Advanced Manufacturing

A Roadmap for unlocking future growth opportunities for Australia

NOVEMBER 2016

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CSIRO FUTURES

CSIRO Futures is the strategic advisory and foresight arm of Australia's national science agency.

CSIRO FUTURES

CSIRO Futures is the strategy and innovation advisory business of Australia's national science agency. We work with senior decision makers in Australia's largest companies – and government – to help them translate science into strategy and plan for an uncertain future. We build on CSIRO's deep research expertise to help our clients create sustainable growth and competitive advantage by harnessing science, technology and innovation.

CSIRO MANUFACTURING

CSIRO Manufacturing plays a leading role as Australian manufacturing shifts focus from heavy industry to high tech products based on sustainable and advanced processes. We harness our science and engineering skills, equipment and international connections to keep Australian manufacturers globally competitive.

ACKNOWLEDGEMENTS

We are grateful for the time and input of industry representatives consulted throughout this project and the many researchers who provided invaluable review and feedback on this report.

We would also like to thank the Advanced Manufacturing Growth Centre and the Manufacturing Business Unit Advisory Committee for their input.

CSIRO Foreword

One hundred years ago, Prime Minister Billy Hughes imagined a national science agency that would "lead the manufacturer into green pastures by solving for him problems that seemed to him insoluble" and "open up a thousand new avenues for capital and labour". A century later, today's CSIRO is still focused on the excellent science that drives breakthrough innovation, and gives our businesses and industries the edge in an increasingly competitive global marketplace. And today, just as Hughes imagined, we're still working closely with industry to align our science with their needs.

We renewed this commitment in our Strategy 2020, which sets out our vision to be Australia's Innovation Catalyst through deep collaboration for the benefit of Australia. 'Customer First' is the first pillar of our strategy, and we've prioritised the way we work side-by-side with our customers and partners to tackle the big challenges facing their industries. We're committed to responding with agility and creativity to find the right solutions for unique projects, and spending more time understanding the specific requirements of industries and businesses. This customer-centric approach doesn't just extend to how we work with our partners; it is also reflected in our broader research agenda.

CSIRO conceptualises the major trends shaping Australia's future, including the Australia 2030 Report, Our Future World: Global Megatrends report, and the Australian National Outlook. We believe Advanced Manufacturing has a bright and bold future in this country. This Industry Roadmap report identifies a range of opportunities that could secure the future competitiveness and success of manufacturing in Australia. But building this future relies on a collaborative approach from the research, education, government, industry and investor communities. CSIRO is committed to continuing to channel resources into this effort, including bringing our world-class science and solutions to the table.

Responding to the disruption facing every part of the Australian landscape requires nothing short of deep collaboration. We look forward to working closely with the Industry Growth Centres as they further map out their roads to success. Together, we can apply world-class scientific and technological expertise to our unique Australian challenges and chart a course for long term sustainable prosperity for our nation.

Dr Larry Marshall
CSIRO Chief Executive

AMGC Foreword

It is my pleasure to jointly endorse the CSIRO Roadmap for Advanced Manufacturing. Working together with the CSIRO demonstrates that our sector can achieve greater outcomes when we collaborate as encouraged and combine our talents to advance manufacturing in Australia.

In 2015, the Advanced Manufacturing Growth Centre (AMGC) was formed as part of the Federal Government's Industry and Innovation Agenda. Our primary focus is to ensure we build a relevant, viable and globally competitive manufacturing sector. This will steer how we meet and respond to the extraordinary transformation underway in manufacturing not only here at home, but across the globe.

We know that manufacturing is changing, and fast. We now live and transact in a global marketplace where consumers enjoy an unprecedented abundance of choice, and where the relentless pace of technological change continues to push the boundaries of how our goods and services are made and experienced.

Our manufacturing sector has the potential to seize upon a larger portion of these new opportunities and markets. However, in order to do so, we must equally realise that in many ways our current methods of manufacturing may not be taking advantage of the full value of our local resources to gain that competitive edge, and closely held beliefs on what makes us competitive may also need to change.

The AMGC's Sector Competitiveness Plan (SCP) and this Roadmap complement one another in helping Australian manufacturers position for growth and sustainability, with the SCP providing detailed international competitiveness benchmarking analysis. Our report reveals compelling evidence that we can solve fundamental challenges if we agree as a nation to align behind a well-chosen number, yet highly effective set of initiatives. Applying a stronger emphasis on commercialising our ingenuity, looking to overseas markets for exports versus relying solely on a domestic market, and most importantly learning to better collaborate across the full spectrum of industry and research organisations.

Our partnership with the CSIRO has produced two manufacturing collaboration hubs in Victoria with more hubs across Australia to be established in 2017. Together, we aim to utilise these hubs as way for firms to showcase their technology leadership in producing solutions suitable to link into global supply chains. This is one example of collaboration that can make a significant impact beyond our borders and back here to our national economy.

I trust that you will find the contents of this report of great use as it contains the many essential factors needed for raising our global competitiveness.

Dr Jens Goennemann
Managing Director
Advanced Manufacturing Growth Centre Ltd

Executive Summary

Executive summary

Vision

Over the next 20 years, Australia's manufacturing industry will transform into a highly integrated, collaborative and export-focused ecosystem that provides high-value customised solutions within global value chains.

Australian manufacturing can and must be a thriving component of Australia's economy through the application of advanced manufacturing technologies, systems and processes. The sector will focus on pre-production (design, R&D) and post-production (after-sales services) value-adding, sustainable manufacturing and low volume, high margin customised manufacturing.

The development and adoption of digitally connected technologies is important for all growth opportunities, as is the significant shift towards a more collaborative mentality. At the centre of this vision is an ecosystem where businesses, research, education and customers work together, embracing volatility and the opportunities that emerge from it.

A changing global landscape

Manufacturing markets across the world are being transformed by both demand and supply side drivers. The megatrends depicted in Figure 1 represent long term shifts in the sector that are creating new business models, social structures and cultural paradigms. To inform strategic decision making today, Australian manufacturers and their supporting ecosystem (industry bodies, suppliers, research, education, investors and governments) must consider what the global manufacturing landscape will look like over the coming decades.

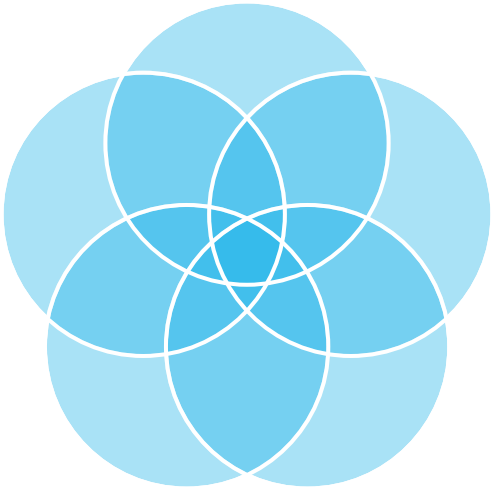
FIGURE 1 – GLOBAL MANUFACTURING MEGATRENDS

MADE TO MEASURE

Advances in technology and greater consumer expectations are causing a shift from mass production of goods to bespoke solutions

SUPPLY CHAIN TRANSFORMATIONS

Specialisation is promoting greater collaboration in some markets while technological advancements are enabling the vertical integration of others



SERVICE EXPANSION

Manufacturers are expanding their role in the value chain from making 'widgets' to developing tightly integrated service-product bundles

SUSTAINABLE OPERATIONS

Resource scarcity and increasingly valued environmental and social credentials are encouraging manufacturers to look for more efficient and sustainable processes and operating models

SMART AND CONNECTED

Advances in data capture and analytics are optimising operations across the manufacturing value chain and the factory floor

Australia's competitive landscape

Australia's role in this evolving global landscape will be dependent on the comparative advantages and disadvantages of manufacturers and their supportive ecosystem. Globalisation, digitalisation and the increased demand for more bespoke and complex solutions are causing Australia's long-standing disadvantages such as high labour costs, geographical remoteness and a small domestic market to be less important. However, manufacturers are also failing to capitalise on the full potential of Australia's advantages.

Globalisation, digitalisation and the increased demand for more bespoke and complex solutions are causing Australia's long-standing disadvantages to be less important.

Opportunities for growth

In considering Australia's competitive position in this rapidly changing global market, three broad opportunity themes have been identified. These themes are not mutually exclusive and strategic growth opportunities exist for manufacturers under each, with the largest falling across all three.

Customised high-margin solutions

- DESIGN SERVICES: From bespoke co-design with customers to manufacturer-less manufacturing
- SUPERIOR COMPONENTRY: From components with improved characteristics to components with completely new characteristics
- NOVEL PRODUCTS: From upgrades to existing products to complex and integrated novel solutions in health, defence and aerospace

Sustainable manufacturing

- BUSINESS MODELS AND PROCESSES: From reduced land use and wastage to closed-loop material use
- PRODUCTS: From energy efficient products to products designed with recycling, recovery and collaborative consumption in mind

Selling services

- MAINTENANCE AND REPAIR SERVICES: From static monitoring, diagnostics and predictive services to ingestible / embedded and intelligent sensors
- WORKFLOW MANAGEMENT SERVICES: From wearable tracking devices and bundling of add-on services to performance-based contracts and interactive platforms that allow informed decision making
- HEALTH AND BIOSECURITY SERVICES: From discrete monitoring functions to integrated and continual reporting for advanced warning

Enabling science and technology

Strategic growth opportunities for Australia's manufacturing sector will be underpinned and supported by significant technological innovation from public and private research communities. In an increasingly competitive global landscape, continual improvement and investment in R&D is the only way to remain competitive. The following technologies support product differentiation through superior and customised attributes; efficiency improvements across production floors and value chains; and real-time monitoring for data driven decision making.

In an increasingly competitive global landscape, continual improvement and investment in R&D is the only way to remain competitive.

TABLE 1 – ENABLING SCIENCE AND TECHNOLOGY SUMMARY

	NOW	IN THE FUTURE
Sensors and data analytics	Predominantly used during production (remote monitoring of single attributes such as temperature or flow rates).	Applied across the value chain, including predictive maintenance, logistical tracking for operational efficiencies, quality control and service offering (when integrated into end product).
Advanced materials	Reactive use to address specific product limitations e.g. enhanced durability, weight, look and feel.	Proactive integration at early design phase to offer multiple novel attributes e.g. biocompatibility, biodegradability, energy efficiency and self-repairing.
Smart robotics and automation	Replace workers for tasks that are complex, high precision, repetitive, dull or hazardous e.g. handling operations and robotic welding.	Assistive robots that work collaboratively with humans and each other, with improved sensing, awareness and decision-making capabilities that allow full autonomy and self-learning behaviour.
Additive manufacturing (3D printing)	Prototyping and one-off production runs of customised high-value complex metal componentry and low-value consumer products, with high capital costs stalling wider spread adoption.	Reduced capital costs will allow greater adoption of the technology for production of complete complex products and associated advanced business models such as customer-led design processes and just-in-time production.
Augmented and virtual reality	Predominantly restricted to gaming and consumer electronic markets, with limited use in the manufacturing sector.	Used to overlay product designs with end-use environments, optimise machine settings in the virtual world, facilitate remote collaboration and train or guide workers through complex/dangerous tasks.

Enabling actions

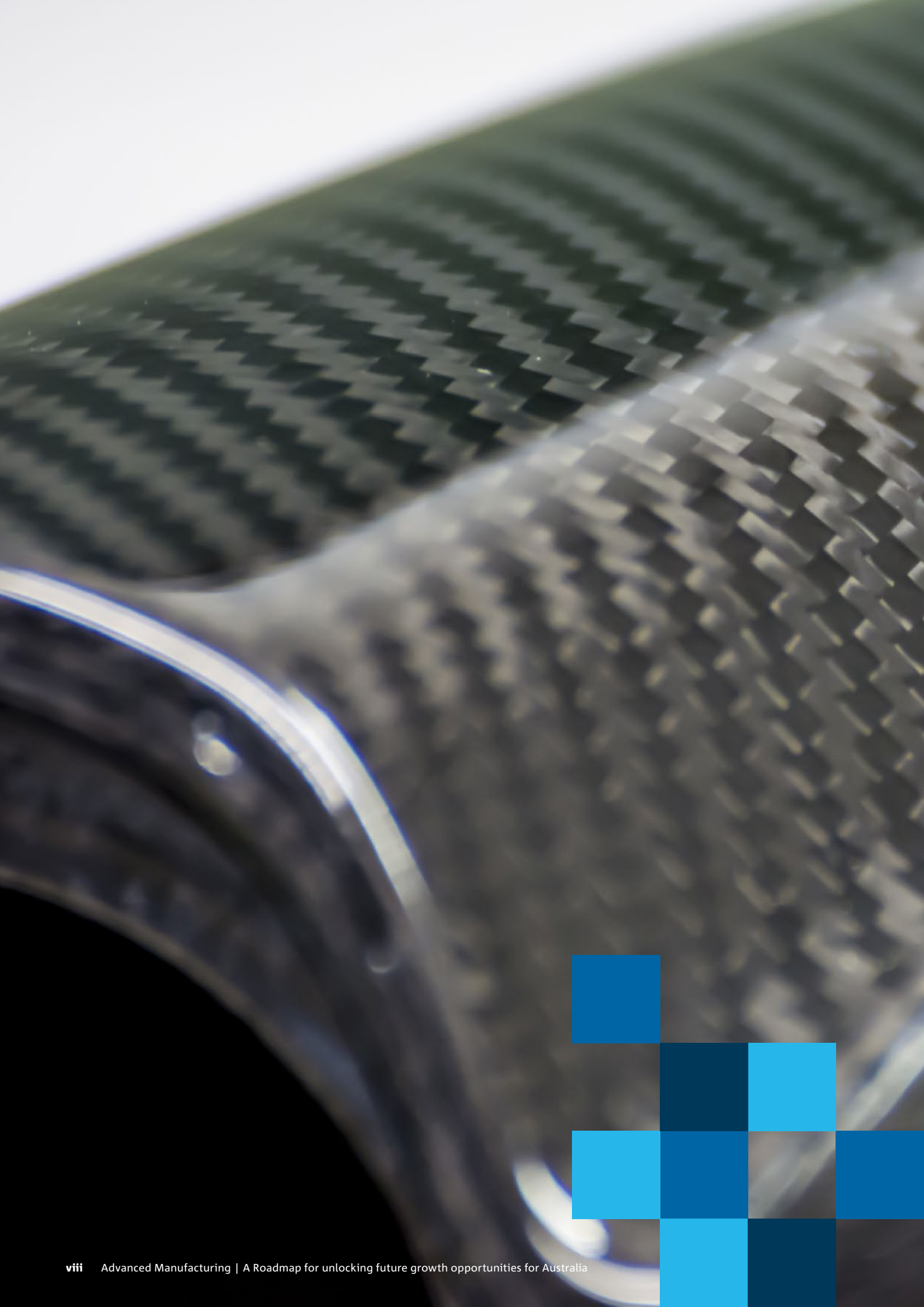
In order to pursue the strategic growth opportunities and realise the full potential of their enabling science and technology areas, Australian manufacturers must proactively transform the way they run their businesses, investing in new knowledge and practices. Positioning for sustainable growth will require business changes both internally (new skillsets, cultures and operating systems) and externally (participation in global value chains and collaboration models).

Improving Australia's place in the global manufacturing sector requires bold innovation leadership and investment now. If Australian businesses do not act today – both individually and collaboratively – they risk losing access to emerging markets and new sources of competitive advantage to international competitors. Together, the Australian manufacturing ecosystem has the potential to unlock a new wave of growth; one that builds on Australia's high-value adding activities in R&D, design and after-sales services. Future success will be determined by the decisions made from here forward and the quality of the science, technology and business conversations that underpin them.

Positioning for sustainable growth will require business changes both internally and externally.

TABLE 2 – ENABLING ACTIONS SUMMARY

Global value chains (GVCs)	Skills, training and the workforce	Collaboration and culture
BUSINESS ACTIONS		
• **Promote capabilities internationally** through increased licensing, novel sales approaches and targeting GVCs from product creation stage. • **Align digital systems** with world-leading best practice to improve interoperability with global partners. • **Increase knowledge sharing** with experienced Australian GVC operators.	• **Develop digital literacy, leadership and strategic management, customer interface** and **STEM skills.** • **Develop programs** to improve skills recruitment and development e.g. graduate programs, structured training courses and site tours. • **Increase diversity** in the workplace – specifically a greater representation of young and female employees.	• **Increase use of joint-investment models** e.g. pooling of SME funds and co-investment with research organisations. • **Invest in cloud computing and collaborative software** to allow greater value chain communication and rapid adaptation to changes in demand. • **Develop business placement opportunities for researchers** to enhance knowledge sharing.
ECOSYSTEM ACTIONS		
• Address interoperability barriers by implementing **more appropriate and sophisticated industry data standards**, in consultation with companies. • Identify and implement **effective and streamlined standardised regulation and compliance protocols** both within and between jurisdictions. • Conduct social research studies to better **understand and address social licence to operate issues** for the adoption of enabling technologies in different global markets.	• More closely **integrate theory and industry application in tertiary education courses**, including developing additional industry placement opportunities for tertiary students. • **Promote manufacturing** as the destination for new creative, high-skilled and interdisciplinary jobs to address public perception issues and attract skilled labour. • **Develop tailored training courses** for the re-skilling of transitioning employees and for researchers to enhance pitching/ presentation skills.	• **Improve business access to advanced manufacturing research facilities** for education and early product development. • **Encourage the development of consortia bidding** through government procurement strategies. • **Support planned co-locations** of business, research and/or education.



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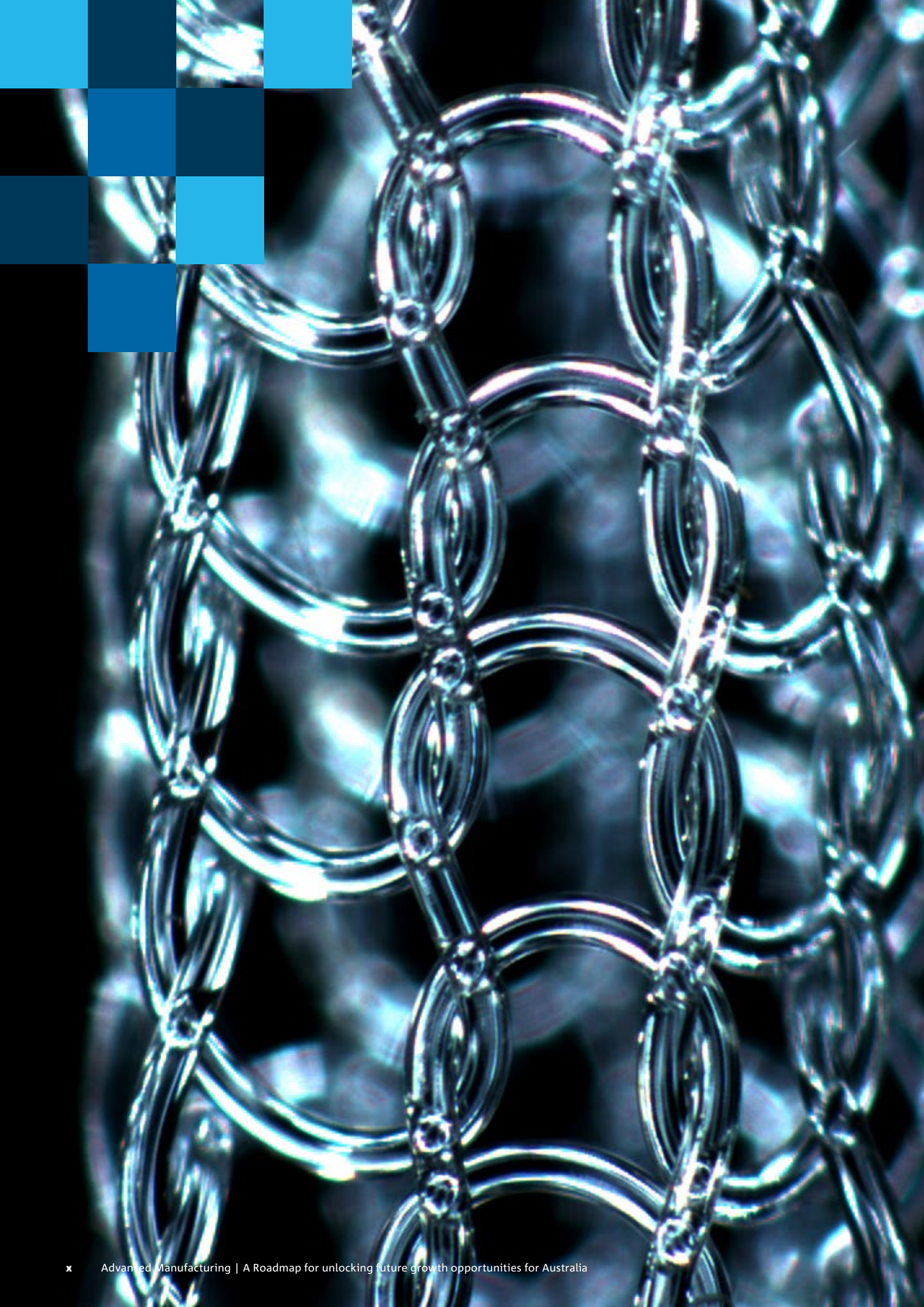


Introduction

1 Introduction

Globally, the manufacturing sector is changing rapidly, driven by changing trends and emerging technologies.

