STAYING AHEAD OF THE GAME

HOW AUSTRALIA CAN HARNESS NEW TECHNOLOGIES IN THE MINING AND OIL AND GAS INDUSTRIES TO ADD OVER $70 BILLION TO THE ECONOMY IN 2030 AND CREATE THOUSANDS OF NEW JOBS IN THE DOMESTIC SUPPLY CHAIN

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strategy x economics

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How Australia can harness new technologies in the mining and oil and gas industries to add over $70 billion to the economy in 2030 and create thousands of new jobs in the domestic supply chain.

Prepared for NERA and METS Ignited

APRIL 2019

TABLE OF CONTENTS

This report provides an economic analysis of the potential opportunities and impact of technologies such as data analytics, automation and robotics on Australia's mining and oil and gas industries in the next decade. It was commissioned by the Industry Growth Centres for Mining Equipment, Technology and Services (METS Ignited) and National Energy Resources Australia (NERA) and prepared by AlphaBeta as the first in a series of reports and activities to help Australian resources companies, their suppliers, educators, researchers, and governments understand the opportunities that enthusiastically adopting digital automation technologies will bring to growth, skills and employment across Australia's regions and cities.

For simplicity, we refer to the mining and oil and gas industries as the "resources industries" or "sector" in the remainder of this report. We also refer to the rapidly developing data analytics, automation and robotics technologies as "automation technologies". These technologies are delivered by the equipment, technologies and services sector, which we refer to as the "supply chain" for automation technologies for the resources sector.

Australia has some of the most competitive mining and oil and gas operations in the world. With its abundance of natural resources, the continent is home to five of the 25 largest mining companies globally and on track to become the world's largest exporter of LNG. The companies in these industries have for years been at the forefront of operational excellence and technological innovation, enabling them to become an important source of exports, high-paying jobs and national wealth.

In addition to its wealth of natural resources, Australia has one of the world's most innovative resources sectors, one that has supported a strong, innovative supply chain and millions of jobs and communities around Australia while also earning Australia a huge export income. For over 100 years, Australian technological innovation and resourcefulness has been at the forefront of some of the sector's most important developments including remote operating vehicles, horizontal drilling, airborne exploration technologies, energy-efficient comminution, mineral flotation, and subsea technologies such as long subsea tiebacks. The sector has also invested heavily in technologies to minimise waste and deliver world-leading environmental and safety performance. Today, global technological developments and the transition to a low-carbon future present Australia's resources and energy sector with an opportunity to build on this record.

❚❚ *Australia has some of the most competitive mining and oil and gas operations in the world.* **❚❚**

Data analytics, automation and robotics technologies continue to transform the resources sector. Technology has for decades been an integral part of manufacturing and agriculture, often shouldering the dirtiest and most dangerous work. Data analytics tools and digital transactions software have since begun to disrupt banking, telecommunication and retail. Now, technology is transforming the mining and the oil, gas and energy industries: self-driving trucks are hauling ore across pits, wireless sensors are monitoring pipeline networks, and robots are repairing equipment in dangerous environments undersea and underground.

Australia cannot turn a blind eye to this development. The increasing use of technology is a global phenomenon. Australia must be at the forefront of technological progress or risk other countries taking the lead in these globally competitive markets.

Internationally competitive commodity-based industries are price-sensitive and must keep abreast of, if not lead, innovation that drives efficiency and productivity. Failure to innovate and adopt evolving technologies would have large negative impacts on the national economic benefits and employment available in the sector. The question for Australian industry is how to be a positive adopter of technological and business model innovation in these fields. We have a choice to lead or lag.

The purpose of this report is to attempt to predict the nature and scale of **how Australia's resources industries, including both the producers and their supply chains, might change** if they fully embraced the latest advances in operational technologies such as analytics, automation and robotics. **The report further analyses what these changes mean for employment and workforce development (especially in the operations areas across regional Australia), and the wider economy.**

To estimate the impact of these technological changes, this report analyses **30 types of technological innovation** considered most relevant. More than four dozen interviews with industry and technology experts support the findings.

The analysis reveals a tremendous opportunity for Australia. Embracing the use of automation technologies in Australia's resources industries could, if coordinated and well-managed, add **$74 billion in value** to the Australian economy, in both regions and cities, and create over **80,000 new jobs**

by 2030. Managing change well is not just about adoption, but is also about seizing new opportunities in technology supply and developing the required workforce skills.

With its existing competitive advantages, Australia has the potential to further develop a world-class capability in the development and integration of all of automation technologies, become the primary technology supplier to local resources producers, increase exports and generate tens of thousands of new jobs. The export potential of these technologies (not measured) is also likely to be in the tens of billions by 2030.

The benefits from deploying these technologies in Australia's resources industries can be spread across the economy. New technologies will create new opportunities for primary firms to be more productive and internationally competitive, to discover and access new resources, and to expand. This in turn would boost local suppliers and the wider economy. A growing use of automation technologies would also generate **indirect social and economic benefits**, including significant environmental and safety performance improvements and a smaller industrial footprint.

These opportunities are real. Australia has the right foundation to lead the adoption and development of automation technologies in the resources industries through its world-renowned, highly competitive resources technology supply chain. Local universities, research institutions and a host of small innovative technology firms have already developed strong technical expertise in applying automation technologies to Australian resources operations. The appetite for new technology is strong and a prime example of our innovation is the fact that Australian technology developers already produce the majority of the world's specialist mining software. Other companies serve this growing market in aspects such as design, installation and maintenance. The breadth of skills, capabilities, technologies and services contributing to efficiency and productivity in the resources sector will expand in coming years.

To realise this vision, Australia needs to be bold. Policymakers, mining and oil and gas companies, education providers, researchers and regional development organisations need to work together to ensure Australia provides the right environment for local technology service providers to thrive in the increasingly competitive globalised environment.

These benefits will not come automatically. If Australian equipment, technology and services suppliers are unable to support miners and energy producers in their drive to automate large parts of their operations, these producers will be forced to import advanced equipment and services, seriously shrinking the economic opportunity for Australia. In this scenario, Australia would become a passive recipient of technologies produced elsewhere instead of spearheading the technological progress itself. **The full economic, social, environmental and safety benefits of these technologies will only materialise if a globally competitive domestic supply chain is created to participate in this transition.** Unless the domestic supply chain actively participates, the opportunity to generate an estimated $32 billion of benefits and 265,000 jobs will be lost.

Government and industry are already contributing to the growth of a domestic supply chain capable of supporting primary firms' adoption of advanced automation, including supporting world-class research and development programs.

A concerted push to reset the national agenda and fully embrace the economic opportunity from these emerging technologies is needed. To build vibrant, innovative, internationally competitive and export-capable supply chains, firms, researchers and government will need to work together.

A four-step roadmap will lead Australia to success:

1. Strengthen collaboration. Industry, government, education providers and researchers need to join forces and commit to developing this technology together. This report is a call to action. The collaboration needed for this national agenda will be fostered by establishing a central leadership forum, jointly funded by industry and government, to steer the development of the automation technologies supply chain for the resources sector.

2. Create and support national clusters. Australia needs to establish cross-industry automation technologies clusters, for example for remote operating centres with advanced capabilities in visualisation or robotics / drones / remote operating vehicles (ROVs). These clusters would reach across Australia as a networked set of hubs of interconnected businesses, suppliers, and associated institutions. International best practice shows that clusters—at the right location, and with the right governance and branding—can facilitate innovation, collaboration and knowledge sharing. Based on best practice, these clusters will become the platform to help technology suppliers network, collaborate, find and develop talent, and explore new business opportunities in both the regional and metropolitan centres across Australia.

3. Expand the entrepreneurial ecosystem. Australia needs to become a thriving entrepreneurial marketplace for commercialising ideas. Several elements could help primary firms, suppliers and universities produce innovative, market-ready technology, including a joint innovation fund, a joint roadmap, public registries of suppliers, Living Labs, and commercial innovation accelerators.

4. Boost skills and R&D. Industry, education providers and governments need to intensify efforts to build a pipeline of talent to meet the rising demand for skills and innovation, including transitioning today's workforce into the workforce of the future. Building a strong basis for R&D and skills in emerging automation technologies is a priority if Australia's resources industries want to remain internationally competitive in the long run. This would also involve developing new cross-industry and cross-community training programmes in data analytics, automation and robotics as well as research collaborations between Australian and international universities in these technologies. Australia could also strengthen R&D efforts in these technologies by enhancing and establishing more cross-industry innovation hubs that include research focused on pre-competitive innovation. Such institutes combine R&D in several industries from agriculture, mining and oil and gas to manufacturing, construction and defence and attract scale-up opportunity from corporate organisations.

❚❚ The full economic, social, environmental and safety benefits of these technologies will only materialise if a globally competitive domestic supply chain is created to participate in this transition. ❚❚

2

DIGITAL TECHNOLOGIES ARE TRANSFORMING THE RESOURCES INDUSTRIES

This chapter provides an overview of relevant digital automation technologies, their current levels of maturity and their potential benefits for resources companies.[1] The roadmap presented in this report comprises our assessment of around 30 of the most common and impactful use cases of such technologies in the resources industries.

TAKING STOCK: 30 USE CASES OF DIGITAL AUTOMATION TECHNOLOGIES FOR THE RESOURCES INDUSTRIES

Automation technologies to enhance operations in the resources industries can be divided into three broad categories:[2]

- **Operational hardware** – digitally enabled hardware tools capable of operating independently of workers or that are remotely assisted by workers to perform or improve activities that have traditionally been carried out manually or with worker-operated machinery.

- **Connected worker** – technology that leverages mobile, sensor, asset tracking, analytics and wearable technology to more effectively execute the work activities of an industrial or field worker.

- **AI and connected ecosystem** – artificial intelligence tools and algorithms to process vast amounts of operational data, and software to integrate systems and optimise autonomous equipment/services for maximum operational performance.

A detailed list of technologies under each category can be found in TABLE 1.

TABLE 1: A review of key automation technologies

This report highlights 30 use cases of automation technologies that are most relevant for the resources industries today and in the future. The technologies included in this review were selected based on insights from interviews and a review of literature and best practices at key firms. The chosen technologies are not comprehensive but represent many of the technologies that are emerging. They were measured for impact and assessed across the value chain. Despite best efforts to create mutually exclusive categories, a number of these technologies overlap.

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1. Digitalisation and automation use machines to perform tasks that have in the past been done by humans. It includes a broad range of technologies such as advanced analytics, Artificial Intelligence (AI), robotics and 3D printing (additive manufacturing) which are collectively referred to as 'automation technologies' in this report.
2. The categorisation and technologies are not mutually exclusive. Categorisation aligned with World Economic Forum (2016) Digital Transformation Initiative, available here: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/white-paper-dti-2017-mm.pdf.

MINING

Phase	Technology	Description
AI and Connected Ecosystem		
Exploration	Geospatial analysis	Algorithms applied to geospatial data to detect viable ore bodies and analyse existing ore bodies (e.g. detect impurities).
Development	Intelligent design software (e.g. digital twins)	Simulation software that allows analysis and testing of mine sites, operations and scenarios to inform decision making, for training, and to predict and prevent equipment failure.
Production and logistics	Predictive maintenance	Use of real-time and historical data to anticipate problems concerning equipment or sites.
Production and logistics	Machine learning / data analytics	Application of historical and real-time data to optimise the resource-to-market chain.
Operational hardware		
Production	Autonomous drills	Drills that navigate the mine site and drill designated areas using a range of sensors and GPS.
Production	Autonomous continuous miners	Machines that are capable of both cutting and crushing the rock face (typically used underground).
Production	Autonomous excavators / shovel swings	Machines that excavate and shovel ore without operator intervention using GPS, Lidar etc.
Production	Autonomous load-haul-dump trucks	Vehicles that can haul, load and dump ore without operator intervention, using sensors.
Production	Autonomous ancillary vehicles	Various ancillary vehicles on a mine site – e.g. water trucks (used for dust control, compaction) – could be automated.
Production	Autonomous unmanned aerial vehicles	Remote-controlled drones are used as an alternative to terrestrial survey mapping, with other potential uses including pit wall mapping and spare parts transportation.
Production	Maintenance robots	Use of aerial or land-based robots for dangerous or repetitive maintenance tasks (e.g. robotic tire changers).
Production	3D printing	Additive manufacturing (3D printing) to construct spare and bespoke parts.
Logistics	Autonomous rail	Trains which transport ore from the mine site to the port without operator intervention.
Logistics	Autonomous ship loading	Use of video cameras, thermal imagers, lasers and sensors to load a ship from a central control room.
Production and logistics	Digitalised sensor networks	Sensors that collect physical, chemical and other data, converting it into a digital format for analysis.
Rehabilitation	Autonomous vehicles	Use of autonomous vehicles to fill-in land. Advanced sensor technology required due to the unstable ground conditions.
Rehabilitation	Smart sensors	Use of smart sensors and data analytics to monitor environmental conditions.
Connected Worker		
Production and logistics	Remote operations centres	Monitoring / operation of equipment from a remote operations centre, using advanced IT systems and virtual reality technologies.
Production	Use of wearables	Technologies that enable workers to interact with the sensors, robots and systems around them, or that otherwise augment the worker.

OIL AND GAS

Phase	Technology	Description
AI and Connected Ecosystem		
Exploration	Machine learning applied to seismic data	Faster processing of seismic data using machine-learning algorithms.
Development	Intelligent design software (including digital twins)	Use of algorithms to optimise processing plant design and to re-design rigs for autonomous operation.
Production	Predictive maintenance	Use of real-time and historical data to anticipate issues with offshore, onshore and subsea assets.
Production	Machine learning / data analytics	Application of historical and real-time data to optimise the resource-to-market chain.
Operational hardware		
Development	Unmanned, intelligent drilling	Complete automation of an already highly automated drilling process, supplemented by data analysis for more efficient drilling.
Production	4D seismic imaging	Acquisition, processing and interpretation of repeated seismic surveys of a producing field to analyse the seismic impact of production.
Exploration	Autonomous vehicles	Autonomous vehicles (aerial and subsea) powered by renewable energy and currents collecting data on exploration targets.
Production	Subsea processing and subsea tie-backs	Processing oil and gas on the seafloor rather than on a fixed or floating platform, where fields are located in harsh / deep-sea conditions.
Production	3D printing	Additive manufacturing (3D printing) to construct spare and bespoke parts for platforms and plants.
Production	Caretaker robots	Autonomous robots (land, subsea, aerial and amphibious) for dangerous / remote maintenance work and data gathering.
Production	Autonomised, digitised sensor networks	Wireless sensor networks that collect physical, chemical and other data, converting it into a digital format for decision-making.
Connected Worker		
Production	Use of wearables	Technologies that enable workers to interact with the sensors, robots and systems around them, or otherwise augment the worker.
Production	Remote operations centres	Monitoring / operation of equipment from a remote operations centre or other safe location, using advanced IT systems and virtual reality technologies.

2.1 USE OF AUTOMATION TECHNOLOGIES IN THE RESOURCES INDUSTRIES WILL LIKELY OCCUR IN THREE WAVES BETWEEN NOW AND 2030

In coming years, these technologies will continue to evolve and become even more valuable to mining and oil and gas companies than they are today. The development will likely occur in three stages.

EXHIBIT 1

Three stages of development in automation technology to 2030

	Present ① **Automated equipment** ⚙	**2025** ② **Connected, digitized pieces of equipment** 🔧	**2030+** ③ **Integrated value chain** 🔗
Example technology	Proprietary drones, autonomous haulage systems, autonomous underwater vehicles	Smart sensors that both monitor and control equipment in plant / mine	Automated machinery and equipment that is working in concert together e.g. drills, trucks, shovels
Level of interoperability	Low: technologies developed by a handful of OEMs; not standardised or interoperable	Medium: equipment and data from a range of different vendors capable of operating together	High: open source platforms which allow integration and inter-operability across value chain
Drivers	• Safety • Operational and capital productivity	• As with stage 1 • Reduced automation costs	• As with stages 1 and 2 • Integration benefits / access to new resources
Level of automation	Mainly semi-automated tech; but with some full automation	Most equipment now fully automated; limited self-learning	Equipment and processes capable of self-learning and making decisions without human input
Data aturity	Low: identifying value of existing data sets using machine learning	Medium: filling gaps in datasets to enhance machine learning	High: Advanced data analytics across value chain
Size of the prize[1]	Additional annual GVA generated in 2017-18 by automation in: • Mining = $3B • Oil and gas = $0.5B	Additional total annual GVA generated in 2025-26 by automation in: • Mining = $33B • Oil and gas = $5B	Additional total annual GVA generated in 2030-31 by automation in: • Mining = $65B • Oil and gas = $9B

Source: Interviews, AlphaBeta analysis
1 Total GVA across economy including primary firm impact, supply chain and wider economy.

◼ Phase 1 (today): Individual equipment automation

Most of today's mine sites and oil and gas assets are being transformed by the digitalisation of individual pieces of equipment. For example, sensors can monitor equipment by constantly collecting activity data and alerting staff of irregularities in running an operation. They can capture information about the effectiveness of a drill rig by measuring the drill hole, detect corrosion on an underwater pipe or provide constant information about vehicle locations. However, operation of the individual pieces of equipment is generally difficult to integrate as much of the advanced equipment is owned by a handful of original equipment manufacturers (OEMs), and technology from different manufacturers does not easily interact.

In this phase, automation is partial and not complete. For example, excavators or underwater vehicles are often tele-operated, but still require substantial involvement from operators. A lack of IT capability and patchy data also means that the full potential of real-time data analytics is not achieved.

■ **Phase 2: Connecting equipment**

By about 2025, mining and oil and gas companies will have likely entered a new phase in their efforts to create the fully integrated and automated mine or plant.

While the technology uptake in the first phase was primarily characterised by digitalisation of individual pieces of equipment, the second phase will be marked by the growing interoperability of that equipment and adoption of new automation technologies currently in development. By 2025, technology experts and industry participants expect that almost all resource producers will have automated substantial parts of their operations: most equipment on mine sites and in oil and gas plants will be fitted with an array of wireless smart sensors that monitor and control the movement of machines and operation of plants.

Technology manufacturers will spur this development by increasingly standardising their products, pressured by large producers that need their equipment to be interoperable. This is expected to open up the market for new competitors and lead to growing use of unbranded automation technology. It should also bring about new opportunities for companies in the supply chain. As the market for automation technologies expands and technological progress becomes more entrenched, the data quality will improve along with the ability to analyse data using machine learning and AI. These types of developments provide a particular opportunity for Australian suppliers into both oil and gas and mining; suppliers that are already well-respected for success in integrating point solutions and technologies developed by others.

■ **Phase 3: Connecting the whole value chain**

In a final phase, potentially starting around 2030, companies will continue to automate their production as they seek to realise very large benefits from technology integration.

At this stage, many technologies will be highly interoperable across the entire value chain, from drilling through to shipping. Different pieces of equipment will work in concert to perform highly complex tasks with unprecedented efficiency. For instance, systems integration software will enable operations to become more responsive to factors such as customer demand for a certain grade of ore (instantly identifying where this ore is located and drilling for it) and operational issues (such as automatically diverting trucks to the nearest available loader).

Most equipment is expected to be fully autonomous by 2030. It will also be capable, to varying degrees, of using advanced data analytics and self-learning software to continuously find ways to improve product quality and operational efficiency. The increasing digitalisation and integration of resources operations will substantially improve productivity, reliability and safety, as well as reducing the sector's environmental footprint.

2.2 DIGITAL AUTOMATION TECHNOLOGIES COULD ADD OVER $50 BILLION IN VALUE TO THE MINING INDUSTRY IN 2030, BOOSTING ITS VALUE ADDED BY AS MUCH AS 58 PER CENT

The automation technologies featured in this report have the potential to make resources extraction in Australia more productive, efficient and valuable through:

■ Higher operational productivity – automation can reduce the cost of intermediate goods (goods that are used within a year of purchase) and labour while increasing output. For instance, autonomous load-haul-dump trucks consume less fuel than a manned truck.

