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EXECUTIVE SUMMARY

Horizon Scan 6 is the second and final of the two Horizon Scans conducted for the Predicting New and Emerging Industries for the Australian Agricultural Sector project. These two Horizon Scans have expanded on the watchlist of emerging technologies compiled during the Detecting opportunities and Challenges for Australian Rural Industries project [1]. The technologies presented in this Horizon Scan report have also been selected based on their potential to contribute to the development of emerging agriculture industries. Seven emerging technologies have been identified and are outlined in this report. The domains they span are diverse, including information and communications, data analytics, renewable energy, urban informatics and computation.

EDGE COMPUTING

Edge computing is a computing topology in which data storage and analysis is kept close to where it is collected, without needing to be sent to the cloud. Computing is done locally on edge devices, such as sensors and equipment that collect data, or on other locally connected devices, such as smartphones and other dedicated hardware. Perhaps one of the most relevant applications of edge computing is that it provides a solution for operating Internet of Things (IoT) in remote areas with limited or no internet connectivity.

EXTENDED REALITY

Extended reality technologies create experiences that blur the boundaries of real and digital environments. Augmented reality, virtual reality, 360° video and wearables all fall under the umbrella of extended reality. With extended reality, real life situations can be mirrored in virtual reality simulations allowing people to experience hazardous or rare
situations without fear of making mistakes. People in remote areas can access the same digital experiences as people in cities. Learning experiences can be more engaging to improve retention of information and be more relevant to the next generation of workers.

**WIRELESS INTERNET DELIVERY**

Wireless internet delivery is a ubiquitous technology category that provides internet access to our smartphones and connected devices. While most people are familiar with this technology category, it is undergoing constant iteration and development. 5G is the next generation of wireless internet technology. It brings faster internet with the flexibility to provide connectivity over large distances as well as high-speed concentrated connectivity. 5G will have a significant effect on our lives by allowing people to interact with an unprecedented ecosystem of connected devices. *High altitude wireless internet delivery* is the creation of wireless internet networks in the stratosphere, which provide internet to locations on the ground. This is typically enabled by the use of drones, however, air balloons have also been used. The primary application of this technology is to provide internet to places lacking connectivity, such as rural and remote areas.

**QUANTUM COMPUTING**

Quantum computers operate on completely different principles to general-purpose computers. Where the information units used by general-purpose computers are processed sequentially to solve problems, the information units used by quantum computers can be in many states and relationships. This means that computation can occur simultaneously to converge on solutions to problems rapidly. In short, quantum computers are best suited to solving complex modelling problems that would not be possible using general-purpose computers. Quantum computers could have significant impact for agriculture by improving the methods for producing ammonia-based fertiliser.

**ARTIFICIAL PHOTOSYNTHESIS**

Artificial photosynthesis is the process of producing energy using only water and sunlight as inputs. The energy produced by artificial photosynthesis is in the form of hydrogen. When separated from water, this hydrogen can be stored and converted to electrical energy without producing any harmful by-products. Artificial photosynthesis technology has also been used to directly produce liquid fuels. The generation of electricity and liquid fuels using artificial photosynthesis has considerable application potential and could potentially have an impact wherever industrial energy is required.

**SMART CITY**

Smart cities aim to advance the liveability, sustainability and economic benefit of an urban area through the use of technologies such as Internet of Things, artificial intelligence and cloud computing. The expectation is that the convergence of these technologies in urban systems will create environments that profoundly improve living experience, while taking care of all the necessary aspects of supporting a city and its residents. There are considerable smart city initiatives occurring around the World, including Australia where a total of $50 million in funding was recently awarded to a variety of projects.
INTRODUCTION

This report presents the second and final of the two Horizon Scans conducted for the Predicting New and Emerging Industries for the Australian Agricultural Sector project. The design of this Horizon Scan was intended to serve two purposes. The first purpose was to further expand the current watchlist of emerging technologies developed during the four Horizon Scans conducted as part of the Detecting Opportunities and Challenges for Australian Rural Industries project. The development of this watchlist forms part of AgriFutures Australia’s strategic vision to ensure the long-term prosperity of Australian rural industries through the anticipation of technologies that present potential opportunities and challenges now and in the future. This report has contributed to the watchlist with the identification of seven emerging technologies that have the potential to impact Australian rural industries. With this, the final watchlist of emerging technologies now stands at a total of thirty-nine, which demonstrates the extensive opportunities for technology innovation and technology integration within the rural industries.