These changes are causing the weaknesses that have previously hindered Australian manufacturing – high labour costs, geographical remoteness and a small domestic market – to be less impactful in the future. Advanced manufacturing processes and systems are bringing Australia closer to the rest of the world and opening up markets where the nation has comparative cost advantages.

Investment in science and technology will be core to unlocking new and emerging opportunities, as will a greater focus on global markets, improved recruitment and retention of high-skilled employees and increased collaboration with other businesses and the research community.

Australian manufacturing can and must be a thriving component of Australia's economy through the application of advanced manufacturing technologies, systems and processes.

VISION

Over the next 20 years, Australia's manufacturing industry will transform into a highly integrated, collaborative and export-focused ecosystem that provides high-value customised solutions within global value chains.

1.1 A vision for Australian manufacturing

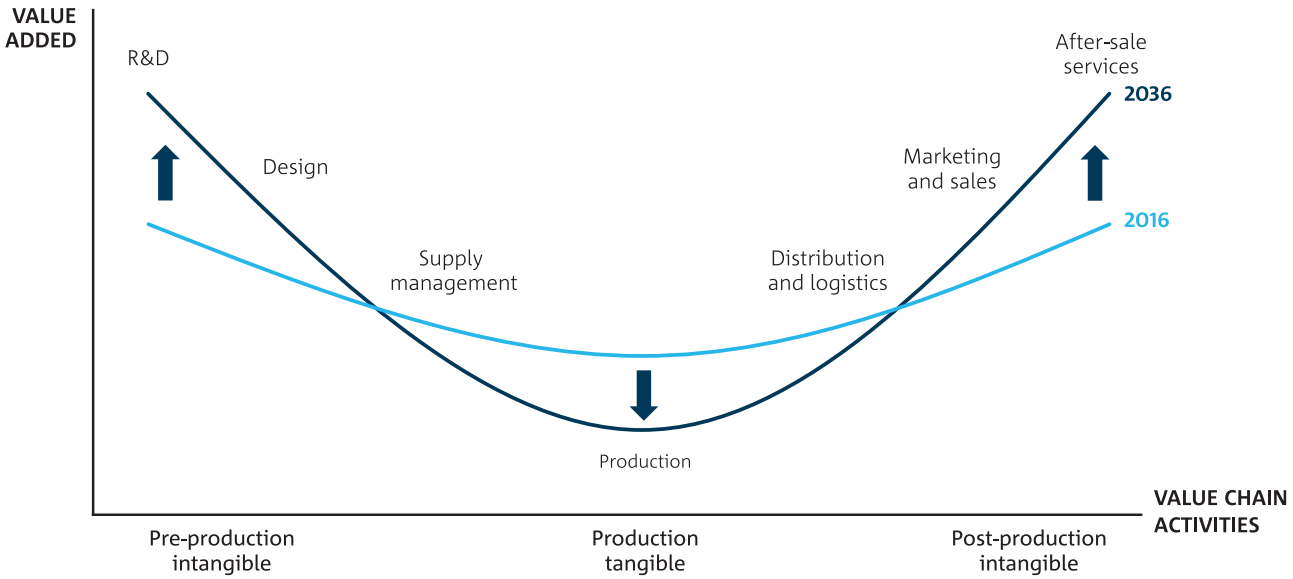
Under this vision, Australian manufacturers will be more customer and export-focussed, deeply integrating within global value chains. The sector will place greater focus on pre-production (design, R&D) and post-production (after-sales services) value-adding, and sustainable and high margin customised manufacturing (see Figure 2).

While the nation will retain its traditional strengths such as food product, machinery and equipment manufacturing, the majority of manufacturing growth will come from increased global value chain operations in aerospace and defence; transport; pharmaceuticals and medical technologies; scientific instruments; and mining equipment, technology and services.

The development and adoption of digitally connected technologies is important for all growth opportunities, as is the significant shift towards a more collaborative mentality. At the centre of this vision is an ecosystem where businesses, research, education and customers work together, often in co-located clusters to allow for improved transfer of knowledge. These interactions enhance the number and impact of technology breakthroughs and increase the rate at which these innovations are commercialised.

Rather than aiming to grow into large businesses, Australian Small and Medium Enterprises (SMEs) shift from the micro to medium scale, operating within niche markets that supply to multinational organisations as well as being exporters in their own right. Retaining their agility and adaptability allows Australian SMEs to continually meet changing customer demands. While the global manufacturing market continues to transform, Australian manufacturers – both big and small – will learn to embrace the volatility and build resilience into their strategic planning. This rate of change is no longer feared, but instead seen as an unlimited supply of emerging opportunities.

FIGURE 2 – VISION FOR AUSTRALIAN MANUFACTURING: SHIFT IN FOCUS TOWARDS PRE- AND POST-PRODUCTION VALUE ADDING



Adapted from Stan Shih's 'smiling curve'

1.2 This report

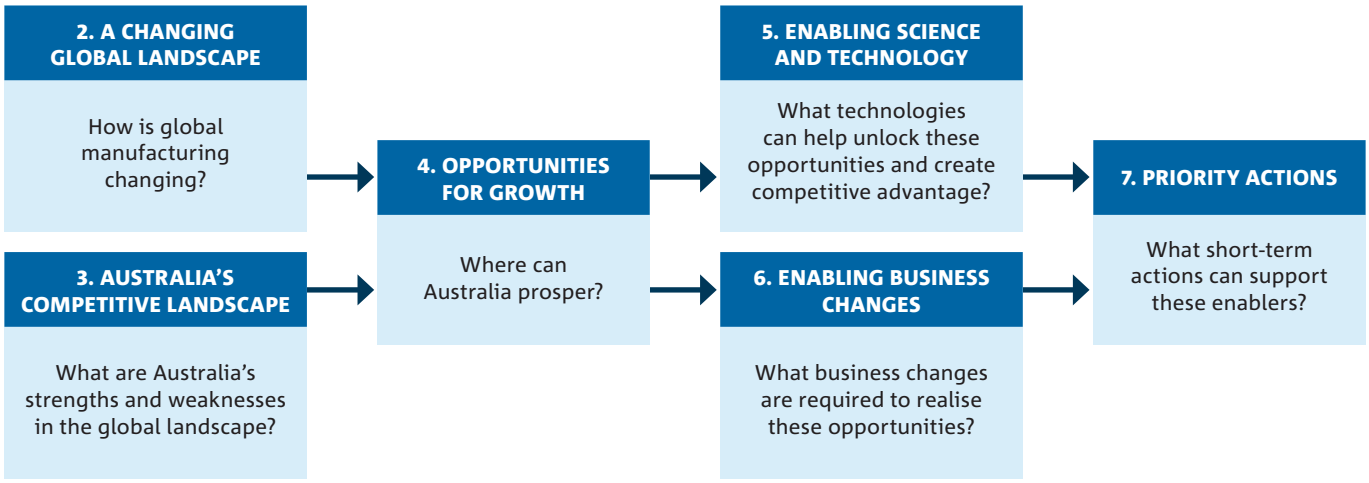
This Roadmap seeks to support Australian manufacturing in its transition to a high-value and export-focused sector by understanding current and emerging trends, ascertaining market opportunities and challenges, and identifying key business and R&D enablers. To achieve this, CSIRO has worked closely with businesses to develop this Roadmap which is intended as a bridge between high-level sector strategies and specific technology roadmaps.

A strong manufacturing sector is central to unlocking national economic prosperity through its influence on infrastructure development, job creation, R&D, productivity, export earnings, and flow on impacts to other sectors.[1,2] As parts of the sector continue to experience contraction, it is more important than any other time in Australia's history that manufacturers seek out and pursue innovative opportunities to meet the changing needs of their current and emerging customers. This will involve focussing on a selection of key opportunities that play to Australia's national strengths.

Due to the breadth of sectors and industries impacted by manufacturing, this report highlights three major opportunity themes (rather than specific opportunities) for Australia's manufacturing sector. These themes are strongly linked to Australia's comparative advantages and the business drivers, potential disruptors and technology developments of manufacturing globally.

To capitalise on these opportunity themes, businesses and the supporting manufacturing ecosystem (industry bodies, suppliers, research, education, investors and government) need to invest in a variety of science, technology and business enablers. This report discusses these enablers and recommends actions that are designed to best position Australian manufacturing for the long-term opportunities identified.

FIGURE 3 – REPORT STRUCTURE



1 Deloitte (2016). *2016 Global Manufacturing Competitiveness Index*, London.

2 Department for Manufacturing, Innovation, Trade, Resources and Energy (2012). *Manufacturing Works - A Strategy for driving high value manufacturing in South Australia*, Government of South Australia, Adelaide.

This industry-led document targets a range of stakeholders, with the aim of encouraging businesses to work cohesively with the entire manufacturing ecosystem to address challenges and act on identified enablers.

CHAPTER	KEY AUDIENCE AND PURPOSE
CHAPTER 2 – **A CHANGING GLOBAL LANDSCAPE**	• Assist **businesses** in understanding long-term drivers of change and disruptive trends that need to be considered in strategic planning.
CHAPTER 3 – **AUSTRALIA'S COMPETITIVE LANDSCAPE**	• Assist **businesses** in understanding inherent strengths of the sector that can be further leveraged, and barriers that require action, to unlock opportunities for global competitiveness. • Assist **industry bodies, research** and **governments** to improve awareness of areas where greater business engagement and joint-solution development is required.
CHAPTER 4 – **OPPORTUNITIES FOR GROWTH**	• Direct **businesses** towards growth areas of manufacturing where Australia can compete over the coming decades. • Provide **investors**, both public and private, guidance on future growth areas for Australian manufacturing.
CHAPTER 5 – **ENABLING SCIENCE AND TECHNOLOGIES**	• Improve **business** awareness of the current state of key enabling technologies and the future possibilities they could unlock if invested in today. • Provide **investors**, both public and private, guidance on research priorities.
CHAPTER 6 – **ENABLING BUSINESS CHANGES**	• Highlight key **business** issues that are limiting sustainable competitiveness for the sector. • Provide **businesses, research, education** and **government** recommendations for addressing these issues.
CHAPTER 7 – **CONCLUSION**	• Provide considerations for **businesses, industry bodies, research, education, investors** and **governments** in planning and implementing recommendations.

1.3 Industry consultation

The development of this Roadmap was industry-led with Australian manufacturers – both local and global – providing direction and input across all chapters (see A.1 for a list of contributing parties). Industry consultation consisted of three elements:

INDUSTRY WORKSHOPS

Three workshops were held to bring together businesses from a range of manufacturing industries and discuss the future opportunities and needs of the sector over a 20 year time horizon. A small number of government, education and research community representatives were also present to provide diverse perspectives while still allowing manufacturers to drive the conversations.

INDUSTRY INTERVIEWS

One-on-one interviews were held with additional manufacturing businesses to supplement, test and refine the workshop outputs.

INDUSTRY SURVEY

A survey was distributed amongst businesses and industry bodies to identify Australia's manufacturing comparative advantages and disadvantages.

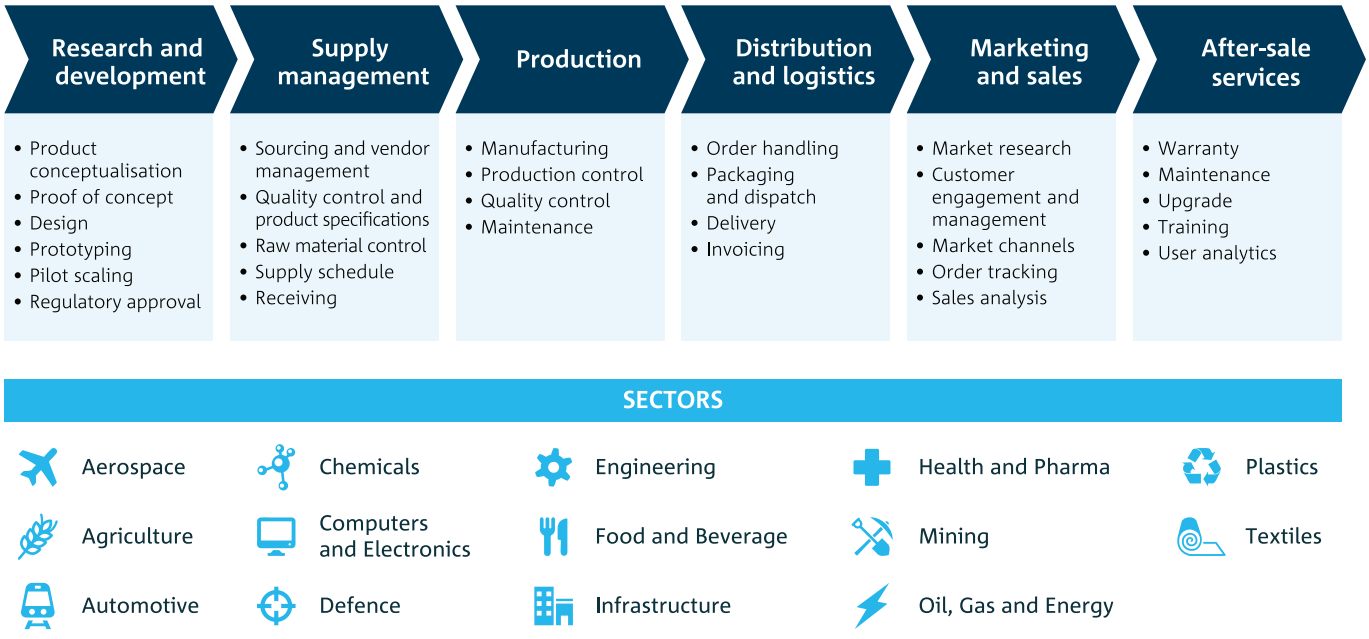
1.4 Defining Advanced Manufacturing

This report defines advanced manufacturing as the set of technology based offerings, systems and processes that will be used to transition the current manufacturing sector into one that is centred on adding value across entire supply chains. Advanced manufacturers are companies that rapidly create or adopt these technologies.

Figure 4 outlines the current manufacturing supply chain and a selection of the many diverse sectors that manufacturing industries support. Additional complexity occurs when delving into each sector's unique supply chain, feedback loops and intermediary goods. Advanced manufacturers can be found performing activities from the initial research and development stage through to after sale services and increasingly end of life management.

Advanced manufacturing can be applied equally to traditional manufacturing industries and those that are being continually discovered through the expansion and evolution of the sector. For example, an expansion of the current supply chain into product disposal or re-use would see a range of advanced manufacturing products, systems and products be heavily utilised.

FIGURE 4 – SIMPLIFIED CURRENT MANUFACTURING SUPPLY CHAIN



1.5 Manufacturing in Australia

Australian manufacturing has an important multiplier effect on the Australian economy, stimulating jobs, investments and sales in other downstream sectors.[3] It has been estimated that, as a general rule, every $1 generated from manufacturing flows through to an additional $1.25 expenditure in the rest of the economy.[4] However this figure could be significantly improved.

The Australian manufacturing sector has been in a state of transition for many decades. Over the past 30 years, Australian manufacturers have been challenged by lower tariffs, low cost competitors from emerging economies and rapidly changing technologies. Being so closely integrated with a wide variety of sectors, manufacturers are required to constantly adapt to changes in other Australian sectors – such as Australia's economic base shifting from agriculture to mining and now to services.

Australia's manufacturing sector is made up of a disproportionate number of small firms, with 87% employing between 1 and 19 staff.[5] Most of these SMEs do not operate on a global scale, but many have the potential.

These challenges, coupled with the lack of a clear and unified direction for future growth, have resulted in a sustained contraction of many manufacturing industries that has led to a decline in share of GDP (8.5% to 6.1% in the 10 years to 2014-15) and employment which fell by over 120,000, the most of all Australian sectors over the same period.[6] In absolute terms, output today is around the same level it was just over a decade ago.[7]

These metrics have been brought to the attention of the general public through the exit of recognised multinational automotive manufacturers, causing significant reputational damage to Australian manufacturing.

However these trends are not unique to Australia. Most advanced economies have experienced similar declines – although perhaps not as severely as Australia[8] – and many of these statistics do not capture the blurring boundaries between manufacturing and the sectors it supports.

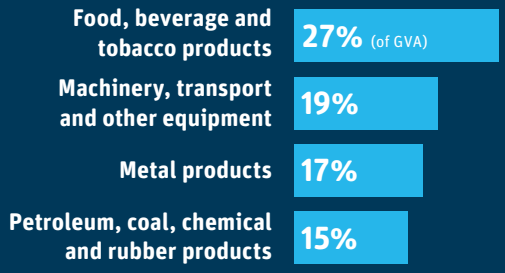
What is less well publicised is the rise of high value-adding advanced manufacturers, who are poised to build on Australia's comparative advantages and increase the sectors contribution to economic growth and global trade.[9] The adoption of advanced manufacturing offerings, systems and processes could see Australian businesses enter and create new manufacturing industries. Companies that invest in these new and innovative directions today will position themselves to lead the sector into a period of sustainable competitiveness.

MANUFACTURING SNAPSHOT

Australia's Manufacturing Sector in 2014–15

$98.1 billion Gross Value Added (GVA)

Australia's largest manufacturing industries include:



Manufacturer's expenditure on research and development reached $4.84 billion in 2013–14

Source: ABS (8104.0, 8165.0, 5206, 5368), CSIRO Analysis.

3 Australian Business Foundation (2011). *Manufacturing Futures,* NSW Business Chamber, Sydney.
4 Australian Industry Group (2006). *Manufacturing Futures – Achieving Global Fitness.*
5 Department of Industry, Innovation and Science (2016). *Manufacturing Data Card - September Quarter 2015*, Australian Government. [Online] Available from: http://www.industry.gov.au/INDUSTRY/MANUFACTURINGPERFORMANCE/Pages/ManufacturingDataCard.aspx Accessed 18/10/2016
6 Department of Industry, Innovation and Science (2016). Manufacturing Data Card - September Quarter 2015, Australian Government. [Online] Available from: http://www.industry.gov.au/INDUSTRY/MANUFACTURINGPERFORMANCE/Pages/ManufacturingDataCard.aspx Accessed 18/10/2016
7 Reserve Bank of Australia (2016). *Bulletin – June Quarter 2016.*
8 Reserve Bank of Australia (2016). *Bulletin – June Quarter 2016.*
9 Withers, G. et al (2015). *Australia's Comparative Advantage*, report for the Australian Council of Learned Academies. Melbourne.

A changing global landscape

2 A changing global landscape

Manufacturing markets across the world are being transformed by both demand and supply side drivers.

On the demand side, emerging economies in Asia and other developing regions are rapidly expanding the size of the consumer pool, adding an additional 1.8 billion people by 2025.[10] At the same time, consumers in developed economies are demanding new products at increasing speed. While much of the consumer demand relates to software (apps and internet connectivity), these services can only evolve so far without new and advanced hardware being developed.

Continuing to meet the evolving demands of developed economies while addressing the differing needs of new consumers in developing economies is adding significant complexity to the sector.[11]

On the supply side, advances in technologies such as additive manufacturing (3D printing), smart materials, sensors and automation are allowing the development of new products and services with superior qualities. The digital connectedness of humans and machines across factory floors, supply chains, products and services is changing the way manufacturing businesses shape their operations, utilise staff, collaborate and continually improve their offerings.

As access to technology continues to grow globally and developing countries leapfrog intermediary technology stages to compete with developed providers, first-mover technology advantages are becoming short lived if not supported by strong intellectual property. This is creating a constant need for business evolution and providing new forms of differentiation and value adding.

To inform strategic decision making today, Australian manufacturers, the research community and governments must consider what the global manufacturing landscape will look like over the coming decades.

2.1 Global Manufacturing Megatrends

A megatrend is defined as a substantial shift in social, economic, environmental, technological or geopolitical conditions that may reshape the way a sector operates in the long-run.[12] Megatrends occur at the intersection of many trends; they are not mutually exclusive and the trends that make up one megatrend can influence or contribute to another.

CSIRO has identified five megatrends evident in global manufacturing that will have significant impact on the sector over the next 20 years. These were developed by applying CSIRO's Global Megatrends[13] to the manufacturing sector and refining the output with both research and business communities.

10 Manyka, J. et al (2012). *Manufacturing the future: the next era of global growth and innovation.* McKinsey Global Institute.
11 Adams, N. et al (2014). *Equipping Australian Manufacturing for the Information Age. iManufacturing – Is Australia ready?* CSIRO, Australia.
12 Hajkowicz, S. (2015). *Global Megatrends – Seven Patterns of Change Shaping Our Future,* CSIRO Publishing, Canberra.
13 CSIRO Futures (2016). *Australia 2030: Navigating our uncertain future*, CSIRO, Canberra.

Global Manufacturing Megatrends

MADE TO MEASURE

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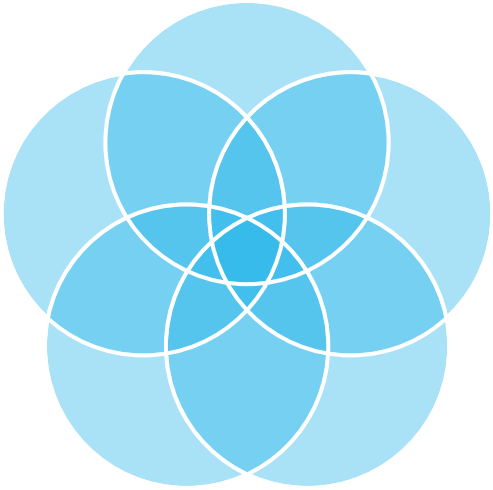

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SMART AND CONNECTED

Advances in data capture and analytics are optimising operations across the manufacturing value chain and the factory floor

MADE TO MEASURE

Advances in technology and greater consumer expectations are causing a shift from mass production of goods to bespoke solutions.