■ Improved capital productivity – automation can reduce expenditure on equipment, plants and machinery, while improving asset utilisation. For example, autonomous trucks have improved utilisation (as they take less breaks than in today's operations) and lower maintenance costs.

■ Access to new resources – automation technologies can reduce costs enough to make previously unviable projects feasible or increase the rate at which new resources are found.[3] For example, ore bodies can now be identified via airborne geophysical techniques and mapped using autonomous or remotely operated drilling rigs.

■ Systems integration – digital technologies can be used to integrate automated plants and equipment, especially on greenfield sites and plants. This increases overall efficiency and productivity, for example, by linking automated trucks and drills in concert.

■ Society and the environment – automation technologies can significantly improve workplace safety as well as reduce energy use. These types of impacts are not part of this report's analytical model, but are important benefits and are qualitatively discussed (with supporting figures) in section 4.5.

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3. Non-automated technologies will also influence the sector's access to new resources. Though a recognised impact, it is out of this report's scope.

Applying digital automation technologies across Australia's resources sector would boost the sector's productivity and create substantial value for the Australian economy. To calculate the potential impact of this automation, the analysis compares two scenarios: one scenario where the uptake of automation technologies in the resources industries continues; and another scenario where no further automation will take place, resulting in a constant Gross Value Added (GVA) to 2030.[4]

Without further automation, GVA from the mining industry held constant would be $90 billion in 2030 (see EXHIBIT 2).

With additional automation, the mining sector could generate $142 billion in GVA in 2030, an increase of 58 per cent relative to the no-automation scenario.

EXHIBIT 2

Automation technologies are estimated to add $52 billion in value to the mining sector in 2030, lifting total value added by 58%

Sources of automation value in Australian mining
Gross Value Added in mining in 2030, $B 2015
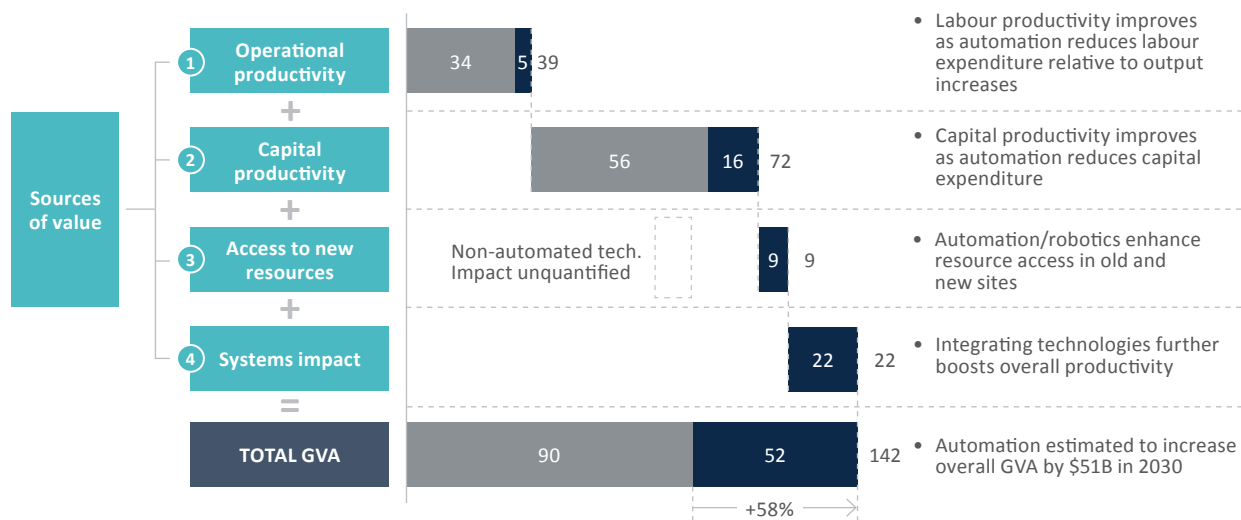
Sources of value		GVA	Impact	Total	Notes
1	Operational productivity	34	5	39	Labour productivity improves as automation reduces labour expenditure relative to output increases
+					
2	Capital productivity	56	16	72	Capital productivity improves as automation reduces capital expenditure
+					
3	Access to new resources	Non-automated tech. Impact unquantified	9	9	Automation/robotics enhance resource access in old and new sites
+					
4	Systems impact		22	22	Integrating technologies further boosts overall productivity
=					
	TOTAL GVA	90	52	142	Automation estimated to increase overall GVA by $51B in 2030

+58%

- Access to new resources is a 0.6% increase in available resources due to automation/robotics
- System impacts are a 0.9% increase in total factor productivity per technology due to integration
- These figures were derived from industry interviews. See Appendix for further details

Source: AlphaBeta analysis

4. Gross Value Added is defined as the value of goods and services produced in a sector minus the cost of intermediate goods used in production. The figure for capital productivity was derived by calculating the shares of expenditure on labour and capital and applying those proportions to total GVA. Though an unlikely scenario, assuming a constant GVA in the years to 2030 assists in isolating the effect of automation from 2018 onwards and makes modelling more tractable. See Appendix for further details.

EXHIBIT 3

These technologies are responsible for increasing overall value added in primary mining firms by $52 billion in 2030

Automation & robotics impact on total mining Gross Value Added
Additional value uplift in mining based on expected take up and impact, $B 2015

Note: Only primary firm GVA in 2030

Exploration & Development
- Geospatial analysis
- Intelligent design software

Production
- Autonomous drills
- Autonomous continuous miners
- Autonomous excavators / shovel swings
- Autonomous load-haul-dump trucks
- Autonomous ancillary vehicles
- Autonomous unmanned aerial vehicles (drones)
- Autonomous robots
- 3D printing / Additive manufacturing
- Connected worker tech
- Predictive maintenance
- Integrated data analytics & machine learning
- Remote operations centres
- Digitised sensors networks

Logistics
- Autonomous rail
- Autonomous ship loading

Rehabilitation
- Autonomous vehicles to fill in the land
- Smart environmental sensors

Source: Interviews, AlphaBeta analysis

Some digital technologies could have larger impacts than others. For example, integrated data analytics and machine learning are expected to have the greatest impact, increasing value added in the sector in 2030 by about $10 billion, followed by intelligent design software with a $7 billion impact (EXHIBIT 3). This is unsurprising, as the use of integrated data analytics can greatly improve equipment utilisation e.g. it can be used to identify and remedy bottlenecks in production. Similarly, intelligent design software can generate significant equipment, construction and procurement savings. As shown in EXHIBIT 3, digital technologies stand to improve mining operations across the entire value chain.[5]

> **❝ Applying digital automation technologies across Australia's resources sector would boost the sector's productivity and create substantial value for the Australian economy. ❞**

5. The rate of uptake of automation has been modelled as a smoothly increasing function between 2017 and 2030. This assumption made modelling more tractable. In reality, automation uptake will unlikely be steady and rather occur in large shifts. The ultimate impact of automation in 2030 can be assumed to be similar, whether automation occurs gradually or in leaps.

2.3 DIGITAL AUTOMATION TECHNOLOGIES COULD ADD $8 BILLION IN VALUE TO THE OIL AND GAS INDUSTRY IN 2030, BOOSTING ITS VALUE ADDED BY 30 PER CENT

Automation technologies are also set to improve the operations of oil and gas companies in Australia, albeit on a smaller scale given the sector's size relative to mining. Without further automation, GVA could be $27 billion in 2030, with $8 billion of this value derived from operational productivity and $19 billion from capital productivity (see EXHIBIT 4).

Applying further digital automation technologies, the oil and gas industry could generate $35 billion in GVA in 2030, an increase of 30 per cent relative to the no-automation scenario. The industry will create more value in the Australian economy because automation technologies will improve its overall productivity through systems integration, enhance its capital productivity, and make it easier for companies to access new resources.

As at 2017, the oil and gas industry has automated a sizeable portion of its value chain, meaning workers mainly undertake

non-automatable tasks. Consequently, AlphaBeta estimates that the use of automation technology will only marginally reduce operational costs in the oil and gas industry between 2017 and 2030. This is anticipated to occur through a small reduction in some current roles being offset by a small rise in the workforce elsewhere due to an automation-related increase in oil and gas output.

Some automation technologies will likely lead to greater productivity gains in the oil and gas industry than others. Data analytics, predictive maintenance, and sensor networks are expected to have the largest impact (EXHIBIT 5). These technologies are particularly beneficial in the production phase where, among other things, they can boost plant utilisation (as plant shutdowns will be shorter and less frequent) and reduce maintenance costs (due to continuous monitoring by sensors and predictive maintenance analytics).

EXHIBIT 4

Automation technologies are estimated to add $8 billion in value to the oil and gas sector in 2030, lifting total value added by 30%

Sources of automation value in Australian oil and gas
Gross Value Added in oil and gas in 2030. $B 2015
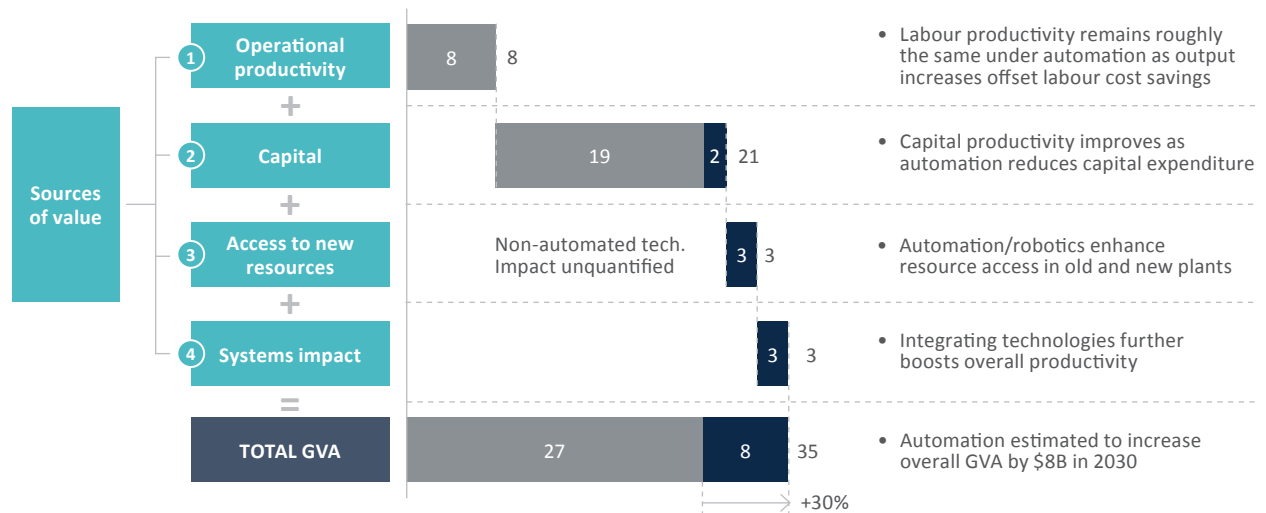
- Labour productivity remains roughly the same under automation as output increases offset labour cost savings
- Capital productivity improves as automation reduces capital expenditure
- Automation/robotics enhance resource access in old and new plants
- Integrating technologies further boosts overall productivity
- Automation estimated to increase overall GVA by $8B in 2030

- Access to new resources is a 0.6% increase in available resources due to automation/robotics
- System impacts are a 0.9% increase in total factor productivity per technology due to integration
- These figures were derived from industry interviews. See Appendix for further details

Source: AlphaBeta analysis
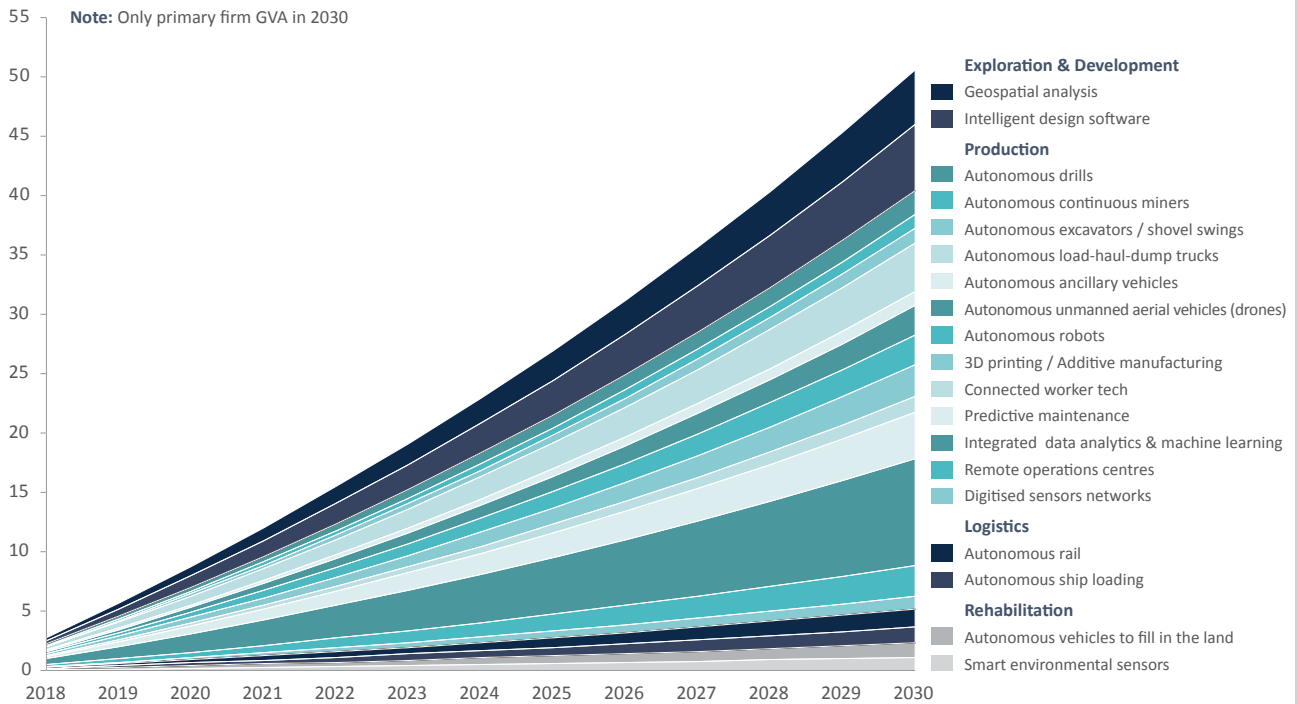
GVA without automation ■ Impact of automation

EXHIBIT 5

These technologies are responsible for increasing overall value added in oil and gas by $8 billion by 2030

Automation & robotics impact on total oil and gas Gross Value Added
Additional value uplift in oil and gas based on expected take up and impact. $B 2015

Note: Only primary firm GVA in 2030

Legend:

Exploration
- Autonomous aerial vehicles
- Enhanced seismic data analytics

Construction
- Fully automated drilling
- Intelligent design software

Production
- 4D seismic imaging
- Autonomous underwater processing
- Predictive maintenance
- Data analytics & machine learning
- Autonomous robots
- Autonomised sensor networks
- Human assistance technology
- Tele-remote operations

X-axis: 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030

Source: Interviews, AlphaBeta analysis

3 CASE STUDIES:

HOW AUTOMATION TECHNOLOGIES WILL SHAPE THE FUTURE OF RESOURCES INDUSTRIES PRODUCTION

This chapter demonstrates, via several case studies, how automation technologies will likely transform the resources industries between now and 2030. Several case studies illustrate how new technologies could evolve over time and change the complex interplay between workers, suppliers and the wider economy.

3.1 AUTONOMOUS TRUCKS ARE MAKING THE LOAD HAUL CYCLE MORE PRODUCTIVE, SAFE AND ENERGY EFFICIENT

Each day in Western Australia's Pilbara region, around 200 high-tech trucks carry ore and waste around mine sites. The key difference between these trucks and traditional vehicles: there is no one at the wheel. The futuristic scenes unfolding in the Pilbara are made possible by a wide range of technologies on board the truck, including high-precision global positioning systems (GPS), communications antennas, on-board computers, advanced sensors to detect other vehicles, and radars. Operations managers and mine planners program and monitor the trucks' routes.

In the future, improved algorithms and hardware will allow the trucks to respond better to changes in road and traffic conditions, and communicate with other autonomous equipment (for example, queuing at loading and dumping areas). As costs decrease, mining managers expect to also automate water trucks and other vehicles working alongside the haulage trucks.

Impacts

Our research shows that the economic benefits of using autonomous trucks are substantial, both for primary companies and for the wider economy.

Unlike manned trucks, autonomous haulage systems do not fatigue, they take less breaks than in today's operations, and have lower maintenance costs. According to major mining companies, the use of autonomous trucks can increase the daily amount of ore processed at a mine site by between 15 and 30 per cent.[6]

Of particular importance is that autonomous haul trucks can significantly improve workplace safety as well as consume less fuel than a manned truck, thus improving capital productivity.[7]

Technology will certainly change the way people work in mining. While there will be fewer manned trucks, opportunities will emerge for workers to transition to new roles such as the role of a 'builder' who continuously updates a digital mine plan so that autonomous trucks know where to go.[8]

As shown in EXHIBIT 6, a positive impact on employment will eventuate if a high proportion of supply chain goods and services are sourced domestically. In such a scenario, job losses in heavy vehicle driving could be more than offset by a combination of an increase in jobs in the primary firm (as new roles arise in maintenance and programming), in the supply chain (as the use of autonomous trucks increases demand for goods and services such as sensor technology), and the wider economy, from increased mining and supply chain activity.

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6. AlphaBeta interviews with major mining companies; Mining Magazine (2017), 'BHP to double autonomous trucks at Jimblebar', available at: http://www.miningmagazine.com/development/automation/bhp-to-double-autonomous-trucks-at-jimblebar/.

7. Rio Tinto (2018), 'Driving Productivity in the Pilbara', available at: http://www.riotinto.com/ourcommitment/spotlight-18130_18328.aspx and iTNews (2016), 'Fortescue reveals automated truck gains', available at: www.itnews.com.au/news/fortescue-reveals-automated-truck-gains-434559.

