MINERALS COUNCIL OF AUSTRALIA

SUBMISSION TO HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON EDUCATION AND EMPLOYMENT INQUIRY INTO INNOVATION AND CREATIVITY: A WORKFORCE FOR THE NEW ECONOMY

---

11 MARCH 2015

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

The minerals industry is a fundamental source of Australia's comparative advantage in the global economy and a major contributor to the nation's innovation effort. Any notion that mining sits in a different category to so-called 'innovative and creative' industries of the future is flawed conceptually and without any empirical foundation.

Notwithstanding the downturn in commodity prices, mining remains Australia's second largest industry and Australia's largest export earner by a very wide margin. Australia's mining capital stock is now almost four times what it was at the start of the mining boom. Mining produces more gross value added per employee (double the finance sector) and pays Australia's highest wages.

Innovation is central to maintaining Australia's comparative advantage in minerals and energy by supporting more competitive, safer and more environmentally sustainable operations. The mining sector spends nearly $3 billion a year on research and development (R&D) and is an exemplar of collaboration with research bodies. Innovation is neither the preserve of 'start-ups' nor confined to the so-called 'new economy'.

The mining sector is a prolific inventor and developer of specialised technologies, with a total of 6,539 Australian mining inventions filed for patent between 1994 and 2011 by operating miners, the Mining Equipment, Technology and Services (METS) sector, and publicly funded entities like CSIRO. In addition, the Australian minerals industry contributes hundreds of millions of dollars annually through a range of innovative partnerships with research bodies. The dividend from this collaboration has been substantial across mine safety, extractive technologies, automation, energy efficiency, low emissions technologies and environmental practices and biodiversity protection.

A high level of innovation in the sector has traditionally been the means by which the mining industry has sought to overcome so-called 'depletion effects'. It has also been part of the industry's response to the sharp contraction in commodity prices since 2012. In a survey of MCA member companies, 70 per cent of respondents cited 'R&D and adoption of new technologies' as important or very important to achieving future improvements in productivity.

Critically, the minerals industry's contribution to Australian innovation depends upon high-value, high-wage jobs in a diversity of professions, including engineers, environmental scientists, geologists, geophysicists, mathematicians and financial officers. Mining produces more gross value added per employee than any other industry (double the finance sector) and pays Australia's highest wages. Mining also accounts for the largest industry share of micro start-up businesses and is one of the largest contributors to job creation by these businesses.

The MCA has invested over $48 million into minerals higher education since 2000, and in partnership with universities across the country, has developed a world-class minerals education sector that is delivering the skills needed in the industry today. However, the sector must also provide future graduates with the skills the minerals industry will need in the decades to come.

The Australian Government should urgently address the structural weaknesses emerging within the minerals higher education sector by sensible higher education reforms that combine fee deregulation with strong safeguards to ensure the viability of niche minerals-related disciplines.

The Australian Government should also consider adopting proven work integrated learning (WIL) programs that help businesses improve their competitiveness and productivity through better use of knowledge, technology and skills that reside within the Australian academic knowledge base (such as the UK Knowledge Transfer Partnerships being trialled by the Queensland Government).[1]

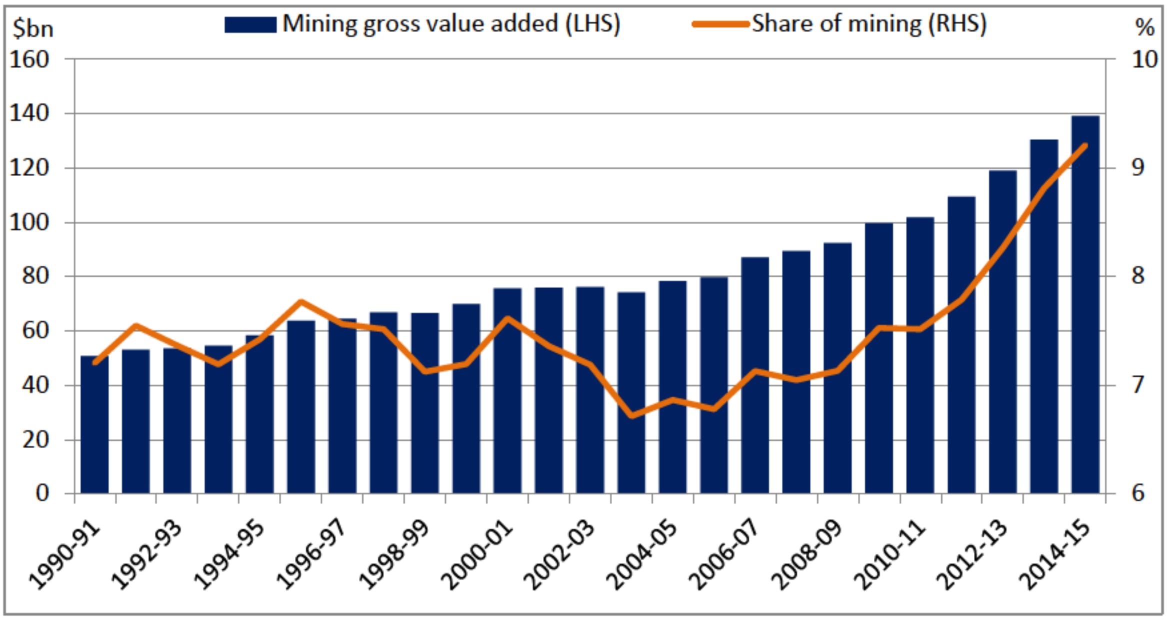
[1] Commonly accepted definition of WIL include *integrating theory with the practice of work*; *engagement with industry and community partners*; *planned, authentic activities*; and *purposeful links to curriculum and specifically designed assessment*. See Daniel Edwards, Kate Perkins, Jacob Pearce and Jennifer Hong, *Work Integrated Learning in STEM in Australian Universities – Final Report*, Office of the Chief Scientist, 2015, iv.

2. AUSTRALIA'S MINERALS INDUSTRY IS A WORLD-LEADING INNOVATOR

Mining represents a growing share of the economy

Notwithstanding the downturn in commodity prices, mining remains Australia's second largest industry after services, representing 9.2 per cent of total industry value added (**Chart 1**).[2]