The second purpose of this Horizon Scan was to assist with the identification of emerging agriculture industries that will potentially develop due to the influence and application of emerging technologies. This purpose falls within the broader aim of the Predicting New and Emerging Industries for the Australian Agriculture Sector project. Thus, the seven emerging technologies presented in this report were selected based on the opportunities they provide to support the development of emerging agriculture industries or to improve aspects of already established agriculture industries. Given the relationship of this Horizon Scan to the scanning for new Industries, this report
begins by visualising the potential relationships that the technologies identified have to previously reported emerging industries [2], as well as their contribution to newly reported emerging industries [3]. Following this, each of the identified emerging technologies are presented, including infographics and scenario images that outline technology trends and the potential applicability of the technologies to Australian rural contexts.
This report presents seven emerging technologies with potential impact for Australian rural industries. The domains they span are diverse, including information and communications, data analytics, renewable energy, urban informatics and computation. As the technologies presented in this Horizon Scan are situated in the context of investigating emerging technology based agriculture industries, they can be positioned in two ways:

1. Providing additional support for the emerging technology based agriculture industries that were identified in the first Emerging Industries – Agriculture and Technology report [2].

2. Contributing to the identification of additional emerging technology based agriculture industries reported on in the second Emerging Industries – Agriculture and Technology report [3].

While these two options represent two distinct positions, Figure 1 shows that most of the technologies are positioned to both support already identified industries and to inform newly identified industries. This demonstrates the potentially broad applicability of emerging technologies in the Australian rural industries. In the following sections, each technology is presented on a single page explaining current applications and forecast. Infographics communicate the potential impact of the technology for rural contexts, as well as temporal and geographical trends of the technologies based on patent data, if available. Illustrative scenarios have been included for select technologies to further communicate potential applications in Australian rural industries.
FIGURE 1. IDENTIFIED TECHNOLOGIES AND THEIR RELATIONSHIP TO EMERGING AGRICULTURE INDUSTRIES AND OPPORTUNITIES.
EDGE COMPUTING

Edge computing is related to cloud computing. Where cloud computing is based on routing data through centralised data centres in the cloud, edge computing keeps data close to where it is collected by performing computation at the network edge [4]–[7]. Edge computing can be done on local devices, such as smartphones and other dedicated hardware [4], [8], and can also implement local and regional data centres if more processing power is required [8].

APPLICATION

Edge computing has been used to collect, store, filter and then send data to the cloud where it is processed [9]. While future edge computing devices will still serve these functions, dramatic increases in compute power and storage capacity is allowing edge devices to act with greater independence from the cloud and handle computing tasks locally [6], [9]. Computation of data at the network edge addresses some of the limitations of cloud computing. One of the most notable of these is bandwidth, which has not increased at the same rate as data-processing speeds [6]. Thus, with the number of connected devices and their creation of data increasing rapidly, bandwidth limitations are being noticed in the form of data latency [5], [6], [10]. Processing data at the edge can alleviate these issues by enabling efficient processing with shorter response times, while also reducing unnecessary network traffic, which frees up bandwidth for services that do require the cloud [6], [7]. Edge computing provides a solution for operating Internet of Things (IoT) in remote areas with limited or no internet connectivity. Further advances in edge computing power will increase the data processing and IoT capabilities in these areas [10]. In addition to addressing issues of bandwidth and connectivity, edge computing also alleviates some concerns over data safety and privacy [5], [11].

FORECAST

The model of cloud computing with centralised resources is shifting toward a decentralised structure enabled by edge computing [12]. Cloud computing will not disappear, but rather growth will slow because there are not many new opportunities left in the cloud – they now lie at the edge [5]. For edge computing to take advantage of the new opportunities, it must build on the core storage and compute capabilities that are already offered by cloud computing while bringing them closer to the consumer and in more application contexts [6], [12]. For many consumer edge computing devices, the industry is moving toward managed devices, where companies exert a level of control over the device. While this results in a consistent product experience, it also limits user control as functionality is guided [5].
**EXPERT OPINION**

Experts were surveyed and asked to rate the impact of edge computing technology on a 5-point scale. On average, responses show that edge computing technology is perceived to have very-high potential impact for Australian rural industries. Equipment capable of on-board data analysis without requiring an internet connection was highest rated. This was followed by local processing of data, rather than relying on cloud services.

