Emerging technologies in agriculture:

Regulatory & other challenges

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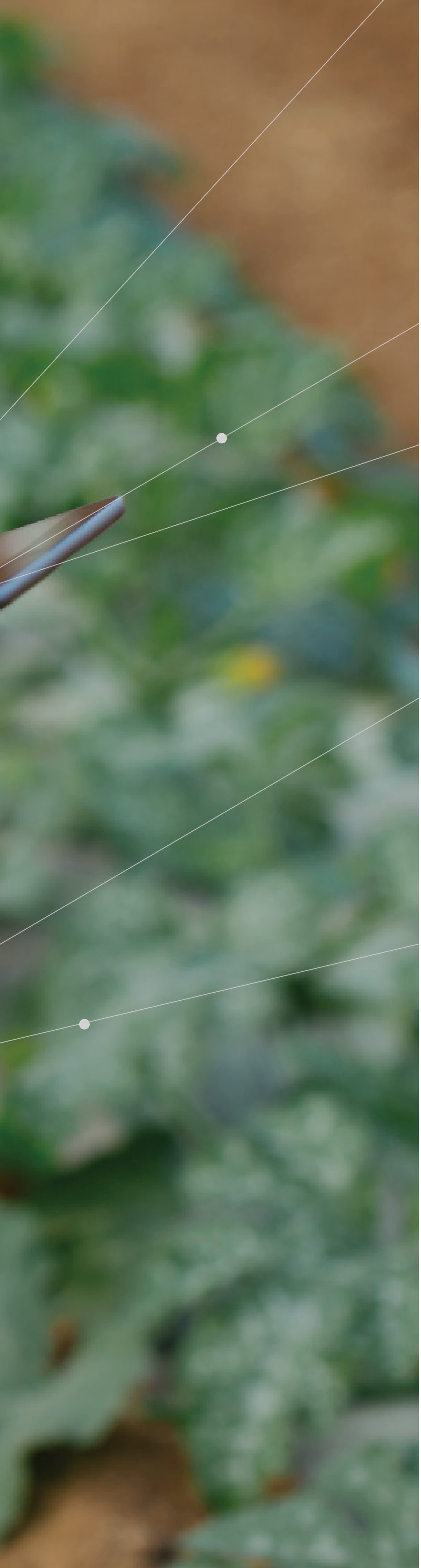

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Emerging technologies in agriculture: regulatory & other challenges

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Foreword

The development and convergence of technologies is occurring at a faster rate than regulation. Policy and regulation have not necessarily kept pace with the rapid advancements in some technologies, and policy makers must balance opportunities with public safety.

As a cross-sectoral issue, governments, Rural Research and Development Corporations (RDCs) and industries have a role to play to proactively understand the regulatory barriers and opportunities that may restrict or prohibit the agriculture sector's ability to adopt technology or conversely safeguard access to it.

This project delivers information to equip government, industry and RDCs with a better understanding of regulations needed to manage the adoption and uptake of emerging technologies, as well as the opportunity cost of getting it wrong.

This report has been produced under AgriFutures Australia's National Rural Issues Program. It is an addition to AgriFutures' diverse range of over 2000 research publications and it forms part of our National Challenges and Opportunities arena, which aims to identify and nurture research and innovation opportunities that are synergistic across rural sectors.

Most of AgriFutures Australia's publications are available for viewing, free downloading or purchasing online at: www.agrifutures.com.au.

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Executive Summary

Australia's agricultural sector has a long tradition of developing and adopting new innovations to improve productivity, competitiveness and quality of agricultural products.

Technological innovations, dominated today by developments in the digital world, have been described as the third and most recent 'revolution' to affect the agricultural sector, following on from the mechanical and scientific revolutions that have influenced the sector in the past.

That the rapid evolution of recent technologies represents both opportunities and challenges for Australia's agricultural sector has been well established. Recent investigations by the House of Representatives Standing Committee on Agriculture and Industry (Smart Farming, 2016), the Department of Agriculture (Agricultural Competitiveness White Paper, 2015), the Productivity Commission (Regulation of Australian Agriculture 2016), as well as international authorities such as the Organisation for Economic Co-operation and Development (OECD) (Innovation, agricultural productivity and sustainability in Australia, 2015) have all highlighted the importance of capitalising on the productivity gains that emerging technologies can deliver.

To achieve this there is a pressing need to understand and address the environmental and social risks and challenges that new technological innovations may pose for the agricultural sector and the broader population. An enabling environment that addresses the risks — including a responsive policy and regulatory framework — can build public awareness and provide public confidence, attract public investment and encourage innovation in Australia's agricultural sector. However, like all kinds of government intervention, regulation needs to be fit-for-purpose.

This project builds on previous AgriFutures research on emerging technologies in the agricultural sector.

It had three objectives:

1. Identify the eight technologies that are expected to have the greatest impact on Australian agriculture over the next 5 to 10 years
2. Identify and document the regulatory barriers and opportunities for each of the eight technologies, and the opportunity cost of not addressing them
3. Identify and document possible regulatory controls or actions to address the risks, and who may be responsible for implementing them.

In order to address the first objective, the ACIL Allen team examined a list of emerging technologies and assessed them against selection criteria:

- What is the potential scale of the impact of the technology on the Australian agriculture in the next ten years?
- What is the potential breadth of impact of the technology on the Australian agricultural sector in the next ten years?
- Does it appear likely that the technology could have potential/possible adverse social and environmental impacts that may require regulation?
- Is there evidence of public concerns about these technologies that may need to be addressed?
- Is there a body of research about the barriers to adoption and regulatory options which would allow a closer examination of the issues?

The results of the assessment were provided to AgriFutures in a Discussion Paper. Agreement was reached on nine technologies for further examination. The regulatory and other barriers to adoption of these technologies are presented in this report. The key issues have been summarised in fact sheets. In addition, two case studies have been provided which extend the discussion through consideration of relevant developments in Australia.

The technologies examined in the chapters of this report are summarised below, including commentary on actions that should be considered to overcome barriers and accelerate up-take.

Nanomaterials are very small particles, wires or tubes. Because of their unique small dimensions, these materials can be highly reactive. This can be useful in agricultural applications such as nanopesticides with greater solubility than their conventional counterparts. In Australia, FSANZ, NICNAS and APVMA are all involved in regulation of nanotechnology in agriculture and food. Shared responsibility generates considerable regulatory uncertainty for potential agricultural applications of nanotechnology. This report advocates rural R&D corporation funding for nanotechnology applications with near-term commercial potential. It also suggests taking test cases to the regulators, industry engagement in international discussions and publicity for successful applications of nanotechnology to raise awareness of the benefits for agriculture from this technology across the broader public.

Crowd-sourced funding (CSF) is a technology-based innovation which provides new models for raising capital. The applications in agriculture have tended to be for specialty products or niche markets and many of the capital raisings are relatively small scale. Australia's CSF legislation will still be the most restrictive in the world, even after amendments currently in the Commonwealth Parliament are passed. This report proposes direct communication with federal law-makers to get the current Bill passed by the Senate and to secure commitments from the Treasurer to further changes that will bring Australia's legislation more into line with best practice overseas. In the meantime, establishing a CSF intermediary that specialises in agrifood should be discussed with organisations such as FinTech Australia.

Microgrids are small-scale electricity networks which are particularly useful for remote communities with unreliable grid connections. They can integrate electricity generated from different (often local) sources and interconnect with the main grid as desired. In additional to technical constraints, Australia's national energy market rules and regulations have not been designed to readily accommodate microgrids. As microgrids have been the considered in recent parliamentary inquiries (and associated recommendations for funding/policy action), this report proposes that the agricultural sector sets up a working party to follow-up on the Commonwealth and Victorian Parliamentary inquiries, explore regulatory changes with the Department of Energy and Environment and additional demonstration projects with ARENA.

Nutritional genomics (nutrigenomics) describes the effects of certain ingested nutrients and other food components on gene expression and gene regulation in people, animals and crops. It determines individual nutritional requirements based on genetic makeup as well as the association between diet and chronic diseases. Applications in agriculture include modifying crops to produce higher levels of desirable human dietary elements, such as long chain omega-3 fatty acids in crops (for cardiovascular disease) and to improve animal health. The challenges for nutrigenomics lie in establishing clear genome-nutrition relationships. This report suggests that R&D corporations should fund research, development and demonstration projects to provide clear evidence of the links between genomics and nutrition in animals and seek to jointly fund with the NHMRC similar projects establishing benefits to humans (which will result in new growth opportunities in the agrifood sector).

Robotics describes machines capable of performing tasks as delicately as human can, as well as the complicated, tough or repetitive tasks which humans prefer not to do. A variety of different sorts of robots are increasingly being used in agriculture, including some that operate on the ground in horticultural applications, overhead robots (drones) that can spray crops and even all-terrain robots that can muster cattle. Greater use of robots may be limited by uncertainty around legal liability for accidents and a lack of standards which create interoperability problems. Adoption of standards could result in use of open source software, allowing farmers to customise robot activities. This report suggests that AgriFutures should become involved in coordinating / providing training in the design, use and maintenance of agricultural robots. The report also proposes that AgriFutures provides farmer-friendly guidance on a range of issues that farmers need to be aware of when investing and using robots.

Sensors are devices that detect, measure and report. In the farm environment they can provide data on moisture levels, temperature, plant condition, the location and health of livestock and the presence (or absence) of chemicals and bacteria. There are a variety of different types and some suffer from reliability issues (which can be caused by dirt, for example). RFID tags are a form of sensor used in the livestock industry. Sensors also suffer from a lack of standards. Sensor systems connected to networks can provide valuable real time information but can have cybersecurity vulnerabilities and problems where internet capacity is limited. This report advocates R&D corporation funding for the development of more robust and more affordable sensors for use with animals and working with industry organisations to establish performance standards for sensors used in agriculture. Funding demonstration projects may also help to promote the uptake of sensors by farmers.

Drones or unmanned aerial vehicles (UAVs) can be piloted remotely from a ground-based radio controller. Their relatively low cost and capacity to collect data on crops, animals and infrastructure has resulted in rapid uptake in the agricultural sector. Applications such as weed detection, fire monitoring and pesticide treatment are starting to appear. This report proposes that the sector should engage with CASA to reduce the regulation of drones in agriculture, including remove the line-of-sight requirement for large properties. For agricultural owner-operators and contractors, an up-to-date information paper to clarify legal liabilities and a standard operation manual that meets CASA's requirements would overcome some current barriers.

Synthetic biology and gene editing are recent developments which involve the rational design and construction of novel nucleic acid or protein sequences/pathways. Gene editing makes it possible to selectively remove a targeted section of DNA and repair the strand. It allows more rapid breeding of new crop varieties. One notable application of synthetic biology has been the addition of a Pacific Chinook gene and promoter to the Atlantic Salmon genome. The modified fish grows more rapidly. This report suggests that the introduction of synthetic biology to benefit the agricultural sector in Australia could be accelerated by seeking the removal of state moratoria on GM crops and supporting arguments that gene deletions do not require regulation. A demonstration project using gene drives to eliminate an agricultural pest could also be considered.

Artificial intelligence (AI) involves technologies with the ability to perform tasks that would otherwise require human intelligence, such as visual perception, speech recognition, and language translation. It has many applications, however in agriculture its use appears likely to grow only slowly. Specific regulation of AI in agriculture is not likely, but there could be spill-over effects from more general regulation. At this time, the discussion about the risks arising from AI is framed in terms of codes of conduct and guidelines. However, autonomous operations raise legal liability issues and security concerns. This report recommends publicity for successful applications of AI in agriculture to build public confidence in this technology and continuation of the partnership between Hort Innovation and ACFR to apply AI research outcomes in agriculture.

Peter Gooday, Executive Director of Australian Bureau of Agricultural Resource Economics, has noted that:[1]

“Two of the big challenges Australian agriculture is facing at the moment are climate variability and increased competition in key export markets. Innovation in Australian agriculture is working to address both issues. Increased use of data, automation, genetics and communication technologies all present opportunities but they all come with challenges we must solve.”

Conclusions

This report draws on domestic and international research to highlight how these challenges are being resolved and the insights this provides for Australian agriculture. The report focuses on the barriers, limitations and opportunities posed by new technologies, and the approaches that may help to mitigate these and support the uptake of technological innovations in agriculture.

The report concludes with a brief discussion of three overarching themes: the importance of public trust in the governance of technologies used in agriculture; the need to build agricultural workers and farmers competencies in specific areas of information technology; and the continued importance of collaborative research and experimentation with new technologies, yet that extends its focus to the regulatory options and their implications.

In addition, more specific strategies are suggested for AgriFutures to pursue. They include:

- building public awareness and trust in agricultural applications of emerging technologies through publicity of success stories
- focusing investment in research, development and demonstration, together with government, to address questions of public and environmental safety and different regulatory approaches
- engaging directly with regulators to heighten awareness of the issues for agriculture and address excessive regulation
- participating in national and international discussions that may lead to regulation of technologies relevant to agriculture.

[1]ABARE 2017, Outlook 2017 Press Release: Innovation underpins the global competitiveness of Australian agriculture, accessed on 18 May 2018 at http://www.agriculture.gov.au/abares/news/media-releases/2017/innovation-underpins-global-competitiveness-aus-ag

Section 1

Introduction

Introduction

The technologies that will transform Australian agricultural practices in the 21st century have been the subject of much anticipation and discussion in Australia in the recent past. At a 2016 G20 meeting Australia's Agricultural Scientist, Dr Kim Ritman argued that digital services, data collection and analysis; automation and robotics; new gene technologies for plant and animal breeding; climate change adaptation and mitigation tools; and biosecurity technologies, are the technologies to watch.[2]

In 2016 AgriFutures developed a series of fact sheets about emerging technologies that are anticipated to change the way agricultural products are made, marketed and transported. The fact sheets focus on: sensors, artificial intelligence, gene editing, nanomaterials, robots, synthetic biology, the Internet of Things, and 3D printing. The fact sheets provided a high-level introduction to some of the emerging policy and regulatory issues these technologies raise.

This report builds on AgriFutures work in two ways:

- it revisits the technologies and refreshes the list of those that are anticipated to have a significant impact on Australian agriculture
- it surveys Australian and international research to expand the understanding of the regulatory issues these technologies may raise.

This chapter sets out the approach taken to these two tasks. It also briefly describes the main concepts.

1.1 Methodology

1.1.1 Discussion Paper

The emerging technologies of relevance to agriculture and their possible regulatory issues were documented in a Discussion Paper. The Paper considered AgriFutures series on transformative technologies,[3] CSIRO's Rural Industry Futures,[4] AgriFutures Horizon Scans 2 and 3[5] and the AgriFutures Cross-industry Innovation Scan.[6] It also considered the report of the Productivity Commission[7] on the Regulation of Australian Agriculture and the House of Representatives Standing Committee on Agriculture and Industry report on Smart Farming.[8]

The Discussion Paper briefly summarised 17 technologies and assesses these against a set of selection criteria that were designed to identify those that have the greatest potential for Australian agriculture (in the next 5 to 10 years) yet also raise concerns as to their potential social and environmental impacts (both positive and negative). The following criteria were used:

- What is the potential scale of the impact of the technology on the Australian agriculture in the next ten years?
- What is the potential breadth of impact of the technology on the Australian agricultural sector in the next ten years?
- Does it appear likely that the technology could have potential/possible adverse social and environmental impacts that may require regulation?
- Is there evidence of public concerns about these technologies that may need to be addressed?
- Is there a body of research about the barriers to adoption and regulatory options which would allow a closer examination of the issues?

Each of the technologies were rated against these selection criteria on a scale of 1 to 5, with five being the highest score. Recognising that related work on emerging technologies that is significantly progressed, such as the issues of big data and related applications in 'precision agriculture' under examination of by the Australia Farm Institutes P2D Project, the final selection was agreed with AgriFutures (Table 1.1).

Table 1.1 Technologies considered

Technologies short-listed	Technologies long-listed
Sensors	Big data
Artificial intelligence	The Internet of Things
Synthetic biology (and gene editing)	3D printing
Nanomaterials	Augmented reality
Robotics	Solar transmission
Unmanned aerial vehicles (drones)	GPS
Crowd funding	Smart dust
Nutritional genomics	
Microgrids	

Source: ACIL Allen Consulting

The Discussion Paper noted some of the common characteristics of emerging technologies and the challenges that this poses for research about their regulation. For instance, some technologies with great potential for agriculture are the product of advancements in other fields, such as medicine or transportation, and are therefore the subject of unrelated laws.

1.1.2 Literature review

The literature review canvassed international and domestic academic research about the regulatory issues arising from the adoption and uptake of the shortlist of emerging technologies, with a particular focus on risks and regulation. Grey literature formed a significant part of this review, including the work of international bodies and committees, government inquiries, and industry news letters, among other examples.

A sample of the search databases that were canvassed includes:

- Australian Public Affairs covering over 550 journals covering Australia's political, economic and social affairs
- Informit covering Australian subject specific bibliographic databases, including the Australian Family & Society Abstracts Database, Health & Society Database, Humanities & Social Sciences Collection, Families & Society Collection and Multicultural Australia and Immigration Studies and the Indigenous Studies Bibliography
- CAB ABSTRACTS coverage of the worldwide literature on agriculture and allied fields
- AGRIS coverage of international database documents worldwide agricultural literature which reports on research results, food production, and rural development

Extensive referencing has been provided in the summary of findings for each technology (see Chapters 2 - 9).

1.2 This report

Whiles laws are the most obvious form of regulation, governments and industry stakeholders adopt a variety of approaches to influence or control behaviour. These reflect the urgency of the issue, the nature of the stakeholders and the regulatory approaches that have come before. For instance, voluntary rather than mandatory codes may be an incentive for early adopters of a technology, while engagement in international collaborations to develop standards around emerging concerns for product safety may be appropriate and effective alternatives to the introduction of laws or rules. In light of this, the report has taken a broad view of regulation and has drawn attention to opportunities for where applicable.

For most of the examples examined, Australia lags behind leading agriculture competitors in best-practice regulation and in adopting the emerging technologies discussed in this report. For example, Australia's crowd-sourced equity funding legislation is much more restrictive than a number of our competitors, and Australian adoption of nutritional genomics in the form of functional foods lags well behind Canada.

This report briefly describes each technology and its application to agriculture. Issues, barriers and risks impacting on the adoption of these technologies are discussed. Where possible, each chapter identifies steps that could be taken by the agricultural sector to facilitate the more rapid utilisation of technologies which will raise productivity and provide new opportunities for growth in the sector.

