Automation and Sector Impacts Research 2016

Food Manufacturing Sector Outlook

Scottish Enterprise

optimat
strategies for success

Report

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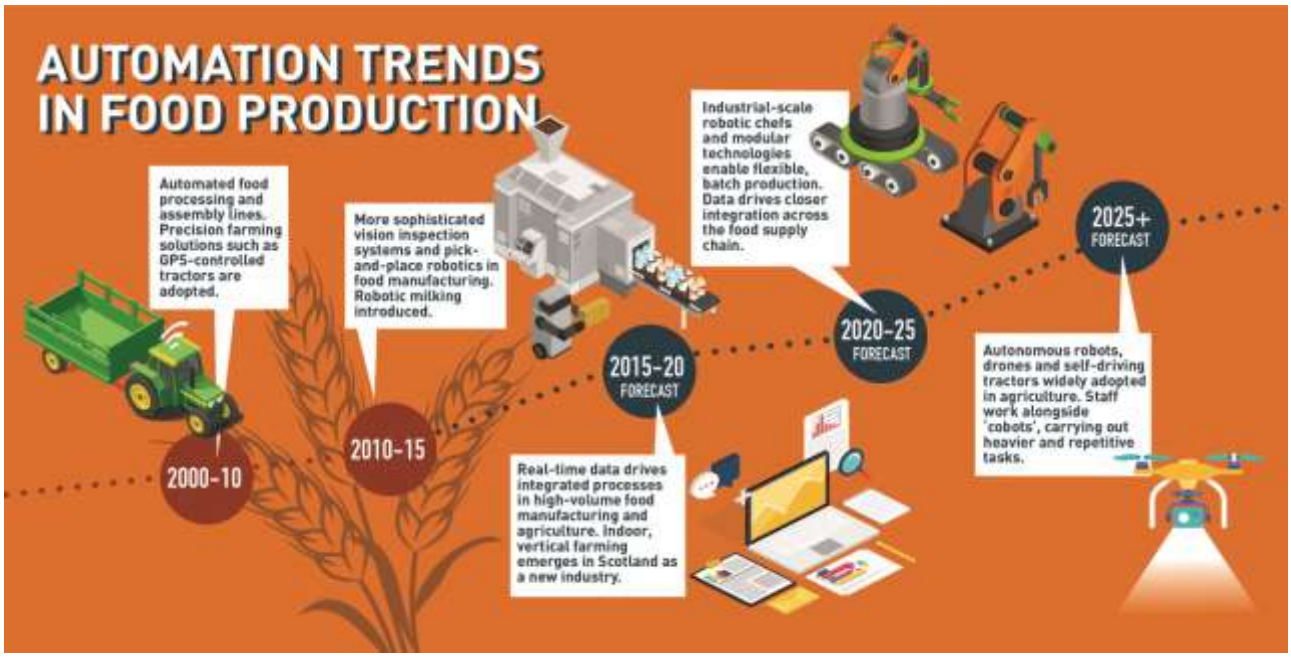
Executive Summary

This report considers current and future adoption of automation by the food manufacturing and agricultural sectors in Scotland to 2025 and beyond. It has been developed with contributions from sector companies and industry representatives in this area. The key findings of the report are:

- Scotland has a thriving and very successful food and drink sector that is well supported by the industry leadership organisation, Scotland Food & Drink, as well as its partners, covering all sub sectors and economic and business development support
- The pace of technological development and the decreasing cost of practical solutions for the food sector are increasing interest and adoption of automation solutions
- The adoption of automation solutions is a significant opportunity for businesses in the sector to benefit from increased productivity, increased yield, resource efficiencies, cost reductions and compliance with strict industry regulations. It also allows manufacturers to have more control over their processes to achieve high levels of accuracy, traceability, consistency and quality
- Automation in the food manufacturing and agricultural sectors covers a wide range of solutions from physical automated process lines and robotics to digital systems and sensors, with an increasing trend towards convergence of the physical and digital technologies to produce new, cost effective solutions that can support analysis and decision making
- The structure of the sector in Scotland is characterised by the large number of SMEs, many of which are based in rural locations
- Different types of automation will require different levels of investment. Some automated production lines will require significant capital investment by companies and the payback period may be 10-15 years. Other solutions will take advantage of technologies that have come down in price in recent years due to advances in technologies and the reduction of moving parts (such as pick and place robotic equipment), providing business with new opportunities to adopt new innovative solutions to create more efficient processes
- There are many examples of businesses in Scotland already having adopted highly automated processes. The drinks sector is a clear example of where this has been successfully adopted over the last 10-15 years – this has generally been driven by compliance and the financial strength of the larger businesses operation in the sector. Many of the larger, well known food manufacturers have also invested heavily in automation solutions to create efficiencies and improve the quality and consistency of the product. There are also examples of small scale automation in SMEs and micro-businesses that have either identified an opportunity to be innovative or as a reaction to other business challenges
- The agricultural sector is one in which there is a significant amount of manual labour and, as such, there is significant potential to develop and adopt new automation technologies, particularly due to the ageing workforce and the concerns regarding a lack of young people that want to work in the sector

- Increased levels of automation will inherently require a different or new set of skills from the people working in the sector now and via education of the future workforce. Technicians, engineers and trained operatives are already being developed within business that have the capacity to upskill their workforce. New training and further education options will need to be developed and delivered in the future to maintain equip the sector as it adopts more automated solutions



This report provides examples of current and emerging automation technologies relevant to the food manufacturing and agricultural sector in Scotland (as illustrated above and explained throughout the report) and uses stakeholder input to develop a vision for 2025. The report comments on key issues that need to be addressed to achieve this and makes recommendations for companies, industry representatives and the public sector.

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1. Purpose and overview of the research

1.1 Objective of the work

This report is one of three similar reports, with the other two focusing on automation in construction and in financial and business services. The key findings of all three reports are summarised in a separate Strategic Overview report. The objective of this report is to provide an overview of the current level of adoption of automation in the Scottish food manufacturing sector and identify how this might change over the period to 2025. The report identifies examples of automation that have been adopted by the food and drink sector in other countries and potential future applications that are currently at research and demonstrator stage.

1.2 The research process

Research for this report was carried out during August and September 2016. This involved a combination of secondary and primary research. The sources of secondary research are listed in Appendix A, with detailed references provided as footnotes throughout the report. The primary research obtained feedback from industry bodies as well as organisations currently operating in the sector in Scotland. Industry stakeholders provided insight from the perspective of current practice, challenges and drivers as well as industry growth and development.