**INNOVATION TRENDS**

As edge computing devices advance and on-board compute power increases, it is increasingly possible for data to be analysed in real-time by the devices that collect the data, without the need for internet connectivity [9], [13]. This real-time data processing allows for context-aware applications. Edge devices in proximity to other edge devices can communicate real-time data such as location and behaviours. This can allow the devices in the system to act in relevant ways, such as by delivering useful information based on context [14].

Equipment that can process and act on data in the field, without requiring access to the internet

Processing complex data locally rather than needing to upload it to cloud services for processing

The ability to process ‘Big Data’ and develop insights from that data without a high-bandwidth internet connection

Data collected and analysed by edge devices and shared among other edge devices

Data can be shared to a gateway to be processed locally or sent to the cloud
EXTENDED REALITY

Extended reality refers to the spectrum of technologies used to create experiences that blur the boundaries of real and digital environments [15]. Augmented reality (AR), virtual reality (VR), 360° video and wearables all fall under the umbrella of extended reality [16]. A common depiction of the technology is the merger of VR and AR functionality into a single device that can switch between the augmented real world and experiences entirely in simulated environments [16], [17]. However, extended reality also incorporates other paradigms of interaction and human experience including visual, aural, olfactory and haptic [15].

APPLICATION

One of the most valuable characteristics of extended reality is removing distance from people’s interaction with one another, with objects and environments, as well as with less tangible constructs such as data [15]. This has immediate impact for learning and skill development [18], [19]. Real life situations can be mirrored in VR simulations allowing people to experience hazardous or rare situations without fear of making mistakes. People in remote areas can access the same content as people in cities. Learning experiences can be more engaging to improve retention of information and be more relevant to the next generation of workers [19].

A compelling application of extended reality is pairing the technology (e.g. AR, VR) with artificial intelligence systems, including data analytics, robotics, and smart environments. This would provide an environment where people can interact seamlessly and collaboratively with data and digital systems in real-time [20]. For such purposes, brain-computer interfaces are seen an ideal fit with extended reality. This pairing would allow people to interact in intuitive and naturalistic ways, which is particularly valuable in environments where gestural or physical interaction is not suited [21].

FORECAST

Current extended reality technologies (AR, VR, 360° video) have limited modes of interaction which can be awkward and restrict the application of the technology [21]. These will need to be expanded as technology capabilities improve. For use in training environments, it will be important to identify well suited scenarios and use-cases, and then design compelling user experiences [19]. While the base technologies are already commercially available, key areas of innovation will be technology confluence, such as the integration of eye-tracking [16], [18] and built-in analytics so that emotional and behavioural responses to situations can be captured and learned from [18], [19].
EXPERT OPINION

Experts were surveyed and asked to rate the impact of extended reality technology on a 5-point scale. On average, responses show that extended reality technology is perceived to have very-high potential impact for Australian rural industries. Rich communication between people without the need to be located in the same place were the capabilities of extended reality perceived to be of highest impact, followed by immersive training in the field.

INNOVATION TRENDS

Removal of distance is highlighted as one of the most significant capabilities of extended reality technology. The technology can create a platform for immersive and engaging communication between people in any number of environments [15], [19].

As new technologies enter the agriculture sector, such as robotics and wireless sensor and actuator networks, extended reality could provide farmers access to essential expertise - remotely. Collaborations could form irrespective of proximity to improve decision making and productivity.
Wireless internet delivery is a ubiquitous technology category. At present, the most widely used wireless internet delivery technology is 4G (LTE), which is used to connect smartphones and other devices to the internet. Familiarity with this technology is high. 88% of Australians own smartphones and use them extensively; 35% of people check their phone within five minutes of waking up, and even more use their phones during mealtimes and with family and friends. The primary reason for this is to access digital content delivered through wireless internet [22]. While we are familiar with wireless internet delivery, the technology is constantly being iterated and developed to provide improved capabilities. There has also been strong efforts made by a number of internet platform technology companies (e.g. Facebook and Google) to bring internet, and their services, to places that currently lack connectivity.

