A CRITICAL REVIEW OF INTERNATIONAL CLUSTER AND OTHER SECTOR-SUPPORT INITIATIVES IN THE MINING EQUIPMENT & MACHINERY SECTOR

Ian Steuart

June 2019

This paper forms part of a series of studies on the challenges of industrialisation undertaken by the Industrial Development Think Tank (IDTT). Established in 2017, the IDTT is supported by the Department of Trade and Industry (the dti) and is housed in the Centre for Competition, Regulation and Economic Development (CCRED) in partnership with the SARChI Chair in Industrial Development at the University of Johannesburg.

Table of Contents

1. Introduction

Recent cross-country research has emphasised the critical role of building local capabilities if countries are to benefit from global value chains and technological changes.[1] The growth of the machinery and equipment sector has created direct employment growth, with many more jobs in related activities. Improving the competitiveness of the industry therefore has the potential to replace imports and to grow exports, especially in other African countries.

Clustering is now a well-established policy tool across all industries for companies to build the necessary capabilities to penetrate new markets and achieve the scale necessary to meet the needs of larger clients situated in regional and/or global supply chains, stimulate innovation, and, ultimately, increase profitability. As Michael Porter argued in his seminal work, *The Competitive Advantage of Nations*, "As clusters develop, resources in the economy flow toward them and away from isolated industries that cannot deploy the resources as productively."[2]

Building on the CCRED IDTT metals, machinery and equipment (MME) paper completed in 2018, this report presents a critical review of selected cluster and other support initiatives in the global mining equipment and machinery industry in the context of the challenges and opportunities presented by the Fourth Industrial Revolution (4IR) or Industry 4.0. Specifically, the review includes national and, where possible, sub-national technology and industrial policies supporting the mining equipment and machinery sectors in Australia and Canada. The report benefited from face-to-face interviews with sector stakeholders and Queensland Government officials in Brisbane, Australia in March 2019 and telephone interviews with sector stakeholders and Federal Government officials in Canada.

Section 2 considers the implications of 4IR for the mining equipment and machinery sector while Section 3 considers the link between clustering and Industry 4.0 in more detail. Section 4 provides an overview of clustering and the South African mining equipment and machinery innovation ecosystem. Section 5 provides a detailed review of relevant initiatives supporting the mining equipment and machinery sectors in Australia and Canada. Section 6 concludes and draws out some key policy implications for South Africa.

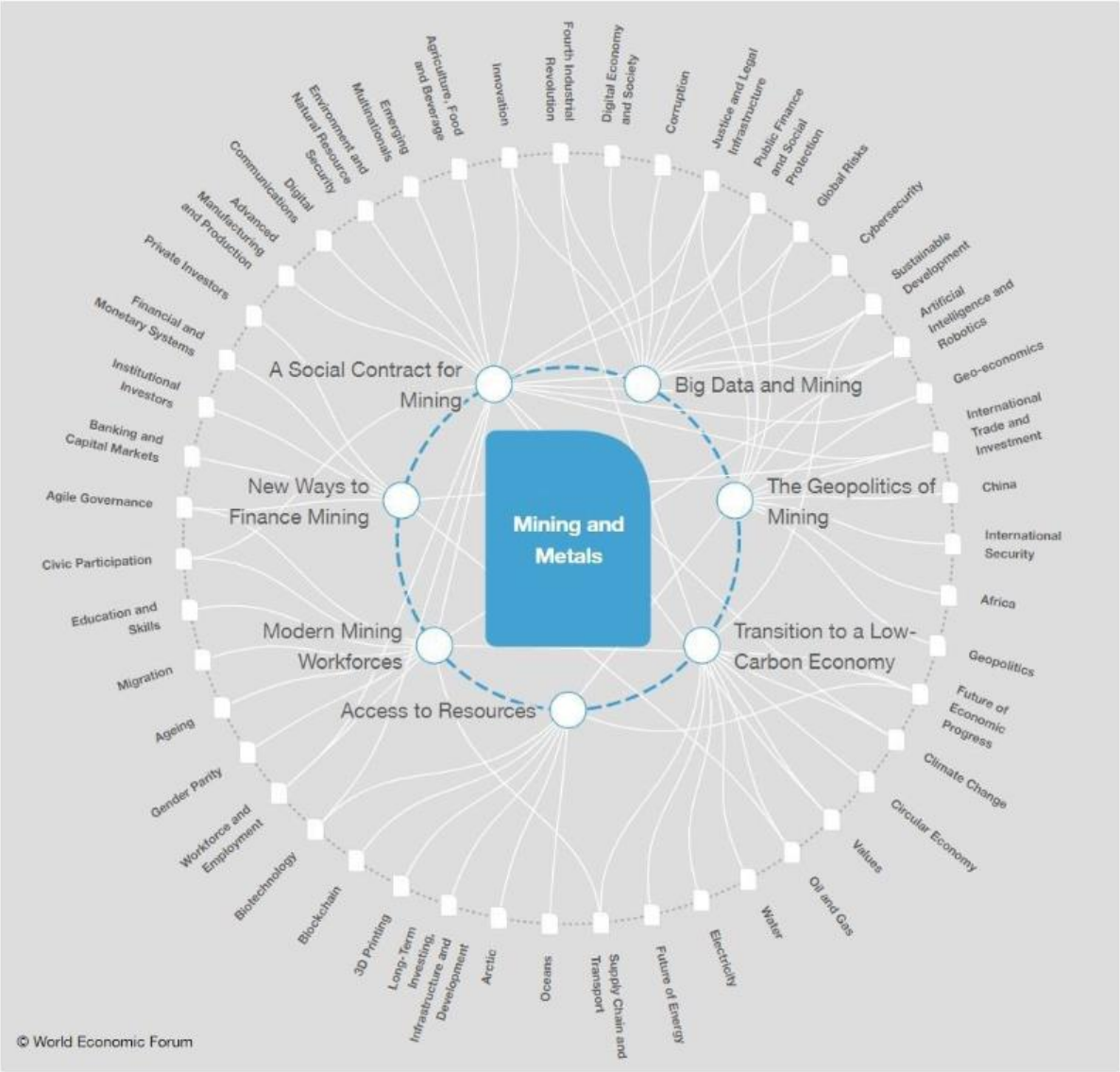
2. Mining Equipment & Machinery and the Fourth Industrial Revolution

While mining activity varies according to the type of metals and minerals extracted from the earth, there are basically two types of mining processes – surface mining and underground mining. Each process involves an array of different machines and equipment but generally these include mining drills and tools, earth movers, crushing equipment and machines, feeding and conveying equipment, etc.

As mineral resources in low-risk areas become exhausted, mining companies must either master new technologies for extraction and processing, or venture into frontier areas where extraction has not previously been economically viable.[3] Increasingly this will involve the use of high-technology operations, complex machinery, and data-intensive applications. Thus as the process of extraction becomes increasingly complex and as 4IR itself advances, mining is becoming ever-more connected to and integrated with a host of other services and technologies (see Figure 1).

[1] See Fagerberg, J., B-A Lundvall, M. Srholec (2018) 'Global value chains, national innovation systems and economic development', *European Journal of Development Research*, June 2018.
[2] Michael E. Porter (1990): *The Competitive Advantage of Nations*. Macmillan Press, UK.
[3] https://www.weforum.org/agenda/2019/03/seven-trends-shaping-the-future-of-the-mining-and-metals-sector/

Figure 1: Mapping the Connections to Mining



In addition, constantly evolving technologies and business models will require mining company employees to develop new skills. The sector will have to increasingly compete with the IT sector to attract top talent from universities in order to drive its digitalization and automation processes,[4] governments and companies will have to work together to help transition workers that cannot be absorbed by an automated mining sector to new activities through retraining and transitioning programs, and the speed at which mining companies will be able to rollout new technologies at their mine sites will be closely linked to the host government's and labour unions' acceptance of reduced employment and procurement opportunities.[5] The activities and linkages within and between mining machinery and equipment and other industries underscores the importance of building an ecosystem that includes services that will drive the industry's present and future competitiveness.

Policy makers and industry players would therefore do well to recognize that the scope of products and services provided by South African companies to the mining industry is much

[4] For example, South Africa's leading Articulated Dump Truck manufacturer, Bell Equipment, is exploring the development of fully autonomous vehicles.
[5] Ibid.

broader than machinery and equipment alone and that the definition sector should be expanded to include technology and other service providers even if their mining customers only account for a fraction of their total revenue. Looking at the industry more holistically will contribute to dispelling the commonly held notion of mining as a low-technology industry. It will also promote the sector as a much wider constellation of innovative, technology-focused, mining-related organisations. This will not only lay the foundations for more a systematic analysis of the linkages between but it will present opportunities for leveraging strategic, state-driven intervention across a "dynamic minerals innovation complex" as well as base capabilities in the industry for lateral migration into other areas.

3. Clusters and Industry 4.0

Clusters initially described industries at the national level that succeeded in international competition. Over the course of the 1990s, the concept of a cluster increasingly came to mean a geographically proximate group of companies and other institutions located close enough to each other to allow extensive interpersonal contact and for firms to benefit from a variety of externalities generated by the grouping. While it is evident from many studies that clusters cannot be artificially "manufactured", cluster-based industrial development strategies have become enormously popular. As Johnston points out in his review of Australian cluster development, "clusters have become recognized as potentially effective vehicles for enhancing competitive advantage, and governments around the world have sought to develop mechanisms to identify actual and potential clusters and to promote their formation and operation". Clusters not only "enhance economic performance through increases in the productivity of member organizations" but also have the potential to "drive the pace and direction of innovation, stimulation of the formation of new businesses, and access to new knowledge and learning."[6]

Given the context of the Fourth Industrial Revolution, it is worth asking whether clustering is compatible with Industry 4.0. While there is not an accepted definition of Industry 4.0, it is generally understood to be characterized by a range of new technologies, including cloud computing, big data, the Internet of Things (IoT), and augmented reality as well as smart material, smart products, and smart machines, that are fusing the physical, digital and biological worlds, impacting economies and industries, and changing the way we work and even relate to each other.[7] By enabling coordination and the increased integration of geographically dispersed and distributed activities, Industry 4.0 may, at first sight, appear to diminish the role of – or at least stand in opposition to – "the sticky and location-specific offer of clusters".[8]

ICTs have flattened the world in a variety of ways and have enabled us to perform certain tasks from a distance. They have also radically increased the returns to "being smart" (i.e., to knowledge and knowledge-intensive activities).[9] Technologies associated with Industry 4.0 will accelerate both of these trends. More and more companies in diverse sectors will seek to adapt these technologies as an ever-larger source of their competitiveness and as a prerequisite for successful participation in global value chains regardless of their size. To do this requires specific circumstances for the diffusion and modification of knowledge; it requires

[6] Ron Johnston (2004): *Clusters: A Review of their Basis and Development in Australia*. Innovation, 6:3, 380-391, DOI: 10.5172/impp.2004.6.3.380.
[7] https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab
[8] Marta Götz & Barbara Jankowska (2017): *Clusters and Industry 4.0 – do they fit together?* European Planning Studies, DOI: 10.1080/09654313.2017.1327037
[9] CDE (2015): *Cities – Pathways to Prosperity: A presentation by Edward Glaeser*. https://www.cde.org.za/cities-pathways-to-prosperity/

the sort of mastery and adaptive activity that stems from "close and continuous interaction with other enterprises like suppliers, subcontractors, competitors and consultants, as well as with other actors such as public R&D institutes, universities, venture capital funds and export marketing or training institutions".[10]

Clusters do not only possess certain attributes of the knowledge-intensive economy such as universities and applied research institutes but, under the right set of supportive conditions, they also provide the foundations for the rapid accumulation and adaption of knowledge so essential to Industry 4.0. Thus, far from being in opposition to Industry 4.0, clusters will remain an appropriate instrument of modern industrial policy as the Fourth Industrial Revolution gathers pace. But not all clusters will automatically play a prominent role in Industry 4.0. As the case studies of cluster initiatives in mining equipment and machinery in Australia and Canada show, the success of particular cluster initiatives depend on the entire ecosystem of support in addition to cluster-focused strategies and policies.