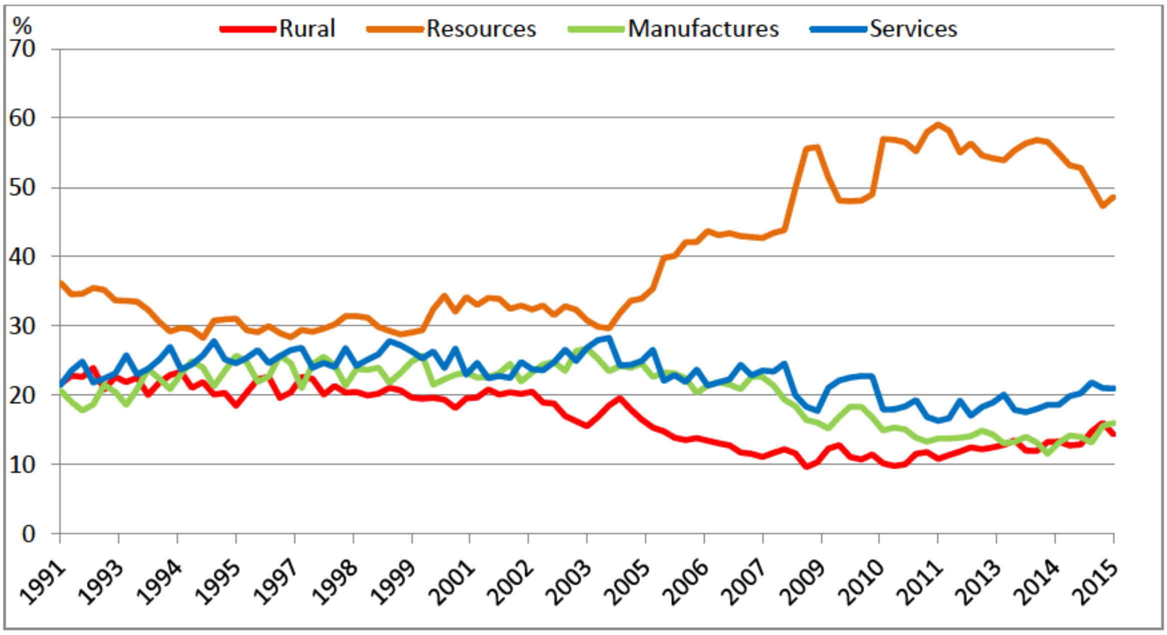
Chart 1: Mining real value added ($billions and % total industry, chain volume measure)



Source: Australian Bureau of Statistics

Mining is also Australia's largest export earner by a very wide margin, accounting for 54 per cent of total export earnings in 2014-15 (**Chart 2**).[3]

Chart 2: Australia's exports of goods and services (shares of total)

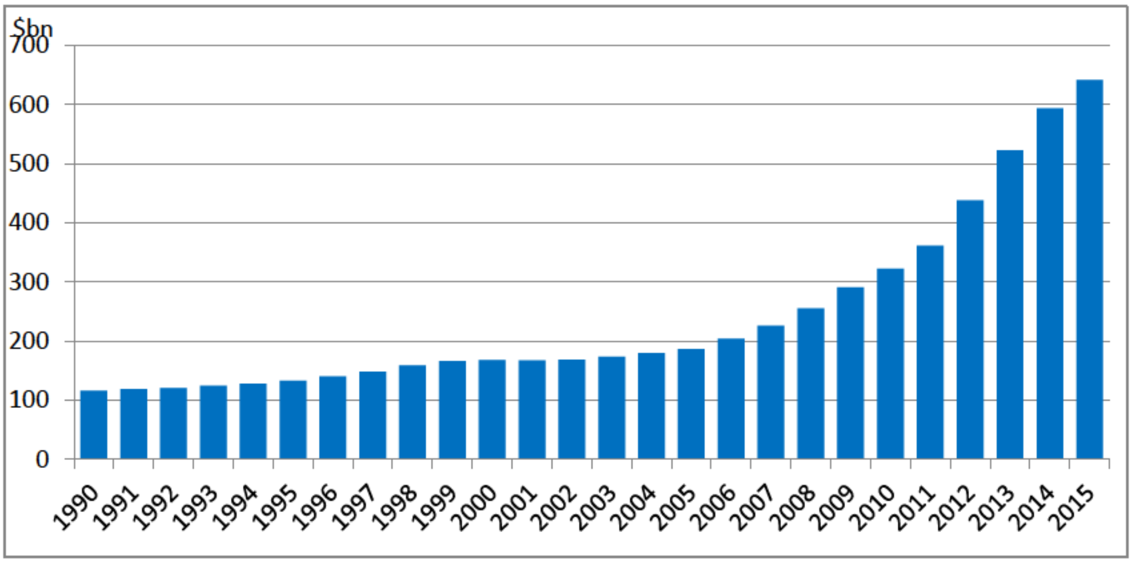


Source: Department of Industry, Innovation and Science

[2] Australian Bureau of Statistics, *Australian System of National Accounts*, *2014-15*, ABS catalogue number 5204.0, released on 30 October 2015.
[3] Department of Industry, Innovation and Science, *Resources and Energy Quarterly – December Quarter 2015: Statistical data*, released on 22 December 2015, Canberra.

Further, Australian mining's net capital stock is now almost four times what it was at the start of the mining boom, growing from $167 billion in 2000-01 to $641 billion in 2014-15 (**Chart 3**).[4]

Chart 3: Australian mining's net capital stock (chain volume measures)



Source: Australian Bureau of Statistics

There is simply no empirical basis to the claim that Australia is transitioning to a 'new economy' in which mining will no longer constitute a key comparative advantage.

Innovation underpins Australia's comparative advantage in minerals

Innovation refers to a change in the method of supplying goods or services, whether through new products, new processes for producing existing products, new forms or work organisation, improved handling of material or the opening up of new markets or sources of supply. From the perspective of firms (and the economies in which they reside) innovation is not an end in itself but a means of gaining a competitive advantage or adapting to changing market conditions. Firms that fail to keep up the pace of innovation eventually collapse under the pressure of shrinking markets or high costs.[5]

It is worth emphasising that innovation is 'purely a matter of business behavior', internal to the competitive process.[6] A successful innovation policy must proceed from the fact that market competition – not government fiat – ultimately determines which new combinations of inputs become successful innovations. The proper role of government is to encourage innovation across the economy, not to promote particular innovations or favoured industries.

Australia's minerals exports have risen from around one-third of Australia's total exports of goods and services in 2004-05 to 45 per cent in 2014-15.[7] Yet it is not widely appreciated that Australia's comparative advantage in minerals is maintained and enhanced through continual innovation. Official data suggest that the mining sector spends nearly $3 billion on R&D annually, or nearly $1 in $6 of all business R&D spending in Australia.[8] Similarly, expenditure on minerals exploration – an operating expense analogous to market research – was $1.6 billion in 2014-15.[9]

[4] Australian Bureau of Statistics, Australian System of National Accounts, *2014-15,* ABS catalogue number 5204.0, released on 30 October 2015.
[5] Joseph Schumpeter, *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process, Volume 1*, Martino Publishers, 1939, pp. 84, 91, 94f.
[6] Joseph Schumpeter, *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process, Volume 1*, Martino Publishers, 1939, p. 86.
[7] Department of Industry, Innovation and Science, Resources and Energy Quarterly publication series.
[8] Australian Bureau of Statistics, Research and Experimental Development, Businesses, Australia, 2013-14, catalogue number 8104.0, ABS, released on 4 September 2015.
[9] Australian Bureau of Statistics, Minerals and Petroleum Exploration, Australia, June 2015, ABS, released on 31 August 2015.