1.3 Definition of automation in the food manufacturing sector

Within the food and drink sector there are some key areas of automation and robotics that should be highlighted. These are:

- Automation through the use of control systems to perform tasks that would otherwise have been carried out by humans
- The use of robots to perform heavy and/or repetitive work to maximise productivity and cost effectiveness
- The use of robots to perform more complex tasks by linking it intelligently to other machines for sequence control and via the use of sensors in order that it can react to variation in materials, components or the environment
- Robotic vision systems that can be more effective than humans in terms of accuracy, consistency, efficiency, hygiene and cost effectiveness

Automation has also become a key element in ensuring competitiveness from UK manufacturing industries in response to threats from low labour costs in other parts of the world[1]. Often, however, the largest benefits can be provided by improvements not envisaged at the start of the project.

[1] www.bara.co.uk/definition-of-robots.html

1.4 Scope of the research

The food and drink sector in Scotland is wide and diverse and spans the activities of agriculture, fishing and aquaculture and food and drink manufacture. It is classed as a priority sector for Scotland and is one of its most successful. The industry is vital to Scotland's economy; it creates jobs and wealth and has an impact on health and sustainability as well as playing an important role in attracting people and investment to the country.

While food manufacturing was initially cited as the focus for this sectoral report, the research highlighted two key areas that would impact from further use and investment in automation and robotics technologies; these are food manufacturing and agriculture. These will, therefore, form the scope of the report and summarised as the 'food supply chain'.

1.5 Sector overview

Food and drink (including agriculture and fisheries) is identified in Scotland's Economic Strategy as one of the key growth sectors where Scotland has a comparative advantage and an opportunity to increase productivity and growth.

In 2014, the food and drink sector in Scotland had a turnover £14.4bn and gross value added of £5.3bn.

Total food and drink sector exports stood at £4.9bn in 2015 with drink exports continuing to account for the majority – 78% (by value) of Scotland's total food & drink exports. Food exports have achieved significant growth in recent years and now account for over £1bn of exports.

Employment within the sector exceeded 119,000 in 2014, accounting for 4.7% of overall employment in Scotland. Agriculture and fishing represents 60% of employment within the sector, with these parts of the industry providing key inputs to the Scottish food and drink sector as a whole and being a major supplier of raw materials to the UK industry.

Food and drink manufacturing employs almost 39.5% of people in Scotland's food and drink sector and is the largest manufacturing sector in both Scotland and the rest of the UK. In Scotland, it accounts for 14.2% of the total Scottish manufacturing output. The food and drink manufacturing sector in Scotland has grown at twice the rate of the UK average, increasing 43% in Scotland, compared to 21% in the UK, between 2008 and 2014.

1.6 Characteristics of the sector

Reputations for premium, health and provenance are key to the success of Scotland's food and drink markets, with seafood, whisky, red meat, dairy, baked goods and soft drinks of primary importance in both domestic and export markets. The environmental aptitudes of unspoilt landscapes, fertile land and clean air strengthen the proposition, together with the ambition, capability and foresight of companies to address global trends. Scotland Food & Drink (SF&D) is the industry leadership organisation that works with trade organisations, public sector organisations and academia to grow the value of the sector and to support the vision of

Scotland as a 'Land of Food and Drink'. The collaborative approach taken in supporting the sector to grow and develop has been a key element in Scotland's success and its international reputation for quality.

Scotland's food and drink sector is characterised by a high number of SMEs. In March 2015 there were 17,290 business registered as operating within the food and drink sector in Scotland, with 98.9% of these being small (0-49 employees). These small businesses accounted for 53.8% of all employment in the sector.

This characteristic contributes to the issue that, despite a world class research base, Scotland (and the UK) currently lags behind other areas of Europe in terms of innovation. SMEs in particular are less likely to engage in collaborative innovation. This is reflected most strikingly in the sectors spend on R&D (as measured by Business Enterprise Research Development, BERD), which was £19 million in 2014, a decrease of 12.9% since 2013. Spending on R&D in this sector represents only 2.1% of the total BERD spend in Scotland.

Scotland does, however, have a significant number of academic and research institutions that are carrying out work to pursue innovative new products and processes to support businesses and the sector as a whole. The uptake of new technologies, in the area of automation and robotics, however, is generally slow, as evidenced by both secondary and primary research. Trends within the industry, however, are now beginning to impact on future business processes that may drive the uptake of more sophisticated and advanced automation and robotics technologies.

2. Vision for 2025

2.1 Food supply chain

The key elements of the 2025 vision for the food supply chain are set out below. (Note that the codes (*FM1*, 2, etc.) refer to examples considered in Section 5.2)

- The internet of things *(FM1)* and the smart use of data has driven efficiencies in processes that were already highly automated (e.g. spirits production) to further eliminate downtime and maintenance issues as well as support decision making for management and engineers. It also extends back to the farmer who is integrated into the wider process enhancing traceability and production planning for the whole supply chain
- Robots have become simpler to use – they have fewer moving parts, can be updated easily and have controllers that can be integrated with other robots – modular systems are commonplace, allowing increased flexibility in the production of food products. Robotics and automation provide the required level of flexibility to businesses that need to react to the changing needs of consumers and retailers
- Robots and humans work together to perform a variety of tasks – these 'cobots' *(FM2)* will not necessarily perform all activities in a process but will become co-workers, carrying out heavier, repetitive tasks alongside humans – this is thanks for vision and sensor technology developments *(FM3)*as well as advanced in computing power
- Deep learning *(FM4)* is being introduced in robots to eliminate the need for pre-programming to further simplify the use of robots in different applications (robotics

manufacturer FANUC showcased its deep learning robot in Japan in 2015, which used trial and error to determine how to complete tasks)

- Farmers are becoming more like office managers - given the significant level of technology integration, farmers are using real time data from a number of sources across the farm – sensors on cattle, sensors in field *(FM5)*, drone data *(FM6)*, weather modelling, etc. – to make decisions related to operation of the farm
- Small robots (agribots) *(FM7)* are being used to autonomously scout, sense and treat invasive pests and pathogens and use micro amounts of pesticides and chemicals to treat crops. This means that less chemicals and pesticides are being used resulting in better tasting produce, reduced costs of production and more sustainable growing conditions
- Fruit picking and harvesting robots *(FM8)* are now available to farmers to reduce the significant labour requirements of this process. Soft fruits are grown at a height that allows the robots to easily access the fruit. Although this is not yet widespread, it is an exciting development that is addressing a real need within the industry
- Climate change, across the globe, has increased concerns over food security and Scottish researchers and businesses are capitalising on opportunities to develop new ways to grow crops
    - Urban farming *(FM9)* is becoming increasingly common to address shortages across the globe – this is also being carried out in a sustainable way by reusing heat from locally sited factories through collaborative arrangements
    - Vertical farming *(FM10)* has now been proven a successful alternative to outdoor food production and is a fully automated process, within minimal human intervention – a number of facilities have been established across the country and are demonstrating excellence in research and development for Scotland