4. Clustering and the South African Mining Equipment & Machinery Innovation Ecosystem[11]

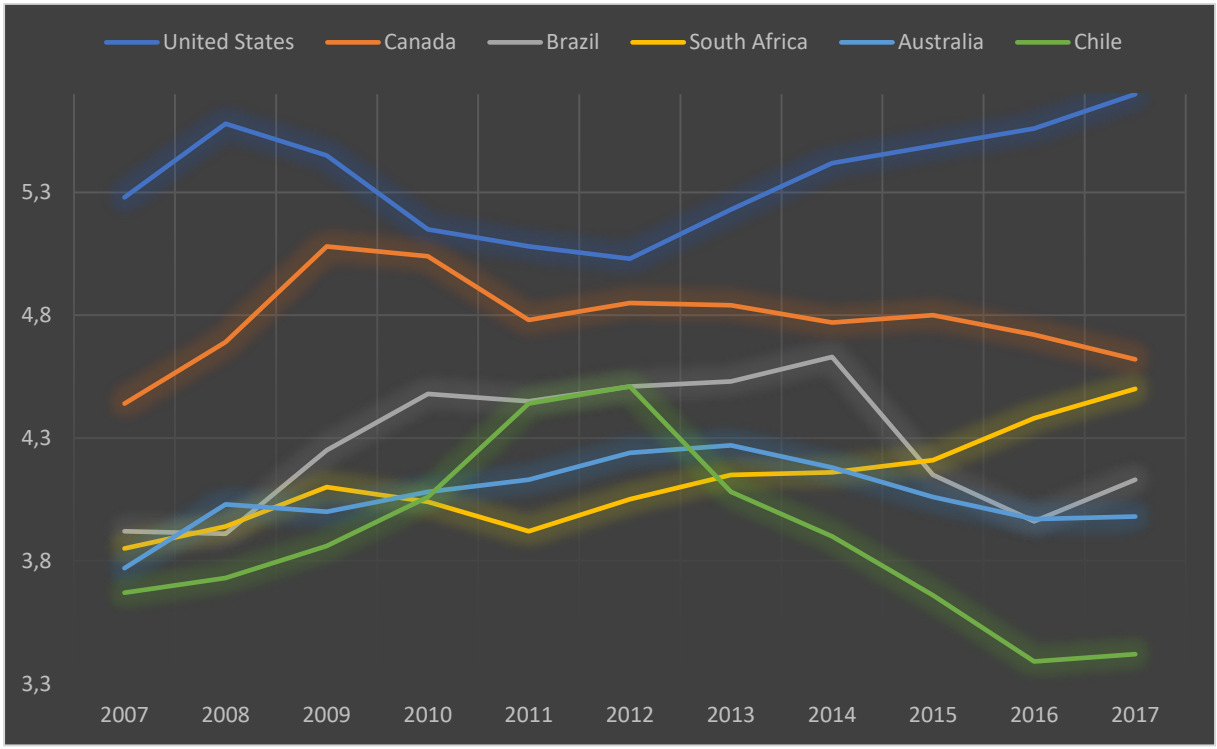
Each year, the World Economic Forum's Executive Opinion Survey is used to derive a number of indicators which are, in turn, used in the calculation of the WEF's Global Competitiveness Index (GCI). One such indicator, the "State of Cluster Development", provides the basis for a comparison of cluster development across 151 countries. According to the most recent published survey (2017/18), cluster development is most advanced in the United States, the UAE, Germany, the Netherlands, the UK, Hong Kong SAR, Italy, Qatar, and Singapore. South Africa ranks 29th out of 151 countries, five places behind Canada (24th) and 22 places ahead of Australia (51st). South Africa's cluster development score has improved consistently since 2011 with a year-on-year average growth rate of 1.59% for the time period 2007 to 2017. Compared to the US, Canada, Australia, Brazil and Chile, South Africa has the highest year-on-year average growth rate at 1.59% whereas Chile has the lowest year-on-year average growth rate at -0.52% (see Figure 2).

The WEF's Executive Opinion Survey captures the opinions of business leaders in each participating country. The responses, and hence the indicators from which they are derived, are therefore subjective, despite being tested for statistically excessive perception bias once they have been aggregated at the country level. The question that is put to business leaders is relatively straightforward: "In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services, and specialized institutions in a particular field)? [1 = non-existent; 7 = widespread in many fields]" although it is not clear how a business leader in a particular industry would necessarily know of the depth of cluster development in other sectors unrelated to their field. Despite these obvious shortcomings, the indicator provides the only evidence for the relative strength of cluster development in both OECD and non-OECD countries. On this basis alone, there is cause for cautious optimism about the state of cluster development in South Africa, at least since 2011.

[10] UNCTAD (2005): *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D*

[11] This section is based on a draft written Maria Nkhonjera, Economist/Junior Researcher at the Centre for Competition, Regulation and Economic Development (CCRED), South Africa.

Figure 2: State of Cluster Development, Selected Countries, 1-7 (Best)



Source: World Bank TCdata360; World Economic Forum Global Competitiveness Index

Finally, it is worth noting that a high score on cluster development does not automatically correlate with a high overall score on competitiveness. New Zealand, for example, ranks 44th on the state of cluster development but 13th on the 2017/18 Global Competitiveness Index. By contrast, South Africa ranks 29th on the state of cluster development but 61st on the overall competitiveness index. In short, there is more to competitiveness than clustering alone.

4.1. Clustering in mining machinery and equipment

Previous IDTT research has revealed a group of highly dynamic firms in the South African mining machinery and equipment industry that have built skills through on-the-job learning, private training initiatives and collaborations with universities. They have made prudent investments in up-to-date capital equipment and have worked out where they can be leaders in incremental product development. The corporate culture tends to be one of shared learning and capability development, whether they participate in formal cluster initiatives or not. The research also notes, however, that these firms – along with similar groups of companies in other sectors such as fresh fruit, clothing and textiles, and yellow metals – will remain islands of industrial success without a significant increase in technological skills and much higher rates of investment.[12]

There are currently three main clusters or cluster groupings in the mining machinery and equipment sector in South Africa:

1. Following the 2015 Mining Phakisa[13] and on the basis of recommendations contained in the dti's Resource Capital Goods Development Plan Study, a group of manufacturers, ranging from large SA-based multinationals to smaller specialized and

[12] IDTT (2019): *Towards a Digital Industrial Policy for South Africa: A Review of the Issues*.
[13] An initiative led by the Presidency to bring together all stakeholders in mining in order to develop a shared vision and long-term growth strategy for the sector's transformation.

emerging companies, came together in 2015 to establish the Mining Equipment Manufacturers of South Africa (MEMSA) with support from the dti's Cluster Development Programme (CDP).[14] MEMSA defines itself as a cluster committed to promoting the benefits of cooperation for its members in the development of skills and technology, domestic and export markets, and the realisation of a SADC-wide market for capital goods. Strategic direction and governance is provided by a Board which includes representatives of MEMSA member companies. According to its website, the cluster has a number of active programmes in place, including on skills development and localisation and supply chain development. Located in the Mandela Mining Precinct (see below), the cluster seems well-resourced and committed to improving the innovative capabilities of the sector.

2. The second major grouping of mining machinery and equipment clusters is housed by the South African Capital Equipment Export Council (SACEEC). These include the South African Mineral Processing Equipment Cluster (SAMPEC), the South African Shaft Sinking, Equipment and Services (SASSES) cluster, and the Valves and Actuators Manufacturers of South Africa (VAMCOSA).[15] The success of the SACEEC group of clusters is mixed. VAMCOSA is well-established and has excelled in promoting local designation, in tandem with the dti, others have been slow to take off. The SASESS cluster, however, has been inactive since 2017 because of an inability to find a champion for the cluster on a permanent basis. SAMPEC was heavily involved in the post Mining Phakisa supply development preparation process although at the time of writing the ITDD MME report, it was struggling to attract members given the diversity inherent in the mineral processing industry and the consequent challenge of settling on a set of clear value propositions that would benefit all the players in the industry.

3. The third major grouping of mining equipment and machinery related clusters has emerged from a private initiative supporting "a demand-driven revitalisation of manufacturing capacity in South Africa". Initiated by Recapitalise South Africa, a specialist services and change management company, the RSA Clusters Programme has established four non-profit clusters, namely the Casting, Forging and Machining Cluster of South Africa, the Electro Technical Industry Cluster of South Africa, the Rail Manufacturers Cluster of South Africa, and the Fabrications Cluster of South Africa. An Infrastructure Cluster and a Composites Cluster are in the process of being established. Each cluster has its own constitution and code of ethics, and is underpinned by an integrated cluster management platform developed by RSA. Of the four established RSA clusters, the Casting, Forging and Manufacturing Cluster of South Africa and the Electro Technical Industry Cluster are of particular relevance to the mining equipment and machinery industry (members include manufacturers of grinding media, mill liners, excavator teeth, and control systems and instrumentation, respectively). Both clusters collaborate with MEMSA.

[14] Although not strictly part of the mining innovation ecosystem *per se*, the dti's Cluster Development Programme (CDP) has provided support to a number of mining equipment and machinery clusters, including MEMSA and the RSA Clusters Programme. The CDP is an incentive programme that aims to promote industrialisation and enhance the competitiveness of South African enterprises by supporting the development of clusters and industrial parks. The CDP is a pilot programme that ended in April 2018 to allow the dti to assess its impact and to formulate recommendations for a second phase of cluster support.

[15] See Rustomjee, Z., Kaziboni, L. and Steuart, I (2018): *Structural transformation along metals, machinery and equipment value chain – Developing capabilities in the metals and machinery segments*. CCRED Working paper 2018/7.

Of the above clusters, MEMSA, SAMPEC, and the two RSA clusters – the Casting, Forging and Machining Cluster of South Africa and the Electro Technical Industry Cluster of South Africa – are embedded in the Mandela Mining Precinct programme and heavily focused on supply chain development in their respective sectors.

