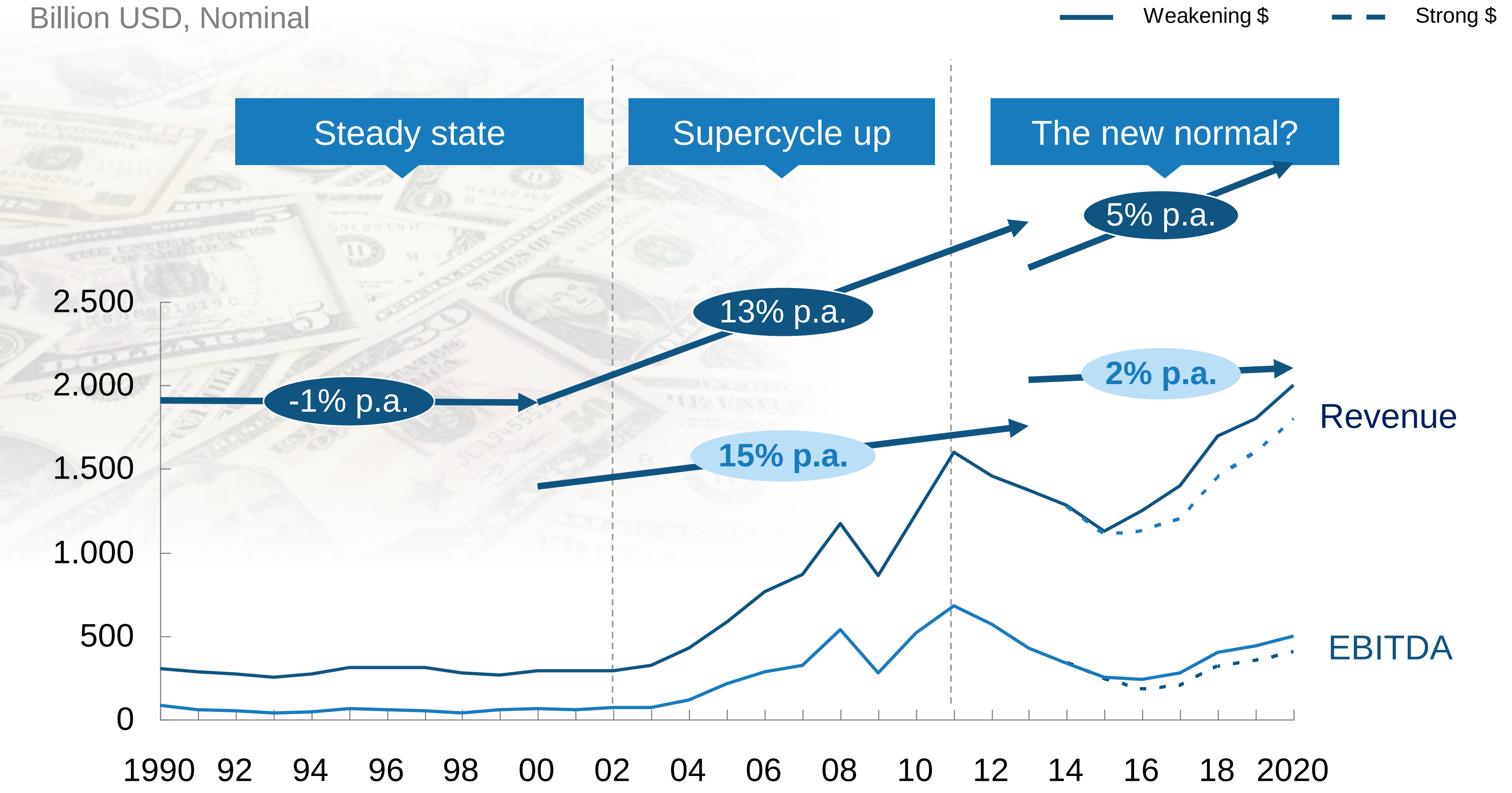
① NO RETURN OF THE SUPERCYCLE

MINING EXAMPLE

At current price and demand levels, multiple commodities are seeing shrinking margins. Slow future growth is expected