The Australian minerals industry is a world leader in developing and adopting transformative technology – from the commercialisation of the 'froth flotation' process for minerals recovery in the 1860s in Broken Hill, to the introduction of remote-controlled trucks for moving iron ore in the Pilbara in the 2000s. As the Department of Industry, Innovation and Science points out:

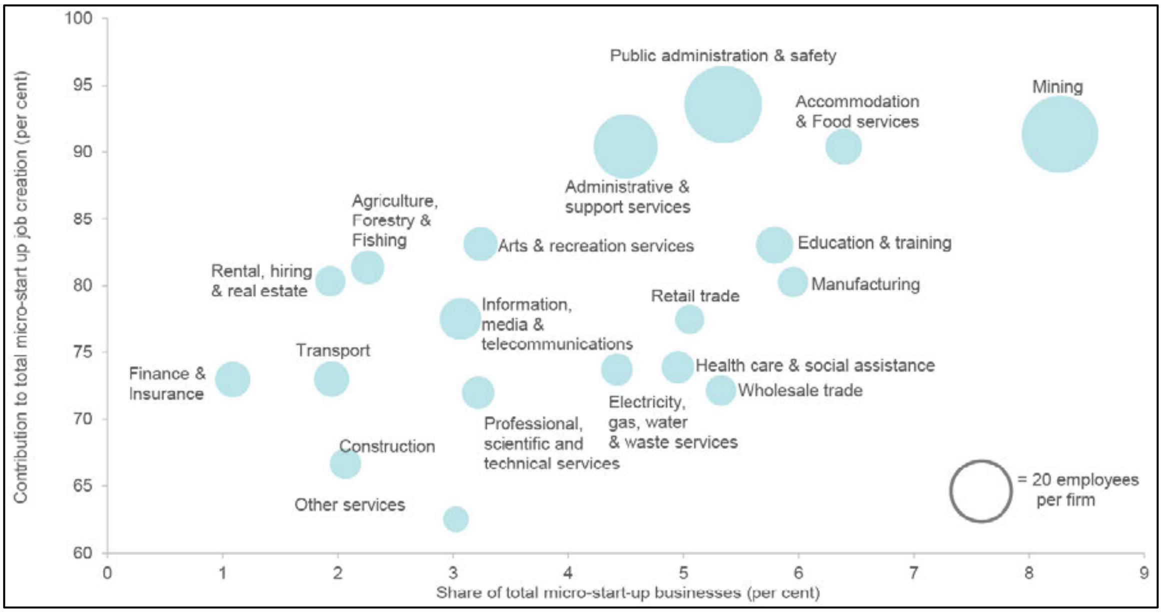
> Australia's innovation and economic performance of the past decade has been dominated by the mining sector, which has … exploited its comparative advantage to generate enormous growth in investment, output and exports.[10]

Similarly, the CSIRO notes that: 'Innovation has been instrumental in the development of energy and minerals resources'.[11]

The mining sector is a prolific inventor and developer of specialised technologies, with a total of 6539 Australian mining inventions filed for patent between 1994 and 2011 by operating miners, the Mining Equipment, Technology and Services (METS) sector, and publicly funded entities like CSIRO. Australian mining technology is exported globally, with patent filings overseas showing major markets include the United States, Canada, China, Japan, Europe, Russia, Brazil and Mexico.[12] The Australian Government's newly established METS and National Energy Resources Australia Growth Centres will add further innovative capacity to Australian mining.

To maintain this level of invention the mining sector recognises the limitations of the 'invent-it-ourselves' model [13] and regularly connects with high growth start-ups across Australia. These agile teams offer mining companies cutting-edge technologies or answers to complex business problems not readily available within the industry. Government analysis has shown that mining has accounted for the largest industry share of micro start-up businesses and has been one of the largest contributors to job creation by these businesses over the past decade or so (Chart 4).[14]

Chart 4: High-growth start-ups: industry shares and contributions to job creation



Source: Department of Industry, Innovation and Science

A high level of innovation in the sector has traditionally been the means by which the mining industry has sought to overcome so-called 'depletion effects'. These effects include the running down of

[10] Department of Industry, Innovation and Science, *Australian Innovation System Report*, 2015, p.11.
[11] CSIRO, *Unlocking Australia's resource potential*, 2015, p.4.
[12] Emma Francis, *The Australian Mining Industry: More than Just Shovels and Being the Lucky Country*, IP Australia, 2 June 2015, pp. 6, 22, 30.
[13] Larry Huston and Nabil Sakkab, *Connect and Develop: Inside Procter and Gamble's New Model for Innovation*, Harvard Business Review, Vol. 84, No. 3, March 2006.
[14] Luke Hendrickson, Innovation Research, Department of Industry, Innovation and Science, *Where does employment growth come from?* Presentation to the Industry Innovation Workshop 2015, 15 September 2015, p. 8.

resource deposits, increased effort required to process saleable ores from extracted material, the adoption of more complex methods of extraction in expanded mines, and the extraction of deposits that are further away or deeper in the ground (Box 1).

Box 1: Prime Minister's Prize for Innovation celebrates new minerals processing technique

Australian mining innovation was celebrated by the award of the Prime Minister's Prize for Innovation for 2015 to Professor Graeme Jameson AO at the University of Newcastle. The Jameson Cell revolutionised the 'froth flotation' technique for minerals processing by using smaller and fizzier bubbles to capture ultra-fine and valuable minerals. More than 300 units are used worldwide to process ore as well as coal and metals. This technique cost $65,000 to develop but has retrieved fine export coal particles worth $36 billion.

Professor Jameson has revised his technology with the NovaCell. This device captures bigger grains, potentially reducing mine operations' energy use by 15 per cent and boosting Australia's export income by $100 billion.[15] There is no better contemporary demonstration of why mining is synonymous with the 'ideas economy'.

In a survey of MCA member companies, 70 per cent of respondents cited 'R&D and adoption of new technologies' as important or very important to achieving future improvements in productivity.

The Australian minerals industry is an exemplar of innovation through collaboration

The Australian minerals industry has an unparalleled record of collaboration with research institutions in the search for more competitive, safer and more sustainable ways of doing things. Partnerships with higher education providers include the Rio Tinto Centre for Mining Automation at the University of Sydney and the Rio Tinto Centre for Advanced Mineral Sorting and Julius Kruttschnitt Mineral Research Centre at the University of Queensland, the world-leading Centre of Excellence in Ore Deposits (CODES) at the University of Tasmania, Iluka's partnership with the University of Western Australia's School of Plant Biology to research rehabilitation and conservation of rare shrub-lands, and BHP Billiton's investment towards establishing a new engineering zone at the University of Western Australia.

Further examples of successful collaboration between industry and scientific researchers include:

- **Cooperative Research Centre Mining (CRCMining),** which operates to deliver transformational research and innovations that maximise mining productivity and enhance resource utilisation, safety and sustainability ($12.2 million in 2013-14 with $6.2 million contribution from industry, now wholly funded by industry).[16]
- **Cooperative Research Centre Optimising Resource Extraction (CRC ORE),** which works to improve the efficiency and cost-effectiveness of mineral extraction ($100 million over six years from July 2015, including around $65 million in cash and in-kind support from industry).[17]
- The **Australian Coal Industry's Research Program (ACARP),** which aims to improve the industry's competitiveness, safety and environmental performance ($273 million in funding to 1,468 projects since ACARP's inception in 1992).[18]
- The Australian black coal industry's **COAL21 Fund,** which invests in the demonstration of low emissions coal technology ($300 million committed to date).[19]

[15] Jake Sturmer, 'Engineer Graeme Jameson picks up Prime Minister's science prize for billion-dollar bubbles', *ABC News,* 21 October 2015.
[16] CRCMining, *Transforming Mining: Annual Report 2013-14*, p. 41.
[17] CRC ORE, *About Us.*
[18] ACARP, *What is ACARP? The Australian Coal Industry's Research Program*; *Annual Report 2015*, p. 3.
[19] Minerals Council of Australia, *About COAL21*.

- **AMIRA International** – a mining industry vehicle headquartered in Melbourne that leverages R&D – has developed almost 700 projects and attracted $578 million of investment since 1959.[20]
- **The Cooperative Research Centre for Greenhouse Gas Technologies** (CO2CRC), a world leading collaborative research organisation comprising participants from the mining industry, universities, and government research organisations focusing on carbon dioxide capture, geological sequestration and storage (CCS) researching and aiming to demonstrate technologies to reduce the costs of capturing CO_2 by 75 to 80 per cent.