4.2. The wider innovation ecosystem and policy framework

Prior to the 2015 Phakisa, the Council for Scientific and Industrial Research (CSIR), with support from the Department of Science and Technology (DST), developed the South African Mining Extraction Research, Development & Innovation (SAMERDI) Strategy. Post-Phakisa, the SAMERDI strategy was adopted as the R&D strategy for the mining sector that would achieve the outcomes of the Phakisa.[16] The SAMERDI programme was developed as a collaborative research programme between the CSIR and the University of Johannesburg, the University of Pretoria, and the University of the Witwatersrand. The programme receives, on average, about R60 million per annum from government, via the DST, and about R30 million from Industry via the Minerals Council South Africa.[17]

The SAMERDI programme is made up of the following thematic/focus areas:

1. *Longevity of Current Mining*: to increase the efficiency of extraction, improve Occupational Health and Safety, and reduce costs.
2. *Mechanised Drill and Blasting*: to develop fully mechanised mining systems that will allow for remote drilling and blasting of narrow, hard rock mines (in particular gold and platinum mines).
3. *Non-Explosive Rock Breaking*: to find ways of "seeing through the rock" by creating an accurate, three-dimensional model that can be used for real-time planning and design work.
4. *Real-Time Information Management Systems*: to improve the flow of real time information for monitoring and control, leading to an increase in proactive interventions that can correct for deviations and unsafe conditions.
5. *Successful Applications of Technology Centred Around People*: to better understand the human resource requirements and change management implications associated with increased automation and mechanisation of South African mining processes.

The innovation system for mining was further reinforced by the establishment of the Mandela Mining Precinct in 2016. The Chamber of Mines Research Organisation (Comro) was a significant factor in South Africa becoming the global leader in mining research in deep level, narrow-reef mining, as well as block caving mining in the diamond and copper industries. This was the direct result of co-investment by Chamber of Mines member companies which, in today's money terms, amounted to some R400 million a year.[18] Comro was replaced by CSIR Miningtek when the Chamber of Mines transferred Comro to the CSIR in 1993. In 2016, the old Comro facility in Melville, Johannesburg, was reopened as the CSIR Mandela Mining Precinct with an initial three-year research budget of ZAR 450M, to coordinate research activities toward the revitalisation of mining for South Africa's mining operations through the development of next-generation mechanised mining systems.

Established as a public-private partnership between government, mining companies, manufacturers of mining equipment, research organisations and academia to foster collaboration and innovation, the precinct is home to over 50 staff, ranging from interns to

[16] Ibid.
[17] Engagements with Mandela Mining Precinct, 2 May 2019
[18] MacFarlane, A. (2017): *Mining research and development reborn - the Mining Precinct*, Journal of the Southern African Institute of Mining and Metallurgy, vol.117, n.12.

researchers, principal investigators, and programme managers. Governance has been addressed through the establishment of a steering committee, with representation from key stakeholders, operating similar to that of a board.[19] Of particular interest in the context of this report is SiMINE, a collaborative, purpose-built mining simulation centre used "to expose and build Systems Thinking capability" and "for testing Mining 4.0 technologies and organisational design".

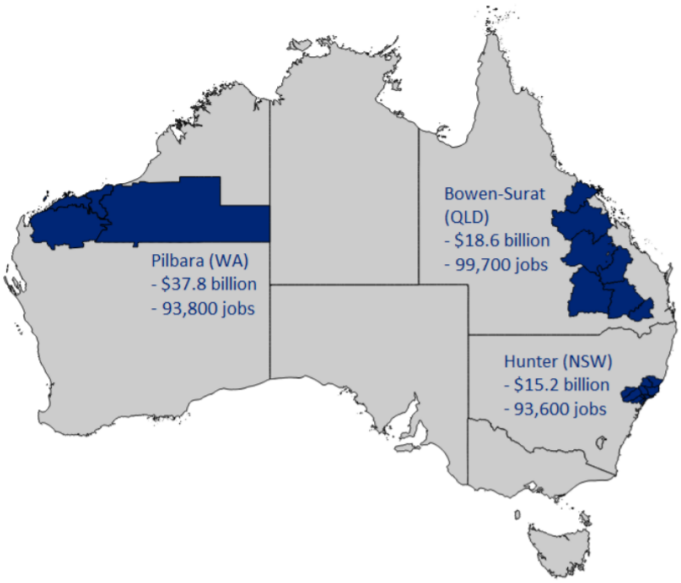
5. Key Initiatives Supporting the Mining Supply Sector in Australia & Canada

Section 5 considers the mining equipment and machinery ecosystems in Australia and Canada. The section focuses on METS Ignited in Australia and the support it provides to the Australian mining and equipment industry in the context of relatively strong and well-coordinated intra-government policy frameworks, the Sudbury Mining Cluster in Canada, and the newly established Canadian Government's Innovation Superclusters Initiative.

5.1. The Australian Mining Equipment, Technology and Services (METS) sector

A 2017 Deloitte report estimated the mining and mining equipment, technology and services (METS) sectors' total economic contribution to Australia was A$236.8 billion in 2015-16, representing around 15% of the Australian economy.[20] This economic activity supported over one million full-time equivalent (FTE) jobs across Australia, which represented around 10% of total FTE employment at the time. While this economic activity is distributed across Australia, there are a number of regional areas where mining and METS activities make a particularly significant economic contribution to output and employment, the Pilbara region in Western Australia, The Bowen-Surat region in Queensland, and the Hunter region in New South Wales (see Figure 2).

Figure 2: Regional economic contribution, mining & METS, 2015-16[21]



[19] Ibid.
[20] Deloitte (2017): *Mining and METS: engines of economic growth and prosperity for Australians*. Report prepared for the Minerals Council of Australia.
[21] Ibid.

In 2012, the Australian METS sector employed around 265,000 people and generated sales worth over A$71 billion. Between 1998-2013, the sector grew roughly five-fold and achieved export revenues comparable to those of the Australian automotive industry.[22] Comprised of firms that provide specialised products and solutions for mineral exploration, extraction and mining supply chains and driven by the expansion of mining investment and production both within and outside Australia, the METS sector has "achieved a remarkable level of internationalisation, with the majority of firms having offshore offices or subsidiaries."[23]

Before 2013, there was little evidence in the years of public policies facilitating either new venture formation or formal commercialisation infrastructure in the Australian METS sector. Indeed, the challenges faced by the sector were remarkably similar to those that the South African mining equipment and machinery faces currently: [24]

- Largely transactional relationships between miners and METS companies which left much value "on the table" and put Australia at a disadvantage compared to other more collaborative competitor regions such as Scandinavia where key clusters of miners and METS work together across the value chain.
- Poor track record of successfully transferring public sector research into commercial outcomes, despite having some of the strongest mining-related research institutions in the world.
- Weak collaboration between companies as measured by the OECD (a critical measure of innovation).[25]

Some of these challenges still persist along with others that appear to more entrenched. For example, few Australian METS companies have emerged as major global OEMs, inhibiting access to global supply chains of the Tier One mining companies while Australian capital markets lack depth, especially in early stage and long-term capital, and, combined with weak management skills, limit growth in business scale. As discussed in Section 2, the Fourth Industrial Revolution is bringing with it disruptive technologies that are both a threat and an opportunity, and their impact on the industry is accelerating at an exponential rate. Finally, the Australian METS sector is facing competition from new and emerging markets such as China and India.

Since 2013, a significant amount of federal, state (provincial) and private sector resources has been deployed to support the sector, including the establishment of METS Ignited in 2015. While some challenges persist (see below) specialised METS sector companies involved in construction, professional and technical services, technical equipment manufacturing, contract mining (including exploration), transport services, basic equipment manufacturing, wholesale trade, and ICT services now produce over A$40 billion GVA per annum, employ over 300,000 people, and outstrip national economic growth rates with a sustained average growth rate of around 7%.[26]

[22] Don Scott-Kemis (2013): *How about those METS? Leveraging Australia's Mining Equipment, Technology and Services Sector*. Minerals Council of Australia.
[23] Ibid.
[24] METS Ignited (2016): *Mining Equipment, Technology and Services (METS) ten year Sector Competitiveness Plan (SCP)*
[25] OECD (2017), *OECD Science, Technology and Industry Scoreboard 2017: The digital transformation*, OECD Publishing, Paris, https://doi.org/10.1787/9789264268821-en. (Collaboration on innovation rankings provided for OECD members only.)
[26] Figures supplied by METS Ignited (2019).

5.1.1. METS Ignited

METS Ignited (MI) was established late 2015 to assist the Australian METS sector in strengthening its position as a global hub for mining innovation. Located on the main campus of the Queensland University of Technology in central Brisbane, with an established node in Melbourne and second node planned for Perth, MI is one of six national, not-for-profit Industry Growth Centres wholly funded by the Australian government (see box below).

It is important to note that MI is not a cluster *per se* but rather a government-supported organisation established to assist companies in the METS sector to reach their maximum potential. MI is involved the establishment and development of METS clusters such as the Bowen Basin Cluster, which is discussed in more detail in section 5.1.2 below.

Box 2: Australia's Industry Growth Centres[27]

The Industry Growth Centres (IGC) Initiative, developed by Australia's Department of Industry, Innovation and Science, is helping Australian firms to be more internationally competitive by enabling industry sectors to build capability and stronger industry systems through a collaborative, industry-led approach. There are six Growth Centres operating in sectors of competitive strength and strategic priority:

- Advanced Manufacturing Growth Centre (AMGC);
- Cyber Security Growth Centre (AustCyber);
- Food and Agribusiness Growth Centre, known as Food Innovation Australia Limited (FIAL);
- Medical Technologies and Pharmaceuticals Growth Centre (MTPConnect);
- Mining Equipment, Technology and Services (METS) Growth Centre (METS Ignited); and
- Oil, Gas and Energy Resources Growth Centre, known as National Energy Resources Australia (NERA).

As not-for-profit organisations led by a board of industry experts, IGCs link capability and industry need through national networks, and highlight industries' knowledge requirements to the research and education sectors as targets for collaboration efforts. To date, IGCs have:

- Committed A$46.4 million (approx. ZAR 470 million) to 137 projects and leveraged more than A$63.2 million (ZAR 640 million) from industry and research partners with the total direct value of these projects exceeding A$109 million (over ZAR 1 billion);
- Established collaborations with 14 currently-funded Cooperative Research Centres (CRCs; see 3.1.5 below) including the newly announced Cyber Security CRC, Digital Health CRC, Fight Food Waste CRC, Future Fuels CRC and MinEx CRC;
- Cooperated to develop CSIRO's (the Commonwealth Scientific and Industrial Research Organisation – Australia's equivalent to the CSIR) Sector Roadmaps;
- Provided over 1,500 participants with the opportunity to connect to markets and supply chains at domestic and international trade shows;
- Delivered 350 skills workshops on 17 topics to over 10,000 participants; and
- Collaborated on 17 regulatory reform projects.

Strategic objectives

MI has four strategic objectives:

1. Accelerating the commercialisation of innovation in METS;
2. Increasing capabilities within the sector;
3. Growing METS exports;
4. Regulatory reform in the METS sector.

MI has a strong focus on Industry 4.0. The most recent round of MI collaborative project funding (see below) has allocated resources to the commercialisation of innovation in robotics and automation, data analytics, data platforms, and IoT. The Queensland government is funding cluster initiatives in the state through MI which include a focus on Industry 4.0

[27] https://www.industry.gov.au/strategies-for-the-future/industry-growth-centres;
Dept. of Industry, Innovation and Science, Background Information for Cooperative Research Centre Applicants

capabilities, products, and services. MI also runs a Masterclass on Workforce 2025 that is focused on preparing METS companies for the changing skills requirements of Industry 4.0.