[2] Ritman K 2016, Innovation and biosecurity contributions to global food security, 2016 G20 Meeting of Agricultural Chief Scientists, 31 May 2016, accessed on 18 May 2018 at https://www.macs-g20.org/fileadmin/macs/Annual_Meetings/2016_China/Presentations/0531-1000-AUSTRALIA.pdf– [3] AgriFutures, various dates, accessed on 14 February 2018 at http://www.agrifutures.com.au/publications-resources/publications/?fwp_rural_industry_search=technology– [4] Hajkowicz S and Eady S (CSIRO) 2015, Rural industry futures, accessed on 12 February 2018 at https://rirdc.infoservices.com.au/downloads/15-065– [5] AgriFutures various dates, accessed on 14 February 2018 at http://www.agrifutures.com.au/publications-resources/publications/?fwp_rural_industry_search=horizon%20scan–
[6] AgriFutures 2016, Cross industry innovations scan, accessed on 14 February 2018 at http://www.agrifutures.com.au/publications/cross-industry-innovation-scan/
[7] Productivity Commission 2016, Regulation of Australian Agriculture: Inquiry report No.79, accessed on 18 May 2018 at https://www.pc.gov.au/inquiries/completed/agriculture/report/agriculture.pdf– [8] Australian Parliament 2016, Smart farming: Inquiry into agricultural innovation, House of Representatives Standing Committee on Agriculture and Industry report accessed on 18 May 2018 at https://www.aph.gov.au/~/media/02%20Parliamentary%20Business/24%20Committees/243%20Reps%20Committees/AgInd/AgInnovation/Report.pdf?la=en

Section 2

Nanomaterials

Nanomaterials

The term 'nanomaterial' refers to a material (or its component particles) that is measured in the scale of nanometres.[9] They can take the form of particles, wires or tubes. There are various definitions of nanomaterials. The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) working definition is:[10]

> "...industrial materials intentionally produced, manufactured or engineered to have unique properties or specific composition at the nanoscale, that is a size range typically between 1 nm and 100 nm, and is either a nano-object (i.e. that is confined in one, two, or three dimensions at the nanoscale) or is nanostructured (i.e. having an internal or surface structure at the nanoscale)"

Naturally-occurring nanomaterials are common. They exist in the human body in blood, body fat and certain viruses. The wax layer on some plants contains nanomaterials as do volcanic ash, bushfire emissions, ocean spray, fine sand and dust.

2.1 Relevance to agriculture

Nanotechnology has a wide range of applications in agriculture.[11] For example, nanotechnology can contribute to improved pest management and crop protection through better efficacy of pesticides. The unique chemical and physical properties of nanomaterials, particularly high surface area, high reactivity and 'tunable' pore size (i.e. pore size that can be modified or manufactured to requirement), can be used to advantage in many agricultural applications.

Nanotechnology applications include nanopesticides.[12] These may contain a nanoscale active ingredient that because of its very small size has increased solubility, therefore more active ingredient is taken into the cells of the plant than is the case with conventional pesticides. Alternatively, a nanopesticide may be a nanoscale material that is used as a carrier or coating for a conventional active ingredient. The carrier or coating can be formulated to be slow release or to release the active ingredient in response to a trigger, such as the chemicals released by a plant in the presence of a pathogen.

Nanotechnology-enabled products are also expected to enhance the bioavailability of nutrients.[13] The unique chemical and physical properties of nanomaterials present many possibilities for the development of nanofertilisers. Research is currently focused on three main forms: nutrient contained within a nonporous nanomaterial for direct application to plants; conventional fertiliser coated with nanoscale polymer film; and nutrient delivered as particles or emulsions at nanoscale dimensions.

A recent development is conventional fertiliser or nanofertilisers coated with polymer containing nanoscale biosensors to control nutrient release from the granules. Canadian researchers have developed a polymer coating on urea granules that incorporates biosensors that respond to plant roots releasing chemical signals to stimulate micro-organisms in the soil to mineralise nitrogen from organic matter by changing the permeability of the polymer coating and releasing nitrogen from urea granules as required by the plant.[14]

Nanomaterials can also be used to improve animal health products. For example, smart products can be designed to deliver increased concentrations of medicine at the affected tissue or organ and decreased concentration in healthy non-target tissues. While globally there are a growing number of animal health and veterinary nanotechnology products available, there is limited take up in Australia.

Other potential applications of nanomaterials include additives in stock feed to enhance availability of minerals and vitamins to the animal and protect it against mycotoxins and food-borne pathogens. Self-regulating drugs, delivered by nanomaterials, provide opportunities to better regulate livestock growth and improve fertility. In food-producing animals, nanotechnology provides many opportunities to reduce the use of antibiotics.

Some of the other potential uses of nanomaterials include:

- as potential delivery systems of DNA to plant cells, in order to transform the plant's genetics for a range of agronomic advantages
- as highly sensitive biochemical sensors — electrochemically-active nanomaterials such as carbon nanotubes, nanofibres and fullerenes could be used to closely monitor environmental conditions, plant health and plant growth
- biochemical sensors such as nanodots could play a role in pesticide detection and determining soil nutrient status
- using nanomaterials, such as nanoclays and nanozeolites, to enhance the water-holding capacity of soil
- improving water quality and safety in treatment and filtration processes (e.g. nanoporous membranes could remove arsenic, viruses, bacteria, organic material, nitrates and salt from groundwater and surface water), and
- using graphene to detect heavy and/or toxic metals in water.

While it is believed that there is currently little use being made of nanotechnology in food, future applications of nanomaterials include use in food packaging. For example, nanoparticles of clay will make packaging more robust, a nanoform biopolymer (vegetable origin) can make packaging more water resistant and easily recyclable, and nanosilver in packaging would act as a disinfectant.

Food packaging that contains nanomaterials or nanosensors that are sensitive to air and / or moisture changes, or can indicate temperature changes, leakage or spoilage, have the potential to improve food quality and public health.

2.2 Issues and risks

The main challenges to the adoption of nanomaterials by the agricultural sector are the significant costs of developing commercial products. Uncertainty about public attitudes to nanotechnology and the regulatory requirements are also barriers to adoption.

Companies developing agricultural products based on nanomaterials must balance the investment required to develop, test, validate and register a product compared to likely returns from what may be a relatively small market. At present, the regulatory requirements, discussed below, are very uncertain and are almost certainly discouraging investment.

Public attitudes

Uncertainty about nanomaterials among some consumers also tends to encourage caution on the part of product developers, even though it is worth noting that the public's attitude to nanomaterials is not overly negative. An Australian government survey found that about half of respondents believed that the benefits of nanomaterials outweighed the risks.[16] Similarly, a survey by University of Sydney found that the public regarded nanomaterials differently to, and more favourably than 'chemicals'. A US review of nanomaterials had a similar result, finding that the public seemed to be unconcerned about many applications of nanotechnology, except in areas where there is pre-existing social concern, such as pesticides. Thus public attitudes may not be a major barrier to the adoption of nanotechnology in Australian agriculture.

Regulatory issues

Regulatory aspects of nanotechnology in the agrifood sector in fifteen countries were reviewed by Amenta et al in 2015.[17] Concerns have been raised about nanomaterials when they enter the environment and the food chain. As a result, OECD countries have used existing regulatory arrangements or, in the case of the EU, introduced some nanotechnology-specific regulation. Regulation of nanomaterial differs significantly between countries, which is a potential problem for Australian exporters. Even the definition of a nanomaterial varies between countries.

In Australia, products containing nanomaterials are regulated by several different authorities, including:

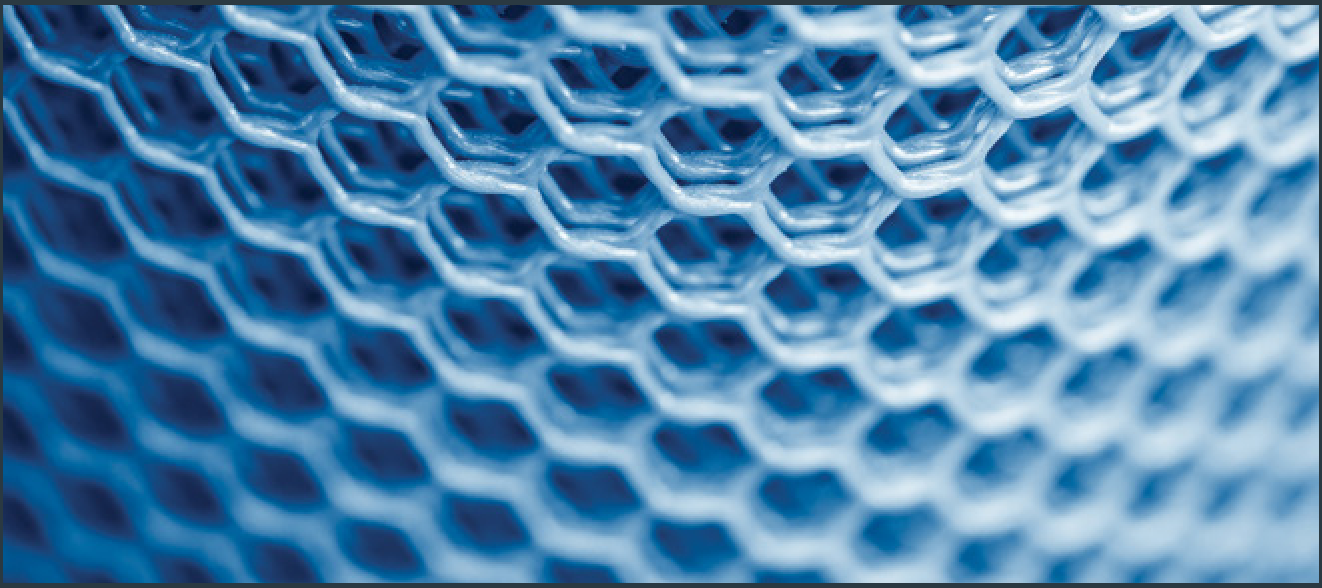
- Food Standards Australia New Zealand (FSANZ) (for food)
- Therapeutic Goods Administration (for medicines and some sunscreens)
- National Industrial Chemicals Notification and Assessment Scheme (for cosmetics and sunscreens, as well as industrial chemicals)
- Australian Pesticides and Veterinary Medicines Authority (APVMA) (for pesticides and animal medicines).

> "...existing regulatory frameworks developed for macroscale chemicals will be used to regulate nanomaterials. Over time, however, the framework will evolve as new information highlighting limitations in the current risk assessment paradigm becomes available."

In 2015 the APVMA issued a report on regulatory considerations.[18] The report concluded that:

FSANZ has adopted a range of strategies to help manage any potential risks to public health and safety associated with nanotechnologies in foods. Any new food manufactured using nanotechnologies that may present safety concerns has to undergo a comprehensive scientific safety assessment before it can be legally supplied in Australia or New Zealand. FSANZ's Application Handbook[19] states that in cases where particle size is important to achieving the technological function, or may relate to a difference in toxicity, information must be provided on particle size, size distribution, and morphology, as well as any size-dependent properties.

Fact Sheet: Nanomaterials



Background

- Nanomaterials are very small particles, wires, tubes and pores with a dimension in the order of nanometres (a nanometre is one billionth of a metre). Naturally-occurring nanomaterials are common in everyday life. They exist in the human body in blood, body fat and certain viruses.
- Nanotechnology has a wide range of applications in agriculture:
  - nanomaterials can be used to improve animal health products
  - nanomaterials in additives in stock feed to enhance availability of minerals and vitamins and protect animals against mycotoxins and food-borne pathogens
  - nanotechnology provides opportunities to reduce the use of antibiotics in food production animals.
- Nanomaterials are viewed as a way to meet the world's growing demand for food, water and energy without increasing the consumption of natural resources. The International Food Policy Research Institute, the UN Food and Agriculture Organisation and the European Union have called for more research into the role of nanotechnology in improving farm production and water safety.

Regulatory issues

- The range of potential applications of nanotechnology in the agrifood sector is very diverse, including improvements in determining soil nutrient status, smart fertilisers, animal health products and food packaging. In all cases, these applications are yet to receive regulatory approval, so at this time farmers are unable to use these nanotechnology applications.
- The regulation of nanotechnology products is complex and potentially involves Food Standards Australia New Zealand (FSANZ), the National Industrial Chemicals Notification and Assessment Scheme, the Therapeutic Goods Administration and the Australian Pesticides and Veterinary Medicines Authority.
- Uncertainty about nanomaterials among some consumers has made product developers cautious, even though an Australian government survey found that about half of respondents believed that the benefits of nanomaterials outweighed the risks. Similarly, a survey by University of Sydney found that the public regarded nanomaterials differently to, and more favourably than 'chemicals'.
- To accelerate the uptake of nanotechnology, the agricultural sector needs to invest in research, development and demonstration, perhaps by creating a fund to support agricultural nanotechnology projects that have commercial potential in the near term.

2.3 Opportunity costs

It is difficult to assess the costs to Australia's agriculture sector from any delay in taking up nanotechnology. This is because the range of potential applications of nanotechnology in the agrifood sector is very diverse, including improvements in determining soil nutrient status, smart fertilisers, animal health products and food packaging. In all cases, these applications are yet to receive regulatory approval, so at this time there is no impact on Australia's competitive position from not using these nanotechnology applications.

However, the moment applications of nanotechnology receive approval in other major agriculture-producing countries, Australia will be disadvantaged if our regulatory system has not kept pace with regulatory systems in these other countries. The economic cost to Australian producers will be reflected in a fall in agricultural productivity relative to our competitors. Thus if the coated urea fertiliser cuts farm costs by ten per cent for the same level of production for Canadian farmers, Australian users of urea could be potentially bearing annual additional costs of the order of $4.6 million.[20,21,22]

An additional cost of this size is not large in comparison with the value of production which is enhanced by the use of urea fertiliser. However if much of these costs are concentrated in just one subsector of agriculture (e.g. dairying where margins are thin), even a disadvantage of this magnitude is a problem.

This example illustrates the risks of not keeping Australia's regulatory system up-to-date with those of other countries. If five other applications of nanotechnology in agriculture were to incur similar cost disadvantages, the problem could become serious.

2.4 Action required

There is general agreement that nanotechnology will have a broad impact on agriculture, with significant impact of productivity. Nanotechnology is predicted to revolutionise agriculture and food in the same way that hybrid varieties, synthetic chemicals and biotechnology have done in the past.

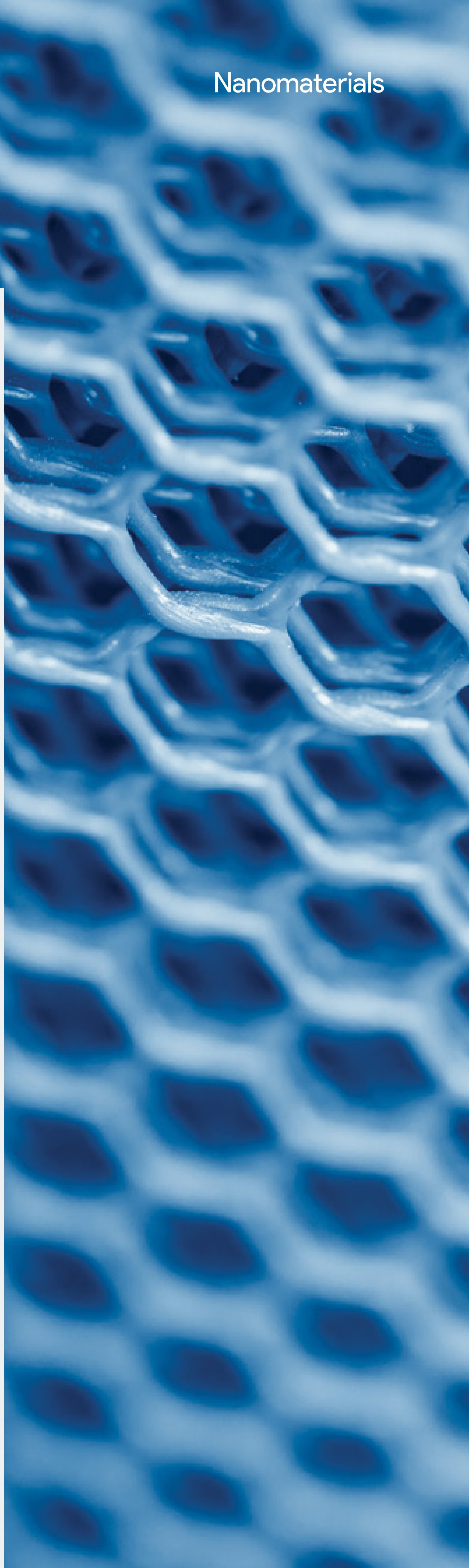
Nanomaterials are seen as one way to meet the world's growing demand for food, water and energy without increasing the consumption of natural resources. Organisations such as the International Food Policy Research Institute, the UN Food and Agriculture Organisation and the European Union, have called for more research into the role of nanotechnology in feeding the world, by improving farm production and water safety.

Input products formulated using nanomaterials are generally regarded as more environmentally friendly and require less energy, water and non-renewable resources to manufacture. In 2016 there were 3000 registered patents for pesticides developed using nanotechnology. This indicates the potential for future commercial applications of nanotechnology in agriculture.[23] However, adoption of products using nanomaterials in Australian agriculture is likely to be slow until:

- farmers can see clear and demonstrated benefits over conventional materials
- consumer demand is sufficient to convince developers to invest, and
- economies of scale cause costs to fall.

To accelerate the uptake of nanotechnology, the agricultural sector needs to take a number of steps:

- invest in research, development and demonstration. AgriFutures could create a fund to support agricultural nanotechnology projects that have commercial potential in the near term — success with some of the potential applications listed earlier in this chapter will increase broader adoption and build public confidence
- encourage the developers of promising applications of nanotechnology to explore financing through crowd sourced funding
- publicise successful applications of nanotechnology in the agricultural sector to increase public understanding of the benefits that this technology can bring to the sector



- engage in international discussions on safety issues regarding nanotechnology (e.g. agricultural sector participation in OECD and Food and Agriculture Organisation of the United States (FAO) discussions — other countries do this)
- work with regulatory agencies to fund safety testing of agricultural products involving nanotechnology
- to remove current uncertainty, demand that the APVMA clarify their regulatory intentions — the 2015 report leaves the APVMA's role in regulation of nanotechnology unresolved
- develop test cases involving the application of nanotechnology in the agrifood sector to put before NICNAS and FSANZ with a view to forcing these agencies to sort out their position on this technology. In the event that the outcomes are not considered satisfactory they can be challenged in the courts or addressed through legislative amendments.

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[9] A nanometre in one billionth of a metre i.e. 10-9 metre– [10] NICNAS undated, NICNAS working definition of industrial nanomaterial, accessed on 18 May 2018 at https://www.nicnas.gov.au/notify-your-chemical/data-requirements-for-new-chemical-notifications/data-requirements-for-notification-of-new-industrial-nanomaterials/nicnas-working-definition-of-industrial-nanomaterial– [11] Manjunatha SB, Biradar DP and Aladakatti YR 2016, Nanotechnology and its applications in agriculture: A review, J. Farm Sci., 29:1-13– [12] Kah M and Hofman T 2014, Nanopesticide research: Current trends and future priorities, Environment International, 63:224-235, accessed on 18 May 2018, https://doi.org/10.1016/j.envint.2013.11.015– [13] Amenta V, Aschberger K, Arena M, Bouwmeester H, Botelho Moniz F, Brandhoff P, Gottardo S, Marvin HJP, Mech A, Quiros Pesudo L, Rauscher H, Schoonjans R, Vittoria Vettori M, Weigel S and Peters RJ 2015, Regulatory aspects of nanotechnology in the agri/feed/food sector in EU and non-EU countries, Regulatory Toxicology and Pharmacology, 73:463-476 [14] http://www.agrifutures.com.au/wp-content/uploads/publications/16-055.pdf – [15] FSANZ undated, accessed on 23 February 2018 at http://www.foodstandards.gov.au/consumer/foodtech/nanotech/Pages/default.aspx– [16] AIC 2012 Enabling technology futures: a survey of the Australian technology landscape National Enabling Technologies Strategy Expert Forum, accessed on 18 April 2018 at https://industry.gov.au/industry/IndustrySectors/nanotechnology/Publications/Documents/EnablingTechnologyFutures.pdf https://industry.gov.au/industry/IndustrySectors/nanotechnology/Publications/Documents/EnablingTechnologyFutures.pdf– [17] Amenta *et al* 2015, op cit.– [18] APVMA 2015, Nanotechnologies for pesticides and veterinary medicines: regulatory considerations Final report, accessed on 13 February 2018 at https://apvma.gov.au/node/15626–[19] FSANZ undated, accessed on 15 February 2018 at http://www.foodstandards.gov.au/code/changes/pages/applicationshandbook.aspx [20] 158,000 tonnes x $290 x 0.1 [21] ABS Fertiliser use, Australia, year ended 30 June 2015, accessed on 19 July 2018 at http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/4627.0Main%20Features72014-15?opendocument&tabname=Summary&prodno=4627.0&issue=2014-15&num=&view= [22] Index Mundi commodity prices accessed on 19 July 2018 at https://www.indexmundi.com/commodities/?commodity=urea&months=360&currency=aud [22] RIRDC (undated) National Rural Issues Transformative technologies – nanomaterials.

