

Local Industrial Strategy | Evidence base report

Collaborative Innovation in the West of England

February 2019

The West of England has innovative businesses in a wide variety of industries. These firms help drive economic growth in the region by developing new products or ways of working. And collaboration across sectors can identify new uses for technology. We have researched some examples of industries with an innovative presence in the region to understand the drivers of innovation. This report discusses the factors that support or constrain collaborative innovation in the West of England, before presenting the detailed case studies of innovative sectors.

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Introduction

Innovation is a crucial element of economic growth. By developing and applying new products and services, or new production processes, businesses can raise the productivity of their staff and the value of their outputs. Successful collaboration contributes both to the creation of new ideas, and to the application of technology to new sectors. The West of England has a robust ecosystem that promotes such collaborative innovation, and the Local Industrial Strategy seeks to understand how to build on this success in the future.

The West of England has strong foundations of research and development, and support for commercialisation and business growth. In addition, the regional economy is driven by a wide range of industries from aerospace to advanced manufacturing, creative to robotics, finance to food. This diverse range of activity coupled with the geographical size of the region facilitates interaction between sectors. Collaboration between traditional industries and our creative, digital and tech sectors can spark world-class innovation. Applying these new ideas and technologies across industries presents an opportunity to raise business productivity across the region. Rapid shifts in digital and connected technology affect industrial processes and production, and the West of England's strength across a diverse range of disciplines provides an opportunity to ensure its future products and manufacturing processes are globally competitive. As a consequence, the Local Industrial Strategy is seeking to understand, facilitate, and maximise the value of this collaboration.

This research will help us to understand how best to support the creation of innovation in the region, to foster high-growth businesses and strength in growing industries. We know, however, that the results of innovation must also be spread effectively among existing businesses to make the most of productivity improvements. Subsequent research will look in more detail at how effectively the region's businesses are at adopting and applying innovation.

Approach of research

Research for the Local Industrial Strategy sought to understand how businesses in the West of England create innovative new products and services, how existing strong industries collaborate, and what features of the economy support successful areas of growth. In particular, we want to understand:

- how these fusions can create new sectoral strengths and also drive productivity across a range of industries;
- what factors promote the development of collaborative innovation in the region;
- the barriers that constrain successful collaboration;
- the potential for such innovative activity to contribute to clean and inclusive growth; and
- ultimately how to shape a strategy that encourages new cross-sector innovation to develop and flourish.

To assess these questions we are investigating some significant existing examples of collaborative innovation in the region through 16 deep dive investigations (listed below). The topics covered by the initial deep dives are prominent areas of activity in the region with innovative businesses, partnerships or research facilities already established. They represent cross-overs between industries in which the West of England already has a strong foundation. Some are applications of innovation, and some are enablers of change in a wide range of sectors.

There will be other topics in which the cross-fertilisation of ideas, materials, production technology and products offers potential for future growth. The current deep dive areas are not intended to be exhaustive, but understanding the development of existing clusters will help us to identify the future opportunities, and to support the emergence of new collaborative innovation.

The areas of deep dive research are:

- Artificial intelligence (AI)
- Clean energy
- Composite materials
- Connected and autonomous vehicles (CAV)
- Creative digital
- Cyber security
- Fintech, reg-tech, and law-tech
- 5G technology and Internet of Things
- Food and drink manufacturing
- High performance computing (HPC)
- Immersive technology
- Life sciences
- Medtech and digital health
- Propulsion systems
- Quantum technologies
- Robotics

Individuals, typically informed local experts in the appropriate field, were invited to act as deep dive leads and asked to populate a standard template document, consulting with industry and universities as appropriate. This was supported with data gathering around employment levels. The results were discussed at a workshop with all the leads. This helped to identify a number of common themes across the enablers and barriers to successful innovation.

To develop an understanding of the labour market supporting these deep dive areas we analysed data scraped from online job postings. This gives an impression of the scale, skills, and types of jobs advertised within sectors. There may be overlaps in these data across sectors, so the figures should be treated as indicative of the general scale within the region, rather than definitive.

Enablers of growth in collaborative innovation

This section discusses a number of factors that have been identified from the research so far as contributing to the creation of innovation in the region to date.