In the following sub-sections, two emerging wireless internet delivery technologies are presented: 5G and high altitude wireless internet delivery. Together, these represent significant technologies that will improve the capabilities of wireless internet, and potentially bring internet to more people in more locations.
5G

5G is the next generation of wireless internet technology. It is an evolution of the currently used 4G or LTE technology based on new technology and spectrum bands [23]. The provision of a range of spectrum bands, from low (<1GHz) to high (>6GHz) frequency, will allow for flexibility of both connectivity over large distances and high-speed concentrated connectivity, respectively. In addition to speed and coverage, 5G will deliver significant improvements to cost, network reliability, network access at high speeds (vehicles moving up to 500km/h), and bandwidth to facilitate massive connectivity (1 million connections/m²) and ultra-low latency connectivity (1 millisecond) [24].

APPLICATION

5G will support and expand the scale of many existing internet connected applications and will ultimately have a broad impact on our social and professional lives. Improvements to network speeds, latency and bandwidth will enable people to engage with high-demand and immersive communications applications, such as augmented and virtual reality [25]. Massive connectivity will enable significantly higher densities of these connected devices at home and at work [24], [26]. The potential of 5G, however, is not just increasing the scale of existing connectivity, but also facilitating new paradigms of connectivity [26]. 5G will allow people to interact with an unprecedented ecosystem of connected machines. These will take on part of our cognitive load and allow us to focus on other things [26]. 5G will support wider application of self-driving cars and tactile internet applications (e.g. remote surgeries and machinery operation) that rely on ultra-reliable and low-latency connectivity [27].

FORECAST

South Korea and the USA are expected to offer their commercial 5G services in 2019 [23]. Australian telcos (Optus and Telstra) are similarly aiming for early 2019, which has begun with Telstra’s rollout in selective areas of the Gold Coast [28]. China is a significant factor in 5G development, with ZTE and Huawei both positioned as leaders in the development of technologies underlying 5G [27]. Although 5G offers low frequency bands that can cover large distances, initial availability of 5G will be in urban areas [23]. In dense urban zones, there is a high subscriber rate with high-revenue density. In comparison, rural areas do not offer comparable profit potential. As with previous mobile internet specifications, it is likely that the cost will not justify deploying 5G in many rural areas [29].
HIGH ALTITUDE WIRELESS INTERNET DELIVERY

High altitude wireless internet delivery is the creation of wireless telecommunications networks in the stratosphere, which provide internet to locations on the ground. These networks are enabled by high altitude platform stations (HAPS), which are usually unmanned aircraft carrying the necessary technologies [30]. Most recent projects have used fixed-wing drones, however, high altitude wireless internet delivery using air balloons is being pursued by Loon, a subsidiary of Alphabet [31]. Irrespective of type, HAPs projects aim to develop solutions that can achieve long endurance, and thus often utilise solar and rechargeable batteries. HAPs are positioned above 20km so that they are positioned above strong wind currents and commercial aircraft flight paths [30].

APPLICATION

HAPS have the primary application of delivering internet to areas without access. Recent initiatives have targeted commercial uses of HAPs systems. Loon states that they aim to provide internet to rural and remote areas [31]. Aquila, a large fixed-wing drone developed by Facebook, was part of the company’s continuing vision to bring internet to those without [32]. Alphalink (alphalink.space), a berlin start-up, similarly identifies bringing internet to places without access as its key direction, but also cites applications for surveillance, disaster management, and monitoring high-risk wildlife areas. Airbus’ (airbus.com) Zephyr S and Zephyr T are designed for military applications. They offer a range of capabilities including internet in remote areas, RADAR, LIDAR, imagery, and voice and data communication [33].