Funding, membership and structure

While MI encourages companies to become "Network Associates", it is not a paid membership organisation. There are other membership-based organisations in the sector, such as Austmine, the industry body for the Australian METS sector, MESCA, the Mining and Energy Services Council of Australia, AusIMM, the Australasian Institute of Mining and Metallurgy, and the Minerals Council of Australia (MCA), with which MI works closely to grow the sector.

Initial funding for MI was A$ 20 million (approx. ZAR 206 million) over four years with over 75% allocated to the MI Collaborative Project Funds (see below). An additional A$10 million (approx. ZAR 103 million) was allocated to METS Ignited by the government to continue for a further two years.

MI is industry-led with a Board and senior executives with extensive knowledge and experience in mining, METS and business sectors. In line with its objectives, MI has five General Managers for industry engagement, education, international markets, finance, and communication in addition to a Chief Executive Officer and support staff.

International partnerships

MI has a well-developed international strategy that is providing pathways for Australian METS companies to expand overseas. The CEO and GM for International Markets attended the 2019 Prospectors & Developers Association of Canada (PDAC) convention in Toronto with support from Austrade, the Australian government's trade, investment and education promotion agency. While in Canada, MI also established dialogue with the Sudbury Mining Cluster (see section 5.2.2 below) and Finnish mining tech companies.

In 2017, MI completed Australia's first exchange program between Australian METS companies and their Chilean counterparts. Called METStech Passport, the program was a collaboration between MI, Austrade and Expande in Chile. The two-week exchange involved an in-depth look at the Chilean mining ecosystem to provide the Australian METS with an opportunity to learn where they could add value. The second exchange program launched in March 2019.

The METS Sector Competitiveness Plan (SCP)

All six IGCs are responsible for publishing Sector Competitiveness Plans, 10-year strategic visions that highlight opportunities and activities to boost productivity and drive cultural change in each priority sector. Each Plan contains Industry Knowledge Priorities, a summary of knowledge and technology gaps in the target sector to be addressed by collaborative research to underpin innovation and enhance productivity and competitiveness.

The METS SCP, published by MI in 2016, recognises the interdependence of the METS sector, mining, research and government and lists the following Industry Knowledge Priorities:

1. Building capable, innovative and collaborative export-savvy businesses;
2. Advancing explorations, mining and extracting technologies;
3. Advancing automation and mining beneficiation technologies such as selective mining, comminution, classification, reducing tailings/reject streams, in-situ recovery, small-scale robotics for continuous mining, bio-leaching and nano-technology;
4. Advancing knowledge and understanding of modular solutions, standardisation and interchangeability;
5. Improved mining energy efficiency and remediation;

6. Improved social sustainability and safety;
7. Advancing sensors, data analytics and data/information systems, including connectedness and human machine interfaces.

Since 2016, MI has been delivering systematically on the recommendations contained in the SCP and has seen considerable involvement of the ecosystem through the MI Collaborative Project Funds discussed below.

MI Collaborative Project Funds

The MI Collaborative Project Funds is an A$15.6 million (approx. ZAR 160 million) initiative to support, encourage and fund collaboration through matched investment for projects with clear commercialisation applications in the mining and METS sectors. Projects must demonstrate collaboration between two or more METS companies and a customer / end-user, such as a mining company, system integrator or OEM and must be industry-led with clear commercialisation applications that address one or more of the following:

- Industry Knowledge Priorities (IKPs) in the SCP;
- Key mining challenges;
- Establishment of METS Living Lab nodes/sandpits as part of an industry-wide "Living Lab" network;[28]
- Blue sky opportunities where solutions do not currently exist and where developing a solution would bring significant and long lasting benefits to mining companies and to the Australian METS sector;
- Other industry-led projects that can demonstrate they will deliver a sustainable advantage to the METS sector.

Specifically, MI through the Collaborative Project Funds initiative seeks to invest in ideas that will strengthen the productivity, competitiveness and innovative capacity of the sector and to deliver results on a national scale that have sector-wide impact, including for SMEs.

Funding is accessed through a two-stage competitive bidding process involving an initial application (expression of interest) and a detailed proposal. To date, three funding rounds have taken place since MI was established. Applications for the third round of funding closed at the end of August 2018 and had a particular focus on developing capabilities in analytics, automation and robotics at any point in the national METS value chain. While the inclusion of research organisations is encouraged, MI does not fund research per se, only projects that have already attained some degree of commercialisation, typically projects with a technology readiness level (TRL) of 4 or above and ideally projects with a TRL of 6 or higher.[29] Examples of projects funded by the first two rounds of the MI CPF are provided below.

[28] Broadly based on the successful MIT and European industry innovation models, "Living Labs" is a way of improving the systematic translation of good ideas actual commercial outcomes by encouraging project-based collaboration between innovators (researchers and METS providers) and end-users (miners) to address problems in real/near-real world testing environments. A Living Lab supports innovation through: Collaboration (building collaborative projects that bring industry partners together from across the innovation system - mining, METS suppliers and research); Scale (focusing on projects to address industry challenges that require industry, research and government to work together); Testing (Providing real, near-real and virtual mine test-beds to develop and demonstrate products); Capability (developing expertise in innovation and collaboration across research, METS and the mining industry); and Commercialisation (support in finding paths to market for new ideas, products and services). A crucial factor throughout the above is **end-user driven development**.

[29] Technology readiness levels (TRL) are a method of classifying technology maturity as one moves from TRL 1, where the research had been initiated to TRL 9 where the technology has been commercialised and has been in the market for some time. In science and engineering, TRL 6 refers to prototype demonstration or engineering/pilot-scale, similar (prototypical) system validation in a relevant environment.

Box 3: MI Collaborative Project Funds projects

- Austmine's *Women in STEM: METS Career Pathway Program* is an initiative designed to increase the awareness of women studying STEM subjects at university and of the possibilities a career within the METS sector can hold. It is an integrated program combining networking events, online tutorials and an industry-paid internship that will create an informed and experienced community of future female employees for the METS sector.
- Unearthed Solutions has developed a multi-faceted program to encourage greater METS company involvement in early-stage innovation activities, including a global hardware competition focussed on SME participation, a METS-focussed hackathon event, and the launch of an Accelerator program providing seed funding, expertise and access to industry mentors.
- The *Resources Ready Online program* is a structured series of seminars and workshops delivered by the Resources and Engineering Skills Alliance (RESA) to companies working in, or seeking to enter, the supply chain of the mining and oil and gas sectors. The program will expand the previously South Australian-centred training nationally to provide companies with in-depth industry knowledge and skills delivered using an innovative blend of in-person and online delivery.
- The Coalition for Energy Efficient Comminution (CEEC) *Energy Curves program* provides free benchmarking tools to help miners identify how to reduce energy intensity and increase productivity. The program runs workshops across Australia for mining and METS companies, sharing successful implementation case studies and operational data to define and investigate a wide range of industry solutions and collaboration opportunities.
- Establishment of a dedicated Living Lab at the University of Western Australia to enable METS companies to trial their technologies to demonstrate performance to mining companies without the difficulty and expense of testing on mine sites.
- The *Emapper digital platform program* enables mining companies to meet their environmental rehabilitation obligations with greater certainty, more detail and at a significantly reduced cost by providing a complete picture of rehabilitation progress online in real time.
- IMDEX is using MI funding to overcome an existing lack of geological data by enabling the collection of real-time data during blasthole drilling, and therefore producing more efficient blast designs.
- Micronised Mineral Systems is demonstrating a new process for treating residual water on mine sites so it is environmentally benign at a much-reduced operating and capital cost.
- Resolution Systems is developing sophisticated fleet management software which allows different operational areas of mine sites to communicate with one another and increase mine truck fleet productivity by 20%.

Masterclasses

MI works collaboratively with the Australian government's Entrepreneur's Program (see section 3.1.5 below) and Austmine to deliver the MI Masterclass series, an ongoing series of facilitated workshops targeted at senior executives within the METS and wider mining ecosystem.

MI provides masterclasses in the following:

- Digital Disruption
- Effective Capital Strategies
- Winning More Business
- Workforce 2025

All elements of the Masterclass series reflect the importance (challenges and opportunities) of Industry 4.0. The digital Disruption Masterclass, for example, assisted METS companies in understanding the data and digital disruption landscape in mining and the need to evolve both strategically and operationally in anticipation of digital disruption, and developed an action plan for change. Workforce 2025 addresses the need to adapt to Industry 4.0, an evolving workforce and the changing nature of work itself.

MI Accelerator programs

In 2017, MI and the Queensland Government launched the "Igniting METS" pilot program to accelerate the commercialisation rate of mining technologies in Australia. Igniting METS was the first of its kind in Australia and delivered a pilot technology accelerator for METS innovations ready to be implemented into the mining industry. The pilot accelerator was used to inform the operation of future METS-focused accelerators around the nation. Igniting METS was operated by KPMG through its Energise accelerator format, the largest of its kind in the Asia-Pacific region.

The RISE Accelerator Program is a 12-week national program built on the success of Igniting METS. The program is supported by the Queensland and Western Australian governments and the MI and NERA Industry Growth Centres, and has been developed to spearhead innovation into industry and equip small and medium-sized METS companies with the skills, capabilities and support to develop their innovation, access markets, and grow their businesses.

Participants are divided into two cohorts (Brisbane and Perth). A detailed description of innovations supported by the RISE Accelerator program is provided below.

Box 4: RISE Accelerator funded innovations

Brisbane cohort

- Compella Compression has developed a coal seam gas compressor to minimise hole-wellhead pressure in order to accelerate gas production without the release of oil into the system. This compressor is designed to meet the specifications of the Coal Seam Gas industry in Queensland, which no product on the market currently does.
- Connec Industrial Power designs and manufactures High Voltage (HV) power connectors made from polymer. These connectors are non-conductive and are between 25-50% lighter than the existing metal products on the market. Operators are able to achieve up to a 50% increase in operational efficiency through the quick and safe installation of these innovative HV connectors.
- Conveyor Innovations International have designed an intelligent idler roller that automatically detects conveyer failures through their integrated iMonitor microelectronic device. The device records temperature, vibration and operational hours of conveyer systems to prevent failures and unscheduled shutdowns, minimise labour costs and reduce waste on site.
- Kelly's Australia provides an innovative solution to the removal of rubber coatings from infrastructure in-situ through the provision of their ultra-high pressure water jetting. This service achieves cost savings for clients by preventing equipment outages and production downtime.
- Magman provides a software solution which enables mine operators and contractors to accurately track the movement of explosives stock in and out of their magazines, eliminating the requirement for time consuming and ineffective paper based systems. This cloud-based solution provides a more efficient and transparent process for managing explosive stock movements and stocktakes, increasing the level of auditability to allow compliance with increasingly rigorous regulatory requirements.
- Modulr Tech is a software company specialising in building data-centric pilot software projects for businesses in the natural resources industry. Their unique development service model allows companies to quickly explore and test high-value software project ideas with minimal risks and upfront costs.
- Team Airconstruct's "AirConnect Assist Intelligence" is a predictive maintenance platform for air-conditioning units that alerts the owner of an approaching failure. The system utilises machine learning to analyse operational data for faults and generates an appropriate work order by identifying the technical skill-set required to fix the problem.
- TEAM Group has developed a wireless monitoring solution that continuously assesses the condition of roller-screen beds in Coal Handling and Preparation Plants. The solution allows for the efficient planning of outages rather than reacting to unexpected stoppages, and is able to predict certain failures up to three weeks in advance.

