

THE FUTURE OF MINING

Minjng Journal intelligence
Independent global mining research and reports

A NEW BEGINNING?

An exclusive survey of the
world's top 200 miners



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THE FUTURE OF MINING

A NEW BEGINNING?

"The trend is your friend ...

Until the end when it bends."



The mining industry's reliance on high commodity prices to drive competitive investment returns has again been graphically illustrated over the past 20 years when an unprecedented China-fuelled investment binge in the decade from 2002-03 was bookended by periods of anaemic growth and sector under-performance.

While mining capital and operating costs ballooned around the globe during the 'China boom' profits soared on historically high commodity prices. However, that period of prosperity was relatively shortlived – as it has tended to be through centuries of extraction of the world's valuable minerals.

The biggest profits were generated by companies sitting on tier-one mineral deposits: grade and scale easily trumping operating excellence and strategic prowess as the cornerstone differentiator in the global mining business.

The industry's growth-at-any-cost mantra turned hollow when commodity demand softened and prices plunged, leaving many miners with unsustainable debt burdens and no longer capable of generating the cash flows needed to service debts, maintain business capex at the right levels, and deliver regular, sector-defining dividends (a big industry-sell focus during the boom).

About the survey

Mining Journal's annual survey of the world's top 100 miners ranks companies based on market value and also mining-related sales revenues. The top 100 is framed from a larger pool of more than 200 miners generating significant revenues from production activities. These companies were canvassed in the second half of calendar 2015 for input into a survey about the immediate and mid-term future of the global mining industry.

More than 120 of the world's significant miners provided feedback, making this the most comprehensive survey of its type completed in recent years. The Top 200 encompasses companies producing US\$40-45 billion a year of mining revenues, all the way down to \$100 million or less of annual mining revenues.

The results provide vital references points for discussions about future industry investment in exploration, new development projects, technology, research and supplier partnerships, equipment, and CSR, and other compliance.

For companies not blessed with the best deposits past warnings about creeping costs (to develop and run mines), growing geopolitical, geological and geometallurgical barriers, and rising risks – all cast as future existential threats to many in the industry – are today's reality.

Investors may well be returning now as markets bottom and opportunities are sought, but many both inside and outside the mining sector see a pressing need for the industry's best to be defined as much by business management aptitude through cycles, and 'smarter mining', as they have been in the past by the piles of easy money made from high-quality deposits in mostly friendly jurisdictions, when market windows have been wide open.

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One experienced industry executive said: "Investors have to like our industry and the only reason they like us is if we give them good returns. If we don't give them good returns they won't like the industry. They can put their money wherever they want: they get a choice."

"So the industry is in a predicament and there really is a question about whether we have a long-term, sustainable value-creation proposition for investors. The way we are creating long-term, sustainable value in our industry, I think, needs a major rethink."

The period 2002 to 2012 not only saw the global mining industry's biggest ever decade of capital investment as companies rushed to supply China's burgeoning steel-making, manufacturing and construction sector, but also other fundamental changes in the industry. Consolidation and globalisation of the industry accelerated; the productivity and cost discipline of the 1990s was obliterated by freewheeling spending on production growth; and the technologies transforming other industries started to impact exploration and mining.

Further to this, the mining industry began presenting itself – to investors, prospective workers and leaders, and governments – as an industry of the future.

The self-described "dinosaur" industry of the 1990s finally started to embrace technological change. The industry – particularly modern mine and infrastructure development – spread geographically, and so did the risks. New threats emerged; new reporting and compliance rules came into force; and markets expanded to levels that weren't foreseen in the early 2000s.

What of the future?

The latest boom ended with mega-projects in mature and emerging mining jurisdictions locked away – perhaps for a very long time. What are the keys to their economic development in future? What is going to make these, and other projects more attractive to investors in future?