Section 3

Crowd-sourced Funding

Crowd-sourced Funding

Crowd-sourced funding (CSF) comprises several approaches to raising money in the form of donations, debt or equity from large number of individuals (the crowd) via an on-line platform.

CSF is a twenty-first century phenomenon with origins in the UK and USA, and subsequently established in quite a number of countries including New Zealand and, more recently, Australia. CSF was originally designed to raise money for the development of products that would not attract bank or venture capital finance. The intended advantages of CSF are minimal regulation, rapid fund raising (where successful) and building a relationship with potential customers.

There are four basic types of crowdfunding:

- donation-based—where individuals provide funds with no expectation of benefits
- reward-based—which involve some future benefit (e.g. for a winery of food start-up, a modest amount of free or discounted product) for investors who contribute more than a specified minimum amount
- equity-based—where investors provide funds in return for shares, with the expectation of future financial benefits, and
- debt-based—where borrowers obtain unsecured loans from investors who expect to get repaid but may accept a low or zero interest rate.

3.1 Relevance to agriculture

The FAO has reported that while there was a need to invest about $US209 billion annually in agriculture over the decade to 2013, only $US142 billion was invested annually. CSF intermediary AgFunder believes it can help address the shortfall.

Australian agriculture is capital-intensive with total farm debt reaching $60 billion in 2013. Capital investment to maintain farm productivity growth rates through to 2050 could be as high as $600 billion. This will create pressures on the sector to look for alternatives to debt finance.

The major use of CSF in agriculture to date has been to finance small specialised growers, producers of food processors. Examples include new small-scale producers wanting to grow and market products such as heirloom organic fruit and nuts, and clubs which purchase grain-fed animals from growers and distribute meat through buyers' clubs. These types of CSF tend to involve small amounts of funding, generally up to $200,000.

Some CSF projects in agriculture can involve larger scale investment. One of the best-known agricultural examples is Flow® Hive, which enables the easy extraction of honey from beehives. The Australian inventors initially sought $US70,000 which they raised through Indiegogo in around five minutes, going on to eventually raise more than $US12 million. Flow Hive now sells its products in more than 130 countries.

Other Australian examples include the purchase of a 150ha grazing property through DomaCom. In this case, local farmers plan to lease farms bought through crowd funding. Landcare and Pozible have formed a CSF partnership and are reported to have considered projects such as fish hatcheries, new sheds, saving endangered species, and planting trees in bushfire affected areas.

Kickstarter and Indiegogo (both US-based) are two of the best-known intermediaries operating on-line sites that facilitate CSF. As of April 2018, more than 397,00 projects had been launched on Kickstarter. Other sites that are active in agriculture include Crowd Carnivore (Australia), Barnraiser (USA) and AgFunder (USA). AgFunder looks to invest in the $US 0.5 - 1.5 million range. Kickstarter and Indiegogo, Pozible (Australia) and PledgeMe (New Zealand) support a range of new ventures including the development of games, novels and other new products. AgFunder sees its self as part of the sustainable food movement, while Crowd Carnivore links producers of grass-fed animals directly with consumers.

3.2 Issues and risks

CSF could contribute to an expansion of agricultural production in Australia. However, there are some significant uncertainties for CSF investors and project sponsors in Australia.

Australia's restrictive CSF legislation

Australia's CSF legislation is considered to be one of the most restrictive in the world.[25] Under current Australia legislation, only unlisted public companies with assets or income less than $25 million can access equity-based CSF. Companies cannot raise more than $5 million per year and each investor has to be treated as a separate shareholder, limiting equity-based CSF to 50 investors per business. There are also caps on individual investments. Amendments to extend CSF to propriety (private) companies have been before the Australia Parliament since September 2017 but have yet to be passed. While seven equity-based CSFs licenced by ASIC (e.g. OnMarket, Equitise and Birchal) none are specialising in agrifood.

Uncertainty and cost of raising capital

The success rate for equity-based CSF is relatively low (Barnraiser claims 65 per cent, Kickstarter's success rate is reported to be around 30 per cent). Success rates for some small donation-based CSF intermediaries are higher. Generally, if the project's funding target is not reached, no funds are collected (e.g. Pozible).

CSF intermediaries commonly charge fees amounting to 5-10 per cent of funds raised. AgFunder takes a 20 per cent interest as well as an administration fee.

Managing the expectations of CSF investors

CSF is likely to attract inexperienced small retail investors who may have expectations that are difficult to meet. This is particularly the case for reward-based and equity-based CSF. It is difficult and potentially expensive for investors to do due diligence on CSF investment projects, and there is very little investor protection. As with any new business, a longer-term strategy (including possibly an exit strategy) is important.

Raising funds through CSF is not straightforward

World Bank analysis suggests that entrepreneurs seeking finance through CSF tend to underestimate the amount of effort and resources required for a successful CSF campaign.[26] Choosing the most appropriate intermediary is also important. International CSF raising necessitates meeting regulatory requirements in more than one country and involves additional costs.

Taxation

The Australian Tax Office has provided guidance on tax treatment which depends on the type of crowdfunding and the role of the taxpayer (promoter, intermediary and contributor).[27] However some aspects of the taxation of amounts received through crowdfunding are largely untested.[28]

3.3 Opportunity costs

In the period 2012-17, US-based AgFunder has invested around $US37 billion[29] ($A50 billion) in financing new ventures in the agrifood sector. Australia's economy is approximately one fifth the size of that of the USA. So had Australia had an AgFunder operating in this period, crowd-sourced funding could have provided an additional $10 billion dollars investment into the sector. This illustrates Australia's opportunity cost to date from not having a competitive CSF regime over the period 2012 17.

To highlight this lost opportunity more starkly, in 2017, AgFunder invested $US10.1 billion ($A13 billion). Adjusting this for the size of the Australian economy, there is a potential lost agrifood investment of $A250 million per week, every week that Australian lawmakers delay the passage of the current amendments.

It should also be noted that AgFunder is only one of the CSF intermediaries investing in the agrifood sector in the USA. In addition, although some AgFunder investment is in downstream food projects, there are benefits which flow back to producers in the form of increased demand and, in some cases, price premiums.

3.4 Action required

Until amendments to Australia's CSF legislation, currently before the federal Parliament, are passed the vast bulk of Australian companies cannot access equity-based CSF. Even when the amendments are passed, there is expected to be a six-month delay before they come into force and this will still leave a number of other restrictions that make CSF in Australia less attractive than in other countries. It is likely that, over time, these restrictions may be eased to bring Australian CSF more in to line with that of other countries.

While the scale of funding available through CSF in Australia limits its impact, success with CSF can lead to subsequent investment from venture capitalists and other sources. Australian experience with CSF is still recent, so its full potential is yet to be explored. However, until there are changes in the Australian CSF legislation, the use of this type of financing in agrifood is likely to be limited to small projects.

The agricultural sector needs to impress on federal lawmakers the need to:

- remove the six-month delay provision from the amendment Bill, and get it passed by the Senate
- recognise the potential; benefits to growth in the agriculture sector from liberalising Australia's CSF legislation by asking the Treasurer to:
  - increase the cap on individual investors
  - remove the cooling off period (inappropriate for this sort of investment)
  - increase the asset/revenue limit to $50 million
  - separate the provisions for public listed companies from those applying to propriety companies (leaving audited accounts requirements for publicly list companies) (Membership of the Senate Economics Legislation Committee which reviewed the CSF Bills in 2016 and 2017 is listed at the front of two Senate reports)[30,31]
- explore with organisations such as FinTech Australian the possibility of creating an Australian equity-based CSF specialising in the agrifood sector (i.e. and Australian equivalent of AgFunder or Barnraiser. By encouraging investors into downstream agrifood ventures, such a CSF would increase the demand for Australian agricultural products.
- publicise CSF success stories in agriculture to illustrate the range of possibilities and to inspire others to use this new form of investment.

> It should also be noted that AgFunder is only one of the CSF intermediaries investing in the agrifood sector in the USA. In addition, although some AgFunder investment is in downstream food projects, there are benefits which flow back to producers in the form of increased demand and, in some cases, price premiums.

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[24] See ASIC 2018, Crowd-sourced funding, 12 March 2018, accessed on 11 April 2018 at http://asic.gov.au/regulatory-resources/financial-services/crowd-sourced-funding/ [25] Dawkins T (CEO and co-founder of cause-driven crowdfunding platform StartSomeGood) 2018, quoted in Crowd-Sourced Equity Funding could help grow the social enterprise sector, accessed on 11 April 2018 at https://probonoaustralia.com.au/news/2018/01/crowd-sourced-equity-funding-help-grow-social-enterprise-sector/ [26] World Bank 2016, Crowdfunding in Emerging Markets: Lessons from East African Startups, accessed on 12 April 2018 at https://openknowledge.worldbank.org/handle/10986/23820 [27] ATO 2017, accessed on 11 April 2018 at https://www.ato.gov.au/individuals/income-and-deductions/income-you-must-declare/crowdfunding/ [28] Deloitte undated, Crowdfunding the farm – not so taxing? 21 June 2017, accessed on 11 April 2018 at https://www2.deloitte.com/au/en/pages/consumer-business/articles/crowdfunding-farm-not-so-taxing.html [29] AgFunder 2017, Year in review: AgriFood Tech investing report, access on 19 July 2018 at https://research.agfunder.com/2017/AgFunder-Agrifood-Tech-Investing-Report-2017.pdf [30] Economics Legislation Committee 2016, Corporations Amendment (Crowd-sourced Funding) Bill 2015 [Provisions] February 2016, accessed on 28 June 2018 at https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Crowd_funding/Report [31] Economics Legislation Committee 2017, Corporations Amendment (Crowd-sourced Funding) Bill 2016 [Provisions] February 2017 accessed on 28 June 2018 at https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Crowdsourcedfunding16/Report

Case study:
FlowHive

Crowd-sourced funding

Crowd-sourced funding (CSF) is a new way of raising money in the form of donations, debt or equity from a large number of individuals (the crowd) via an on-line platform. CSF is a twenty-first century phenomenon with origins in the UK and USA. It was originally designed to raise money for the development of products that would not attract bank or venture capital finance.

The advantages of CSF are minimal regulation, rapid fund raising (where successful) and building a relationship with potential customers. There are four basic types of crowdfunding: donations to worthy projects, contributions that will attract a future reward (product or service), equity investments and interest-free loans. An internet-based intermediary assists the funding process.

Crowd-sourced funding provides a new way of financing new developments in food and agriculture. Intermediaries that are active in agriculture include US-based Barnraiser and AgFunder. The major use of CSF in agriculture to date has been to finance small specialised growers or producers of niche market food products. These types of CSF tend to involve small amounts of funding.

Flow Hive provides a successful example of Australian use of CSF. Flow-Hive not only raised the necessary funds but also created a strong demand for the product.

CSF in Australia

Australia's CSF legislation is considered to be one of the most restrictive in the world. Under current Australia legislation, only unlisted public companies with assets or income less than $25 million can access equitybased CSF. Companies cannot raise more than $5 million per year and each investor has to be treated as a separate shareholder, limiting equity-based CSF to 50 investors per business. There are also caps on individual investments.

Amendments to extend CSF to propriety (private) companies have been before the Australia Parliament since September 2017. Until these amendments are passed, the vast bulk of Australian companies cannot access equity-based CSF.

Even when the amendments are passed, there is expected to be a six-month delay before they come into force and this will still leave a number of other restrictions that make CSF in Australia less attractive than in other countries.

Seven equity-based CSFs have recently been licenced by ASIC, but none are specialising in agrifood. Until there are further changes in the Australian CSF legislation, the use of this type of financing in agrifood is likely to be limited to small projects.

Lost opportunities

In the period 2012-17, US-based AgFunder has invested the equivalent of $A50 billion in financing new ventures in the agrifood sector. Australia's economy is approximately one fifth the size of that of the USA, so had we had an AgFunder operating in Australia, in this period, crowd-sourced funding could have provided an additional $10 billion dollars investment into the sector. This is Australia's opportunity cost to date from not having a competitive CSF regime over the period 2012-17.

In 2017, AgFunder invested $US10.1 billion ($A13 billion). This is equivalent in Australia to potential lost agrifood investment of $A250 million per week, every week that amendments to the legislation are delayed.

Although some AgFunder investment is in downstream food projects rather than in primary production, there are benefits which flow back to producers in the form of increased demand and, in some cases, price premiums.

What needs to be done

The agricultural sector needs to:

- impress on federal lawmakers the need to remove the six-month delay provision from the amendment Bill, and get it passed by the Senate
- recognise the potential; benefits to growth in the agriculture sector from liberalising Australia's CSF legislation by asking the Treasurer to:
  - increase the cap on individual investors
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  - separate the provisions for public listed companies from those applying to propriety companies (leaving audited accounts requirements for publicly listed companies)
  - explore with organisations such as fintechs the possibility of creating an Australian equity-based CSF specialising in the agrifood sector (i.e. Australian equivalent of AgFunder or Barnraiser). By encouraging investors into downstream agrifood ventures such as CSF will increase the demand for Australian agricultural products
  - publicise CSF success stories in agriculture to illustrate the range of possibilities and to inspire others to use this new form of investment.

Flow® Hive

Flow Hive is the story of an Australian beekeeper who used CSF to support the development and manufacture of a new system for extracting honey from European bee hives.

This invention was launched on the US-based Indiegogo crowd-funding site in February 2015, in order to get the funds required to put the idea into full production. The response was very strong, and more than $US2 million was raised in just one day. Eight weeks later, more than $US12 million had been raised and 24,000 orders for the product had been received from 140 countries.

At the time, it was the fastest to reach $US1 million, the fastest to reach $US2 million, the most successful campaign ever launched on Indiegogo and the most successful crowdfunding campaign ever launched outside the USA.

There are several factors that appear to have been important in Flow Hive's success:

- the simple pitch: 'Turn the tap and watch as pure, fresh, clean honey flows right out of the hive and into your jar. No mess, no fuss, no expensive processing equipment and without disturbing the bees.'
- protection of intellectual property: a provisional patent was registered before the crowdfunding campaign was launched
- effective marketing: for example, the inventors appeared on TV talk shows and have been interviewed for newspapers and magazines
- a responsive market: word of the product and the capital raising spread rapidly via social media and the internet to the global beekeeping community.

Section 4

Microgrids

Microgrids

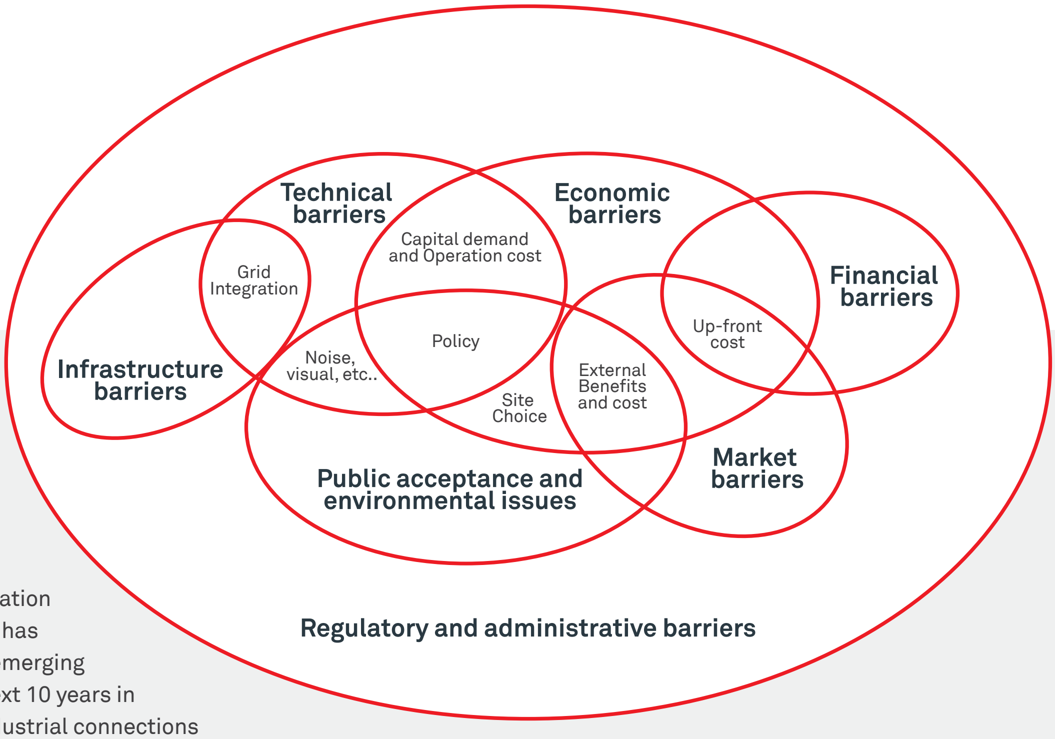
Microgrids are small-scale, self-contained electricity networks. Like mainstream electrical grids, microgrids generate, distribute and control power however typically in closer proximity to where the power is being consumed.

Microgrids interoperate with existing power systems, information systems, and network infrastructure, and are capable of feeding power into the larger grid during times of grid failure or power outages.

Traditionally microgrids have been powered by fossil fuels, however recent technological advances make it possible to integrate them with renewable energy sources.32 For instance, as the cost of solar photovoltaic (PV) has decreased dramatically over the last 5-10 years, there has been increasing consideration of diesel/solar hybrid solutions to reduce fuel expenditure and increased contribution of decentralised generation (solar PV) to Australia's electricity mix in grid connected areas.

However, solar PV technology in isolation is not sufficient to deliver a microgrid solution. Microgrid solutions require energy storage and/or diesel generation to provide energy demand during night times or on cloudy days when solar is not available. The emergence of commercially available battery storage products in the last two to three years is rapidly reducing its cost, and driving an increasing number of individual consumers, businesses and communities to consider solar PV and battery based off-grid solutions.