The following are some practical examples of world-leading research and innovations generated by these collaborations:

- **SmartCap** – a wireless system of sensors built into a baseball cap that measures driver/operator drowsiness and displays it on a monitor in the cab. Major mining companies implementing the technology have found the risk of fatigue-related safety incidents is being reduced. The SmartCap is now being considered and adopted by other sectors such as maritime, defence, aviation, and transport and logistics (CRCMining, Anglo American Metallurgical Coal, ACARP and 13 other industry partners).[21]
- **Groundprobe** – radar technology that monitors the stability of open cut mine slopes and walls and forewarns mine workers of instability through an alarm system, credited with saving 20 lives in its first year of commercial use (University of Queensland, ACARP, CRCMining and CRC for Sensor Signal and Information Processing).[22]
- **Callide Oxyfuel Project** – successful capture of CO_2 from a coal-fired power plant in Central Queensland. Callide is the world's largest demonstration of oxyfuel technology to date (COAL21, CS Energy, Glencore, Schlumberger, J-POWER, Mitsui & Co. and IHI Corporation).[23]
- **Future Reef Map** – the first project to monitor ocean chemistry along the entire length of the Great Barrier Reef. Rio Tinto's bauxite shipping vessel *RTM Wakmatha* is fitted with sensors that continuously collect samples and record data during the ship's regular voyages from Weipa to Gladstone and back (Rio Tinto Alcan, CSIRO and the Great Barrier Reef Foundation).[24]
- **Bush Blitz** – Australia's largest nature discovery project that has already identified more than 900 new species and has added thousands of species records to what is already known, helping Australia to protect its biodiversity for generations to come (Australian Government, BHP Billiton Sustainable Communities and Earthwatch Australia).[25]
- **Grade Engineering** – a new set of techniques for assessing and conducting the extraction of ore. Grade Engineering maximises high-value ore going to processing by using innovative coarse separation technologies and modified circuit designs to remove low-value ore as early as possible in the extraction and pre-concentrate phases. The value of ore sent to processing is increased with no significant impact on the rate of extraction (CRC ORE in collaboration with the mining and METS industries).[26]
- **Geology and Mass Mining project** – new guidelines for the mining of large underground rock masses that enhance the capture and utilisation of geological data for predicting the

[20] AMIRA International, *Who we are*.
[21] SmartCap, *Saving lives is our priority*.
[22] Department of Industry, Innovation and Science, *Saving Lives and Profits at Groundprobe, 2014*; Groundprobe, *Our company: history*.
[23] CS Energy, *Callide Oxyfuel Project.*
[24] Rio Tinto, 'A natural wonder', *Mines to Markets,* Issue 6, November 2014.
[25] Bush Blitz, *home*.
[26] CRC ORE, *Transforming mining productivity with grade engineering: reversing the trend of declining feed grade and quality*.

results of cave creation and blasting. Use of the guidelines is shown to increase the efficiency of these operations (WH Bryan Mining and Geology Research Centre, University of Queensland, sponsored by Newcrest Mining, Anglo American and Glencore).[27]

- **Modelling The Water, Energy and Economic Nexus** – ACARP project that first identified geographic pressure points on water resources in Queensland between the coal mining, coal seam gas and agriculture industries, and then developed plans to better manage water resources.[28]
- **Longwall automation landmark project** – ACARP, partnering with CSIRO, Glencore and other industry participants, produced information to help develop automated technology for longwalls in underground coal mines to increase productivity and improve safety by reducing interactions with machinery in hazardous underground areas.[29]

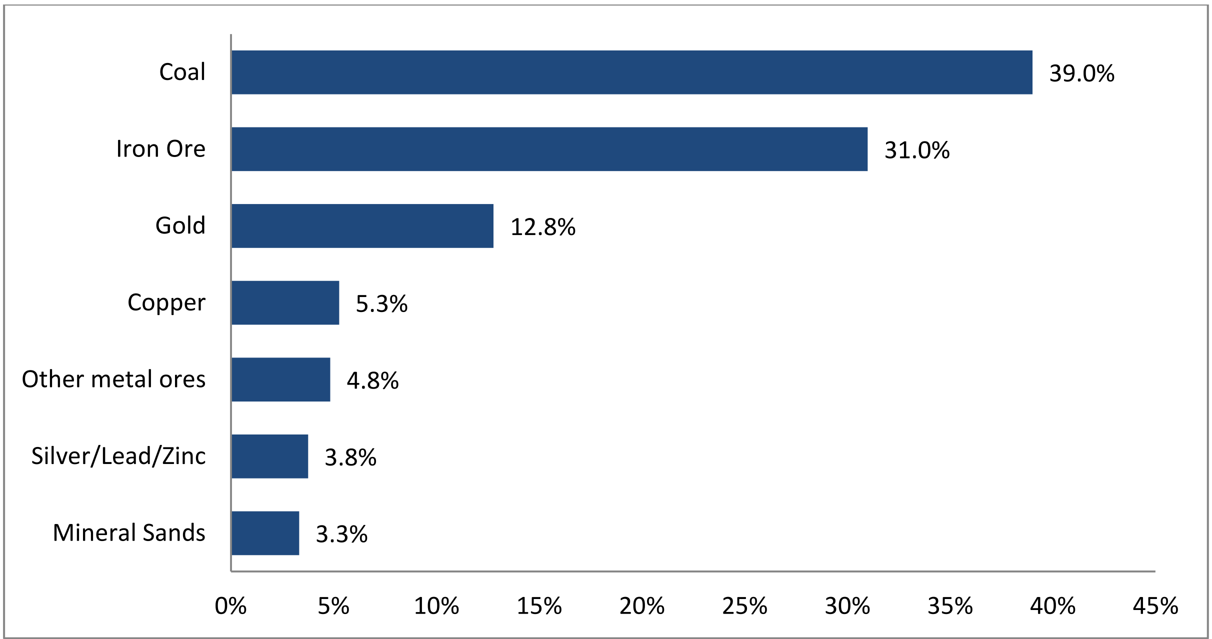
[27] *Geology and Mass Mining,* WH Bryan Mining and Geology Research Centre, Sustainable Minerals Institute, University of Queensland.
[28] Alan Woodley, Greg Keir, Estelle Roux, Damian Barrett, Jackson White, Sue Vink, *Modelling The Water, Energy And Economic Nexus*, February 2014.
[29] ACARP, E-Newsletter, *longwall automation boosts productivity, lowers costs*, October 2013.

3. AUSTRALIA'S MINERALS WORKFORCE TODAY AND TOMORROW

Direct employment in the minerals sector stood at 197,100 persons in November 2015.[30] While down 6 per cent from November 2014, employment in the sector it is still more than 60 per cent above the level of a decade ago (Chart 2).

In FY2015, the largest contributor to employment in the industry was the metal ore sector, employing 49.1 per cent of total mining workforce. Within the metal ore sector, iron ore accounted for the largest share of employment (31 percent), followed by gold and copper.[31] The second largest contributor to employment - and largest employer by a single commodity - was the coal sector, at 39 per cent of total employment. Chart 2 shows that more people were engaged in the mining of this commodity than any other, followed by iron ore and gold.