Significant cost-cutting and restructuring, and then asset rationalisation, has been the industry's response to lower commodity prices and plateauing demand. But how does it build more sustainable delivery and operating models? How does it attract and retain the people it needs to be a 'smart industry' and one that is seen by investors to be truly 'agile' and high-tech?

The industry's social licence to operate is no longer guaranteed in many parts of the world. Risks, be they technical, geopolitical or environmental, are seen to be increasing.

Who will adapt best to this new world – who will be the leaders? What will this mean for investors?

The Future of Mining survey, sponsored by SAP and ABB Enterprise Software, set out to assess how the industry actually sees itself:

- ✓ How and where investments in technology, productivity and exploration are being made.
- ✓ Where the threats are to the 'smart mining' paradigm.
- ✓ How ready the industry is to become more agile, and better at maintaining mobile and fixed capital assets.
- ✓ What premium it is placing on R&D/innovation investment.
- ✓ Where it sees risks.
- ✓ How it sees the regulatory landscape evolving.

The breadth and depth of the global industry response provides benchmark readings.

"[Mining CSR cost] codification . . . is probably coming whether we like it or not, and if the mining industry doesn't propose codification terms, then governments may codify on terms the industry might not like, or have limited input in the policy-making debate and process."

– Julien Naginski, general counsel, Pallinghurst Group

"Enabling technologies are being used in other industries, but they are not being used terribly well in mining. It really is a good time for us to be doing it."

– Rick Howes, CEO, Dundee Precious Metals

"In my opinion it is imperative mining moves very quickly to embrace some of the innovative technologies that are giving other industries a significant edge."

– Tony O'Neill, group director for technical and sustainability, Anglo American

"We figured we better disrupt ourselves in our own way before somebody does an Uber on us."

– Doug Oberhelman, CEO, Caterpillar

"In future . . . their [miners] exposure to the risk of accidents or harmful environmental factors will be much smaller than it is today or will be even eliminated."

– Herbert Wirth, CEO/president, KGHM

"If you execute successfully you'll get your production targets. If you plan and schedule successfully and achieve 100% of what you were supposed to do, and you measure everything, then you can find out where you can do better in certain areas. Each time this cycle goes around you should be getting better. Not many operations do that well."

– Rick Howes, CEO, Dundee Precious Metals

"Uber is a shining example for the taxi market and Airbnb has reinvented the hospitality sector. At first glance, parallels between taxis and mining might not be striking. But these examples prove to us the possibility of transformation through digitisation and forward thinking."

– Chris Griffith, CEO, Anglo American Platinum

"Interest in the exploration and mining of seafloor mineral deposits continues to grow, spurred on by a range of factors including decreasing deposit grades on land and the development of new subsea mining technology."

– Ian Lipton, principal consultant, AMC Consultants

"You're not necessarily going to put your competitors out of business, but when we're seeing lower grades of ore, rising costs of production, and more environmental activism, we just need to get better in a lot of different areas simultaneously, and it's not easy but the one way to do it is through data analysis."

– anonymous Mining Journal survey respondent

"We have to build an interface of trust between early-stage exploration and sophisticated, strategically focused risk capital. That is, trust that capital will be allocated effectively. I don't think that is happening at the moment."

– Jon Hronsky, principal, Western Mining Services

"Longer term we see a technology driven evolution in the industry lifting productivity and efficiency. This is an opportunity for strong management teams to differentiate themselves."

– Morgan Stanley

"A transformational shift is required in the mining industry which needs to be based on questioning everything, innovating, improving, eliminating waste and ensuring the ounces that we produce are profitable ounces. I see these turbulent times as a golden opportunity to make hard decisions and bring on transformational change that, it could be argued, should have happened earlier, but which in reality was much harder to implement during the previous cycle."

– Keith Neumeyer, CEO, First Majestic Silver Corp

"The most bullish comments suggest fully automated mines will be a reality within the next 10-15 years."