Revenues and EBITDA of the global mining industry

Billion USD, Nominal

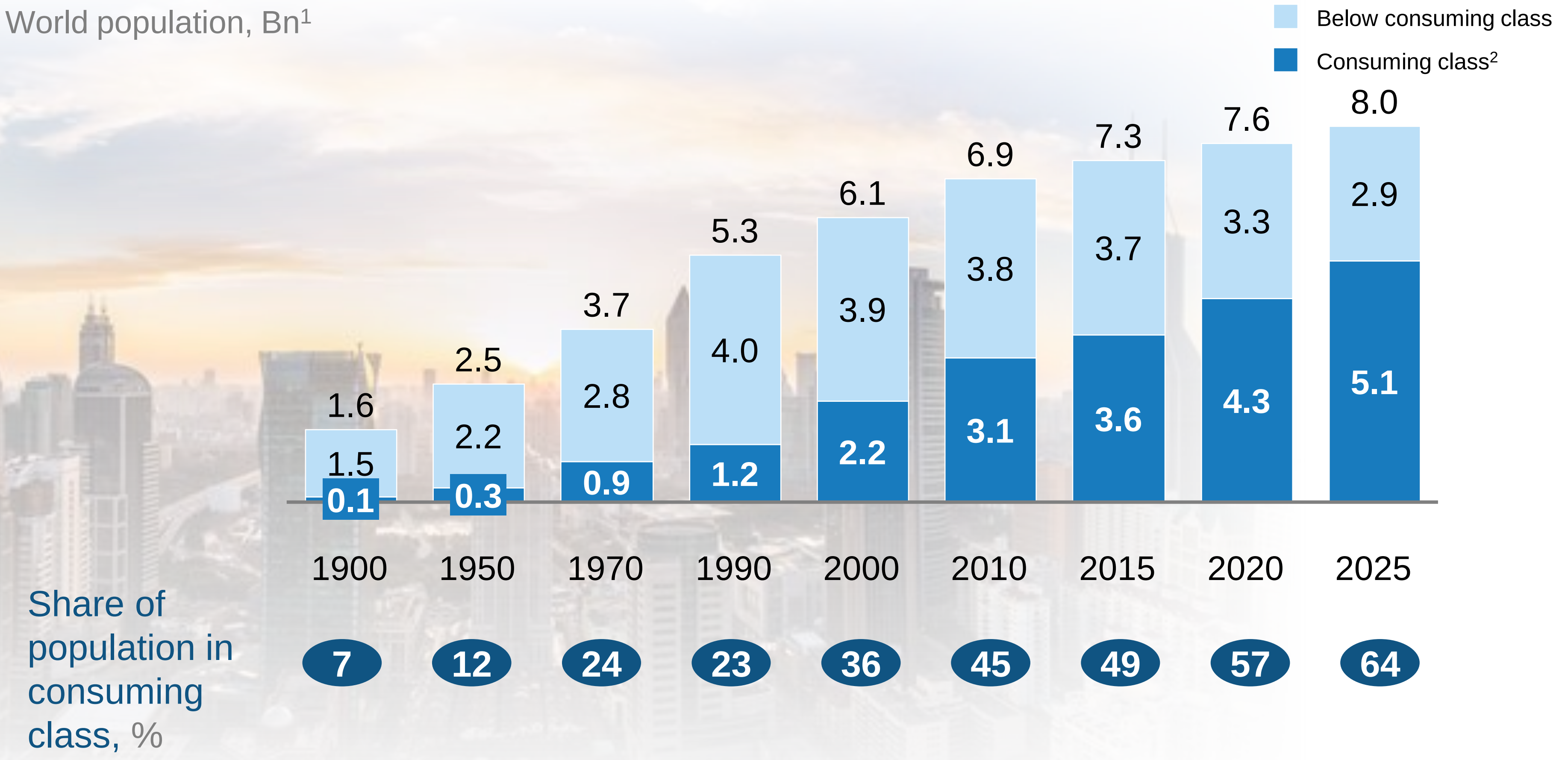


Source: McKinsey Mining Model

1 NO RETURN OF THE SUPERCYCLE

A growing middle class will continue to sustain demand for commodities in the future

The middle/consuming class is set to grow considerably toward 2030



[1] Historical values for 1820 through 1990 estimated by Homi Kharas; 2010 - 2025 estimates by McKinsey Global Institute

[2] Defined as people with daily disposable income above $10 at PPP. Population below consuming class defined as individuals with disposable income below $10 at PPP..

Source: Homi Kharas; Angus Maddison; McKinsey Global Institute Cityscope 3.0

Beyond demographics, future resource requirements will be strongly influenced by a number of global key trends