Creating and using new techniques and technologies at the intersections between industries is an important source of economic development, producing new sources of productivity growth. In some cases, the application of such innovations may drive high growth business clusters. In other instances, the innovation can involve new inputs, production methods, business models or products that can enable productivity gains across a wide range of sectors. In practical terms, many of the technologies discussed in the exemplars below enable change in other sectors, as well as forming part of a business cluster in their own right. Nevertheless, the distinction can help us to identify where our regional strengths are most likely to have impact.

A number of factors have been identified by the deep dive investigations as contributing to the success of collaborative innovation to date. Key factors include strong regional talent pools and formal and informal networks that successfully bring together businesses across sectors. These factors include:

- **Research and development facilities.** These include primary research facilities in the universities, as well as R&D centres that work closely with industry to test and develop products. Examples include the University of Bristol Smart Internet Lab, the Centre for Modelling and Simulation, Bristol Robotics Lab, the National Composites Centre (NCC), the Watershed and Pervasive Media Studio etc. There are several impacts of these centres: in creating innovations that are spun out in new businesses; in collaborating with existing businesses to improve products or services; and in attracting significant businesses from elsewhere to the region. (reported for AI, clean energy, composite materials, creative digital, cyber security, 5G & IoT, life sciences, medtech, propulsion, quantum, robotics)

- **Clustering around large ‘anchor’ businesses** in some, but not all, sectors. The presence of large firms creates spill-overs of skills and promotes innovation in other firms in the supply chain, attracted by proximity. It is emphasised that these may be located within the region, but that benefits are also drawn from the proximity to sites such as GCHQ in Cheltenham and the Met Office in Exeter (reported for clean energy, composites, CAV, cyber security, high-performance computing, immersive)
- **Large talent pools** in some sectors support existing innovative businesses, attract firms from elsewhere, and enable start-ups to find the skills they need. (reported for composites, creative digital, cyber security, fintech, high-performance computing, immersive, life sciences)
- **Support environment** including incubators and co-working spaces, eg Engine Shed, SETsquared, WebStart Bristol, Bristol Games Hub, Food Works^{SW}, etc. These can provide affordable work space, coaching, and help with preparing for and securing investment. They can also help to coordinate programmes within sectors to obtain external funding or research assistance. (reported for AI, fintech, 5G & IoT, food, high-performance computing, immersive, life sciences, medtech, robotics)
- **Networking** that allows new applications of technology to develop. In some sectors, existing industry or cross-sector networks exist that facilitate innovation or coordinate strategy. For example, the West of England Robotics Network helps introduce technology to new industries and identifies new uses. The presence of a range of strong digital businesses can help to attract more niche firms. (reported for clean energy, composites, CAV, cyber security, fintech, life sciences, propulsion, robotics)
- **Local capability in diverse sectors** helps firms to identify and develop new usages, and also to adopt platform technologies that can improve production. The region’s digital and automation strengths, in particular, are cited as valuable enablers of innovation in other sectors. For example, the NCC supports enhanced productivity through use of digital technology in composites manufacture in a variety of sectors. (reported for clean energy, composites, fintech, food)
- **Market-building support.** Experimentation and innovation to address barriers to entry. For example, the Digital Catapult’s IOT UK Boost programme and the 5G Smart Tourism test-bed, and the National Composites Centre’s work with emerging sectors for composite materials applications such as automotive, rail and construction, and with small and medium-sized enterprises (SMEs) regionally and nationally. In some cases this has been assisted by local government leadership, such as council support for community energy groups (reported for clean energy, composites, 5G & IoT)
- **Attractive quality of life** in the West of England helps businesses to attract and retain staff, and for the region to build up effective talent pools of both employees and freelance workers. The region’s vibrancy, with a strong cultural life and exciting cities and rural amenities, help to attract workers to settle in the long-term, as supported by the evidence of inward migration from elsewhere in Britain. (reported for creative digital, life sciences)

Barriers to growth

The deep dive research identified a number of factors that potentially hold back future growth. These factors do not apply in all cases and the mix of constraints differs for each case study. Although in many cases the future shape of the national and global market is uncertain, the barriers with regional dimensions are discussed below:

- **Shortage of affordable workspace**, particularly for start-ups and scaling businesses, and also inward investors. This is particularly pressing for businesses which have moved beyond the start-up stage and wish to continue to grow, when flexible and affordable space is limited. In some sectors this also includes needs for test space or facilities specialised for the industry, such as scientific or food-grade facilities. The life sciences case study provides an example of this, where the creation of the privately-funded Unit DX lab space catalysed the creation of a number of small businesses spinning out from university research; a proposed expansion is expected to fill quickly. Finally, the lack of city-centre space in Bristol may undermine quality of life factors, if development can only occur in outlying areas. (reported for 5G, CAV, composites, creative digital, life sciences, food)
- **Shortage of skills**, particularly in science, technology, engineering and maths (STEM), among local residents. This includes both a mismatch of skills in the immediate term, where training completions are not meeting the needs of recruiting firms. It also includes a longer-term pipeline of skills to enable continued growth. Including Arts alongside the STEM perspective will be important to ensure that the region can continue to successfully combine creative and 'hard' technology sectors to develop successful products. Further, there may also be a challenge in achieving a pipeline of skilled people from a diverse range of backgrounds. In some instances, there may be a lack of appropriate training provision. Finally, for some sectors challenges with **affordability and quality of life** may be limiting the region's ability to attract and retain the talent needed for growth. (reported for 5G, HPC, robotics, composites, quantum, fintech, food, AI, creative digital, immersive, propulsion)
- **Lack of strategic approach and profile within sectors**. In some sectors it was felt that a clearer sectoral strategy, bringing together key private, public, and civil society organisations, would help to coordinate bids for external funding. In addition, some sectors felt that a higher international profile would assist in raising sales externally. (reported for medtech, CAV, composites, clean energy, fintech, creative digital, cyber security, life sciences, food production)
- **Lack of scale or key anchor businesses** in some sectors, leading to a lack of critical mass compared with other regions. In fast-moving industries, small companies may be unable to sustain the level of investment required to keep up with international leaders. In some instances this may be exacerbated by the lack of large-scale manufacturing capability in the region, which leads to the risk of research and development capability being relocated. On the other hand, there may be key businesses in the region that can act as customers for particular technologies, so a lack of large-scale production capability is not always a constraint. (reported for medtech, clean energy, robotics, fintech, AI, propulsion)
- **Funding**. There is perceived to be under-investment in some sectors. London is dominant in venture capital funding and at times this creates pressure for businesses in the region to relocate. There may also be an issue of financing burdens leading to premature sales in early-stage companies. And there is a concern in some cases that the profile of the region's capability and expertise is not high enough to draw the government funding required to sustain key assets. (reported for AI, composites, creative digital, immersive, food, high-performance computing)
- **Lack of co-ordination of investment**, particularly for platform technologies such as 5G. This can limit the effectiveness of investment-promotion activities. (reported for 5G)

- **Lack of specialised business support.** In some cases, businesses may need specialised support to adopt and adapt modern technology within their sector. Generic support may not be well placed to demonstrate the value of such advances, or to assist with adoption.
- **Opportunity to test systems.** There is potential for the region to act as a test-bed for innovative use of technology, to understand how new systems (in transport, for example) work within society. Existing capacity across a wide range of sectors could be used to improve understanding of usage models, adoption patterns, and regulatory and control systems. The region's strengths in both virtual and physical engineering and manufacturing provide a significant opportunity to test digital engineering and high-value design with real products and associated manufacturing processes. (reported for composites, CAV, propulsion, robotics)

Role of collaborative innovation in Clean and Inclusive growth

The principles of clean and inclusive growth run across all elements of the Local Industrial Strategy. As such, the deep dive research on collaborative innovation has assessed the potential impact of these innovations on the quality of future growth. Research on this is still ongoing, but some initial findings include:

On clean growth, a number of the technologies offer potential for reducing the carbon-intensity of transport and energy systems. Composite materials allow creation of lighter, longer-lasting and more fuel-efficient vehicles. Autonomous vehicles and digital-enabled transport systems offer potential for reductions in traffic, emissions, and air pollution. Furthermore, many of the technologies can be manufactured at low carbon-intensity, although the extent of current activity in this field is unclear. Consumer-facing sectors such as food production are beginning to identify ways of reducing or reusing waste, improving packaging, and improving the sustainability of supply chains. Finally, it was noted that in some cases the workforce in the region is highly engaged with environmental issues and this presents an opportunity for leadership and experimentation.

On inclusive growth, the growth of these sectors offers potential for growth of new businesses and new jobs. Much of the employment in these sectors would likely require specialised skills, although the barriers to entry to skills vary by sector, being lower for example in creative and digital sectors. Careful management of the skills pipeline would be required to translate this into greater inclusion, to ensure that by design we deliver opportunities for economic participation to all residents, not just those who find engagement easiest. Outreach programmes by business can help to encourage aspiration within non-traditional groups, such as Unit DX school visits for example.