In Australia, microgrids' growing appeal is that they offer an alternative to rapidly rising electricity costs, and ageing infrastructure that continues to need to serve large and remote geographic areas. To date microgrids have found application in remote and island communities, campus style facilities such as universities, and commercial or industrial applications such as data centres and military bases.33



Source: Amjad *et al* 2017

Figure 4.1 Barriers to Microgrid Development

4.1 Relevance to agriculture

While there are a significant number of microgrids in operation around the country, research has concluded that the four key emerging market segments over the next 10 years in Australia are: new remote industrial connections (e.g. mines); new remote commercial connections (e.g. farms); existing remote small community connections (e.g. townships); and existing small customers (e.g. around 3.5 MWh per annum).[34]

Microgrids benefit the agricultural sectors and communities by improving the certainty of energy supply. They can mitigate the costs associated with outages from the main power grid, as well provide competitively priced energy. Power outages can be problematic to farm businesses because they lead to systems failures that cause problems with livestock, irrigation and produce (e.g. failures in electric fencing, refrigeration, and water pumps), among other examples.[35]

The steadily falling cost of both renewable energy and storage technology means that clean energy microgrids make economic sense for those that have previously relied on diesel power. Hydro Tasmania's microgrid projects on King and Flinders Islands have shown the effectiveness of renewables to reduce diesel use, while in Western Australia hybrid microgrids, installed by Horizon Power in the remote inland town of Marble Bar in the Pilbara region, maximise use of solar power by combining it with diesel generation and a flywheel storage system.[36]

Microgrids can also reduce the vulnerability of rural communities to natural disasters like cyclones and bush fires that can interrupt the energy supply and affect critical facilities such as communications, waste management, health care and emergency response systems.[37]

4.2 Issues and risks

Uncertainties in Commonwealth and State/Territory Government policies in relation to renewable energy targets and the price paid for energy have undermined the development of the microgrid market in Australia. In addition, uptake has been constrained by technical, financial and infrastructure issues, as illustrated in Figure 4.1.[39]

In general, microgrids (referred to by COAG as one of several 'stand-alone systems') are currently not captured under the national electricity frameworks and are subject to limited regulation under jurisdictional legislation.[40]

There are different perspectives on the risks and regulatory issues raised by microgrids. The COAG Energy Council believes that there are a number of reasons to justify regulation of stand-alone systems, including:

- they supply an essential service for which there is a need for continued supply, reliability and access
- they may exhibit characteristics of natural monopolies and therefore require measures to simulate competitive outcomes
- there are consumer protection considerations to address inequality in bargaining power that may arise.

Energy Networks Australia, on the other hand, argues that the current regulatory framework serves as a barrier to efficient deployment of fringe-of-grid microgrids due to issues associated with disconnecting customers from the grid under the National Electricity Rules. These relate to: the cost recovery of microgrid assets, including non-traditional network assets such as generation; customer protections, including service levels, price controls and access to full retail competition; and the regulation of third party access arrangements.

The regulatory risks and challenges of microgrids are closely related to the ownership model that underpins the delivery of its energy and its interconnection with the national electricity system. A broad range of models exist, such as:

- Landlord model – a landlord installs a microgrid onsite and provides power to tenants under a lease agreement
- Coop model – multiple individuals or companies cooperatively own and manage a microgrid to meet their power needs, and to provide to others under contract
- District model – an independent firm (of local body such as a Council) owns and manages a micro-grid and sells power to multiple customers in the area
- Distribution Network Service Provider (DNSP) mode which is a stand-alone system supplying a remote or edge of grid area.[41]

Two recent Parliamentary Inquires (in Victoria and federally) and research by the COAG Energy Council have heard evidence that a range of regulatory issues exist; two are explored below.

Customer protection

The current design of the energy market is based on the idea that customer choice of energy provider (in a competitive wholesale market with monopoly networks regulated) allows for the lowest price for consumers, mediated by a licensed retailer operating under National Energy Retail Rules. Some microgrid operating models remove the choice of retailer, essentially locking consumers within a microgrid to a single provider. This raises a set of consumer protection challenges, such as the management of unplanned outages, dispute processes reliability and service quality.

Local energy trading

Under models in which locally generated energy is traded, the consumer receives billing credits for the amount of electricity exported. The transfer is virtual not physical, such as in the case of solar garden in which communicate purchase a share in a solar farm located in a remote location, and members receive credits on their electricity bill for the electricity generated by their share of the farm.

The Victorian Parliamentary Inquiry (2016) heard from many local government alliances that while there are no legislative barriers to local energy trading, current electricity network charges make it not financially viable to do so. Currently, electricity bills charge consumers for using the entire distribution network, not solely the parts that they use.

A rule change was proposed to the Australian Energy Market Commission in 2016 but was ruled against because of the risk local network credits would increase average prices for other consumers.[42]

4.3 Opportunity costs

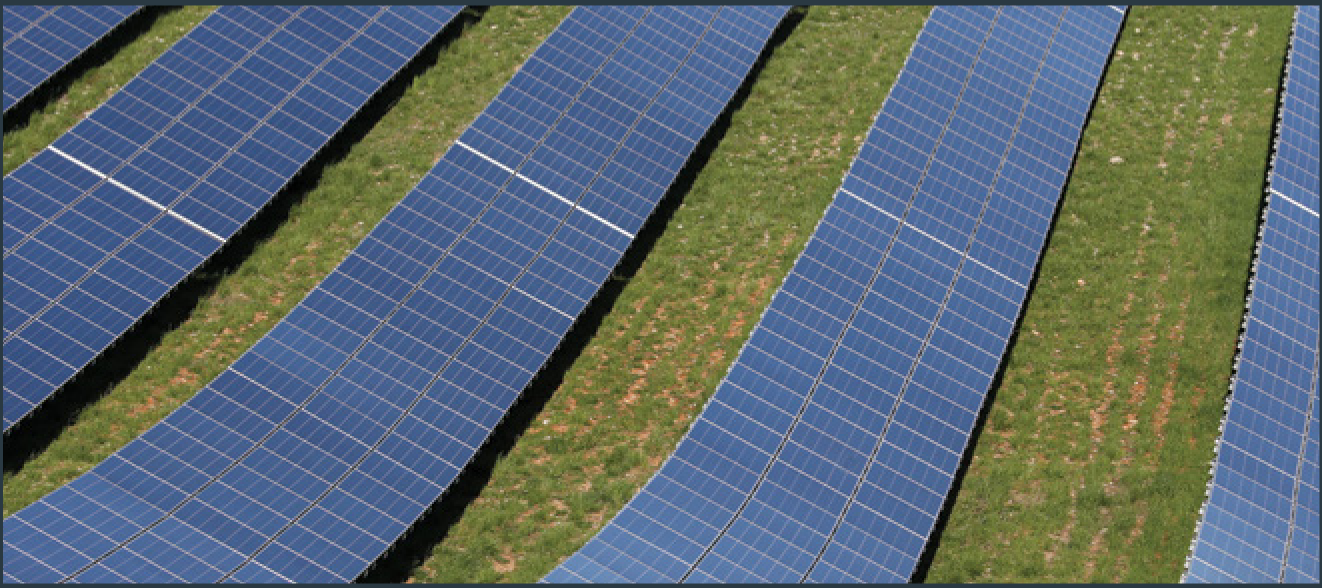
Microgrids provide energy, reliability, power quality, environmental and outage avoidance benefits. No calculations of the value of these benefits in Australia have been identified. However examples from other countries may be useful. For example, a microgrid to support a sewage pumping station in New York State (providing a service to 2,850 employees) was shown to have net annualised benefits of $US712,048 ($A916,861) and a benefit cost ratio of 2.39.[43]

A comparator in population terms could be Canowindra in NSW (2,381 residents). However the size of Australian farming communities in remote locations would likely have a smaller population, with a higher delivered cost of diesel for backup generators than in New York State. In more remote areas of Australia with small farming populations, the opportunity cost of loss of electric supply is likely to be high and would likely be fully offset through the use of microgrids. With annual benefits per microgrid approaching $A1 million from the sewage pumping station example, remote agricultural communities could potentially enjoy significant benefits, impacting on the profitability and lifestyle of these communities. There would be thousands of communities in regional Australia that could benefit from microgrids.

A 2016 Australian report has estimated that, subject to new regulatory arrangements, most businesses connections located more than 3km from the grid will be lower cost if connected to stand alone power systems. Some 27,000 such connections could be expected by 2050 with an annual saving of $700 million, mostly to farms.[44]

Removing barriers to the adoption of microgrids is therefore of considerable importance. A number of business models for microgrids are emerging[45] in the USA and Australia should ensure that our regulatory environment allows these models to be available here.

Fact Sheet:
Microgrids



Background

- Microgrids are small-scale, self-contained electricity networks. They generate, distribute and control power to nearby consumers. Applications include remote and island communities, university campuses and data centres.
- Microgrids interoperate with existing power systems, information systems, and network infrastructure, and are capable of feeding power into the larger grid during times of grid failure or power outages.
- Microgrids can benefit the agricultural sectors and rural communities by improving the certainty of energy supply. They can reduce power outages, helping to avoid systems failures that cause problems with livestock, irrigation and produce (e.g. failures in electric fencing, refrigeration, and water pumps).

Opportunity cost

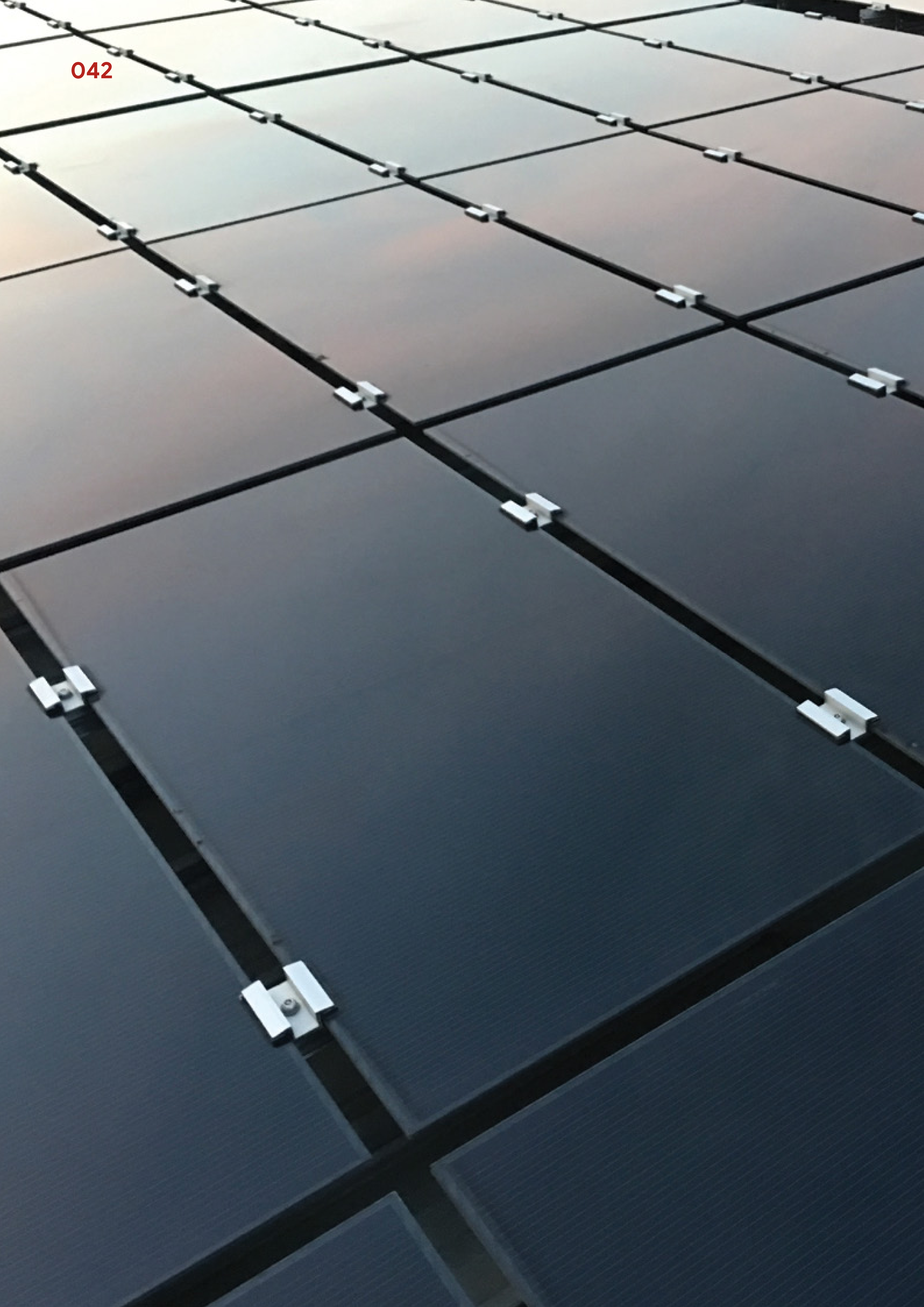
- One Australian source has estimated that by 2020, most small business rural connections that are greater than 3km from the grid will enjoy lower costs if connected as a stand-alone power system, while larger irrigation-based agriculture will need to be more than 8km from the grid in order for a stand-alone system to be viable. A 2016 Australian report has estimated that, subject to the removal of regulatory barriers, 27,000 such connections could be expected by 2050 with an annual saving of $700 million.

Regulatory issues

- Australia's electricity services are undergoing historic transformation and, as new services and technologies become available, opportunities to move off grid are becoming increasingly attractive.
- Microgrid solutions are challenging to implement without changes to existing network cost recovery frameworks and pricing. Investigations into regulatory approaches and incentive structures, as well as demonstration projects and scenario modelling that would support the emerging market for alternative energy delivery in Australia are underway.

Action required

- The agricultural sector can support easier access to microgrids by:
  a. establishing a working party to follow up on the Commonwealth and Victorian Parliamentary enquiries
  b. exploring regulatory changes with the Department of Energy and Environment
  c. seeking support for demonstration projects from ARENA
  d. commissioning detailed analysis of overseas regulatory and market management practices to incorporate microgrids into national networks.



4.4 Action required

Microgrids are both an aspect and an outcome of the massive changes taking place in electricity networks including: digital metering, big data and predictive analytics, and energy storage systems.[46] These developments make microgrids increasingly more attractive and effective as an alternative energy supply. While there is significant activity—both policy driven and practical—around microgrids in Australia at present, inquiries by state and federal parliaments have concluded that there is significant work to be done in the technical, infrastructural and regulatory domains for microgrids to flourish.

The recent Victorian Parliamentary Committee Inquiry noted that community-based energy projects faced a number of barriers and that regulatory arrangements created disincentives for the establishment of microgrids.[47] The Committee concluded that community groups should be cautious about developing community microgrids until the technical, safety and regulatory aspects of their operation are fully explored in the various trials running throughout Victoria (see Box 11.1 later in the report for an example involving the dairy industry).

Likewise, the Commonwealth Parliamentary Inquiry[48] into modernising Australia's electricity grid recommended further investigation of new market and regulatory approaches to support alternative energy delivery, while still ensuring a flexible, secure and responsive National Electricity Market, to be driven by the COAG Energy Council. Recommendations included reviewing subsidies and incentive schemes, and funding feasibility studies into changing the current grid while safeguarding reliability and consumer protections on the edge of the grid. Opportunities for participation in a submissions process will arise from this, led by the Commonwealth Department of Energy and Environment.

More practically, the Australian Renewable Energy Agency (ARENA) supports a portfolio of projects for the development of microgrids, including fringe-of-grid (e.g. Lakeland Solar and Storage), remote off-grid (e.g. Hydro-Tasmania's King Island project) and new residential developments (e.g. Brookfield Energy Australia's Huntlee development). ARENA's microgrid and off-grid portfolio attempts to showcase the potential for high penetration, affordable renewable energy systems integrating generation, demand and network requirements. They encourage cross sector partnerships, and approaches to participate are encouraged.

The agricultural sector can advance the case for microgrids by:

- Setting up a working party to follow up on the Commonwealth and Victorian Parliamentary enquiries by exploring regulatory changes with the Department of Energy and Environment and additional demonstration projects with ARENA
- commissioning detailed analysis of overseas regulatory and market management practices to incorporate microgrids into national networks.

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Section 5

Nutritional Genomics

Nutritional Genomics

Nutritional genomics (Nutrigenomics) is one aspect of nutritional genetics. Nutrigenomics is establishing the effects of ingested nutrients and other food components on gene expression and gene regulation in people, animals and crops.

It determines individual nutritional requirements based on genetic makeup as well as the association between diet and chronic diseases. While much of the focus of nutrigenomics is on human health, there are important implications for and applications in agriculture. [49]

The five basic principles of nutrigenomics, as applied to humans and animals, are: [50]

- Substances contained in the food can directly or indirectly affect a genome through changes in its structure and gene expression
- Under certain circumstances and in some individuals the diet can be an important risk factor for the development of the number of diseases
- Some genes regulated by active substances in the diet probably play a crucial role in the onset, incidence, progression and severity of the disease
- The degree to which diet influences the balance between health and disease may depend on an individual's genetic makeup
- Nutritional intervention is based on the knowledge of an individual's nutritional status and needs as well as genotype (individualized nutrition) and can be used for prevention, mitigation or healing the chronic diseases. Nutritional genomics can be targeted to benefit animals or crops, but ultimately the benefit flow to human growers and consumers.

5.1 Relevance to agriculture

Nutritional genomics has potential applications in plants (crops) and animals. It can involve modifying or creating new breeds / varieties of plants and animals to provide additional or higher levels of a desirable human dietary elements. For example, synthetic biology has been used to provide crops with enhanced production of long chain omega-3 fatty acids.[54] When consumed by humans, these compounds may reduce cardiovascular disease.[55]

Golden rice is a variety which has been genetically engineered to biosynthesise beta-carotene, a vitamin A precursor, in the endosperm. Rice naturally produces beta-carotene in its leaves but not in the edible grain. Golden rice has been developed for areas of the world that have a shortage of dietary vitamin A, a deficiency which is estimated to kill 670,000 children under the age of 5 each year. Rice is a staple food crop for over half of the world's population. It provides 30–72 per cent of the energy intake for people in Asian countries, making it a useful crop for targeting vitamin deficiencies.[56]

A further example of the application of nutrigenomics lies in improving animal health and managing pest and disease outbreaks by tailoring feed and nutrients. Gene analysis techniques make it possible to understand many of the factors controlling the regulation of gene transcription and evaluate gene expression profiles. These techniques provide information that is being used to examine key reproductive, developmental, and performance characteristics in cattle. They are providing a significant amount of new information that can be used to understand and diagnose key issues that limit reproductive performance.

Nutrigenomics also provides the possibility of customising the feed for individual high value animals, based on genetic analysis. For example, with sensors on dairy cows, customised feed can be provided to animals as they exit a milking facility.

The related field of functional genomics enables agricultural researchers to investigate how gene expression and regulation contributes to complex production traits at a genome-wide level. The US Department of Agriculture has a blueprint for their efforts in agricultural animal genomics.[57] The development and application of functional genomics techniques in agriculture is expected to have a significant positive impact on animal producers and public food supplies. Results generated from functional genomics studies are expected to be integrated with quantitative genetics to provide agricultural producers with means to improve the efficiency, sustainability, bio-security as well as social acceptance of agricultural animal production.[58]

Nutrigenomics can provide the agricultural sector with opportunities to increase production and provide market opportunities for enhanced products that meet particular human dietary needs.

5.2 Issues and risks

Nutritional genomics raise a number of issues, ranging from uncertainties about regulation to disagreements about the labelling of products. Nutritional genomics is a fast-evolving field that straddles the food-medicine distinction, something which is proving to be a problem in relation to regulation.

There are uncertainties about the links between chronic disease and nutrition. In relation to human nutrigenomics there are concerns about direct public access to nutrigenomic products and services.[59]

Providing evidence of specific genome-nutrition relationships

Nutrigenomic agricultural products can be expected to attract a price premium. However, genomic variation makes it difficult to provide the evidence of specific genome-nutrition relationships that is needed to convince growers, consumers and regulators. This is a barrier to growth in the application of nutrigenomics and, in turn, limits the opportunities for the agriculture sector is providing nutrigenomic products to the market. It is likely that over time as further research is undertaken, there will be results that demonstrate genome-nutrition links.