Green economy

Sharing economy

Circular economy

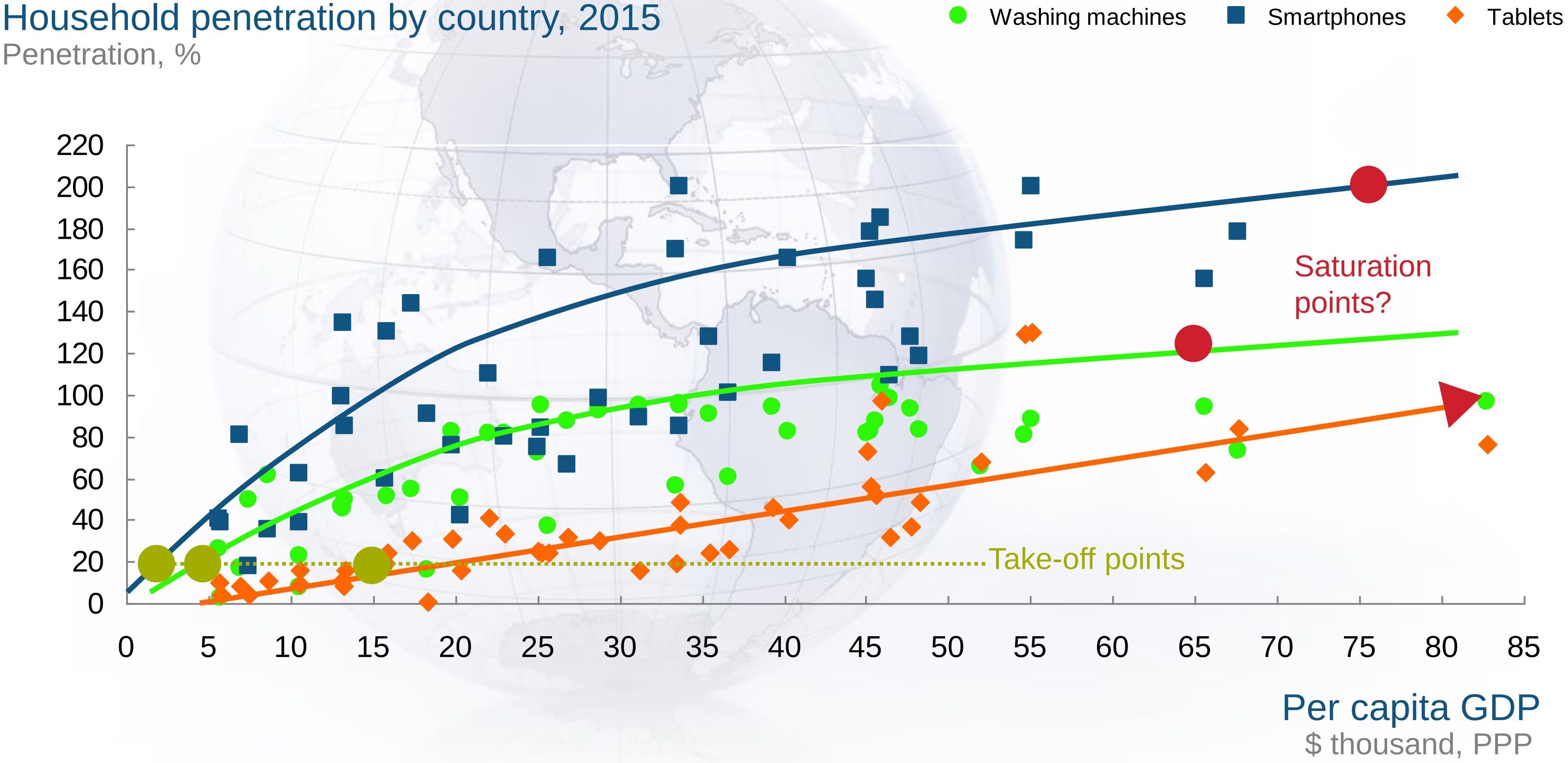
Automation & miniaturization

Source: McKinsey and Company

The shape of the adoption curve of different products varies across types and countries, leading to very different market growth patterns

Household penetration by country, 2015

Penetration, %



End product, and subsequently **material demand** will be dependent on penetration into countries with different **cultural values and geographies. "Technology" materials will outgrow "basic" materials**