FORECAST

The nature of high-altitude wireless delivery presents many challenges. Most significant is creating lightweight designs that can tolerate strong winds [34], low temperatures, intense solar radiation and low pressures [30]. The future is looking promising, though. Loon has recently left the experimental stage, obtaining full company status, independent of Alphabet [35], [36]. Facebook’s Aquila project has gone in the opposite direction, having shuttered down in 2018 [32], [36]. However, this does not necessarily indicate that the program was infeasible. According to Facebook, their decision was in response to several leading companies exploring their own HAPS projects. Facebook is now actively working with companies, such as Airbus, as well as participating in aviation advisory boards to develop the systems and policy to make the technology work [37], [38].
**Wireless Internet Delivery**

**5G - High Altitude Wireless Internet Delivery**

**Expert Opinion**

Experts were surveyed and asked to rate the impact of wireless internet delivery technologies on a 5-point scale. On average, wireless internet delivery technologies were perceived to have very-high potential impact for Australian rural industries. Gaining access to fast and accessible internet that allows for enhanced communication over long distances is a priority for Australian rural industries, and accordingly, these capabilities were rated very highly by participants.

**Innovation Trends**

A critical capability of high altitude wireless internet delivery is to provide continuous internet service over a large area. Airbus’ Zephyr has achieved over 14 days of continuous flight powered only by solar [33]. While still in development, Alphalink’s model 3 is initially targeting 100 days of flight, with the hope to extend that to over a year or more with improved solar and battery technology [34]. Advances in drone technology allows these systems to be sent where needed, for example specific rural areas [29]. Loon’s balloon navigation system has been developed to such an extent that winds can be predicted and thus groups of balloons can be sent to specific areas. This is an essential development to ensure that there is a consistent delivery of balloons and connectivity to the areas that need it [31].
Quantum computers are not the same as the computers that are so ubiquitous today. In computers that we are familiar with, basic information units, called bits, can have one of two values: 0 or 1. Bits are processed sequentially to solve problems [39]. Quantum computers operate on completely different principles [40]. Their operation is based on the quantum state of subatomic particles [41]. In quantum computers, information units are called qubits (quantum bits). Unlike bits, qubits can be in many states simultaneously until read - this is known as superposition [41], [42]. Qubits can also be ‘entangled’ with other qubits so that the state of one qubit can influence the state of others. This entanglement means that problem solving is not restricted to a linear process. Computation can occur simultaneously to converge on a solution rapidly – much faster than general-purpose computers [39], [41].

APPLICATION
The application of quantum computers is different to general-purpose computers [41]. Quantum computers are suited to computing a limited set of algorithms and solving specific mathematical problems that would not be possible or would take too long on a general-purpose computer [39], [41]. A particular strength of quantum computing is the creation of new data sets, such as through running simulations [43]. These types of problems are found a range of areas, including machine learning, cryptography, molecular modelling, image analysis and weather forecasting [41]. Molecular modelling has been a particularly strong area of interest [40], [44]. A specific problem is modelling the Haber-Bosch process, an artificial nitrogen fixation method used for the production of ammonia, the basic ingredient of most fertiliser [40]. The Haber-Bosch process requires metal catalysts to fix nitrogen [45]. This requires high pressure and high temperatures which requires intense energy inputs [42], [46]. It is hoped that quantum computers can simulate new ways of nitrogen-fixing that can significantly reduce energy requirements [46].

FORECAST
Quantum computers have been under development for decades, but it has only been in the past 5 years that significant progress has been made. Quantum computers have vast potential and could have a transformational effect on technology development [39]. Although several large companies (Google, IBM and Microsoft), as well as several smaller start-ups, are building and testing quantum computers today [47], the technology required for transformational applications is at least 5 to 10 years away [39]. At this stage, the likely scenario is that quantum computers will be used for highly specific applications, and do not pose a threat to traditional computing [39].
**QUANTUM COMPUTING**

**EXPERT OPINION**

Experts were surveyed and asked to rate the impact of quantum computing technology on a 5-point scale. On average, responses show that quantum computing technology is perceived to have high potential impact for Australian rural industries. Both applications, reducing the energy required to produce fertiliser and producing more efficient chemical pesticides and fertilisers, were perceived to be of equal potential impact.