Perth cohort

- A60N has developed a patented sub-sea Deposit Management System (DMS) which prevents calcareous, sedimentary and marine growth deposits from forming on oil and gas equipment interfaces. The solution allows for the most efficient management of sub-sea assets by ensuring equipment is changed out as planned, saving unexpected vessel use and equipment delays.

- Beruseal / Carbontech Composite Systems – Beruseal has designed a Quickseal Clamp system that allows for the on-line repair of leaks with pre- manufactured sealing enclosures to prevent equipment downtime. Carbontech Composite systems has developed Revowrap, a repair solution that uses epoxy resin and carbon fibre. The product restores pipeline systems to their original design parameters in situ, and allows for the system to return to its maximum operating pressure without plant shutdown.
- Using machine learning, DIGATEX provides clients with market-leading artificial intelligence (AI) tools to transform existing engineering data and documents into intelligent digital information required for building and managing digital assets and driving business transformation.
- Gecko Telemetry have developed a Remote Telemetry Unit (RTU) for small and midcap mines that works out-of-the-box without needing any other fixed infrastructure. Through designing RTUs that are self-sufficient, scalable and readily-deployable, Gecko have created a remote monitoring and automation solution that is affordable and accessible to all.
- Innovative Blasting Technologies is an advanced technology company which has developed a revolutionary in-hole tool to survey blast holes in mining. Their flagship product, the Drill Hole Tracer, is capable of surveying blast holes five times faster than existing methods (MEMS Gyroscopes), with greater accuracy and at a significantly lower cost than competitors.
- OrwayIQ has developed MillROC (Milling Remote Optimisation Consulting) that analyses operational data in a holistic manner via a cloud-based server to identify trends and hidden relationships. This information is visualised, modelled, ad compared to a KPI dashboard to allow for continuous reporting of circuit efficiency.
- Tan Ninety have developed a paperless platform for the mining and resource industry which facilitates efficient communication and collaboration between front-line personnel and management. The software also allows for automatic data collection to generate insights and predictions to inform decision-making.

In addition to “Igniting METS” and the RISE Scale-up Accelerator program, the Queensland government is supporting MI to pilot regional pre-accelerators under different formats to determine their role in the overall acceleration of mining innovation.

5.1.2. Bowen Basin Cluster

Much like South Africa, although possibly less so since 2011 (see Figure 2), clustering as an approach to enhanced competitiveness and industrial development has achieved only very limited success in Australia. The vast majority of clusters that were deliberately established with Norwegian support in Australia in the early 1990s failed because they were neither suited to Australian conditions nor failed to entrench a cluster consciousness in participating firms. Moreover, according to the Acting CEO of MI, Australian SMEs generally need to be convinced of the benefits of clustering in terms of increased sales or decreased costs within a relatively short 12-18 month timeframe for them to adopt clustering as a viable business model. If the benefits of clustering are not apparent within that window then the likelihood that Australian SMEs will exit a cluster are very high indeed. While this is anecdotal evidence, it does point to the need for persistence among smaller firms participating in cluster initiatives and a measure of financial support for emerging clusters before they reach a level of maturity and sustainability.

In the case of the Bowen Basin Cluster, and possibly in response to previous unsuccessful attempts at establishing industrial clusters in Australia, MI has adopted a gradual, “ground-up” approach to clustering. Located in northern Queensland in a major coal producing region containing one of the world’s largest deposits of bituminous coal, the Bowen Basin Cluster represents the first MI-initiated clustering initiative for the Australian METS sector. The cluster is informal and participating companies do not pay a membership fee. A key element of the cluster program is the provision of matched funding to METS companies in the region with complementary areas of expertise to accelerate the commercialization of innovation into local mining operations and provide a pathway to international opportunities.

Four consortia of companies in the Bowen Basin region have received initial funding from MI which has been matched by industry partners, bringing the total program value to almost

A$1.5m (approx. ZAR 15.1 million). The projects funded by the initiative will help to commercialize solutions for conveyor belt spillage, cheaper access to rapid prototyping, training for new underground mining operators, and health and safety improvements to mines in the Bowen Basin. As with the Collaborative Project Funds, MI has selected consortia that have a minimum viable product; in other words, the product is beyond the development stage and has been piloted or demonstrated in some form. Details of pilot cluster projects are provided below.

Box 5. Pilot Bowen Basin Cluster projects

- **MyneSight**
  - Project: Simulated Underground Mine Facility for training and research
  - Total project value: $785,000 [approx. ZAR 8.1 million]
  - Develop and establish a combined training and research Simulated Underground Mine in Mackay. This will be a pilot for the future, and world-leading, Australian Training and Research Underground Mining Simulator (ATRUMS).
- **Active Adrenalin**
  - Project: Holistic Safety Project
  - Total Project Value: $312,400 [approx. ZAR 3.2 million]
  - Active Adrenalin and Nutricula Psychology have collaborated to establish a scientific and innovative approach to worker wellness in the resource sector. There are 3 key objectives of the Holistic Safety Project: (1) To develop a measurement tool to assess physical, mental, and emotional wellbeing in the form of resilience and psychological safety; (2) to deliver a strategic Holistic Safety Training program to positively influence the assessment; and (3) to validate the link between worker wellbeing and safety performance.
- **Macdonald Cordell / Aurecon**
  - Project: Carryback-S Materials Handling Aid – Full Conveyor Application Trials
  - Total project value: $200,000 [approx. ZAR 2.1 million]
  - This project is a pathway for commercialisation of a spray-on product for conveyor belts that reduces carryback. Carryback is an industry-wide problem of fine dust from the product falling off the belt, resulting in both wear to conveyor components, and additional clean-up of the work area. Carryback-S can be likened to “Scotch-guarding” the belt, making the conveyor belt slippery so that the fine dust stays with the product, instead of sticking to the belt.
- **Split Spaces**
  - Project: Mining Tech - Rapid Prototyping Solution
  - Total project value: $200,000 [approx. ZAR 2.1 million]
  - Making rapid prototyping of mining and engineering solutions more accessible, by reducing cost through collaboration in the Bowen Basin region. This project will facilitate access to the infrastructure needed to undertake rapid prototyping, without the need for a costly commercial service or for each firm in the region to individually invest in this capability.

The Bowen Basin is still a new initiative (recipients of initial funding were announced in July 2018). While it is too early to gauge its success or otherwise, it is hoped that participants in the pilot program will realise the benefits of “coopetition” and will begin to formalise the cluster over time. Importantly, MI’s role is not limited to the provision of funding alone: the centre has been instrumental in establishing a cluster steering committee and at the time of writing this report was looking to recruit a cluster development manager who will provide long-term support for facilitation and growth of the Bowen Basin businesses throughout the lifetime of their projects.

5.1.3. Robotics and Automation Cluster Launch

In response to the increasing proliferation of robotics and automation technologies within the mining ecosystem, MI and the Queensland Government are looking to establish a Robotics and Automation cluster in SE Queensland to promote innovative and commercially viable solutions through greater firm-level collaboration. A Robotics and Automation Cluster kick-off meeting was held by MI in April 2019 and included presentations by industry leaders on new

developments in remote asset monitoring, autonomous mine vehicles and robotics as well as existing robotics and automation capabilities in South East Queensland.

5.1.4. Other initiatives

This section describes public and private initiatives that form part of the METS innovation ecosystem and provide complementary support to MI.

Cooperative Research Centres (CRCs)

The Cooperative Research Centres (CRC) program was established by the Australian government in 1990 to improve the effectiveness of Australia's research effort. Administered by the Commonwealth Department of Industry and Science, the program links researchers with industry and government with a focus on research application. The close interaction between researchers on the one hand and end users on the other is the defining characteristic of the program. The CRC Program offers support to industry, research and the community through two elements:

- **Cooperative Research Centre (CRC) grants** – supporting medium- to long-term, industry-led collaborations, up to 10 years.
- **Cooperative Research Centres Projects (CRC-P) grants** – supporting short-term, industry-led collaborative research, up to 3 years.

A CRC is a company formed through a collaboration of businesses, industry associations, universities and government research agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and other end users. The CRC undertakes research and development with the objective of producing utilitarian outcomes for public good that have positive social and economic impacts.

CRCs operate across the Manufacturing, Information and Social Services, Mining and Infrastructure, Agriculture, Environmental Services, and Medical Service sectors and applicants are actively encouraged to engage with the appropriate IGC to identify emerging research challenges relevant to industry. Since the commencement of the program, there have been 19 CRC selection rounds, resulting in the establishment of over 215 CRCs. Applications for the 20th selection round opened in May 2018 and outcomes were due to be announced in March 2019.

A key strength of a CRC lies in its governance. Overall activities are adaptively managed by the CRC management team and Board to maximise national benefits by terminating, redirecting or accelerating projects. CRCs also provide a mechanism for realising unanticipated commercial opportunities, i.e. in cases where technologies have applications beyond the interests of the commercial partners, the CRC can pursue these through the creation of spin-off companies or licenses, for example.

Shorter-term, CRC-P Grants were introduced in 2016. Successful CRC-P applicants are provided grant funds for up to three years for collaborations to solve industry problems and improve the competitiveness, productivity and sustainability of the Australian industries. CRC-Ps must have at least two Australian industry organisations including at least one small or medium-sized enterprise (SME), and one Australian research organisation.

Since its commencement, the CRC Program has been regularly reviewed. In 2012, the Allen Consulting Group evaluated the economic, environmental and social Impacts of the CRC Program. The report found that "between 1991 and 2017 almost A$14.5 billion (approx. ZAR 150 billion) of direct economic impacts are estimated to have accrued from CRC produced technologies, products and processes. This includes A$8.6 billion (approx. ZAR 90 billion) of

impacts materialised from 1991 to 2012 and a further $5.9 billion (approx. ZAR 60 billion) of imminent impacts estimated to occur over the next five years."[30]

Notable CRC's (past and present) within the resource sector include: MinEx CRC (2018 - c. 2028); CRC for Optimising Resource Extraction (2010 - 2021); Deep Exploration Technologies CRC (c. 2009 - c. 2019); CRC Mining (2003 - present); CRC for Landscape Environments and Mineral Exploration (2001-2008); and CRC for Mining Technology and Equipment (1991-2003) (replaced by CRC Mining).

Provincial

The Queensland Government was instrumental in bringing MI to the state (states and were invited to bid for the right to host the Industry Growth Centres within their territories). In addition to the national funding MI receives, the Queensland Government committed a further A$6 million to drive the early development and piloting of national METS sector initiatives in Queensland and supporting activities directly of benefit to the state.