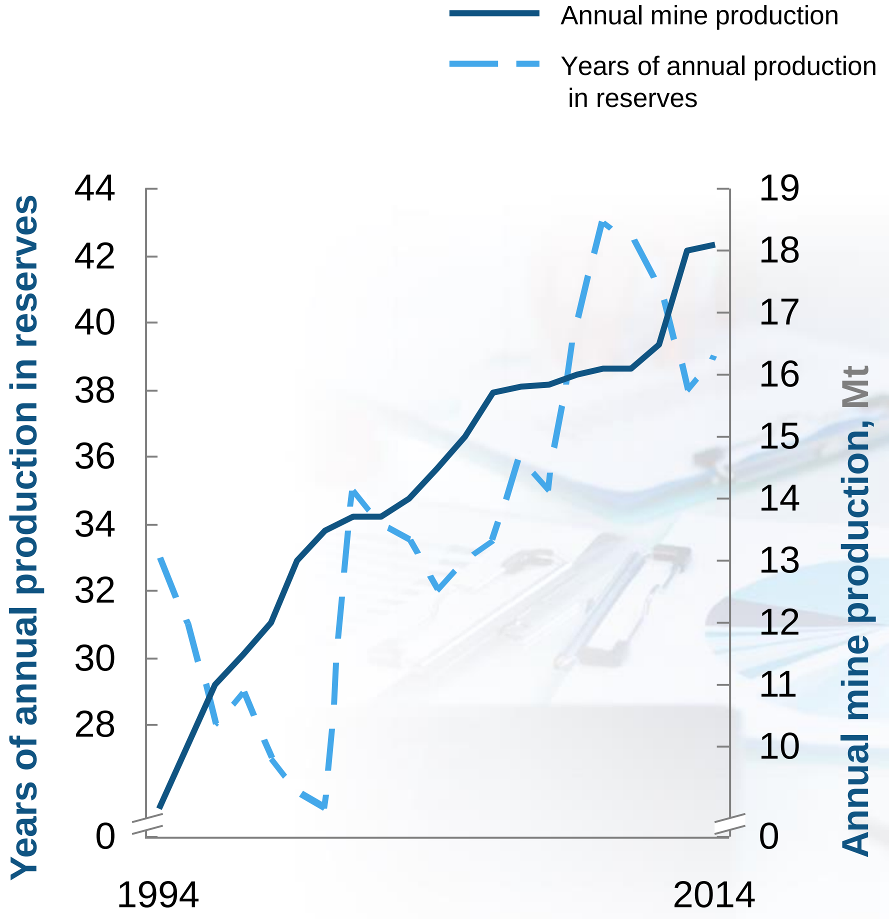
Source: Euromonitor; McKinsey Global Institute analysis

2 AVAILABILITY OF SUPPLY

There is no supply squeeze, but a squeeze on accessible low cost supply

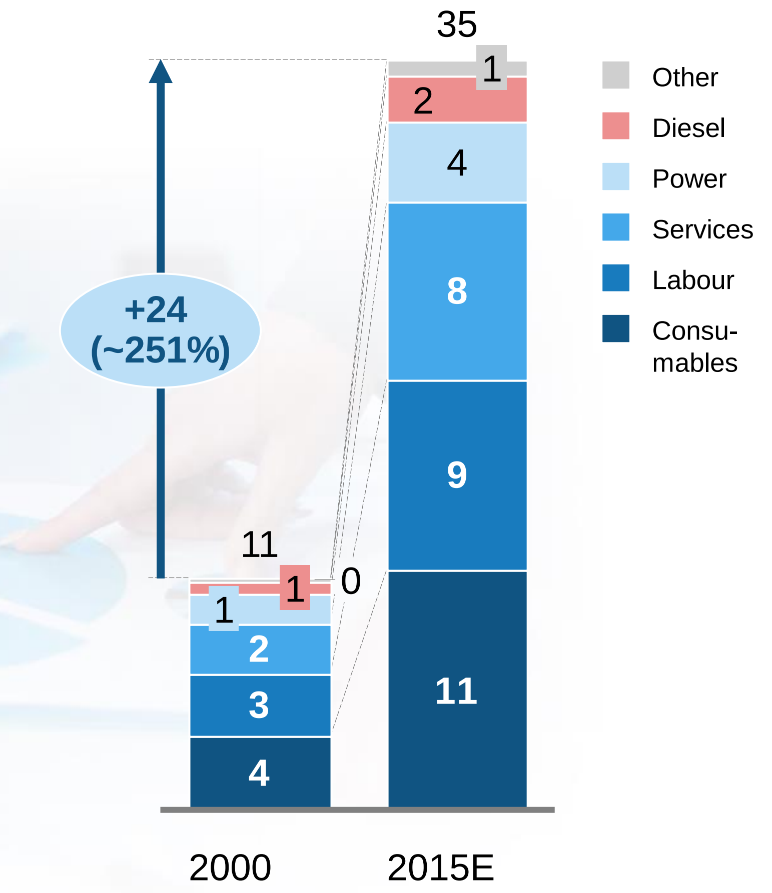
COPPER EXAMPLE

Mine production continues to increase, while years of production left shows volatility



2000 to 2015 minesite cost increase1

$/t ore milled



1 Weighted average across 369 minesites and 46 countries

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Source: Industry research, Press search