There are a number of high level benefits and implications of this increased adoption of automation by the food supply chain. These can be split to demonstrate this for both food manufacturing and for agriculture. For the food manufacturing sector these benefits are:

- The industry has become an attractive sector for young graduates to work in and this is enabling the adoption of robotics and advanced manufacturing
- Productivity has increased significantly resulting from the increased efficiency in factory processes and the ability to operate both 24/7 and with flexibility when required
- Businesses are able to comply with increasingly stringent regulations as well as meet demands for high quality products thanks to the advanced automated vision inspection systems *(FM4)* that are efficient and effective as well as control systems that eliminate human error and reduce human intervention. They also help to reduce waste and any associated costs
- The sector has continued to be one of Scotland's most important industries thanks to the ability to meet global competitors head on while maintaining Scotland's reputation as a 'land of food and drink' with its natural larder and quality products

- Businesses in the sector have been able to reinvest in new technologies due to the increased efficiencies in their operations, creating additional opportunities for employment, upskilling and training of the workforce
- There is a significantly increased awareness of the benefits of adopting automation technologies throughout the supply chain, with the biggest shift being in SMEs, many of which had previously been reluctant to invest.

The high level benefits and implications of this increased adoption of automation by the Scottish agricultural sector are:

- Enhanced productivity from primary production processes and more flexible operations to address real time needs on farm
- Increased yield from farming operations due to the efficiencies created by automating processes and using (big) data to its full advantage
- Increased profit for primary producers and hence the ability to reinvest in the economy and in new technologies at all stages within the supply chain
- Significant reduction in pesticide and chemical use in agriculture leading to a reduced environmental impact for framing operations. This is also beneficial from a cost perspective as well as preventing further depletion of natural resources
- A balanced approach between automation and craft/niche production has been maintained – this has always been particularly important for Scotland's brand as a land of food and drink. By automating time consuming processes and mundane tasks and introducing robotics to enable precision agriculture to flourish, famers are able to spend more time on key strategic tasks as well as using their time look after crops and herds better
- Scotland has managed to enhance its reputation as a food producing nation and is now able to compete better in the global market place
- Scotland is a leading player in research and development in Agri-tech and is demonstrating the potential to other nations interested in increasing their uptake of such technologies.

3. Market Drivers and Barriers

3.1 Drivers

Automation and robotics clearly has the potential to support industry growth and create a more sustainable and profitable future for Scotland's food businesses. Based on both secondary research and industry players, the key drivers for the increased uptake of automation in the food sector include:

- Price competitiveness – downward price pressure from supermarkets means that businesses need to reduce costs and increase productivity where possible. Interestingly, some industry articles suggest that manufacturers have been reticent to make public their desire to automate for fear of margins being squeezed further by multiple retailers
- Compliance with regulation and legislation (e.g. health and safety, environmental) – each sub sector will have its own compliance issue but there are some key areas where automation can have significant benefits by removing manual processes (e.g. spirit production)
- Increasing lack of available skilled and unskilled labour within some key sectors of the industry – in the past there was an abundance of lower cost (often migrant) labour and businesses used this, as needed, to fulfil their requirements. During those times, the demand for automation was particularly low as the cost/benefits did not outweigh the benefits and flexibility of lower cost labour. In recent years, however, the availability of such labour has decreased, impacting on both costs and productivity. The impending Brexit fall out may exacerbate this situation, with both desk research and industry experts indicating that businesses are worried about the potential implications related to available labour
- Rising cost of labour - with the introduction of the National Living Wage this is also a driver for the increased uptake of automation and was listed in a recent UK wide survey[2] as the biggest challenge facing firms
- Flat lining productivity – this is an important driver towards automated process, particularly in low margin operations where an increase in productivity can have a huge impact on the success, and survival, of the business
    - In 2015, the UK's gross capital formation[3] was around 17% of GDP[4], indicating low levels of investment that have impacted on productivity
- Demand for quality, traceable and consistent products – achieving high levels of this is made possible with automation and robotics technologies. Industry consultees indicate that this is an important aspect in considering potential investments to factory settings

[2] Bank of Scotland Research Series – Food and Drink, 2016

[3] Capital formation is a term used to describe the net capital accumulation during an accounting period for a particular country, and the term refers to additions of capital stock, such as equipment, tools, transportation assets and electricity

[4] World Bank

- Return to flexible batch systems - changing consumer tastes and demand for more and differentiated products have led to a requirement for automated multi-functional and flexible equipment. This gives manufacturers greater control and with new technologies emerging that will support this need, the benefits of automation could be significant
- Lack of young people that want to work in agriculture - this is a worrying trend and one that is driving change and a move towards the increased use of automation within the agricultural sector. The average age of farmers in Scotland is estimated to be 58, with many having no successor in place. Automated process will make farming easier for an ageing population but may also make it more attractive to the next generation
- Increasing urbanisation of the world's population - as the population grows and more people live in urban environments, there are challenges to be faced with regards to sustainable food and farming practices, scarcity of raw materials and supply of sufficient, nutritious food stuffs. The use of new automation and robotics technologies can support the sector in addressing these issues

The challenges highlighted here are really driving businesses to look at investing in new and emerging technologies that have the potential to create opportunities in an increasingly competitive market place, both at the domestic and international level.

3.2 Barriers

A summary of the key barrier to the adoption of automation within the food manufacturing and agricultural sectors in Scotland (from both secondary research and discussions with industry players) is provided here.