The Queensland Government is also heavily involved in supporting the state's advanced manufacturers and start-up companies, many of which are in the METS sector, through a range of initiatives:

- Queensland's **Advanced Manufacturing Benchmarking Program** assists businesses to measure their performance and practices which subsequently informs their choice of a suite of business improvement measures offered by the Department of State Development, Manufacturing, Infrastructure and Planning or other agencies to help them grow and innovate.
- The **Boosting Business Productivity Program** comprises a series of workshops, forums and specific programs delivered across the state to strengthen business model development and management skills, increase participation in global supply chains, and address rising energy and other input costs.
- The **Advanced Manufacturing Transition Package**, supported by a network of "best practice" advanced manufacturing businesses, includes a series of workshops and forums delivered across the state to develop digital business capability and assist in new technology identification and absorption.
- **Jobs Queensland** is developing the state's Skills, Training and Workforce Development Strategy to prepare businesses for technical and workplace requirements of Industry 4.0. The strategy will include analysis of issues across the manufacturing components of the METS sector with a focus on the skills required to transition METS manufacturers from broad-based manufacturing to advanced manufacturing models.

In addition to the above, Queensland has established the **Engineering, Construction and Resources Innovation (ECRi) Hub** to support the development and uptake of innovation in the engineering, construction and resource industries. The broad goals of the ECRi Hub are to create opportunities for collaboration, help innovators get to market, match solutions to industry challenges, and drive economic benefit. The Hub aims to connect selected start-ups or more established SMEs with professional skills, services and knowledge that can improve their ability to commercialise new ideas/technology.

[30] Allen Consulting Group (2012): *The Economic, Social and Environmental Impacts of the Cooperative Research Centres Program*, report to the Department of Industry, Innovation, Science, Research and Tertiary Education, Canberra, September.

Finally, the Queensland Government's Advance Queensland Initiative has a number of programs and funding opportunities that can assist Queensland METS companies innovate a and grow. These include:

- The **Industry Attraction Fund** aims to attract businesses to Queensland by either relocating or establishing new projects in the state. The fund supports job creation, regional growth, increased innovation and the building of local supply chains.
- The **Knowledge Transfer Partnerships** program supports businesses with two-thirds of the cost of hiring a graduate to work on an innovative project.
- The **Ignite Ideas Fund** supports the development of new or improved products, processes or services to secure investment, launch into global markets and grow business.
- The **Industry Accelerator Program**, including the Igniting METS accelerator (see above), supports the development and market-testing of new products and services, positioning participants to seek investment and expand their customer base.
- **Innovate Queensland** is a series of capacity building workshops, webinars and collaboration activities aimed at innovators, entrepreneurs and organisations designed to help SMEs implement practical innovation and technology commercialisation solutions, grow their business through innovation activities, and create jobs.

Industry

Austmine, Australia's leading industry body for the Australian Mining, Equipment, Technology and Services (METS) sector, has developed an **Innovation Mentoring Programme** for the METS sector. Mentees receive a minimum of 10 hours' one-on-one mentoring with an innovation expert within the METS sector and have access to an additional five hours' group training and guidance through face-to-face and online sessions. Austmine also partners with the Australian Government in delivering its **Entrepreneurship Programme** for the METS sector and the Oil, Gas and Resources Sector. The Entrepreneurs' Programme is an Australian Government initiative to promote business competitiveness and productivity by providing free, confidential support to SMEs that want to improve performance or drive growth. Independent, industry-experienced, Business Advisers and Facilitators based around Australia work one-on-one with SMEs to identify the most appropriate services within the programme. They also work with larger companies to improve capability and efficiency of the supply chain. While the programme is individually customised, typical areas of assistance include: (i) Digital Strategy; (ii) Product and service development/commercialisation; (iii) Marketing and Communications strategies to improve communication of business capability; (iv) Business and diversification strategy; (v) Operational improvements; (v) Market research; and (vi) Access and connections to a network of research and development expertise.

Along with the one-on-one assistance, the Entrepreneurs' Programme provides access to training and knowledge development through its Learning Events programme. Learning Events are run in conjunction with Austmine and cover a broad range of topics from improving cash flow, to how to win more work and export development. Learning Events are run as half or one-day workshops or webinars, and are free to attend.

Unearthed Solutions is an Australian company that specializes in designing and organizing open innovation events for the resource industry. These events, or "idea contests", take the form of online challenges, in which registered participants compete for a money prize by solving a challenge proposed by a corporation, or "hackathons", intense, 54-hour activities that take place in a specific location during which teams of students, innovators, and entrepreneurs collaborate to prototype technological solutions to operational challenges posed by partner companies. The last Unearthed hackathon took place in Sydney from 12-

14 October 2018. Event partner, Australian gold mining company, Evolution Mining, provided participants with data sets to solve three operational challenges: (1) modelling concealed gold at Evolution's Mt Rawdon open-pit mine; (2) optimising truck payload and cycle speeds at the Cowal gold mine; and (3) minimising the amount of waste mixing with ore at Evolution's Cracow underground mine. In addition to hackathons and online competitions, Unearthed Solutions has also launched a six-month "mentor-driven accelerator program" to provide support to entrepreneurs to transform their technology prototypes to commercially ready products for global markets.

Mining3 is a fully industry-funded research organisation and CRC spin-off. Formally, CRC for Mining Technology and Equipment and then CRC Mining, Mining3 is generally regarded as the most successful entity to emerge from the CRC program. Mining3 comprises members from mining companies, mining equipment, technology and service providers (METS), and researchers and is directed by its mining industry members to develop and deliver transformational technology to improve the productivity, sustainability, and safety of the mining industry.

5.2. Canada

According to data compiled by the Mining Association of Canada, the Canadian mining industry directly employs 426,000 workers across the country in mineral extraction, smelting, fabrication and manufacturing, and indirectly employs an additional 208,000. In 2017, the minerals sector directly and indirectly contributed C$97 billion (over ZAR 1.1 trillion), or 5%, to Canada's total nominal gross domestic product. Mining also accounted for 19% of the value of Canadian goods exports in 2017. However, the latest edition of MAC's annual "Facts and Figures" report warns that the mining sector in Canada is in decline and will continue to decline in the absence of coordinated government support. In particular, the report notes a significant disparity between Canada and Australia in mining FDI as a percentage of total FDI as well as a continued fall in Canada's share of international exploration investment.[31]

5.2.1. The Mining Supply and Services (MSS) Sector

In Canada, the METS sector is referred to as the Mining Supply and Services (MSS) sector. While Statistics Canada does not collect data on the Canadian MSS sector, an economic impact study conducted in 2014 by PricewaterhouseCoopers LLP for the Canadian Association of Mining Equipment and Services for Export (CAMESE) surveyed 913 companies based in the province of Ontario that consider themselves mining suppliers.[32] The study estimated the MSS sector contributed over C$6.2 billion (approx. ZAR 71 billion) to Ontario's GDP and was a source of over 68,000 jobs in 2011. These jobs are estimated to have generated nearly C$4.6 billion (approx. ZAR 53 billion) in salaries and wages and nearly C$1.5 billion (approx. ZAR 17 billion) in government tax revenues. For comparative purposes, the study found that the direct economic impact of the MSS sector was larger than the size (GDP) of the information and communication technology manufacturing industry and the motion picture and sound recording industries in Ontario.

A study published by University of Toronto's Rotman School of Management in 2012 on the impact of mining on the provincial economy found that direct employment in mining in Ontario exceeded 16,000. Thus, with 41,000 direct jobs, the MSS sector provides 2.5 times the number of direct jobs as mining itself. Finally, by comparing the direct contribution of mining to Ontario's GDP with the direct contribution of MSS to Ontario's GDP, the MSS sector is estimated to be 77% as important to Ontario's economy as mining itself. Given that Ontario

[31]The Mining Association of Canada (2018): Facts and Figures report
[32] PwC (2014): Pan-Ontario mining Supply and Services Sector Economic Impact Study

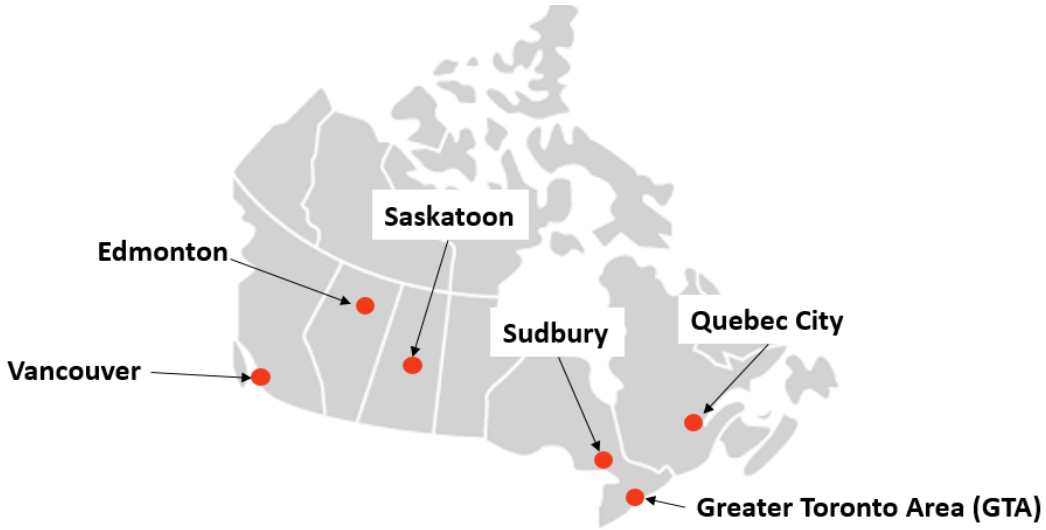
is the largest economy in Canada, with a GDP roughly twice that of neighbouring Quebec, Canada's second largest economy, the strategic importance of the MSS sector to Canada's economy is clearly evident.[33]

The MSS sector in Canada is represented by the Mining Suppliers Trade Association Canada (MSTA Canada), the Canadian equivalent of Austmine in Australia. MSTA Canada was previously known as the Canadian Association of Mining Equipment and Services for Export, which was originally founded as the Ontario Mining Equipment and Service Exporters in the 1980s. The rebranding of MSTA Canada occurred in 2017.

5.2.2. MSS Clusters

The MSS sector in Canada is made up of several distinct and globally recognized mining clusters. Each cluster is comprised of a dense and critical mass of resource companies, innovative small to medium sized product and service supplier companies, post-secondary institutions, industry associations, incubators and accelerators. Provincial and federal governments support these clusters with several funding programs and tax incentives that foster the research and development, innovation and commercialization of new products and services.

Figure 3: Key Canadian mining clusters



Source: MSTA (Mining Suppliers Trade Association)

Each of the Canadian mining clusters contains unique strengths, while sharing significant overlap with other clusters. For example, the Greater Toronto Area cluster has developed a critical mass of expertise in mining finance and other professional services related to mining (i.e. finance, accounting, legal, and engineering and environmental consulting) as well as water and energy technology development. The Sudbury cluster (see below) has a deep-rooted history of mining operations and a well-integrated mining innovation ecosystem, with globally-recognized expertise across all life-of-mine disciplines. Vancouver has developed into the primary global hub for mineral exploration and has a dynamic ecosystem of organizations providing pioneering advances in next-generation mining. The Quebec City and Montreal clusters have developed globally-recognized expertise in mineral processing, advanced sensing, and engineering services. Saskatoon has recognized expertise related to water treatment, environmental remediation, and engineering services, and has developed

[33] http://www.mining.com/web/new-survey-of-hidden-supply-sector-nearly-doubles-mining-contributions-to-ontarios-economy/

unique, globally-leading programs for Indigenous-focused training. Edmonton is the service and supply hub of oil sands development in Northern Alberta.