– Citi Group

"The mine of the future isn't just a mine with disparate bits of technology chucked into it – it's a modern, vibrant, sophisticated workplace. In the immediate future our automation programme is high on our priority list. Where the biggest opportunity or gain comes [further] into the future . . . is in the area of data and predictive analytics. Information is where we're turning our minds heavily to."

– Greg Lilleyman, head of technology and innovation, Rio Tinto

>200 of the world's largest miners surveyed



Main driver of alternative sourcing



76 companies

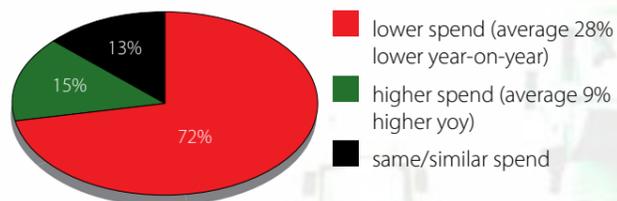
Budgeted greenfields/brownfields exploration

us\$990m
2015

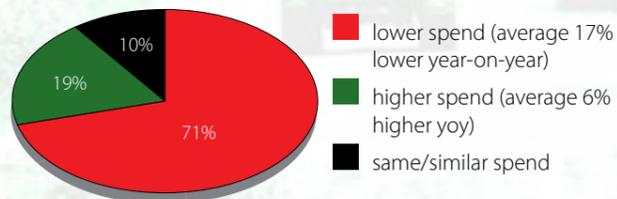
us\$714m
2016



Mobile mining equipment capex 2015 vs 2014



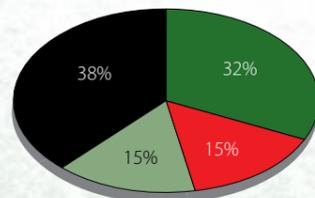
Mobile mining equipment capex 2016 vs 2015



Mobile equipment capex 2015

Top three areas

- Surface / underground trucks
- Surface / underground loaders
- Surface / underground production/development drills
- Ancillaries



Capital equipment maintenance spend

34% up
63% down
3% same/similar



Highest capex per commodity 2016

- 21%** gold
- 19%** industrial minerals
- 15%** coal
- 11%** copper
- 7%** iron ore
- 5%** silver
- 4%** nickel
- 3%** PGMs
- 2%** oil sands

Mining/processing capital equipment sourced from OUTSIDE traditional centres

(US, Canada, Japan, Sweden, Finland, UK, Germany, Poland, France, South Africa and Australia)

Top 5 'alternative sourcing' markets

- China
- Russia/FSU
- India
- Chile
- Mexico



Increased sourcing from 'alternative' markets 2016



“Empowering our customers with actionable information through intelligent mining systems maximises productivity, drives operational sustainability, and ultimately enables the mining industry to deliver profitability throughout commodity cycles.”



Information-driven productivity across the enterprise

As the market-leading supplier of IT/OT solutions to the mining sector, ABB's customers achieve productivity outcomes essential to their success with information that provides key insights for critical decisioning – not just for one process – but across their entire operation.

Working with the world's leading mining companies, we're enabling the digital transformation. Today we see a productivity shift well underway – a shift that is the catalyst for determining the next generation of industry leaders. The findings from the Future of Mining survey show us how this digital age will drive the next revolution through integrated operational visibility and advanced information technology and analytics.

Leading mining organizations all have one thing in common: they strive to make better quality decisions faster, streamlining production processes and embracing information – transforming their operations into insight-driven powerhouses. ABB provides these insights across all aspects of the mining organization:

Production Management
Ensuring the right material of the right quality at the right place at the right time

Enterprise Asset and Workforce Management
Enabling the assets to deliver the production demands in a profitable and sustainable way

Material Management
Optimising supply chain and inventory to meet the demands of production

Sales & Marketing
Maximise the profits from the fulfillment of contracts based on the market demands

Empowering our customers with actionable information through intelligent mining systems maximises productivity, drives operational sustainability, and ultimately enables the mining industry to deliver profitability throughout the commodity cycles.