There is also some scope for technology to increase accessibility and quality of public services, and potentially enable improved services to diverse groups within our communities through (for example) greater personalisation. For example, autonomous vehicles or 'mobility as a service' systems may enable increased public transport provision to under-served areas. Regional strengths in health and social care may enable innovative approaches to the challenges of an ageing population.

Methodological note

To develop an understanding of the labour market supporting these deep dive areas we used Labour Insight tool provided by Burning Glass. Labour Insight uses web scraping technologies to collate labour market information for online job postings; this can then be searched using certain criteria e.g. geographical area, time period, employers, skills etc. For the purposes of the deep dive research we collated data for the following:

Geography: West of England

Time Period: Year to date

Key Words: A list of key words were provided by the deep dive leads; these key words relate specifically to their area of activity and cover a mix of skills, technologies and applications.

We worked with the deep dive leads to ensure that the list was as comprehensive as possible to ensure meaningful returns. However, there are inevitably rogue returns where other industries use the same technologies or have the same acronyms e.g. CAV gets picked up in Secondary Education. Where possible we have removed the obvious anomalies from the data to ensure that it is as reflective of activity in the deep dive area as possible. There may also be instances where the key word has been picked up in an advert but the job is not directly involved in the activity, it is just an example of the activity carried out by the company recruiting – again every effort has been made to remove these from the data outputs; however, this is much harder to do and some anomalies will have been included in the final figures.

Data outputs include

- Top Employers
- Occupations
- Job Titles
- Skills
- Salary information
- Demand map - this is based on the Bristol Travel to Work Area

In many cases the sample size of the return is quite small; this is due to the nature of the activity of the deep dives as 'new and emerging' specialisations; however, data included does not go lower than 100.

Artificial Intelligence

Definition

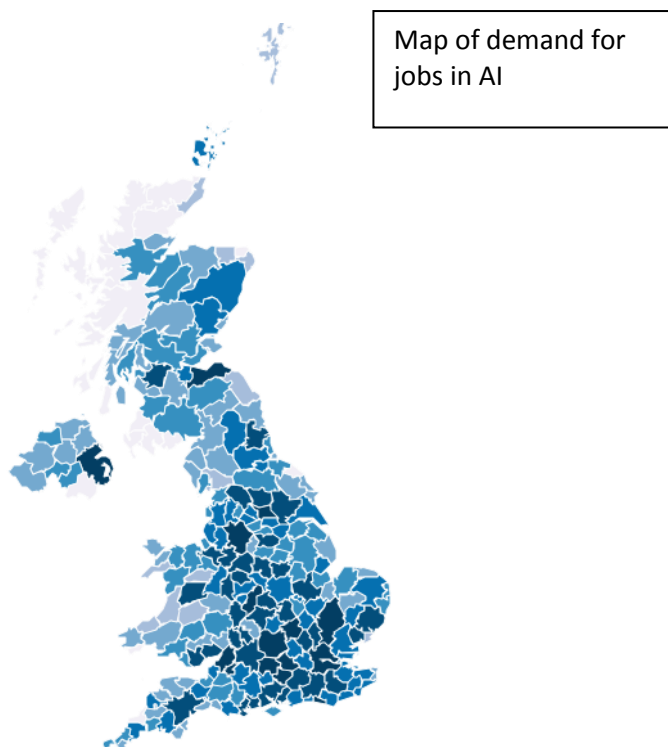
Artificial Intelligence (AI) is a technology built on the foundation of high-performance computing, algorithms and data. It involves the development and application of intelligent machines with the ability to perform tasks that would otherwise require human intelligence, such as visual perception, speech recognition, and language translation. AI is already beginning to permeate our daily lives and as the capability of machines for specific tasks evolves beyond those of humans, it has the potential to significantly impact all industrial sectors and every aspect of business.

Geographical Reach

The UK is viewed as a global thought leader in artificial intelligence and machine learning. Four of the world's top 20 universities for Computer Science reside in the UK, which results in the UK being 2nd in the world after only the US for influence of AI Academic Publications (H-Index), 4th globally by number of publications in AI and Machine Learning (behind US, China and Japan) and 3rd globally by number of citations in AI (behind the US & China). The AI sector in the UK is being actively supported to ensure this position is maintained.