- Scale - the industry in Scotland is defined by the large number of SMEs operating across all aspects of food manufacture and agriculture. The scale of operations, therefore, has often been a challenge when looking to automate processes. The rural location of many businesses in the sector also presents a barrier when looking to support the automation of their processes.
    - There are examples of SMEs using automated production technologies but, in general, the uptake of automation is low within the sector in Scotland among SMEs. Often products are handmade or require elements of hand finishing, which can be very expensive to automate on a smaller scale of operation. Even within some large organisations, premium products will require hand finished packaging and labelling as the scale of that product range is not sufficient to warrant change
- Awareness of the applications and benefits of automation – consultations with industry representatives suggest that there is a general lack of awareness of the potential for automation across the sector. While business may be aware of the more mainstream applications and uses of such technologies there is less knowledge and understanding of smaller, niche or innovative ways in which such technologies can be applied and the benefits of doing so. There has also been a belief that automation is unsuitable for the assembly of soft, variable, fragile, slippery natural products, which has discouraged capital investment in automation

- Entry Cost – historically, the entry cost of robotics has been high, particularly for SMEs. Research suggests that the cost of the technology has come down in recent years and that it can be significantly more affordable, in terms of payback period, than perceived. Short term contracts from supermarkets, which are the norm in the UK, do not provide sufficient security for many SMEs to invest in new technologies as the payback period can be too long in relation to uncertainty over returns
- Technical Support - for companies that do invest in automation, discussions with industry players suggest that there is a lack of technical support engineers that are close to the customer. If a piece of equipment was to break down, the ability for an engineer to be there quickly is a necessity and if this is not available then there are likely to be significant operational and productivity issues. A high level of available technical support will underpin the adoption of advanced manufacturing technologies. Scotland is currently very well served by systems integrators and so the software side of automation is less vulnerable from this perspective (and it can be accessed remotely) but discussions with industry representatives indicate existing problems in servicing hardware such as production lines and robotic equipment
- Timing - investing in the right technologies at the right time has been a challenge for businesses in Scotland. There have, in many ways, been missed opportunities for businesses to invest in automation and so a big step forward is now required. Investment in innovative processes or automation systems need to be taken carefully to ensure that it will futureproof the business and create a more sustainable operation

4. Current patterns of adoption of automation

4.1 Food manufacturing

The food manufacturing sector is one that has embraced automation over the past 40 years with the use of advanced machinery to carry out high volume, repetitive tasks such as packaging and labelling. It is an intensive energy and materials user as well, which has driven measures to increase environmental performance by reducing energy consumption and minimising the use of packaging. More flexible production processes that are energy efficient and self-controlling will become increasingly common place.

At this time, there is widespread use of highly automated and robotic processes, particularly for end of line packaging, palletising, bottling, etc. *(FM11)*. Some organisations in Scotland are using automated sorting equipment, which can reduce the number of inspectors required on the line and lead to reduced costs in production. This also addresses issue regarding the availability of labour.

More recently, highly effective and sophisticated pick and place robots *(FM12)* have allowed automation to move further up the production line but this tends to be for high volume, long life, single product lines. Adoption of this type of automation is being driven by the advances in technology that now allow more difficult and problematic areas as well as product lines Advanced vision systems *(FM13)* and improved integration of the robotic controller are also being incorporated into systems to improve the design and increase the usability of the equipment.

The latest generation of pick and place robots usually contain fewer moving parts – 20% fewer in the case FANUC[5], one of the leading players in the sector, which is believed to have contributed to a fall in prices, making the technology more affordable to manufacturers. Crucially, it appears that equipment suppliers to the food and drink sector are working more closely with robotics manufacturers to provide more sophisticated and advanced solutions that can be applied within the sector.

Some examples of companies in Scotland that have or are currently automation technologies in Scotland include:

- Whisky blending and bottling sites across Scotland have highly automated production process due to the levels of compliance placed on the sector and the need to eliminate human error e.g. Diageo, Edrington, etc.
- Colour sorters give the packer or processor labour saving and efficiency of operation for added value and cost savings over traditional methods of inspection. This is particularly effective in automating the manual inspection of fresh fruit and vegetables (in business such as Baxters) and for other harvested products such as nuts, seeds and grains (e.g. John Hogarth Ltd for its oatmeal and pearl barley)

[5] http://www.foodonline.com/doc/uk-food-industry-warms-up-to-robotics-0001

- Tunnocks is a business has invested heavily in robotic equipment over the years, with the first robotic packer purchased in 2010, significantly increasing efficiency for the firm
- Albert Bartlett and Sons is investing in robotic packaging technologies. The operation at Airdrie has 25 packaging lines for potatoes, each of which uses robotic technology to sort and grade the potatoes
- Macphie of Glenbervie is the UK's leading independent food ingredients manufacturer. Tracking the very latest innovations in automation, and learning from similar manufacturing plants in the US, the business has adopted both robots and automated machinery at its Glenbervie plant. This investment in advanced manufacturing technology has allowed the company to reduce manual handling risk as well as upskilling by providing value-added jobs for the workforce[6]
- Speyside Cooperage is using a robot to aid the refurbishment of whisky barrels. The robot in the system is primarily used to load and unload the barrels into a horizontal lathe and has led to a much quicker process that has increased the company's capacity *(FM14)*

4.2 Agriculture

Within agriculture there are some good examples of where automation is being used effectively to increase output and productivity and to alleviate labour constraints. The sector, however, has been slow to embrace such technologies and much of the work carried out is still manual labour.

Some examples of where automation technologies are currently being employed in Scotland include the following:

- The dairy sector is now using robotic milking systems *(FM15)* to support farmers with this labour intensive task. Within the UK, 5% of dairy farms are currently using robotic milking systems but this is set to increase as they account for around 30% of all new milking systems purchased[7]

Mackies of Scotland *is an example of a business successfully having adopted robotic milking systems. It is currently one of the largest robotic milking farms in Europe, having recently upgrades all of its equipment with systems that are designed around the welfare of the cows. This new style of farm management allows a 500 strong herd to be managed by only three people[8].*

- The automated health monitoring of cattle, via sensor technologies, *(FM16)* is also being carried out in Scottish farms to help farmers maximise the management of their herds. The technology can, for example, monitor the general health and well-being of cows as well as helping farmers to increase the herd's pregnancy rate and in turn maximising yield

[6] A Manufacturing Future for Scotland, 2016
[7] Royal Association of British Dairy Farmers
[8] http://www.mackies.co.uk/our-farm/our-cows/more-about-our-cows.html

__Cuil Farm__ in Dumfries & Galloway has 440 milking cows and has been using health monitoring systems to maximise the yield of its herd and has benefitted from a significant increase in the pregnancy rate of its cows. The systems can be monitored from anywhere, 24/7.

The __Silent Herdsman__ system, a private VC-funded company from Glasgow recently acquired by Afimilk, a global provider of dairy farm management solutions, developed a neck mounted sensor to monitor cow's behaviour and health. This can be monitored from a farmer's mobile application to allow less time to be spent directly observing the herd and more time breeding and treating cows automatically identified by the system[9].

- Another piece of equipment being used within agriculture at present is automated drones. Within the UK and Scotland these tend to be used for monitoring land and for crop surveillance. Drones are a relatively low cost piece of technology but the potential for precision agriculture, depending on the development of legislation of drones for commercial use, could present real opportunities for small and medium scale farmers

Scotland's Rural College, __SRUC__, is currently conducting research on the advantages that could be reaped by farmers through the use of Unmanned Aerial Vehicles (UAVs) or drones, which includes: the ability to detect weed species at an early stage of crop growth; enable crop biomass to be evaluated throughout its growth cycle; helping to identify the health of crops during their growth cycle, including nutrient status, water stress and pest infestations[10].