Chart 2: Employment level by commodity type FY2015, percentage of total mining workforce



Source: ABS, BIS Shrapnel

The mining industry is an important source of employment in Western Australia, Queensland and New South Wales. Together these states account for 90 per cent of mining employment. Mining employment is also critically important to many regional and remote communities in Australia, with mining accounting for up to 50 per cent of employment in some regional centres.[32]

A large proportion of the workforce is highly skilled; 63 per cent hold a Certificate III level qualification or higher, which is above the national average. Five per cent of the workforce is currently apprentices and trainees.[33] One in five workers also hold a bachelor degree or higher.[34] The level of education within the workforce reflects the importance of trade and professional occupations to the mining industry. In fact mining is one of the largest employers of professionals across the occupational groups (Table 1).[35] Indirect employment consists of professional, scientific and technical services occupations.

[30] Australian Bureau of Statistics, *Labour Force, Australia, Detailed Quarterly catalogue number 6291.0.55.003*, released 17 December 2015.
[31] BIS Shrapnel, *Chart Pack – Resources and infrastructure industry sector*, SkillsDMC, 2016.
[32] Australian Workforce and Productivity Agency, *Resources sector skills needs 2013*: Report to the Australian Government, Australian Government, AWPA, Canberra, 2013.
[33] National Centre for Vocational Education Research, *Apprentices and trainees 2015 - June quarter*, NCVER, 2015.
[34] Department of Education, *Industry Outlook: Mining*, Canberra, 2014.
[35] Australian Bureau of Statistics, *Labour Force Survey, annual average 2014*, Canberra, 2014.

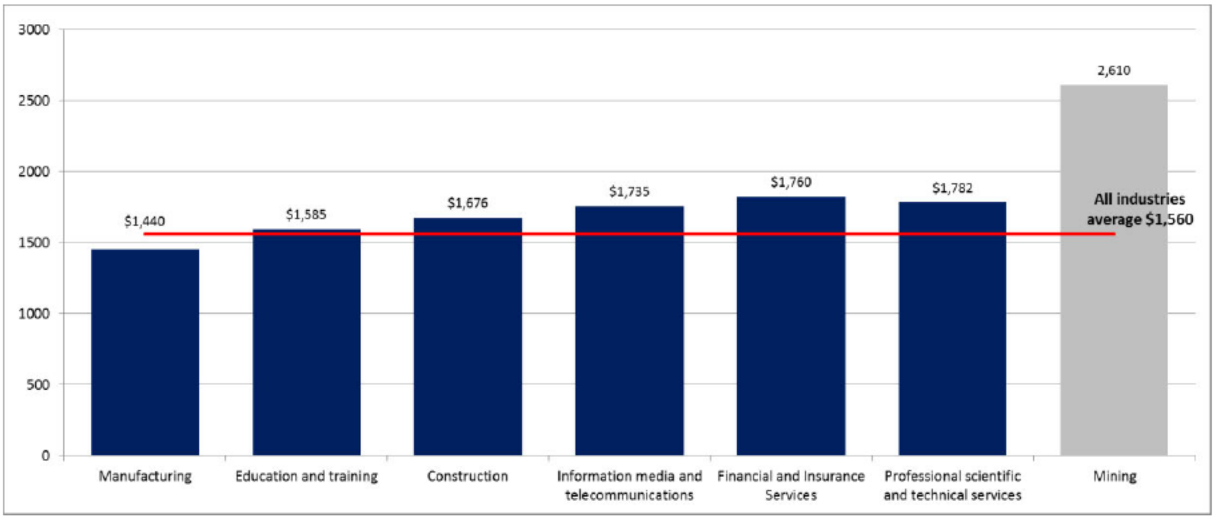
Table 1: Major professional occupations at 2014

Professional Occupations - Mining	Industry ranking by employment	Direct Employment	Indirect Employment
Mining engineers	1	12,592	-
Production managers (mining)	1	9293	-
Geologists and geophysicists	1	7150	4976
Metallurgists	1	966	1749
Industrial, mechanical and plant engineers	3	4070	9302
Surveyors and cartographers	3	2017	7670
Environmental scientists	3	1836	11,883
Chemical and material engineers	3	873	1398
Environmental health officers and OHS advisors	4	2910	5850
Engineer managers	4	1342	7392

Source: ABS Labour Force Survey, annual average 2014

The capital intensity of modern mining means that Australia's mining workforce is highly productive. Mining produces more gross value added per employee than any other industry (double the finance sector) and pays Australia's highest wages. Average (full-time) adult total earnings were $2605 per week in November 2015, 73 per cent higher than the average for all industries excluding mining (Chart 3).[36]

Chart 3: Average weekly wages by industry



Source: ABS

[36] Australian Bureau of Statistics, *6302.0 - Average Weekly Earnings, Australia, Nov 2015, Table 10H, ABS,* February 2016.

Looking ahead, the industry's future prosperity will continue to depend on a professional and semi-professional class of highly skilled and technology-literate technical experts, including operators, engineers, environmental scientists, geologists, geophysicists, mathematicians and financial officers. Various technologies are already changing the future shape of Australia's workforce (e.g. cloud, software and analytics) and are already being used by the industry (Box 2).[37]

Box 2: Global minerals industry leaders on Australia's highly skilled, innovative workforce

Sam Walsh, CEO, Rio Tinto

> We spend as much time mining big data as we do iron ore … There are teams of people pouring over complex 3D data to pinpoint rich ore bodies. And we can now predict precisely when and where a piece of equipment will fail by analysing billions of bytes of data from equipment sensors.
>
> These new systems have seen us hire a new breed of miner – technologically savvy people with breathtaking computer and analytical skills – and transformed the productivity our operations.
>
> Many of our 'miners' now spend their shifts in the air-conditioned comfort of offices monitoring autonomous vehicles, supervising ship-loading, sharing expertise and developing mine plans thousands of kilometres from an active mine site.[38]

Andrew Mackenzie, CEO, BHP Billiton

> As our industry grew, we helped create a skilled workforce. Opportunities within the sector have attracted the best and brightest from overseas and through world class training and education programs developed home-grown talent …
>
> We know Australians have the brains and abilities, the quality institutions and the market and business sophistication to match the best in the world.
>
> To become an exporter of new ideas, Australia must become a leader in education and research and develop a pipeline of talent, knowledge and skills, especially in the STEM subjects.
>
> We need to work more closely with leading universities and with other research organisations such as CSIRO. Collaboration with these institutions will stimulate and shape the development of technologies, create scientific research that aligns with commercial needs, and foster an educational environment that inspires our best and brightest students to apply their intellectual know-how to industry in Australia.[39]

The technology changes present opportunities for the existing workforce to upskill and take on more challenging roles. It also presents opportunities for highly skilled specialists from non-traditional occupations to use their skills in a dynamic and highly integrated workplace. As the Committee for Economic Development of Australia (CEDA) point out:

> Technological change has frequently created losers, but when job losses have been caused by productivity-enhancing technologies, they have tended to create demand via higher incomes and lower prices, which have generated new jobs economy-wide.[40]

When Rio Tinto introduced driverless trucks at its Hope Downs 4 iron ore mine in 2014, it required entirely new roles, such as controllers who control and monitor the automated vehicles; pit controllers who manage how the vehicle operates on site; and specialists in communication and systems engineering (new entrants), who provide detailed fault diagnostics.[41] Driver labour did reduce, but more challenging and interesting roles were created for existing staff and new entrants to support the automated technology.