8. See Chapter 3 of this report for a case study on developing skills in the mining and oil and gas industries.

EXHIBIT 6

Automation of vehicles may have a positive net impact on GVA and employment across the economy as a whole (*positive* supply chain scenario)

Impact of introducing automation technologies
Total economy impact on GVA in 2030. $B 2015

■ Primary firms   ■ Supply chain   ■ Wider economy

GVA without automation	18.4	10.6	12.1	41.1

Automation impact
- Primary firm: 2.4
- Supply chain: 1.9
- Wider economy: 2.1

+16%

GVA with automation	20.9	12.5	14.2	47.5

Employment in haulage before automation	30	106	83	219

Automation impact
- Primary firm: -15, 2
- Supply chain: 19
- Wider economy: 15

+9%

Employment after automation	17	125	98	239
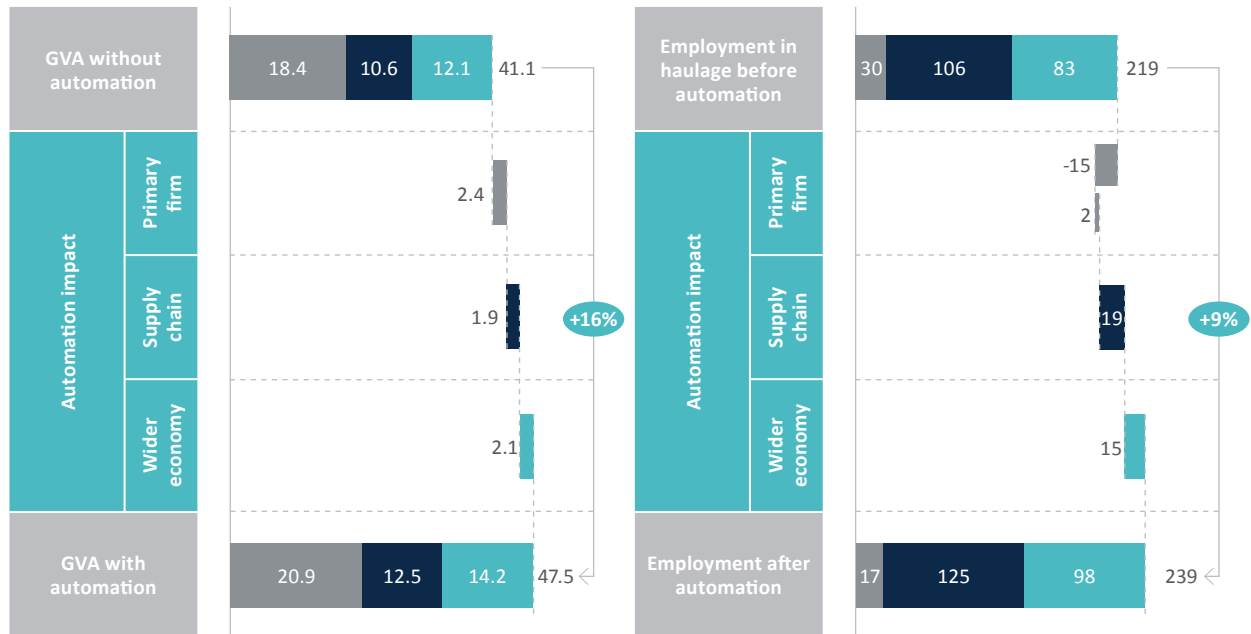
Source: Interviews, ABS, Alpha Beta modelling
1 Assumes GVA / worker of $100 – 150k in supply chain / wider economy versus haulage GVA per worker of $600k - see Appendix for further details;
2 Assumes global competitors elasticity of supply of 0.35 and elasticity of demand of -0.25

Supply chain opportunities

As mining companies embrace autonomous trucks, suppliers are also set to benefit. At the moment, a handful of international original equipment manufacturers (OEMs) such as Caterpillar, Komatsu and Sandvik dominate the manufacture and supply of autonomous trucks worldwide. Meanwhile, Australian mining equipment, technology and services (METS) companies are largely providing the secondary support for automation, including installing and maintaining wireless networks, sensors and other technologies. While the larger components of autonomous haul trucks are likely to continue to be imported, many of the other components can be produced here, including analytics software, and data architecture linking software and hardware. Australian companies can also continue to be involved in the assembly and maintenance of heavy equipment as it evolves from manned to autonomous, and export capability can be grown where local METS companies are involved in developing next-generation automation.

In a best-case scenario, local METS companies could add as much as $1.9 billion in GVA to the Australian economy (see EXHIBIT 6) from supporting autonomous truck technology.[9]

9. See Chapter 3 of this report for a detailed analysis of the conditions for Australia supply chain access.

3.2 AN INTEGRATED, AUTOMATED IRON ORE MINE COULD BE 60 PER CENT MORE PRODUCTIVE THAN AN EQUIVALENT MINE TODAY

By 2030, Australia's largest new iron ore mines could be fully automated. At these mines, in the resource-rich Pilbara region, technology rules. Satellite systems guide autonomous trucks from the pit to the crusher. Sensors monitor the actions of drillers, excavators, conveyor belts and other equipment. Systems integration software ensures that all equipment works seamlessly together to extract high-grade ore with maximum efficiency. Wireless systems send out alerts if machinery fails, requiring repair and inspection crews to venture out into the desert heat only when urgently needed. Virtual reality headsets allow these workers to simulate tasks and prepare for field trips. On site, they use smartphone technology to transmit live data and images back into the air-conditioned control room for further evaluation.

These key technologies will drive the mine of the future:

1. **Autonomous machinery** equipped with thousands of sensors at each stage of iron ore production, including drilling, loading, the haulage cycle, processing and rail.

2. State-of-the-art **IT systems**, sensors and data analytics which aggregate and analyse data across the entire value chain, to optimise mine operations and anticipate issues before they arise.

3. **Connected worker technologies** such as virtual reality headsets and smart devices used in many applications including in training and equipping worker with real-time data for decision-making.

Impacts

Individual autonomous technologies are expected to make mining operations significantly more productive (as evidenced by the previous case study on autonomous trucks).

The combination of these individual technologies should allow the removal of workers from potentially dangerous areas such as the pit and enable a re-design of the mine. For example, the mine of the future would allow narrower roads and steeper walls, so previously inaccessible ore could be mined.

Interviews with mining technology experts suggest that the biggest productivity gain would come from the systemic effect of fully integrating multiple autonomous technologies. Such integration allows mining companies to harvest large, accurate data sets from sensors on autonomous technology, which improves the quality of data analysis. Our modelling shows that a mine redesign and the combined use of autonomous technologies could lift productivity by around 60 per cent compared to an equivalent mine today. Around 30 per cent of this increase could come solely from the effects of system integration.[10]

There will be other benefits: as evidenced by the previous case study on autonomous trucks, autonomous technology is expected to make mining operations safer (as workers are no longer exposed to dust, noise and vibration when operating heavy machinery) and more energy efficient.

In terms of jobs, a positive impact on employment will occur if a high proportion of supply chain goods and services are sourced domestically (see EXHIBIT 8). While routine jobs will tend to disappear at the frontline, these will be offset by new jobs in the producer firm (as new roles arise in maintenance and programming), in the supply chain (as increased iron ore production enhances demand for goods and services such as data analytics), and the wider economy, from mining and supply chain activity.

EXHIBIT 7		
KEY STATS: Advanced Iron Ore Mine in 2017 and 2030[11]		
	Iron Ore Mine (2017)	**Iron Ore Mine (2030)**
Workers on site	500–1,000	~150 (with a further 100–200 in regional maintenance hubs)
Utilisation of processing plant	80–90%	98%
Annual output (wmt)	2,750	~3,200

10. AlphaBeta modelling based on interviews with primary and supply chain firms.
11. 2030 scenario based on interviews with primary firms and AlphaBeta modelling.

Supply chain opportunities

As with autonomous trucks, suppliers are also set to benefit from the transition to fully integrated and highly autonomous mines. Given the high levels of mine digitalisation, key opportunities for Australian METS companies will open up in the provision of data analytics, systems integration and data architecture linking hardware and software.[12] Australian METS firms could also continue to play a stronger role during the implementation of automation technologies by providing maintenance services. In a best-case scenario, local METS companies could add as much as $700 million in additional economic value to the Australian economy from supporting a single fully integrated and autonomous iron ore mine (EXHIBIT 8).

EXHIBIT 8

Autonomous iron ore mining can deliver a positive net impact on GVA and jobs across the economy as a whole *(positive supply chain scenario)*

Impact of an autonomous mine on GVA
Total economy impact on GVA in 2030. $B 2015

Impact of autonomous mine on employment
Employment levels, '000s of persons, 2030

Legend: Primary firms | Supply chain | Wider economy
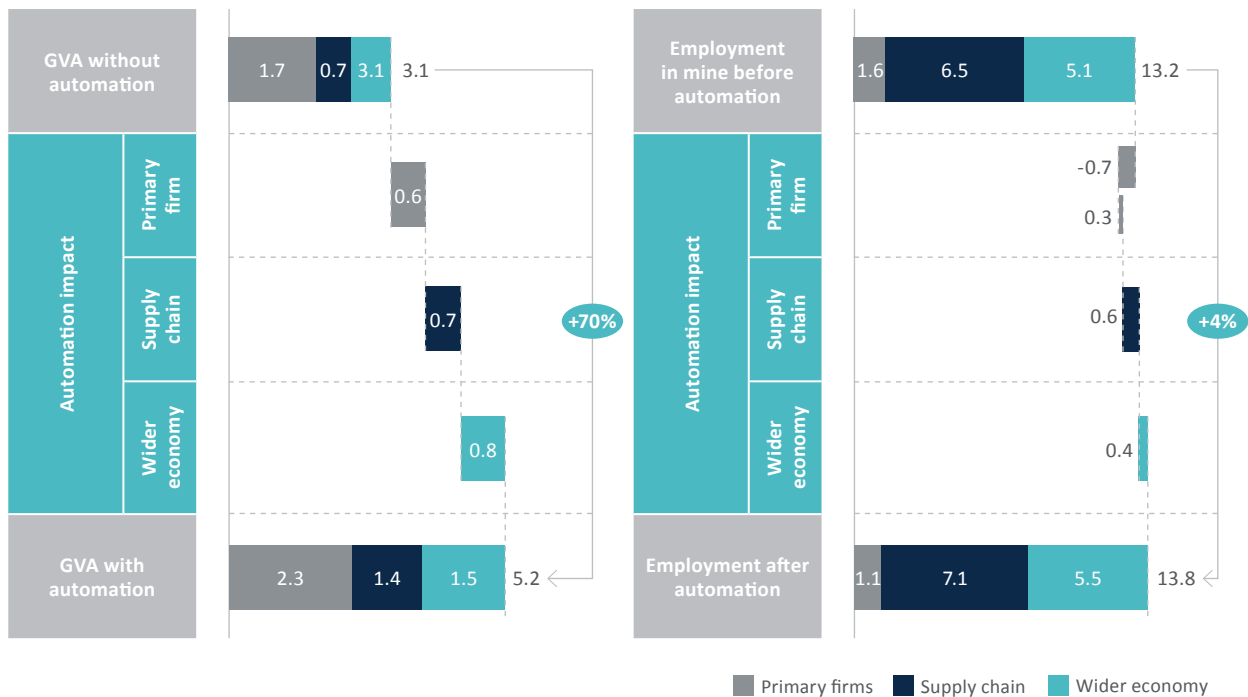
Source: Interviews, ABS, AlphaBeta modelling
Note: ~800 direct roles in mine; GVA per worker in mining is ~$1M; ~8x GVA per worker in supply chain/wider economy. See Appendix for details on ratio of primary firm workers to supply chain and wider economy.

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12. See Chapter 3 of this report for a detailed analysis of the conditions for Australian supply chain success.

3.3 AN LNG PLANT OF THE FUTURE COULD BE AROUND 30 PER CENT MORE PRODUCTIVE THAN AN EQUIVALENT PLANT TODAY

By 2030, an onshore LNG plant will be highly automated and more compact than its present-day equivalent. Intelligent design software (including a digital replica of the plant) will be used to streamline plant design. This can be useful to identify, for instance, where piping can be reduced. The plant itself will be fitted with thousands of wireless sensors that monitor an array of things, including temperature and pressure. Engineers at a high-tech operations centre can then use machine-learning algorithms to analyse this information and detect potential flaws in the plant's operational efficiency. Specialist repair teams, often a combination of robots and humans, are tasked to resolve any issues. Robots are sent into the noisiest and most dangerous plant areas, supported by workers wearing augmented reality glasses and other high-tech equipment. 3D printers allow them to quickly replace bespoke parts and reduce costly downtime on a plant.

These technologies will underpin the plant of the future:

1. **Caretaker robots**, which use sensors and artificial intelligence to detect a problem, and which can physically manipulate things (for example, turning a valve).

2. **Systems integration software, sensors** and **advanced data analytics**, which aggregate and analyse data to optimise plant design and operations (for example, by improving the reliability of the plant) and to anticipate issues before they arise.

3. **Connected worker technologies** such as smartphones and virtual reality headsets, which use real-time sensor data for decision-making and worker training.

Impacts

Industry experts estimate that advances in technology could **lower the construction costs** of a future LNG plant by around **5 to 10 per cent**. Looking at current construction costs, the potential savings are large: Woodside's Pluto LNG project cost around $15 billion to develop in 2012. Replacing workers with robots in dangerous parts of the operation will decrease the need for safety areas and enable a more compact plant design. Intelligent design software could also reduce equipment and procurement costs.

Our modelling shows that the benefits from plant redesign and the combined use of other technologies could lift productivity by around 30 per cent compared to a present-day plant (see EXHIBIT 9), largely driven by improvements in plant utilisation (plant shutdowns will be shorter and less frequent) and reduced maintenance costs (due to continuous monitoring by sensors and predictive maintenance analytics).

There will be other benefits as well: automation technologies are expected to make jobs safer for workers by reducing their exposure to hazardous environments (such as extremely hot and noisy plant areas). It is also expected to increase energy efficiency (a more compact plant will need less energy to run).

As with the autonomous mine, there could be a positive effect on jobs if a high proportion of supply chain goods and services are sourced domestically. Frontline employment reduction due to automation technologies could be more than offset by an increase in employment in the producer firm (as new roles arise in maintenance and programming, and as operations expand), in the supply chain (as increased LNG production increases demand for goods and services such as data analytics), and the wider economy, from oil and gas and supply chain activity.

Supply chain opportunities

Suppliers can expect to benefit from the transition to an automated, digitalised LNG plant. Australian suppliers of automation technologies face opportunities to provide data analytics, systems integration software, and niche hardware (such as wireless sensors).[13] They can also continue to provide support to primary producers when implementing new automation technologies through project management services. In a best-case scenario, as shown in EXHIBIT 9, local supply chain companies could add as much as $100 million in additional economic value to the Australian economy from supporting a single LNG plant of the future.

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13. See Chapter 3 of this report for a detailed analysis of the conditions for Australian supply chain success.

EXHIBIT 9

Automation technologies in O&G can deliver a positive net impact on GVA and jobs across the economy as a whole *(positive supply chain scenario)*

Impact of an autonomous O&G plant on GVA
Total economy impact on GVA in 2030. $B 2015

Impact of autonomous O&G plant on employment
Employment levels, '000s of persons, 2030

	GVA	Employment
Without automation	2.4 / 1.0 / 1.2 → 4.6	1.6 / 8.6 / 7.4 → 17.6
Primary firm	0.6	-0.8
Supply chain	0.1	0.3 / 0.5
Wider economy	0.1	0.4
Net	+14%	+2%
With automation	3.0 / 1.1 / 1.2 → 5.3	1.1 / 9.1 / 7.8 → 17.9

Primary firms ■ Supply chain ■ Wider economy ■
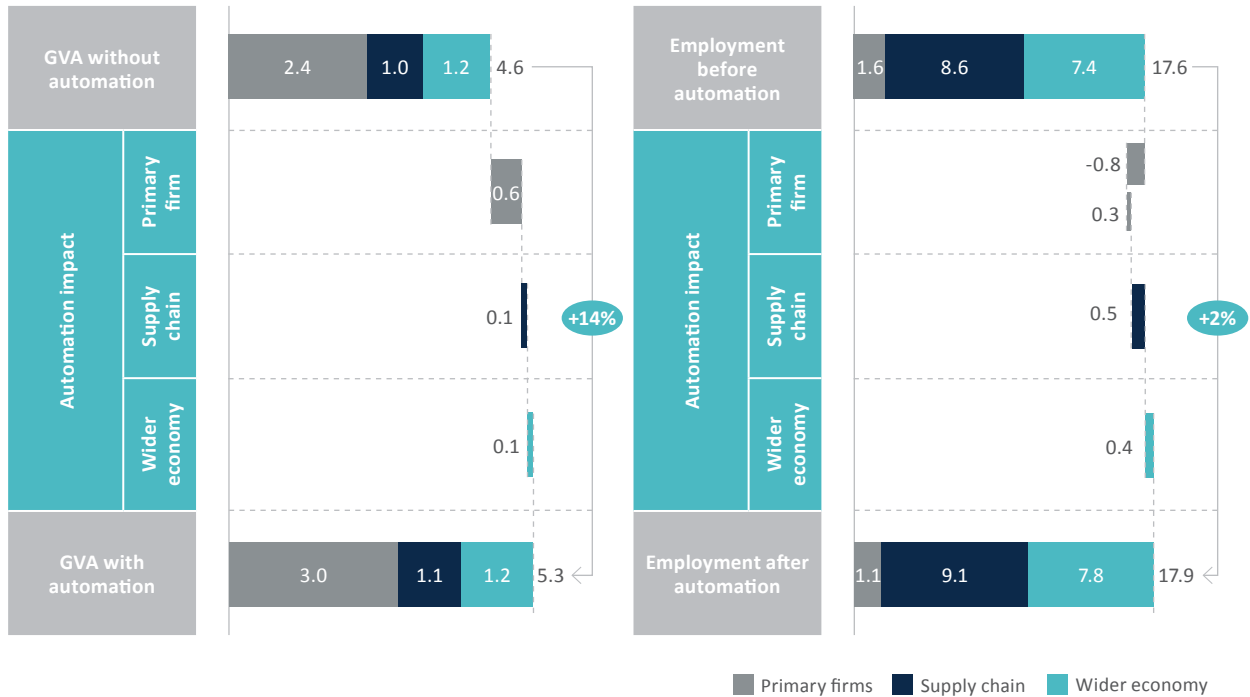
Source: Interviews, ABS, Alpha Beta modelling
Note: GVA per plant worker is ~$1.5M and GVA per worker in supply chain/wider economy is ~$150k. See Appendix for details on ratio of primary firm workers to supply chain and wider economy.

> **Our modelling shows that the benefits from plant redesign and the combined use of other technologies could lift productivity by around 30 per cent...**

DIGITAL TECHNOLOGIES IN THE RESOURCES INDUSTRIES COULD BOOST AUSTRALIA'S ECONOMY BY OVER $70 BILLION IN 2030 – IF OUR SUPPLY CHAIN ADAPTS

Automation technologies in the resources industries present a significant opportunity for domestic supply chains and the wider economy. The size of the prize for Australian suppliers and the economy depends on how well resources industries, suppliers, government and research institutions work together in fostering a conducive environment for business – one that allows the supply chain to adapt to the evolving technology needs of mining and oil and gas companies across the country.

This section examines:

- the impact of automation technologies on the **suppliers to Australian resources firms**, which will vary depending on how successfully they adapt to the changing requirements of producers; and

- the **wider economic impact** stemming from changes in household spending arising from the application of automation technologies to resources industries.

4.1 THIS REPORT CONSIDERS THE TOTAL IMPACT OF AUTOMATION TECHNOLOGIES ON THE RESOURCES FIRMS, THEIR SUPPLIERS AND THE WIDER ECONOMY

The uptake of automation technologies in the Australian resources industries will not just affect the producers but will ripple through the economy. The previous chapter examined the impact of automation on GVA and employment in the resources firms. Automation will have impacts beyond the resources firms. To estimate the full impact of these technologies in Australia, two additional impact areas need to be distinguished (see EXHIBIT 10).

Supply chain impact: There will be a ripple effect on suppliers from the uptake in automation technologies at a primary firm level. For example, as emerging automation technologies are implemented, the resources sector will need to source more advanced equipment, software, and technology from its supply chains.[14]

Wider economic impact: Automation-related changes in the resources industries will ripple through the entire economy. We expect that enhanced competitiveness in these industries will most likely lead to Australia's share of global output increasing in the future. To produce this increased output, additional workers and inputs will be required from the supply chains. The higher income received by workers in the resources sector and its supply chains will likely increase their household spending on goods and services from a range of other industries, leading to further positive activity in the economy.[15]

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14. The analysis used to measure the supply chain/wider economic impact is based on industry interviews and ABS Input-Output data.
15. As above.

EXHIBIT 10

The 'Total Economic Impact' of digital analytics, automation and robotics technologies has 3 components

Total economic impact of automation and robotics technologies

	Primary impact	+	Supply chain impact	+	Wider economy
Description:	Impact on mining and oil and gas companies		Impact on the supply chain supporting those companies		Impact on broader economy i.e the effect of changes on household income/spending
Method:	• Interviews with firms • Case study analysis • Demand elasticity determines response to productivity gains		• Interviews with supply chain firms • Input-Output analysis • Analysis of imports, capex and opex expenses		• Input-output analysis

Total Economic Impact

Output:	GDP / GVA	Jobs	Capex	Productivity

Image courtesy of MineARC Systems

**The uptake of automation technologies in the Australian resources industries will not just affect the producers but will ripple through the economy.**

METHODOLOGY BOX:
HOW WE CALCULATE IMPACTS ON THE SUPPLY CHAIN AND WIDER ECONOMY

We estimated supply chain and wider economic impacts by first calculating pre-automation supply chain and wider economic impact multipliers from ABS Input-Output tables. The multipliers quantify the effect of an output increase in resources industries on GVA in their supply chains and the wider economy. For example, the multiplier in 2012-13 was such that a $1 increase in output from the oil and gas industry would generate $0.25 of GVA in its supply chain.