Over 6000 users in 75 countries depend on CCLAS, our leading LIMS for mining and mineral processing. Hundreds of mining operations worldwide use ABB's MineMarket and Production Accounting to manage production from extraction to fulfillment. And, with 35 years of experience, Ellipse is the leading Enterprise Asset and Workforce Management solution in the mining sector globally.

Get connected with ABB's Enterprise Software Product Group for smarter information-driven productivity and faster decision making across your mining enterprise.

Contact us today at info.pges@abb.com
Learn more by visiting www.abb.com/enterprise-software

Smart is the new big

The Aspermont Mining Intelligence survey of top-200 miners found technology-led mining execution system (MES) improvements figured prominently in companies' ongoing efforts to lift productivity. A McKinsey report on mining industry productivity released this year pointed to a worldwide (multi-commodity/multi-region) decline of as much as 28% in the past decade. The report, and others, have highlighted improvement in physical output of commodities in the wake of capacity expansions, at reduced labour levels. Economic productivity, affected by the lower prices received for many commodities, is also said to have improved on the back of previous high levels of investment, leading to substantially higher output, lower current capex and opex levels, and efficiency dividends from investment in technology.

More than half (55%) of 104 responses to a question about the top-three productivity drivers nominated ICT-buttressed 'intelligent mining' as they key to improvement. Similar numbers indicated fleet, drill and blast, and mill optimisation programmes and projects would be major factors, while 44% said workforce reductions and 'sweating assets' were still on the agenda. Mechanisation continues to be a productivity booster in many jurisdictions.

“The general manager who's going to manage a mine in 2030 probably left school in 2010 and graduated from university last year or this year, and he's learning the same old things. We're saying we need to fundamentally change our business, but I don't see, at least from my experience in dealing with a lot of the universities, I don't see a lot of the [new technologies and strategies around them] in the curriculum. I'm not sure whether much of this is being taught. So I think we are lagging on the side of what we need to do in order to develop people, not only at university but also right the way through [technical college systems in the major mature mining countries] ... so from the basic technical disciplines to the top of the university disciplines. There is a gap there. I don't think we are doing enough.”

Nearly 85% of respondents indicated gains would come relatively quickly – in the next 6-12 months – while 14% said it might take 1-2 years. Productivity gains of 5-10% were anticipated by 16% of respondents; 36% said a 10-20% productivity improvement was in the offing; and 8% could see bigger gains (+20%).

Top three productivity improvement steps



- 55%** OT-IT integration/data-led decision making/intelligent mining
- 54%** Fleet/drill and blast/mill optimisation programmes/projects
- 44%** Workforce reductions/'sweating assets'
- 32%** Remote/telemote control system application
- 16%** Increase mechanisation
- 6.8%** Semi-autonomous/autonomous equipment use

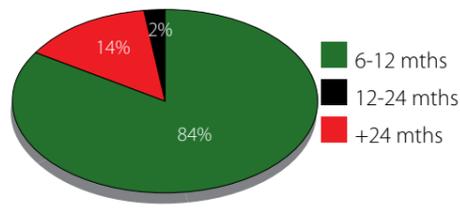
Citi Research: “We expect [large miners] to focus on improving productivity/cost structure by introducing more efficient technologies.” Productivity gains of 20-60% were expected to come from technology-led changes. We asked survey respondents if this focus was likely to become pervasive in the industry, and what quantum of productivity improvement might result. Was the range indicated by Citi in late 2014 optimistic or pessimistic?

61 responses

97% ✓ said **MORE PERVASIVE**

80.3% ✗ said **TOO OPTIMISTIC**

When will the steps have a business impact?