As part of the National Industrial Strategy [1], the Government has outlined its ambition for AI to be adopted by businesses across the country. There has been significant investment in the AI industry, for example, through the UK Government's £1 billion AI Sector Deal and investment in the UK has now exceeded £3.8 billion. Furthermore, the Royal Academy of Engineering and the Digital Catapult are working to provide guidance and tools to support effective use of AI by businesses across the UK. The West of England plays significant role in the development of the sector which by its nature is nebulous and unconstrained by traditional boundaries. Because of its close association with High Performance Computing and Cyber Security, the local cluster extends North toward Cheltenham, Gloucester, Herford and Malvern, East into Wiltshire and West across the Bristol Channel into Cardiff/Newport.

In Numbers



Growth and employment in the West of England:

- In terms of scale and density of skills requirements within the sector Bristol and Bath together sit behind only London, Manchester and Cambridge in terms of the volume of job vacancies advertised over the past 12 months with London ahead by a very wide margin.
- Only London, Cambridge, Edinburgh and Reading have greater levels of AI-specific skills density with London and Cambridge showing levels 50% higher than Bristol and Edinburgh 25% higher.
- The median salary for all advertised roles was £44,800 and the mean £50,700

Growth and employment nationally:

- According to PWC [5], AI and robotics will support the creation of 7.2m new jobs by 2037 but will lead to the loss of 7m jobs in manufacturing and other sectors during the same period with 20% of jobs to be automated over the next 20 years with no sector unaffected.

Growth and Employment globally

- The World Economic Forum [6], states the market value of AI technologies will increase at a compound annual growth rate of over 60% to 2022.
- McKinsey [7] have established the potential impact for AI to have on industrial productivity as being £630B by 2035 and providing a major improvement in GVA.

Business and Skills

All of the major regional engineering original equipment manufacturers (Airbus, RR, GKN, EDF...) are already investigating the potential of impact AI related technology on their engineering and manufacturing operations, as well as enhancing product performance through improved reliability or increased autonomy. This opportunity is still only in its infancy and a huge untapped market exists whilst most AI companies focus on the financial and consumer sectors. The major computing companies in the region NVIDIA, CRAY, ORACLE are all investing heavily in this technology to ensure their platforms offer the capabilities that developers and end users require to train and implement AI solutions.

There are numerous AI development companies in the West of England, and two start-ups in particular have acted as anchor businesses for the region [8]. Graphcore develops processors to accelerate AI applications, whilst FiveAI, a Cambridge-based company, has set up an office in Bristol to develop autonomous vehicle technology and has received a grant from the UK government to work on a project to develop self-driving cars to pilot in London to cut traffic congestion and free up parking spaces.

AI is currently an enabler to most industry sectors and companies in the region are providing applications to meet their needs. For example, AutonoMe provide a service to the health care industry, by helping people with learning disabilities to develop and evidence their independent living skills in cooking, cleaning, safety and personal hygiene. Kudan and Rovco are both developing AI technologies for robotics applications and Urban Hawk are developing surveys, data analytics and visualisations in urban landscaping. In the manufacturing space start-ups Smartia, Miminal and KADlytics are starting to develop solutions to understand industrial processes and thereby improve productivity. AI will have a major impact on the Creative Sector by automating content generation and improving the gaming experience through improved emulation of the real world. Other applications of AI development in the region include speech recognition provided by XMOS and business analytics provided by companies such as Cognisess and finally YellowDog, who use machine learning to predict completion times for cloud based computations.

In the research space, the Centre for Modelling and Simulation (CFMS) is developing a range of AI based solutions to improve all aspects of the engineering and manufacturing process from enhanced design space exploration to automated process monitoring and quality control. The National Composites Centre is running a number of programmes in the application of AI in composites manufacturing. The NCC is leading the national High Value Manufacturing Catapult's work on digital design, which has significant scope for use of AI. The University of Bath offers postgraduate courses in Robotic Engineering and the study of the two-way relationships between natural and artificial intelligence. The University of Bristol offers a postgraduate course on Artificial Intelligence and an undergraduate degree in Robotics. The University of the West of England (UWE) hosts the Bristol Robotics Laboratory which is the largest academic centre for robotics in the UK, underpinning regional skills development in the field.

It is however the work of smaller start-up companies, together with the ambitions of the large advanced engineering original equipment manufacturers, that sets the West of England apart from other locations. In particular, the application of AI technologies across other sectors, which builds upon the region's strengths in technology, clean growth and ethical use of AI and public policy. This unique combination offers an opportunity for AI to address local needs and become a key regional export.