As automation technologies alter the combination and amount of inputs used in the resources industries, the supply chain and wider economy multipliers will evolve. We derived post-automation multipliers by combining the post-automation goods and services required by the resources sector, and the sector's total output with the average multipliers spanning 2006-2013. We used the average multipliers over 2006-2013 to capture the resources industries' long-term relationship with suppliers and the wider economy. As automation technologies are implemented between 2017 and 2030, the supply chain and wider economy multipliers adjust from pre-automation levels to post-automation levels.

For the different supply chain scenarios, we adjusted the multipliers by varying the market share of the domestic supply chain. We consider two scenarios:

Strong domestic supply chain scenario:

Mining – Domestically sourced intermediate goods at 89 per cent (compared to a baseline market share of 87 per cent) and capital goods at 35 per cent (compared to a baseline market share of 25 per cent).

Oil and gas – Domestically sourced intermediate goods at 90 per cent (compared to a baseline market share of 88 per cent) and capital goods at 25 per cent (equivalent to the baseline market share).

Weak domestic supply chain scenario:

Mining - Domestically sourced intermediate goods at 84 per cent (compared to a baseline market share of 87 per cent) and domestically sourced capital goods at 5 per cent (compared to a baseline market share of 25 per cent).

Oil and gas - Domestically sourced intermediate goods at 83 per cent (compared to a baseline market share of 88 per cent) and capital goods at 5 per cent (compared to a baseline market share of 25 per cent).

The scenarios and baselines were constructed based on a combination of historical ABS Input-Output data and industry interviews. See the Appendix for further detail.

4.2 A STRONG DOMESTIC SUPPLY CHAIN WOULD BRING THE TOTAL BENEFITS OF AUTOMATION TECHNOLOGIES IN MINING UP TO $65 BILLION IN 2030 AND GENERATE NEW SUPPLY CHAIN JOBS

Companies in the mining sector will need to increase their automation adoption rates to remain internationally competitive. If domestic suppliers adapt to their evolving needs, for example by developing and supplying advanced equipment, they too will see benefits. Employment growth in the supply chain could more than compensate for employment changes in the mining sector due to automation. Australia will, however, forfeit this opportunity if domestic suppliers lose market share to foreign competitors with superior data analytics, automation and robotics capabilities.

EXHIBIT 11

Automation technologies in mining could add $65 billion to the Australian economy

Impact of introducing automation technologies
Total economy impact on GVA in 2030. $B 2015

Mining total economic values without automation	90	56	64	210

- Current value of mining including direct industry output supply chain and wider economic impact

Automation impact

Primary firm — 52
- Positive impact of value uplift from productivity, capital efficiency, access to new resources, systems integration and other benefits
- Output uplift from improved competitiveness

Supply chain — 6 — +31%
- Automation has two impacts on the supply chain: 1) reduces value due to the operations being more productive and requiring fewer inputs and 2) increases value due to greater output
- In this case it is assumed a high proportion of intermediate and capital goods are sourced domestically (see sensitivity analysis)

Wider economy — 7
- Wider economic benefits are positive due to strong domestic supply chain participation. Alternative scenarios are considered in the sensitivity analysis

Mining total economic value with automation	142	62	71	275

- The total gain is due to the impact of improved value driving higher competitiveness and higher output as well as more activity in the supply chain

Source: Interviews, ABS, AlphaBeta analysis

▮ Primary firms ▮ Supply chain ▮ Wider economy

❝ *As automation technologies alter the combination and amount of inputs used in the resources industries, the supply chain and wider economy multipliers will evolve.* ❞

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16 We assume steady state growth without automation, meaning the total economic value of mining without automation remains constant between 2017 and 2030.

17 Domestic supply chain success (i.e. a strong domestic supply chain) in mining is characterised by an 89% market share for the supply of intermediate goods and a 35% share for the supply of capital goods and equipment. See Appendix for further details.

The current total economic value of mining in Australia is approximately $210 billion (see EXHIBIT 11). This includes $90 billion in mining itself, $56 billion generated by mining suppliers, and $64 billion generated in the wider economy through increased consumer spending.[16]

As outlined in the previous chapter, the application of automation technologies in mining could generate $52 billion of value due to uplift in the industry's productivity and output. The output increase is driven by the fact that automating companies will become more internationally competitive.

If the domestic supply chain successfully adapts to the mining industry's automation technology needs, in 2030 automation could generate $6 billion in the domestic supply chain off the back of the estimated $52 billion value uplift in mining (see EXHIBIT 11).[17] This is driven by two different effects of automation on the supply chain.

First, automation reduces value in the supply chain because a more productive mining sector requires fewer intermediate good inputs. For example, predictive maintenance could help companies minimise usage of spare parts by keeping machines operating closer to peak performance for longer.

Second, automation increases value because companies require more intermediate goods and machinery/equipment to produce more output in response to enhanced global competitiveness. For example, Australia could capture a greater share of global mining output because of its automation-induced productivity gains. If Australia has a strong domestic supply chain, one that fully harnesses the automation opportunity, the second effect would dominate and the overall value would increase.

In addition to the supply chain effect, the implementation of automation technologies could also generate $7 billion in wider economic benefits in 2030. The additional jobs and income that increased production will create in mining and its domestic supply chain will, in turn, lead to higher household spending on goods and services (for instance, clothing), which in turn will increase the production across a range of other industries, thus creating broader economic benefits.

Overall, in 2030, automation technologies could increase the value generated in the Australian economy by mining from $210 billion to $275 billion, an increase of 31 per cent.
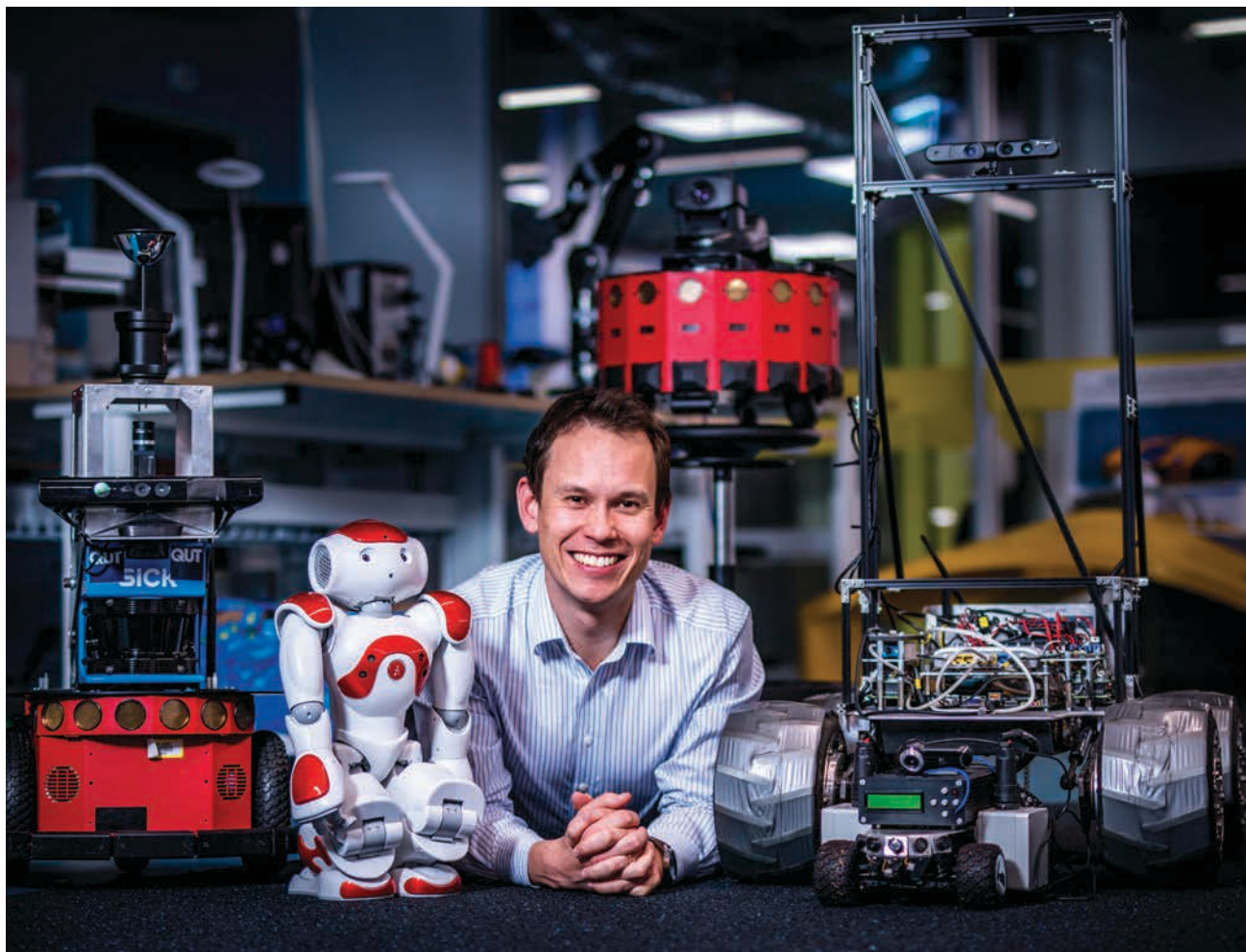
> **Mining is estimated to account for more than 1.1 million jobs in the Australian economy, the majority of which are indirectly supporting the mining industry.**

EXHIBIT 12

Automation technologies in mining could create 77,000 net jobs across the economy

Impact of automation on employment
Total economy impact on GVA in 2030. $B 2015

Employment before automation: 148, 562, 441 — **1,151**	• Number of jobs supported by the mining industry, including workers employed in mining directly, workers employed in supply chain firms and workers employed across the economy as a result of spending by households employed by mining or its supply chain
Primary firm: -77	• Loss of jobs in the primary firms as a direct result of higher productivity, but before taking into account the uplift from increased output and competitiveness
Primary firm: 42	• Increase in number of jobs created in the primary firms as a result of increased competitiveness and higher output
Supply chain: 63 (+7%)	• Additional employment in the supply chain from increased demand for intermediate and capital goods
Wider economy: 7	• Additional employment in the economy stimulated by household spending which is brought about by wages paid by mining and its supply chain to increase output
Employment after automation: 114, 625, 489 — **1,228**	• Total uplift assumes a high proportion of intermediate and capital goods are sourced domestically. Sensitivity analysis will vary this assumption

Source: Interviews, ABS, AlphaBeta analysis

Legend: ■ Primary firms ■ Supply chain ■ Wider economy

As companies implement more robots, sensors and artificial intelligence across mine sites and oil rigs, they will deploy fewer workers to routine, manual tasks (see the mining, and oil and gas case studies for further details). This technological shift will change the jobs profile in the mining and oil and gas industries profoundly.
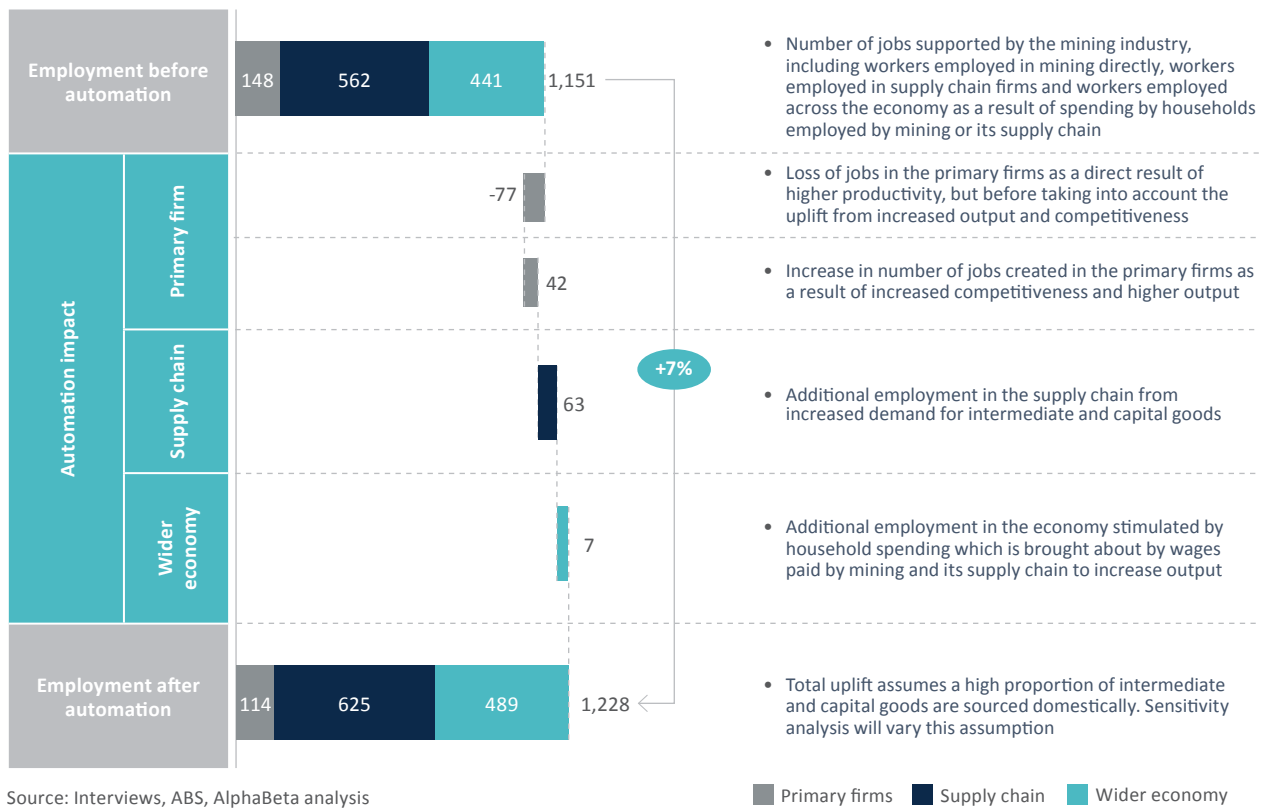
Mining is estimated to account for more than 1.1 million jobs in the Australian economy, the majority of which are indirectly supporting the mining industry. Currently, an estimated 148,000 people in Australia are directly employed by mining, while roughly another one million mining-dependent jobs exist in the supply chain and the wider economy (EXHIBIT 12). Therefore, the future impact of automation technologies on jobs largely depends on the degree to which domestic suppliers successfully adapt to the changing needs of their customers. A strong, technologically capable domestic supply chain could see employment supported by mining grow in the period to 2030, as shown in EXHIBIT 12.

The implementation of automation technologies will see two parallel effects that will change the nature of employment within the mining industry. There could be up to 77,000 jobs impacted in 2030 as automation technologies undertake more of the "dirty, dull and dangerous" routine tasks.

This impact could be more than offset firstly by about 42,000 jobs expected to be created in 2030, as for example, mine workers shift to new roles such as programming autonomous mining equipment, and from increased competitiveness and growing output. Secondly, if domestic suppliers to the Australian mining industry successfully adapt to the automation age, new jobs will emerge among suppliers. AlphaBeta estimates this demand could generate 63,000 additional jobs created in the supply chain. As they automate, mining companies will demand capital goods, such as advanced equipment and software, as well as intermediate good inputs, such as building materials, to increase their output (see EXHIBIT 12).

Furthermore, the stimulus from increased household spending by those employed in mining and its supply chain could generate an estimated 49,000 additional jobs in 2030, leading to an overall increase in the number of jobs supported by the Australian mining sector.

In the best-case scenario, the new jobs created in the Australian economy could deliver a substantial net increase in employment within, and supported by, the broader mining sector. It is worth understanding that this result can only come about if:
- the domestic mining supply chain participates and adapts to automation technologies;
- the mining companies broaden their supply chain engagement to new supply chain participants; and
- workers are reskilled and deployed in the new jobs, some of which will involve more complex, creative and interpersonal skills.
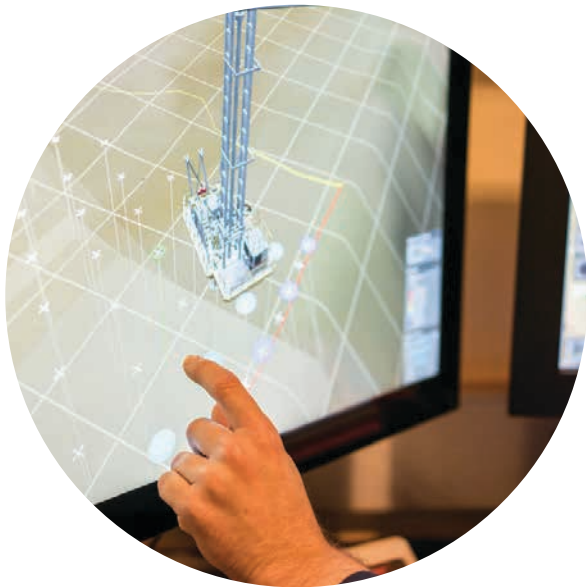
4.3 A STRONG DOMESTIC SUPPLY CHAIN COULD DRIVE UP TOTAL BENEFITS FROM AUTOMATION TECHNOLOGIES IN OIL AND GAS TO $9 BILLION IN 2030

Automation could have far-reaching economic benefits beyond the oil and gas industry. Currently, the oil and gas industry adds $51 billion to the Australian economy, of which $27 billion in value is generated directly, and $24 billion is generated indirectly through the industry's impact on supply chains and the wider economy (EXHIBIT 13).

If automation in the Australian oil and gas industry continues and the domestic supply chain fully embraces this trend, up to $1 billion of additional value could be generated in the domestic supply chain, and a further $1 billion in the wider economy. This would take the total economic value the oil and gas industry in Australia could generate in 2030 to $60 billion.[18]

EXHIBIT 13

Automation technologies in oil and gas could add $9 billion to the Australian economy

Impact of introducing automation technologies
Total economy impact on GVA in 2030. $B 2015

Oil and gas total economic value without automation	27 / 11 / 13 → 51	• Current value of oil and gas including direct industry output, supply chain and wider economic impact
Automation impact — Primary firm	8	• Positive impact of value uplift from productivity, capital efficiency, access to new resources, systems integration and other benefits • Output uplift from improved competitiveness
Automation impact — Supply chain	1 +18%	• Automation has two impacts on the supply chain: 1) reduces value due to the operations being more productive and requiring fewer inputs and 2) increases value due to greater output • In this case it is assumed a high proportion of intermediate and capital goods are sourced domestically (see sensitivity analysis)
Automation impact — Wider economy	1	• Wider economic benefits are positive due to strong domestic supply chain participation. Alternative scenarios are considered in the sensitivity analysis
Oil and gas total economic value with automation	35 / 12 / 14 → 60	• The total gain is due to the impact of improved value driving higher competitiveness and higher output as well as more activity in the supply chain

Source: Interviews, ABS, AlphaBeta analysis

■ Primary firms   ■ Supply chain   ■ Wider economy

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18 Domestic supply chain success (i.e. a strong domestic supply chain) to oil and gas is characterised by a 90% market share for the supply of intermediate goods and a 25% share for the supply of capital goods and equipment.

There are implications for employment, as shown in EXHIBIT 14. Currently, the oil and gas industry supports over 200,000 workers in the Australian economy, of which 18,000 are directly employed by oil and gas producers. Jobs in other industries supported by oil and gas could increase if Australia's supply chain fully adapts to the increasing levels of automation required in the oil and gas industry.