TECHNOLOGY
+
INVESTMENT

= SAFETY + EFFICIENCY
+ PRODUCTIVITY
x PROFIT

Technology has had a material impact on Rio Tinto's operational improvement drive at its Western Australia iron ore division, helping to make it the lowest cost producer in the world a decade after current CEO Sam Walsh stood on a Brisbane wharf watching automated straddle cars shifting cargo: seeing mine trucks in their place. Rio Tinto now wants to go much further, to change its mining DNA and not just skinnier FY2015-16 margins.

Automation has figured in most of the headlines, but the change is more about information.

"The mine of the future isn't just a mine with disparate bits of technology chucked into it – it's a modern, vibrant, sophisticated workplace," says Rio Tinto head of technology and innovation, Greg Lilleyman.

"In the immediate future our automation programme is high on our priority list.

"Where the biggest opportunity or gain comes [further] into the future ... is in the area of data and predictive analytics. Information is where we're turning our minds heavily to."

Depending on who adapts fastest during the worsening global mining credit crunch, more companies will set off in pursuit of the leader and the business improvements on offer. Anglo American is carrying more unwanted historical baggage than Rio, in the form of operational challenges and debt. But it shares a similar strategic vision for the role of technology.

"In my opinion, it is imperative mining moves very quickly to embrace some of the innovative technologies that are giving other industries a significant edge," says Tony O'Neill, Anglo American's group director for technical and sustainability.

"One example is big data. Its analytic capabilities will give us fresh insight into our business that could have huge spin-offs in areas such as safety, production optimisation, equipment maintenance, and the leadership and engagement of our people."

Canada's MaRS Market Intelligence said in a report on mining and metals sector IoT appeal: "If mining automation is the poster child of mining innovation, then the Internet of Things is arguably the 'printing press. Indeed, by enabling the IoT miners could unlock benefits beyond mining automation and enhance existing or new information technology products and services."

Big data analytics is shaping as a bona fide game-changer for the mining industry, where talk of factory-style production and even lean operating principles has been around for some time but the supporting information management tools used in best-practice applications elsewhere has been missing. That is, mining has been and is a big data generator. Mine information management technology development and use has definitely been on an upward-moving curve since the mid-1990s. It's not a Google-type curve, but progressive. Still, a new focus on operations/information technology integration, analytics and business-intelligence driven decision making is crucial to miners' efforts to make IT transformational.

"I don't think we've even cracked the door open yet on what the opportunities for the use of all that data and information is going to bring to us," Lilleyman says.

"But we're starting to."

Deloitte Americas mining leader chairman Glenn Ives says: "The real changes that have to happen [in mining] are akin to what happened in manufacturing. Compare a car plant in the 1970s with the car plant that Tesla uses to build its new cars. There are sensors on everything today. There are robots doing everything.

"Mining today still looks like a car plant maybe in the late 70s, but certainly not one in the 90s. Data are not fed together, and that's the key. That's what's got to happen. IoT systems with sensors, full data analytics, and automation capabilities will bring marked improvement to both mining productivity and efficiency just as it did for manufacturing."

The inaugural Aspermont Mining Intelligence 'Future of Mining' survey of the world's top 200 miners emphatically underlined the value of high-powered computing, cloud services (increasingly), BI and data analytics to miners today, with predictive analytics set to become doubly important in the next 5-10 years.

Of 116 responses to a question asking which technology, or technologies, will have the biggest impact on a miner's business (safety, efficiency, productivity, profit) in the next 12 months, and then the next 5-10 years, 61, or 52.6%, said high-powered computing in one form or another was important now. More than 92% said it would become increasingly significant. Big data analytics and BI was seen by 40.5% of respondents to be capable of impacting businesses this year, while nearly 96% of respondents believed it would be changing mining outcomes in 5-10 years.

By contrast, less than 14% said automation and robotics would impact the bottom line, or improve safety, in the next 12 months, with about 35% saying it could conceivably impact significantly in 5-10 years. Half the respondents expect remote control systems to be changing their business in 5-10 years, up from 28.4% now. High-precision guidance technologies are also expected to have a far greater impact into the future, with 53.4% of respondents nominating them compared with 14.6% now.