Enablers of Growth

From a business perspective, the West of England is extremely well placed to benefit from the development and application of AI related technology. With the strength and depth of advanced engineering companies within the region and the inherent digital capabilities from the advanced electronics and computational community, there is a major opportunity to develop a strong regional presence in this field capable of competing on a global scale.

Several local initiatives have helped start-up companies by providing investment and support. Notably, SETsquared, which is a unique enterprise partnership between the five leading research-led UK universities of Bath, Bristol, Exeter, Southampton and Surrey, has twice been ranked as the Global No. 1 Business Incubator. Based in the region they provide a wide range of highly acclaimed support programmes to help turn ideas into thriving businesses and since their launch they have supported over 3,500 entrepreneurs helping them raise £1.5bn investment. Bristol Private Equity Club, is a group of individuals all involved in their own businesses, who have invested in several companies both across the country and within the West of England. In addition, the Oracle Start Up Cloud Accelerator has provided support to many local companies, helping break down the barriers that limit success and providing exceptional start-ups with a path for future growth. Furthermore, organisations such as WebStart Bristol and Engine Shed provide start-ups with incubator services and introduce companies to potential investors.

The University of Bristol is now a partner in the Alan Turing Institute (ATI) providing access to a network of academic excellence in the field of AI across the UK. Being a national entity enables ATI to deliver benefits that a single university could not deliver alone. Crucially, The ATI has convening power, bringing together the best talent in the data science and AI community to speak to industry, policy-makers, and the public. Its mission is to make great leaps in data science and artificial intelligence research in order to change the world for the better.

Investments in facilities such as Bristol and Bath Science Park and Future Space at UWE has provided an environment in which new companies can thrive and grow working collaboratively to develop, and demonstrate technology but most importantly educate those in the region as to the opportunities it can offer (e.g. CFMS AI for Industrial Inspection and Cray/NVIDIA Deep Learning Workshops). In a similar vein, the West of England Robotics Network led by Bristol Robotics Laboratory supports the development of new companies such as Perceptual Robotics by showcasing

developments in the field, in order to build a strong supply chain in robotics and autonomous systems.

Barriers to Growth

Whilst the potential of AI to have a major impact on the productivity of UK companies is clear, realising it is a huge challenge for industries that are naturally risk averse, principally as a result of dated internal infrastructure, limited internal knowledge and awareness. To make matters worse there are insufficient AI start-ups and scale-ups with adequate domain knowledge to commercially exploit this space. Access to the skills and resources needed to develop the industrial AI solutions that can feed off the rapidly growing data sources created by the likes of Industry 4.0 is the main challenge facing companies across the UK. Whilst some industrials have developed small internal capability, it is well below the critical mass needed, and the prospect of being able to recruit to the numbers required is some way off due to high market demand. The recent review of the AI sector [9] endorses this finding, recommending a large-scale investment in skills development to build the future workforce needed to address the challenge. With all companies seeking the same skills the resource costs will be driven up by demand, pricing some out of the market. The gap between supply and demand for university places remains large generally with more than ten candidates for each available masters degree place. There are three fundamental solutions to this problem: import skills, retain skills created within the region and to convert skills from the native talent pool. The latter will bring the greatest opportunity for inclusive growth and could become the focus of a Talent Institute for the region. The Government recognises the need to provide advanced skills for AI technologies and has announced a major reform of technical education with the launch of apprenticeships, T levels and investment in STEM subjects. At a higher level, industry will be investing to fund a masters degree program with an integrated internship, targeting an initial cohort of 200 students per year.

The UK has a vibrant research community for AI (e.g. the Alan Turing Institute) with a good track record of start-up companies (e.g. Darktrace) capable of attracting significant inward investment. Problematically, the latter are rapidly acquired by large companies of the character of Google, Amazon, Facebook, and Apple prior to addressing the industrial challenges our major manufacturers face. From a recent survey [2], only 1% of all AI start-ups in the UK are focussed on manufacturing as their primary market and the high concentration of skills around London illustrates the fields of application driven by the financial and service sector markets. Capability in the regions is far weaker and application in engineering and manufacturing is considerably less mature, as access to subject matter experience and large amounts of data to train these systems is needed to realise robust industrial solutions. This is a major barrier to entry to those markets and if the UK is to achieve the expected improvements in productivity (20-30%) [7] action is now required or the UK is in danger of being out-paced by developments across the globe.