Unlike the Bowen Basin Cluster formally established by METS Ignited, the Canadian MSS clusters appear to have both developed organically and developed a sense of "self-conscious" as a cluster. Consequently, while federal and provincial government support these clusters in a variety of ways, the support itself does not seem to be as coordinated and deliberately integrated as that provided by the Australian government through METS Ignited.

The Sudbury Cluster

The Sudbury cluster is perhaps the most well-known of Canadian MSS clusters. It's evolution from a colonial frontier mining town into the largest integrated mining centre in the world with a population of around 160,000 people is well-documented.[34]

Until the 1970s, Sudbury's fortunes were closely aligned with the performance of two mining companies, Inco (now Vale) and Falconbridge (now Glencore), and have fluctuated accordingly. A paternalistic relationship existed between the city and the industry resulting in the mining companies exercising a high degree of control over municipal investments, service delivery and even political representation.[35]

Job losses as a result of increased consolidation and mechanization provided the impetus for the creation of the Sudbury Regional Development Corporation in 1974 in an attempt to transform the city's image and align city plans with Sudbury's economic development objective of attracting new business and reducing its reliance on mining. The release of a development strategy for Sudbury in 1978, known as "Sudbury 2001", marked a shift in traditional approaches that were typically influenced by the mining companies or driven by the government. Instead, "Sudbury 2001" took a more inclusive approach that used consensus building to define a long-term vision for Sudbury. In the 1980s, Inco and Falconbridge began to explore opportunities to increase productivity that included new investments in research, technology, equipment automation and process improvements to reduce environmental impact of their mining and smelting activity.

By 1991, the Sudbury Cluster was well established and showed significant growth potential when it was identified by Michael Porter in one of the key documents in developing Canada's innovation strategy[36]. However, as Robinson notes, the cluster suffered from a persistent lack of provincial champions throughout most of the 1990s which hindered its development despite the federal government adopting the cluster approach in 1994 and the cluster itself presenting a clear opportunity to both build on Canada's existing strength in resource production to develop industries based on advanced technologies. A turning point was reached in 1998 when the Ontario government announced it would transfer of the Ontario Geological Survey and offices of the Ministry of Northern Development and Mines from Toronto to the campus of Laurentian University in Sudbury in an effort to attract additional industry in northern Ontario by concentrating government assets in the region.[37]

Although the presence of the OGS helped to make Sudbury a centre for exploration and stimulated mining-related research, practical progress in providing cluster-based support to

[34] See, for example, David Robinson (2005): *The Mining Supply and Service Sector: Innovation Policies and the Delivery Gap*, Institute for Northern Ontario Research and Development, Laurentian University.
[35] Ibid.
[36] Michael E. Porter and Monitor Company (1991): *Canada at the Crossroads: The Reality of a New Competitive Environment*.
[37] David Robinson (2005): *The Mining Supply and Service Sector: Innovation Policies and the Delivery Gap*, Institute for Northern Ontario Research and Development, Laurentian University.

Sudbury continued to be limited. Further turning points were reached with the establishment of the Sudbury Area Mining Supply and Service Association (SAMSSA) and the Centre of Excellence for Mining Innovation (CEMI) in Sudbury in 2003 and 2007 respectively. SAMSSA, a membership-based organisation, formally represents and champions the interests of the Sudbury Cluster and offers a range of services to its members, including training and trade promotion. CEMI, a not-for-profit corporation collaboratively funded by industry and government, addresses key gaps in the innovation system through the development of technical innovations in ore discovery (FindMine), heat and rock stress in deep mines (DeepMine), mine productivity and operational performance (ValueMine), and environmental impact and sustainability (SustainMine) as well as facilitating their commercial viability.

In addition to CEMI, the Sudbury Cluster is also home to four post-secondary education institutions – Cambrian College, Canadore College, College Boreal and Laurentian University – providing over 75 mining-related programs between them, the Mining Innovation Rehabilitation and Applied Research Corporation (MIRARCO), a not-for-profit, research-focused corporation owned by Laurentian University that delivers applied research to key challenges in the mining sector, and NORCAT, formerly the Northern Centre for Advanced Technology, a not-for-profit technology and innovation centre inspired by the Finnish innovation centres and providing health and safety training for the mining industry, occupational health and safety services, and product development assistance to small, medium and large industrial enterprises.

In summary, the Sudbury Cluster has grown organically over the course of many years. It is a mature cluster held together by the historical presence of mining companies, the existence of over 500 MSS companies within the boundaries of Northern Ontario, and a critical mass of mining-related teaching and research institutions and agencies. Given the uniqueness of the Sudbury Cluster in the Canadian mining ecosystem and wider system of innovation, it was therefore surprising that the federal government rejected a Sudbury-led proposal to establish a pan-Canadian mining supercluster focused under Innovation Superclusters Initiative. The ISI is described in section 5.2.3 below.

5.2.3. The Innovation Superclusters Initiative[38]

In February 2018, the Canadian government announced that it would be investing up to C$950 million (over ZAR 10.1 billion) to “encourage large-scale collaboration through the acceleration of business-led, regional innovation superclusters with the greatest potential to build world-leading innovation ecosystems and enhance economic growth”. The investment, to be matched dollar-for-dollar by the private sector, is expected to create more than 50,000 middle-class jobs and grow Canada’s economy by C$50 billion (approx. ZAR 573 billion) over the next 10 years. Like clusters, superclusters are dense area of business activity containing a critical mass of large and small companies, post-secondary and other research institutions. Superclusters build on the advantages of a cluster by offering stronger connections, a long-term competitive advantage, global brand recognition, and an outsized positive impact on job creation and economic growth.

Based on the UK’s Catapult Programme and the German Fraunhofer Institutes, the ISI is managed by Innovation, Science and Economic Development Canada. Superclusters were selected on the basis of detailed proposals from industry-led consortia. The central objective for applicants was the proposal of a Supercluster Strategy that would support the long-term growth of the cluster in terms of the creation of major commercial opportunities, productivity

[38] Based on interviews with Ryan McEachern, Managing Director of the Mining Suppliers Trade Association of Canada (MSTA Canada) and Mark Naddaf and Yanick Clement-Godbout, Innovation Canada. Additional information on the ISI can be found here: http://www.ic.gc.ca/eic/site/093.nsf/eng/00008.html

enhancements, and job creation. Supercluster Strategies were structured around five themes of activity eligible for co-investment:

Box 6: ISI themes

- **Technology leadership.** Collaborative projects that directly enhance the productivity, performance and competitiveness of Member firms, such as:
  - collaborative R&D projects
  - demonstration or prototype development projects with benefits for multiple firms
  - development of production methods and processes involving industry and academic partners
  - private-sector led commercialization projects
- **Partnerships for scale.** Activities serving a target group of cluster firms to enable their growth, including by increasing domestic demand for cluster products and services or by facilitating expansion, such as:
  - linking start-ups with strategic partners (e.g., 'pitch days')
  - offering business mentoring, consulting and coaching
  - supply chain development or integration efforts for cluster SMEs with local anchor firms
  - partnering with a public stakeholder/organization that provides access to capital and financing
- **Diverse and skilled talent pools.** Activities enhancing regional labour force skills and capabilities or initiatives addressing industry needs for talent, such as:
  - a recruitment campaign to repatriate Canadian talent to the cluster; development of curricula linked to industry's needs and workforce integration programs for student
  - development and promotion of specialized certifications in areas of technology leadership; re-training programs (e.g., digital skills) for existing workforce
  - assessment of industry's current or anticipated workforce needs; or building awareness of industry demand for skilled talent across stakeholder groups (e.g., students, workers, firms, universities and vocational colleges, policymakers)
- **Access to innovation.** Investing in and providing access to assets, services or resources that benefit a range of cluster firms over a period of time, such as:
  - support for access to specialized technical services
  - installation of and access to dedicated laboratory or cutting-edge equipment
  - acquisition and assertion of jointly held intellectual property
- **Global advantage.** Activities and initiatives that position the cluster and its strengths as world-leading, enable firms to seize market opportunities, and attract international investments and partnerships, such as:
  - cluster promotion
  - investment attraction to cluster region; studies to identify new global markets for cluster products and services
  - participation in or leadership of trade missions to key geographic markets
  - development of regulatory or policy proposals to enhance domestic technology advantage
  - development and promotion of new international standards that embed Canadian approaches.

In addition to a Supercluster Strategy, full applications had to include, at a minimum, 10 private-sector enterprises – including at least two large firms (500+ employees), at least one medium firm (100-499 employees), at least four small firms (1-99 employees), and at least one other small and medium-sized enterprise (1-499 employees) – and one post-secondary institution (e.g., university, college, polytechnic).

Proposals were selected according to the following key criteria:

Box 7: ISI evaluation criteria

Impact and Strategic Importance

- The vision, mission and for supercluster aligns with ISI objectives and addresses industrial challenges in sectors of economic strength.
- The anticipated economic growth and industrial benefits of the proposal for Canada includes increased productivity and competitiveness of firms in the cluster and key sectors of economic strength, and the creation of business outcomes for participants.

Capabilities and Assets Aligned to Proposal

- The innovation ecosystem must have the capacity, technology capabilities, know-how and assets to achieve the objectives of the Superclusters Strategy. The proposals provide evidence of potentially highly innovative sectors of strength and strategic importance to Canada in the cluster.
- Proposals leverage key private, public and academic assets within the cluster region, as well as elsewhere in Canada at a large scale.

Implementation and Governance

- *Implementation Plan:*
  - Proof of commitments, including cash investment and in-kind contributions, which reflect the program's ambition and objectives.
  - Suitability of budget allocated to fulfil commitments.
  - Adequacy of plans for establishment of Entity and launch of activities.
  - Definition of clear and realistic project timelines and milestones to deliver on the activities outlined in the Supercluster Strategy.
- *Organization Model and Capacity:*
  - Demonstration of a sound governance model that reflects private-sector leadership and takes into account diversity of participating organizations.
  - Identification of executives with adequate leadership and management capabilities to ensure program success.
  - Identification of participants with adequate experience and a solid track record on innovation and collaboration.
  - Evidence of a sound project selection mechanism that is aligned with program objectives.
  - Adequacy of approach to manage revenues and finances.
  - Demonstration of a membership model that is open and provides opportunities for relevant organizations of various types and scales to participate, and fosters collaboration between organizations.
  - Suitability of data collection mechanism and results reporting strategy
  - Demonstration of an Intellectual Property (IP) Strategy that maximizes benefits for Canada, incentivizes member commitment and spurs innovation. Evidence of a strategy that provides frictionless IP and support for the development, acquisition, management, and defence of IP.