Regulation of nutrigenetic tests

In 2013 the EU adopted new regulations[60] on "food for specific groups" (i.e. food intended for infants and young children, food for special medical purposes, and total diet replacement for weight control). This regulation aims to protect specific vulnerable groups of consumers, people with specific medical conditions and people undertaking energy-restricted diets to lose weight) by regulating the content and marketing of food products specifically created for and marketed to them. It also aims to increase legal clarity for business and to facilitate correct application of the rules. It also covers labelling.

The functional food and health products market in North America is more than $US 500 billion per annum. Canada's 2016 human nutrition regulations are part of Health Canada's Healthy Eating Strategy. This regulation has provided opportunities in agriculture: Canada is the largest producer of hemp seed and edible by-products in the world.[61]

In Australia, the Therapeutic Goods Administration (TGA) requires that applications arising from nutritional genomics must be supported by stringent validation of claims.[62] Nutrigenetic tests are defined by the TGA to encompass all nutritional genomic assays that fall under the definition of a therapeutic good. Nutrigenetic tests are regulated under TGA's in vitro diagnostic (IVD) Framework, that commenced in 2010. This prohibits, with minor exceptions, the supply of self-testing IVDs for serious disease markers.

While this regulation has brought some order into what could have been a market where product claims lacked an evidence base, it is likely to have dampened interest in developing nutrigenomic products, including products based on inputs from the agricultural sector.

Gene technology regulation

To the extent that nutritional genomics involves genetic modification of plants or animals, approvals from the Office of the Gene Technology Regulator (OGTR) may be required. While OGTR processes are well-established, they take time to complete and involve costs (trials involving the application of GM in agriculture can be expensive). The use of some synthetic biology techniques may, however, not require OGTR review (see the chapter on Synthetic Biology).

Improving animal health

The application of genomics has a role in improving animal health, through a process involving the identification of disease resistant genes in breeding animals. As genetic tests become available and testing costs fall it will become possible to reduce the impact of animal diseases through selective breeding. This could be particularly useful for intensive pig production, which tends to be undertaken in relatively controlled conditions where health status is important.[63] The main barrier is likely to be the cost and reliability of the genetic tests.

Fraud may damage the consumer market for nutrigenomic products

Unethical companies in other countries have been found to incorrectly tested DNA samples and have sold nutrigenomic products based on the results of this testing. Some of these companies sell products of dubious value in health terms, for high prices[64] Media reports of these activities may damage the market for future agricultural nutrigenomic products.

5.3 Opportunity costs

There has been little research on benefits to the agriculture sector from nutrigenomics. Most work to date has focussed on health benefits for humans[65] and, while there is an impact from human nutrigenomic benefits that can flow back to agriculture, it has not been possible to find a quantifiable example for this report.

It is therefore important for Australia to be prepared to take advantage of emerging applications of nutrigenomics as they become recognised and accepted in other parts of the world.

The demand for functional beverages in Australia is growing at 3.9 per cent per annum, driven by increased health consciousness on the part of consumers. The demand for these beverages is an indicator of potential demand for nutrigenomic products. The functional beverage market in Australia is expected to be $431 million in 2018-19. The industry is expected to maintain its growth and reach $511 million by 2023-24. This growth will rely heavily on new health-related products.[66] Nutrigenomics could play a significant role in this growth, if research provides the evidence for health benefits. ACIL Allen estimates that the contribution of nutrigenomics to this market could be more than $100 million per annum within a decade.

Fact Sheet:
Nutritional Genomics

Background

- Nutrigenomics is demonstrating the effects of ingested nutrients and other food components on gene expression and gene regulation in people, animals and crops. It determines individual nutritional requirements based on genetic makeup as well as the association between diet and chronic diseases.
- Examples of nutrigenomics include modifying or creating new breeds or varieties of plants and animals to provide additional or higher levels of a desirable human dietary element. For example, increasing the production of vitamin A in rice can save the lives of hundreds of thousands of children in Asia.
- A further example lies in improving animal health and managing pest and disease outbreaks by tailoring feed and nutrients. Gene analysis techniques provide information that can be used to examine key reproductive, developmental, and performance characteristics in cattle. The main barriers to the adoption of this approach are likely to be the cost and reliability of the required genetic tests.

Opportunity costs

- The significant growing demand for functional beverages in Australia is an indicator of the economic potential for nutritional genomics. This industry is expected to grow to $511 million by 2023-24.

Regulatory issues

- Variations in the genomes of individual animals make it difficult to provide the evidence of specific genome-nutrition relationships that is needed to convince consumers and regulators that nutrigenetic changes are beneficial. Until there is stronger evidence of genome-nutrient relationships, opportunities for the agricultural sector to provide beneficial nutrigenomic products will be limited.
- Nutritional genomics faces uncertainties about regulation and disagreements about the labelling of products. As a fast-evolving field that straddles the food-medicine distinction, nutritional genomics attracts multiple sources of regulation.
- Agricultural applications of nutritional genomics may attract less regulation than human applications. But until further research establishes a stronger evidence base, the application of nutrigenomics in agriculture may be limited.

Action required

- The agricultural sectors R&D corporations should fund research, development and demonstration projects to provide clear evidence of the relationship between genomics and nutrition in animals — this could lead to the adoption of new feeding practices by growers, increasing agricultural productivity and potentially creating markets for new animal-derived products.

5.4 Action required

Nutritional genomics faces considerable regulatory uncertainty, compounded by lack of solid evidence of some of the claimed links between nutrition and genomics in humans and animals. Agricultural applications of nutrigenomics face some uncertainties but may attract less regulation than human applications. However, until further research establishes a stronger evidence base, the application of nutrigenomics in agriculture may be limited.

To address some of the uncertainties about nutrigenomics, the agricultural sector should take the following steps:

- R&D corporations should fund research, development and demonstration projects to provide clear evidence of the relationship between genomics and nutrition in animals — this could lead to the adoption of new feeding practices by growers, increasing agricultural productivity and possibly creating markets for new animal-derived products
- AgriFutures should seek to jointly fund with the NHMRC, studies to seek to demonstrate some highly prospective links between nutrition and genomics in humans and, if necessary, engage in discussions with the TGA to ensure that consumer protection provisions do not stand in the way of realising genuine benefits
- where links between genomics and nutrition can be demonstrated, the relevant R&D corporations should explore food labelling endorsements with organisations such as the Heart Foundation
- AgriFutures should seek to emulate the development of the functional food market in North America by drawing on Canadian experience in developing and promoting these foods — this could create new opportunities for Australian agriculture.

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Section 6

Robotics

Robotics

Robots are machines that can be programmed to collect and process data, operate autonomously, sense and respond to their surroundings and move themselves (or their parts) around their environment. Recent advancements in the field robotics have been made possible by the use of microprocessors and microcontrollers with the intelligent combination of servo motors, sensors and actuators.[67]

Robotics is the continuous endeavour of robotics engineers to make machines capable of performing tasks as delicately as human can do and the complicated, tough and repeated tasks which humans would prefer not to do. Robotic applications are applied to different machine types and structures, such as stationary robots, wheeled robots, aerial robots and legged robots.68

6.1 Relevance to agriculture

Agriculture accounted for a quarter of all service robotics sales in 2014, more than any other civilian industry.[69] Research about the robotics market through to 2038 has identified milking (both mobile and static), autonomous small robots (data scouts, weeding etc), autonomous tractors, robotic implements, robotic fruit picking, and agricultural drones (spraying helicopters) as the main areas of potential development for the agricultural sector.[70] The Director of Research and Innovation at the Australian Centre for Field Robotics, Prof Sukkarieh, recently stated that:

> "Robotics and automation technology provides the grower with greater knowledge of their farm state, and the capacity for acting in real-time, their increasing efficiency, reliability and productivity while minimising environmental impact"

At present, some of the things robots aid farmers with include inspecting crops, counting yields, milking cows, digging weeds and herding livestock.[71] Their most prominent application has been in the development of auto-steer machinery such as tractors that can be directed by GPS that controls the movement of the vehicle along set pathways. The most common applications of robotics in agriculture are AgBots that are variously equipped with sensors for navigation, including cameras and encoders. The fully-autonomous 'Agbot ll' was demonstrated for the first time in Bundaberg in late 2016 and is estimated to have the potential to save Australia's farm sector $1.3 billion a year by reducing the costs of weeding crops by around 90 per cent.[72]

Another example is 'swarm robots' (SwarmBots) which are small, lightweight, high-tech robotic machines that operate in swarms to undertake key tasks within cropping systems, such as planting, weed and pest control, fertiliser application and harvesting. SwarmBots operate through the use of software applications, with two applications already finalised — weed spraying and turf mowing.

Australia has lead development of the world's first cattle station custom robot - the SwagBot — which is an omnidirectional electric robotic ground vehicle that is capable of navigating difficult cattle station environments such as water crossings and steep ground. Recent developments include the ability to measure the temperature of an animal from a distance and notify a person if an animal is unwell.[73]

Robotics are also increasing being adopted in Australia's dairy industry. Robotic milking systems. have been available since the 1990s but are increasingly popular: there were 34 robotic milking systems in Australia in 2015 (0.5 percent of dairy farms) a growth of 8 percent in one year.[74] Included in the benefits of robotic milking are that cows enter the facility when they chose, and by identifying each cow and monitoring its health via analysis of its milk, customised rations and medication can be provided.

6.2 Issues and risks

Robotics is an expansive field for which the regulatory issues are highly context specific; the issues generated by autonomous vehicles with pesticide spraying capabilities are very different from those of milking machinery, for example. There are however a number of themes across the literature, discussed below.

Legal liability

The use of autonomous robots on farms raises questions about their liability, particularly where they have the potential (or there is a perception of this potential) to cause damage to people, property or crops. For example, if the robot is involved in the application of pesticides that have the potential to damage the environment.[75]

The European Parliament recently passed a resolution suggesting robots be granted 'legal status' so that they could be held accountable for damage they might cause, triggered by the need to clarify liability laws surrounding self-driving cars. In response, members of the European Council strongly cautioned against such a move. They argued that it assumes that robots have the autonomy to make complex choices and make mistakes — an assumption that drastically overestimates their abilities. In the USA the Brookings Institution has suggested that a new federal agency is needed to regulate robots.[76]

Propriety software

Recent research by the Queensland University and the Australian Government's Strategic Investment in Farm Robotics Program[77] found farmers were frustrated by the closed systems of proprietary software characteristic of commercially available robots and wanted an open source model for developing and evolving software for AgBots. Relatedly, farmers argued that rural communications infrastructure is often not adequate enough to reliably have remote access to unmanned robots, and that the skills needed to operate multiple digital systems or interfaces were generally lacking in farm labour.

Standards

The Australian Centre for Field Robotics informed the 2016 Australian Parliamentary Inquiry into Innovation in Agriculture that a lack of coordinated data and safety standards for robotic systems is preventing their incorporation onto the farm, and that such standards would enable interoperability betwe

6.3 Opportunity costs

Robotics have a wide variety of applications in agriculture, making it challenging to estimate the opportunity costs of any take-up of this technology that is lower than that of our competitors.

The greatest advantage that robots offer farmers is their ability to reduce operating costs. For a farm investing $100,000 per annum on insecticides, herbicides, and fertilisers, it is claimed that robots could reduce these costs by 40 per cent due to the bots' ability to spread chemicals in the precise locations and in optimum volumes.[79] Queensland University of Technology's Agbot II is able to not only identify and spray weeds, but using its robotic vision it can decide in real time which weeds should be sprayed with herbicide and which should be removed by mechanical or thermal methods. This robot is claimed to be effective and efficient and is predicted to be able to save Australia's farm sector $1.3 billion per year.[80,81] This is for just one application of robots in agriculture. Other applications discussed above could have equally large impacts, with significant opportunity costs if the uptake of this technology is delayed. Accelerating the adoption of robots in agriculture is important is Australia is to maintain its international competitiveness in

agriculture.s robot is claimed to be effective and efficient and is predicted to be able to save Australia's farm sector $1.3 billion per year.[80,81] This is for just one application of robots in agriculture. Other applications discussed above could have equally large impacts, with significant opportunity costs if the uptake of this technology is delayed.

6.4 Action required

While there are technical issues to be resolved as robotics becomes increasingly common in agriculture, such as standards and data access rights, there are also broader considerations for governments to address. One of the most significant is the need to bridge the divide between traditional agricultural and technological education. It is critical to the adoption of robotics in agriculture that support is provided for the next generation of people capable of conceiving of, designing and maintaining robotics in agricultural settings; and working closely with farmers to educate them about the risks and liabilities (and their rights and responsibilities) on the farm.

In his address to the ATSE National Technology Challenges Dialogue in 2016, Professor Sukkarieh argued that introducing rural and regional student to hands-on robotic technologies and activities would give them exciting new career options, potentially enticing young people back to agriculture.[82] This point was also made by Dr Matt Wenham, ATSE Executive Manager of Policy and Projects, who suggested that agricultural workers in the digital age are mechanical and robotics engineers, computer scientists and hydraulic engineers.[83] Speaking of the future of small scale robots, SwarmFarm's company chairman (and former Queensland Premier) Campbell Newman has said he believes there is a need to prepare regional Australia for technological jobs — "people who can write code, people who can repair robotic systems and develop things for farmers' new applications."[84]

To ensure the continued development of robotics applications in agriculture, there is a case for greater training development and delivery in coordination with farmers, technology companies, education providers and researchers. While courses that bridge agriculture and technology exist in Australia, practical advances for farmers in advanced technologies like robotics may require more intensive collaborations, driven by farmer-identified needs. An example is provided by the AgTech Innovation Centre in the USA.[85]

There is also a need for farmer-friendly guidance that sets out the risks and liabilities of adopting different robotics products on the farm. The guidance should demystify common concerns with insurance, ethics, standards, data ownership and protection with the aim of addressing both the real and perceived rights and responsibilities of farmers, and sources of additional legal advice.

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Fact Sheet: Robotics

Background

- Robots are machines that can be programmed to collect and process data, operate autonomously, sense and respond to their surroundings and move themselves around their environment. The most common applications of robotics in agriculture are AgBots that are variously equipped with sensors for navigation, including cameras and encoders.
- In agriculture, robotics applications anticipated for greatest adoption include milking (both mobile and static), autonomous small robots (data scouts, weeding), autonomous tractors, robotic fruit picking, and agricultural drones (spraying helicopters).

Opportunity costs

- The greatest advantage of robots for farmers is to reduce operating costs. For a farm investing $100,000 per annum on insecticides, herbicides, and fertilisers, robots could reduce these costs by 40 per cent due to the bots' ability to spread chemicals in the precise locations and in optimum volumes.
- Agbot ll, demonstrated in Bundaberg in late 2016, is estimated to potentially save Australia's farm sector $1.3 billion a year by reducing the costs of weeding crops.

Regulatory and other issues

- Regulatory issues for robotics are highly context-specific. The regulatory issues for autonomous vehicles with pesticide spraying capabilities are very different from those used in milking sheds.
- Autonomous robots on farms can be liable for damage to people, property or crops. There is a need for farmer-friendly guidance that addresses common concerns (such as insurance, ethics, liabilities, data ownership and protection) and clarifies the rights and responsibilities of farmers.

Action required

- For the potential of robotics to be realised, the agricultural sector needs to train or attract people with skills in mechanical and robotics engineering, computer design and coding. While courses that bridge agriculture and technology exist in Australia, the adoption by farmers of advanced technologies like robotics requires more intensive collaborations, driven by farmer-identified needs.
- There is also a need for standards that support greater interoperability of robotic hardware and software systems. Lack of coordinated data and safety standards for robotic systems is slowing take-up.

Case study:
Robotics

The Technology

- Robots are machines that can be programmed to collect and process data, operate autonomously, sense and respond to their surroundings and move themselves (or their parts) around their environment. Recent advancements in the field robotics have been made possible by the use of microprocessors and microcontrollers with the intelligent combination of servo motors, sensors and actuators.
- Robotics is the continuous endeavour of robotics engineers to make machines capable of performing tasks as delicately as human can do and the complicated, tough and repeated tasks which humans would prefer not to do. Robotic applications are applied to different machine types and structures, such as stationary robots, wheeled robots, aerial robots and legged robots.
- At present, some of the things robots aid farmers with include inspecting crops, counting yields, milking cows, digging weeds and herding livestock. Their most prominent application has been in the development of auto-steer machinery such as tractors that can be directed by GPS that controls the movement of the vehicle along set pathways. The most common applications of robotics in agriculture are AgBots that are variously equipped with sensors for navigation, including cameras and encoders.

Robotics in Australia[1]

- In Australia, labour costs for fruit and vegetable farmers can range for 20 to 40 percent of operational costs, and farmers often experience a shortage of skilled labour. Robotic technologies help to address this challenge.
- Two Australian agricultural robots have attracted particular attention: Harvey, which has been picking capsicums and RIPPA (Robot for Intelligent Perception and Precision Application) which tends lettuces.
- Harvey combines robotic vision and automation to identify and pick capsicums. It achieved a detachment rate of 90 per cent in 2016 and work has been underway to increase this figure. Harvey has been developed by QUT with support from the Queensland Government. There are plans to adapt the technology to other crops such as mangoes and avocados.
- RIPPA can estimate yield, spray weeds and fertiliser in a lettuce crop. It includes a collection of sensors and sophisticated algorithms that can detect (and spray) weeds from amongst the crop as well as foreign objects such as stone, glass or metal. The next step is to build systems that can remove the weed and the foreign object, thereby reducing the need for labour and providing greater assurances of food safety. RIPPA is being developed at Sydney university with support from Hort Innovation.

[1] Note to AgriFutures: Pictures of the technologies describes below can be found at: https://research.qut.edu.au/digital-agriculture/projects/harvey-the-robotic-capsicum-sweet-pepper-harvester/ http://www.farmweekly.com.au/news/agriculture/general/politics/robot-that-detects-weeds-what-a-rippa/2753518.aspx

Lost opportunities

- Robotics have a wide variety of applications in agriculture, making it challenging to estimate the opportunity costs of any take-up of this technology that is lower than that of our competitors.
- The greatest advantage that robots offer farmers is their ability to reduce operating costs. For a farm investing $100,000 per annum on insecticides, herbicides, and fertilisers, it is claimed that robots could reduce these costs by 40 per cent due to the bots' ability to spread chemicals in the precise locations and in optimum volumes.
- Queensland University of Technology's Agbot II is able to not only identify and spray weeds, but using its robotic vision it can decide in real time which weeds should be sprayed with herbicide and which should be removed by mechanical or thermal methods. This robot is claimed to be effective and efficient and is predicted to be able to save Australia's farm sector $1.3 billion per year. This is for just one application of robots in agriculture.
- Accelerating the adoption of robots in agriculture is important is Australia is to maintain its international competitiveness in agriculture

What needs to be done

- It is critical to the adoption of robotics in agriculture that support is provided for the next generation of people capable of conceiving of, designing and maintaining robotics in agricultural settings. Professor Sukkarieh of the Australian Centre for Field Robotics has argued that introducing rural and regional student to hands-on robotic technologies would give them exciting new career options, potentially enticing young people back to agriculture. This point was also made by Dr Matt Wenham of the Academy of Technology and Engineering who suggested that agricultural workers in the digital age are mechanical and robotics engineers, computer scientists and hydraulic engineers.
- To ensure the continued development of robotics applications in agriculture, there is a case for greater training development and delivery in coordination with farmers, technology companies, education providers and researchers. While courses that bridge agriculture and technology exist in Australia, practical advances for farmers in advanced technologies like robotics may require more intensive collaborations, driven by farmer-identified needs.
- There is also a need for farmer-friendly guidance that sets out the risks and liabilities of adopting different robotics products on the farm. The guidance should demystify common concerns with insurance, ethics, standards, data ownership and protection with the aim of addressing both the real and perceived rights and responsibilities of farmers, and sources of additional legal advice.