Other technologies seen to have much latent potential to improve mining efficiency, profits and safety include IoT and connectivity devices (21.6% saying important now/70% in 5-10 years); technologies, including software, that facilitate OT-IT integration visibility and integrity – the so-called single version of the truth – and open up optimisation possibilities (19.8%/53.4%); and survey technology technologies such as laser, drone and satellite (19.8%/97.4%).

Again, for many respondents who nominated this latter field, it was all about the survey data and making better use of it.

Non-IT technologies seen to have potential to grow in importance were headed by new generation rock-cutting machines and tools (6% now, 26.7% tomorrow), and ore sorting and pre-

concentration systems, while future applications of inpit crushing/conveying (IPCC) systems, the new breed of mine tunnelling machines, and vertical conveyors, are seen to be limited at this stage.

'New frontier' insitu and subsea mining technologies (and methods) continue to arouse interest, and research funding, and they have their supporters.

New developments in downhole geophysics are seen as important, and set to become more significant, while alternatives to diesel, gas and traditional grid power are expected to become increasingly influential as mining cost and sustainability drivers.

"The most bullish comments suggest fully automated mines will be a reality within the next 10-15 years."

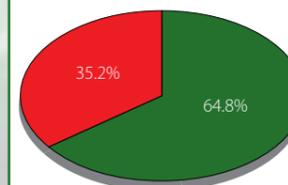
Citi says it can see one in 10 new surface mine trucks bought in the next 3-5 years being autonomous units – representing something like half a percent of the current installed global fleet [some 40,000+ trucks]. It uses BHP Billiton as one reference point in making this forecast.

This is a possible 20-fold increase in autonomous truck deployment rates.

Which technologies will impact the most, and when?

Technology	Within 1 year	5-10yr horizon
Automation/robotics	13.8%	35.3%
Remote/telemetric control	28.4%	50%
HP guidance/control	14.6%	53.4%
High-power computing/cloud	52.6%	92.2%
Big Data/predictive analytics	40.5%	95.7%
IoT/connectivity	21.6%	9.8%
OT-IT integration	19.8%	53.4%
HP satellite/drones/laser survey/imaging	19.8%	97.4%
New-gen rock-cutting machines/tools	6%	26.7%
Ore sorting/pre-concentration	26.7%	28.4%
Truckless mining/IPCC	0.9%	9.5%
Hard-rock tunnelling machines	1.7%	10.3%
Vertical conveying systems	0	12%
Insitu mining	1.7%	14.6%
Gaming-type visualisation/software	14.6%	25%
Subsea mining	1.7%	7.8%
Downhole geophysics	16.4%	19%
Mini-nuclear/solar power/fuel cells	2.6%	22.4%

In a Mining Journal webcast, Mary Cummings, head of Duke University's Humans and Autonomy Laboratory in North Carolina, and advisor to Rio Tinto and other companies, said mining companies that did not invest in building knowledge, skilled teams, and physical infrastructure needed to accommodate tomorrow's automated mines and supply chains, would not be competitive in 10-15 years. We asked respondents if they agreed or disagreed with the statement.



71 responses

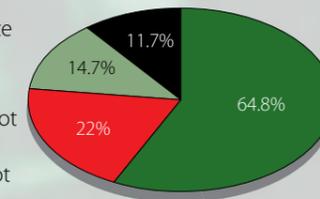
NO

YES



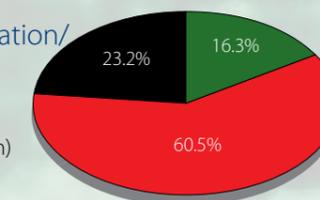
What are the biggest threats to the so-called 'smart mining' era?