Of the 50 entities that submitted Letters of Intent (i.e., expressed interest), only nine were invited to make a full application. This included the CLEER (Clean, Low-energy, Effective, Engaged and Remediated) Supercluster, prepared on behalf of the mining sector by CEMI, MSTA and other organisations that aimed to build on the existing mining innovation ecosystem to make Canada a global leader in clean resource development and the responsible sourcing of raw materials. Of the nine short-listed entities, the following five Innovation Superclusters were selected and officially announced by the Minister of Innovation, Science and Economic Development on 18th February 2018:

1. Digital Technology Supercluster
2. Protein Industries Supercluster
3. Advanced Manufacturing Supercluster
4. AI-Powered Supply Chains Supercluster (SCALE.AI)
5. Ocean Supercluster

A list and description of the five Innovation Superclusters is provided on the following page. It should be noted that while the CLEER Supercluster proposal was not selected, many companies serving the Canadian MSS sector are members of the above superclusters.

Table 1. Innovation Superclusters Initiative overview

	Digital Technology Supercluster	Protein Industries Supercluster	Advanced Manufacturing Supercluster	AI-Powered Supply Chains Supercluster (SCALE.AI)	Ocean Supercluster
Regional concentration	British Columbia	Prairie provinces (Manitoba, Saskatchewan, and Alberta)	Ontario	Based in Quebec and spanning the Quebec-Windsor corridor	Atlantic Canada
Technology focus	Virtual, mixed and augmented reality; data collection and analytics; quantum computing.	Agri-food enabling technologies, including genomics, processing, and information technology (IT).	IoT, machine learning, cybersecurity, additive manufacturing (3D printing).	Artificial intelligence and supply chain technology.	Digital sensors and monitoring, autonomous marine vehicles, energy generation, automation, marine biotechnology and marine engineering technologies.
Sample activities					
Technology leadership	Undertaking collaborative research and development projects that will create integrated platforms, connect digital solutions to customers, and drive service improvements, such as improved access to remote care for Indigenous communities.	Undertaking collaborative technology projects for the creation of high-quality germplasm, smart production, novel process technology and product development.	Undertaking leading-edge applied research and technology development projects related to product and process design, and more.	Undertaking activities to develop next-generation AI-powered supply chain platforms and integrate cutting-edge technologies such as robotics.	Undertaking collaborative technology projects to digitize marine operations (e.g. autonomous marine vehicles, sensor networks).
Partnerships for scale	Helping start-ups and small and medium-sized companies grow by connecting them with resources, technology adopters and investors.	Undertaking activities to provide businesses with expertise on financing and capitalization and linking start-ups with strategic partners to scale.	De-risking technology acquisition, including support for technology demonstration and scale-up projects.	Establishing a match-making system for industry players to solicit new solutions from start-ups and SMEs.	Providing seed funding and a technology brokerage service to connect technology providers and end users of all sizes and across sectors.
Diverse and skilled talent pools	Undertaking activities to attract and retain women and underrepresented groups to the supercluster, and providing digital skills training for those working in traditional industry sectors.	Undertaking projects that target leadership opportunities for women and underrepresented groups, as well as certification programs for digital skills to promote wide-scale adoption of data analytics and artificial intelligence for improved nutrient and crop management.	Supporting training secondments in research centres and work-integrated learning programs, including for women and underrepresented groups.	Undertaking activities to establish a baseline for diversity in the industry, build AI and supply chain literacy and increase academic programs for high-demand skill sets.	Undertaking activities to attract leading talent, and working closely with post-secondary institutions to empower youth and encourage the participation of more women and underrepresented groups in science, technology, engineering and math.

Access to innovation	Developing virtual environments for rapid experimentation and testing.	Undertaking activities to support data sharing and value-chain development for plant-based proteins.	Mapping sources of technology and expertise and providing a solutions concierge service for manufacturers and technology firms.	Undertaking activities for secure data exchange and maximizing the cross-compatibility of technologies and innovations.	Providing access to facilities for prototyping and testing.
Global advantage	Undertaking activities to reinforce Canada's brand as a destination for global talent and innovative companies.	Undertaking international trade missions and market research, and developing a venture capital fund to seize global market opportunities and attract international investment and partnerships.	Undertaking activities to enhance supplier capabilities in international supply chains and attract talent and investment mandates to Canada.	Undertaking activities to connect to international standards forums and embed Canadian intellectual property, platforms and approaches into new standards.	Advancing the establishment of a Global Ocean Tech Alliance to collaborate with other countries leading ocean innovation.
Participants	More than 270	More than 100	More than 130	More than 110	More than 110
Website	https://www.digitalsupercluster.ca/	https://proteinindustriescanada.ca/	https://www.ngen.ca/	https://scaleai.ca/	https://oceansupercluster.ca/

6. Concluding Remarks and Implications for South Africa

Reflecting the latest positions of each country on the WEF's State of Cluster Development Index, clustering in the mining equipment and machinery sector in South Africa sits somewhere between METS Ignited on the one hand and the Canadian Government's Innovation Superclusters Initiative on the other. Based on interviews with METS Ignited staff, it does appear that clustering in South Africa's mining equipment and machinery sector is more advanced than clustering in Australia's mining equipment and machinery sector. There is certainly a better developed sense of "cluster consciousness" among South African mining equipment and machinery firms than their Australian counterparts as evidenced by well-established industry clusters such as MEMSA and, to a lesser extent, SAMPEC and the two clusters established by the RSA Clusters Programme, the Casting, Forging and Machining Cluster of South Africa, the Electro Technical Industry Cluster of South Africa, the Rail Manufacturers Cluster of South Africa.

In fact, the involvement of the above clusters in the Mandela Mining Precinct and their collaboration with each other, hints at the emergence of a South African mining equipment and machinery supercluster along the lines of those established through the Canadian Government's Innovation Superclusters Initiative. The difference between any of the Canadian superclusters and the emergent mining equipment and machinery supercluster in SA is that the latter appears to be evolving "organically" and without direct or explicit support from the state. There may well be firms in other sectors in South Africa that lack a clear sense of cluster consciousness and, therefore, deliberate, ground-up efforts along the lines of MI's Bowen Basin Cluster would be a more appropriate clustering strategy in those sectors. However, if one looks at the state of cluster development in the South African mining and machinery sector in purely narrow terms then there is clearly cause for optimism.

It is also worth noting that the Mandela Mining Precinct is, in its aims and objectives if not its institutional structure, similar to METS Ignited. That is to say, the Mandela Mining Precinct can be considered, in Australian terms, an industry growth centre for South Africa's mining equipment and machinery sector. Again, a key difference between METS Ignited and the Mandela Mining Precinct is that the former is one of six national, not-for-profit Industry Growth Centres wholly funded by the Australian government while the latter is a public-private partnership between the South African government, mining companies, manufacturers of mining equipment, research organisations, and academia. What does come through very clearly from how METS Ignited was established and how it operates is the extent of coordination between national and provincial government and how other policies, strategies and interventions support the work of METS Ignited and contribute to building the innovative capacity, and ultimately the competitiveness, of the sector as a whole.

Based on the review of cluster and other initiatives supporting the mining equipment and machinery sectors in Australia and Canada the following three implications may be drawn:

1. Government support is not necessary in realising the shorter-term benefits of clustering, i.e., decreased costs and increased sales, but the importance of coordinated state support rises when considering the longer-term benefits of clusters related to innovation and the absorption and commercialisation of technology. From the review of initiatives supporting industrial development Australia and Canada, it is evident that, echoing Mazzucato, the state is "thinking big" by envisioning a direction for technological change and investing in that direction. Through the Australian Industry Growth Centres and the Canadian Innovation Superclusters Initiative, Australia and Canada (respectively) are not just attempting to fix market failures but

are trying to create markets by creating a network of willing agents that are keen to seize opportunities across the entire innovation chain and engage in bottom-up experimentation.

2. Clustering is more important than ever before in the context of 4IR but a narrow focus on clusters alone undervalues the importance of other initiatives to build innovative capabilities and competitiveness. As the evidence from Australia shows very clearly, clustering must be part of a much wider, integrated system of support, especially if clusters are going to provide the additive benefits of responding to the challenges and opportunities of Industry 4.0. METS Ignited is not a cluster *per se* but an "Industry Growth Centre" mandated to improve the performance of the METS sector. Cluster development strategies and policies are part of that but they are not the sole focus. This partly explains why Australia ranks beneath South Africa in the WEF's State of Cluster Development index but ranks much higher than SA in terms of overall competitiveness. The State of Cluster Development is one of 10 indicators used to construct one of 12 pillars that compose the Global Competitiveness Index. While one may disagree with how the GCI is constructed the fact remains that there is more to competitiveness (and innovation) than clustering alone.

3. A truly supportive ecosystem depends crucially on a coordinated approach between national and provincial government as well as sufficient capacity at the provincial level. The lack of support provided to the Sudbury Cluster throughout most of the 1990s was due to the almost complete lack of champions at the provincial level. Provincial policies in Ontario during the 1990s also prevented Laurentian University from developing programs around the mining industry. The effect was to inhibit the development of the research base for the mining industry in Sudbury until 2002 when Laurentian University was allowed to create programs in Precambrian Geology and Natural Resource Engineering. A stand-out feature of the mission to Brisbane in March 2019 to meet with METS Ignited and other stakeholders was the active involvement of the Queensland Government in supporting METS Ignited and the METS sector in the state. The Queensland Government has its own METS 10-year Roadmap and Action Plan as well as a range of initiatives to support industrial development, innovation and start-up activity in the state which are backed by the human resources to implement them.

So what does this mean for clustering in South Africa in general and, more specifically, clustering in the mining equipment and machinery sector?

1. The dti's Cluster Development Program should be reinvigorated but it should not be used as a blunt tool to support all kinds of clusters in every sectors. A new CDP could, for example, be used to stimulate cluster consciousness among firms in the same way as METS Ignited is stimulating the development of a proto cluster in the Bowen Basin. A separate programme (or component of the CDP) could provide more targeted support to clusters – based on an assessment of their specific needs and requirements – as they mature.

2. Cluster development in South Africa must be part of an integrated strategy to develop innovative capabilities and improve industrial competitiveness. More effort should be made to develop coordinated partnerships between the dti, DST, provincial governments, and the private sector in this regard. The competitiveness of an individual company depends on the network of other firms and institutions, including public institutions such as universities and science councils, as well as the degree of

coordination and alignment between national and sub-national policies, strategies, and plans.

3. Continued collaboration between the four mining equipment and machinery related clusters embedded in the Mandela Mining Precinct should be encouraged. If a supercluster does emerge, the dti and DST should consider designing a targeted programme of support for the cluster along the lines of the Canadian Innovation Superclusters Initiative.

4. More use should be made of open innovation models and initiatives to strengthen and deepen the innovation ecosystem for mining equipment and machinery in South Africa and to make it more inclusive. The role of industry, universities, and local government is crucial in this regard.

5. Finally, by focusing (at least nominally) on mining equipment and machinery we are potentially underestimating the extent of South Africa's mining supply industry. Mining equipment and machinery must be thought of as distinct from mining (which it is) and in much broader terms (which it likely is not). It is important to remember that the METS sector in Australia was not defined until a landmark Austmine survey in 2013 revealed the extent of the mining supply industry and its contribution to growth and employment. There then followed a significant amount of federal, and state-led support to the METS sector, which included METS Ignited. Government support is necessary but in order to define its scope we need to understand the size of the sector we are dealing with. Unless we go through the process of identifying/defining those elements that constitute METS (to use the Australian terminology) and aggregating them, any policy or initiative that attempts to support the sector may be mis-specified, or worse, counterproductive.