Section 7

Sensors

Sensors

Sensors are devices that detect, measure and report on factors such as moisture levels, temperature, plant condition, the location and health of livestock and the presence (or absence) of chemicals and bacteria.

Sensors can take many different forms.For example, biosensors use livin organisms, enzymes and antibodies to detect pesticide residues and bacteria. Others detect electromagnetic radiation in the ultraviolet to visual to infrared spectrum.

7.1 Relevance to agriculture

Sensors can provide a range of different data to farmers. Remote sensors, installed on satellites, drones or aircraft can provide information on crop development and crop condition. For example, information provided by sensors can tell a farmer when it is necessary to irrigate a crop or spray it to counter a disease or pest present.

Sensors located at a milking shed can read a tag or microchip on the ear of a dairy cow and allow farmers to monitor the milk supplied by individual cows. They might also measure a cow's temperature and provide early detection of health issues that require veterinary treatment. Sensors are widely used in horticulture to monitor conditions in greenhouses and vineyards. In greenhouses, sensors are often incorporated in automated control systems that help to manage temperature and moisture.

Sensors can also be an important tool for helping farmers to manage their compliance with food safety and environmental regulation. For example, radio-frequency identification (RFID) tags are widely used in monitoring livestock from birth to slaughter in order to provide traceability. Similarly, there are applications for monitoring cold chain logistics by means of RFID. For example, the use of microbial growth models combined with information from an active RFID allows the prediction of microbiological safety and quality of foods, by monitoring the environment without recourse to further microbiological analysis. In this way, immediate decisions on the quality and/or safety of fresh produce can be made based on the temperature profile of the supply chain.

Sensors are used by irrigation companies to measure and control water within the supply network and for delivery to the farm. Irrigators use on-farm sensors to ensure the accurate application of water to a crop, which reduces costs, helps to prevent waterlogging and reduces water waste. Sensors are also important in accounting for water use by different parties and ensuring compliance with environmental regulations.

Recent advances in ground-based sensors have potential applications in agriculture. Networks of sensors and smart devices can be connected by low power wireless area networks (LPWANs). In some cases, these networks use existing mobile telecommunications networks. Some LPWANs have a 50km range.

Sensors can provide the basis for better informed decision making in agriculture. The ability of farmers and growers to efficiently collect sensor data from multiple sources in real time and respond accordingly can enable faster and more effective decision making, which in turn should enable productivity gains.

The Australian Farm Institute estimates digital agriculture will provide gains of 10 - 15 percent in cropping systems.[86] Meat & Livestock Australia's preliminary findings on the impacts of digital agriculture suggest productivity gains could be in the range of 4 - 9 per cent for animal production monitoring and 4 - 13 per cent for animal health monitoring. In addition, sensing technologies could contribute to digital agriculture delivering a 13 - 26 per cent productivity gain for soil fertility improvements and 9 - 11 per cent for better feed allocation in livestock systems.[87]

7.2 Issues and risks

Reliability issues

Sensors need to report accurately, consistently and in a timely manner. Performance standards have been developed for some sensors. However, there is some evidence that sensors can become unreliable as a result of incorrect settings, dirt and GPS errors. The liabilities for faulty and incorrect data appear to be subject to Common Law.

Data ownership

The question of who owns some data collected by sensors is a complex issue. Farmers would argue that they should own their data for commercial reasons. However, proponents of digital agriculture suggest the value of data will be in its consolidation into regional sets. The situation is further complicated in situations where multiple parties are providing hardware and software to a farmer. Parties such as developers, systems integrators, agronomists, other farmers and telecommunications providers are likely to have access to the raw data for interpretation and support purposes.

Access to raw data is an area of concern, particularly where it could led to negative consequences for the farmer. For example, data on herd health might be used in campaigns to undermine farmers. Banks and insurance companies could use predictive yield data to determine whether to provide a loan or insurance.

Standards

There are no uniform standards for sensors, so it is difficult to assess the capacity and value of available products. The only good data is accurate data, so sensors must be robust and reliable. If sensors fail or transmit faulty data, they have the potential to harm business operations. A lack of standards can slow down adoption as farmers wait for evidence of the value of the technology and identify the most suitable sensors for meeting their needs.

If sensors are faulty and transmit incorrect data, then the manufacturer would be liable for compensation. If the data is interpreted incorrectly leading to damages or losses on farm it can be assumed that normal liabilities or indemnities relating to operator error would apply.

System security

Malicious software, like the Stuxnet worm, specifically target programmable logic controllers that interface with sensors. Cybersecurity may also be a problem, particularly if the integrity of cloud-based storages is compromised by virus or hacking events. Again, it is difficult for nations to make policy in relation to global applications and it is not clear where potential business losses could be recovered in the event of a cyber-attack.

Managing large volumes of data

Sensors generate large amounts of data. In 2013 it was estimated that only 22 per cent of data collected globally was stored in a way that made it suitable for analysis, and less than 5 per cent of that data was analysed. It is estimated that by 2020 the amount of data available for analysis could be as much as 35 per cent of all data collected. This is clearly an enormous volume of data to analyse and turn into information that has useful application.

If farmers are using sensors to transmit data wirelessly, then the quality and capacity of the internet to cope with that volume will be important. The difficulty accessing reliable internet in parts of rural and regional Australia is well documented. The capacity of existing internet connections and low levels of downloadable data will restrict the gathering and storing of big data.

Technical support

There are concerns among agricultural industry representatives that the lack of technical support personnel to process data into information is already having a negative impact on the Australian grain industry's productivity, particularly around the peak periods of planting and harvest. There are concerns that as the number of sensor applications increase, farmers, agronomists and advisers may not be equipped to translate the data into formats suitable for effective decision-making.

7.3 Opportunity costs

It has been estimated that, with the use of sensors (both remote and proximal) and variable rate technologies, Australia's gross value of agricultural production could be increased by $2.3 billion per annum.[88] To achieve these gains, sensors would have to be used in conjunction with other technologies (e.g. big data, actuators, etc).

Sensors are already available for a number of applications in agriculture. However the take-up of sensor technology varies widely. While cotton growers have a 78 per cent adoption rate (mainly collecting data on water use), the rate for grains is 48 per cent and beef only 10 per cent.[89] This suggests that there is scope for increased use of sensors. Addressing barriers to the take-up of sensor technology has the potential to provide significant gains for Australian agriculture.

7.4 Action required

The use of sensors (including RFID) is still a relatively young market with good growth potential. The number of applications is expected to grow in the next years. To date, innovation rather than cost reduction has been the driver for sensor adoption. However, some applications of sensors are helping farmers to improve their productivity at a price that makes the necessary investment economically attractive.

However, cost is a barrier to the wider adoption of sensors. For example, an average RFIDs can cost roughly 20 - 30 cents per tag. This is costly compared to barcode labels, which costs less than one cent. The higher cost of an RFID tag makes it uneconomic to incorporate them on individual retail items with relatively low unit value, such as fruits and vegetables.[90] The Rabobank survey[91] found that less than 40 per cent of farmers using sensors identified an improvement in profitability from their use.

Hence, R&D to reduce the costs of RFID tags to below one cent is continuing. R&D is also underway in areas such as improving the readability of RFID tags, improve the battery life in active tags and increase the variety of information collected by sensors and improve the ability to process the data collected. A few small Australian companies working in this area (e.g. Myriota) have the potential to make a significant contribution to increasing Australian agricultural productivity.

The agricultural sector could gain significant benefits from improvements in sensors by doing the following:

- R&D Corporation funding of the development of new more robust and more affordable sensors, particularly for use with animals
- supporting some demonstration projects that take advantage of the functionality of active RFIDs and provide an acceptable return on investment in these devices (possibly in the dairy industry)
- publicising successful applications of sensors in agriculture so that growers are aware of the possibilities from using these devices — expanding agricultural demand for sensors will bring the price down and result in the development of the more robust products that the sector needs
- demanding more government action to improve Australian internet security — sensor networks need better protection from hacking
- work with industry organisations to establish performance standards for sensors used in agriculture, which would encourage adoption, as farmers would be better able to compare different sensors and identify the sensors that are best able to meet their needs.

[86] Keogh, M and Henry, M 2016, The Implications of Digital Agriculture and Big Data for Australian Agriculture, Research Report, Australian Farm Institute. [87] RIRDC 2016, Transformative technologies – Sensors, publication No 16/032 [88] Perrett E, Heath R, Laurie A and Darragh L 2017, Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia, November 2017 [89] Rabobank 2017, Does sensor adoption make cents? accessible on 31 July 2018 via https://www.rabobank.com.au/media-releases/2017/170801-agtech-does-sensor-adoption-make-cents/ [90] Ruiz-Garcia L and Lunadei L 2011, The role of RFID in agriculture: Applications, limitations and challenges, Computers and Electronics in Agriculture 79:42–50, accessed on 18 May 2018 via https://www.sciencedirect.com/science/article/pii/S0168169911001876 [91] Rabobank 2017, Op cit.

Fact Sheet: Sensors

Background

- Sensors are devices that detect, measure and report on information such as moisture levels, temperature, plant condition, the location and health of livestock and the presence of chemicals or bacteria.
- Sensors can take many different forms (e.g. biosensors use living organisms, enzymes and antibodies to detect pesticide residues and bacteria, while other sensors detect electromagnetic radiation in the ultraviolet to visual to infrared spectrum). Radio-frequency identification (RFID) tags are widely used with sensors to monitor livestock and provide traceability.
- Sensors can provide the basis for better informed decision making in agriculture. They enable farmers and growers to efficiently collect data from multiple sources in real time, supporting faster and more effective decision making.

Opportunity costs

- A recent estimate put the potential benefits from greater use of sensors (both remote and proximal) in Australian agriculture at $2.3 billion per annum. To achieve these benefits sensors would have to be used in conjunction with other technologies such as big data.

Regulatory and other issues

- Sensors need to report accurately, consistently and in a timely manner. However they can become unreliable as a result of incorrect settings, dirt and GPS errors. Establishing sensor performance standards would enable users to better compare different products and identify those that are best able to meet their needs.
- The cost of sensors is a barrier to adoption. While an average RFID currently costs roughly 20–30 cents per tag, a barcode label costs less than one cent. R&D is underway to improve the readability of RFID tags, improve the battery life in active tags and increase the variety of information collected.
- The integrity of cloud-based sensor data can be compromised by viruses or hacking events. Malicious software can specifically target programmable controllers that manage sensors. Sensor systems need to be designed to address such threats.
- The ownership of, and access to sensor data collected on a regional basis can raise issues for individual farmers. The difficulty accessing reliable internet in parts of rural and regional Australia is well documented. The capacity of existing rural internet connections may restrict the gathering and storing of farm data.
- The lack of technical support personnel to process and interpret sensor data is having a negative impact on agricultural productivity. Farmers, agronomists and advisers may not be equipped to manage and interpret data for effective decision-making.

Action required

- The agricultural sector could gain significant benefits from improvements in sensors by doing the following:
- R&D Corporation funding of the development of new more robust and more affordable sensors, particularly for use with animals
- supporting projects that demonstrate the functionality of active RFIDs and provide an acceptable return on investment (e.g. in the dairy industry)
- publicising successful applications of sensors in agriculture so that growers are aware of the possibilities from using these devices — expanding agricultural demand for sensors will bring the price down and result in the development of the more robust products that the sector needs
- demanding more government action to improve Australia internet coverage and security
- work with industry organisations to establish performance standards for sensors used in agriculture, which would encourage adoption, and help farmer to identify the sensors that best meet their needs.

Section 8

Drones

Drones

Drones are unmanned aerial vehicles (UAVs) piloted remotely through a ground-based controller with a communication system between the two. The degree of automation involved can vary between remote control by a human operator or autonomously by onboard computers. While the first application of UAVs has been primarily military, they may be used commercially or privately. In Australia, their operation is regulated by the Civil Aviation Safety Authority (CASA).

Commercial and recreational use of UAVs has focused on aerial photography, data collection and agriculture. The capacity of UAVs to record an array of data for later analysis makes them ideal for surveillance and monitoring activities.

8.1 Relevance to agriculture

The use of UAVs in agriculture has increased over the last five years and has expanded from simple applications such as crop spraying and livestock monitoring, to multi-spectral imaging used to identify early signs of plant stress. In 2015, the Scottish Agriculture Office noted the following applications of UAVs in land management:[92]

- surveying large crop areas for poor growth
- check on animals in large grazing areas, with the possibility of automatic counting
- infrastructure management, such as roofs of building, field drainage, and the state of fencing
- efficient inspection of trees, invasive species, and
- light payload delivery.

In addition to these uses, Australian applications include crop stress, disease surveillance, fire monitoring, weed detection and property surveying and monitoring.[93]

Advances in technology and reductions in production costs have made more sophisticated use of UAVs available to the agricultural sector. Multi-spectral imaging, particularly near-infrared, can detect stressed crop or weeds and help create normalised digital vegetation index (NDVI) maps. The resulting data can also be linked to GPS-enabled treatments such as fertiliser or pesticide and herbicide application, thereby improving yield and reducing input costs. Sophisticated UAVs have also been used to create 3D images of the landscape to plan for future expansions and upgrading.[94]

8.2 Issues and risks

The issues and risk surrounding the use of drones focus on operator management and minimising the impact of their use on the public with regard to safety, privacy and trespass. A common concern in many countries is ensuring that the regulatory framework keeps pace with technological advances and common usage of drones and does so in a manner that supports beneficial use and minimises public harm.[95]

In Europe there is a variety of different regulatory requirements for UAVs. The European Commission commenced a project to collate rules and regulations relevant to UAVs in 2017.[96] Although national safety rules apply, the rules differ across the EU and a number of key safeguards are not addressed in a coherent way. For this reason, the European Aviation Safety Agency (EASA) has recently started a move towards an EU regulation for drones.[97] Adoption is expected by the end of 2018.

Canada adopted new regulations to control ‘recreational’ drones in 2017. These are more restrictive that similar US regulations.[98] Transport Canada is proposing a national standard of drone regulations in 2018 to overcome what up to now has been “a patchwork quilt of varied applications of the regulations from province to province”.[99] In the USA drones are regulated by the FAA. The impact on agriculture of FAA regulation of drones was reviewed in 2015[100] US regulation appears quite restrictive.

The Food and Agriculture Organization has published a guide to laws governing the use of UAVs. As of April 2016, 73 per cent of African, Caribbean and Pacific Group countries did not have any rules or regulations in place; 19 per cent had some regulations in place; and 8 per cent were in the process of formulating them.[101]

Certification

The use of drones is regulated by CASA under Part 101 of the Civil Aviation Safety Regulations 1988. While CASA had first issued guidance and regulations regarding unmanned vehicles in 2002, significant amendment of these regulations did not occur until September 2016.

Between 2002 and 2016, the use of drones for commercial purposes required the operator to be CASA certified with such use defined as “any remotely piloted aircraft operated for… hire and reward, remuneration, or any other consideration”. The certification process involved a remote piloting certificate and an operating certificate.

The rules in place since September 2016 provide for commercial operations of very small drones (weighing less than 2 kg) to be conducted without the need for a remote pilot license or operator’s certificate, provided that standard operating conditions established in the new regulations are followed. Small drones (2 - 25 kilograms) can be operated over a person’s own land for certain purposes and under the standard conditions without the need for certification and a license. These “certain purposes” are defined as the commercial use of the drone (i.e. as a contribution to the person’s business or commercial operations) but without remuneration being made to the drone operator.

The use of medium drones (25 — 150 kilograms) for the same purposes and under the standard conditions now only require a remote pilot's license. Operators of large drones, as well as smaller drones for other nonrecreational purposes, are still required to obtain a remote pilot license and operator's certificate. Large drones must also have airworthiness certification.[102]

Safety

The standard operation conditions required by CASA are premised on the need for public and operator safety. These conditions regulate the height and distance of drone flight and define the meteorological conditions for flight. They include:

- drones may only be flown during daylight and at an altitude no higher than 120m
- visual line-of-sight must be maintained (able to see the drone with your own eyes and without the aid of any device such as binoculars or remote visual feed)
- the drone must be kept at least 30m from other people and maintain a distance of at least 5.5km from controlled aerodromes, and
- drone cannot be flown over or near an area affecting public safety or where emergency operations are underway (without prior approval).[103]

Privacy

The legislative and regulatory framework for privacy in Australia has been described as a 'fractured landscape' consisting of Commonwealth, state, territory and common law principles.[104] In general, the Commonwealth Privacy Act (1988) and the Australian Privacy Principles provide for the protection of personal information collected by government agencies and many private sector organisations. There is no overarching privacy protection for individuals and the Act is not intended to protect against intrusions into an individual's private seclusion. There are state and territory provisions against the use of surveillance devices to record or monitor private activities, although their applicability to drones may be undermined by the language of the legislation where there are specific references to outdated or fixed technology.[105]

The standard operating conditions required by CASA which limit non-certified commercial use to the operator's private property appear to address any privacy concerns that may be raised in relation to agricultural use of drones.

Trespass and nuisance

Issues of trespass and nuisance may be more relevant considerations in the agricultural use of drones. Current provisions state that no action for trespass or nuisance can be taken by reason of the ordinary flight of an aircraft over any property at a 'reasonable' height. However, an intrusion into airspace over another person's property may amount to trespass if it is at a height the interferes with the 'ordinary use and enjoyment' of the occupier.[106]

The current CASA regulations do not provide guidance on the flight of height to avoid trespass. However, as with privacy concerns, the standard operating conditions and certification requirements would appear to minimise the risk of trespass and nuisance in agricultural applications.

8.3 Opportunity costs

Currently increased yields of 10 per cent are commonly being reported for the use of drones in Australian table green vegetables, orchards, banana plantations and olive groves.[107] In addition, broad acre farmers are reported to be expecting a 5 per cent increase in yield from the use of drones. A wheat belt farmer with 20,000ha and a yield of 2.5 tonnes per hectare at $180 per tonne could expect a payback on $450,000 in just one year on the basis of a $50,000 investment in a drone. Other sources claim that 20 per cent increases in yield are possible.[108] If the regulations governing the use of drones are relaxed, benefits to producers/growers would be very large. Australia currently has approximately 12 million hectares planted in wheat.[109] If just 2 million additional hectares of wheat crop were to gain benefits commensurate the example described above, the wheat growing sector would be $2 million per annum better off.

Deregulating the use of drones and taking other steps to increase their use will provide significant benefits to the sector.

8.4 Action required

The use of NDVI mapping is not new to agriculture and has been used through satellite and aircraft-based surveying for almost a decade in Australia. However, drones can provide far more detailed map resolution, measuring areas within centimetres, compared to metres, and do so more cheaply than satellite or aerial surveying.

Recent research has identified the benefits and challenges that arise from UAV mapping. Research teams from Deakin University's Centre for Regional and Rural Futures have investigated the use of UAVs to produce detailed spectral data to inform water and crop management and predict crop yield. Results from the research indicate that early and targeted use of UAV-assisted NDVI mapping is beneficial although refinements to imaging and data analysis will further improve results.[110,111]

The use of UAVs in agriculture is likely to increase as image quality improves and data compression becomes more cost effective. These improvements will lower cost inputs, increase efficiency and crop yields. At the moment, the costs of UAVs or UAV-assisted agronomy and the need to maintain 'ground truthing' or visual inspection of crops to differentiate between weeds and crops are a deterrent to faster uptake.