Customers are increasingly demanding bespoke solutions that meet their unique needs in place of more generic products. This demand is boosted by rising income growth in developing regions as well as the billions of people transitioning out of poverty and into middle income classes in BRICS economies (Brazil, Russia, India, China and South Africa).

At the same time, additive manufacturing tools, new materials and computer-controlled processes are becoming rapidly more available to manufacturing businesses. This is allowing the growing customer demands to be met through the development of highly customised outputs for individuals and niche markets. In extreme cases, products of one for markets of one.[14] For many markets, this is seeing a sharp move away from the more traditional 'assembly line' form of production.

Advances in ICT are allowing direct customer input into the design phase of their bespoke solutions, lowering the costs and cycle-times of these processes to more closely match those of standardisation and mass production.[15] The Made to Measure megatrend will also see more manufacturers build to order rather than build to stock, reducing the need for intermediaries that create value by holding inventory.[16]

SERVICE EXPANSION

Manufacturers are expanding their role in the value chain from making 'widgets' to developing tightly integrated service-product bundles.

Customer demands are shifting away from products and towards services and experiences. At the same time, global connectedness continues to grow rapidly. This is allowing people, businesses and governments to obtain information, perform transactions and interact with each other, and machines, through virtual platforms.

These drivers are causing manufacturers to shift from a product-focused business model to a client-centric model.[17] In order to better understand the needs of their customers, meet more of their needs and maintain the relationship for longer, manufacturing companies are taking greater control of operations further down the supply chain (closer to the customer). The Service Expansion megatrend is shifting the activities and profit base of manufacturers towards the provision of ongoing services for the products that the company supplies.[18]

Also driving this megatrend is an increasing proportion of customers who do not want the financial and environmental burden of product ownership. Companies like Uber and Airbnb have reconceptualised physical products as services through collaborative consumption, shifting the economics of usage from product to service, and changing to platform based business models.[19]

Now sectors are beginning to see established corporate businesses adjust to the shift. For example, large automakers are launching their own car sharing platforms such as Ford2Go, DriveNow (BMW) and Park24 (Toyota). These collaborative models incorporate access to products (cars) with ancillary services such as parking, servicing and tolls. Business models based around this shared use of assets incentivises manufacturers to provide more robust products – aligning the incentives of producers and users – and allows the creation of new service based revenue streams.[20]

14 Adams, N. et al (2014). *Equipping Australian Manufacturing for the Information Age iManufacturing – Is Australia Ready?* CSIRO, Australia.
15 Foresight (2013). *The Future of Manufacturing: A new era of opportunity and challenge for the UK Project Report,* Government Office for Science, London.
16 Hagel, J. et al (2015). *The Future of Manufacturing: Making things in a changing world*, Deloitte University Press.
17 KPMG (2014). *Industrial Manufacturing – Megatrends Research*. KPMG Europe LLP.
18 Adams, N. et al (2014). *Equipping Australian Manufacturing for the Information Age. iManufacturing – Is Australia ready?* CSIRO, Australia.
19 Hagel, J. et al (2015). *The Future of Manufacturing: Making things in a changing world*, Deloitte University Press.
20 Foresight (2013). *The Future of Manufacturing: A new era of opportunity and challenge for the UK Project Report,* Government Office for Science, London.

SMART AND CONNECTED

Advances in data capture and analytics are optimising operations across the manufacturing value chain and the factory floor.

Global manufacturing is being disrupted by the Internet of Things (IoT)[21] – often referred to as the 'Industrial Internet' (US) or 'Industrie 4.0' (Germany/Europe) when applied to industry. The Internet of Things is a concept that has been evolving for over a decade as the number of electronic devices and the number of connections between devices, humans and machines, increases. The convergence of technologies like sensors, automation, intelligent robotics, embedded electronics and their internet connectivity is enabling the integration of data across manufacturing functions and supply chains.[22]

On the factory floor, smart equipment, machinery and control systems are becoming increasingly interconnected and constantly measuring and calibrating themselves to maximise efficiency. The next 20 years will see a range of cognitive systems being used in manufacturing that can adapt and learn from operating experience. Intelligent robotics are becoming more affordable and their agility provides manufacturers with competitive advantage through better quality assurance, management of resources, and reduced costs.[23]

An increasing number of manufacturers are also using embedded sensors and devices in their products to monitor performance, diagnose issues and unlock additional smart service possibilities – an intersection with the Service Expansion megatrend.

SUSTAINABLE OPERATIONS

Resource scarcity and increasingly valued environmental and social credentials are encouraging manufacturers to look for more efficient and sustainable processes and operating models.

The next 20 years will see the world population grow by hundreds of millions of people and the continued rapid industrialisation of emerging economies. These factors will see demand grow for key manufacturing inputs such as energy, minerals and water – all of which have limited supply in the natural world.

Global water demand from manufacturing is forecast to increase 400% between 2000 and 2050.[24] Manufacturing industries also use around 30% of global energy with demand expected to grow by 40% to 83% through to 2050.[25]

With growing concerns around the known and unknown consequences of greenhouse gas emissions and climate change on natural systems, manufacturers are also experiencing pressure from their customers who are increasingly demanding products that are made sustainably and that operate sustainably – using less energy and fewer materials.[26] Increasingly, manufacturers will shift towards lifecycle cost management to improve value chain efficiency and meet customer demands for sustainable operations.

21 Chui, M. et al (2010). *The Internet of Things,* McKinsey Quarterly, McKinsey&Company.
22 King, S. et al (2014). *Make for Asia – The emerging Asian middle class and opportunities for Australian manufacturing,* CSIRO, Australia.
23 King, S. et al (2014). *Make for Asia – The emerging Asian middle class and opportunities for Australian manufacturing,* CSIRO, Australia.
24 OECD (2012). *OECD Environmental Outlook to 2050: The consequences of inaction, Highlights.* Organisation for economic co-operation and development, Paris.
25 Philibert, C. (2015). *Renewable Energies for Manufacturing Industries*, RE Industry workshop December 2015, Paris, International Energy Agency. [Online] Available from: http://www.iea.org/media/workshops/2015/cop21/otherevents/4DecPhilibert.pdf Accessed 18/10/2016.
26 MIT Technology Review (2013). *Technology Review May/June*. [Online] Available from: http://www.technologyreview.com/magazine/2013/05/

SUPPLY CHAIN TRANSFORMATIONS

Specialisation is promoting greater collaboration in some markets while technological advancements are enabling the vertical integration of others.

Greater demand for customised products is making it increasingly difficult for manufacturers to meet every need of all of their customers – limiting the pace of the Service Expansion megatrend. This is causing many manufacturers to focus on specialised niches, with the number of both niches and players growing over time. This fragmentation is primarily occurring, and will continue to occur, across markets with high levels of digitisation that are based around small, non-complex products, largely due to the reduced transport costs along the supply chain.[27]

The specialisation of these markets is creating a greater need and appetite for collaboration as each organisation only provides part of the final solution. Advances in digital technology and connectivity are allowing businesses to organise activities between firms and locations – each specialising in, and adding value to, a different part of the supply chain. Research can be conducted in one place, engineering in another, and manufacturing in a third.[28]

The globalisation of supply chains and open source software are also driving collaborative design and development processes, with open source software/design providing access to new ideas for design possibilities and new information on how products are used.[29]

In markets based around more complex products, technologies such as 3D printing are causing the opposite effect. Here, supply chains are being disrupted and condensed by the integration of multiple stages. Such technology allows a single company to design, prototype and manufacture a product in close proximity to the end user.

27 Hagel, J. et al (2015). *The Future of Manufacturing: Making things in a changing world*, Deloitte University Press.
28 World Economic Forum (2012). *The Future of Manufacturing - Opportunities to drive economic growth,* Geneva.
29 Foresight (2013). *The Future of Manufacturing: A new era of opportunity and challenge for the UK Project Report,* Government Office for Science, London.

Australia's competitive landscape

3 Australia's competitive landscape

While Australia's competitive position can change as a result of national decisions and sectoral disruptions, the identified advantages and disadvantages discussed in this section are likely to be relevant to strategic planning over the next 20 years.

Advantages can be lost if not continually invested in, while disadvantages can become advantages by being prioritised and addressed. Opportunities that leverage Australia's comparative advantages and minimise disadvantages will be more defendable and sustainable.

The following comparative advantages and disadvantages were identified by Australian businesses through the industry workshops and survey (see 1.3).

3.1 Australia's Comparative Advantages

EDUCATION AND RESEARCH SKILLS

High education levels (vocational and higher education) and access to world-class research institutions are becoming increasingly important as advances in manufacturing techniques and processes require a more skilled and educated workforce. Tertiary level education rates in Australia have grown each year since 2001 and are well above the OECD average (37% vs 30%).[30,31] This is a relatively untapped advantage at present, as many of the best graduates choose career pathways outside of manufacturing and close to half the current manufacturing workforce is without a post-school qualification.[32]

Globally, Australia is recognised as having a notable competitive strength in the access to, and quality of, its education system – ranked 9th for higher education and training.[33] This is evident in the number of tertiary education and research institutions that perform well above world standard in fields of research relevant to manufacturing (see Table 3).[34] Further, CSIRO ranks in the top 1% of the world's scientific institutions in 15 research fields.[35]

Workshop participants noted that many of Australia's brightest graduates – specifically in science, technology, engineering and mathematics (STEM) fields – move into research organisations that support businesses through R&D. Australia's research community was considered to be excellent at problem solving for industry, with strong expertise in a range of areas including energy, advanced materials and additive manufacturing.

30 Hajkowicz, S. et al (2016). *Tomorrow's Digitally Enabled Workforce: Megatrends and scenarios for jobs and employment in Australia over the coming twenty years,* CSIRO, Brisbane.

31 OECD (2015). *Australian Manufacturing in the Global Economy*, Study for the Australian Government, Department of Industry, Innovation, Science, Research and Tertiary Education.

32 Australian Workforce and Productivity Agency (2014). *Manufacturing Workforce Study,* Australian Government.

33 Schwab, K. et al (2016). *The Global Competitiveness Report 2016–2017*, World Economic Forum, Geneva.

34 Australian Research Council (2015). State of Australian University Research 2015–16: Volume 1 ERA National Report, Australian Government. [Online] Available from: http://era2015.arc.gov.au/ Accessed 18/10/2016

35 Australian Trade Commission (2016). *Why Australia – Benchmark Report 2016*, Australian Government.

TABLE 3 – PERFORMANCE OF AUSTRALIAN UNIVERSITIES IN FIELDS OF RESEARCH APPLICABLE TO MANUFACTURING (2015)

FIELD OF RESEARCH	NUMBER OF AUSTRALIAN UNIVERSITIES WITH:	
	PERFORMANCE ABOVE WORLD STANDARD	PERFORMANCE WELL ABOVE WORLD STANDARD
Mathematical Sciences	11	7
Physical Sciences	4	11
Chemical Sciences	13	6
Earth Sciences	14	1
Environmental Sciences	17	9
Biological Sciences	15	4
Information and Computing Sciences	5	4
Engineering	14	5
Technology	6	3
Medical and Health Sciences	18	8
Built Environment and Design	3	0

Source: Australian Research Council 2016

QUALITY AND STANDARDS

In saturated markets, or markets where quality is prioritised over cost, Australia can differentiate itself by leveraging its strong reputation for quality and standards. In the Reputation Institute's 2016 rankings, Australia was rated the fourth most reputable country globally.[36]

From food quality and safety to the operational reliability of heavy machinery, Australia's quality assurance protocols, business transparency and reputation for delivering a high standard of product are valuable and recognised attributes in the global marketplace. This provides partners and customers with the confidence that the goods and services developed by Australian manufacturers are safe and reliable.

SMALL AND MEDIUM-SIZED ENTERPRISES (SMEs)

Being flexible and nimble in a rapidly changing sector is critical to sustaining success. While the pace of change within larger businesses can be impeded by their size, SMEs can be more agile and have strong innovation potential if linked into global markets. Further, larger businesses typically develop solutions to their problems internally whereas SMEs require connections and pooling of knowledge and resources to generate scale or specialise in niches of larger value chains (micro-multinationals). Having existing connections and a culture of collaboration will be critical as global customers demand more bespoke solutions.

36 Reputation Institute (2016). *2016 Country RepTrak – the most reputable countries in the world.*

Many Australian advanced manufacturers are SMEs rather than large-scale enterprises.[37] In 2015, around 87% of the 83,000+ manufacturing businesses in Australia employed between 1 and 19 employees.[38] More importantly, in contrast to large firms these SMEs are innovative by OECD standards, ranking 5th out of 29 OECD countries in business innovation.[39] While much of this potential is yet to be realised, Australia has around 1,000 to 1,500 successful micro-multinationals across industries such as defence electronics, medical devices, renewables and precision engineering.[40]

ACCESS TO ASIA

With China and India emerging as economic powerhouses, new export markets, trade relations and business models will emerge for Australia. By 2022, China's middle class alone is expected to rise from 300 million to 630 million, accounting for 45% of China's population and consuming goods and services worth an estimated US$3.4 trillion (24% of GDP).[41]

Australia's geographic proximity, time zone, free trade agreements and strong business and cultural ties will assist in capitalising on these opportunities. The higher rates of immigration between the two continents has resulted in a diverse set of Asian language skills being present in Australian organisations, with around 2.1 million Australian's speaking an Asian language. These strong ties to Asia see international manufacturers look to Australia as a gateway into emerging and booming Asian markets.

COMPARATIVE ADVANTAGES

- High educations levels with access to world-class research institutions
- Strong reputation for quality, safety and reliability
- Growing number of innovative SMEs
- Strong ties to emerging and booming Asian markets

OTHER COMPARATIVE ADVANTAGES

Other Australian comparative advantages identified by industry in workshops and the survey include:

- **Early adopters** – Australia has a history of being a beta-tester market for new technologies and are early adopters of consumer devices which may encourage international investment and collaboration.
- **Political and economic stability** – Australia has a stable political system; low levels of terrorism and social unrest; and has demonstrated economic resilience throughout the 'dotcom crash' and the global financial crisis. This stability is attractive to international companies.
- **Natural resources** – Australia has an abundance of non-renewable resources (natural gas, coal, titanium, uranium, rare earths) that are used as inputs in a range of manufacturing processes and product creation. The nation is also rich in renewable resources (wind, water, solar) that can be used to sustainably power manufacturing processes. Australian manufacturers are in a strong position to utilise these resources directly by value-adding or indirectly by developing and exporting systems for their use.
- **Intellectual Property (IP) laws** – Australia boasts a strong legal system that supports the creation and protection of IP and licensing for the commercialisation of innovations.

37 Withers, G. et al (2015). *Australia's Comparative Advantage*, report for the Australian Council of Learned Academies. Melbourne.

38 Australian Bureau of Statistics (2016). *8165.0 - Counts of Australian Businesses, including Entries and Exits, Jun 2011 to Jun 2015,* Canberra. [Online] Available from: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8165.0 Accessed 18/10/2016

39 Hendrickson, L. et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.

40 KPMG (2015). *Future state: Australian manufacturing and smart specialisation.*

41 Australian Trade Commission (2015). *Northern Australia: Emerging opportunities in an advanced economy,* Australian Government

3.2 Australia's Comparative Disadvantages

Much has been written and discussed about the comparative disadvantages of Australian manufacturing in the global context. These discussions typically focus on three areas:

- **High labour costs** – making it difficult to compete on price;
- **Geographical remoteness** – restricting access to many global markets due to high transportation costs; and
- **A small and dispersed domestic market** – making it difficult to achieve scale and associated economies of scale.

These characteristics will not disappear in the next 20 years and justify the need for Australian businesses to transition their strategic competitive positions towards providing value through differentiation rather than cost and to identify areas where Australian production costs are competitive. For example, Australia has a wage cost advantage for high-skill workers in aerospace and medical technologies – around 40% below the US.[42]

The digitisation of manufacturing and the shift towards bespoke solutions are causing all three disadvantages to become less important. Opportunities for growth can be identified where these disadvantages are less relevant or segments of the market where they act as advantages. For example, Australia's isolation offers advantages in terms of pests and disease control for agriculture and food manufacturing.

In order to strengthen Australia's competitive position in global manufacturing, businesses, governments and research organisations also need to focus on addressing comparative disadvantages that can be influenced. The following comparative disadvantages represent characteristics of Australian manufacturing that are more susceptible to change than the three highlighted above.

The digitisation of manufacturing and the shift towards bespoke solutions are causing all three disadvantages to become less important.

RISK AVERSE CULTURE

With a history of continuous contraction in traditional manufacturing industries and transformation across the entire sector, the majority of Australian manufacturers are finding it difficult to escape a survival mentality. Businesses are feeling the need to focus on the short-term as a priority to ensure they will exist in the long-term. Industry workshop participants noted that a complacent 'set in our way' culture and more conservative approaches to investment are further compounding the lack of strategic planning and action for long-term sustainability and growth.

Australian manufacturers fear competition rather than thrive on it. Further, many businesses view their competitors as other local manufacturers, demonstrating a lack of awareness of the global marketplace. This is resulting in a reluctance to participate in business-to-business collaboration – a critical factor for innovation and growth for businesses with small domestic markets.

SEGREGATED NATIONAL AGENDA

Numerous organisations have been established at the national, state and regional level by both governments and industry to develop plans and initiatives to strengthen various manufacturing industries. While this support and buy-in for manufacturing within Australia is critical for its future, these organisations have largely been developed independently and often have overlapping objectives and industry audiences, forcing competition for the same pool of funds.

Australia lacks a more streamlined and consistent bi-partisan national agenda under which these organisations can be streamlined and structured. This includes the need for greater alignment across research, business and government regarding priority industries and associated funding. Best practice examples include Germany and Japan, where governments establish and support research and education sectors that are more tightly integrated with manufacturing businesses, collaborating to develop innovative solutions to specific industry needs. Both nations have higher spending on R&D than Australia.[43]

42 Advanced Manufacturing Growth Centre analysis.

43 OECD (2016). *Gross domestic spending on R&D (indicator).* doi: 10.1787/d8b068b4-en [Online] Available from https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm, Accessed on 18/10/2016.

COMMERCIALISATION

Australian manufacturing businesses and researchers are excellent at solving problems but poor at commercialising these innovative solutions. In the 2016 global innovation rankings conducted by Cornell University, INSEAD and WIPO, Australia ranked 11th for Innovation Input but 27th for Innovation Output, highlighting Australia's poor performance in translating input into output.[44]

Two key drivers sit behind this disadvantage. The first is a relatively small pool of seed funding and capital. While larger businesses can leverage profits or accumulate higher debt, Australia's large share of SMEs are stifled by a lack of investment in early-stage businesses and ideas.

The second driver is a misalignment in incentives between business and research organisations. While business KPIs focus on revenue and profit, the research community is heavily incentivised by publications rather than interactions with businesses or commercialisation. This misalignment discourages collaboration and prevents Australian manufacturing from realising the full commercialisation potential of Australian innovation.

STAFF TRAINING AND DEVELOPMENT

Australian manufacturers do not capitalise on the full value of staff development, an issue consistently raised in all industry workshops and many survey responses. However, analysis has shown that – particularly for micro businesses – Australia invests above the OECD average proportion of gross value added into firm-specific on-the-job training.[45] Further investigation is required to determine whether this contradiction is due to manufacturing being at the low end of this national data, or because the investments made in training are not generating value.

Evolving manufacturing business models, technologies and processes are rapidly impacting required skillsets, however many businesses noted that they require more structured and up-to-date training avenues for maintaining world-class practices and capabilities within their workforce. On-the-job experience based training and capability expansion is essential in adapting to the changing demands on manufacturers as well as in ensuring high retention rates of quality STEM graduates.

COMPARATIVE DISADVANTAGES

- High number of reactive and risk averse businesses
- A complex ecosystem with overlapping and inconsistent support
- Poor commercialisation of local innovation
- Inadequate focus on preparing workforce for future needs

OTHER COMPARATIVE DISADVANTAGES

Other Australian comparative disadvantages identified by industry in workshops and the survey include:

- **Digital infrastructure** – Australia's global ranking for internet speed (average peak connection speed) dropped from 30th to 56th between September 2013 and July 2016.[46],[47] Internet speed is a critical enabler to doing business in global supply chains. Digital infrastructure is important in all markets as advanced digital technologies and data analysis become business-as-usual in manufacturing. Businesses anticipate the rollout of the National Broadband Network will negate much of this disadvantage, however they also reported that rollout delays are causing them to be at a disadvantage for longer than necessary.
- **Public perception** – Much of the Australian public believes manufacturing in Australia is dying; partly due to the recent well-publicised closure of automotive factories. Further, manufacturing is not often thought of as a desired career path among young students. These factors are limiting the number of quality students seeking out employment across the spectrum of manufacturing industries thus reducing the injection of new ways of thinking into the sector.
- **Quality and quantity of leaders** – With a large portion of Australia's manufacturing businesses having 'family-owned' roots, those in leadership positions are less likely to have had sufficient external experience to learn novel or more sophisticated approaches to business planning and staff management.