The overall employment effect is expected to be positive. While the continuous automation of tasks in the oil and gas industry could see up to 8,000 jobs impacted in 2030, this
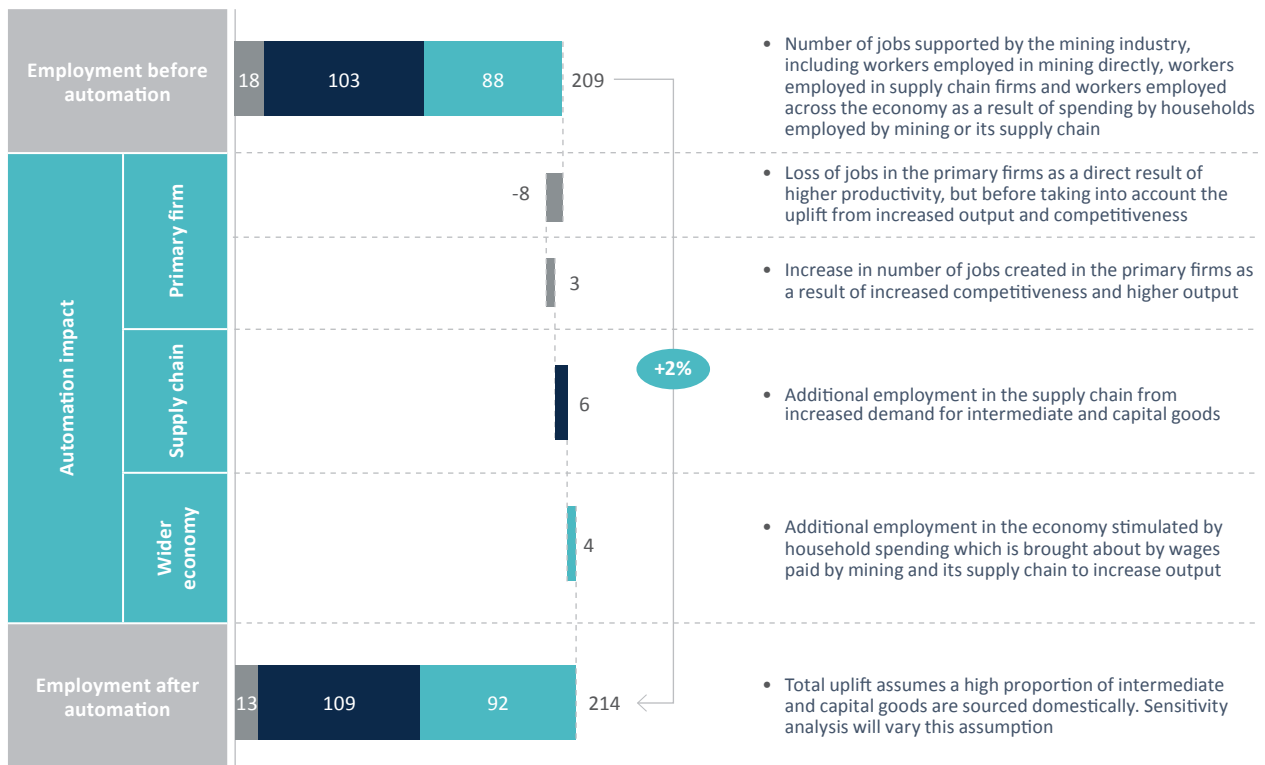
direct impact would be more than offset by an increase of about 3,000 new jobs due to the industry's improved competitiveness and output. These new jobs could include data analysts that can manipulate and interpret the vast amount of data generated by sensors on rigs, plant and other assets. Further, up to 10,000 new jobs could emerge across the supply chain and in the wider economy. As a result, the implementation of automation technologies in the oil and gas industry is expected to lead to a net increase in jobs across the economy if Australia successfully adapts its supply chains.

EXHIBIT 14

Automation technologies in oil and gas could create 5,000 net jobs across the economy

Impact of automation on employment
Employment levels, 000's of persons, 2030

- Number of jobs supported by the mining industry, including workers employed in mining directly, workers employed in supply chain firms and workers employed across the economy as a result of spending by households employed by mining or its supply chain

- Loss of jobs in the primary firms as a direct result of higher productivity, but before taking into account the uplift from increased output and competitiveness

- Increase in number of jobs created in the primary firms as a result of increased competitiveness and higher output

- Additional employment in the supply chain from increased demand for intermediate and capital goods

- Additional employment in the economy stimulated by household spending which is brought about by wages paid by mining and its supply chain to increase output

- Total uplift assumes a high proportion of intermediate and capital goods are sourced domestically. Sensitivity analysis will vary this assumption

Primary firms   Supply chain   Wider economy

Source: Interviews, ABS, AlphaBeta analysis
Note: Components may not sum to total due to rounding

30

4.4 THE SUPPLY CHAIN AND WIDER ECONOMIC GAINS FROM AUTOMATION TECHNOLOGIES IN THE RESOURCES INDUSTRIES ARE AVAILABLE IF DOMESTIC SUPPLIERS ADAPT

Australia's economy has a lot to gain from developing a technology-driven, adaptive and future-orientated domestic supply chain to the mining and oil and gas industries. However, if the supply chain does not supply this technology and cedes market share to foreign companies, some of the benefits to the Australian economy from automation technologies in the resources industries could be lost.

For example, the total economic value generated in the Australian economy by mining could be up to $27 billion lower in 2030 if the domestic supply chain does not adapt. In this case, Australia's mining suppliers would lose market share, as producers would be forced to buy advanced equipment and software from overseas suppliers to meet their automation needs (see EXHIBIT 15).[19] The automation demand of producers would still create jobs, but these jobs would mostly emerge overseas, not in Australia.

A strong domestic supply chain would maximise the benefits from implementing automation in the mining sector within Australia. Under such circumstances, the mining industry could generate about $275 billion of value in the Australian economy in 2030. This could decline to about $248 billion if the domestic market share were to weaken (EXHIBIT 15).
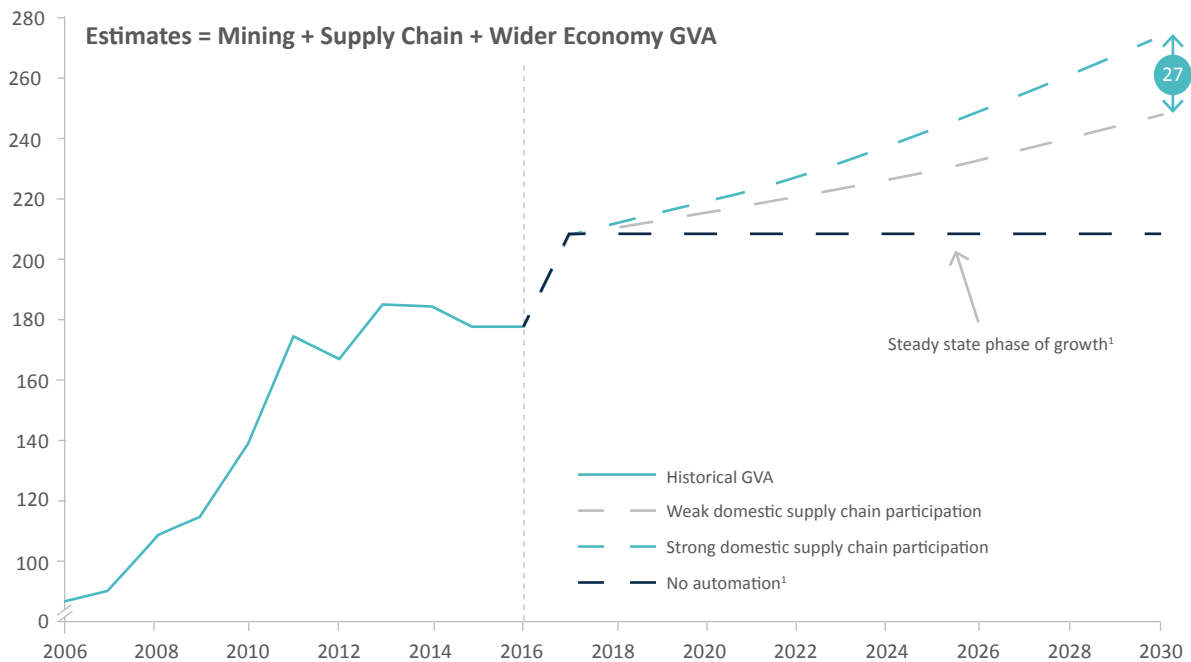

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19   Total GVA is the combination of GVA within mining itself, its supply chain and any wider economic GVA attributable to mining. For the no-automation baseline, we have assumed steady state growth from 2016-17 onwards. Though an unlikely scenario, it assists in isolating the effect of automation and makes modelling more tractable. The weak domestic supply chain scenario for mining assumes primary producers source 84 per cent of intermediate goods and 5 per cent of their capital goods domestically. The strong domestic supply chain scenario assumes primary firms source 89 per cent of their intermediate goods and 35 per cent of capital goods domestically. The scenarios were constructed based on a combination of historical ABS Input-Output data and industry interviews.

EXHIBIT 15

Benefits are $27 billion lower in 2030 if the local supply chain fails to adapt as mining automates

Estimated total annual Gross Value Added generated in the Australian economy by mining
Billons, 2015 AUD

Estimates = Mining + Supply Chain + Wider Economy GVA

Steady state phase of growth[1]

— Historical GVA
— — Weak domestic supply chain participation
— — Strong domestic supply chain participation
— — No automation[1]

1 No automation case is for analytical simplicity. It is not likely in reality as primary firms will need to automate.
Source: AlphaBeta analysis

The difference in job creation is equally large. If the **domestic supply chain fully adapts** to the growing automation needs of producers in Australia, over 220,000 new jobs could be created in the Australian economy in 2030 (EXHIBIT 16). This includes jobs in mining, its supply chain, and the wider economy. As a result, the total number of jobs supported by mining in Australia could gradually increase to more than 1.2 million by 2030.

These positive employment impacts could be reversed where **domestic suppliers fail to adapt** to the needs of automating customers. If Australian suppliers to the mining industry fail to develop the capabilities needed to supply inputs, such as advanced equipment, software, and technology, they could lose market share to foreign technology suppliers. In this case, the total number of jobs supported by the mining sector could decline to about 1 million between 2017 and 2030. The risk is that the mining supply chain in particular will lose much of its job creation potential, as the sourcing of automation technologies moves overseas.

The large gap between the strong and weak supply chain scenarios represents a forgone opportunity for Australia – an opportunity to stimulate employment in the domestic supply chain.

EXHIBIT 16

Over 220,000 jobs could be created in the Australian economy in 2030 if the local supply chain adapts as mining automates

Estimated annual no. of jobs generated in the Australian economy by mining
Number of jobs, '000

Total jobs = Mining + Supply Chain + Wider Economy jobs

If the domestic supply chain does not adapt, job losses due to automation may not be compensated by job creation in the supply chain and wider economy

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35

– – – Jobs in mining - with automation
– – – Jobs in mining - no automation
– – – Total jobs supported by mining - low domestic supply chain participation
– – – Total jobs supported by mining - high domestic supply chain participation

Y-axis: 1,250 / 1,200 / 1,150 / 1,100 / 1,050 / 1,000 / 150 / 100 / 50 / 0

X-axis: 2017-18, 2018-19, 2019-20, 2020-21, 2021-22, 2022-23, 2023-24, 2024-25, 2025-26, 2026-27, 2027-28, 2028-29, 2029-30, 2030-31

Source: AlphaBeta analysis
Note: No-automation scenario is included for analytical simplicity. It is not likely in reality as primary firms' current automation efforts are expected to continue.
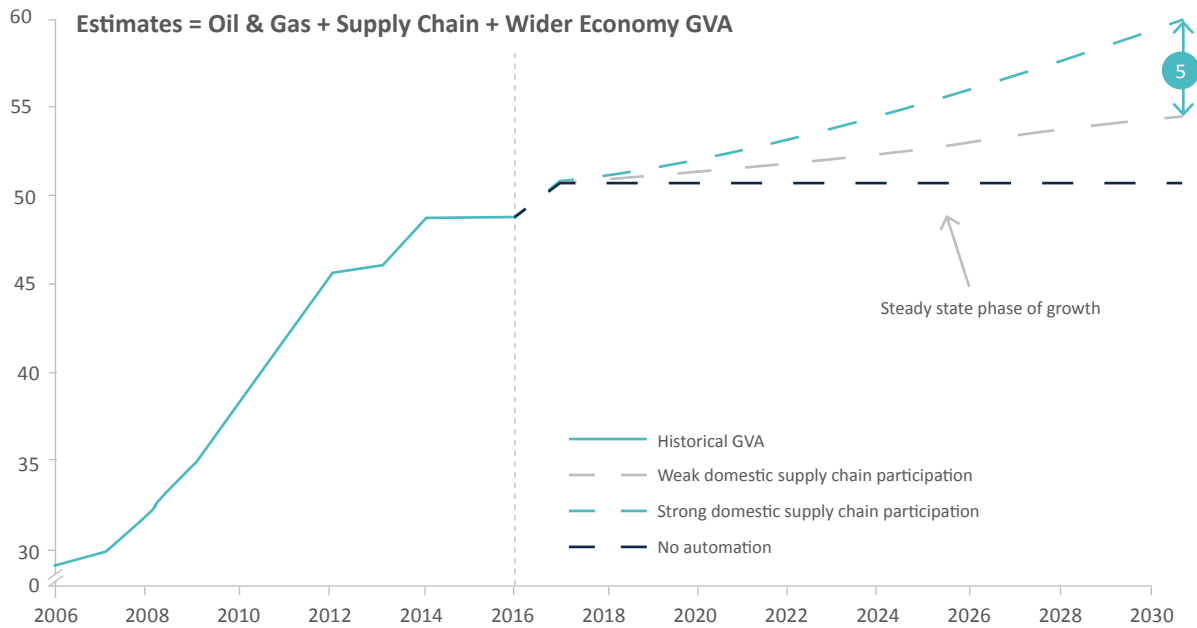
The domestic supply chain to the oil and gas industry faces the same challenge over the coming decade. As shown in EXHIBIT 17, strong supplier involvement during automation could see oil and gas generate up to $60 billion of value in the Australian economy in 2030. In contrast, if suppliers fail to adapt to the industry's needs, the total value generated could be $5 billion lower.[20]

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20   The weak domestic supply chain scenario for oil and gas assumes primary producers source 83 per cent of intermediate goods and 5 per cent of capital goods domestically. The strong domestic supply chain scenario assumes primary producers source 90 per cent of intermediate goods and 25 per cent of capital goods domestically.

EXHIBIT 17

Benefits are $5 billion lower in 2030 if the local supply chain fails to adapt as oil and gas automates

Estimated total annual Gross Value Added generated in the Australian economy by oil and gas
Billons, 2015 AUD

Estimates = Oil & Gas + Supply Chain + Wider Economy GVA

Steady state phase of growth

— Historical GVA
-- Weak domestic supply chain participation
-- Strong domestic supply chain participation
-- No automation

Note: No-automation scenario is included for analytical simplicity. It is not likely in reality as primary firms' current automation efforts are expected to continue.
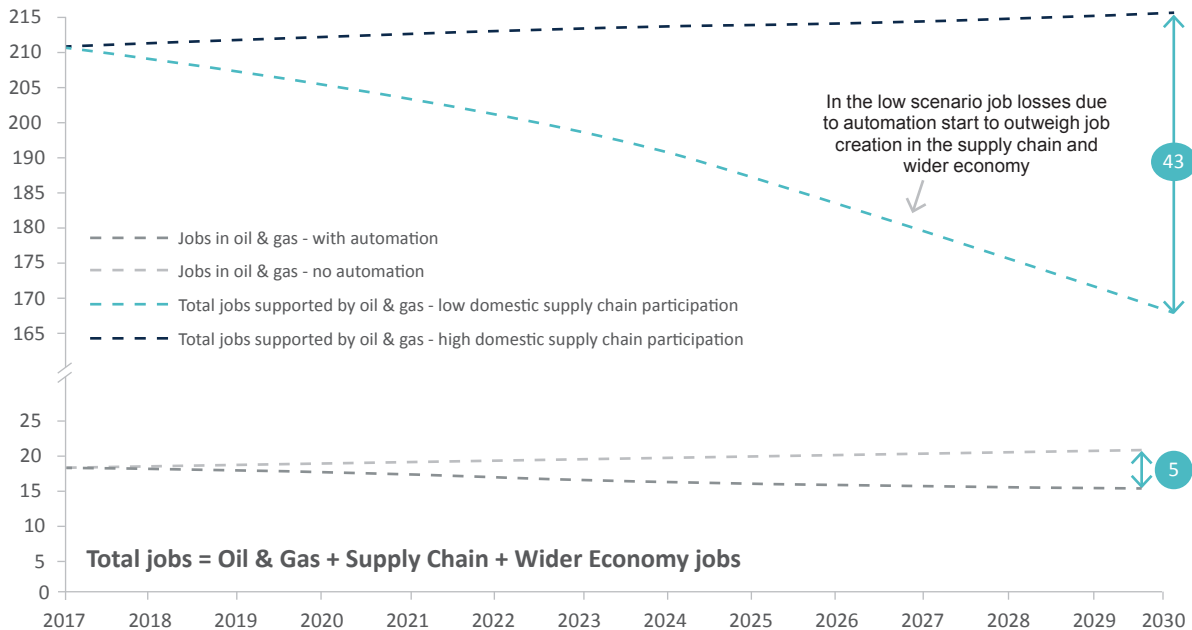Source: AlphaBeta analysis

...the oil and gas industry is expected to remain stable under strong domestic supply chain involvement...

Similarly, the degree to which oil and gas suppliers in Australia respond to the energy industry's growing need for automation technologies will have a considerable effect on employment. While the number of jobs supported by the oil and gas industry is expected to remain stable under strong domestic supply chain involvement, job losses could occur if suppliers fail to embrace the automation opportunity as primary firms will use overseas suppliers instead. The analysis shows that over 40,000 jobs are at stake in 2030 because they are dependent on the strength of Australia's oil and gas supply chain (EXHIBIT 18).

EXHIBIT 18

Over 40,000 jobs could be created in the Australian economy in 2030 if the local supply chain adapts as oil and gas automates

Estimated annual no. of jobs generated in the Australian economy by mining
Number of jobs, '000

Source: AlphaBeta analysis

4.5 THERE WILL BE SIGNIFICANT SAFETY AND ENVIRONMENT BENEFITS FROM THE IMPLEMENTATION OF AUTOMATION TECHNOLOGIES

Automation technologies also stand to bring significant non-economic benefits to the resources industries, most notably by improving worker safety and the environment.

Interviews with industry participants revealed that most major incidents in mining operations arise from vehicle-to-vehicle contact. The use of automated trucks in mining haulage operations has seen a reduction in the number of these incidents in mine sites, reducing safety-related haulage incidents by 50 per cent or more on average. Indeed, at one mine site, a fleet of self-driving trucks was responsible for reducing truck-related incidents by over 80 per cent.

The safety impact extends beyond haulage. Industry sources estimate that approximately 70 per cent of all incidents involving workers on mine sites could be mitigated if more automated technologies were used. For example, autonomous robots could reduce maintenance-related injuries to workers,

as dropped objects during maintenance are a major source of serious injury. Similar benefits would apply to oil and gas where robots can be deployed on offshore platforms, often in remote areas in high hazard plants and in confined spaces.

Meanwhile, automation technologies could generate substantial environmental benefits. For example, industry participants noted that since automated vehicles are generally more fuel efficient, mining companies could lower their diesel fuel use by 10 to 20 per cent if they shifted to autonomous haulage.

These technologies also stand to make mine sites and oil and gas plants smaller and more efficient, minimising their environmental footprint, and reducing energy usage and waste. In preparation for the 'mine of the future,' companies are also incorporating renewable energy solutions alongside automation technologies.

BUILDING SUCCESSFUL TECHNOLOGY CLUSTERS IS KEY TO MAXIMISING BENEFITS TO THE LOCAL SUPPLY CHAIN

Australia has the opportunity to become a world-class producer of automation technologies for the resources industries. Australia has a greater demand for automation technologies than anywhere else in the world, providing the foundations of a highly competitive resources automation technology supply chain. For example, 60 per cent of all specialist mining software is currently developed in Australia.