The growth in demand for 'beyond line of sight vehicles' and the regulatory response to their use has implications for Australian agriculture. The large acreage commonly seen in Australian agriculture is likely to lead to strong demand for this type of drone and their operationalisation will be shaped by the regulatory response.

The agricultural sector should engage with CASA, with a view to reducing the regulation of drones used in agriculture in the following ways:

- the restriction to line-of-sight operations is not appropriate for large farms — CASA should be asked to remove this requirement for rural properties over a specified size
- the requirements for a commercial operators' certificate include a requirement to develop an operations' manual and an operations library. The operations manual must set out how the commercial operator (in this case, the farmer) plans to safely manage the risks inherent in operating a remotely piloted aircraft. It includes training, compliance, maintenance, route designation and other key obligations. For operations on farmland, all this appears to be excessive. A standard operational manual should be developed by the Department of Agriculture and Water, in consultation with CASA, for use in agriculture
- agricultural users of drones need to understand their legal liabilities — an information paper prepared by an appropriate legal authority would be useful for agricultural contractors and owner-operators — it would need to be kept up-to-date to reflect emerging case law
- farmers also need up-to-date information on where to go for training in the use of drones.

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Fact Sheet:
Drones

Background

- Drones are unmanned aerial vehicles (UAVs) piloted remotely through a ground-based controller with a communication system between the two. They can be controlled remotely by a human operator or operate autonomously with onboard computers.
- Agricultural applications of drones include aerial photography and data collection. Their capacity of UAVs to record an array of data for later analysis makes them ideal for surveillance and monitoring activities.
- Agricultural applications of drone are now expanding to crop spraying and livestock monitoring. Multi-spectral imaging can detect stressed crop or weeds and help create digital vegetation index maps. The resulting data can also be linked to GPS-enabled fertiliser or pesticide and herbicide application, thereby improving yield and reducing input costs.

Opportunity costs

- Increased yields of 10 per cent are commonly being reported for the use of drones in Australian green vegetables, orchards, banana plantations and olive groves. Broad acre farmers are reporting an expecting 5 per cent increase in yield from the use of drones.
- A wheat belt farmer with 20,000ha and a yield of 2.5 tonnes per hectare at $180 per tonne could expect a payback of $450,000 in just one year on the basis of a $50,000 investment in a drone.
- If the regulations governing the use of drones are relaxed, ACIL Allen estimates that the benefits to producers/growers would be more than $2 million per annum.

Regulatory and other issues

- The use of drones is regulated by Civil Aviation Safety Authority (CASA). CASA regulates the height and distance of drone flight and the meteorological conditions for flight. Drones can only be flown during daylight hours, at least 30 metres from other people and within a 'line of sight' from the operator.
- Restrictions on the use of drones limits their use in Australian agriculture. The certificate requires an operations' manual and an operations library that includes training, compliance, maintenance, route designation and other obligations.
- Agricultural users of drones need to understand their legal liabilities. An information paper prepared by an appropriate legal authority, would be useful for agricultural contractors and owner-operators. It would need to be kept up-to-date to reflect emerging case law.

Action required

- The agricultural sector should engage with CASA to reduce the to line-of-sight operation restriction for rural properties over an agreed size, and streamline the requirements for the commercial operators' certificate.
- A standard operational manual should be developed by the Department of Agriculture and Water, in consultation with CASA, for use of drones in agriculture.

Section 9

Synthetic Biology & Gene Editing

Synthetic Biology & Gene Editing

Synthetic biology involves the rational design and construction of novel nucleic acid or protein sequences/pathways that would not be expected to arise through natural selection. It involves a convergence of advances in chemistry, biology, computer science, and engineering. Synthetic biology is a new field that emerged in the early 2000s.

Gene editing (also called genome editing) involves a group of what is often referred to as new breeding technologies (NBTs) that can be used to change an organism's DNA, allowing genetic material to be added, removed, or altered at particular locations in the genome. Several approaches to gene editing have been developed. The best-known technology, which is faster, cheaper more accurate and more efficient than other methods, is known as CRISPR-Cas9.[112,113]

Gene editing is a key tool used in synthetic biology. It allows more rapid breeding of crop varieties compared to traditional breeding or even to genetic manipulation (GM) techniques[114] Gene editing is more precise and much quicker that GM.

Gene drives cause a gene to spread through a population at a rate faster that would normally be the case. Naturally occurring gene drive mechanisms have been known for some time. Advances in gene editing have made it possible to design synthetic gene drives. Proof of concept studies have demonstrated the effectiveness of gene drives in the control of vector-borne diseases by suppressing the pest population involved (e.g. fruit fly or mosquitos).[115]

9.1 Relevance to agriculture

Although traditional plant breeding has been very successful in increasing yields, it can take more than ten years to develop new improved varieties using this approach. To meet the needs of a growing world population, increases in crop production of around 100 per cent are going to be needed by 2050.[116] Synthetic biology and gene editing provide the tools to achieve this target. The advantages of gene editing over conventional and earlier transgenic approaches are the low cost, ease and speed of use, lack of transgenes permanently introduced into crop germplasm, and the high level of multiplexing possible (i.e. editing of multiple gene targets).[117]

Synthetic biology

Synthetic biology has applications in industry, medicine, the environment and agriculture. In agriculture, synthetic biology can be used to address animal diseases, the development of disease-and pest-resistant crops, and the development of crops to provide specialty chemicals and biofuels.

For example, AquAdvantage salmon is a genetically modified Atlantic salmon developed by AquaBounty Technologies. A growth hormone-regulating gene from a Pacific Chinook salmon and a promoter from another fish species were added to the Atlantic salmon's 40,000 genes. This increases the speed at which the fish grows without affecting its ultimate size or other qualities.[118] The USFDA approved the application to sell the AquAdvantage salmon to US consumers in November 2015, stating that "AquAdvantage salmon is as safe to eat as any non-genetically engineered (GE) Atlantic salmon, and also as nutritious."[119]

Synthetic biology has also been used to help combat bovine tuberculosis through the development of a new tuberculin skin test. This new test, displayed on polyester beads, has high specificity.[120] Managing this disease is a significant problem is other countries. It is not present in Australia.

Transgenic oil seeds can provide an additional source of long chain polyunsaturated fatty acids for human consumption, reducing cardiovascular disease.[121]

Gene editing

Results of gene editing are already in the US market, include non-browning Arctic™ apples and mushrooms (see below). New breeding technologies have been used to confer mildew resistance in wheat by disrupting three genes.[122] The drought resistance of maize has been enhanced by gene editing.[123]

Gene drives

Using gene drives to control organisms that damage important crops or carry crop diseases would provide a major boost to agricultural productivity and competitiveness. Introducing genes that reverse pesticide or herbicide resistance would help farmers to continue to control insects and weeds by chemical methods. Suppressing or modifying invertebrate pests would also be valuable for farmers. Targets for suppression include fruit fly pests, various moths, mites, thrips and other pest invertebrates.

9.2 Issues and risks

Synthetic biology and gene editing are expected to raise the same sorts of concerns as genetic modification (GM) when it was first introduced more than twenty years ago. After more than 20 years' experience with GM canola there are still a ban on growing this crop in South Australia and Tasmania.

Public acceptance

One of the challenges is to explain to the public that gene editing is different from GM. Rather than inserting a foreign gene (as is the case for GM), gene editing involves editing an existing gene to speed up the development of an organism. This is something that could happen normally over time. Some media appears unable to distinguish between GM technology and gene editing.[124]

Organic farmers have expressed opposition to proposed changes to the OGTR regulations. There is a risk that some of the more contentious applications of gene editing in relation to human embryos in China will spill over into opposition to gene editing in agriculture.

Regulation

In the USA, approval has been given for the non-browning Arctic™ apple, developed using a synthetic biology technique to 'silence' four genes.[125] In April 2016, the USDA's Animal and Plant Health Inspection Service decided that the first CRISPR-edited food, a non-browning white button mushroom, did not need to be regulated. More recently, in June 2017 the USFDA competed a consultation period on food derived from plants produced using gene editing.[126] It is not clear what changes in regulation, if any, will follow.

Currently, gene editing in Australia is subject to the same regulatory provisions as GM. In 2012 and 2013, FSANZ convened workshops that concluded that food derived from gene edited crops with small deletions (e.g. those produced using CRISP) did not need to be considered to be GM, but where inserted genetic material was involved, GM regulations should continue to apply. FSANZ is currently reviewing how the Food Standards Code applies to food derived using new breeding techniques in plants and animals.[127] The period for comment closed on 19 April 2018 and is expected to be completed in mid-2018. If it is decided to amend the Code, this could take more than another year.

However the Gene Technology Regulator has been conducting a review of the regulations and is reported as having the view that "if there is no risk case to be made when using these new technologies, in terms of impact on human health and safety for the environment, then there is a case for deregulation."[128] Following a consultation period which closed in February 2018, the Regulator is considering the issues raised in submissions and finalising draft amendments to the regulations. The Regulator may then propose the amendments to the Commonwealth and State and Territory governments for their agreement. If there is agreement, the OGTR will commence the Commonwealth regulation-making process.[129] If the changes proposed by the OGTR are not accepted, there will additional costs and delays in obtaining approvals for Australia's agriculture sector.

Potential impact on trade

There is a risk that other countries to which Australia exports agricultural commodities and food may place barriers to the entry of gene-edited products. There is also a risk that other countries (particularly the USA and China) may move ahead faster than Australia in approving agricultural applications of synthetic biology and gene editing, putting Australian growers at a competitive disadvantage.

Specific issues with CRISPR-cas9

A study published in 2013 reported that the use of CRISPR-cas9 resulted in unintended changes in other parts of the genome[130] More recently, another study claimed to find more than 100 unintended large genetic deletions or insertions from the CRISPR-cas9 editing.[131] This paper has now been retracted.[132] While off-target deletions/insertions may not be considered to be a serious problem in agriculture, additional research may be required before approvals can be sought.

Specific issues with gene drives

There are two issues which are expected to delay the implementation of gene drives. One arises from the use of gene drives to insert heritable traits. While this could result is the elimination of pests such as cane toads, its use in mosquitos is more problematic. Eliminating the ability of mosquitos to carry certain viruses would likely be acceptable but eliminating a species of mosquito could have unintended consequences. This is an area where international agreement may be needed before species with heritable traits are released into the environment.

9.3 Opportunity costs

Synthetic biology also has a wide range of applications in agriculture. For example, it has the potential to reduce production costs by improving resilience to pests and diseases. The cost of the top ten invertebrate pests in grain crops in Australia has been examined in a 2013 report commissioned by the GRDC.[133] If the application of synthetic biology to these crops resulted in just a 10 percent reduction in the damage done by these pests, the benefit would be $A36 million annually. Similar economic gains may be possible in animal agriculture, where the cost of parasite, pest and viral diseases of Australian cattle and sheep amount to billions of dollars annually.[134] At present only a few applications of synthetic biology have been approved (in the USA)[135] but more are likely to follow in the near future.

If Australia is to avoid seeing competitors move ahead of us in the adoption of synthetic biology the regulatory environment may need to be updated to the extent necessary to allow the rapid adoption of synthetic biology and gene drives.

Fact Sheet:
Synthetic Biology and Gene Editing

Background

- Synthetic biology involves the rational design and construction of novel nucleic acid or protein sequences/pathways that would not be expected to arise through natural selection. It involves a convergence of advances in chemistry, biology, computer science, and engineering.
- Gene editing involves a group of new breeding technologies that can be used to change an organism's DNA, allowing genetic material to be added, removed, or altered at particular locations in the genome. The best-known of these technologies is CRISPR-Cas9.
- Synthetic biology and gene editing provide tools to make rapid improvements in plant genes. They also have applications in animal species.

Opportunity cost

- The application of synthetic biology to bring about a 10 per cent reduction in the impact of the top ten invertebrate pests in Australia's grain crops could result in benefits of more than $36 million per annum.
- US regulators have approved the use of this technology to increase the growth rate of Atlantic salmon. Australia's farmed salmon production in 2015-16 was worth $A718 million.

Regulatory and other issues

- Synthetic biology and gene editing are expected to raise the same sorts of public concerns as genetic modification (GM) did when it was first introduced even though these new techniques do not usually involve the introduction of different genetic material.
- Regulation of synthetic biology and dene editing in Australia is yet to be resolved, with the Office of the Gene Technology Regulator and Food Standards Australia and New Zealand currently reviewing the need for regulation.

Action required

- The agricultural sector can take steps to accelerate the introduction of synthetic biology in Australia by:
  - pressing the case for national consistency in gene regulation
  - campaigning for the removal of state moratoria on GM crops
  - supporting arguments that gene deletions do not require regulation by OGTR
- AgriFutures should closely monitor an international project to use gene drives to target feral rodents on islands — if this project is successful it could open the way for applications of gene drive technology to rid Australia of some agricultural pests.

9.4 Action required

When articulating the benefits of synthetic biology and gene editing, it is important for the agricultural sector to explain how these technologies differ from GM, and the nature and significance of benefits to consumers as well as to growers.

The use of new breeding technologies such as CRISPR-cas9 face some regulatory uncertainty. Agricultural applications of synthetic gene drives are going to have to await further research and debate. Some additional regulation is likely.

Proposed actions

The agricultural sector can take steps to accelerate the introduction of synthetic biology in Australia, including:

- pressing the case for national consistency in gene regulation, as recommended by the House of Representatives Standing Committee on Agriculture and Industry[136]— the agricultural sector should campaign for the removal of state moratoria on GM crops (as recommended by the Productivity Commission, 2016)[137]
- AgriFutures should closely monitor a project being undertaken by an international consortium (which includes CSIRO) called GBIRd (Genetic Biocontrol of Invasive Rodents), developing gene drives to target feral rodents on islands[138]— if this project is successful it could open the way for applications of gene drive technology to rid Australia of some agricultural pests
- supporting arguments that gene deletions do not require regulation by OGTR
- AgriFutures should support research to demonstrate the effectiveness of gene drives in eliminating a selected agricultural pest, or cane toads in Australia — picking a low-risk project that is likely to command public support.

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[112] CRISPR-Cas9 is an abbreviation for clustered regularly interspaced short palindromic repeats and CRISPR-associated protein 9 [113] NIH undated, What are genome editing and CRISPR-Cas9? accessed on 18 April 2018 at https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting [114] Genetic manipulation, also called genetic modification or genetic engineering, is the direct manipulation of an organism's genes using biotechnology. It includes the transfer of genes within and across species boundaries to produce improved or novel organisms. New DNA is obtained by either isolating and copying the genetic material of interest using recombinant DNA methods or by artificially synthesising the DNA. GM technologies have been used since the 1970s. 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Section

10

Artificial Intelligence

Artificial Intelligence

Artificial Intelligence (AI) is not a new field. The first academic workshop on the then emerging field of AI took place in September 1955.

More recently, rapid advances in other digital domains, such the increased capacity of sensors, data storage and computer processing capacity have been drivers for more rapid progress in AI.

A 2018 report by the UK House of Lords into AI found that there was no widely accepted definition of AI.[139] The report noted that this was perhaps unsurprising given the absence of any widely-accepted definition of organic intelligence, against which AI is often compared. The report decided to adopt the definition used by the UK Government in its Industrial Strategy White Paper,[140] which defined AI as:

> "Technologies with the ability to perform tasks that would otherwise require human intelligence, such as visual perception, speech recognition, and language translation."

AI refers to a set of techniques aimed at approximating some aspect of human or animal cognition using machines. The UK House of Lords report identified a number of common terms used in the field of AI, namely:

- Algorithm — A series of instructions for performing a calculation or solving a problem, especially with a computer
- Expert system — A computer system that mimics the decision-making ability of a human expert by following pre-programmed rules, such as 'if this occurs, then do that'
- Machine learning — One particular form of AI, which gives computers the ability to learn from and improve with experience, without being explicitly programmed
- Neural network — Also known as an artificial neural network, this is a type of machine learning loosely inspired by the structure of the human brain, and
- Deep learning — A more recent variation of neural networks, which uses many layers of artificial neurons to solve more difficult problems.

10.1 Relevance to agriculture

The McKinsey Global Institute has examined the learnings from over four hundred case studies of the adoption of AI.[141] They concluded that 'deep learning' techniques could contribute up to 40 per cent of the total potential value that AI could provide. The report concluded that the application of AI could potentially improve performance in the agriculture sector by 55 per cent, compared to using other more conventional analytics techniques. McKinsey estimated that AI could potentially add between 1 and 9 per cent to the 2016 revenues of various industries. However, they also noted that the amount of benefit that might ultimately be gained depended on competitive and market dynamics and the decisions made by organisations and governments. In the case of the agricultural sector they estimated the potential value of AI to be $0.1 - 0.2 trillion. This corresponded to between 2.4 and 3.7 per cent of sector revenues.

Agricultural applications of AI, especially on—farm, appear likely to grow only slowly. Likely early adopters include areas such as horticulture and crops. For example, a robotic system (called LettuceBot) has been developed by the US firm Blue River Technology. The system can be towed across a field, take 5,000 photos of plants per minute, and use computer-vision algorithms to identify surplus plants and spray targeted bursts of herbicide directly on them. LettuceBot can identify over 1.5 million lettuce plants per hour and act 90 times per second, all with 2.5 cm precision.

10.2 Issues and risks

Regulatory issues

Currently there are few regulatory issues associated with the use of AI in agriculture. Any future regulation of AI is likely to be driven by its use in sectors other than agriculture, but there could be spill-over effects.

The nature and scale of the risks posed by AI is the subject of much study. Concerns centre on issues of privacy, safety and certification, taxation and public accountability, among others. The UK House of Lords report found that

Blanket AI—specific regulation, at this stage, would be inappropriate. We believe that existing sector-specific regulators are best placed to consider the impact on their sectors of any subsequent regulation which may be needed.

It did however recommend that a cross-sector ethical code of conduct, or 'AI code', suitable for implementation across public and private sector organisations which are developing or adopting AI. It identified five overarching principles for such a code:[142]

- Artificial intelligence should be developed for the common good and benefit of humanity
- Artificial intelligence should operate on principles of intelligibility and fairness
- Artificial intelligence should not be used to diminish the data rights or privacy of individuals, families or communities
- All citizens have the right to be educated to enable them to flourish mentally, emotionally and economically alongside artificial intelligence, and
- The autonomous power to hurt, destroy or deceive human beings should never be vested in artificial intelligence.

Legal issues

One of the most obvious features that separates AI from other technologies is its ability to act autonomously. This is an area where there are growing concerns as the scope of tasks delivered by AI become increasingly complex, such as driving a car. These include the issue of determining legal liability in situations where a decision made or informed by AI has an adverse impact on someone.

Several of the experts that gave evidence to the UK House of Lords Select Committee on AI argued that legal liability is a major societal hurdle to overcome before widespread adoption of AI could become a reality.[143]

This view was reflected in a recent comment by Prof Genevieve Bell, Director of the 3A Institute, who in a recent interview with InnovationAus.com noted that:[144]

As working AI systems become liberated from mere rule-based decision making, and move into independent thought, we will need a raft of ethical and regulatory links into these machines to ensure everything from physical safety to legal compliance.[145]

The UK House of Lords Select Committee on AI report concluded that it is possible to foresee a scenario where AI systems may cause harm. However, it was not clear whether new mechanisms for legal liability and redress in such situations are required, or whether existing mechanisms are sufficient. They recommended that the adequacy of existing legislation to address the legal liability issues of AI should be examined and, where appropriate, remedies to ensure that the law is clear should be implemented.