44 Cornell University, INSEAD and WIPO (2016). *The Global Innovation Index 2016 – Winning with Global Innovation*, Ithaca, Fontainebleau, and Geneva.
45 OECD (2015). *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society,* OECD Publishing, Paris.
46 Akamai (2013). *Volume 6, Number 3 – The State of the Internet 3rd Quarter, 2013 Report,* Cambridge.
47 Akamai (2016). *Volume 9, Number 2 –* Akamai's *State of the Internet Q2 2016 Report,* Cambridge.

Opportunities for growth

4 Opportunities for growth

The rapidly changing market and technology environment creates an impetus for change, resulting in manufacturing companies and nations that are willing to deploy new innovations to ensure survival in the future.

In considering Australia's competitive position in this rapidly changing global market, three broad opportunity themes have been identified – Customised high-margin solutions; Sustainable manufacturing; and Selling services. Strategic growth opportunities exist for manufacturers under each of these themes, with the largest falling across all three.

This section provides example opportunities and case studies under each theme discussion to highlight their relevance to the many industries that make up, and are influenced by, manufacturing. Where businesses or industries are not leaders in their field, they need to pursue opportunities under these themes by being 'fast followers' through the adoption of technologies and approaches from overseas.[48]

TABLE 4 – SUMMARY OF OPPORTUNITY THEMES

OPPORTUNITY THEME	
Customised high-margin solutions	• DESIGN SERVICES: From bespoke co-design with customers to manufacturer-less manufacturing • SUPERIOR COMPONENTRY: From components with improved characteristics to components with completely new characteristics • NOVEL PRODUCTS: From upgrades to existing products to complex and integrated novel solutions in health, defence and aerospace
Sustainable manufacturing	• BUSINESS MODELS AND PROCESSES: From reduced land use and wastage to closed-loop material use • PRODUCTS: From energy efficient products to products designed with recycling, recovery and collaborative consumption in mind
Selling services	• MAINTENANCE AND REPAIR SERVICES: From static monitoring, diagnostics and predictive services to ingestible / embedded and intelligent sensors • WORKFLOW MANAGEMENT SERVICES: From wearable tracking devices and bundling of add-on services to performance-based contracts and interactive platforms that allow informed decision making • HEALTH AND BIOSECURITY SERVICES: From discrete monitoring functions to integrated and continual reporting for advanced warning

48 Bell, J. et al (2014). *The role of science, research and technology in lifting Australian productivity.* Report for the Australian Council of learned Academies, Melbourne.

4.1 Customised high-margin solutions

THE OPPORTUNITY THEME

Rising income growth in developing regions coupled with the increasing expectations of customers in developed economies is creating demand for more specialised and customised product offerings. This demand is driven further by consumer awareness and technology availability and maturity.

Manufacturing customised solutions provides businesses with greater opportunities for product differentiation and increased service bundling (see Selling services opportunity theme). Integrating customers into the design of these products can offer increased loyalty, deeper consumer insights and a stronger value proposition.[49]

Customised high value manufacturing creates opportunities for larger profit margins across the entire value chain; from research and development to after-sale services and end-of-life management. These solutions are typically manufactured for markets where quality factors (reliability, strength, durability, low weight, in-built sensors, low defect or failure rate) are valued over cost.

It has been estimated that 71% of consumers interested in personalised products and services would be willing to pay a price premium, with one in five of these consumers willing to pay a premium of 20%.[50]

These solutions are high-skill, technology and R&D intensive; enabled by emerging state-of-the-art manufacturing and digital technologies, and usually require companies to invest and maintain expert knowledge in domains that underpin their products and services.[51] This investment in domain knowledge can produce other benefits, including enhanced absorptive capacity and improved identification of new market opportunities.

DRIVING MEGATRENDS

- Made to Measure
- Sustainable operations
- Supply chain transformations

Case study

Oventus[52]

An estimated one million Australians suffer from sleep apnoea, which can lead to high blood pressure, stroke, irregular heartbeats, heart attacks and diabetes. Traditional treatments can be problematic for patients, with issues such as chronic jaw pain, teeth loosening, teeth wear, ongoing adjustment or nasal obstruction.

Using a 3D scanner to map a patient's mouth, Australian medical device company Oventus, with help from CSIRO, can now print a mouthpiece which prevents dangerous pauses in breath during sleep. Printed from lightweight titanium and coated with a medical grade plastic, the breakthrough O_2Vent device is customised for each patient. The novel 'duckbill' design allows air to flow through to the back of the throat, avoiding obstructions from the nose, the back of the mouth and tongue.

The Oventus O_2Vent is effective as a standalone technology or can be connected to a continuous positive airway pressure machine for more advanced treatment. Attracting a price premium due to its customised fit, the device retails for around $1,700 with rebates available from private health insurers.

49 Deloitte (2015). *The Deloitte Consumer Review - Made-to-order: The rise of mass personalisation.* Deloitte LLP, London.

50 Deloitte (2015) *Press Release: Making it personal – One in three consumers wants personalised products,* [Online] Available from: http://www2.deloitte.com/uk/en/pages/press-releases/articles/one-in-three-consumers-wants-personalised-products.html Accessed 18/10/2016

51 Department for Manufacturing, Innovation, Trade, Resources and Energy (2012). *Manufacturing Works - A Strategy for driving high value manufacturing in South Australia*, Government of South Australia, Adelaide.

52 CSIRO Website, *Putting sleep apnoea to bed with 3D mouthguard,* [Online] Available from: http://www.csiro.au/en/Research/MF/Areas/Metals/Lab22/Mouthguard Accessed 18/10/2016

Why Australia?

Australia is a high-cost country, especially for manufacturing. Wages, property, energy and transport costs are comparatively high and are continuing to increase. Between 2004 and 2014, Australian manufacturing wages increased by 48%. Along with decreasing productivity and high exchange rates, Australian manufacturing is the least cost competitive of the world's 25 leading exporting economies.[53]

While these factors make it difficult for Australia to compete against low-cost economies in low-margin commoditised markets, the nation has a cost advantage when it comes to complex and high value solutions that require innovation and advanced skills – around 40% cheaper than the US in aerospace and medical technology manufacturing.[54] Further, customisation decreases the importance of scale economies, helping to address the limitations of Australia's small domestic market.

Ranked 5th in the OECD for innovation,[55] Australia's large proportion of SMEs are well suited to rapidly adapting to changing and divergent customer demands for increased customisation. SMEs can also specialise in niches for high-value products, manufacturing highly specialised and integrated products and componentry for target markets where Australia has a natural advantage, such as mining, food and agriculture and defence. Through servicing the small domestic market, Australian manufacturers are experienced in profitably manufacturing low volume, niche products.[56]

Case study

Carbon Revolution[57]

Carbon Revolution pioneered the commercial production of carbon composite car wheels which are made from a single piece of material. Until recently the wheels have been sold as an after-market product for high-end cars, costing US$15,000 per set. However in 2015 Ford Motor Company announced a deal that involved Carbon Revolution supplying wheels for their high performance Mustang Shelby GT350R, making them the first company in the world to supply mass-produced carbon fibre wheels on standard equipment for a major automaker.

The business has invested heavily in in-house research and development capabilities as well as collaborations with local research organisations to exceed original equipment manufacturer standards for their products. This has resulted in wheels that weigh up to 50% less than conventional aluminium equivalents and reduced carbon emissions by up to 6%. Looking forward, Carbon Revolution is now investigating opportunities in aerospace and industrial markets.

53 Sirkin, H. et al (2014). *The Shifting Economics of Global Manufacturing,* The Boston Consulting Group, Boston.

54 Advanced Manufacturing Growth Centre analysis.

55 Hendrickson, L. et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.

56 Future Manufacturing Industry Innovation Council (2011). *Trends in manufacturing to 2020: A foresighting discussion paper.* Canberra.

57 Australian Advanced Manufacturing Council Website, *Carbon Revolution,* [Online] Available from: http://aamc.org.au/portfolio-items/carbon-revolution/ Accessed 18/10/2016

INDUSTRY OPPORTUNITIES

High-margin customisation presents opportunities across a range of industries. In medical technologies and pharmaceuticals for example, quality is often prioritised over cost as personalised devices and medicines require high levels of reliability, durability and bio-compatibility. These products are typically at the smaller end of the size spectrum, reducing the cost of exporting goods from Australia's geographically remote location. Likewise, in defence and aerospace, failure rates must be negligible and premiums can be charged for high quality and extensive testing of customised products.

There may also be opportunities in Australian industries that are undergoing contraction. While a lot of heavy industry is moving offshore, investment can make sense when targeting niche heavy industry such as components for the Australian Future Submarine Program.

Table 5 lists a selection of opportunities for Australian manufacturers to produce customised high-margin solutions across a time horizon.[58] These examples demonstrate the breadth of opportunities across manufacturing industries as well as how the nature and application of these opportunities are likely to change over time.

TABLE 5 – INDUSTRY OPPORTUNITIES FOR CUSTOMISED HIGH-MARGIN SOLUTIONS

SHORT TERM (0 – 3 YEARS)	MEDIUM TERM (3 – 10 YEARS)	LONG TERM (10+ YEARS)
DESIGN SERVICES		
From bespoke co-design with customers...		**...to manufacturer-less manufacuring**
• Rapid prototyping services for new product and component solutions. • In-store DIY experiences for consumer goods (e.g. personalised jewellery, home hardware). • After-market vehicle customisation and restoration.	• Sensors, actuators and computing hardware that are designed to be easily retrofitted to existing equipment and with legacy software, systems and technologies.	• Platforms where customers can send their electronic designs to shared-access 3D printers and control the entire process.
SUPERIOR COMPONENTRY		
From components with improved characteristics...		**...to components with completely new characteristics**
• Light-weight carbon fibre composites to reduce aircraft weight. • 3D printed prosthetics, dental and bone implants. • Customised medical instruments and surgical tools.	• 3D printed spare part solutions for out-of-production parts. • 3D printed vehicle componentry with superior strength, durability and weight characteristics.	• Advanced surface materials or integrated sensors that can communicate operating properties of component or whole product to operator.
NOVEL PRODUCTS		
From upgrades to existing products...		**...to complex and integrated novel solutions in health, defence and aerospace**
• Remotely operated vehicles for extreme environments (e.g. mine sites, fire and rescue, warzones). • Personalised sporting goods (e.g. golf clubs that are weighted based on user profile). • Customised tissue and simple 3D printed organs used in transplants.	• Smart chairs, smart beds, and smart pillows that will self-adjust to minimise pressure points and optimise comfort. • Self-repairing pipes to reduce maintenance and shut-down costs for oil and gas producers. • Precision medicines that are developed by considering distinct age, genetic and lifestyle combinations for increased efficacy.	• Complex 3D printed organs that adapt and grow with their environments. • Biomarkers for in-situ disease detection. • Self-healing military vehicles and apparel. • 3D printed parts that are integrated with smart materials, sent to space, and programmed to self-assemble. • Pipes that expand when demand increases.

58 Time horizons should be viewed as a guide only, with factors such as business maturity and existing capabilities impacting how quickly a business could act on any given opportunity.

4.2 Sustainable manufacturing

THE OPPORTUNITY THEME

The need for sustainable practices and technologies in manufacturing is being driven by both demand and supply side pressures. These include competition for critical and increasingly scarce manufacturing resources such as water, raw materials and energy; declining productivity; increasing requirements for accountability and transparency of operations; consumer preferences; and a growing operational impact of social licence.

Manufacturing industries have the potential to become a driving force for realising a sustainable society. A recent global study found that 59% of executives believe that sustainability initiatives are improving their growth and profits, spurring global investment in innovative sustainable products and processes.[59] Opportunities for creating value in sustainable manufacturing span the entire supply chain and product lifecycle, including production processes, products and end-of-life disposal/ recycling of products.

A recent global study found that 59% of executives believe that sustainability initiatives are improving their growth and profits, spurring global investment in innovative sustainable products and processes.

Sustainable processes can include reducing costs, resources and emissions through cleaner energy sources and leaner processing techniques; smarter design using innovative technologies such as advanced and high performance materials and 3D printing; and maximising efficiency across value chains. Doubling energy productivity within Australian manufacturing by 2030 could reduce the cost of the sector's energy use by $5 billion per annum.[60]

DRIVING MEGATRENDS

- Sustainable operations
- Supply chain transformations
- Smart and Connected

On the product side, demand is increasing for products that contribute to reducing a customer's environmental footprint during use, such as electric vehicle technologies, water-efficient products, energy-saving consumer products, and solar and wind energy products. While demand is present, these product opportunities are often heavily reliant on government off-sets and investment in supporting infrastructure.

Demand for sustainably manufactured products is likely to increase over the coming years, becoming an important social licence issue. A range of indices and sustainability scales will be developed over the short term that allow consumers and businesses to easily understand the sustainability of products and value chains to make informed decisions. Examples that already exist include Walmart's Sustainability Index and the Dow Jones Sustainability Index.

Opportunities will also emerge for businesses that embrace the circular economy concept, taking responsibility for whole-of-life impacts. Businesses can achieve step-change improvements to resource efficiency through waste reduction, recycling, remanufacturing and reuse. Although waste intensity[61] in the manufacturing industry has increased 31% between 1996-97 and 2013-14, there are signs of growth in the reuse and recycling of manufacturing waste. The value of waste products (waste materials with a positive value, e.g. scrap metal) supplied to the Australian economy increased 18% in the year to 2010-11 to reach $5.4 billion; of which manufacturing accounted for approximately 14% ($741 million).[62] In addition to reducing the costs associated with wastage, participating in a closed-loop economy can offer manufacturers exposure to new and potentially untapped value chain partners.

59 Rigby, D. et al (2015). *Management Tools & Trends 2015,* Bain & Company.

60 Australian Alliance to Save Energy (2014). *Re-energising Australian Manufacturing – Doubling energy productivity by 2030 to improve the competitiveness of the manufacturing sector*, November 2014, Concepts for discussion, Draft version 1.0.

61 Waste intensity is measured in waste (tonnes) generated per million dollars of gross value added (GVA). Waste intensity is a measure of waste generation arising from economic production. *Source: Australian Bureau of Statistics, 4655.0 - Australian Environmental-Economic Accounts, 2016 – Glossary.*

62 Australian Bureau of Statistics (2016). *4655.0 - Australian Environmental-Economic Accounts, 2016,* Canberra. [Online] Available from: http://www.abs.gov.au/ausstats/abs@.nsf/mf/4655.0 Accessed 18/10/2016

The global 'green market' (the market for low-carbon products) has been estimated to be worth over US$5 trillion and is expected to grow.[63] At present, the price difference between sustainably manufactured goods and more traditional options is large enough to discourage many from switching, however, this gap will close significantly in the next decade through technology improvements. Failure to adapt to increased transparency and stricter government imposed requirements for sustainability could result in reputational damage and missed opportunities within these emerging markets.

Why Australia?

Australian businesses are feeling the pressure of sustainable manufacturing drivers more so than many other countries, providing an incentive to be first movers. Australia's high education levels facilitate greater awareness of sustainability issues which translates into higher levels of domestic demand for sustainably manufactured products.

Accounting for approximately 20% of Australia's energy consumption,[64] manufacturing is Australia's largest industrial consumer of electricity and most energy intensive sector.[65,66] With electricity prices increasing over 60% for manufacturing businesses over the 10 years to June 2013,[67] companies that become more energy efficient stand to reduce costs, increase productivity and gain competitive advantage.

In addition to addressing Australia's resource intensity challenges, this opportunity theme is also supported by national comparative advantages. Australia's large land area, abundance of renewable energy sources and strong agricultural sector positions the nation well for opportunities in sustainable food and water technologies and renewables such as wind, hydro and solar. Australia's expertise in mineral extraction techniques and technologies can also be leveraged in the melting and re-purposing of discarded or end-of-life metal products.

Case study

Waste Converters / Smart Recycling[68]

Waste timber in the form of pallets takes up costly space either in the landfill bin or on-site storage areas for almost all manufacturers. In 2014FY Australia generated over 500,000 tonnes of timber waste with around 340,000 tonnes ending in landfill.

Waste Converters / Smart Recycling buy and sell second-hand pallets and manufacture reusable pallets, skids, crates and boxes. Through the re-use and re-manufacture of timber pallets, they assist over 2,000 local organisations to reduce their landfill costs and carbon footprint. Timber that is unsuitable for packaging or resale is mulched to produce a variety of quality landscaping mulches.

This business provides customers with a cheaper source of pallets, reduces their energy and landfill costs and creates a sustainable recycling loop. It is estimated that every 1 tonne of softwood pallet repaired and re-used (~40 pallets) results in a reduction of 0.7 tonnes of CO_2 emissions and 1 tonne diverted from landfill.

63 OECD (2011). OECD Sustainable Manufacturing Toolkit – Start-up Guide, [Online] Available from: http://www.oecd.org/innovation/green/toolkit/48704993.pdf Accessed 18/10/2016

64 Department of Industry and Science (2015). *2015 Australian energy update*, Commonwealth of Australia, Canberra.

65 Energy intensity: gigajoules (GJ) of energy consumed per millions of dollars of Industry Gross Value Added.

66 Australian Bureau of Statistics (2016). *4604.0 - Energy Account, Australia, 2013-14,* Canberra. [Online] Available from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4604.0 Accessed 18/10/2016

67 Swoboda, K. (2013). *Energy prices—the story behind rising costs,* Parliament of Australia, [Online] Available from: http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook44p/EnergyPrices Accessed 18/10/2016

68 More information about this case study can be found at https://aspire.csiro.au/case-studies/timber-and-pallet-recycling.

Case study

Sundrop Farms[69,70]

Producing food in the context of a rapidly growing global population and increasingly limited arable land and fresh water supplies causes many challenges for sustainable food production. Sundrop Farms is pioneering sustainable desert horticulture in Australia with its 20 hectare installation in Port Augusta. In a first-of-a-kind system, tomatoes are being produced on a large scale using only seawater and sunlight for power, water, heating and cooling.

A ten-year contract with Coles supermarkets to supply 15,000 tonnes of truss tomatoes per annum has provided the basis for securing $100 million in finance from venture capital firm KKR, enabling the expansion from pilot facility to a fully operational 20-hectare farm. The initial project has been supported by the SA Government and Clean Energy Finance Corporation. Sundrop now plans to set up similar operations in arid regions around the world.

INDUSTRY OPPORTUNITIES

Sustainable manufacturing presents opportunities across a range of industries, particularly those with high water, waste and energy intensity. For example, the most energy intensive manufacturing industries in Australia are the primary metal/metal product manufacturing and food product manufacturing industries. These two industries account for 59% and 10% of the total manufacturing sector's electricity consumption respectively, yet represent 2.6% and 12.8% of the total number of manufacturing businesses in Australia.[71]

Advanced materials for light weighting

A kilogram reduction in weight of a short-haul aircraft can equate to a saving of 80 metric tons of CO_2 per year.[72] Opportunities exist within all industries to find more efficient and sustainable material flow systems.
For example, waste from one process, business or industry could be used as input to another, older products (or their components) can be used for lower value purposes, and raw materials can be extracted to create new products.

Advanced materials for light weighting: A kilogram reduction in weight of a short-haul aircraft can equate to a saving of 80 metric tons of CO_2 per year.

Table 6 lists a selection of industry opportunities for Australia to gain from sustainable manufacturing applications across a time horizon.[73] These examples demonstrate the breadth of opportunities across manufacturing industries as well as how the nature and application of these opportunities are likely to change over time.

69 Straight, K. (2016). *Sundrop Farms pioneering solar-powered greenhouse to grow food without fresh water*, ABC News. Available from: http://www.abc.net.au/news/2016-10-01/sundrop-farms-opens-solar-greenhouse-using-no-fresh-water/7892866> Accessed 12/10/2016

70 Vorrath, S. (2016). *World-first solar tower powered tomato farm opens in Port Augusta,* Renew economy. Available from: http://reneweconomy.com.au/2016/world-first-solar-tower-powered-tomato-farm-opens-port-augusta-41643 Accessed 7/10/2016

71 Australian Bureau of Statistics (2016). *8165.0 - Counts of Australian Businesses, including Entries and Exits, Jun 2011 to Jun 2015, Data Cube: Survival of Businesses by Main State by Subdivision by Turnover Size Ranges, June 2011 - June 2015,* Canberra.

72 Air France Case Study (2011). *In a world first, Air France organizes lowest CO2 emissions flight.* [Online] Available from: http://www.safug.org/assets/docs/case-studies/air-france1.pdf Accessed 18/10/2016

73 Time horizons should be viewed as a guide only, with factors such as business maturity and existing capabilities impacting how quickly a business could act on any given opportunity.