- Another piece of technology being used is the driverless tractor *(FM17).* Soil compaction from the use of tractors is a serious problem and can reduce crop yield for farmers. This technology, however, allows the farmer to auto steer the machinery, confining wheels or tracks to specific narrow strips. This reduces soil compaction, which in turn increases the absorption of water, reduced fertiliser run-off and soil erosion. Although this technology has been around for some time, it is believed that only a small percentage of farms in the UK currently use this technology due to the perceived extra cost involved
- Apps *(FM18)* and the controlled use of data is also something that is becoming more commonplace within Scotland's agricultural sector. The farming sector is using apps in all sorts of ways from estimating a farm's GHG emissions to assessing the economic value of livestock manures

Overall, the availability and application of data is a powerful driver for more integrated farming methods that may control farm machinery or support decision making processes.

[9] http://www.afimilk.com/silentherdsman
[10] http://www.sruc.ac.uk/info/120118/crop_clinic/1366/uavs_for_land_use_research

5. Leading edge developments

Automation has huge potential within the food sector in the UK, which has generally not seen significant innovative advances in recent years.

Some examples of leading edge developments from both within and out with Scotland, within this sector, include:

- The use of automation and robotic systems to control recipe management and reduce material movement and waste in food production. These systems will also allow for more flexible, batch production *(FM19)*

*One of the most advanced developments in the UK at present is **APRIL** – Automated Processing Robotics Ingredients Loader[11]. The company, Peterborough based OAL, has been working with the University of Lincoln to develop this technology, which it believed will disrupt the food manufacturing sector. The technology is known as robotic chefs and claims to be able to significantly reduce the number of operators required for food production. This flexible manufacturing technology claims to have unlimited process configurations that can heat, mix, homogenise, combine and fill. The company received a £60,000 Agri-Tech growth grant for the development of the system and there appears to be significant commercial interest in the technology from companies in various sectors of the industry, including Scottish based businesses, as it expects to be able to achieve 7-14% bottom line improvements.*

The APRIL robot was launched in April 2016 and is still under development but it has significant potential to change the way in which food is produced.

- Vertical farming in a controlled environment is on the increase as farm land becomes more scarce and the benefits of reduced transportation, reduced labour costs and the sustainable use of scarce natural resources are demonstrated

Intelligent Growth Solutions[12] *is an organisation that has been set up in conjunction with the James Hutton Institute and demonstrates the pioneering work being done to automate the growing of fruit and vegetables. The yet-to-be-constructed demonstrator facility will grow crops in a large building, which technically could be situated anywhere, and will produce a consistent, year-round supply of food. It will be controlled by artificial intelligence and will use novel lighting technologies and sensors within the £2.5M facility. While there are other examples of vertical farming across the UK and beyond, this is different in that it will use robotics and sensors to automate the process. The project owners say that total automation is technically feasible and presents benefits such as the small footprint of the facility, reduced food miles and more energy efficient production processes. This type of facility is one that could be seen as a new type of farm in the future and the ability to be fully automated may present real opportunities on a global scale.*

[11] http://april.oalgroup.com/
[12] https://www.intelligentgrowthsolutions.com/demonstrator/

*A pilot project between wholesale supermarket Metro and indoor farming start-up **Infarm**[13], the Kräutergarten ('herb garden'), uses hydroponic principles to grow plants out of nutrient-rich water. The plants are stacked vertically and housed in a protected environment, and the Infarm app monitors all aspects of the farm technology, controlling factors like pH level. This specific project is the first in-store farm in Europe, producing food to be sold directly from the supermarket, with shoppers are able to see the produce being grown.*

- Urban Farming, like vertical farming, is a response to the looming issues of a growing population, increased demand for food production and sustainability in farming

*The **UK's first underground farm**[14] produces a daily crop of herbs that goes to London's fresh produce market at New Covent Garden and a home delivery service (called Growing Underground). The founder of the business states that the advantages of underground farming as being a controlled environment and the closeness to the customer. He says that the fresh herbs can be on a restaurant plate within four hours of being harvested – 24 hours at most. The improvements in technology over the last five years are cited as being key to the viability of the venture.*

***Panasonic** has diversified into crop growing in one of its assembly plants in Japan. This makes use of unused space and technologies already possessed by Panasonic, putting them to use with an optimum balance between automation and manual processing. It is growing low-potassium lettuce for people with kidney disease and has plans to collaborate with the healthcare sector.*

- There are some interesting examples of automated farming operations and/or technologies emerging in other countries to address demands for lower cost and more efficient food production *(FM20)*

*A Japanese company will open the **world's first "robot farm"** as an attempt to fill labour shortages created by the country's ageing population[15]. The company states that from mid-2017, industrial robots would carry out all but one of the tasks required to grow the tens of thousands of lettuces that will be produced each day. The robots will re-plant young seedlings as well as water, trim and harvest crops but seeds will still be planted by humans. It is believed that the new indoor farm will improve efficiency and reduce labour costs by half, with 98% of the water being recycled. Japan's has a shrinking agricultural sector, with the average age of farmers being 65.9 in 2011. This reflects the drive in the country for more automated processes and application in agriculture.*

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[13] https://infarm.de

[14] https://www.theguardian.com/environment/2016/apr/26/growing-underground-the-fresh-herbs-sprouting-beneath-londoners-feet

[15] https://www.theguardian.com/environment/2016/feb/01/japanese-firm-to-open-worlds-first-robot-run-farm

FarmBot Genesis[16] *is an open-source hardware platform optimised for small-scale soil-based food production, designed to grow food in an automated and precise fashion. FarmBot "plants seeds, waters them and uses sensors to learn about the soil, the plants and the environment in order to farm smarter". The system allows the robot to grow a wide variety of crops in the same area at the same time and uses a camera and advanced computer vision software to allow the robot to monitor the garden and detect weeds when they emerge.*

- Automated harvesting is generally seen as the Holy Grail within the agricultural sector due to the need for a significant number of people to carry out such activities. There are a number of projects being carried out across the globe to develop this technology, which is relatively difficult due to the nature of the produce and often a requirement for a change in the way the product is grown
  - In Japan, a robot has been developed by Shibuya Seiki and the national agricultural and food research organisations that can pick strawberries at a rate of one every eight seconds[17]
  - Panasonic has begun field tests of a robot that uses camera and image sensor technologies to detect ripe tomatoes on the vine, before picking them without damage[18]
  - In the US, a strawberry harvesting machine is being prototyped that harnesses high powered computing power, colour sensors and small metal baskets attached to robotic arms to puck ripe strawberries from below deep green leaves[19]
  - Another US company is prototyping a robotic harvester that uses commercially available vision sensors and software that enables the machine to recognise only ripe strawberries ready for picking[20]
- Cobots – small scale agricultural robots are both a cause and consequence of the decrease in unskilled (migrant) labour within the UK. There are examples of them being used in unmodified industrial environments, working alongside people to carry out more physically demanding tasks