The higher education sector will be a key partner in developing skills required from new entrants and in upskilling the existing workforce. A Rio Tinto case study on automation and what it means for

[37] Committee for Economic Development of Australia, *Australia's future workforce?*, CEDA, June 2015.
[38] Sam Walsh, *How technology has changed mining*, *Australian Financial Review*, 15 November 2015.
[39] Andrew Mackenzie, *Speech to the Minerals Council of Australia at Minerals Week*, 3 June 2015.
[40] bid, p.8.
[41] Michael Gollschewski,, 'Case study: Automation and Australia's future workforce', in CEDA (Eds) *Australia's future workforce?*, Melbourne, 2015, p. 73.

Australia's future workforce highlights the importance for students to look beyond narrowly focussed discipline streams:

> As we move forwards with automation systems, we will need specialists in computing, systems and diagnosis, and the upskilling of maintenance people to service and maintain the technology.
>
> These 'employees of the future' will have good operational knowledge and detailed systems knowledge of the automated system. This will enable them to trouble shoot, conduct investigations, generate meaningful corrective actions, manage continuous improvement, and contribute to operational procedures and training materials.[42]

The case study further points to the future skillsets students will need to successfully integrate into an automated work environment:

- A shift to more specialisation, where employees will need specialist skills in 'computing, systems and diagnostics'.
- Strong core discipline knowledge, as well as good operational knowledge, and literacy of the automation system.
- Programming and analytical skills, by which employees will validate and analyse data to increase efficiency in operations and within system behaviours.
- Engineers and scientists will require very strong technical skills across a range of areas that will help improve the operational performance in areas that include, but will not be limited to, process control, advanced mathematics and modelling, and interpersonal skills.
- Strong collaboration and interpersonal skills.[43]

Australia's higher education sector will play a vital role in ensuring the future workforce is equipped with the necessary skills for the mining jobs of the future.

[42] Michael Gollschewski, 'Case study: Automation and Australia's future workforce', in CEDA (Eds) *Australia's future workforce?*, Melbourne, 2015, p. 71.
[43] ibid, pp.70-72.

4. MINERALS HIGHER EDUCATION IN AUSTRALIA: THE STATE OF PLAY

Australia is a world leader in minerals higher education. Australia's minerals education system has morphed from a system on the brink in 2000 to a unique, innovative and powerful model of collaboration with industry that produces world-class graduates.

In February 1998 the Minerals Council of Australia (MCA) commissioned a major report into the state of minerals higher education in Australia. The report, 'Back from the Brink – Reshaping Minerals Tertiary Education' identified a system beleaguered by acute shortages of talented academic staff, small student numbers and high relative costs, and under-resourcing of minerals departments.[44] In the wake of the then industry downturn and resultant rationalisation of minerals-related programs, the report warned of an impending crisis facing the minerals industry due to the tertiary education system's incapacity to meet future skills needs.

In response the MCA established the Minerals Tertiary Education Council (MTEC) in 2000 to oversee the investment of direct funding from MCA members to partner universities involved in mining engineering, metallurgy and minerals geoscience. Since its inception the MCA has invested over $48 million in minerals tertiary education through MTEC, an average of $3 million per year. Over 4300 students have undertaken MTEC supported programs.

Industry, through MTEC, is able to ensure that courses and graduates meet current and emerging industry requirements. Additionally, students have the potential of direct exposure to work based learning opportunities, and companies have access to a pool of industry-ready graduates.[45] However, the future innovative minerals workforce is under threat.

Structural weaknesses resurfacing

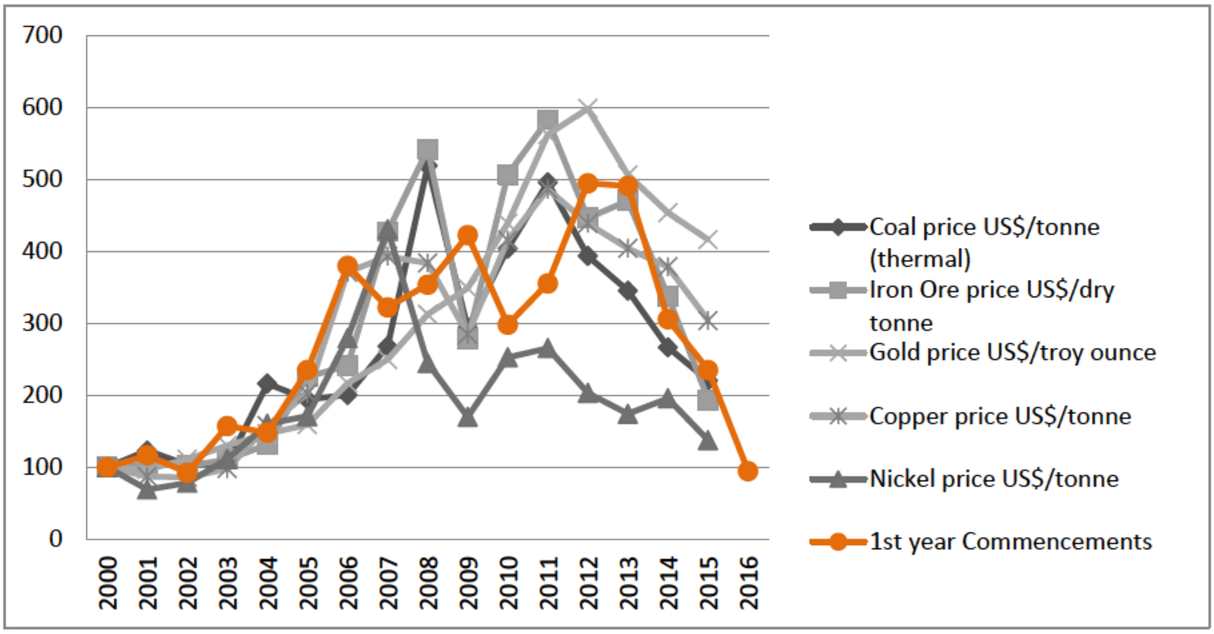
The underlying structural weaknesses in minerals tertiary education, identified in 'Back from the Brink', have resurfaced as major concerns within industry and in university minerals department and schools.

Minerals higher education in Australia experienced strong growth in enrolments across minerals-related disciplines from 2004 to 2012, as a result of the unprecedented growth within Australia's minerals industry. Since 2012 the industry has moved from the construction to production phase, where high demand for labour is not required. Decline in labour demand has been exacerbated by falls in commodity prices, which in turn has impacted on the pipeline of new professionals in the key disciplines of mining engineering, metallurgy and minerals geoscience. Undergraduate intakes for most minerals higher education disciplines in Australia have experienced notable declines.

Mining engineering graduates, for example, lag the economic cycle by four years (the length of the degree). As chart 4 reveals, there is a strong causal link between commodity prices and mining engineering commencements. Estimates of 2016 commencing students into mining programs across Australia show that enrolments will be at levels last seen in 2000. There is a genuine threat of program closure because of critically low enrolment levels in programs that are traditionally high cost to universities to run.

[44] Minerals Council of Australia, *Back from the Brink: Reshaping Minerals Tertiary Education*, MCA, Canberra, 1998.
[45] Peter Noonan, *Review of the Minerals Tertiary Education Council*. Report to the Minerals Council of Australia, Melbourne, 2015.