TABLE 6 – INDUSTRY OPPORTUNITIES FOR SUSTAINABLE MANUFACTURING

SHORT TERM (0 – 3 YEARS)	MEDIUM TERM (3 – 10 YEARS)	LONG TERM (10+ YEARS)
BUSINESS MODELS AND PROCESSES		
From reduced land use and wastage...		**...to redistribution and closed-loop material use**
• Application of continuous flow chemistry methodologies to unlock easier scaling up/down of operations, footprint reduction, lower energy use and just-in-time manufacturing. • Enhanced waste recovery systems (e.g. steam from heat used to power steam turbines). • Improved industrial symbiosis where wastes and by-product from one industry is used as raw material for another. • Technologies for food waste processing and re-purposing (e.g. fuel, feedstock).	• Renting out of underutilised resources (staff, machinery, equipment, vehicles) to other businesses. • Technologies to reduce heat loss in process industries. • Software-based energy monitoring and planning systems to reduce overall energy consumption. • Application of just-in-time production for reduced transport and storage requirements.	• Factories located near value chain partners and customers for reduced transport and logistics requirements. • Niche value chain partners who specialise in the identification, collection and processing of discarded products for re-use, re-cycling and re-manufacturing.
PRODUCTS		
From energy efficient products...		**...to products designed with recycling, recovery and collaborative consumption in mind**
• Double-glazing glass for thermal insulation (reduced energy costs) at residential and commercial properties. • Lightweight materials for wind turbines. • Drawing on Australia's free air space and terrain diversity to develop and test aerial drones for surveillance activities (e.g. replacing heavy vehicle use for crop monitoring, worker tracking, transport of small goods). • Supercapacitors and efficient batteries for hybrid and electric cars, and miniaturised for Internet of Things.	• Robots that specialise in the disassembling of discarded or end-of-life assembled products. • Green building materials (plastics, chemicals, cement, steel) for construction and infrastructure. • Large scale energy storage devices from local materials for in-home renewable energy storage. • Self-service housing with integrated recycled water, food waste processing and renewable energy.	• Waste material from metal product manufacturing processed into feedstock for 3D printing. • Atmospheric energy harvesters that collect and store ambient and concentrated forms of naturally occurring energy. • Artificial production of protein and leather to replace inefficient livestock farming. • Substitution of virgin materials with secondary materials in medical products (e.g. intravenous containers).

4.3 Selling services

THE OPPORTUNITY THEME

Customer preferences – both intermediary and end users – are shifting away from tangible products and towards services and experiences. Growth in services is being driven by ageing key consumer groups in developed economies demanding healthcare services and rising incomes in emerging economies (as the share of household consumption spent on services increases with per capita income).[74]

Globally the average service-providing manufacturer receives over 30% of sales as services,[75] with expansion into services offerings seen as core to growth by 86% of global manufacturers, largely due to the significantly higher profitability of service based offerings.[76] Service integration allows manufacturers to create a direct relationship with customers. This increases the chance of loyalty and upselling by being able to better understand customer needs and by offering a differentiated or customised product-service bundle which is harder to imitate.

Globally the average service-providing manufacturer receives over 30% of sales as services, with expansion into services offerings seen as core to growth by 86% of global manufacturers, largely due to the significantly higher profitability of service based offerings.

Providing services requires different selling methods and business models to conventional manufacturing but delivers businesses with additional revenue that has traditionally been captured by other value chain participants such as retailers. This shift will require manufacturers to develop their customer interface skills as well as back-end systems that support service-based offerings, such as cloud-based customer relationship management systems.

DRIVING MEGATRENDS

- Service expansion
- Supply chain transformations
- Smart and connected

Case study

Detmold[77]

In 2012, the Detmold Group was approached by a multinational food company who were seeking a high quality end-to-end packaging solution that could be delivered in a short timeframe. From this request, Detmold's centre for R&D, concept creation and rapid prototyping in packaging (LaunchPad) was born.

With studios in Australia and China, the LaunchPad team provides rapid integrated product development services, such as design, prototyping, sample making, materials engineering, artwork and printing. The Detmold Group has invested heavily in equipment and software, including digital printers capable of instant printing on its full range of packaging materials, and flatbed cutting machines that can deliver client samples on actual production materials minutes after design concepts are completed.

This process allows a business's lead time to commercialisation to reduce from over 12 months to just one day. Detmold has seen 50% growth since the introduction of LaunchPad and a four-fold increase in new clients.

74 Dobbs, R. et al (2016). *Urban World: The global consumers to watch,* McKinsey Global Institute, McKinsey & Company.
75 Visnjic, I. and Van Looy, B. (2012). *Servitization: Disentangling the Impact of Service Business Model Innovation on the Performance of Manufacturing Firms*. ESADE Business School Research Paper No. 230.
76 Macaulay, J. et al (2015). *The Digital Manufacturer – Resolving the Service Dilemma*, Cisco, San Jose.
77 Food Innovation Australia Limited (2016). *Celebrating Australian Food and Agribusiness innovations.*

The long-term contracts associated with services provide greater financial stability through more predictable and ongoing revenues and costs. Where new products typically require expensive re-tooling and investment in untried technologies, new services often avoid these costs and so have a lower risk profile for pursuing economic growth.[78]

The simplest method of entering the services market is to offer a service that complements an existing product offering, such as maintenance, support, and installation. This is a relatively cheap option for manufacturers to develop the skills, processes and systems required to be successful in this growing market.

More sophisticated models could include collaborative consumption or the integration of services at the design stage of a product. The most extreme example of the latter is where customers are only buying the product as a way of accessing the service. In this instance, the product might even be a loss leader for the service.

Why Australia?

With commoditised goods markets being dominated by large and low-cost economies, the services market is particularly crucial for manufacturers in high-cost nations like Australia. Diversifying into the services market is one solution to the pressure felt by local manufacturers to differentiate in order to participate in global value chains.

Australia's fast moving and innovative SMEs are another advantage for this opportunity theme. Australian SME manufacturers ranked 5th in the OECD for innovation, while Australian SME service sector businesses ranked 7th.[79]

Manufacturers are well positioned to leverage Australia's large pool of services skills, with the services sector accounting for 60% of GDP and around 80% of jobs.[80] The service sector also has experience in selling abroad, with service exports accounting for almost 20% of total exports and growing at a rate of 3.2% annually over the five years to 2014.[81] Not only do businesses have the potential to leverage these skills, but the large services market in Australia also generates the required demand to drive technological innovations that support service provision.

Finally, Australia's high level of education positions the sector well for succeeding in service markets which require a higher-skilled workforce.

Case study

ANCA Tools

ANCA's multi-axis grinding machines are enhanced with integrated solutions for automation, part measurement and quality control and machine status monitoring and reporting.

ANCA is currently delivering a solution to Japan to be integrated into a customer's unmanned, factory wide automated production system. ANCA machines are fed parts from a separate conveyor line – reading a linked RFID (radio-frequency identification) chip on the part. Using that data, the ANCA machine accesses the factory is enterprise resource planning system to retrieve tool information specific to the customer's purchase order and automatically generates the required grinding program.

In-built measurement systems on the machine ensure part dimensions are maintained in tolerance and corrections applied as required. This allows ANCA's customer to produce bespoke tools in batch sizes of one, all the while running unmanned. By integrating machines into highly automated production systems, customers can realise significant cost reductions while also reducing lead times to their customers.

The customer plans to take advantage of ANCA's newly developed machine Management Suite. This will allow remote, real time production monitoring of the machines, as well as machine data collection that can be used for future process enhancement or predictive maintenance activities.

78 KordaMentha (2013). *Australian manufacturing – redefining manufacturing*, Publication No. 13-03.

79 Hendrickson, L., et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.

80 Office of the Chief Economist (2015). *Australian Industry Report 2015,* Department of Industry, Commonwealth of Australia, Canberra.

81 Department of Foreign Affairs and Trade Website, *The importance of services trade to Australia,* [Online] Available from: http://dfat.gov.au/international-relations/international-organisations/wto/pages/the-importance-of-services-trade-to-australia.aspx Accessed 18/10/2016

INDUSTRY OPPORTUNITIES

Adding or integrating services to products presents opportunities for all manufacturers. Service provision is most progressed in industries where Australian manufacturers have a strong reputation for quality, authenticity and uniqueness. Businesses have already begun to extend this trust to their services in aerospace, defence and medical technologies.

For decades, aircraft engine manufacturers like Rolls Royce and General Electric have been offering performance-based service and logistics agreements to customers. These services involve a fixed warranty and operational fee for the hours engines are running, meaning that in addition to making the product, the manufacturer takes care of installation, after-sales maintenance, repair, overhaul and overall service and parts management.[82] Customers value a trusted supplier taking over responsibility and risk for these tasks and manufacturers can increase profit margins by improving their efficiency.

Looking to the future, a number of technology developments will enable new service offerings, including increased uptake and application of sensors, smart devices, additive manufacturing, big data analytics and cloud computing.[83] For example, the collection, analysis and interpretation of longitudinal medical data through implanted sensors will allow for superior data-driven decision-making compared to current 'snapshot' diagnostics.

Table 7 lists a selection of industry opportunities for Australia to gain from selling services – both domestically and abroad – across a time horizon.[84] These examples are non-exhaustive however demonstrate the breadth of opportunities across manufacturing industries as well as how the nature and application of these opportunities are likely to change over time.

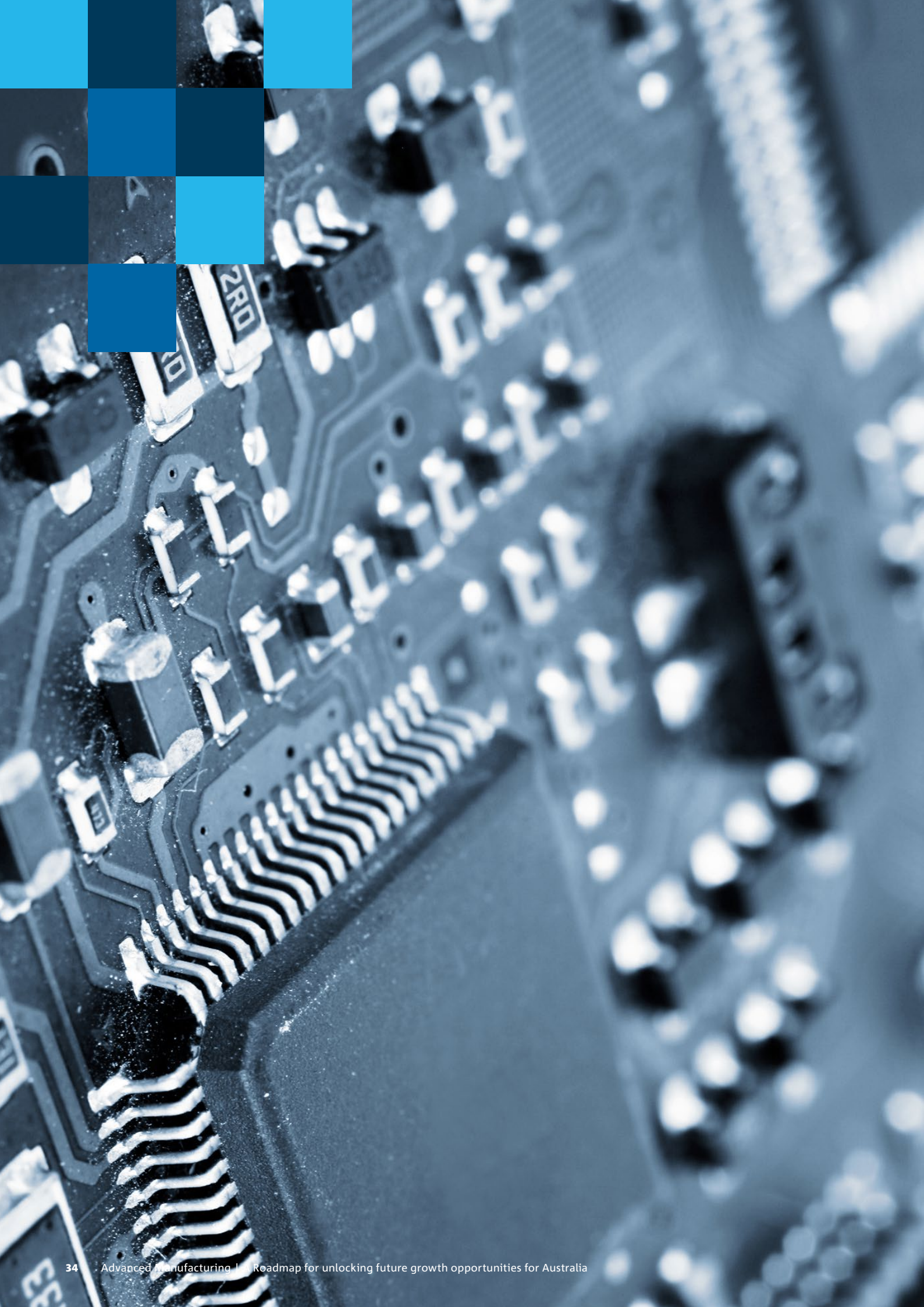
82 Deloitte Research (2006). *The Service Revolution in Global Manufacturing Industries*, Deloitte Development LLC.

83 Rehse, O. et al (2016). *Tapping into the Transformative Power of Service 4.0,* BCG Perspectives.

84 Time horizons should be viewed as a guide only, with factors such as business maturity and existing capabilities impacting how quickly a business could act on any given opportunity.

TABLE 7 – INDUSTRY OPPORTUNITIES FOR SELLING SERVICES

SHORT TERM (0 – 3 YEARS)	MEDIUM TERM (3 – 10 YEARS)	LONG TERM (10+ YEARS)
MAINTENANCE AND REPAIR SERVICES		
From static monitoring, diagnostics and predictive services...		**...to intelligent sensors**
• Condition monitoring, diagnostics and predictive maintenance of heavy machinery (e.g. turbines, engines, chemical processing equipment, ore sorting machines).	• Multi-site orchestration and control of autonomous equipment and vehicles maintenance systems.	• Sensors directly incorporated into materials that allow monitoring of equipment and infrastructure properties such as stress or changes due to heat.
WORKFLOW MANAGEMENT SERVICES		
From wearable tracking devices and bundling of add-on services...		**...to performance-based contracts and interactive platforms that allow informed decision making**
• Incorporation of GPS, imaging and video feeds in transport tracking systems to maximise efficiency across value chain logistics. • Monitoring of staff location in widely dispersed and/or hazardous environments (e.g. mines, chemical plants, oil-fields). • Service and logistics agreements for aerospace engines that involve fixed fee for installation, testing, training, after-sales maintenance, repair, overhaul and overall servicing. • Online prototyping and design services for 3D printing. • Service contracts for new mining equipment products that include overhaul, replacement or repair at end-of-life.	• Remote support services through light-weight and durable wearable cameras that provide live feed from onsite field technicians. • Condition monitoring and diagnostics of a component or product across its value chain, providing maintenance and scheduling insights. • Selling the guarantee of performance-based metrics in the aerospace sector (e.g. flying time, fuel efficiency). • Algorithms, platforms and processes to reduce burden of data cleansing and integration.	• Monitoring insights from packing and assembly robots that capture information on product quality and counts. • Data collection and analysis of quarry wall feeding into autonomous decision making about where to mine next. • Sensor-embedded industrial fridges that automate direct ordering and transport of food from factory to fridge, based on stock levels. • Data analytics of de-identified big data sets that have been collected through monitoring services connected to products (e.g. public health analysis or product use analysis). • Drone delivered on-demand packages (food, tools, spare parts).
HEALTH AND BIOSECURITY SERVICES		
From discrete monitoring functions...		**...to integrated and continual reporting for advanced warning**
• Packaging sensors that provide condition monitoring for perishable food across the value chain. • Physical and psychological therapy performed through virtual reality.	• Ingested or embedded biological sensors that track the biochemical health of livestock through probing biosystems.	• Monitoring of staff health through implanted biosensors in high risk industries and workplaces (e.g. commercial truck driving, mines, chemical plants, oil-fields). • Embedded sensors in food or individual packets that report quality through real-time visual cues. • Prosthetics controlled by artificial intelligence.



Enabling
science and technology

5 Enabling science and technology

Strategic growth opportunities for Australia's manufacturing sector will be underpinned and supported by significant technological innovation from public and private research communities. Sustained growth in the sector will require proactive investment and translation of enabling science and technology.

In order to acquire the benefits associated with these long-term technology breakthroughs, businesses need to plan and invest today. Significant competitive advantage can be gained through the fast and efficient adoption of new technologies,[85] with investment in R&D central to maintaining a strong position in global value chains, growing exports and ensuring sector growth.[86]

In order to acquire the benefits associated with these long-term technology breakthroughs, businesses need to plan and invest today.

Looking forward 20 years, it is difficult to understand the vast changes that will occur in technology; many of today's nascent technologies and ideas will be further developed, however, there will also be completely unforeseen and radical changes. One certainty is the importance of IoT devices and systems in driving breakthroughs and applications across all fields of research. The broader suite of digitally connected technologies has been estimated to generate productivity gains of 5-8% on average over the next 5 to 10 years after considering the cost of materials, with industrial component manufacturers who invest in these technologies estimated to experience up to a 30% improvement.[87]

Convergence of technologies through innovative combinations will transform industries and generate growth greater than the sum of their parts.[88] Examples include the convergence of fast DNA sequencing and analytics to allow for more precise decisions regarding patient health, and enhanced computing power and robotics to accelerate the automation of manual work. New disruptive technologies will also come from outside the manufacturing sector.

This chapter aims to raise business – particularly SME – awareness of key enabling science and technology areas for the future of manufacturing in Australia. Each discussion includes a list of research priorities that describe the challenges that the research community is currently focussed on and is expected to address or overcome in the next decade. Businesses can use the list to better understand current technological barriers, benchmark their own preparedness based on their current experience or investments in each area, and consider how upcoming advances could support their operations, create new IP and unlock new opportunities.

These technologies are applicable across many diverse industries, are typically combined in their application and represent a selection of enablers rather than an exhaustive list.

85 Williamson, R. et al (2015). *Technology and Australia's future: New technologies and their role in Australia's security, cultural, democratic, social and economic systems*, Australian Council of Learned Academies, Melbourne.

86 Hendrickson, L. et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.

87 Rüßmann, M. et al (2015). *Industry 4.0: The future of productivity and growth in manufacturing industries*, BCG Perspectives.

88 Hagel, J. et al (2015). *The future of manufacturing: Making things in a changing world*, Deloitte University Press.

TABLE 8 – ENABLING SCIENCE AND TECHNOLOGY SUMMARY

	NOW	IN THE FUTURE
Sensors and data analytics	Predominantly used during production (remote monitoring of single attributes such as temperature or flow rates).	Applied across the value chain, including predictive maintenance, logistical tracking for operational efficiencies, quality control and service offering (when integrated into end product).
Advanced materials	Reactive use to address specific product limitations e.g. enhanced durability, weight, look and feel.	Proactive integration at early design phase to offer multiple novel attributes e.g. biocompatibility, biodegradability, energy efficiency and self-repairing.
Smart robotics and automation	Replace workers for tasks that are complex, high precision, repetitive, dull or hazardous e.g. handling operations and robotic welding.	Assistive robots that work collaboratively with humans and each other, with improved sensing, awareness and decision-making capabilities that allow full autonomy and self-learning behaviour.
Additive manufacturing (3D printing)	Prototyping and one-off production runs of customised high-value complex metal componentry and low-value consumer products, with high capital costs stalling wider spread adoption.	Reduced capital costs will allow greater adoption of the technology for production of complete complex products and associated advanced business models such as customer-led design processes and just-in-time production.
Augmented and virtual reality	Predominantly restricted to gaming and consumer electronic markets, with limited use in the manufacturing sector.	Used to overlay product designs with end-use environments, optimise machine settings in the virtual world, facilitate remote collaboration and train or guide workers through complex/dangerous tasks.

5.1 Sensors and data analytics

Sensors measure or detect properties of the environment they are in and can be configured in many different ways – standalone, integrated or embedded into products or materials, combined with other sensors, wearable or implantable.

BENEFITS OF TECHNOLOGY

Sensors can detect a vast and growing number of different properties including physical attributes of products (temperature, pressure, flow rates), locations and usage patterns.[89] This enables real time monitoring, diagnostics, tracking, control and even automated responses through IoT connectivity.

While sensors will facilitate an explosion in the amount of data captured, these advances are relatively useless if not accompanied by equal or greater improvements in networking infrastructure and data analytics. The latter will allow informed and automated decision making to create efficiencies across value chains and factory floors, as well as improving safety, quality control, traceability and product provenance.

Data analytics can improve the operational efficiency of the entire manufacturing process, enabling activities such as real time productivity monitoring, predictive maintenance and supply chain optimisation. It is estimated that a big data/advanced analytics approach to manufacturing can result in a 20 to 25% increase in production volume and up to 45% reduction in downtime.[90]

MARKET CONSIDERATIONS

Sensors are becoming cheaper, smaller, lighter and less energy hungry. With the continued digitisation of the manufacturing sector and advances in materials development, it is expected that one trillion sensors will be connected to the internet by 2025.[91]

Globally, the market for sensors in the manufacturing sector is estimated at US$8.7 billion in 2016, with rapid growth expected over the following decade as manufacturers invest in factory upgrades.[92] Recognised as an area of opportunity, the 'Prime Minister's Industry 4.0 Taskforce' was established in early 2016 to help drive common standards for the industrial internet and define ways that Australian industrial innovation can be more connected, and be a more competitive participant in the future of global manufacturing.[93]

OPPORTUNITY THEME	ROLE OF SENSORS AND DATA ANALYTICS
Customised high-margin solutions	• Sensors integrated into high-margin products to add to unique selling proposition. • Types and combinations of sensors can be integrated into products based on specific needs of customer.
Sustainable manufacturing	• Energy monitoring and planning systems during production and intralogistics to reduce overall energy consumption • Reduced inputs and wastage through operational efficiencies across value chain
Selling services	• Predictive maintenance, remote monitoring and diagnostics • Data analytics on product usage as a complementary offering to existing products

89 Frost & Sullivan (2016). *Global Sensor Outlook 2016*, Mountain View.
90 McKinsey Digital (2015). *Industry 4.0: How to navigate digitization of the manufacturing sector.* McKinsey&Company.
91 World Economic Forum (2015). *Deep Shift Technology Tipping Points and Societal Impact*, Geneva.
92 Marketsandmarkets (2016). *Industrial IOT Market – Global Forecast to 2020.*
93 Connolly, J. (2016) *Industry 4.0 and Australia's economic transition,* [Online] Available from: https://www.linkedin.com/pulse/industry-40-australias-economic-transition-jeff-connolly Accessed 18/10/2016

FUTURE RESEARCH PRIORITIES: CREATING ADVANTAGE THROUGH RESEARCH

Sensor improvements

- Self-powering sensors through improvements in battery developments such as miniaturisation, increased capacity and density, and the use of sustainable sources of energy where available (e.g. solar).
- Wireless connectivity of in-situ remote sensors through on-board electronics.
- Improved durability and sensitivity to function in high temperature, harsh or remote environments while producing reliably calibrated data.
- Improved depth sensors to enable 3D machine vision.
- Combined and integrated sensors to collect multiple information types and reduce the overall number of sensors needed.
- Intelligent/smart sensors able to process data on board, enabling real-time highly accurate decisions and corrective action.
- Biodegradable and bio-compatible sensors for use in medical technologies, agriculture, and environmental monitoring.