With these competitive advantages, Australia is well positioned to enhance our world-class supply chain of companies supplying automation technology to the resources industries. Such a supply chain could generate billions of dollars a year in domestic revenue. To realise this vision, Australia needs to be bold. Policymakers, resources companies, education providers, and researchers need to work together to ensure Australia develops the right environment for local technology suppliers to thrive in an increasingly competitive globalised environment. This section examines:

- Australian supply chain capabilities in the resources sector with respect to competitive factors around automation technologies

- Challenges that Australia faces in expanding its local supply chain

- Key actions that Australia can take to build a competitive local supply chain including the formation of digital analytics, automation and robotics clusters[21]

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21   A concentration of companies with a similar specialisation in a single geographical area

5.1 AUSTRALIA HAS THE FOUNDATIONS TO CREATE A HIGHLY COMPETITIVE AUTOMATION TECHNOLOGIES SUPPLY CHAIN

A strong platform for automation technologies growth already exists in Australia. Demand for automation is high in Australia, largely due to the need to be globally competitive and a strong appetite for reducing costs, improving efficiency and safety and creating new value via advanced technologies from resources companies operating in Australia. Australian technology developers have sprung into action in recent years to meet the growing local and global demand.

Many original equipment manufacturers (OEMs) in the resources industries now choose Australia as the place to undertake final testing of new automated and robotic solutions. Queensland has become a strong marketplace for software development and application, featuring companies such as RCT and Mineware, and research organisations such as CSIRO / Data 61. Similarly, Western Australia has become a testbed for developers of innovative mining technologies. Caterpillar and Komatsu both chose Western Australia to trial and launch their first autonomous haulage systems. Epiroc, the Swedish industrial manufacturer (formally Atlas Copco), first deployed new commercial autonomous drills here.

Oil and gas operators are also driving growth in Australia's resources industries automation technologies supply chain. While retaining their global headquarters offshore, six of the seven largest international oil and gas companies have established regional headquarters in Perth and Australia is now the world's largest LNG producer, in turn supporting the growth of local LNG technologies and capabilities.[22] Their demand for automation technologies is increasing, as producers seek to lift the productivity and safety of their operations.

In interviews with over 50 experts and industry representatives from the international resources community for this report, both business leaders and policymakers indicated they welcome the opportunity to build a world-class automation technology supply chain in Australia. However, many also noted a lack of coordination to channel their efforts. Pockets of collaboration already exist in Australia, for example, between educational institutions and large mining and oil and gas companies.[23] Coordinated city-wide, state-wide or national efforts to create clusters of automation technologies suppliers in Australia are now opportunities.

A literature review of global best practice reveals that digital and automation technology supply chains are most successful when organised in clusters. This means providing a concentrated space for all firms, researchers, education providers and government officials to work together, to commercialise new technologies, to attract and develop talent, and to increase private investment in research and development.

> ❝ *A strong platform for automation technologies growth already exists in Australia. Demand for automation is high in Australia, largely due to the need to be globally competitive and a strong appetite for reducing costs, improving efficiency and safety and creating new value via advanced technologies from resources companies operating in Australia.* ❞

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22   WA Government (2016), 'WA Innovation: Facts & Figures'. Available at: http://gcio.wa.gov.au/wp-content/uploads/2016/06/FactsFigures.pdf.

23   For example, Australian Centre for Energy and Process Training is a partnership between WA's South Metropolitan TAFE and the oil & gas industry. South Metropolitan TAFE and Rio Tinto have also recently partnered to set up an automation training program.

5.2 AUSTRALIA HAS A SIGNIFICANT OPPORTUNITY TO DEVELOP THE SUPPLY CHAIN VIA THE SUCCESS FACTORS OF COLLABORATION, INNOVATION AND SCALE-UP OF FIRMS

A review of success factors that have given rise to strong innovation sectors in 15 leading resources technology regions around the world shows that nine underlying drivers are critical for the development of a globally successful automation technology supply chain. These drivers are:

1. Sufficient domestic demand for local suppliers from mining and oil and gas companies with strong global market potential

2. Significant quantity and scale of mining and oil and gas technology suppliers

3. Superior technology and/or technological capability

4. High levels of innovation and research in new and emerging technology areas

5. Commercialising and scaling early stage technology and companies

6. Sufficient skills and capabilities through university, TAFE, and industry education and training in automation, especially for the resources industry

7. High levels of collaboration and engagement between and among mining companies, oil and gas operators, technology suppliers, universities and research institutions

8. Low levels of regulation and taxation and government facilitation of access to international markets

9. Quality and availability of transport, electricity, digital and communications infrastructure

While Australia is well placed to develop a strong export-competitive supply chain due to the high appetite and large demand for innovative technologies from its resources companies, its local business environment has some fundamental weaknesses.

To achieve its aspiration of maintaining its position as a world-leading resources industry through to 2030, Australia must lead the development and deployment of emerging data analytics, automation and robotics technologies by continuing to accelerate efforts to create a business-friendly environment.

Opportunities exist to:
- foster collaboration between industry, policymakers and education providers in the automation technologies sector.
- increase data analytics, automation and robotics R&D activity.
- accelerate the commercialisation of promising technologies.
- improve industry's ability to scale up and attract workers with the right skills and capabilities.

ACCELERATING COLLABORATION IN AND ACROSS SECTORS

Global analysis shows that collaboration is essential for a highly competitive supply chain. The automation technologies sector can only thrive when government, resources firms, suppliers, universities & TAFEs, industry bodies and research institutions are working together. This means Australia's resources regions and cities need to foster stakeholder networks if they want to become major global forces in automation technologies.

Industry interviews reveal closer collaboration between resources firms and local suppliers will ensure the suppliers develop products or services that exactly meet customer needs. Similarly, improved collaboration between suppliers and researchers will ensure the development of new technologies.

Many stakeholders noted the need for increased collaboration between resources firms to develop joint industry and technology standards, as well as skills and training programs, the world-class Australian Centre for Energy and Process Training (ACEPT) in the oil and gas industry being a notable example.[24] The need for improved collaboration is not confined to the resources industries.[25] Global indicators of collaboration between industry and researchers place Australia lower on the scale than is desirable. Decisive action is required to ensure Australia continues to produce world-leading innovation. Without stronger R&D partnerships between industry and researchers, Australia will be limited in creating an export-competitive resources automation industry.

Nonetheless, there are some individual success stories of promising collaboration in the resources industries. An example is the strong research and development partnership between engineering supplier Olitek and gold miner Newcrest.

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24 The oil and gas industry has led the way with South Metropolitan TAFE's Australian Centre for Energy and Process Training (ACEPT), a training industry partnership between TAFE, the WA Government and the oil and gas majors.

25 Australian Government Department of Industry, Innovation and Science (2016), 'Australia Innovation System Report 2016 2030: Prosperity through innovation – A plan for Australia to thrive in the global innovation race.' Available at: https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/Australian-Innovation-System/2016-AIS-Report.pdf

EXHIBIT 19

Olitek and Newcrest: A technology development partnership

Small technology companies know that ongoing investment in research and development is crucial for innovation. But without a clear understanding of customer needs, many firms are struggling to understand where their R&D efforts will pay off most. Australian engineering company Olitek has overcome this challenge – thanks to a R&D partnership with Newcrest Mining, one of the world's largest gold miners. The collaboration offers an example of what can be achieved when suppliers and primary resources companies work together.

Olitek manufactures specialised equipment for mining companies, such as an Explosive Charge-up Unit used in underground mining, as well as shipping container loaders, and control systems to allow safe operations for loading, securing, and tipping storage containers into trucks.

The collaboration with Newcrest has helped Olitek to sharpen its R&D focus, investing predominantly in the development of technology that Newcrest needs. It shares funding risks and intellectual property rights with

Newcrest. The miner also ensures that workers on the ground and the operations team are onside with the use of the new technology.

James Oliver, Managing Director of Olitek, says the key to success is to be immersed in the mining process: "With Newcrest, we go to the pit or the underground, observe the task that needs to be automated and get true buy in from the operators. We then go and design practical solutions with continuous involvement with the miner." As a result of the R&D partnership, Olitek says it has made inroads in developing new explosive equipment for both underground and open pit mining.

Tony Sprague, Group Manager Mining Technology at Newcrest is pleased with the progress being made. "When the new technology solutions arrive at site, our maintenance and operations teams are already familiar with them as they have had a hand in the design. Through this collaboration model with Olitek, Newcrest can move much faster."

STRENGTHENING INNOVATION AND R&D

If Australia wants to become a world-leading producer of innovative, high-quality mining technology, it needs to develop strong public and private investment in R&D. Research and development is critical for producing innovative ideas and new services or products. Strong R&D requires government funding, private funding and collaboration between industry and education providers. A strong foundation of collaborative R&D in Australia's resources industries would allow firms to access infrastructure, data and talent that would be difficult to access individually. Interviewees indicated: a stronger focus by universities on commercialisation of innovative ideas would be beneficial; that research projects need to develop commercial solutions in shorter time frames; and that in some cases, university IP management restricts commercialisation. Despite advancements in this area, research organisations have the opportunity to take further steps to address these areas.

IMPROVING OPPORTUNITIES TO DEVELOP AND COMMERCIALISE TECHNOLOGY

Commercialisation of early stage technology, and the scaling of small to medium companies, is critical to creating a concentration of technology suppliers. Innovative companies are often more profitable and more productive.[26] When exporting, innovative companies typically are also growing fast, hire more skilled people and create more jobs. To successfully commercialise an innovation, firms need access to funding, the ability to test new technology, to incubate new products and ideas, and to access large customers.

Many small to medium sized companies seeking funding to support their growth have limited knowledge of the drivers for investment by venture and investment funds. There is a need for additional financial support to commercialise innovation, with faster cycle times and simpler processes for good companies to access funds.

26   MIT Sloan Management Review (2017), 'Are innovative companies more profitable?' Available at: https://sloanreview.mit.edu/article/are-innovative-companies-more-profitable/.

Policy to encourage investment and funding that supports the commercialisation of innovative data analytics, automation and robotics in the resources industries would act as an incentive for more businesses to develop innovative solutions for the sector.

This funding issue is brought to light when reviewing other resource technology developers. Attracting more venture capital and investment funding is key to the growth of automation; industry needs to collaborate on profiling existing strengths in this area and improve its knowledge of the criteria sought by investment bodies. A 2016 report by Startup WA estimated investment in innovation to be $14 per person in the Netherlands, $54 in Norway, $81 in the United States, and $183 in Israel. In Western Australia and Queensland venture capital and private equity funding of technology start-ups is $6.61 and $5 per person respectively.[27]

A total of 45 per cent of participants in Startup WA's mining survey (n=40) identified access to capital as the greatest challenge start-ups and SMEs face.

The 2016 report found that only seven per cent of WA's tech start-ups were in the mining industry. Survey respondents acknowledged the growing number of incubators in Australia (13 in WA, including two incubators specifically focused on resources). However, many stated that Australia was behind world leaders in Tel Aviv, Toronto, and Cambridge.

Surveys and interviews also signalled that access to primary firms is another big hurdle for suppliers. Without access to a customer, especially an early customer, their ability to generate income and scale is very limited.

DEVELOPING SKILLS AND CAPABILITIES IN THE WORKFORCE

Ensuring Australian workers have the skills and capabilities to take up new business and work opportunities presented by new resources technologies will be fundamental to the success of the resources supply chain. Without the development of this talent pipeline, there will be a lack of technological development, a gap in technology entrepreneurs in the resources industries, and a likely fall in supplier productivity.

Currently, Australia does not have the talent capacity to support a strong resources automation industry in Perth and/or Brisbane. For example, in 2014, Western Australia, a state with 11 per cent of Australia's population, produced only seven per cent (335) of information and communications technology (ICT) graduates.

TAFE and universities both have a role to play to address the supply of the future workforce. TAFE has the ability to rapidly adapt to these changing skill requirements for existing and new workers, while universities provide a highly skilled workforce with graduates able to contribute to the development of innovation three to five years into the future.

There are signs that education providers and industry are beginning to recognise the need for improved training and skills development (see EXHIBITS 21 and 22). New education programs are emerging, such as the work in Western Australia led by South Metropolitan TAFE (see EXHIBIT 20).

EXHIBIT 20

TAFE, Government & Industry prepare young West Australians for the jobs of the future

In resource-rich Western Australia, mining executives, government officials and educators have joined forces to train the next generation of skilled workers for the mining automation industry.

When teachers at South Metropolitan TAFE learned that more mining companies were using autonomous trucks to ship commodities across the nearby Pilbara desert, they decided it was time to change their curricula. To them, the latest advances in autonomous mining technology offer a real career opportunity for their students in a rapidly changing world of work.

But which skills will students need to qualify for future jobs in the mining technology industry? TAFE officials realised they needed to get industry and governments on board. After several months of consultation, last year they launched a new cross-sector training course to prepare students for the automation age in the mining, oil and gas industries.

The course will cover data analytics, robotics, computing, and information technology. Brand-new training facilities will allow students to get hands-on and experiment with the latest mining technology in a lab environment. The first students are expected to start in 2019.

Mining giant Rio Tinto was the first big company to join the collaboration, but TAFE officials hope that they can win further support from companies in the resources sector and beyond.

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27   Startup WA (2016), 'Western Australia 2015–16 Startup Ecosystem Report.' Available at: http://www.startupwa.org/blog/2016/7/25/wa-startup-ecosystem-report-2016.

EXHIBIT 21

Roy Hill is supporting its workforce as it embraces the future autonomous mine

Roy Hill is embracing the opportunities that automation presents. Roy Hill operates a substantial mining project in Western Australia's Pilbara region and, like many other resources companies, has started to introduce autonomous technology on site.

For Roy Hill, the change is as much about technology as it is about people. The company has designed a "People Plan" to support its workers through the transition. It is now reassessing its workforce strategy – analysing future work and skills that will be required. Roy Hill is also identifying the training and career pathways to supports its people through these changes.

Significant work is currently being undertaken to analyse re-skilling opportunities for people whose roles will change when mines become partly or fully autonomous. Roy Hill is providing internal training to teach mining workers additional skills and help them transition into new roles, including as data analysts, tele-remote operators,

and maintenance technicians with improved technical knowledge.

But the company is also thinking about a support framework for workers whose roles may become redundant through automation. For instance, it has recently introduced an additional two days per year of career development for everyone in the company to help workers actively manage their careers. It is also exploring career transition services for some of its workforce.

Communication is key. To ensure workers understand the upcoming changes, Roy Hill has already kicked off a series of company-wide consultations to explain its automation strategy and its likely impact on the workforce.

Workers appreciate the transparency and support. In recent feedback, staff said they value the company's proactive approach of managing the transition.

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28   Norwegian Petroleum (2017), 'The service and supply industry.' Available at: http://www.norskpetroleum.no/en/developments-and-operations/service-and-supply-industry/.

5.3 AUSTRALIA NEEDS TO PREPARE TO COMPLETE WITH TECHNOLOGY SUPPLIERS GLOBALLY

The economic opportunity for automation technologies and services in the resources industries has led a number of regions across the world to reshuffle their priorities and put large efforts into the development of fast-growing supply chains of automation technologies. These regions are succeeding because they have developed a coherent strategy among government, industry and educational institutions focused on building "clusters" backed by government investment and policy. Their commitment is producing clear results: stronger research and development, faster commercialisation of new technologies, and a solid talent pipeline of workers with automation technology skills

Clusters consist of a local concentration of core companies of various sizes and levels of maturity. Companies benefit greatly from operating in a cluster as it gives them access to educational and research institutions, investors, industry associations, customers, and all levels of government. Creating such a cluster, or ecosystem, creates a beneficial web of innovation, talent, export capability, and employment.

Three of these key competing regions are:

Arizona: Arizona is famous for its 'Sun Corridor,' a mining automation technologies cluster that stretches from Tucson to Phoenix. Today, the Sun Corridor is considered a best practice example in building advanced facilities for harnessing emerging technology to solve industry problems. It has become particularly popular as a location where big manufacturers including Caterpillar and Komatsu test their latest innovations. To facilitate collaboration, Arizona has created the 'Arizona Technology Council,' a one-stop-shop for businesses working in the field. Representing over 750 local technology suppliers, the council is typically the first place for business seeking to network, collaborate and procure specific technology services and products.

Norway: Norway is a well-known success story exporting oil and gas technology to the world. The country has been a leader in oil and gas automation for over three decades, specialising in semi-manned platforms and automated subsea rovers. Behind the success is a strong network of technology suppliers with deep links into global supply chains. In 2016, 35 per cent of the Norwegian oil and gas technology industry's total sales worth NOK 378 billion came from exports into international markets.[28] Local technology firms collaborate closely with each other and the government: the Norwegian government has helped to establish cluster bodies at a local, state and global level that drive collaboration in cluster areas and offers tax subsidies for suppliers. Equinor, the semi-public oil producer provides R&D funding.

Canada: A world-class technology cluster is now being formed in South-Eastern Canada, known as the 'Toronto-Waterloo Innovation Corridor.' Support from the Government of Ontario has been critical for its development. Policymakers have also been instrumental in reshaping the education sector to strengthen the pipeline of workers with skills in automation technologies. A positive investment climate has helped tech start-ups grow: for example, Canada has the second-highest concentration of banks in the world and is home to US$1.5 trillion in institutional capital.[29]

In the course of this study, a number of experts have also suggested Southern China (e.g. Foshan) as a new and significant potential technology competitor. While the project team has not evaluated this claim in detail for this report, there is indicative evidence that China's overall industrial automation and robotics capability is strong, growing, and seeking international business.

29   McKinsey (2016), 'The Toronto-Waterloo Innovation Corridor.' Available at: https://www.mckinsey.com/global-themes/americas/the-toronto-waterloo-innovation-corridor.

30   Robotics Business Review (2017), 'Why is Pittsburgh ideal for your robotics business.' Available at: https://www.roboticsbusinessreview.com/events/pittsburgh-ideal-robotics-businesses/.

31   Brookings (2017), 'Capturing the next economy: Pittsburgh's rise as a global innovation city.' Available at: https://www.brookings.edu/research/capturing-the-next-economy-pittsburghs-rise-as-a-global-innovation-city/.

EXHIBIT 22

Pittsburgh: From a resources city to a resources automation hub

Pittsburgh, a city on the US east coast, located in a region rich in petroleum, natural gas and coal, has become a hub for some of the world's leading producers of automation technology for the mining, oil and gas industries.

Aptly named 'Robotics Row,' Pittsburgh's city centre has grown into a mini Silicon Valley over time. Today, it is home to over 20 robotics technology ventures, including Uber's self-driving car unit.[30] Mining equipment maker Caterpillar is producing an Autonomous Haulage system, and petroleum giant Shell an offshore inspection robot. From Pittsburgh, these technologies are helping to transform the resources sector around the world.

It has also become a city producing the workers with crucial skills and capabilities for the automation age. Between 2009 and 2015 employment in automation and machinery in Pittsburgh has grown by 6.3 per cent to 6,909 jobs. The city's computing workforce increased by nearly 50 per cent to 17,474 jobs.[31]

While Pittsburgh's natural resource endowment provided the initial lure for specialists offering mining automation technology, its start-up scene is thriving for other reasons. Pittsburgh has achieved what other resource-rich areas haven't: create a strong cluster with a strong vision for the future and the right ingredients for success.

To start with, Pittsburgh has rallied everyone in the sector behind the vision of becoming a world leader in automation technologies. Multinational firms such as Uber, Caterpillar, Komatsu, Apple and Google work closely with local universities Carnegie Mellon University (CMU) and University of Pittsburgh, and other research institutions such as the National Robotics Engineering Center. Formal and informal collaboration networks also link industry with investors, and local and state government officials.

Local university Carnegie Mellon has played a major role in attracting talent to the region – thanks to its reputation as a top-tier institution for math and computer science. Its high-caliber graduates have led Uber, Google, and Apple to set up key operations in Pittsburgh.

Universities have also been instrumental in driving an entrepreneurial culture. Many offer a dual career path combining academic work and commercial development, encouraging students to start their own businesses. Between 2013 and 2015 Pittsburgh universities secured 122 patents leading to the formation of 62 start-up companies.

Strong private venture capital markets and government funding are supporting the local start-up growth. From 2014 to 2015, 84 businesses secured $499m in venture capital – as much as the entire venture capital funding in Australia ($516m in 2014).

Pittsburgh is now a model for other regions worldwide.