Whilst the work being undertaken in the West of England on AI technologies is building on the strengths of the region, the activity itself is not distinct enough from other regions to become a leading region. Investment is another barrier to growth. Currently the industry is supported by angel investors and this is very London-centric. For growth of AI technologies in the West of England to continue, significant local investment is needed in equipment to generate and process data, skills development and underpinning research. This also needs a solid knowledge transfer programme from academia to industry to ensure the benefits of academic research are capitalised upon.

Finally, to propel the growth of AI technologies in the UK, widespread adoption of these technologies is needed. Historically, Government has taken a leading step in uptake of new technologies, such as the uptake of desktop PCs in the mid-1980s. Access to data from local infrastructure and public procurement decisions can help AI technologies to reach their full growth potential.

Relation to Other Deep Dive Areas and Grand Challenges

The region has the vision [13,14] to strengthen, develop and exploit the wealth of innovative capability that exists within the West of England to improve productivity, create new businesses, increase inward investment and provide enhanced employment opportunities for all. As an enabler technology, AI has the potential to provide a unique link between key sectoral deals established within the National Industrial Strategy (aerospace, automotive, construction...) and all of the associated Grand Challenges (AI & Big Data, Clean Growth, Ageing Society and Mobility).

Examples of how AI is already contributing to each of these challenges has been provided above but this simply represents the tip of an iceberg for growth in this field. Many collaborations across sectors already exist, such as that between healthcare and robotics in the UWE Assisted Living Studio where they are developing assistive care solutions to support independent living for an ageing population. More of these initiatives are needed and there is a huge capability shortfall within the sector that needs a new generation of scientists and engineers with the ability to harness this potential into viable and ethically sound industrial solutions [15,16]. AI like no other, will significantly impact (composites, CAV, Cyber Security, Robotics...) or be impacted by (Quantum, HPC, IoT...) all innovative sectors in the West of England and as such has a major role to play in the development of the Local Industrial Strategy. Strengthening the West of England capability in AI will fundamentally shape our ability to address all of the challenges posed by the National Industrial Strategy and through improved productivity, make the regional economy far more resilient in the digital era.

Inclusive growth

The growth of AI technology within modern society provides a major opportunity to improve the wealth, health and welfare of residents across the region but it also provides major challenges which must be managed appropriately to realise benefit for all.

At the heart of this challenge within the region is the Jean Golding Institute (JGI) at University of Bristol which is harnessing the power of big data to address societal challenges such as the monitoring of greenhouse gas emissions or the diagnosis of mental health. The University of Bath is also leading research on the understanding of the ethical application of AI to ensure that all users (and those affected by its use) are treated fairly and appropriately, avoiding the exploitation of individuals' data and encouraging transparency in the development of new AI systems. Society is the source of the majority of data generated and these organizations are working to place people at the heart of this new technological era. It can be used to promote engagement and inclusivity within parts of our community that have often been excluded.

An exemplar project at JGI examined ways of collecting and conceptualising data that might assist cultural organisations to create activities that are attractive to young people in the BAME community. This information is key to understanding engagement in 'cultural activities' around the city and social barriers to entry which can provide insight into approaches for education, recruitment and social wellbeing in disadvantaged groups. In terms of mobility, whilst companies such as FiveAI are pioneering the development autonomous vehicles to improve the efficiency of our road infrastructure, projects such as *FLOURISH* led by UWE and involving industry from across the region is specifically looking at the implications of such transport solutions for the elderly community. Here, AI could make sure that some of the least mobile members of the community can play an active role in society and contribute to the economy of the region.

The required technology co-development from the Digital and Engineering communities for Industry 4.0 [9] will bring about a fundamental change in resource needs, opening the door to a far more diverse skills and knowledge base than seen before. However more needs to be done to make skills

development more open via apprenticeships and other forms of post GCSE study [10]. AI will affect every aspect of our industrial community, from HR to cyber security and from manufacturing to marketing, bringing engineering, humanities, social and computational sciences together in a far more inclusive capability pool that will be required to act together to realise success.