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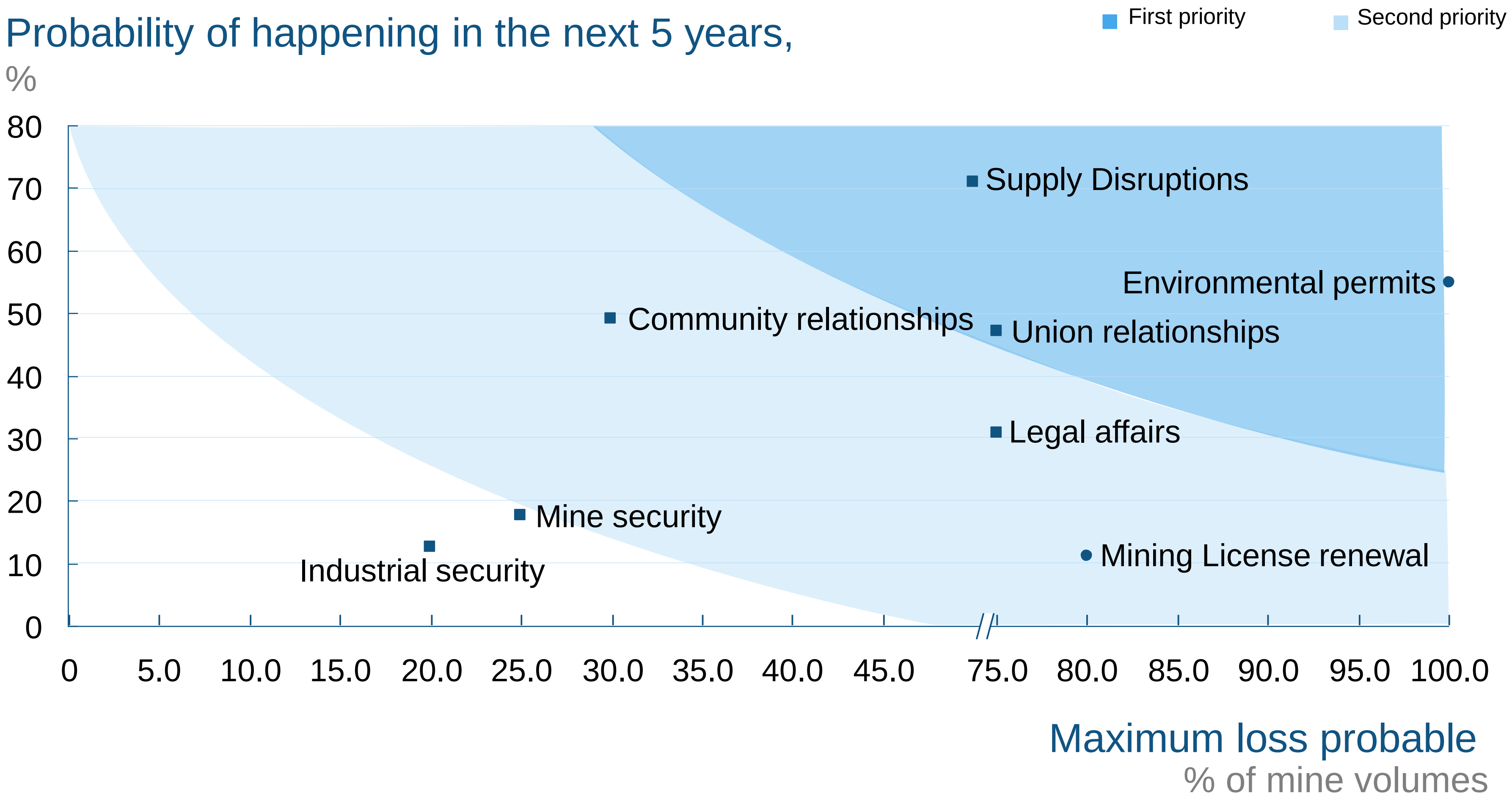
② AVAILABILITY OF SUPPLY

Large scale mining disasters worldwide are bringing environment concerns to the forefront of government and local agendas