Data analytics

- Improved systems for data storage and management that can handle the rapidly increasing amount of data captured.
- Improvements in quality of data captured and development of decision making algorithms to enable autonomy.
- Improved mechanisms for cyber security and data privacy to ensure data integrity and safety, and more valuable and secure data sharing.

5.2 Advanced materials

Advanced materials are new or modified materials that have been engineered to provide superior performance across one or more desired characteristics, including weight; strength; formability; conductivity and self-healing properties.

BENEFITS OF TECHNOLOGY

Whether fully replacing existing components, or being added as coatings or surface technologies, the use of advanced materials can assist with product differentiation by enabling the creation of customised solutions or by adding additional functionality to existing solutions.

Advanced materials play a significant role in the development and application of most novel science and technology areas, including those discussed in this chapter. The convergence of advanced materials with these technologies can unlock a number of opportunities, including 3D printed biocompatible and biodegradable products; renewable energy storage solutions; and robots that can operate in extreme environments.

MARKET CONSIDERATIONS

R&D for advanced materials is strongly tied to specific industry problems rather than focussing on broader engineering challenges. With much of the science already possible, and near infinite in application, the key role of the research community is to identify which combination of techniques is the best to use for any given problem, develop or improve methods for manufacturing, and guide businesses through the adoption of new materials and processes.

While other technology areas will experience a reduction in unit costs over the next 20 years, the focus for advanced materials is instead on expanding the type and number of attributes that materials can possess without a change in price.

Innovations in materials over the next 20 years will help address some of the key challenges society faces: increasing energy and water use, decreasing health and nutrition, and the need for better environmental stewardship and practices. Key markets for advanced materials include agriculture, infrastructure, electronics, energy, healthcare and mobility.[94]

OPPORTUNITY THEME	ROLE OF ADVANCED MATERIALS
Customised high-margin solutions	• Products that offer tailored solutions (novel characteristics) to specific business needs. • Biocompatible coatings for high-value customised medical implants. • Strong, lightweight materials for use in aerospace, automotive and defence.
Sustainable manufacturing	• Products that use natural resources more efficiently, emit fewer greenhouse gases during production and provide energy efficiencies. • Biodegradable materials to reduce long-term environmental impact of products. • Products with longer lifespans due to increased durability and self-repairing properties.
Selling services	• Nano-materials which gather information about a material's surroundings, reacting once a critical state is reached. • Customer designed materials with ideal characteristics. • Continuous data analytics through biocompatible and durable sensors.

94 World Economic Forum (2016). *Advanced Materials Systems- Chemistry and Advanced Materials,* Geneva.

FUTURE RESEARCH PRIORITIES: CREATING ADVANTAGE THROUGH RESEARCH

Process improvements

- More sophisticated tools for testing and selecting the best material science solutions – computer modelling, high throughput screening, visualisation tools, advanced analytical characterisation and analysis.
- Increased reproducibility through use of flow chemistry techniques.
- Repeatable and scalable production processes and parameters to enable adoption of materials with exceptional physical properties.

Material improvements

- Lightweight, high strength materials to reduce carbon emissions and increase fuel efficiency.
- Novel coatings including: thermal barrier coatings (allowing higher operating temperatures), anti-biofouling coatings (preventing adherence of organisms to a surface), superhydrophobic coatings (repelling water), anti-bacterial, cell-signalling and anticorrosion.
- Biomaterials for medical applications such as implants (bone plates, joints, sutures), devices (pacemakers, blood tubes), and biosensors.
- Computationally designed materials with tailored properties to allow for predictable performance for improved safety and cost.
- Smart self-healing and flexible materials that incorporate sensing functions along with mechanisms for the fast in-situ repair of damaged material, and/or the ability to change shape according to need, whilst displaying appropriate mechanical and physical properties.
- Combination products made of multiple compatible advanced materials.

5.3 Smart robotics and automation

Smart robotics and automation involves the design, construction and operation of robots and the computer systems that control them. Traditional forms of these technologies combine the fields of mechanical engineering, electrical engineering and computer science, however, the next 20 years will see further integration with fields such as material sciences, nanotechnology and energy harvesting and storage.

BENEFITS OF TECHNOLOGY

Industrial robots for manufacturing are used to improve productivity and operational flexibility (allowing businesses to run 24-hour production), costs, safety and efficiency by completing tasks that are complex, high precision, repetitive, dull or hazardous. Smart robots can be used to provide assistance to workers or entirely replace them, allowing workers to move to higher-skilled tasks. Examples include autonomous self-guiding vehicles, lightweight robots, tele-supervised robots and collaborative robots (cobots).[95]

In addition to enabling autonomous robots, automation technologies can be used in manufacturing to provide process control; improved safety, quality and operational efficiencies; and energy and asset management functions. These improvements along the production process can allow Australian manufacturers to become economically competitive with low labour cost countries.

Finally, the adoption of robotic solutions can facilitate the on-shoring of Australian jobs. These solutions can replace tasks that were previously outsourced overseas and often require local support and control.

OPPORTUNITY THEME	ROLE OF ROBOTICS AND AUTOMATION
Customised high-margin solutions	• Greater precision and complexity for high value products. • Higher margins generated through productivity and efficiency improvements.
Sustainable manufacturing	• Process optimisation that reduces wastage and consumption of inputs (water and energy), and increases throughput. • Robots with material sensing, dismantling and sorting capabilities for end of life recycling.
Selling services	• Bundled offerings where robot (product) is packaged with monitoring, control and data analytics services. • Pay-per-use models for access to robotics technologies. • Autonomous service delivery (e.g. household appliances, delivery drones).

95 Frost & Sullivan (2016). *Evolution of Robotics—Growth Opportunities in the Age of Industrie 4.0*, Mountain View.

MARKET CONSIDERATIONS

Robotics is expected to become as ubiquitous over the next decades as computer technology is today.[96] In 2014, it was estimated that 1.5 million industrial robots were operational globally,[97] with automated manufacturing functions constituting approximately 10% of all functions.[98] One of the fastest growing segments is mobile robots – with autonomous self-guiding vehicles expected to grow at an annual rate of 70% by 2020.[99]

The key manufacturing industries globally that utilise robotics are the automotive and electronics industries, with the most popular applications being handling operations and robotic welding. Adoption is expected to spread throughout other manufacturing industries as robotics converges with other technologies such as data analytics, sensors and machine learning.

In addition to replacing lower-skilled jobs, robotics and automation are increasing demand for judgement, creativity and problem solving skills, as well as more skilled roles in the deployment, operation and maintenance of robots. Cobots are expected to see rapid market growth over the short term, creating shared workplaces in which a human's intelligence, flexibility and reasoning is combined with the strength, endurance and precision of a robot to increase productivity and responsiveness.[100]

FUTURE RESEARCH PRIORITIES: CREATING ADVANTAGE THROUGH RESEARCH

Industrial robots

- Advanced materials developments focussing on light weighting, energy harvesting, strength, functionality and structural design of robots.
- Materials development to enable 'soft robotics' which have a greater range of dynamic actions and flexibility, with fewer 'robotic' aesthetics.
- Machine vision and sensor developments/ miniaturisation to allow robots to develop perception and situational awareness to safely interact with their environments and humans.
- Increased energy density and miniaturisation of batteries for autonomous robots and software to optimise the use of on-board power.[101]
- Advanced, more dexterous end-of-arm tooling such as intelligent grippers, servo grippers, vacuum grippers, jamming grippers, sizing software for grippers and other application specific grippers.[102]

Software

- Improve interoperability across different systems and establish enabling standards.
- Improved computational ability with the integration of machine learning algorithms, sensors, machine vision, big data, cloud technologies and the internet of things to allow robots to autonomously repair, self-calibrate and change behaviour based on informed situational decision making.
- Improved machine-to-machine communication enabling robots to communicate with each other.
- Development of algorithms that can operate in more dynamic environments with fluid rule sets to facilitate advances in machine-learning / artificial intelligence and situational awareness.

96 Georgia Institute of Technology et al (2013). *A Roadmap for U.S. Robotics – From Internet to Robotics, 2013 Edition.*
97 International Federation of Robotics (2015) *World Robotics 2015 Industrial Robots*, [Online] Available from: http://www.ifr.org/industrial-robots/statistics/ Accessed 18/10/2016
98 Frost & Sullivan (2016). *Evolution of Robotics—Growth Opportunities in the Age of Industrie 4.0*, Mountain View.
99 Frost & Sullivan (2016). *Evolution of Robotics—Growth Opportunities in the Age of Industrie 4.0*, Mountain View.
100 Brea, E. et al (2013). *Lightweight Assistive Manufacturing Solutions: Improving Australia's Manufacturing Competitiveness,* CSIRO, Australia.
101 Frost & Sullivan (2016). *Power Technologies for Drones and Autonomous Robots (TechVision),* Mountain View.
102 Frost & Sullivan (2016). *Evolution of Robotics—Growth Opportunities in the Age of Industrie 4.0*, Mountain View.

5.4 Additive manufacturing (3D printing)

Additive manufacturing (or 3D printing) is a computer-driven process of manufacturing three dimensional products from a digital model by laying down successive layers of a material.

BENEFITS OF TECHNOLOGY

This process allows a reduction in lead times and product development cycle times, reduced waste, and unlocks a myriad of customisation and product differentiation opportunities. Additive manufacturing enables the production of complex, high precision and intricate shapes, providing flexibility in design and customisation. This creates the potential for a range of new products that are not possible with traditional manufacturing techniques, with applications across almost all end user sectors. While the initial capital outlay for additive manufacturing machines and input materials can be considerable, these costs are likely to reduce in the next few years and it is estimated that employing these technologies can result in up to 70% cost savings on prototyping by reducing the requirements for tooling.[103,104]

MARKET CONSIDERATIONS

It is estimated that in 2015 there were between 100 and 150 polymer-based industrial systems and approximately six installed metal-based industrial systems installed in Australia.[105] While additive manufacturing of plastics is cheaper and more widely adopted in industry globally, these low barriers to entry have created significant competition and low margins. There is no clear rationale for Australia to be competing in plastics, however the nation's abundant mineral resources and advanced engineering capabilities form a competitive advantage for the development of metal-based additive manufacturing technologies.

Australia is one of few countries with the potential for domestic capabilities in all stages of the metals additive manufacturing value chain, including: ore extraction, metal manufacture, powder manipulation, consolidation, product design and testing, and production. Australia would face competition from low cost countries for the final production stage, however may be able to retain this value-adding stage on-shore if it were tightly integrated with the preceding steps.

OPPORTUNITY THEME	ROLE OF ADDITIVE MANUFACTURING
Customised high-margin solutions	• Truly customised product attributes (shape, size, strength, texture, tolerance) to match customer requirements. • Prototyping and product development / refinement (small batch production runs) of customised and high margin products. • Rapid prototyping that increases flexibility and tailored product improvement.
Sustainable manufacturing	• Reduced waste and lower material-intensity compared to subtractive manufacturing techniques. • Reduced energy and input usage as no requirement for tooling processes. • Reduced transport and storage requirements through just-in-time production.
Selling services	• Bundling of services such as customisation, design, prototyping, short-run production and just-in-time manufacturing. • Design process integrated with, or performed by, customer. • Increased focus on solutions rather than products.

103 Frost & Sullivan (2016). *Strategic Analysis of the Additive Manufacturing Market in Australia*, Mountain View.
104 Frost & Sullivan (2016). *Emergence of 3D Printing Materials,* Mountain View.
105 Frost & Sullivan (2016). *Strategic Analysis of the Additive Manufacturing Market in Australia*, Mountain View.

Along with new products, additive manufacturing will facilitate the emergence of new business models, a highly skilled and adaptable workforce and increased multidisciplinary collaboration. Hyperlocal manufacturing with printers located near customers is expected to disrupt current manufacturing hubs,[106] and excellence will require greater levels of collaboration across a diverse range of skills – design and creative thinking, software (e.g. CAD), engineering and materials science – in all of which Australia has strengths.

As the price of additive manufacturing decreases over time, it is expected that technology improvements will enable larger product runs, growing from runs of one to ten, to hundreds then thousands, taking market share from casting processes and expanding applications beyond the current manufacturing industries within aerospace, automotive and medical technologies.

FUTURE RESEARCH PRIORITIES: CREATING ADVANTAGE THROUGH RESEARCH

Process improvements

- Improved quality assurance processes to ensure predictable quality, consistency and performance of printed products.
- Improved monitoring, sensing and feedback control to reduce metal movement during layering.
- More sophisticated, specialised modelling packages and skills to produce better designs suited to additive manufacturing techniques (rather than adaptations from subtractive manufacturing).
- Increased speed of production and scalability to enable efficient manufacture of large scale industrial products and components.
- Machine advances to enable printing of integrated dissimilar materials.
- Nanoprinting to enable creation of new advanced materials (e.g. Graphene).

Feedstock improvements

- Advanced materials to enable additive manufacturing of parts that exhibit properties that are competitive with conventionally made parts (particularly for strength).
- Feedstocks with greater tensile strength, durability, flexibility, heat resistance, conductivity and ease of processing.
- Tailored alloys designed specifically for additive manufacturing processes.
- Better and cheaper powdered feedstocks from improved milling techniques and reduced energy requirements.
- Drawing on Australia's mineral processing IP to develop high quality metallic additive manufacturing feedstock.
- Biocompatible and biodegradable materials for use in 3D printed implants.
- Advanced feedstocks for printing of finished goods.

106 Frost & Sullivan (2016). *Strategic Analysis of the Additive Manufacturing Market in Australia*, Mountain View.

5.5 Augmented and virtual reality

Augmented Reality (AR) is the engagement of a user with superimposed computer-generated content over a live view of the physical world, while Virtual Reality (VR) is an artificial, computer generated interactive environment.[107, 108]

BENEFITS OF TECHNOLOGY

Augmented Reality (AR), and to a lesser extent Virtual Reality (VR), are emerging as exciting technologies in the manufacturing sector, with the potential to drive productivity, quality and safety improvements on the factory floor, and increase customer engagement and service provision during product design.

AR can be used to overlay product designs with their end-use environments, guide workers through complex or dangerous processes through field-of-view instructions, and facilitate remote collaboration or control of remotely controlled machinery. The technology provides increased situational awareness, informed decision making, cost and process optimisation and improved safety outcomes.[109]

As VR restricts 100% of a person's 'real world' vision, it is limited in application on the factory floor due to safety issues, however can be used for training simulations and data visualisation applications in the product design phase.

MARKET CONSIDERATIONS

Gaming and consumer electronic markets are the key drivers of developments and research priorities for AR and VR and are continuing to push costs downward. The global market for AR is expected to substantially increase over the next five years, estimated to reach nearly US$120 billion by 2020, with a faster growing set of applications than VR.[110]

While the use of these technologies in the manufacturing sector is currently minimal, it is expected that uptake will reach a critical mass over the medium term (3 – 10 years), with the development of breakthrough systems and content. This is likely to impact the design of both products and factories, with visual markers built-in to allow AR maintenance further down the track.

OPPORTUNITY THEME	ROLE OF AUGMENTED AND VIRTUAL REALITY
Customised high-margin solutions	• Provides end-user interface for design of customised solutions. • AR convergence with additive manufacturing will enable manufacturers to preview digital designs prior to printing and also visualise and monitor during the printing process.
Sustainable manufacturing	• Improved productivity and worker safety through AR guided processes and VR training simulations.
Selling services	• Facilitates immersive customised design and engagement experiences. • Simulations that provide validation of designs and operations prior to implementation or purchase. • Product troubleshooting / post-sale services. • Physical and psychological therapy performed through virtual reality.

107 Frost & Sullivan (2016). *5 Key Augmented Reality Trends: Industrial Manufacturing,* Mountain View.
108 Frost & Sullivan (2016). *Augmented and Virtual Reality Applications in Healthcare,* Mountain View.
109 Frost & Sullivan (2016). *5 Key Augmented Reality Trends: Industrial Manufacturing,* Mountain View.
110 Jude, M. (2016). *Tapping Opportunities in Augmented Reality,* Stratecast, Volume 16, Number #31, Frost & Sullivan, Mountain View.

FUTURE RESEARCH PRIORITIES: CREATING ADVANTAGE THROUGH RESEARCH

Devices

- Improved properties for wireless operation such as:
  - Decreased size and weight of headset / on-board tracking systems;
  - Improved battery life through increased energy density and miniaturisation; and
  - Increased pixel transfer and decreased latency.
- Improved processing power and download size to allow more complex visualisations for longer time periods.
- Improved development and integration of camera devices, such as panoramic and light field cameras to improve display.
- Improved resolution and frame-rates of display fields for phone-based AR and head-mounted equipment.
- Advanced sensors for AR such as depth sensors for 3D impact and Natural User Interface (NUI) sensors, enabling humans to interact with computers in more natural ways through sensory tracking, speech, touch, vision, gestures etc.[111]

User experiences

- Improved solutions for haptics (integration of touch) and audio integration, such as replacing standard keyboard and mouse with voice and gesture commands.
- Alignment of different spatial orientations in the same reality to allow educators and pupils to perform joint-training/tasks in the same VR space.
- Address social licence to operate issues that are imperative to deployment and adoption of AR into industrial use, such as concerns over ethics and privacy with the proliferation of cameras and increase in data.

111 Frost & Sullivan (2016). *Global Sensor Outlook 2016*, Mountain View.

Enabling business changes

6 Enabling business changes

In order to fully realise the strategic growth opportunities and their enabling science and technology areas, Australian manufacturers must proactively transform the way they run their businesses, investing in new knowledge and practices.

Positioning for sustainable growth will require business changes both internally (new skillsets, cultures and operating systems) and externally (participation in global value chains and collaboration models).

Many of the challenges and enablers discussed in this chapter have been known for some time but have been difficult to get right. There is no single or fast acting solution to tackling these challenges. The recommended actions in this section seek to generate incremental progress towards the vision for Australia's manufacturing sector. Actions have been separated into 'business actions' (those which manufacturers should proactively lead) and 'ecosystem actions' (those to be led by industry bodies, suppliers, research, education, investors and governments, in consultation with businesses).

6.1 Global value chains

With a relatively small domestic market and increasingly globalised manufacturing value chains, Australian manufacturers need to shift their thinking from local to global customers and competitors when strategic planning. Participation in global value chains (GVCs) has been linked with increased innovation; R&D and skills development; collaboration; sophisticated management, financing and technology systems; and productivity premiums.[112] Global interactions also provide businesses with critical exposure to new technologies, processes and skills.

Despite these benefits, Australian manufacturing is typically not well linked into GVCs, ranking below the OECD median in the OECD's global value chain participation index.[113] The vast majority of advanced economies saw an increase in the share of imported content in their exports from 1995 to 2011 (backward linkages), indicating a stronger integration into global value chains, while Australia remained relatively constant.[114,115]

Australian manufacturing is typically not well linked into GVCs, ranking below the OECD median in the OECD's global value chain participation index.

112 Hendrickson, L., et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.
113 Hendrickson, L., et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.
114 OECD (2015). *Australian Manufacturing in the Global Economy*, Study for the Australian Government, Department of Industry, Innovation, Science, Research and Tertiary Education.
115 OECD (2015), *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society,* OECD Publishing, Paris.

The nation performs more strongly when it comes to forward linkages – the export of domestically produced goods and services – specifically parts and componentry rather than goods that are produced wholly within Australia. Specific industries where the nation has an advantage in parts and componentry production include aircraft parts, parts of earth moving and mineral processing machines, and specialised automotive parts.[116]

Currently, Australia's strongest participation in global value chains (above world median) is in the manufacturing of food and basic metals,[117] which draw on Australia's historical strengths in agriculture and mining. Without the strong global reputation for quality that these sectors have built, it will be critical for emerging industries and businesses to build trust with global partners. Attracting multinational companies to operate in Australia is an important enabler for these businesses, both as a signalling factor to other international companies and to facilitate the development of cluster-related activities and specialised support services.[118]

Trust is built through providing quality and on-time products and services. For businesses still attempting to enter GVCs, this reliability can be demonstrated by approaching potential partners in person, listening to their needs, revising product prototypes accordingly and quickly presenting more tailored solutions.