Australia fares well against these regions in some areas but lags in others. For example, Australia has a strong financial sector in Sydney and Melbourne, which provides a source of venture capital and private equity to spur innovation in resource technology companies. Australia also has a growing number of world-leading automation technologies programs at universities, for example at QUT and the University of Sydney, engaging local and global industries.

However, Australia is lagging other regions, such as Arizona, in the development of 'active tools' for collaborating and testing technologies such as Living Labs. Australia also lacks formal institutions to foster the cooperation and collaboration between policymakers, business leaders, entrepreneurs and educators. There are outstanding opportunities to leverage existing technology bodies and create clusters of data analytics, automation and robotics expertise in Perth and Brisbane. Arizona's supplier organisation has attracted 700 members while Pittsburgh's has more than 1,400.

5.4 AUSTRALIA SHOULD CREATE WORLD-CLASS RESOURCES AUTOMATION CLUSTERS GENERATING BILLIONS OF DOLLARS A YEAR IN DOMESTIC AND EXPORT REVENUE BY 2030

Australia has the foundations to be a country that has a world-class resources automation technology industry by 2030. Our vision for the sector is comprised of four elements:

- **Leading resources automation technology application and development.** Australia already has a capable and growing automation technology base which, with support, can develop into a world-leading capability. Australia has particular strengths in software, services and remote operations.

- **World-class universities** are crucial to all technology clusters in the world. Without best-in-class technology and the ability to integrate with industry, it is impossible to develop a successful automation cluster.

- **Skills are also vital** to the long-term success of a cluster. These include graduates and research fellows, vocational graduates with automation technology skills and their application in industry.

- **An effective environment for commercialising technologies.** This entails the process of technology development from funding to incubating to testing and marketing. Without this ecosystem for start-ups and scaling up, it is impossible for innovation to be catalysed.

EXHIBIT 23

This is a unique opportunity to build a world-leading advantage in resources-based automation and robotics

VISION
Highly competitive resources automation and robotics clusters generating tens of billions of dollars per year in domestic and export revenue

Leading global resources automation technology **application and development** with best-in-class systems integration, data analytics and automation support technology

World-class resources-focussed **robotics and automation universities collaborating effectively with industry**

Training and attracting thousands of computer engineers / data scientists etc with resources knowledge and **tech-literate operators**

A thriving entrepreneurial scene with **hundreds of start-ups and tens of millions of dollars invested annually**

5.5 FOUR STEPS TO TURN THE AUTOMATION TECHNOLOGIES VISION INTO REALITY

To achieve its vision of establishing a world-class automation industry by 2030, Australia needs to make a strong commitment to create a conducive environment that allows local automation technologies businesses to thrive. This requires government, industry, universities and TAFEs to play key roles as part of a coordinated strategy.

> *Australia has a strong financial sector in Sydney and Melbourne, which provides a source of venture capital and private equity to spur innovation in resource technology companies.*

EXHIBIT 24

Each actor has a key role to play

Role of actors

INDUSTRY
- Takes lead in setting up central leadership forum and establishing clusters
- Sets out priority actions and initiatives; determines collaboration areas and means of collaboration
- Contributes to funding the leadership forum and broader program

GOVERNMENT
- Supports clusters through central leadership forum
- Responds where market failures exist (e.g. skills gaps and lack of collaboration) through means such as grants and vouchers
- State governments provide localised support (e.g. land); federal government provides bespoke initiatives

UNIVERSITIES, TAFES
- Actively participates in central leadership forum
- Works with industry to develop appropriate training and education programs as well as mechanisms for increasing R&D and commercialisation of technology

Their roles are all critical as part of a proposed four-step roadmap to develop a competitive advantage.

EXHIBIT 25

A four step roadmap is proposed to develop this competitive advantage

Recommended actions

CALL TO ACTION

- **Leadership commitment from government, industry bodies, universities** to build world-leading cross-industry clusters around automation and robotics

CREATE CLUSTERS

- **Set up clusters in appropriate location/s** co-located with industry / universities / supply chain
- **Establish an effective brand** for each cluster

DEVELOP AN ENTREPRENEURSHIP ECOSYSTEM

- **Co-ordinate funding** for sponsored programmes, joint industry projects to stimulate scale-up & start-ups
- **Scale up collaboration** through shared plans, public registries of suppliers, Living Labs, incubators etc

BOOST SKILLS & R&D

- **Create a cross-industry approach** to build a strong short- and long-term skills program
- **Partner with leading robotics universities** around the world to immediately kick-start skills & R&D approach

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1. **Call to action.** Leadership across the industry is required to make the clusters a success. Industry, government, universities, research institutions, and supply chain leaders should commit to a shared vision of what can be achieved and how. This leadership forum should also outline an approach to cultural change and how to move from a closed competition model to a 'co-opetition' model which would provide a common platform for the whole sector.

2. **Setting up clusters.** International experience shows that when managed well, clusters can facilitate innovation, collaboration and knowledge sharing to the benefit of all participants. A network of national automation and robotic clusters established in appropriate locations across Australia with the right governance and branding is the best way to operationalise the development of automation technologies, craft a shared identity and ensure effective join-up between participants.

3. **Develop an entrepreneurship ecosystem.** Clusters only work when there is a thriving marketplace for commercial technology. This means an environment where there is access to funding, availability of skills, places to work, locations to innovate and importantly ability to reach potential customers easily. A variety of actions should be taken to strengthen and develop the elements of this process.

4. **Building skills and R&D platform through universities & firms.** Continuing to graduate world class talent to meet the new skills demand and improving the R&D process are two of the biggest opportunities for Australia to remain internationally competitive in the long run. There is evidence of educators and industry transitioning today's workforce to meet current technology and skill demands and to ensure it remains a leader as the adoption of advanced automation accelerates, as well as creating the platform for success in future. In skills, this means accelerated learning to capture the near-term workforce opportunities created by advanced automation technologies and developing a vision of the educational and vocational training needs of the future workforce. In R&D, there is a need to build on Australia's expertise in automation and robotics and develop world class niches as well as find long-lasting and profitable mechanisms for collaboration between universities, research groups and industry.

While it is not within the remit of this report to recommend a complete solution to meeting these opportunities, below is a menu of more detailed impactful actions that could be taken to set up clusters.

ROADMAP IMPLEMENTATION: Recommended detailed actions	Key contributor
Roadmap Step 1: Call to action Bring all key stakeholders: industry, supply chain, government, TAFE, university, others together to determine the drivers for success to setting up clusters	
Identify representatives from key stakeholders to coordinate development of digital technologies for resources sectors	Industry (others participate)
Bring **government, universities, TAFE, other stakeholders** to table and commit to action in this area	Industry
Engage other industries with similar technology as appropriate (e.g. agriculture)	Industry
Roadmap Step 2: Identify a number of potential automation and robotics clusters Take appropriate actions to establish clusters including choosing locations, drafting a strategy, setting up appropriate governance:	
Develop clusters in appropriate locations for resources automation and devise a strategy	Coordinating body / Industry
Establish appropriate governance for each cluster	Coordinating body / Industry
Ensure representation of as many large and small primary firms in the clusters as possible	Coordinating body / Industry
Use industry-led projects and competitions to coordinate funding in the clusters as opposed to top-down approaches	Coordinating body / Industry
Facilitate setting up clusters building on cross-industry cluster knowledge	Government
Roadmap Step 3: Develop an entrepreneurial ecosystem Scale-up and ensure greater collaboration and integration in the entrepreneurial ecosystem around automation and robotics technology:	
Coordinate existing funding to ensure prioritised and efficient commercialisation of key technology	Industry
Facilitate opportunities for resources companies to share vision, high level roadmap and plans for future with sector	Industry
Set up joint locations to test technology such as living labs	Industry
Develop standard models for sharing risk and technology between large firms and supply chain	Industry / Universities
Encourage standardisation of software (and interoperability) so smaller and emerging suppliers can integrate their software easily	Industry
Expand cross-industry collaboration by expanding cluster to adjacent industries / invite other automation and technology providers (e.g. uber, google) to develop projects alongside the cluster	Industry

Introduce targeted specific funding for initiatives (e.g. fast-fail grants, specific grant funding) where there is market failure around the technology	Government
Develop light touch regulation of automation technologies in conjunction with industry	Government
Provide incentives for purchasing / leasing land for testing and development of technologies	Government (state)
Create a public technology supplier registry and mapping of the sector	Government
Roadmap Step 4: Establish a cross-industry skills and R&D approach Develop programs to improve skills in these technology areas and devise specific approaches to incentivising key R&D:	
Mobilise the joint industry skills strategy which outlines a vision for jobs in the sector and approach for standardising and harmonising approaches	Industry
Endorse cross-industry TAFE and university programmes to develop general automation technology skills now and in future (e.g. South-Metro TAFE cross industry program)	Industry
Ensure policy support and resources for comprehensive industry led training and retraining programs reskilling workers for job market	Industry
Profile existing cross-industry research institutes focused on early stage technology	Industry
Investigate access to highly skilled foreign nationals (e.g. visa requirements)[32]	Government
Enhance market and export readiness programs specifically for supply chain firms in the sector	Government
Increase collaborative vouchers available for resources technology industry to help businesses work with researchers on innovative and new products and processes	Government
Set up multiple CRC / CRC-Ps / ARC / ITRPs to develop specific digital technologies where appropriate	Government / Universities / Industry
Communicate current IP ownership agreements for university projects with industry with improved incentives for universities and research institutions to partner with SMEs	Universities, Government
Develop partnerships between Australian universities and world leading automation technology universities such as Carnegie Mellon University	Universities
Investigate ways to create alternative tracks for academic staff that reward industry collaboration	Universities

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32   Australian Government Department of Home Affairs, *Working in Australia*. Available at:
https://immi.homeaffairs.gov.au/visas/working-in-australia/visas-for-innovation/global-talent-scheme.

6

APPENDIX

6.1 CURRENT VALUE AND JOBS GENERATED BY AUSTRALIA'S RESOURCES INDUSTRIES

The resources industries have large impacts on their supply chains and the wider economy. As at 2017, we estimate that mining generates over $200 billion of GVA to the Australian economy, and oil and gas generates about $50 billion (EXHIBIT 26). This includes value added within the industries themselves, their supply chains, and value added induced in the wider economy by spending from households who are employed in the resources sector or the supply chains.

The supply chain and wider economic impacts were calculated using ABS Input-Output tables. These tables outline the inter-industry links within the Australian economy and the sources of industry inputs. Using the tables, we can calculate the effect of an output increase in one industry on its supply chain industries and the household sector.

EXHIBIT 26

Mining currently generates $210 billion of Gross Value Added in the Australian economy, oil and gas generates $51 billion

Current GVA generated by mining and oil and gas
Billons, 2017, 2015 AUD
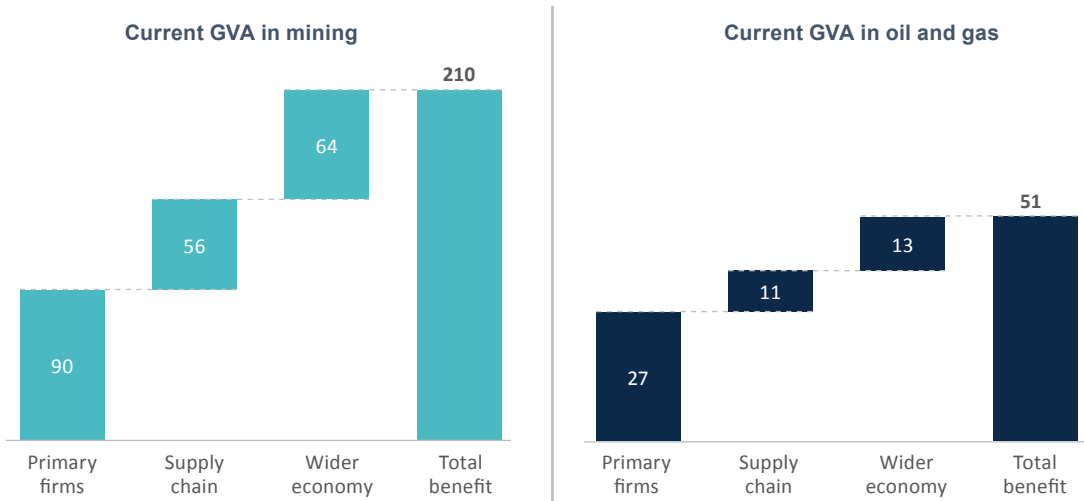
- The supply chains and the wider economy GVA estimates were derived using ABS Input-Output tables.
- These tables detail the inter-industry links within the Australian economy and the sources of mining and oil and gas inputs

Source: AlphaBeta analysis

These strong linkages with other industries mean mining and oil and gas support a substantial amount of employment in the economy. Across the industries themselves, their supply chains, and the wider economy, mining supports over 1 million jobs in the economy and oil and gas supports over 200,000 jobs (EXHIBIT 27).

These estimates were derived from the GVA estimates in EXHIBIT 26 and the GVA per worker in each industry. GVA per worker was calculated using ABS industry and employment data.

EXHIBIT 27

Mining currently supports over 1 million jobs in Australian economy, oil and gas supports over 210,000

Current GVA generated by mining and oil and gas
Number of jobs, 2017
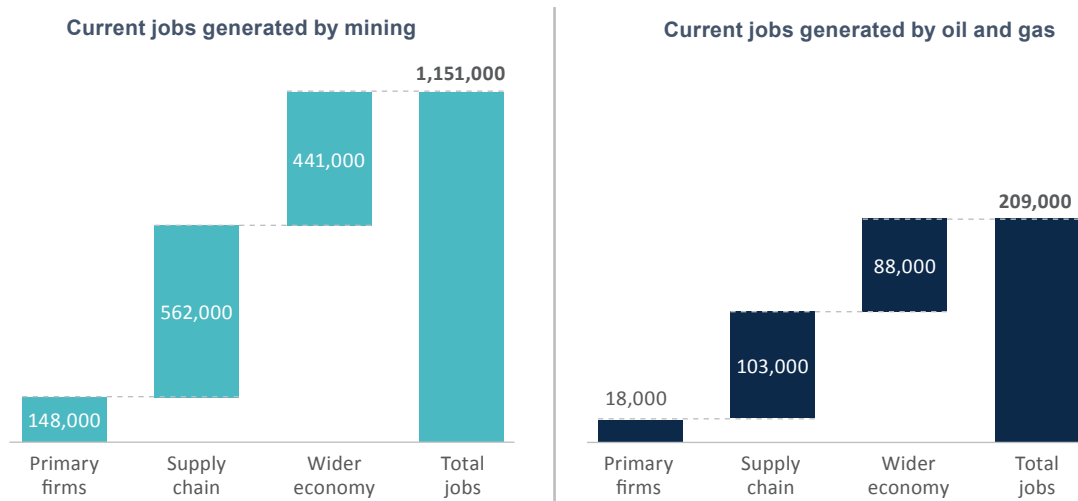
Current jobs generated by mining

- Primary firms: 148,000
- Supply chain: 562,000
- Wider economy: 441,000
- Total jobs: 1,151,000

Current jobs generated by oil and gas

- Primary firms: 18,000
- Supply chain: 103,000
- Wider economy: 88,000
- Total jobs: 209,000

- The jobs estimates were formed using the GVA estimates and GVA per worker within the supply chains and wider economy
- GVA per worker was calculated using the supply chain structure given by ABS Input-Output tables, and ABS data on GVA and employment across all Australian industries

Source: AlphaBeta analysis

In mining, under the strong domestic supply scenario, 35% of capital goods are sourced locally, while in oil and gas the figure is 25%.

6.2 NET PRESENT VALUES OF ESTIMATED GVA GENERATED BETWEEN 2017 AND 2030

Without automation, we estimate that mining will generate NPV $1,617 billion of GVA in the Australian economy between 2017 and 2030 (EXHIBIT 28). Automation, alongside a strong domestic supply chain, could generate up to NPV $160 billion on top of that, this increase driven by value uplift across mining, its supply chain and the wider economy. With weak domestic supply involvement, relative to no-automation, the supply chain and wider economy suffer losses, reducing the overall benefit to about NPV $100 billion.

NPVs were calculated using a 10% discount rate. The rate was set roughly equal to the cost of capital equipment – defined as the sum of the capital depreciation rate and borrowing rate. We calculated the depreciation rate by taking the ratio of depreciation expenditure in the resources industries to their respective net capital stocks. We calculated the borrowing rate by taking the ratio of capital financing expenditure to net capital stock. The data was sourced from the ABS.

EXHIBIT 28

Automation in mining could generate between $99 and $160 billion of additional GVA in the Australian economy between 2017 and 2030

Size of the prize from the uptake of automation and robotics in mining
Net Present Value of additional GVA generated between 2017-2030, billion, 2015 AUD
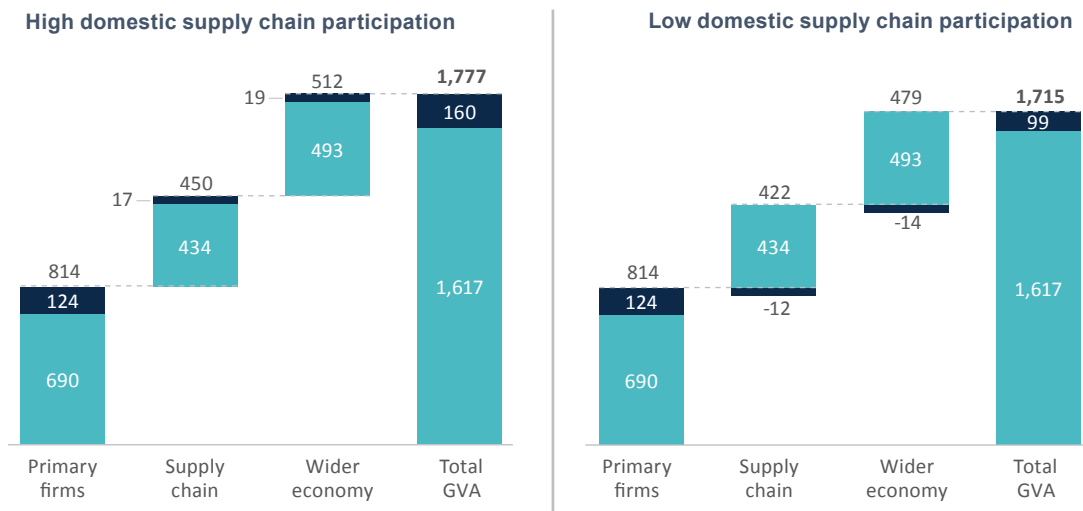
- The high participation supply chain scenario assumes 11% of intermediate inputs to mining are imported, and the low supply chain scenario assumes 16%. These figures were the minimum and maximum import percentages for Australian mining, calculated using ABS data spanning 2006-2013. The import figures were checked against US mining import data spanning 1997-2016.
- The high participation supply chain scenario assumes 65% of capital goods are imported, and the low participation scenario assumes 95%. These figures were calibrated based on data and feedback from industry interviews

Source: AlphaBeta analysis

■ No automation ■ GVA input of automation

In similar fashion, the oil and gas supply chain can contribute or detract from data analytics, automation and digital technology benefits. As shown in EXHIBIT 29, the supply chain and wider economy could contribute NPV $4 billion ($2 billion each) on top of NPV $19 billion benefit generated by automation in oil and gas, bringing the total benefit to NPV $23 billion.

In mining, the supply chain and wider economy upside is larger than the downside, whereas in oil and gas the opposite holds true. This result is driven by the proportion of capital goods sourced locally. In mining, under the strong domestic supply scenario, 35% of capital goods are sourced locally, while in oil and gas the figure is 25%. This difference becomes key as the sectors demand more and more capital goods as automation takes place. The capital good import assumptions were informed by industry interviews.