Chart 4: First year mining engineering commencements versus commodity prices (indexed 2000)



Source: MCA; 2016 commencements are estimates

The supply-side paradox has been described by then Executive Director of Mining Education Australia, Professor Peter Dowd in 2015:

> The inability to sustain the tertiary mining engineering skills base through periods of slower economic activity has wider repercussions in the industry. In times of rapid expansion, such as the period 2003-2012, skills shortages fuel wage inflation, which, in turn significantly reduces productivity. The supply of these skills from the university sector cannot be turned off and on at will; when a degree programme becomes financially unviable at an institution, because of sustained low enrolments, the supply of graduates is turned off by closing the programme and it cannot be turned on again.[46]

To highlight Professor Dowd's cautionary note, at one of the MEA universities, which has traditionally been a strong supplier of four-year trained engineers to the industry, first-year preferences in 2016 has fallen to just five (a 2240 per cent decrease from a high of 117 in 2013). Minerals schools and departments must also now compete for resources within and between universities in an increasingly competitive environment as a result of the introduction of the demand driven system in 2012.

Capacity to meet future professional skills

As noted, the readjustment by many mining companies post the peak 2012 cycle has resulted in a reduction of current and projected labour demand across mining disciplines and occupations.[47] An analysis of government labour demand data and MCA projected enrolments into minerals higher education programs suggests the decline in labour supply (enrolments) will outpace future labour demand in critical technical areas, creating potential skilling issues downstream.[48] For mining engineering the moving average trend for university completions from 2015 to 2019 is expected to decline by 81 per cent.[49] In the same period, labour demand is expected to decline by only 13 per cent.[50]

[46] Information provided by Mining Education Australia (MEA) to the MCA, April 2015.
[47] Department of Employment, *Employment Projections*, 2015.
[48] Minerals Council of Australia, [Supplementary information for review of the 2016-17 Skilled Occupation List – Mining](), MCA, Canberra, 2015.
[49] Estimated from various MEA reports analysed December 2015.
[50] Department of Employment, *Employment Projections 2015*. Provided by Skilled Occupation List (SOL) Team during 2016-17 SOL Stakeholder Consultations.

Ensuring the sustainable supply of graduates with the required skills is critical to the current and future prosperity to the minerals industry. The minerals industry will continue to require a broad base of talented professionals and is concerned at the dramatic reduction of commencements into mining engineering degrees at Australian universities in recent years. The MCA, through its MTEC, remains committed to four national collaborative programs in mining engineering, metallurgy and minerals geoscience, which continue to deliver an important pipeline of skilled professionals to the industry. For minerals higher education to continue to meet the skills the industry needs now and into the future, and avoid a scenario where the sector falls back to the brink, further reforms to higher education funding is urgently needed.

Higher education and institutional reforms

Funding of niche STEM disciplines will only become more expensive for universities as they attempt to keep pace with the technological requirements of innovative industries. Over the next few years, universities will require an additional $7.6 billion to fund projected student growth alone under the demand-driven student system.[51] The failure by previous governments to index higher education funding, coupled with the regulated caps on fees, has seen many university schools and departments become increasingly nonviable under the student numbers-based funding system, especially in minerals-related departments that traditionally have small student numbers and high teaching costs. This has resulted in a need for direct minerals industry investment to secure a future supply of professionals for the industry. Without this industry support many schools and departments would have closed, leaving Australia without the capacity to deliver its own high quality graduates (and relying on skilled migration as an avenue for these skills).

Higher education reforms and a shift in university administration behaviour toward how niche mining and, more broadly, engineering programs are funded at the university level are needed for the longevity of this important profession. The MCA supports reforms that advance innovative pathways to address the skills needs of the future (including para-professional qualifications such as the MINAD program). Given current funding arrangements, however, the MCA believes that fee deregulation alone will not assist students or niche minerals-related disciplines.

Higher education reforms are a necessary step towards securing a sustainable funding outlook for the higher education sector in Australia, in line with market demands. The former Minister for Education, The Hon Christopher Pyne MP, argued that students would be the biggest winners from the now-defeated fee deregulation package through increased student access to tertiary studies and that the overall quality of teaching would improve due to price competition.[52] MCA-commissioned modelling found that high course costs, low and volatile enrolment, and barriers to market entry mean the federal government's higher education reform proposals are not likely to benefit, and, rather, may deter, minerals tertiary education, particularly if relative funding for engineering and science disciplines is reduced and enrolment levels continue to decline.[53]

Reform is also needed at institutional level for students to benefit from fee deregulation. Under current arrangements less than 50 cents per dollar of Commonwealth Grant Scheme (CGS) funding is allocated to MCA's MTEC partner schools and departments by their home institutions (and, in most cases, it is significantly less).[54] These funding level arrangements are not sustainable during times of low student enrolment (as these payments are volume-based). The MCA questions university administration behaviour in not adapting funding allocations for minerals-related programs that consider market conditions.

A fundamental issue is that research in universities is not funded in the way that teaching is funded, resulting in universities redirecting teaching funds into research. The Grattan Institute estimates that,

[51] Department of the Prime Minister and Cabinet, *Regulation Impact Statement: 2014-15 Budget Higher Education Reforms*, PMC, Canberra, 2014.
[52] Pyne, C., *The Hon. Christopher Pyne MP – 'Spreading opportunity and staying competitive – Why we need the higher education reform package'*, address to National Press Club, Canberra, 2015
[53] Acil Allen Consulting, *University revenue analysis*, report to Minerals Tertiary Education Council, 2015.
[54] Information passed on to the MCA by MTEC partner university schools/departments, 2014.

in 2012, at least $2 billion in profits (representing one-fifth) meant for teaching was used to fund research in Australian universities.[55] Andrew Norton suggests that while universities are not doing anything improper in spending money this way, he proposes a fundamental problem with this arrangement:

> [T]he absence of specific teaching funding makes it hard to ensure that any extra money intended to benefit students is actually spent on students.[56]

The minerals industry supports sensible higher education reform that combines fee deregulation with strong safeguards to ensure the viability of minerals-related disciplines. Safeguards should include stronger accountability mechanisms to ensure increased university fee revenue is devoted to teaching and student services.

[55] Andrew Norton, *The cash nexus: how teaching funds research in Australian universities*, Grattan Institute, Melbourne, 2015.
[56] ibid.

5. CHALLENGES IN PREPARING THE FUTURE MINERALS WORKFORCE

The pace of technological change within Australia's minerals industry is already apparent. Technologies such as automation and big data are presently being used across the value chain to increase productivity and reduce risk. These technologies are changing how companies mine, and the skills needed to work in this new environment. The industry also recognises that the pace of innovation within the industry is changing workforce needs at speed, and this presents opportunities and challenges for the minerals education sector.

As noted, the mining industry is a prolific collaborator with education and research organisations. Yet weak industry links, ill-considered commercialisation policies and a lack of exposure to the industry can discourage closer partnerships between the industry and education/research organisations. While there are numerous examples of industry collaborating with structured research entities, university academics and researchers need credibility to be able to develop networks with key industry personnel and ensure they are relevant and that their research findings are applicable. As the training ground for the minerals industry's future innovative workforce, there are policy gaps that are impeding research alignment to industry needs and their ability to prepare the future minerals workforce.

Research impact

The minerals industry is concerned that current policy and funding arrangements may (inadvertently) work against the most effective deployment of Australia's innovation efforts and steer researchers away from more industry-relevant research and training. With Government funding for university research directly linked to the Excellence in Research for Australia (ERA) through the Sustainable Research Excellence scheme, academics in core mining disciplines of mining engineering, minerals geoscience and metallurgy have little choice but to prioritise their career prospects to the detriment of applied innovative research.