Technology to significantly reduce the energy required to create nitrogen-rich ammonia-based fertilisers

Modelling complex molecular reactions to help produce more efficient chemical pesticides and fertilisers

**INNOVATION TRENDS**

Analysis of number of patents published by country shows that innovation of quantum computing technology has been considerable. The USA has been the primary focus of quantum computing technology innovation. The reasonable number of patents filed with the World IP Organisation suggests that the number of multi-country patents for quantum computing technology is likely to increase.

Analysis of number of patents published per year shows that innovation of quantum computing technology has been steadily increasing since 2013.
ARTIFICIAL PHOTOSYNTHESIS

Artificial photosynthesis is the process of producing energy using only water and sunlight as inputs. The process follows the generic model of turning sunlight into energy that plants offer. Photoelectrodes immersed in water absorb sunlight to perform two separate half-reactions that: i. produce oxygen, and ii. Produce hydrogen [48]. This is known as solar-driven water splitting; the decomposition of water into hydrogen and oxygen [49]. The reactions are accelerated using two catalysts, and a membrane is used to prevent the photoelectrochemical cell (PEC) from combusting when hydrogen is in the presence of oxygen [48]. The hydrogen that results from this process can be converted to electrical energy without producing any harmful by-products [49].

APPLICATION

One of the most compelling aspects of artificial photosynthesis is the use of sunlight to directly produce the chemical fuel hydrogen [50]. By doing this, the technology provides a direct and affordable way to store the energy from the sun, thus overcoming one of the most challenging aspects of clean energy [48]. In addition to producing hydrogen directly, there has been recent research investigating the integration of bacteria into the system to generate liquid fuels [48], [51], [52]. In this biosynthetic water splitting system, the bacteria consumes the hydrogen gas produced by the water splitting process to synthesise biomass [51]. This process has been able to achieve a 10% efficiency of converting sunlight into the liquid fuel [48], [51]. The applications for this type of process in the transportation sector are clear and significant [48].

FORECAST

If a commercially viable artificial photosynthesis device can be produced, both to generate electricity and liquid fuels, the application potential is immense and will have an impact wherever industrial energy is required. At present, however, the technology is inefficient and will have trouble competing with other forms renewable energy generation. The above-described biosynthetic system achieved 10% efficiency [48], [51] and other systems have been below 10% [49]. Although progress over the last ten years has been rapid, the technology is still forecast to be 10-20 years away from commercial viability [53]. For it to succeed it needs to be inexpensive, robust, safe and efficient. No more than three of these have been met so far [48].
ARTIFICIAL PHOTOSYNTHESIS

EXPERT OPINION

Experts were surveyed and asked to rate the impact of artificial photosynthesis technology on a 5-point scale. On average, responses show that artificial photosynthesis technology was perceived to have very-high potential impact for Australian rural industries. Applications of artificial photosynthesis to produce renewable electricity and liquid fuels were perceived to be of higher impact than the application of producing ammonia for fertiliser.

INNOVATION TRENDS

Analysis of number of patents published by country shows that innovation of artificial photosynthesis technology has predominantly been focused in the USA. However, the number of patents published for the technology is relatively low, overall. This is likely due to the highly specific nature of the technology.

Analysis of number of patents published per year shows that innovation of artificial photosynthesis has varied over the last six years. While it has increased overall, a consistent pattern is difficult to ascertain from the data.
Smart cities aim to advance the liveability, sustainability and economic benefit of an urban area through the use of technology. While many smart city initiatives have implemented point solutions to improve isolated aspects of city infrastructure and daily life, the broader vision of smart cities is to implement an integrated solution built on cutting-edge technologies such as Internet of Things, artificial intelligence, cloud computing and ubiquitous connectivity [54]. The expectation is to create urban environments that profoundly improve living experience, while taking care of all the necessary aspects of supporting a city and its residents. The underlying direction that shapes smart cities is exploring what can be done better by using new technology [55], [56].