Security issues

Another 2018 report has examined the potential security threats associated with AI.[146] This report argued that as AI becomes more widely adopted it will lead the following shift in the security landscape:

- Existing threats will expand — by using AI, the scale, range and ease of existing attacks is likely to increase
- New threats will emerge — AI could enable persons to stage attack that would otherwise be impractical to launch and. in addition, attackers could seek to exploit the vulnerabilities of AI deployed by defenders, and
- Changes in the character of attacks — attacks utilising AI are likely to target vulnerabilities in AI systems and be especially effective, finely targeted and hard to attribute.

Again, the security of AI is likely to be driven by its use in sectors other than agriculture. However, there could be spill-over effects

Skills

The McKinsey Global Institute's report noted that much of the building and optimisation of AI requires particular skills sets in order to deliver the potential for a step change in performance. Their view is that currently the demand for these skills far outstrips supply, with an estimated 10,000 people globally possessing the necessary skills.

In a recent interview, Calum Pickering, Asia-Pacific economist for global job site Indeed, stated that:[147]

A skills shortage in the rapidly emerging area of artificial intelligence (AI) in Queensland is putting a drag on the state's innovation drive.

Groups such as the Australian Centre for Field Robotics (ACFR) at the University of Sydney and the 3A Institute at the ANU should help to address the AI skills shortage, although there is of course likely to be strong demand from overseas firms for any Australian graduates in this filed.

10.3 Opportunity costs

Artificial intelligence (AI) underpins the use of robotics and drones discussed earlier in this report. For example, AI is being used to identify weeds and diseased plants for removal by robots. Data from drones is processed using AI to identify areas where additional fertiliser needs to be applied. The application where economic gains are likely in the near term is in crop harvesting (apples, strawberries).

Dan Steere, cofounder and CEO of Abundant, is reported as saying that tests in Australia have proved that the company's prototype can spot apples as accurately as a human and pull them down just as gently. His company is planning to have a multi-armed system on sale to growers in 2018. The system uses AI to locate apples and to position the picking arm. He claims that Abundant's system will pick at rates that match crews of tens of people.[148]

Australia's apple harvest in 2014 was approximately 300,000 tonnes produced by more than 600 apple growers. Pickers typically get paid around $A30 per bin (350kg). Assuming that apple-picking robots, using AI, can reduce picking costs by 50 per cent (i.e. allowing for the capital and operating costs of the robots) and that half of the production is picked by robots, the annual saving to the sector would be approximately $A3.2 million. If competitor countries move to robotic picking faster than Australia, our apples will be struggling to maintain their share of the Australian market (relatively few Australian apples are exported).

The apple-picking robot is just one of many applications of AI in agriculture. Australia's agriculture sector is currently contributing more than $60 billion to GDP. If the McKinsey estimates (see above) of the value of AI are correct, this translates to future benefits of between $1.4 and $2.2 billion per annum. Positioning Australian agriculture to take advantage of AI is therefore critical to the future competitiveness of the sector.

Fact Sheet:
Artificial Intelligence

Background

- Artificial Intelligence (or AI) describes technologies with the ability to perform tasks that would otherwise require human intelligence, such as visual perception, speech recognition, and language translation.
- In 2018 McKinsey Global Institute research found that AI could potentially improve performance in the agriculture sector by 55 percent (compared to using other more conventional analytics techniques) and estimated that the potential value of AI to be $0.1 - 0.2 trillion. This corresponded to between 2.4 and 3.7 per cent of sector revenues.
- Current Australian research is exploring building robots that rely on data analytics and automated decision systems that would grant a robot the intelligence to sense and make decisions.

Regulatory issues

- What separates AI from other technologies is its ability to act autonomously, however in the event AI machines cause harm to people or the environment, issues of legal liability are a source of concern.
- The 2018 Australian federal budget included an investment of nearly $30 million in artificial intelligence and machine learning, including the development of a national ethics framework. Australia's Chief Scientist, Alan Finkel, has called for a trust-mark or ethical stamp that would be granted to organisations and products using AI that meet global standards.
- The Australian agricultural sector needs to ensure their views are heard and their needs addressed in the development of a national ethical framework for AI. It also needs to support and promote the work of groups such as the Australian Centre for Field Robotics (Sydney University) and the 3A Institute (ANU) to encourage the translation of research to market opportunities.


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10.4 Action required

Current research is focussed on how to build low-cost, light-weight robots that produce less soil compaction, are more agile in operations and have less input costs. Another objective is to move away from the need to refuel with fossil fuels by using into solar photovoltaics (PVs) and electric motors. A third objective is to build the data analytics and automated decision systems that would sit on a robot to grant it intelligence to sense and then make decisions.

The University of Sydney is developing RIPPA™, (the Robot for Intelligent Perception and Precision Application) for use by the vegetable growing industry. The platform configuration for RIPPA has been designed to make it light, rugged and easy to operate. Mounted on RIPPA is VIIPA™ (Variable Injection Intelligent Precision Applicator) used for autonomous spot spraying of weeds at high speed using a directed micro-dose of liquid. RIPPA has also been demonstrated in an apple orchard. It was able to autonomously follow and change rows. It also demonstrated autonomous real time apple detection and targeted variable rate fluid dispensing using VIIPA.

Proposed actions

To continue to take advantage of Artificial Intelligence to benefit agriculture, the sector should:

- maintain the partnership between the ACFR and Hort Innovation to ensure that current research can find its way onto the market
- publicise success stories regarding the application of AI in agriculture, to encourage adoption of AI in the sector and to build public confidence in the sector's ability to use this technology
- closely monitor current debate on the regulation of AI to ensure that the voice of agriculture is heard in any move towards black-letter law.

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Section 11

Discussion

Discussion

There are many regulatory and related challenges to the uptake of emerging technologies in Australia's agricultural sector. Some of the challenges relate directly to existing regulation, such as removing restrictions such that drones can be used beyond the line of sight, while others involve a broader range of actors and policy considerations, such as the appropriate design of an ethics framework for developers of technologies that use artificial intelligence.

This chapter brings together the findings in the preceding chapters into four overarching themes. These themes draw on insights beyond the individual technologies (and therefore not covered in the preceding chapters) and help to frame the regulatory challenges in their broader context. The chapter concludes by summarising the proposed action items for AgriFutures consideration in the short term.

11.1 Themes

The regulatory and other challenges identified in this report may be grouped in the following four broad themes:

- Theme 1: technology smart skills
- Theme 2: public awareness and trust
- Theme 3: regulatory frameworks
- Theme 4: evidence and collaboration

Table 11.1 highlights whether the research indicates that the themes are currently having a low, medium or high impact on the successful adoption of each of the nine technologies examined in this report.

The following sections draw on domestic and international thinking about each theme more generally, and highlights approaches and considerations for the agricultural sector that were not captured in the preceding chapters about individual technologies.

11.1.1 Theme 1: building technology-smart skills

Debate about the impact of emerging technologies in agriculture often focuses on the topic of labour: technologies are positively associated with helping to address labour shortages, and reducing the burden of intensive manual, repetitive or risky tasks; or negatively associated with fuelling the exodus of people from the agricultural sector as they are replaced by machines or driven out by competitors that may be more quickly harnessed the benefits of a new technology.

Some of the emerging technologies discussed in this report, namely those that involve sophisticated applications of digital technology and data like AI, robotics and senors, raise different, additional issues – of both a conceptual and practical nature. Conceptually, the challenge is that today's technologies do not operate in isolation from other advancements - be they technological or economic or social in nature – and it is not always possible or sensible to restrict the view to a single component of the technology.[149] For the agricultural sector, the University of Melbourne describes the challenge in terms of 'systems':[150]

Table 11.1 The impact of the regulatory and other challenges for each technology

Technology	Theme 1 Technology smart skills	Theme 2 Public awareness and trust	Theme 3 Regulation	Theme 4 Building evidence and collaboration
Nanomaterials	Low	Medium	High	High
Crowd sourced funding	Medium	Low	High	Low
Microgrids	Medium	Low	High	High
Nutritional genomics	Low	Medium	High	High
Robotics	High	High	Medium	Medium
Sensors	Medium	Low	Medium	Medium
Drones	Medium	High	High	Low
Synthetic biology/gene editing	Low	High	High	High
Artificial intelligence	High	High	High	Medium

Source: ACIL Allen Consulting

> "Put simply, innovation requires a focus not just on the 'hardware' (that is, the new idea or technology) but also on the 'software' (the skills and knowledge required to use and derive benefits from the technology) and the 'orgware' (the formal and informal relationships and arrangements between stakeholders that are required to support the successful and sustained deployment of technology)"

The uptake of new technologies is clearly also a practical challenge. The Committee for Economic Development's 2015 report on the future of the Australian workforce[151] concluded that if the agricultural sector is to realise its comparative advantage in the application of information technologies, it needs a greater focus on what it describes as the 'deeper technical skills' which include:

- Architecting which refers to knowing how to integrate computing and communication resource with both off-the-shelf and significant bespoke software engineering. Typical are projects and products that involve data storage and management, cloud computing, provision of (mobile) services, integration of automation into processes.
- Designing which refers to skills in conceptualising new solutions, developing algorithms and optimising processes. It requires deep understanding of a problem space, of users and customers. At one level, this includes user experience and user interface design skills, at another level, it requires deep knowledge of sophisticated mathematics and algorithms in areas including modelling, optimisation, privacy and security.
- Analysing which refers to making sense of data, applying analytics to make predictions and enabling systems to be adaptable, semantic and contextual understanding of information. Analysing requires a deep understanding of areas including probability, statistics, algebra and geometry.

As highlighted in the Table, these skill sets are particularly relevant to technologies that include artificial intelligence, robotics, drones and sensors.

11.1.2 Theme 2: public awareness and trust

In 2018 the World Economic Forum proclaimed that public trust is key to the success of 'fourth industrial revolution' technologies such as gene editing, robotics and nanotech, and cites recent crises in Tesla and self-driving cars, Facebook and Cambridge Analytica, as awakening public discontent with government oversight of technological innovation.[152]

Thinking about the regulation of emerging technologies as a moral and political consideration, not only a technocratic challenge, is increasingly common. The World Economic Forum's approach to building trust and designing appropriate regulatory frameworks and principals for the governance of technology is to bring together expertise from biotech, governance, human rights and behavioural sciences. A similar approach has been taken by the Institute of Electrical and Electronics Engineers, which has worked with 250 world leaders in law, technology and social science to produce ethical standards for technology, and then making them available for public comment.[153] This work has suggests all technologies should be guided by five general principles: protecting human rights; prioritising and employing established metrics for measuring wellbeing; ensuring designers and operators of new technologies are accountable; making processes transparent; minimising the risks of misuse.

The importance of public perceptions about technologies and the capacity of governments to anticipate and respond to risks effectively was noted by the Australian Senate Standing Committee inquiry into smart farming in 2016. Reflecting on gene technology, industry representatives impressed on the Committee that public approval can

fluctuate and is different for applications of the technology to food, therapeutic or industrial applications. Public acceptance of new and emerging technologies is far from a given.

Scholars from the Social Innovation Institute (Swinburne University) argue that that there is a widening gap in knowledge between those creating and using emerging technologies, and those in charge of regulating them, and that all parties should get involved in the ensuring they deliver on public needs.[154] In practical terms, the agricultural sector could be working with influential institutions (particularly Australian governments, technology firms and research bodies) to foster more inclusive public debate about the implications of emerging technologies and how to harness them in the public interest.

11.1.3 Theme 3: regulation

The Productivity Commission defines regulation as any laws or other government rules (such as standards and codes of conduct) that influence or control the way people and businesses behave.[155] As shown in the Table above, regulatory challenges (uncertainties, gaps, overlaps and conflicts) have a significant impact for almost all emerging technologies, and the solutions are far from straight forward.

It is well documented that the agricultural sector is subject to regulation on a number of fronts, including: the acquisition and preparation of land; on farm operations such as cropping, animal husbandry and processing, and is also subject to regulations that apply across the economy, such as regulations covering chemicals, water use, food and labour, and from state, territory and federal governments.[156] While some argued that the agriculture sector suffers under a 'burden of regulation', the Productivity Commission's recent investigations have concluded that regulation is critical to the agricultural sectors ability to function effectively and enables it to benefit from its reputational advantage and access to premium export markets.[157] Regulation that is well designed and well implemented supports the adoption of innovative practices and new and emerging technology in agriculture.

A key challenge in regulating technology in Australia is the significant differences, conflicts and inconsistencies in regulation across the states and territories. Examples in this report include moratoria on genetically manipulated crops (e.g. canola), animal welfare regulations (eg.,robots) and regulation of energy sources and distribution (e.g. microgrids). In each case, this variation creates uncertainty for investors and consumers, and reduces opportunities for economies of scale when companies seek to market these emerging technologies in Australia.

Government's commonly face what can be described as a 'regulatory disconnect' in which new technologies expose gaps in the existing regulation, or present problems for existing regulations, that take time to assess and respond to effectively. Conversely, when governments are under pressure to act quickly, then premature or 'knee jerk' regulation can discourage research, investment and competitive opportunities.[158] Many of the proposals for action in this report encourage the agricultural sector to engage with government and parliamentary processes that have been created in an attempt to respond effectively to the issues raised by emerging technologies.

These complexities compound the challenges that governments face in responding to regulatory issues in a timely and effective manner, to the satisfaction of all stakeholders. As highlighted in the discussion of specific technologies, this is one of the reasons progress has been slow for governments around the world, and further research and collaboration that brings regulators, industry experts, practioners and the public together will be key to moving forward.

11.1.4 Theme 4: evidence building and collaboration

Successful applications of new and emerging technologies in agriculture in Australia are often the product of collaborations between research bodies, government and technology companies, with the financial backing of government over many years.

Public bodies that have access to infrastructure and expertise to systematically trial emerging technologies, together with private interests that are motivated to demonstrate and capture commercial advantages, is crucial to the uptake of technology in agriculture. See Box 11.1. for an example.

Collaboration relies on leadership and vision, policy support and financial assistance from government. Similarly, it requires the active and strategic engagement by the agricultural interest groups with other sectors that are also grappling with the implications of emerging technologies.

In another example, the Australian Council of Learned Academies (ACOLA) Horizon Scanning projects examine significant scientific and technological developments and provide in-depth, multidisciplinary analyses of emerging global issues in science and technology. They focus on developments that demand a considered public policy response to minimise risk and maximise significant economic, social, cultural and environmental benefits in Australia. Of interest to agriculture, upcoming horizon scanning topics include synthetic biology, the Internet of Things, artificial intelligence and machine learning, and what it has called 'next generation' agriculture.

11.2 Looking ahead

The Commonwealth Government's latest budget allocated funds to a number of technological innovations explored in this report. These developments, among others, are opportunities for the agricultural sector to elevate the unique technological challenges it faces and further examine what regulatory responses are required.

The Government will provide $29.9 million over four years to strengthen Australia's capability in artificial intelligence and machine learning. This measure supports innovation in digital agriculture, energy, mining and cybersecurity, through the provision of additional funding to the Cooperative Research Centres Program and focused PhD scholarships and school-related learning to address skill gaps. Importantly, funding has been directed to the development of a technology roadmap, standards framework and a national AI ethics framework to identify global opportunities and guide future investments.

Box 11.1 Virtual microgrids, blockchain and dairy farming

The Australian Renewal Energy Regulator (ARENA) has provided $370,000 for a feasibility study into a 'virtual microgrid' for the Latrobe Valley. A 'virtual microgrid' is a local marketplace of connected energy that allows users to buy and sell electricity within a localised area.

The project will be led by Brooklyn-based energy company LO3 Energy and focuses on 200 dairy farms, over 100 household consumers and around 20 other commercial and industrial customers in the Gippsland region.

It will incorporate solar PV, battery storage, smart appliances and enabling technologies combined with the LO3's exergy peer-to-peer energy trading platform which uses blockchain technology to allow participants to securely buy and sell locally produced renewable energy.

Participants would be linked in an internet-of-things-based marketplace while using AusNet's distribution network. Farmers would be able to participate at no upfront cost through loans provided by the Sustainable Melbourne Fund, repaid through council rates.

The study is expected to be completed by end of 2018, and if successful the pilot microgrid could be rolled out in Gippsland in 2019.

The project involves a consortium of partners including AusNet Services, Sustainable Melbourne Fund, Dairy Australia and Siemens. ARENA believes the feasibility study would be the first step in transitioning one of Victoria's primary agricultural regions towards renewables and would be the first trial of a blockchain-based virtual microgrid in Australia.

Lawrence Orsini, LO3's founder and CEO said: "This is a landmark project for us and the Australian energy industry as it combines a number of our innovative technologies to optimise the use of renewable energy. This microgrid will showcase solutions for this including battery storage to make greater use of solar energy and demand response in which consumers will be paid for choosing to conserve energy at peak times,"

Source: arena media release (28 april 2018) https://arena.gov.au/news/latrobe-valley-virtual-microgrid-allow-dairy-farms-trade-energy-via-blockchain/

The budget has also allocated $36.9 million over three years from 2019-20 (and $12.8 million ongoing) to provide governments, businesses, researchers and individuals with access — through the Digital Earth Australia program — to reliable standardised satellite data. This data can be used to build new digital products and services to interpret and analyse changes to Australia's physical landscape, enabling better understanding of environmental changes, such as coastal erosion, crop growth and water quality. Access to satellite imagery data can assist farmers to monitor animal grazing patterns and increase the efficiency and utilisation of their land. If Australian agriculture is to gain benefits from the technologies discussed in this report, in summary the sector is encouraged to take the following steps:

Build public trust in agricultural applications of emerging technologies through publicity of success stories.

Where the application of the technologies discussed in this report can be illustrated through a success story in the media, this may encourage public understanding and acceptance. Being able to demonstrate that any risks have been considered and appropriate steps taken to address them is also important. Public information campaigns may be necessary in some cases. This is particularly relevant where there is some farmer or public reluctance to embrace emerging technologies such as gene technology, drones and robotics.

Invest in research, development and demonstration

When investing in research, development and demonstration projects, a useful approach is to go for the "low-hanging fruit" and be willing to invest in research that will give comfort to regulators. For some emerging technologies, funding demonstration projects can be a very effective way to address any remaining issues and to show the farming community the benefits. Engaging decision makers and regulators early, as well as education and training providers, is a way to ensure that multiple benefits flow from research investments and more sustainable results are likely.

Engage with regulatory bodies to address excessive regulation

The restrictions on the operation of drones on farmland provide an example where regulations clearly need to be relaxed. This requires discussions with the regulator (in this case CASA) and possibly trials to demonstrate that the agricultural sector can make effective and safe use of technologies without over-regulation. To progress equity-based CSF in agriculture, discussions with federal lawmakers are urgently needed.

Participate in discussions that may lead to regulation of technologies relevant to agriculture

Discussions on technologies that impact on agriculture need to include people with on-the-ground knowledge and experience. It is important that, in areas where new regulation is emerging (or likely to emerge) that the agriculture sector has a "seat at the table". This should include discussions in international fora such as the OECD and FAO. Examples include consideration of synthetic biology by OGTR, and debate about the regulation of AI through a global ethics framework. Standards bodies rely on collaborative effort and provide opportunities for industry engagement.

Bridge gaps in skills and education for farmers interested in agricultural technologies

It is well established that new technologies (their design, adoption, maintenance and improvement) and responding to the regulatory challenges they raise (ethics, standards, liabilities) require different skills than are traditionally those of farmers. The role of identifying and meeting farmers demands for training, the coordination of these new opportunities in a farmer-friendly way, organising funding and facilitating practical collaborations requires creativity, networks and leadership. AgriFutures should consider how best to address this issue.

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