SINGLE MINE EXAMPLE

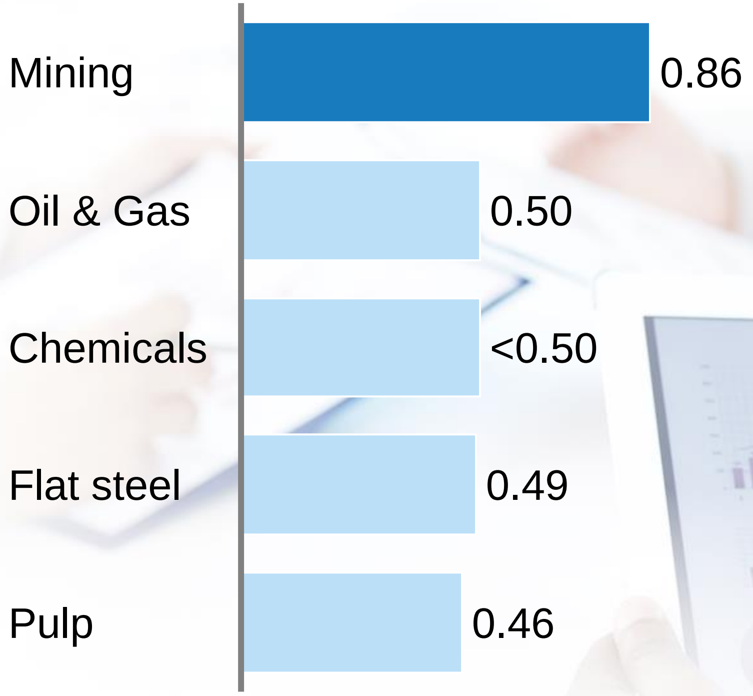


Source: McKinsey

Capital will continue to remain constrained, given the lower risk appetites of investors and lenders and weaker balance sheets

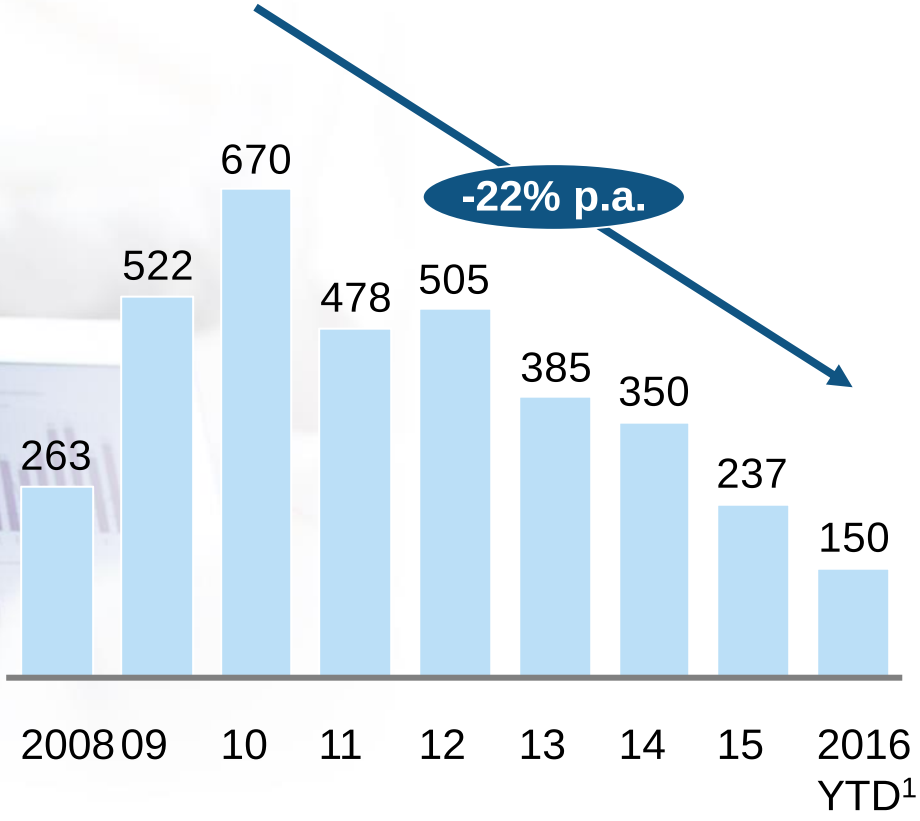
Relationship between current commodity prices and market cap

R², 2000-2013



Bloomberg Mining Index

Index, 2002 = 100



[1] 9 May 2016

Source: McKinsey Value Pools

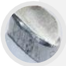
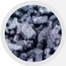
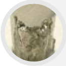
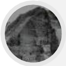
3 PRICING

Margins are expected to slightly improve for most commodities by 2020

Price regime

- 2015 Based on average price
- 2020 Based on Value Pool Model

Expected evolution of price regimes

	Cash cost	Brownfield	Greenfield	Fly-up
 Alumina	2015	2020		
 Aluminum	2015	2020		
 Seaborne coking coal	2015	2020		
 Seaborne thermal coal	2015	2020		
 Copper		2015		2020
 Gold	2015		2020	
 Seaborne iron ore	2015	2020		
 Nickel	2015 2020			
 Phosphate rock		2015	2020	
 Potash		2020	2015	
 Zinc		2015	2020	