**APPLICATION**

The application of smart city technology can already be seen in many urban environments. Smart waste bins, lighting and parking indicators are some common examples [54]. However, there are fewer examples of smart cities in the sense of the broader vision. The most high profile at present is the proposed Quayside development in Toronto. Led by Alphabet's sidewalk Labs, the vision for Quayside is an idyllic environment above ground while essential services are automated and hidden underground. Mostly car free streets, modular buildings and space for people will be prioritised. Underground, autonomous robots will take care of deliveries and waste [55]. Meanwhile, an extensive sensor network will monitor all aspects of daily life. Information on pollution, noise, and people’s movements and their activities will be used to understand and improve the design of the city [57]. Less ambitious in scale, the Sunshine Coast City Council in Queensland has adopted the Smart City Implementation Program which outlines strategy for implementing information and communication technology. This type of initiative is viewed as a way to improve council services to residents, reduce carbon emissions, increase safety, improve quality of life, and stimulate business investment [58].

**FORECAST**

The Australian Government has lent extensive support to developing smart cities. Their Smart Cities and Suburbs program has made $50 million available to projects aimed at improving the liveability, sustainability and productivity of cities and towns in Australia [59]. Forty-nine projects were funded in round one of the program, and also received co-funding from local government, industry and other private sector organisations [59]. One notable outcome of the initiative was that 40% of the successful projects were located in regional areas [60]. While these are good first steps, many of the funded projects are point solutions, such as smart lighting, waste bins and parking. More advanced capabilities, such as those of Quayside will likely bring more profound impacts.
**SMART CITY**

**EXPERT OPINION**

Experts were surveyed and asked to rate the impact of smart city technology on a 5-point scale. On average, responses show that smart city technology was perceived to have high potential impact for Australian rural industries. The provision of autonomous services to distribute and add value to food, as well as smart environments to facilitate a greater emphasis on health and lifestyle, were all perceived to be of similarly high impact.

**INNOVATION TRENDS**

Analysis of number of patents published by country shows the USA as the primary focus of smart city technology innovation. There have also been a substantial number of patents filed with the World IP Organisation, which suggests that the number of multi-country patents for smart city technology is likely to increase.

Analysis of number of patents published per year shows that smart city technology innovation has increased considerably since 2015. Prior to this, the number of patents published per year was consistently low.
The proliferation of digital infrastructure, urban data analytics, and automation in cities worldwide [61], [62] shows that the smart city is an integral and prioritised part of the global urban agenda [62]. The Quayside proposal in Toronto (see page 22) is a prime example of this, combining real-time data analytics and underground services to facilitate a human-centred urban precinct offering improved quality of life to its residents [55]. The success of such proposals will demonstrate the capacity of smart city initiatives to follow through on their potential to transform how we live in cities, and how cities are managed and understood. However, an important factor of this potential transformation that is not well referenced is food and its role in the smart city [62]. The exception to this being the substantial attention that instant food delivery platforms have gained over the
last few years – both in terms of visibility and investment [63]. With services like Uber Eats and Menulog, consumers are getting used to and demanding more control over their food and how they consume it [64]. These services, however, are largely built on closed platforms and have little integration with the smart city initiatives being developed by city governments. In fact, few cities have reported the development of digital ways to interface with food in the city – an oversight considering the potential interesting uses for technology in tracking the movement of food in the city [65]. Technology has the potential to “help monitor, analyse, and manage the real food industry in cities” [66]. The current lack of food initiatives in smart city plans is a significant shortcoming considering the important socio-economic role that food has in city life [62].
CONCLUSION

This Horizon Scan report has outlined seven emerging technologies that present potential challenges and opportunities to the Australian rural industries. As the second and final Horizon Scan completed as part of the Predicting New and Emerging Industries for the Australian Agricultural Sector project, it builds on the previous eight emerging technologies identified in Horizon Scan 5 [67]. In addition, these identified technologies contribute to the broader watchlist established during the previous project, Detecting Opportunities and Challenges for the Australian Rural Industries [1], which now stands at a total of thirty-nine emerging technologies. This volume of technologies, which originate from an incredible diversity of domains, demonstrates the openness to technology innovation and technology transferability within the rural industries. It is recognised that through this potential transferability, there are many nascent opportunities that can be developed.