Harvest Automation[21] *in the US, has developed teams of small, highly intelligent machine that work safely with people to perform the most physically demanding parts of tasks at a significantly reduced cost. This intelligent, adaptive approach to automation 'provides scalable and robust system architecture for robots to work in the most challenging environments'. The robots are also, at the same time, collecting information that can be used for analysis and production planning, with future products planned that will include sensing and image capture technologies. Currently these robots are being used within the nursery and greenhouse*

[16] https://farmbot.io/
[17] http://phys.org/news/2013-09-japan-robot-strawberry-fields-farmer.html
[18] http://asia.nikkei.com/Tech-Science/Tech/Panasonic-develops-tomato-picking-robot
[19] http://www.agrobot.com/
[20] http://www.theledger.com/news/20160727/robotic-strawberry-picker-coming-to-plant-city-company
[21] http://www.public.harvestai.com/

industry but the company is working to expand into areas such as fruit and vegetable production.

- Autonomous Drones

  As mentioned previously, the use of drones in Scotland is confined to monitoring and crop surveillance but an 'aerial revolution' is forecast that is allowing for precision agriculture to take place in countries such as China and the USA, including precise crop spraying to reduce the use of pesticides

5.1 Research

There are numerous examples of research taking place within the UK to support the development of automation technologies for the food sector.

The BBSRC fund many research projects in the bio-economy arena and are looking ahead to the global issues of food security as it supports research projects in agri-tech. Some examples of the projects being supported include:

- Octocopter[22]

  This autonomous drone is being trialled at Rothamsted Research to that it is possible to measure plant growth and monitor crop stress, in reaction to water drought for example, from the air and autonomously. It has multispectral cameras that see in UV, infrared and visible light

- AUTOPIC[23]

  This is a multi-disciplinary project aimed at mechanising the harvesting of soft fruit through the use of autonomous vehicles and robotics. Partners include Harper Adams University, the Shadow Robot Company, Interface Devices Limited and the National Physical Laboratory. It addresses potential future shortages of fruit pickers and their increasing cost in the UK and overseas by researching the essential elements of autonomous agile fruit picking vehicles

- 3D Vision Assisted Robotic Harvesting of Broccoli[24]

  This project will test whether 3D camera technology can be used to identify and select when broccoli is ready for harvesting. It will be a key step towards the development of a fully automatic robotic harvesting system for broccoli, which will significantly reduce production costs

As indicated above, the automated harvesting of crops is a future development that is of great interest to the sector. For Scotland, in particular, automated harvesting of soft fruits is of significant importance.

The UK Government's Agri-Tech Catalyst is also investing in projects that will address some of the world's agricultural challenges from food security and sustainability to weed control and

[22] http://www.rothamsted.ac.uk/news/aerial-eyes-crops

[23] http://www.bbsrc.ac.uk/research/grants-search/AwardDetails/?FundingReference=BB%2fM005496%2f1

[24] https://www.precisionfarmingdealer.com/articles/1497-uk-university-research-may-lead-to-robotic-broccoli-harvester

livestock disease. Some examples[25] of those where automation and robotics is being incorporated in the projects are shown here:

- Automato

  The project aims to address seasonal labour constraints through the development of a cost-effective robotic system that performs on-crop quality and ripeness inspection and then automated harvesting. This brings together knowledge of innovative robotic arms, 3D sensing, and computer vision and object/pattern recognition

- Vision based crop-weed discrimination for automated weeding operations

  This project will investigate the technical foundations for the next generation of robotic weeding machinery, enabling selective and accurate treatment for specific weeds. This technology is a novel combination low cost 3D sensing and learning software together with a suitable weed destruction technique

Within Scotland there are numerous research organisations looking at ways to tackle global trends of food, energy and water security to offer practical solutions for organisations as well as driving growth and innovation within the sector. Such organisations include the James Hutton Institute and The Agricultural Engineering Precision Innovation Centre (Agri-EPI), in which Scotland's Rural College (SRUC) is a partner.

*The **Ari-EPI Centre** is a consortium of key organisations in the field of precision agriculture and engineering. It brings together expertise in research and industry as well as data gathering capacity in all areas of farming, to increase the efficiency and sustainability of the land-based industries. The Centre is exploring how to optimise the performance of highly complex production and processing systems in agriculture. Areas of interest include technologies such as automated vehicles, unmanned aerial vehicles (UAVs or drones), new instrumentation to monitor both operations and in-field performance of cropping systems, as well as sensing and imaging technologies to monitor livestock production in areas such as quality and health.*

The technologies being developed in research institutes today are likely to have an impact on the sector in the medium to long terms depending on their stage of development. It is clear from the examples above that many of these are early stage projects that are developing techniques and approaches that will lead to new, more advanced projects that will potentially lead to commercial applications in the future.

[25] https://www.gov.uk/government/news/16-million-for-new-technologies-to-improve-global-food-production-and-security

5.2 Summary of current and leading edge developments

The developments in automation that have been highlighted throughout this report as summarised in the figure below:

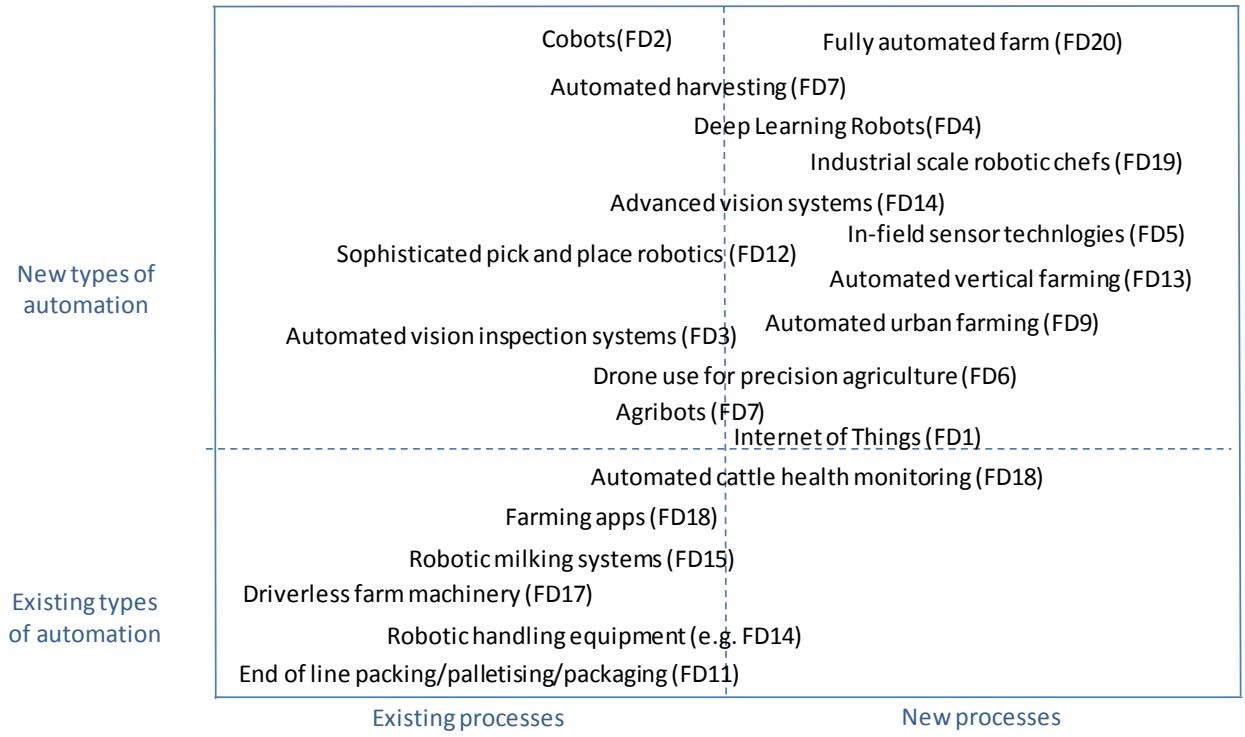

Figure 1: Examples of current and leading-edge developments

The developments are segmented depending upon whether they directly replace a human process or whether the robot achieves an outcome that could not be achieved by a human in an economic way. The developments are also segmented depending on whether they involve existing automation or will require new technology.

6. Analysis of potential implications

This section summarises the key themes identified in previous sections of the report.

6.1 Summary SWOT

The strengths, weaknesses, opportunities and threats related to the increased adoption of automation by the food supply chain in Scotland are summarised below:

Strengths	**Weaknesses**
• There is a strong, industry leadership organisation and significant sub-sector support to grow and develop the sector • Excellent international reputation for food and drink production • Scotland has leading research and academic expertise in food and agriculture as evidenced by its research centres and university courses • There are dedicated Innovation Centres which are directly relevant to the technologies needed to support automation including The Data Lab[26] and Centre for Sensor and Imaging Systems[27]. • Some business in Scotland e.g. high volume food and drinks (soft and alcoholic) manufacturers are already highly automated • Strong presence and expertise in control system and software development in Scotland	• Lack of available technical support (hardware) within food sector to support the implementation of automation and robotic applications in smaller, more niche areas of food manufacture • Lack of knowledge, skills and confidence among SMEs in adopting automated processes • No major robotics suppliers with an established presence in Scotland • Risk aversion among smaller businesses • Requirement for shorter payback periods, compared with other countries across Europe
Opportunities	**Threats**
• Provision of funding support for capex and innovation within food manufacturing businesses, particularly SMEs • Increasingly stringent regulations in the food sector are likely to drive investment in automation • The Scotland Food & Drink Partnership is currently developing its 2030 vision for the sector – if sub sector industry bodies support a drive for automation and help to increase knowledge and implementation of this across the sector it could have a significant impact • Development of cross sectoral learning opportunities, particularly in relation to adaptive and flexible production automation	• Inability to attract new, young people to the sector in skilled engineering jobs (automotive and aerospace sector traditionally more attractive with higher salaries) • Price pressure from supermarkets may increase as they take advantage of companies that develop more cost effective and efficient automated processes • Increasing uptake of automation in other countries in Europe could make Scottish companies and product lines less competitive / attractive

Table 1: Adoption of automation in food production – SWOT

[26] http://www.thedatalab.com/
[27] http://censis.org.uk/

6.2 Key market barriers and potential solutions

The table that follows summarises the key barriers identified through the consultations and secondary research. Potential solutions to overcome these barriers are also identified.

Market Barriers	Potential Solutions
Lack of awareness of potential applications and benefits of automation – particularly from SMEs. Understanding the technologies well enough to enable the correct investment to be made (e.g. not investing in the wrong technologies or those at end of life)	Establish a demonstrator site to highlight the potential of automation and the scale of the benefits that can be achieved - particularly for SMEs (and of niche applications) Development of case studies to inspire companies and to demonstrate the benefits and the challenges of implementing such technologies
High cost of automation and long payback period is often a limiting factor for businesses	Investigate possibilities for a collaborative approach to investment to reduce the cost of the technology or to support its use by local businesses e.g. aggregation of software, collaborative ownership, open access facilities Government grant/loan support for SMEs that find it difficult to justify high capital investment in an uncertain financial climate Use of initiatives already in place to support innovation and R&D, such as SE's Innovation Expert Help and R&D Programme
Availability of relevant technical support and engineering skills within the food sector	Development of initiatives / FE courses to train and upskill/multi-skill the existing workforce – this is for both engineers to develop and support the technologies as well as people to work within the sector to use and operate the equipment. Incorporate automation technologies into food sector educational courses to ensure it becomes the norm and that a base level of awareness and understanding is established at the outset. Investigate the feasibility of supporting development of an automation and technology supply chain or hub in Scotland to support companies across different sectors – engineering support for capital equipment is important and can impact the decision to invest in new technologies.

Table 2: Summary of the barriers and potential solutions to increasing the uptake of automation in the food sector

6.3 Strategic implications 2015-2025

Achieving the vision, described in section two, requires the food supply chain to continue to invest time to develop and evaluate the business case for the further adoption of automation technologies. This includes considering automation technologies that are already developed, those that are emerging (leading-edge) and those at research stage. This requires collaboration with the automation supply chain to develop new solutions. The research suggests that industry bodies and innovation-related organisations understand this need and are keen to see and provide further support in this area.

Within the food supply chain, there are already some good examples of businesses that have embraced automation (partly due to compliance and partly due to necessity in low margin products), reducing costs and creating efficiencies. Sharing this knowledge and experience of business benefits to other companies taking their first steps into automation technologies is an important next step. The food and drink sector in Scotland is praised for its collaborative actions and supply chain cooperation and so harnessing this further could have a significant impact.