Source: McKinsey & Company

Contents

Understanding the macroeconomic context

Assessing the criticality of selected raw materials

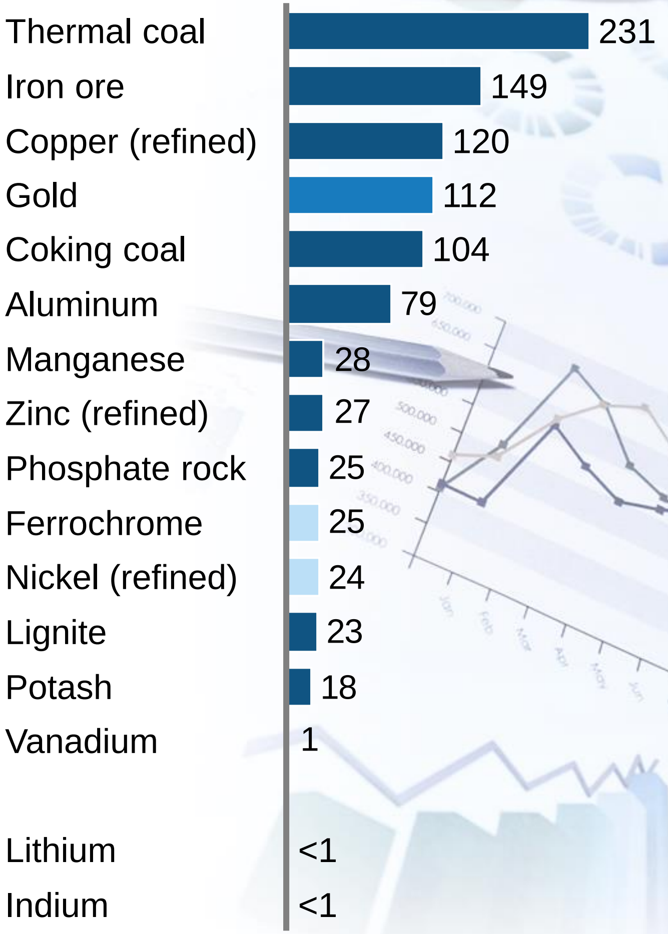
CRITICALITY FRAMEWORK

We have defined a framework to assess criticality of commodities

Type of commodities ■ Bulk ■ Precious metals ■ Minor metals □ Other

Value of raw materials produced

USD bn, 2015



Dimensions of criticality

Supply

- No geological scarcity, but exploration underinvestment
- Many minor metals are by-products (of Al, Cu, Ni, Pb)
- Accessibility issues
- 15-20 years from discovery to production (trend: growing?)
- China's role
- Trade restrictions
- Statistical issues

Demand

- Effects of technology developments (renewable energies, electromobility…) especially on minor metals, rising technological volatility
- Reduction of material intensity (nanotechs, 3D-printing…)
- Substitution effects
- EOL recycling
- Statistical issues

Pricing outcomes

- Fly-ups and sharp decreases due to cyclical imbalances and market anticipations
- Difficult to meet capital requirements

Community and government

- Institutional capacity
- Environmental issues
- Social/community acceptance
- Energy & water requirements
- Transparency/CSR
- Safety criteria

We have classified the materials into four archetypes based on the type of commodity and end-use

	Infrastructure	Consumer
Stable supply “Bulk commodities”	▪ Iron ore & steel for construction ▪ Aluminium for construction and aerospace ▪ Copper for electric cabling	▪ Potash and phosphate for agriculture ▪ Steel and aluminium related to automotive / aerospace
Risky supply “Minor commodities”	▪ Solar power related elements, e.g. Germanium, Indium, Selenium, REE (permanent magnets), Silver, Tellurium ▪ Energy storage elements, e.g., Lithium, Cobalt, Vanadium	▪ ICT driven materials, e.g., Gallium, Indium, PGMs, Tantalum, REEs (permanent magnets, phosphors, fiber optics…) ▪ Aircraft (antimony, beryllium, lithium, refractory metals, scandium, titanium) ▪ … and more!

Criticality of all bulk commodities are expected to stay at medium, with some pricing implications in short term

🟢 Easing criticality

🟡 Medium impact

🔴 Contributing to criticality

Commodity	Criticality	Description
Iron Ore	🟡	▪ **Non-critical with limited opex or capex requirements** project pipeline is sufficient for fulfilling steel demand in the near future; some impact from environmental and local agendas expected
Copper	🟡🔴	▪ **Some criticality expected with price fly-ups in the medium term (5-10 years.** Potential move to aluminium over copper for LV transmission and wiring. Urbanisation, renewables and electromobility will drive demand growth. Mining and beneficiation can cause lasting environmental damage (e.g., acid mine drainage). Energy and water availability can be issues in some places
Aluminium	🟡	▪ **Demand growth remains robust**, partly due to the shift toward light-weight materials in transport. **The major challenge will be adjusting to declining prices through efficiency measures, and controlling Chinese surplus production.**

Most minor commodities show limited criticality driven by secure supply and single end-use requirements