Businesses can also enter GVCs by offering free product trials. If the customer is satisfied with the solution they can be invoiced, and if not, no payment is required. Even if a sale or longer term contract does not eventuate, the business will still gain valuable experience in a GVC which can help further refine their offering.

Finally, digital interoperability with global partners is crucial. This will require joint efforts across research, government and business. Many European countries already have national strategies for unlocking digital connectivity based opportunities - Industrie 4.0 in Germany, the Factory of the Future in France and Italy, Smart industry in Sweden, and Catapult centres in the UK.[119,120] In March 2016, Germany and the US-based Industrial Internet Consortium, announced they would work together to set the global course for digitalisation standards.[121] Linking Australian industry with these efforts will not only open up opportunities in these large international markets but will also address Australia's own domestic interoperability challenges. The Prime Minister's Industry 4.0 Taskforce has been established to ensure Australian connectivity to global standards in this area.

116 Office of the Chief Economist (2016). *Global production sharing and Australian manufacturing 2016*. Department of Industry, Innovation and Science.
117 Hendrickson, L., et al (2014). *Australian Innovation System Report 2014,* Department of Industry, Commonwealth of Australia, Canberra.
118 Office of the Chief Economist (2016). *Global production sharing and Australian manufacturing 2016*. Department of Industry, Innovation and Science.
119 Davies, R. (2015). *Briefing - Industry 4.0 – Digitalisation for productivity and growth,* European Parliament Research Service.
120 Government Offices of Sweden (2016). *Smart industry – a strategy for new industrialisation for Sweden,* Stockholm.
121 Connolly, Jeff (2016). *Prime Minister's Industry 4.0 Taskforce,* [Online] Available from: https://www.linkedin.com/pulse/prime-ministers-industry-40-taskforce-jeff-connolly Accessed 18/10/2016

BUSINESS ACTIONS

- Develop strategies for marketing, acquiring and selling products to GVCs from the product creation stage.
- Develop services (e.g. business management software for use across value chains or product-specific services) that can be used as a differentiator to gain access into GVCs before expanding into other offerings.
- Promote capabilities to global markets by participating in industry-specific international forums, events and trade missions.
- Align digital systems with world-leading best practice to improve interoperability with global partners.
- Connect with businesses who have successfully entered GVCs – either other manufacturing businesses or businesses from globally integrated sectors such as agriculture and mining – to leverage the lessons learnt from their experiences integrating into GVCs.
- Implement novel sales approaches such as free trials and reciprocal arrangements.
- Increase licensing of technologies to/from global players.

ECOSYSTEM ACTIONS

- Address interoperability barriers by implementing more appropriate and sophisticated industry data standards.
- Work with businesses to ensure suitable standards are in place for privacy of data, including appropriate handling, ownership and storage.
- Identify and implement effective and streamlined standardised regulation and compliance protocols both within and between jurisdictions.
- Conduct social research studies to help businesses better understand and address social licence to operate issues for the adoption of enabling technologies in different global markets e.g. data privacy concerns for sensors and analytics; safety of synthetic advanced materials; or job losses associated with smart robotics and automation.
- Examine policy settings to attract more global multinational corporations to operate in Australia, particularly where it provides emerging businesses the opportunity to work in global value chains by servicing local demand and overall benefit to the nation.
- Develop robust cybersecurity solutions for manufacturers that act in anticipation to prevent unauthorised and malicious access to digital infrastructure (robotics, automation, sensors, analytics, augmented reality, cloud technologies and personal devices).
- Develop GVC maps that help businesses identify global partners.

6.2 Skills, training and the workforce

SKILLS AND TRAINING

Australian manufacturing boasts a talent pool of engineers, technicians and designers that are supported by world-class research capabilities. These strengths will remain relevant over the next 20 years as Australian business models shift focus towards the start (design, prototyping) and end (logistics, after-sale services) of manufacturing value chains.

Autonomous machines and additive manufacturing are reducing the labour intensity of manufacturing, significantly lowering the number of low-skilled roles. As this trend continues, capabilities that are more difficult to automate such as the deeply human characteristics of ethics, creativity and intuition will be more important and highly valued. In manufacturing, these attributes will be required by high-skilled knowledge based experts and decision-makers in performing system planning, engineering, exception handling, commercial activities, coordination and orchestration.[122]

Australian manufacturers need to further target the development or acquisition of skills in the following areas:

- **Digital literacy** – Many Australian manufacturers still use paper-based systems or spreadsheets to track customer information.[123] To remain competitive and integrate within more complex global value chains, advanced manufacturers require more sophisticated ICT systems and digital infrastructure such as installed fibre optics. In order to realise the benefits of these platforms, data science and digital skills will be essential across the value chain, spanning the use of design related software during the R&D phase of product development to data analytics and interpretation skills post-sale.

  Digital literacy needs to go beyond strong computer, coding, mechatronics and data management skills to include expertise in smart data systems, communications and data interpretation.[124]

- **Leadership and strategic management** – With a large number of family-owned and run manufacturing businesses, many Australian businesses are led by individuals or teams without significant external experience or more sophisticated approaches to business planning and staff management. Visionaries and entrepreneurs are needed within leadership teams of Australian manufacturing businesses to address the risk averse culture; embracing fast failure and the lessons that come from it.

  These leaders need to be supported by strategically minded managers who can help businesses transition to new business models; improve productivity and innovation; and invest more time into long term planning. It is also important for these managers to be mobile – getting out of the businesses to see first-hand the way that other businesses and research institutes are approaching solutions.

- **Customer interface** – As the line between manufacturing and services continues to blur, advanced manufacturers are forming direct relationships with end-user customers. The integration of marketing and product design will require a higher proportion of softer skills to liaise with customers, identify needs and earn trust by responding to the feedback acquired through revised products and services. Customer engagement staff will also require more front end user experience knowledge to act as a conduit between consumers and design.

  These interpersonal skills will also be critical in enabling stronger levels of business-to-business and business-to-research collaboration. Relationship building is essential to identifying appropriate collaboration partners and should be paired with strong IP and commercialisation expertise to ensure fair agreements are made across global value chains.

122 World Economic Forum (2015). *Industrial Internet of Things: Unleashing the Potential of Connected Products and Services,* Geneva.

123 Salesforce research (2016). *2016 Connected manufacturing service report – insights into manufacturing service.*

124 CSIRO Website (2014). *Australia examines its strengths and sees its future in manufacturing,* [Online] Available from: http://www.csiro.au/en/News/News-releases/2014/Australia-examines-its-strengths-and-sees-its-future-in-iManufacturing Accessed 18/10/2016

- **STEM** – STEM skills are fundamental for advanced manufacturing, especially in product design and development. It is estimated that 75% of emerging jobs will require STEM skills and by shifting just 1% of Australia's workforce into STEM roles, GDP could increase by over $57 billion.[125] Research has shown that students who study STEM are more creative, flexible and able to take advantage of the changes that are predicted in the workforce and workplaces of the future.[126]

  Australian manufacturers often lack clarity around how to best utilise STEM capabilities, with design, modelling and prototyping being under-represented in their business operations - reducing the potential demand for STEM skills.

  On the supply side, Australia ranks well below the OECD average when it comes to the number of STEM graduates as a proportion of total graduates.[127,128] Supply is further stifled by manufacturing's outdated reputation of being centred upon dull assembly lines. Only half of bachelor degree science graduates (including mathematics) seeking full-time work had found it four months after completing their degree (17% below the average for all graduates).[129] This figure is significantly improved for engineering graduates (around 75%) but still below what is expected of an advanced manufacturing ecosystem. Stronger linkages need to be developed between graduates and manufacturers to prevent demand for STEM capabilities outweighing supply and forcing Australian businesses to look offshore for these skills.

These skills will need to be applied to continually converging and diverging industries. Many jobs will require workers to have a broader interdisciplinary skillset, combining deep scientific expertise, software and data skills with softer skills in leadership, creative problem solving, communication and collaboration.[130]

There is also a risk that Australia loses critical skills through the closure of industries (e.g. the automotive production industry). While many of these workers possess skills that can be transferred to higher value-adding tasks in related industries, closures can also mean a loss of critical mass in demand for certain capabilities, resulting in downstream impacts on other sectors. For example, the diminished local demand for OEM expertise is causing medical technology businesses to source these skills offshore – reducing the transfer of tacit knowledge and incremental innovation associated with local collaboration.

Australia can retain at-risk skillsets by investing in emerging markets that demand similar capabilities. For example, the carbon fibre industry could leverage Australia's existing knowledge of car manufacturing processes and automation to boost the production of carbon fibre composite automotive parts.

WORKFORCE

Despite Australia having a strong education system that produces quality graduates – particularly in STEM fields – around 45% of the manufacturing workforce do not hold any post-school qualifications, compared to 39% for all industries.[131] This discrepancy will need to be addressed as demand for more skilled labour increases.

Businesses also need to place greater importance on diversity to ensure an adaptive and innovative workforce. Businesses with gender-diverse management teams outperform peers' earnings before interest, taxes, depreciation and amortisation (EBITDA) by 15% and businesses with ethnically diverse management teams outperform peers' EBITDA by 35%.[132]

125 PwC (2015). *A Smart Move - Future-proofing Australia's workforce by growing skills in science, technology, engineering and maths (STEM),* PwC Australia.
126 Mulcahy, M. (2016). *What is STEM and why is it important?* CSIRO Blog, 8 September 2016 Available from: https://blog.csiro.au/what-is-stem-and-why-is-it-important/ Accessed 7/11/2016
127 Source uses 'natural sciences and engineering' fields of education which correspond to ISCED-97 fields 4 (Science, comprising the life sciences, physical sciences, mathematics and statistics and computing) and 5 (Engineering, manufacturing and construction).
128 OECD (2015). *OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society,* OECD Publishing, Paris.
129 Norton, A., & Cakitaki, B. (2016). *Mapping Australian higher education 2016*, Grattan Institute.
130 World Economic Forum (2015). *Industrial Internet of Things: Unleashing the Potential of Connected Products and Services,* Geneva.
131 Australian Workforce and Productivity Agency (2014). *Manufacturing Workforce Study: Skills to grow competitive, high-end manufacturing,* Factsheet, Australian Government.
132 Mackey, C. (2016). *Manufacturing Megatrends,* Manufacturers Alliance for Productivity and Innovation (MAPI), Arlington.

Despite the benefits of diversity being widely accepted, Australian manufacturing has proved slow in transitioning away from a male dominated workforce. Males make up around 73% of the manufacturing workforce, compared with around 54% for all industries.[133] Anecdotally, Australian businesses fare better when it comes to ethnic diversity.

Business sentiments frequently refer to an over-representation of older workers in the workforce, which were argued to be contributing to the persisting risk/change-averse culture and limiting the supply of newer ways of thinking. However the data does not strongly support this, with the median age in the manufacturing sector being only two years older than the average.[134] With younger professionals and graduates being more attracted to pre- and post-production activities such as design, this minor age difference could be evened out by an increased focus on these activities in the future.

BUSINESS ACTIONS

- Focus workforce skills development on digital literacy, leadership and strategic management, customer interface and STEM skills. For example, enhance capabilities in digital platforms for interacting with customers for either design or marketing.
- Establish graduate programs with clearer career pathways for the attraction and retention of graduates, particularly in STEM fields.
- Implement more structured training programs (both course-based and on-the-job) for staff development and upskilling.
- Develop opportunities for secondary and tertiary education students to tour advanced manufacturing workspaces to better promote the sector as an exciting career path and help debunk existing reputational issues.
- Increase diversity within the workforce (for example through internal quotas) with a focus on increasing the proportion of younger personnel and a greater representation of female employees – particularly in management and leadership teams.

ECOSYSTEM ACTIONS

- More closely integrate theory and industry application in tertiary education courses, including developing additional industry placement opportunities for tertiary students.
- Promote manufacturing as the destination for new creative, high-skilled and interdisciplinary jobs to negate public perception issues and attract skilled labour.
- Provide training to researchers to enhance their skills in pitching/presenting their work to a business audience in order to enhance collaboration and uptake of new technology.
- Develop tailored training courses for the re-skilling of employees who are transitioning out of closing manufacturing industries but have a wealth of knowledge and experience that can be leveraged in growing or emerging industries.

133 Australian Workforce and Productivity Agency (2014). *Manufacturing Workforce Study: Skills to grow competitive, high-end manufacturing,* Factsheet, Australian Government.

134 Australian Workforce and Productivity Agency (2014). *Manufacturing Workforce Study: Skills to grow competitive, high-end manufacturing,* Factsheet, Australian Government.

6.3 Collaboration and culture

Australian manufacturing will need to undergo substantial cultural change in order to realise sustainable growth. Analysis by the Australian Office of the Chief Economist shows that only 16% of Australian businesses have a high performance innovation culture, where innovation is part of the strategy and businesses are outward orientated.[135] To improve manufacturing culture, there is a need to enhance the speed at which businesses are moving away from traditional siloed, protectionist and risk-averse attitudes and towards open, creative and networked interaction. Obtaining the benefits associated with advances in technology and innovation can only be obtained if businesses are prepared to be less conservative and embrace change.

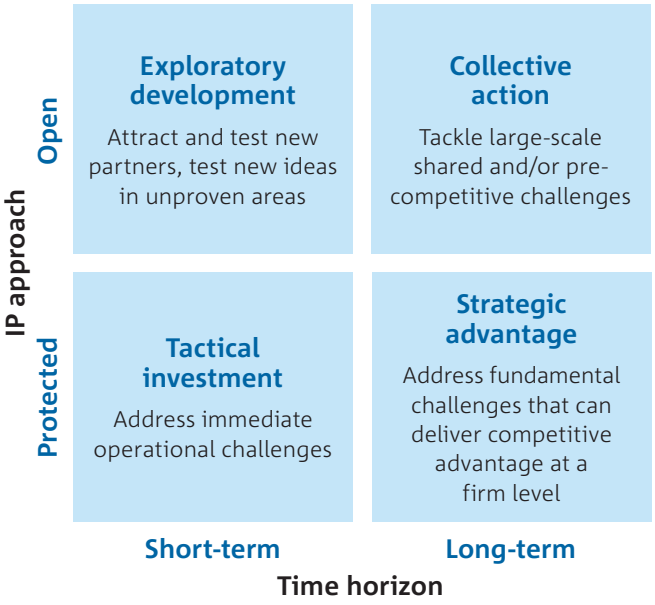
> Only 16% of Australian businesses have a high performance innovation culture.

Collaboration across the value chain and with research organisations and government will be more important than ever before. Most businesses cannot access all the information required to be competitive, so the depth and quality of a company's networks and interactions is critical to its competitiveness.[136] Further, improved collaboration is required to unlock opportunities around industrial ecology.

At present, many collaboration models are overly formal and deter businesses through complex high-cost arrangements. Further, more effort needs to be placed on promoting successful collaboration arrangements and helping manufacturers identify collaboration models that best fit their needs. 'Time to outcome' and 'IP ownership' are two variables that are useful to consider when planning collaboration (see Figure 5).

Similar to having a portfolio of innovation projects, collaboration efforts can also be evaluated as a portfolio using the framework. This allows innovation projects/programs to be regularly reviewed to determine the most appropriate collaboration model(s) and identify opportunities to move a project between different modes depending on objectives and progress.[137]

FIGURE 5 – COLLABORATION FRAMEWORK[138]



BUSINESS-TO-BUSINESS COLLABORATION

In the long-term, sophisticated manufacturing industries will operate within local and global networks that share data, resources and processes. This will unlock significant opportunities for those involved by being able to identify innovative solutions faster through pooled knowledge and experience. A business's absorptive capacity – its ability to identify, assimilate and apply external knowledge for commercial benefit – plays a critical role in collaborative innovation, inter-organisational relationships and comparative advantage.[139]

Australia's strong fear of competition – particularly from local competitors – needs to be overcome in order to successfully operate in future global markets. In the short-term, focussing on pre-competitive business-to-business collaboration would help demonstrate the benefits of collaboration while keeping IP risks minimal. This could be as simple as aggregated purchasing for inputs across businesses to achieve purchasing power and small unit costs.

135 Lalor, A. et al (2015). *Australian Innovation System Report 2015,* Department of Industry, Commonwealth of Australia, Canberra.
136 Withers, G. et al (2015). *Australia's Comparative Advantage*, report for the Australian Council of Learned Academies. Melbourne.
137 CSIRO Futures (2015). *Unlocking Australia's resource potential – Innovation in the energy and mineral resources sector*, CSIRO, Canberra.
138 Adapted from: Perkmann, M. and Salter, A. (2012). *How to Create Productive Partnerships with Universities,* Sloan Management Review. 2012;53(4).
139 Lane, P. and Lubatkin, M. (1998). *Relative absorptive capacity and interorganizational learning,* Strat. Mgmt. J., 19: 461–477.

Case study

Competitor collaboration[140]

Lack of connectivity not only restricts underground communications, but also the ability to communicate vital information between the surface and mines. The current standard practice is to have access points along the mine wall to boost the Wi-Fi signal and to lay fibre optic cabling. Both of these practices are prone to failure due to the Wi-Fi signal being lost or weak, and fibre optic cabling can easily be cut during mining operations.

Nautitech and Northern Light Technologies (NLT) were brought together by a mining company to solve this problem and developed a breakthrough system for underground communication. The solution combines Nautitech's high-bandwidth power line modem with NLT's Wi-Fi communication system that withstands harsh mining environments to create Wi-Fi hotspots around continuous miners and other equipment.

By using portable equipment without wires, vital coverage is provided in areas where it is needed most and allows contractor monitoring, increased worker safety, fleet optimisation, machine performance monitoring, autonomous mining and productivity improvements.

The businesses developed, allocated and agreed well defined and independent engineering task lists and met for several information sharing meetings. As neither business's product could solve the issue independently, they agreed on the price of their other's kit and cross-promoted the products. The prevented issues of IP ownership and opened up additional marketing avenues.

Another enabling collaboration model is the joint-investment in shared capital to minimise the costs of depreciation as systems and equipment are being replaced at a higher rate than ever before.

In the long-term, as customers demand more tailored and rapidly delivered solutions, the co-location of value chains could provide an advantage in just-in-time manufacturing and provide greater opportunities for knowledge sharing.

COLLABORATION WITH THE RESEARCH COMMUNITY

Australia ranks the lowest across OECD countries in terms of collaboration between industry and research.[141] Only a small proportion of Australian manufacturers have a strong awareness and understanding of the breadth of capabilities that lie within the research community. Even fewer have structures in place to take advantage of these world-class problem solving skills and instead rely on limited in-house R&D functions.

At the same time, a more customer focused research community would help to ensure that research projects are aligned to addressing industry's greatest needs and target activities that can be commercialised. Even basic/fundamental research, while having a reduced focus on commercial outcomes, can assist businesses by showcasing projects and allowing businesses to identify the commercial possibilities that the research may unlock.

Collaborative hubs or clusters of aligned capabilities encourage organic knowledge sharing and reduces the costs of collaboration. Bringing multiple businesses and research teams together geographically allows each party to see and hear first-hand the problems and solutions being worked on. Researchers can offer novel solutions to the business problems they observe and businesses can identify markets for the technology being developed by researchers. Clustering is also attractive to multinational businesses as it presents a single site for collaboration. This is already happening in some industries, such as South Australia's aerospace cluster that brings together the Defence Teaming Centre, the Department of State Development and the local defence industry to help connect SMEs with global defence companies.

140 Nautitech (2015). *The communications breakthrough boosting safety and productivity in underground coal mining.*
141 Ferris, B. et al (2016). *Review of the R&D Tax Incentive,* Department of Industry, Innovation and Science, Canberra.

These clusters facilitate the flow of personnel between business and research in both directions. Secondments allow individuals to be fully integrated into the day-to-day operations of their potential collaboration partners. This fosters the identification, discussion and solving of problems in real time through pooled knowledge and experience.

While businesses and research institutes should proactively engage in collaboration for these mutual benefits, government has a role to play in supporting these activities. This report does not seek to discuss regulatory or policy environment requirements, noting that the need for more targeted (sector-specific) R&D incentives, reducing the compliance costs of initiatives relative to benefits and improved clarity around the scope of eligible activities are covered in other reports.[142,143]

BUSINESS ACTIONS

- Increase the application of joint-investment models for combining the funds of SMEs to invest in R&D projects. For example, pooling funds to pay a larger manufacturer with access to R&D, with all parties sharing the economic outcomes and IP.
- Increase the level of co-investment with research organisations to better align incentives. For example, retain generated IP from jointly-funded projects but license the solution to the research partner to sell to non-competing businesses.
- Increase expenditure on R&D to drive the continual development of world-leading innovative products and solutions.
- Invest in cloud computing and collaborative software to allow greater connection to GVCs and enable improved business-to-business and business-to-customer collaboration, allowing manufacturers to adapt almost instantly to changes in demand.
- Establish additional business placement opportunities for researchers, making these secondments part of the core training and development offering of both parties.
- Establish more formal and structured collaboration models to reduce dependency on more transient informal relationships/personnel.

ECOSYSTEM ACTIONS

- Provide SMEs and start-ups with demonstrations of, and open access to, cutting edge advanced manufacturing research, tools and technologies to see firsthand what is possible and to use in early stage design and development.
- Identify synergies across research organisations to avoid unnecessary duplication of projects and equipment, improving clarity for businesses around where capability lies.
- Encourage the development of consortia bidding through government procurement strategies.
- Improve education on the various forms of business-to-business collaboration.
- Support the co-location of businesses, research institutes and education providers.