EXHIBIT 29

Automation in oil and gas could generate between $10 and $23 billion of additional GVA in the Australian economy between 2017 and 2030

Size of the prize from the uptake of automation and robotics in oil and gas
Net Present Value of additional GVA generated between 2017-2030, billion, 2015 AUD

High domestic supply chain participation

Low domestic supply chain participation
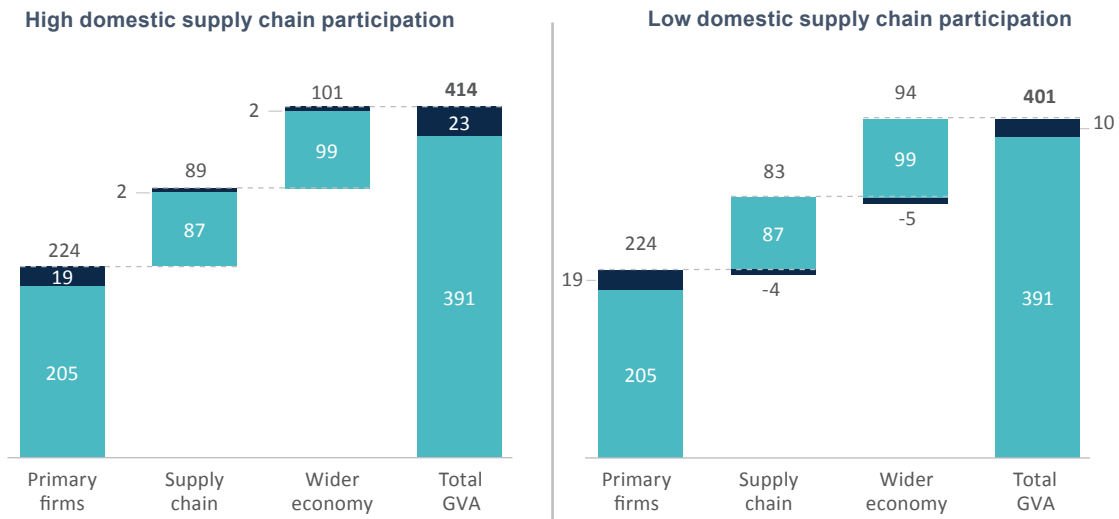
- The high domestic supply chain participation scenario assumes 10% of intermediate inputs to mining are imported, and the low scenario assumes 17%. These figures were the minimum and maximum import percentages for Australian oil and gas, calculated using ABS data spanning 2006 -2013. The import figures were also checked against US oil and gas import data spanning 1997 - 2016, which had similar figures.
- The high scenario also assumes 75% of capital goods are imported, and the low scenario assumes 95%. These figures were calibrated based on data and feedback from industry interviews.

Source: AlphaBeta analysis

■ No automation ■ GVA input of automation

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6.3 ESTIMATED JOBS IMPACT OF AUTOMATION IN 2030

The overall jobs impact of data analytics, automation and digital technologies across the resources industries is contingent on the performance of their supply chains. As shown in EXHIBIT 30 and EXHIBIT 31, automation technologies will bring about job opportunities in those industries, as productivity improves and technology changes are introduced. Leading global companies impacted by these changes are already upskilling their workforce to ensure staff retention, and access to highly skilled workforce in their region.

The overall jobs impact however is more intricate. Research by the World Economic Forum estimates the potential job losses caused by automation and digitisation in the global mining industry to be around 5 percent.[33]

A strong domestic supply chain can more than offset potential job losses in mining and oil and gas, leading to an increase in employment supported by those sectors. If the domestic supply chain does not adapt to the needs of automating mining and oil and gas companies, Australian companies will miss the opportunity to develop their workforce and provide employees with higher paid employment in digital technology enabled positions.

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33   World Economic Forum (2017), *Digital Transformation Initiative, Mining and Metals Industry.*
Available at: http://reports.weforum.org/digital-transformation.

EXHIBIT 30

Automation's overall impact on mining-related jobs in Australia in 2030 depends on the participation of the local supply chain

Jobs impact of automation uptake in mining
Number of jobs, 2030

High domestic supply chain participation

490,000

1,228,000

49,000

77,000

441,000

1,151,000

625,000

63,000

562,000

113,000

148,000

-35,000

| Primary firms | Supply chain | Wider economy | Total jobs |

Low domestic supply chain participation

1,005,000

392,000

441,000

1,151,000

-49,000

500,000

562,000

-62,000

113,000

148,000

-35,000

-146,000

| Primary firms | Supply chain | Wider economy | Total jobs |

- The jobs estimates were formed using the GVA estimates and GVA per worker within the supply chains and wider economy
- GVA per worker was calculated using the supply chain structure given by ABS Input-Output tables, and ABS data on GVA and employment across all Australian industries

Source: AlphaBeta analysis
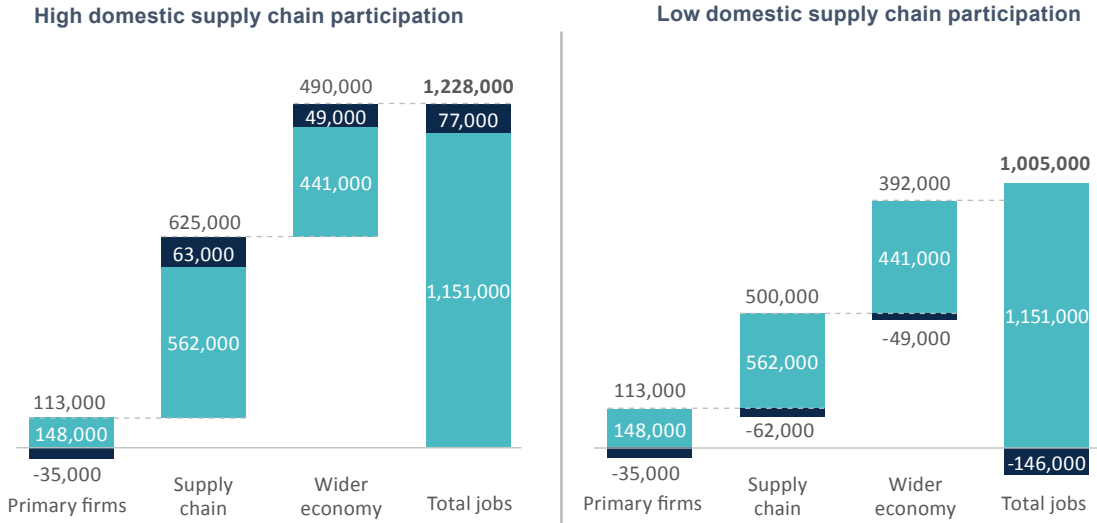
■ No automation ■ GVA input of automation

❝ A strong domestic supply chain can more than offset potential job losses in mining and oil and gas, leading to an increase in employment supported by those sectors. ❞

EXHIBIT 31

Automation's overall impact on oil and gas related jobs in Australia in 2030 depends on the participation of the local supply chain

Jobs impact of automation & robotics uptake in oil and gas
Number of jobs, 2030

High domestic supply chain participation

Low domestic supply chain participation

- The jobs estimates were formed using the GVA estimates and GVA per worker within the supply chains and wider economy
- GVA per worker was calculated using the supply chain structure given by ABS Input-Output tables, and ABS data on GVA and employment across all Australian industries

Source: AlphaBeta analysis
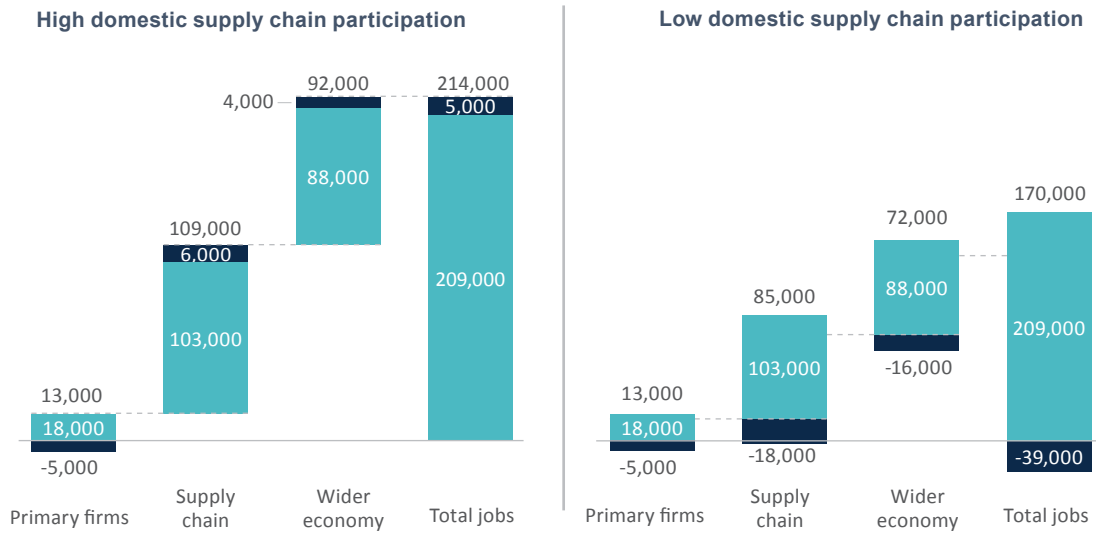
No automation   GVA input of automation

Our research and industry interviews identified 19 analytical automation and digital technologies that would be adopted in the move to digital operations in mining, and 13 technologies in oil and gas.

6.4 TECHNICAL APPENDIX

Modelling overview

Impacts on the resources sector

As summarised in EXHIBIT 32, we modelled the total economic impact of automation in several stages. We first constructed a model whereby each part of the value chain within a mine/oil and gas site produces output according to a Cobb-Douglas specification, using a mix of capital, labour and intermediate goods. We then calculated the pre-automation expenditure shares for each factor of production using ABS mining/oil and gas expenditure data and breakdowns of expenditure across value chain activities from industry interviews.

We then used these expenditure shares, combined with the Cobb-Douglas production function, to calculate the importance of each factor of production to each part of the mining/oil and gas value chain, and the importance of each value chain component to overall production. This process yielded the optimal pre-automation levels of capital, labour, intermediate goods.

Our research and industry interviews identified 19 analytical automation and digital technologies that would be adopted in the move to digital operations in mining, and 13 technologies in oil and gas.[34] Using case studies, and data from mining/oil and gas companies, we then determined the current and expected future uptake of these technologies to 2030, the value chain components they would impact (e.g. production, logistics, etc.), and their impacts on operational expenditure, capital expenditure, and overall productivity.

Given the technology impacts, we calculated the new expenditure shares for each factor of production and the post-automation contributions of each factor to each part of the value chain to achieve the pre-automation level of output. These parameters provided the optimal post-automation levels of capital, labour, and intermediate goods to achieve the same pre-automation level of output.

Resources sector output changes

We next estimated the change in mining/oil and gas output over the course of automation technologies to 2030. We did so by first estimating Australia's current share of global mining, and oil and gas output using data from industry interviews and desktop research.

We assume a competitive global resources sector, which implies company profits remain constant and one global commodity price. As such, to achieve this commodity prices must fall in response to productivity gains. Not all countries will experience the same productivity gains though. To remain competitive, countries with lower productivity gains – and consequently smaller price falls – will reduce output as they match their competitors' prices.

We assume mining competitors in the rest of the world achieve 80% of Australia's productivity gains over the course of automation, with 90% assumed for global oil and gas competitors. Global mining competitors are generally labour-intensive developing countries that are unlikely to invest in capital to the same extent as Australia. Therefore, Australian mining's productivity is conservatively presumed to increase marginally faster. Australia's oil and gas competitors are more likely than its mining competitors to make capital investments.

Given the price changes implied by the model, and the relative productivity changes in Australia and the rest of the world, we derived Australia's post-automation share of global mining, and oil and gas output. Using these new shares and the increase in resource demand stemming from the lower commodity price, we then calculated Australia's post-automation output levels.

This new output level in conjunction with the post-automation Cobb-Douglas parameters, gave the final post-automation optimal mix of inputs.

Impacts on the supply chain and wider economy

These changes to mining/oil and gas outputs and input mixes, in turn influence intermediate and capital good supply chains. They will also impact the wider economy through changes to household spending as households employed within mining/oil and gas and their supply chains alter their consumption due to changes in income. The changes in household spending induce another round of output impacts across the economy.

We estimated these two impacts by first calculating pre-automation supply chain and wider economic impact multipliers from ABS Input-Output tables spanning 2006–2013. The multipliers quantify the effect of an output increase in mining/oil and gas on output/GVA in their supply chain industries and the wider economy. For example, in 2012–13 a $1 increase in output from the oil and gas industry, would generate 25 cents of Gross Value Added in its supply chain.

As data analytics, automation and digital technologies alter the optimal combination and amount of inputs, these supply chain and wider economy multipliers evolve as automation takes place. As such, we created multipliers for each year between 2017 and 2030 as a weighted average of the pre-automation multipliers and the post-automation input structure implied by the model.

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34   We modelled automation uptake as a smooth exponential function with full implementation in 2030.

EXHIBIT 32

The economic model fully specifies the impact of automation technologies on inputs and outputs across the industry, supply chain and broader economy

Approach to modelling the total economic impact of automation and robotics technologies[1]

Estimate pre-automation production

$$Y_{D0} = Af(L_0, K_0, I_0)$$

where:
- Y_{D0} is the output of the direct mining firms before automation
- L, K, I are labour capital and intermediate inputs

Technology example:
- Before automation the vehicle component of the mining industry produces a certain of output with a certain level of inputs of workers, capital and intermediate goods.

Estimate impact of automation on productivity

$$Y_{D0} = Af(L_1, K_1, I_1)$$

where:
- L_1, K_1, I_1 is the new (lower) amount of each input required to produce the same amount of output Y_{D0} after productivity improvements

Technology example:
- Case studies show improvements in productivity of L, K, I
- So automation means the same amount of output can be produced with less workers, capital & intermediate goods.

Estimate increase in output from improved competitiveness

$$Y_{D2} = Af(L_2, K_2, I_2)$$

where:
- Y_{D2} is the output following a supply response, where the firms improved competitiveness leads to greater output

Technology example:
- As a result of improved competitiveness the mining firm increases its output, and employs more inputs to do so.
- This output uplift means that an X% improvement in productivity leads to a reduction of <X% of each factor input.

Estimate total economic impact of automation

$$Y_{T2} = Y_{E2} + Y_{S2} + Y_{D2}$$

where:
- Y_{T2} is the total output after automation including direct, supply chain and broader economic impacts

Technology example:
- Overall, the total impact of automation includes the impact on the mining firms, the impact on the supply chain and the broader economic impact.

Estimate increase on broader economy

$$Y_{E2} = f(Y_{D2}, Y_{S2})$$

where:
- Y_{E2} is the output in the broader economy from activity in the mining industry and its supply chain

Technology example:
- Workers spend money on goods from a variety of industries which ultimately means the whole economy benefits from the change in output in the mining industry and its supply chain.

Estimate increase on supply chain

$$Y_{S2} = f(d_{K2} \times K_2, d_{I2} \times I_2)$$

where:
- Y_{S2} is the supply chain output which is a function of the capital and intermediate inputs and the non-import share d

Technology example:
- Local supply chain firms supply a share of the intermediate and capital goods.
- The amount they supply is bigger the more output and the less of the inputs that are imported.

1 Modelling specifically excludes jobs and GVA from exports

EXHIBIT 33

Primary firm impact assumptions

ASSUMPTION	VALUE	USE	JUSTIFICATION	SOURCES
Outputs increase in proportion to inputs	-	Used to model production in the primary firms	Standard economic assumption	-
Rate of substitution between production inputs is constant	-	Used to model production in the primary firms	Standard economic assumption	-
Firms are price takers	-	Used to model production in the primary firms	Standard economic assumption	-
Capital depreciation rate	4.5%	Used to determine the optimal amount of capital	Calculated as capital depreciation expenditure over net capital stock	ABS 5204, 5625
Borrowing rate	5%	Used to determine the optimal amount of capital	Calculated as capital financing expenditure over net capital stock	ABS 5204, 5625
Systems impact	Up to 20% increase in productivity from systems integration in mining, and up to 10% in oil & gas	Used to determine the productivity impact of combining automation technologies in primary firms	Industry participants advised that integrating technologies could increase productivity in mining by 20-30%, and 10-20% in oil & gas. The model also takes into account the difference between greenfield and brownfield sites.	Industry interviews
Access to new resources	6.25% increase in available resources every 10 years for each applicable technology	Used to determine the impact on access to resources (in existing and new sites) from automation in the primary firms	Industry participants advised that new technology brings about a new resource every 10 years. One new resource relative to the average number of Australian sites of industry participants yields an increase of up to 6.25% every 10 years per applicable technology. This impact is capped at 10% over the automation period.	Industry interviews
Average salary in mining	$150,000	Used to calculate the number of workers in mining	Drawn from ABS Australian Industry data	ABS 8155
Average salary in oil & gas	$239,000	Used to calculate the number of workers in oil and gas	Drawn from ABS Australian Industry data	ABS 8155

EXHIBIT 34

Resources sector output change assumptions

ASSUMPTION	VALUE	USE	JUSTIFICATION	SOURCES
Competition keeps firm profits at baseline levels (i.e. prices fall when productivity increases)	-	Used to determine the output changes in response to productivity improvements	Simplifying assumption to determine output changes in response to productivity improvements. In the absence of competition, companies may not increase output in response to productivity improvements.	-
Elasticity of demand for resources sector outputs	-0.25	Used to calculate global demand movements in response to commodity price changes	Sourced from academic literature examining the impact of commodity supply restrictions on producer country welfare	Fisher et. al 2015
Elasticity of supply of resources sector outputs	0.35	Used to calculate global supply movements in response to commodity price changes	As above	As above
Australia's share of global mining output	15%	Used as a baseline to calculate Australia's post-automation share	Industry participants provided estimates of Australia's output share	Industry interviews
Australia's share of global oil & gas output	10%	As above	As above	As above
Global mining competitors productivity gains during automation	Global mining competitors experience 80% of Australian mining's productivity gains during automation	Used to calculate the extent of commodity price changes within countries and the supply adjustments needed to equalise prices across countries	Global mining competitors are generally labour intensive developing countries unlikely to invest in capital to the same extent as Australia. Therefore, Australian productivity is presumed to increase marginally faster	Industry interviews and desktop research
Global oil & gas competitors productivity gains during automation	Global oil & gas competitors experience 90% of Australian oil & gas' productivity gains during automation	As above	Oil & gas competitors are more capital intensive than their mining counterparts, meaning they can expect productivity gains closer to Australia's gain. Oil & gas is also a global industry where productivity improvements are more likely to flow across countries.	As above

EXHIBIT 35

Supply chain and wider economic impact assumptions

ASSUMPTION	VALUE	USE	JUSTIFICATION	SOURCES
Baseline market share of domestic supply chain to mining – intermediate goods	87%	Used to adjust supply chain multipliers for different supply chain scenarios	Maximum and minimum historical domestic market shares calculated for Australia for 2006 – 2014. Domestic market share also calculated for the US for 1997 – 2016 as a sense check.	ABS I-O tables 2006 - 2014 U.S. I-O tables 1997 - 2016
Strong domestic market share to mining – intermediate goods	89%			
Weak domestic market share to mining – intermediate goods	84%			
Baseline market share of domestic supply chain to O&G – intermediate goods	88%	Used to adjust supply chain multipliers for different supply chain scenarios	As above	As above
Strong domestic market share to O&G – intermediate goods	90%			
Weak domestic market share to O&G – intermediate goods	83%			
Baseline market share of domestic supply chain to mining/O&G – capital goods	25%	Used to adjust supply chain multipliers for different supply chain scenarios	Domestic market shares for the supply of capital goods and equipment sourced from industry participants. Industry participants noted that, relative to mining, the type of capital goods used in oil and gas can be more readily sourced overseas.	Industry interviews
Strong domestic market share to mining – capital goods	35%			
Strong domestic market share to O&G – capital goods	25%			
Weak domestic market share to mining/ O&G – capital goods	5%			
GVA per worker in mining	$100,000	Used to determine employment in the domestic supply chain	Calculated using value added and employment figures from the ABS. ABS I-O table 2014-15 used to weight industries according to supply chain importance.	ABS 8155, I-O table 2014-15
GVA per worker in O&G	$110,000			
GVA per worker across the entire economy	$145,000	Used to determine employment in the wider economy	Calculated using value added and employment in from the ABS.	ABS 8155

αlphaβeta

strategy x economics