🟢 Easing criticality
🟡 Medium impact
🔴 Contributing to criticality

Commodity	Criticality	Description
Indium **(< 0.01 Mt)**	🟢🟡	▪ **Main use: flat displays (LCD, OLED) - Substitutes possible. Slow growth rate.** ▪ **Future: Copper-Indium-Gallium- Selenium thin film solar panels (current market share: 2%)** ▪ **Non-critical. With limited smelter capex requirements production could be increased if needed.** Only +/- 30% of Indium recoverable from zinc ores is currently recoverable. ▪ **Large stockpile** (> 4 years production) from the failed Fanya stockmarket depresses the price ▪ **Main producer: China (49% of total production)**
Lithium **(0.03 Mt)**	🟢	▪ **Main use: Li-ion batteries (44% of Li use). Very high growth rate (+/- 20%/year since 2013).** ▪ **Future: other batteries (metal-air, metal-sulfur …) may replace Li (after 2025?)** ▪ **Non-critical in the ten next years** with further investments; speculative price fly-ups may occur in medium term if CAGR for Li batteries is 11-13% for the 2014-25 period, as foreseen by Avicenne Consulting ▪ **Large resources, much potential for new discoveries. 430 years of 2015 production in known reserves** ▪ Geographically well distributed

Most minor commodities show limited criticality driven by secure supply and single end-use requirements

🟢 Easing criticality
🟡 Medium impact
🔴 Contributing to criticality

Commodity	Criticality	Description
Cobalt (0.12 Mt)	◐	▪ **Main use: Li-ion batteries (in the cathode: 3 of 6 commercially available cathodes contain cobalt) - Substitutes to cobalt possible with performance drop. Growth rate: 11-13%/year.** ▪ **Future:** substitution of Li batteries after 2025? ▪ **By product** of Ni and Cu (64% depends on copper mining in DRC, 34% on Ni mining). China leads (47%) the Co refining ▪ **Large resources.** Deep-sea polymetallic crusts are a huge potential resource in addition to land-based resources
Antimony (0.15 Mt)	🟡	▪ **Main use:** as antimony trioxyde as fire retardant in plastics (electrical cables) and composites (aircraft). (52% of Li use). Other important use: lead-antimony alloy for car batteries. Slow growth rate ▪ **Depletion of reserves (China)** is a cause of concern ▪ Substitution of some composites by Li-Al alloy in aircraft and by lead-calcium alloy in batteries may reduce future demand ▪ **Main producer:** China (77% of the 2015 global production, reserves of its main deposit may be exhausted in 4 years.

Most minor commodities show limited criticality driven by secure supply and single end-use requirements

🟢 Easing criticality
🟡 Medium impact
🔴 Contributing to criticality

Commodity	Criticality	Description
Nickel (2 Mt)	🟢	▪ **Main use:** stainless steel (45% of Ni use), non-ferrous alloys and superalloys (43%). ▪ **Almost flat demand and stockpiles at historically high levels depress prices. Many producers lose money while continuing to produce.** ▪ **Future:** slow growth. Demand for nickel metal hydride batteries used in hybrid electrical vehicles set to decline in favour of Li-ion batteries with less Ni in them. ▪ **Large well distributed resources.** ▪ **High stainless steel recycling rate (60% recyclate in stainless steel products)**
Manganese (18 Mt)	🟢	▪ **Main use:** 91% of the global Mn production being used in steel making,.its market is strongly coupled to the steel market issues. ▪ **Demand for manganese oxide could grow rapidly if LiMn oxide batteries become the favorite choice in electric cars,** but small impact on Mn demand (+0.1 – 0.2 Mt/ year by 2020) ▪ South Africa (32%), China (17%) and Australia (16%) are the main producers.

Most minor commodities show limited criticality driven by secure supply and single end-use requirements

🟢 Easing criticality
🟡 Medium impact
🔴 Contributing to criticality

Commodity	Criticality	Description
Vanadium (0.8 Mt)	◐	▪ **Diversified uses mostly driven by steel applications:** high-strength low alloy steel (46%) non-ferrous alloys and superalloys (43%). ▪ **Vanadium demand could rise sharply** if Chinese regulation requiring the use of 500 Mpa V-HSLA Grade 4 rebars for constructions is effectively enforced**.** ▪ **It could also be supported by the development of vanadium redox flow batteries for energy storage** ▪ **Vanadium is produced as either a by-product of some iron ore deposits** (titaniferous magnetite mined for steel making (64% of the vanadium produced: e. g. the Mapochs mine in South Africa) **or phosphate, coal, oil brines and black shales** ▪ **2014 Production was dominated by China (54%), South Africa (26%) and Russia (18%)**