- Under-investment/inadequate investment
- Lack of vision/leadership
- Supplier/supply ecosystem not broad/large enough
- Not enough collaboration/not collegiate



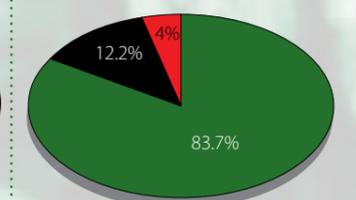
Raise or lower 2016 innovation/technology spending?

- INCREASE (1-5%)
- DECREASE (10-15% reduction)
- SAME



How relevant wearable devices in worker safety improvement in the next 1-3 years?

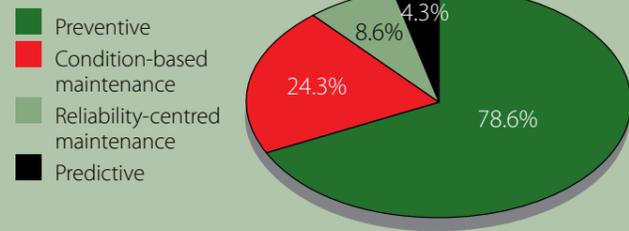
- Highly relevant
- Moderately relevant
- Not very relevant



Most relevant use cases for IoT in mining

- 83.8% Improve workforce safety/labour productivity
- 67.6% Maintenance predictive analytics
- 59.5% Improve asset utilisation/effectiveness
- 56.8% Mine planning/execution effectiveness

Maintenance/asset management process maturity level



Miners see the major benefits from predictive analytics coming from ...

- 86.4%** Predictive maintenance/asset management
- 69.7%** Mine fleet optimisation
- 63.6%** Exploration modelling
- 40.9%** Process plant optimisation
- 16.7%** Workforce/labour optimisation
- 10.6%** Procurement optimisation

Mining's main cyber-threats

- 77.4%** Industrial saboteurs and hackers/criminal groups and activists
- 61.3%** Foreign governments/agencies
- 61.3%** Untrained people/human error (employees)

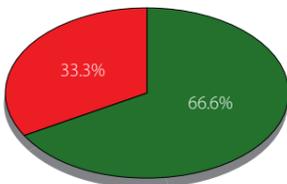


Mining/exploration main business risks

- 69.8%** Licence to operate/project delays and/or extended lead times/security of tenure/geopolitical risk
- 66.7%** Rising costs from lower-grade orebodies; increasing depth/complexity + related funding difficulty/inability to access capital
- 64.6%** Commodity prices/weaker demand/China economic slowdown
- 36.5%** Access to water/cheap power
- 24%** Reserve/resource depletion, combined with inadequate discovery rates
- 16.7%** Skill shortages/greying workforce/brain drain
- 25%** Inadequate R&D investment



Is resource nationalism a more pervasive risk than it was five years ago?



NO 
YES 

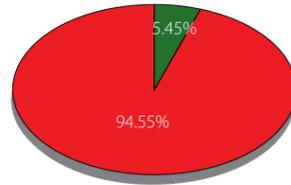


WORLD INITIATIVE OF MINING LAWYERS

The 2015 inaugural World Initiative of Mining Lawyers conference in London heard for the first time about a 'Model Mining Code', and the possible emergence of 'codified' minimum CSR expenditure requirements in the mining industry.

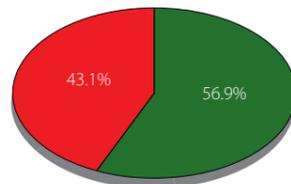
Asked if minimum CSR expenditure requirements should be prescribed in mining codes, the industry response was:

NO 
YES 



But are we likely to see prescribed minimum CSR spending (in royalty or some other form) in the next five years?

NO 
YES 



"The fact our Mine of the Future captures the public's imagination with 'mission control' data centres and autonomous trucks is a good thing if it helps modernise the public's understanding of our industry."

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