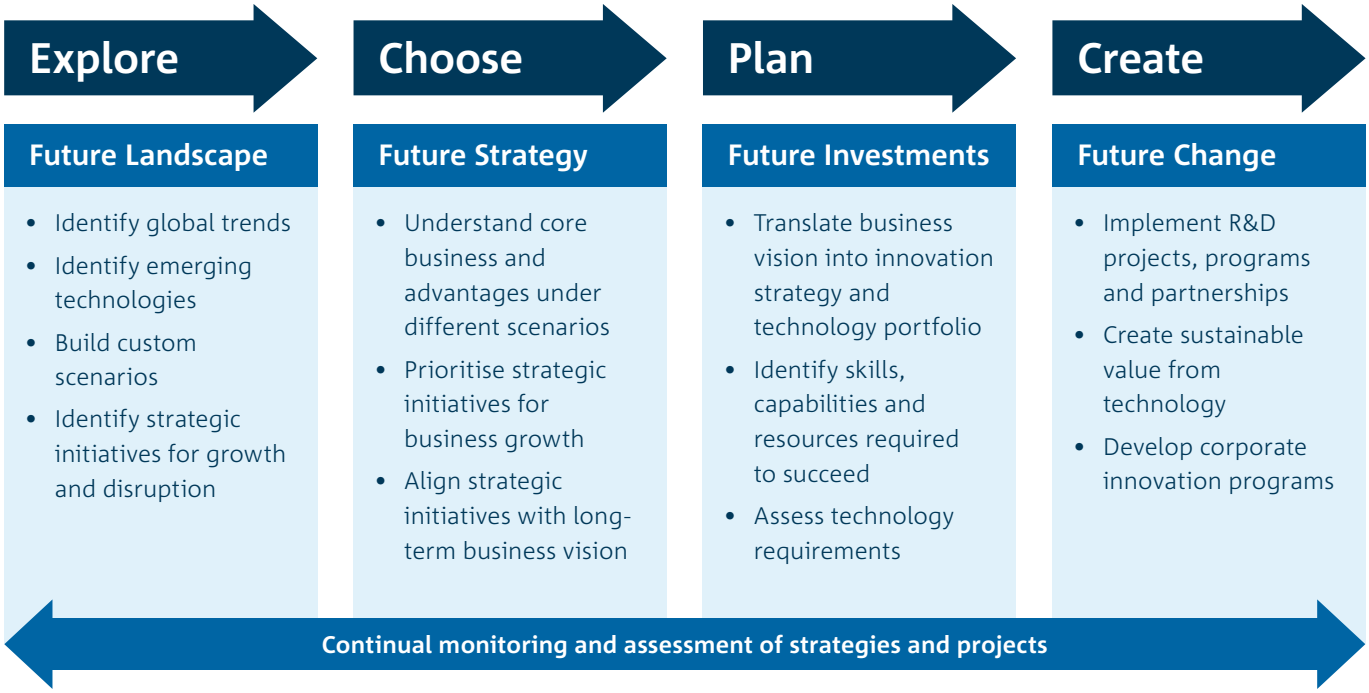
142 Ferris, B. et al (2016). *Review of the R&D Tax Incentive,* Department of Industry, Innovation and Science, Canberra.
143 Advanced Manufacturing Growth Centre (2016). *AMGC Sector Competitiveness Plan.*

6.4 Strategic planning

Each of the enabling business changes discussed need to be key components of individual business strategies. Navigating long-term change requires manufacturers to constantly assess the way they run their businesses – ensuring that scarce resources (labour, capital) are appropriately allocated, that business decisions are underpinned with strong underlying market and technology assumptions and that innovation is proactively applied.

The narrative presented in this report can be continuously applied at a company level to inform strategic decision making. Global manufacturing megatrends, opportunities for growth, and enabling science, technology and business changes can be tailored for individual businesses using the Explore, Choose and Plan steps of the framework depicted in Figure 6. Scenario planning and input for the Create step have been excluded from this report as application is highly company specific, however additional information can be found in CSIRO's *Australia 2030* report.

FIGURE 6 – CSIRO FUTURES STRATEGIC PLANNING FRAMEWORK



Conclusion

7 Conclusion

7.1 Enabling actions

The following table summarises the key themes from the enabling business changes chapter. Actions have been separated into business actions (those which manufacturers should proactively lead) and ecosystem actions (those to be led by industry bodies, suppliers, research, education, investors and governments, in consultation with businesses).

TABLE 9 – ENABLING ACTIONS SUMMARY

Global value chains (GVCs)	Skills, training and the workforce	Collaboration and culture
BUSINESS ACTIONS		
• **Promote capabilities internationally** through increased licensing, novel sales approaches and targeting GVCs from product creation stage. • **Align digital systems** with world-leading best practice to improve interoperability with global partners. • **Increase knowledge sharing** with experienced Australian GVC operators.	• **Develop digital literacy, leadership and strategic management, customer interface** and **STEM skills.** • **Develop programs** to improve skills recruitment and development e.g. graduate programs, structured training courses and site tours. • **Increase diversity** in the workplace – specifically a greater representation of young and female employees.	• **Increase use of joint-investment models** e.g. pooling of SME funds and co-investment with research organisations. • **Invest in cloud computing and collaborative software** to allow greater value chain communication and rapid adaptation to changes in demand. • **Develop business placement opportunities for researchers** to enhance knowledge sharing.
ECOSYSTEM ACTIONS		
• Address interoperability barriers by implementing **more appropriate and sophisticated industry data standards**, in consultation with companies. • Identify and implement **effective and streamlined standardised regulation and compliance protocols** both within and between jurisdictions. • Conduct social research studies to better **understand and address social licence to operate issues** for the adoption of enabling technologies in different global markets.	• More closely **integrate theory and industry application in tertiary education courses**, including developing additional industry placement opportunities for tertiary students. • **Promote manufacturing** as the destination for new creative, high-skilled and interdisciplinary jobs to address public perception issues and attract skilled labour. • **Develop tailored training courses** for the re-skilling of transitioning employees and for researchers to enhance pitching/ presentation skills.	• **Improve business access to advanced manufacturing research facilities** for education and early product development. • **Encourage the development of consortia bidding** through government procurement strategies. • **Support planned co-locations** of business, research and/or education.

7.2 Implementation considerations

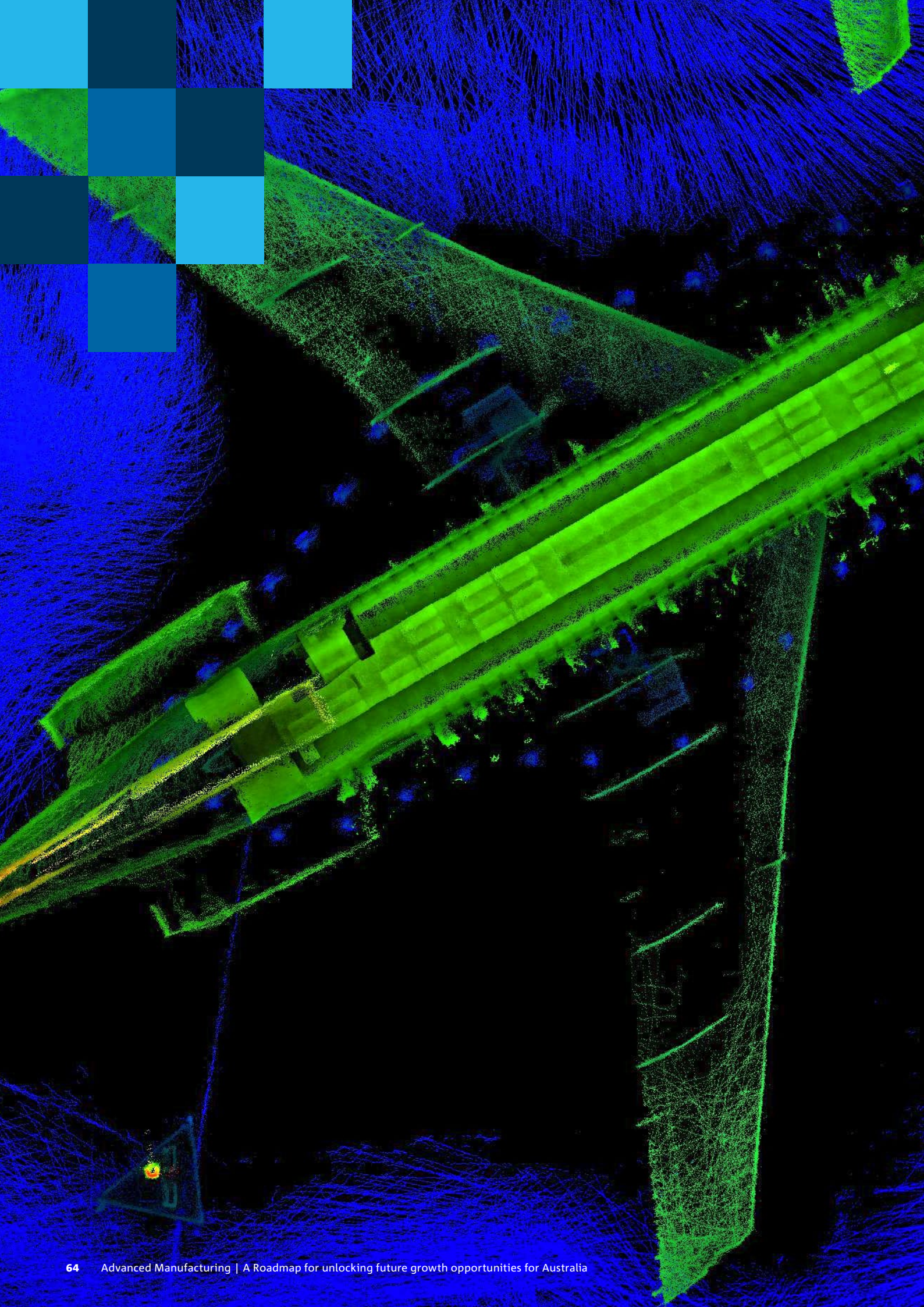
Most of the actions listed above require a collaborative effort across at least two sector stakeholder groups. In order to accelerate or improve the impact of these actions, a number of considerations must be contemplated by these groups to identify the most efficient and effective implementation approach. These considerations include:

- **Recognising national differences:** This report highlights examples of world-leading international manufacturing ecosystems such as Germany and Japan. It is important to acknowledge that – compared to Australia – these regions have different education systems, innovation systems, markets, histories and cultures. While this report recommends aiming to achieve many of their attributes (closely integrated stakeholders, enhanced collaboration, risk taking and consistent government agendas), an exact replication of their successful systems would be unlikely to work in Australia due to these differences. Instead, the sector needs to consider which elements of these international benchmarks could be adapted to suit Australia's context, and whether novel pathways exist due to Australia's unique competitive landscape.
- **Acknowledging pace of cultural change:** It is critical to take into account Australia's high levels of risk aversion when planning and delivering on these recommended actions. While the 20 year vision describes an Australian manufacturing ecosystem that takes calculated risks and invests heavily in novel products, systems and processes, this represents a significant transformation from present day. Cultural change is slow, and in order to achieve this vision, risk incentives (largely provided by government) need to focus on medium-risk/medium-reward solutions in the short-term rather than attempt to incentivise the desired 'end point' behaviours.
- **Tailoring solutions for SMEs:** The vast majority of Australian manufacturers are SMEs. These businesses typically have lower levels of collaboration with research, reduced access to high performing graduates, and less revenue to invest resources (budget and personnel) in strategic planning, however the agility and specialisation of SMEs will be critical in achieving the 20 year vision for Australian manufacturing. In implementing the suggested actions, it is important to ensure solutions are valuable and accessible to SMEs, and that the research community and larger businesses are greater incentivised to collaborate with SMEs.

Transforming Australia's manufacturing sector is not a short-term process, with many industries having experienced significant challenges for decades. Regardless of the actions of the sector over the next few years, positioning Australian manufacturing for sustainable competitiveness is a long-term play. A consistent and supportive policy environment is required over the next decade to provide businesses with stability and allow them to execute long-term strategies.

Relationship building and solution development takes time. Industry is acutely aware of its pain points, but require greater connection with research to understand what science and technology exists that could form solutions. These connections are equally important for the research community, not just to ensure projects are aligned to industry needs, but also because businesses can assist research in identifying markets for technologies under development.

In the long-term, as manufacturers begin to capture the economic benefits of their investment in novel technologies (e.g. cost efficiencies or premiums charged for enhanced quality), it is important that these funds are reinvested into new forms of innovation rather than 'banked'. In an increasingly competitive global landscape, continual improvement and investment in R&D is the only way to remain competitive.



Appendix

Appendix

A.1 Contributing parties

A&I Coatings Pty Ltd

Advanced Manufacturing Growth Centre

Agri Fibre Industries Pty Ltd

Air Radiators Pty Ltd

Ausbiotech

Austeng Pty Ltd

Australian Advanced Manufacturing Council

Australian Manufacturing Technology Institute Limited (AMTIL)

Australian National University

Baraja Pty Ltd

Boeing Australia Holdings Pty Ltd

Bosch (Aust) Pty Ltd

Boundary Bend Olives Pty Ltd

Cap-XX Pty Ltd

Carbon Revolution Pty Ltd

Ceramisphere Pty Ltd

Computer Sciences Corporation (CSC)

Dow Chemical (Australia) Pty Ltd

Economic and Industry Development, Department of State Development (QLD)

Fledge Innovation Labs

Free Engineer

Future First Holdings Pty Ltd

Geelong City Council

Geelong Manufacturing Council

HAYS Specialist Recruitment (Australia) Pty Ltd

Industrial Control Technology Pty Ltd

Industry Capability Network (ICN)

Integra Systems Pty Ltd

IXL Group Pty Ltd

Josie's Transport Group Pty Ltd

Manufacturing Skills Australia

Marand Precision Engineering Pty Ltd

Medina Engineering Pty Ltd

MiniFAB Australia Pty Ltd

Nautitech Mining Systems Pty Ltd

NSW Business Chamber

NSW Department of Industry

Pallion Group Pty Ltd

Plastics and Chemicals Industry Association (PACIA)

Private Individuals

Qenos Pty Ltd

Quickstep Technologies Pty Ltd

Rail Manufacturing CRC

Red Team Research

RedFern Applied

Regional Development Australia Sydney

Regional Development Victoria

Romar Engineering Pty Ltd

Silanna Semiconductor Pty Ltd

South East Melbourne Manufacturers Alliance Inc

Sutton Tools Pty Ltd

Textor Technologies Pty Ltd

Tiller Design Pty Ltd

Titomic Pty Ltd

University of New South Wales

Weir Minerals Australia Ltd

A.2 Other sector planning documents

The following reports provide deeper insights into some of the specific manufacturing trends and concepts covered in this Roadmap:

1. Deloitte (2015). *The Deloitte Consumer Review – Made-to-order: The rise of mass personalisation,* Deloitte LLP, London.
2. McKinsey Digital (2015). *Industry 4.0: How to navigate digitization of the manufacturing sector,* McKinsey&Company.
3. World Economic Forum in collaboration with Accenture (2015). *Industrial Internet of Things,* World Economic Forum, Geneva.
4. Visnjic, I. and Van Looy, B. (2013). *Servitization: Disentangling the impact of service business model innovation on manufacturing firm performance.* Journal of Operations Management.
5. OECD (2015). *Service-manufacturing linkages in OECD Science, Technology and Industry Scoreboard,* OECD Publishing, Paris.
6. Office of the Chief Economist (2016). *Global production sharing and Australian manufacturing 2016.* Department of Industry, Innovation and Science.
7. PWC (2016). *For US manufacturing, virtual reality is for real,* PWC.
8. The Carbon Trust (2012). *Green your business for growth,* The Carbon Trust, London.

OTHER ROADMAPS IN THE CSIRO SERIES

This report is the first of a series of roadmaps that are being developed by CSIRO. Upcoming reports will include:

1. Medical Technologies and Pharmaceuticals – A Roadmap for unlocking future growth opportunities for Australia.
2. Mining Equipment, Technology and Services – A Roadmap for unlocking future growth opportunities for Australia.
3. Food and Agribusiness – A Roadmap for unlocking future growth opportunities for Australia.
4. Oil, Gas and Energy – A Roadmap for unlocking future growth opportunities for Australia.

A.3 Co-contributing funding schemes for Australian SMEs and start-ups

Many of the activities recommended in this report require investment in R&D. The table below lists national and state based funding schemes available to Australian SMEs and start-ups that support innovation and commercialisation.[144]

PROGRAM		PROJECT		
NAME	STATE	VALUE	SME CONTRIBUTION	ELIGIBILITY / NOTES
Innovation Connections	All	< $50k	1:1 cash	• $1.5m - $100m turnover, 3+ years in business. • Grants available for researcher, business researcher and graduate placements.
CSIRO SIEF STEM+ Business	All	< $105k p.a.	1:1 cash	• $1m - $100m turnover. • Projects delivered by early-career researchers.
Accelerating Commercialisation	All	< $1 mil	1:1	• < $20m turnover. • Funds commercialisation, not research and development.
ICon Proof of Technology grant	ACT	$5k-30k	1:1 cash and/or in-kind	• < $2m turnover.
ICon Accelerating Innovation grant	ACT	$5k-10k	1:1 cash and/or in-kind	• < $2m turnover.
TechVouchers	NSW	< $15k	1:1 cash	• < $30m turnover, < 20 employees, 1+ years in business. • Preference for companies not previously engaged in research.
BISI Innovation Voucher	NT	< $25k	40%	• < 100 employees.
Knowledge Transfer Partnerships	QLD	< $50k	1/3 cash	• < 200 employees, 2+ years in business. • Research performed by KTP eligible graduates.
Innovation Voucher program	SA	$10k -$50k	1:2 or 1:1	• < $200m turnover, 1+ years in business. • Contribution 1:2 for SMEs below $5m.
Business Transformation Voucher	SA	< $50k	1:1 cash	• 1+ years in business. • Can include developing new business models or R&D.
BioSA Industry Development program	SA	$50k-250k repayable		• Early-stage/start-ups. • Bioscience and related industry sectors.
SBDF Start-up business grant	SA	< $20k	1:1 cash	• To contribute to starting a new business or buying a business.
SBDF Business Expansion grant	SA	$10k-100k	1:1 cash	• < 20 employees, 1+ years in business.
Innovation Vouchers	WA	< $20k	At least 20%	• < $500k turnover, < 200 employees.

144 Current as at October 2016. For more information on the funding schemes available to Australian SMEs and start-ups see CSIRO's SME Connect Program http://www.csiro.au/SMEConnect

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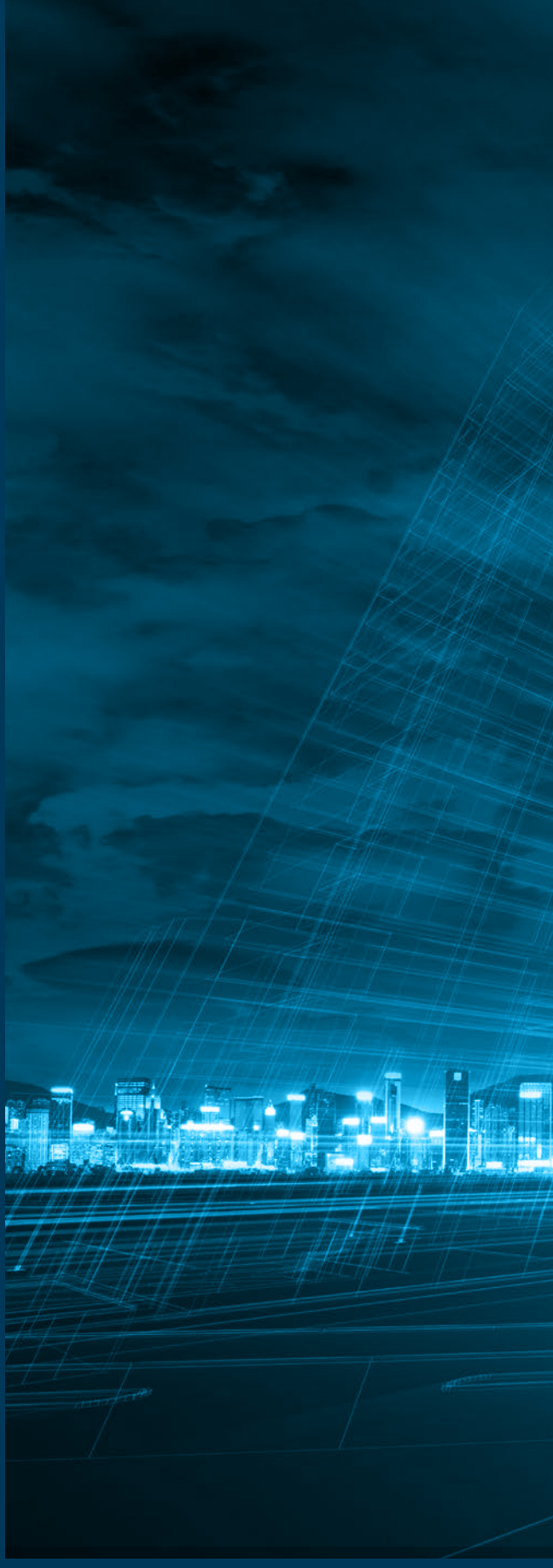

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