An action for the food manufacturing and agricultural sectors relates to the location of businesses across Scotland. Many businesses are in rural locations and these are strategically important for Scotland, including for agri-tourism and for the promotion of Scotland's vision as a 'Land of Food and Drink'. Automation solution for rural locations offer huge opportunities for an ageing workforce and considered actions should take the specific needs of rural business in account.

Scotland has a thriving food and drink sector, well supported by industry bodies and the public sector. There could, therefore, be negative consequences if businesses do not seek to investigate automation technologies as a way to increase competitiveness and penetrate national and international markets. The research suggests that other countries in Europe are investing more heavily in automation, which in turn will reduce costs and increase productivity, potentially allowing then to gain a competitive advantage. While there clearly needs to be a balance between automation and the 'premium' reputation of Scotland's businesses, automation will act as an enabler for businesses facing challenges in today's highly competitive and cost conscious market place.

6.4 Strategic labour market implications, 2015-2025

The adoption of automation across the food supply chain offers opportunities to add to existing efforts to increase its attractiveness to new entrants. Reducing repetitive and potentially hazardous tasks as well as increasing the technical and skilled content of job functions will increase the sector's appeal. This is an important aspect for the future growth and development of the sector that already struggles to access the required technical skills as it competes with more attractive and higher paying sectors such as automotive and aerospace.

A key action for the sector, therefore, relates to education – both of the next generation coming into the sector and those already working within it who will require development of

their existing skills and competencies. The need for more engineers and technicians is well documented and work should continue to address this demand as way to make the sector a more attractive career option. Understanding the required technical capabilities of the future labour force so that training and education courses can reflect the need for expertise in automation and its use is a key step.

An ageing workforce, particularly in agriculture, will require a leap towards the use of automation technologies and robotics to support farmers (from a fatigue and safety perspective) and also to attract a younger generation to the sector. This will, therefore, be a key action for the sector going forward to retain a sustainable agricultural sector in Scotland.

In general, there is widespread concern about the reduction in low cost, unskilled labour in Scotland. The adoption of automation is one response to this evolving issue and actions should be considered to understand the potential for future development.

7. Conclusions and recommendations

This section describes the conclusions and recommendations arising from the research.

7.1 Conclusions

The key messages and findings from the research include:

- Scotland has a vibrant, internationally recognised food and drink sector that is of strategic importance to Scotland's economy. People, product and place are key to the vision of Scotland as a food producing nation and it is understood that automation will be an enabler for the sector, rather than a marketing tool
- Based on the feedback from the research, the uptake of automation and robotics in Scotland is currently relatively low (as is the whole of the UK) due to the high number of SMEs operating in the sector, the historical availability of cheap labour and the perceived high entry cost of robotics technologies
- There is a recognition of the need for investment in automation within the food manufacturing and agricultural sector among industry bodies as well as businesses themselves
    - A 2030 vision for the sector is being developed that is likely to take into account the need for automation technologies and it is envisaged that this will drive actions in this area
- The agricultural sector, in particular, is facing significant issues in the availability of labour and young people coming through that want to have a career in farming – this is leading to an identified need for the uptake of more automated processes
- There is a range of academic research experience in various Scottish universities and research organisations, much of which is focussed on new technologies that support and enable further automation of the sector
- There are many examples of automation technologies being used in both food manufacturing and agriculture, both within the UK and overseas. Many of these technologies could be adopted in Scotland over the next 5-10 years and include, for example, drone technology, modular robotics incorporating vision systems.
- Emerging technologies, prototypes and research technologies address practical issues for those operating in the sector as well as global mega trends (e.g. food scarcity and climate change) and Scotland appears to be well placed to adopt such technologies in the longer term
- Overall there is an appetite for the increased uptake of automation and robotics in Scotland's food and drink sector. Industry bodies are aware of the lack of progress in this are in recent years and are keen to change this but maintain the quality and reputation of Scotland's brand.

7.2 Recommendations

To increase the level of automation being adopted across the food supply chain, the following recommendations could be considered (segmented by actions to be led by companies in the food sector and supply chain, industry bodies and the public sector).

7.2.1 Food sector companies and the automation supply chain

- Promote the benefits of increased productivity, yield, performance and quality in relation to the adoption of automation technologies to increase awareness and viability of such solutions
- Identify opportunities to test the feasibility of technology that has been demonstrated or adopted elsewhere
- Identify opportunities to collaborate with the current and emerging automation supply chain to develop specific automation solutions to meet the needs of the business and/or sector
- Identify opportunities to collaborate with other like-minded companies that are facing similar challenges to understand the potential for cost saving collaborative development or with supply chain partners also seeking integrated automated solutions

7.2.2 The Scotland Food and Drink Partnership

- Raise awareness of the benefits and opportunities of automation technologies at a sector and sub-sector level to demonstrate the feasibility, tangibility and viability of adopting automated solutions in today's challenging environment (e.g. best practice visits, learning journeys)
- Understand the potential of collaboration between innovation centres, research centres and industry players to develop joint projects in key areas of need or to develop demonstrator sites to support increased uptake of automated solutions in this key market for Scotland
- Work with the businesses in the sector (and potentially at a sub sector level) and in the automation supply chain to understand the future labour market skills requirements that will arise as a result of higher levels of adoption of automated solutions
- The Scotland Food & Drink Partnership has successfully worked to grow and develop the sector in recent years. As it develops it vision to 2030, it should now consider the potential of automation as an enabler for increased competitiveness of the sector
- Consider options to develop automation training opportunities at a sector level to meet the emerging needs of businesses and to address barriers faced by many organisations, particularly SMEs
- Consider options to develop collaborative and/or cooperative solutions to support businesses considering the development of automation solutions to increase their competitiveness in the market – this may be particularly relevant in rural areas
- Provide support to those seeking to adopt automated solutions (and encourage uptake among SMEs) through relevant support programmes (for example, SMART

Scotland Grants, Innovation Expert Help, R&D Grant Scheme operated by Scottish Enterprise as well as others such as the FPMC Grant Scheme administered by the Scottish Government)

Appendix A - Bibliography

In addition to the footnote references to specific examples and other evidence, the following sources were used to inform this report:

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Appendix B - Glossary of terms

Term	Definition
Automation	The substitution of human labour by machine labour to carry out physical, cognitive and organising tasks
Unmanned Aerial Vehicle	Also known as 'drones', this is a particular class of automation technology that ranges from direct human control to fully automated inspection combined with the provision of data to allow further automated commands to be issued
Internet of Things (IoT)	IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction
Robotics	A class of automation where programmed machines perform tasks to replace or collaborate with human workers. Robotic systems are typically suited to standardised repeatable tasks

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