A critical factor contributing to the opportunities for developing emerging technologies in the Australian rural industries is a context of rapid change. This includes significant environmental issues such as climate change, resource scarcity and declining biodiversity. It also includes socio-economic trends. There is unprecedented growth in developing nations’ middle class which is driving increased demand for food and material consumption. Meanwhile, consumers in developed nations are increasingly conscious about their consumption patterns, but they are also becoming more demanding of the services and value that they have access to due to the increasing ubiquity and capability of digital technologies. This report, and the broader project that it is a part of, is situated
within this context of rapid change and emerging technology development. It aims to take advantage of the synergies forming between technology development and global trends to identify technology-driven industries that will potentially develop in the Australian agriculture context. While these opportunities have been touched on to a small extent in this report, more thorough discussion can be accessed in the Emerging Industries – Agriculture and Technology [3] report, delivered in November 2018.

As this project now moves toward the final deliverable, a revised watchlist of emerging technologies will be prepared summarising the key technology categories and their application potential in the Australian rural industries. In addition, through a process of engaging with sector experts from several key technology domains, the summary of the watchlist will provide insights into the perceived commercial potential, and importantly, the transferability potential that the identified technologies offer in the future.
REFERENCES


This project employs a concurrent phase, iterative methodology to:

1. scan and extract data from a variety of sources;
2. synthesise this information to identify potential trends and innovations for further investigation;
3. and, communicate these issues through visualisations.

Implementation of each respective project phase, led by data mining, synthesis, and visualisation, occurs across three interactive streams: Discovery; Evaluation; and, Consolidation. These streams are continuous over the course of the project requiring different inputs from each project phase. These inputs from each phase, and their interactivity is represented in Figure 2.
DISCOVERY
Discovery focuses on scanning selected sources to extract relevant data and detect signals of emerging and transformative technologies. Data sources are strategically selected to ensure input from a diversity of domains within an international context. In the current implementation of the discovery stream, sources included select twitter users, patent databases, industry and market reports, and technology news media. Scanning of these sources employs data mining and synthesis concurrently:

- Data mining focuses on scanning the twitter feeds of thought leaders and technology experts in a range of technology and industry domains. These are selected based on the recommendations of QUT experts working in relevant technology domains.
- Synthesis focuses on scanning a broad range of technology news publishers, industry and market reports, and patent databases.

The confluence of data mining and synthesis outputs in the discovery stream results in a list of technologies for further investigation in the subsequent evaluation and consolidation streams.

EVALUATION
Evaluation focuses on filtering the signals identified in the discovery stream. Its implementation leverages expertise from QUT, and Agrifutures Australia through the provided list of innovative farmers, to assess the potential impact of a broad range of emerging technologies. This process uses Delphi style surveys which are deployed in successive rounds.

The initial round of surveys focuses on evaluating a large volume of technologies identified in the discovery stream. This is achieved through presenting a series of simple statements that describe the functionality of a technology, and asking for a rating based on its perceived impact. From these ratings, a shortlist of technologies is compiled for further investigation and ongoing monitoring. Successive survey rounds present a lower volume of questions but require increasingly qualitative responses. It is through this process that we narrow the scope of technologies that are included on the watchlist and that will be monitored throughout future reporting periods. As the evaluation stream progresses, we continue to develop an objective list of criteria to establish the possible scale of impact of each transformative technology. These criteria are re-introduced in successive discovery stages of the project to assist with filtering the large volume of data.
CONSOLIDATION

Consolidation focuses on monitoring technologies on the initial watchlist, and providing a detailed analysis of their potential impact for Australian rural industries. This involves a detailed analysis of the technologies' potential impact for Australian rural industries and developing a rationale for why they should be monitored. This consolidation stream utilises both data mining and synthesis to receive input from a broad range of data, and gain the requisite detail.

Data mining focuses on eliciting deeper analysis of the technologies identified and short-listed during the discovery and evaluation phase. Directed by specific technologies and related keywords, data mining targets social media feeds and patent databases. The outcome of this stage provides assessment of candidate technologies based on metrics such as trends over time, associated keywords and industries to identify the contexts in which the technology is active and where it is receiving innovation, and location.

The data gained from this stage of data mining, and from the evaluation stream, feeds into and directs synthesis. With this direction, synthesis can focus on specific applications and implementations of the technology to better understand and communicate its potential impact for Australian rural industries. Visualisation is then used to bring together the inputs of synthesis and data mining, as well as inputs from the evaluation stream. This includes the development of infographics and scenarios to communicate the watchlist issues and themes.