Rewarding universities for applied research and experimental development will encourage greater collaboration with industry and provide researchers with opportunities to obtain more relevant industry research training. Renewed policy focus thus needs to be given to the impact of research as a measure of research quality in Excellence in Research for Australia (ERA) if better industry-prepared research graduates are to be produced.

The MCA does recognise the substantial investment by the Australian Government in postgraduate research training each year through research block grants – currently over $980 million. Research candidates can access this support through the Research Training Scheme (RTS), the Australian Postgraduate Awards (APA), and the International Postgraduate Research Scholarship (IPRS).[57]

Weak industry links

Some of these industry-wide issues can benefit from longer-term research programs. The MCA estimates that as much as 80 per cent of research in the minerals field is undertaken by university academics, who often have poor or ineffective links to the minerals value chain.[58] This significantly impedes the translation of clever ideas into commercially viable innovation, or industry-relevant training for junior researchers.

To be a successful researcher in Australia's minerals industry, researchers must employ technical and scientific rigour, possess a track record of passionately chasing breakthroughs and be cognisant of the cyclical nature of commodity prices. Researchers must understand the forces that influence the minerals value chain and look to add value to the industry through their research, as opposed to

[57] Australian Council of Learned Academics, *Review of Australia's Research Training System Discussion Paper*, ACOLA, 2015, p.11
[58] Minerals Council of Australia, *Review of Australia's Research Training System*, MCA, Canberra, 2015.

seeking short term commercial gain. The business environment often recalibrates at a different rate to the research approach and this can affect research partnerships.[59]

On the other hand, R&D spend by Australia's minerals industry implies a strong and continued need to for effective research partnerships universities and those researchers described above. The $3 billion annual industry spend on R&D in Australia demonstrates a clear preference for applied research, and continued opportunities for collaboration with industry and implied commercialisation downstream. The outcomes of future research collaborations should be measured by research impact.

Commercialisation impediments

As reported by government, universities engage in commercialisation activities for five main reasons: for the public good, economic growth, industry collaboration, attraction and retention of talented people, and to generate income.[60] All universities do it for the same reason, the mix is just different. If universities (or researchers) focus on the first four, they will get the fifth (revenue generation); however if universities (or researchers) focus primarily on the fifth, it has been observed that '*you are likely to get nothing*.'[61]

Commercialisation policies within universities can work against the collaboration that is needed to develop and commercialise new technology. Typically, universities have new intellectual property (IP) arrangements that mandate a sharing of all commercial returns in thirds: to the researcher, the host faculty, and the commercialisation entity. While designed to encourage entrepreneurial spirit, this arrangement can often have the opposite effect, whereby the researcher is reluctant to share the dividend of their discovery, and the university commercialisation entity often has unrealistic expectations of value when seeking a commercialisation partner, thus leaving an unfavourable risk-reward proposition for the investor.[62]

Problems like this can arise when there is a misalignment of expectations. It is important for researchers, and particularly students, to be grounded in industry experience.

Work experience

Work experience is an essential ingredient for the development of a well-rounded researcher and student, particularly within the engineering discipline. The notable proportion of academics within the minerals education sector with weak industry links also implies a lack of meaningful industry experience. The large-scale vacation work programs offered prior to the peak 2012 period have been scaled back to reflect availability of resources and labour demand needs of mining companies. In response, the MCA is seeking out alternative 'work integrated learning' opportunities for minerals higher education students (and by extension faculty staff). In 2016 the MCA in partnership with the University of Adelaide will roll out the National Exploration Undercover School (NExUS) summer school. Thirty students (plus academic staff) from around the country will participate in a structured three-week program, where they will undertake a mixture of classroom, field-based and site-based activities where industry will play an active role.[63] This is industry's response to the the education and training of future geoscientists relating to the UNCOVER initiative.[64] The ultimate goal of the UNCOVER initiative is to achieve a step-change in knowledge and methodologies in earth sciences relevant to mineral exploration 'beneath the cover'. The collaboration is unprecedented. It includes Geoscience Australia, the CSIRO, industry representatives, cooperative research centres, universities, state geological surveys, and geophysical survey and software development companies.

---

[59] ibid.
[60] Department of Education, Science and Training, *Department of Education, Science and Training (DEST), Best Practice Processes for University Research Commercialisation: Final Report*. DEST, Canberra, 2002, p.47.
[61] Ibid.
[62] Minerals Council of Australia, *Review of Australia's Research Training System*, MCA, Canberra, 2015.
[63] Graham Heinson, Richard Lilly, Gavin Lind, and James Seaford, *National Exploration Undercover School (NExUS)*, unpublished paper in preparation for the Australian Earth Science Convention, Adelaide, June 2016.
[64] UNCOVER, *Background and future funding requirements*, December 2015.

The UNCOVER strategy offers a great opportunity for Australia to lead the world in undercover exploration. At the same time, the UNCOVER Executive and Geoscience Committees recognise that long-term, sustainable funding for geoscience research and technology development, together with government data generation related to priorities identified by UNCOVER, are essential. While industry collaboration is central to the UNCOVER project, ongoing support from both federal and state governments is also vital.

The Australian Government could also raise a national ‘work integrated learning’ program that will benefit students, businesses and educators. The Knowledge Transfer Partnerships (KTP) is a UK-wide programme helping businesses to improve their competitiveness and productivity through better use of knowledge, technology and skills that reside within the UK academic knowledge base. The KTP is part-funded by that government and involves the partnership between a business, a higher education institution and a recent graduate. A faculty member is assigned to supervise the graduate and facilitate the transfer of knowledge and help embed the new capabilities within the organisation. Businesses who participate in this program report post-project growth of around £1 million and the ability to hire two new staff. Academic supervisors report on average the spin-off of three new projects and two academic papers. For the graduates, more than 60 per cent are offered permanent roles at project completion.[65] The Queensland Government is currently trailing a similar program under the same name, which may provide a basis on which to consider a national program.[66]

[65] U.K. Government, *Knowledge Transfer Partnerships: what they are and how to apply*, accessed 1 March 2016.
[66] Queensland Government, *Advanced Queensland Knowledge Transfer Partnership program*, accessed 15 September 2015.

6. POLICY PRIORITIES AND RECOMMENDATIONS

Australia's minerals industry will continue to drive innovation. Mining is enhancing its comparative advantage by the pace and level of investment in innovation. Game changing innovations such as automation, big data and energy efficiency will not only make the industry more efficient, and hence more profitable, but also a safer place to work. Productivity is key, and will result from more effective use of people, equipment and systems across the mining value chain; and an education system that is responsive to changing skills needs and knowledge requirements across all domains including science, technology, engineering and mathematics.

The MCA has invested over $48 million into minerals higher education since 2000, and in partnership with universities across the country, has developed a world-class minerals education sector that presently meets the skills needs of the industry. The central part higher education will play in meeting the future skills needs of the next-generation innovative workforce cannot be understated. However, underlying structural weaknesses, especially around funding and university research impact, threaten the capacity of the minerals education sector to seize this opportunity.

The Australian Government should urgently address the structural weaknesses emerging within the minerals higher education sector by sensible higher education reforms that combine fee deregulation with strong safeguards to ensure the viability of niche minerals-related disciplines.

The Australian Government should also consider adopting successful structured work integrated learning programs that help businesses improve their competitiveness and productivity through better use of knowledge, technology and skills that reside within the Australian academic knowledge (such as the UK Knowledge Transfer Partnerships being trialled by the Queensland Government).