Clean growth

It is clear that our industrial strategy must provide the means to achieve growth whilst mitigating the impact on the environment and AI will be a key means to realise this potential [11,12]. As the world around us becomes smarter from being more connected, AI is increasingly needed to address the so-called '3D' challenges of decarbonisation, decentralisation and digitalisation in energy production. AI can provide the key to understanding the impact of weather patterns to more effectively predict demand and more accurately identify energy production and transmission needs, as performed by Zenotech and Digital Engineering Ltd. in Bristol. This is particularly important in the field of renewable energy where changes in environmental conditions can have a massive impact on the performance of energy sources (wind, solar, tidal...), and these need to be balanced with more traditional carbon or nuclear based power sources. AI enabled systems will be able to more accurately control this energy balance and the transmission demand to optimise the utilisation of low carbon sources of electricity.

Through the use of improved sensing AI can make users far more intelligent regarding their energy consumption needs, adapting behaviour and tailoring usage to more cost-effective price points from suppliers thereby reducing unnecessary peak demand on the national grid. As our society becomes more power hungry (transportation, computing, communications, etc..) the strain on the current network increases and we must exploit AI to achieve the best from existing infrastructure prior to investment in new infrastructure which is costly and will impact the environment. AI technology can also benefit the nuclear industry and the University of Bristol is one of several universities that are part of the National Centre for Nuclear Robotics, a collaborative research project that develops state-of-the-art robotics, sensing and AI technologies to address the major societal challenges posed by nuclear environments and materials.

Within the engineering community AI offers the potential to investigate a far broader design space than previously considered, leading to the development of more efficient aerospace and automotive products. CFMS, in conjunction with the NCC has utilised machine learning techniques to optimise complex manufacturing processes to reduce waste and deliver more quality assured solutions faster. These activities can deliver lighter and far more energy efficient products than ever before and when the environment the operate within is optimised through the use of big data, their collective performance can be significantly enhanced. Furthermore, maintenance schedules and utilisation demand can be predicted thereby reducing the total energy demand of the transport system. A regional flagship in this field is the new Institute for Advanced Automotive Propulsion Systems based on Bristol and Bath Science Park which will monitor and analyse the usage and output from traditional and next-generation propulsion systems to optimise the design and control of powertrain for future automotive vehicles.

Supporting Evidence

1. National Industrial Strategy – Building a Britain Fit for the Future (2017)
(<https://www.gov.uk/government/topical-events/the-uks-industrial-strategy>)
2. UK AI Landscape : <https://medium.com/mmc-writes/artificial-intelligence-in-the-uk-landscape-and-learnings-from-226-startups-70b9551f3e4c>
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Clean Energy

Definition

Clean Growth is defined as growing our national income and achieving economic growth whilst cutting greenhouse gas emissions and enabling sustainable development, often through clean technology. Achieving clean growth, whilst ensuring an affordable energy supply for businesses and consumers, is at the heart of the UK's industrial Strategy.

As a large proportion of our greenhouse gas emissions come from our need for energy, this deep dive focuses on the Clean Energy sector, consisting of: energy efficiency, low carbon energy generation and smart energy solutions.

Clean Growth is considered an outcome or objective and spans across multiple industry sectors. It includes any innovation or business improvement that contributes to improving productivity, whilst reducing emissions.

Geographical Reach

There are very successful clusters of clean energy capability across the UK based around deployment opportunities and supported by regional development organisations. Offshore wind expertise is located on the east coast and marine renewables capability has built up in Scotland.

The UK has led the international market in clean energy expertise and continues to have a strong offering in consultancy, technical and financial capability in this sector.

Historically, Clean Energy was the focus of the previous Government Office South West region, of which Bristol and the West of England was central. Due to several reasons, including the license areas of the Distribution Network Operators, the influence of European funding across Cornwall and Wales, the development of the Hinkley site and surrounding area and the geographic assets of the region, the role of the wider region has been important in the growth of the sector.

In Numbers

Growth and Employment in the West of England:

- The West of England Strategic Economic Plan 2015-30 ranks the low carbon sector first in volume growth sectors in terms of GVA and GVA per FTE, above high tech and professional and legal services.
- The Low Carbon Sector employed at least 5,900 people and generating £333m of GVA in the West of England, as of 2015.

Growth and Employment Nationally:

- The Low Carbon Sector grew nationally by 5% in 2016, nearly three times the rate of growth of the economy as a whole.

Growth and Employment Globally:

- The global renewable energy market is expected to reach \$2,152,903 million by 2025², with Europe expected to witness the highest growth rate, in terms of revenue.
- The global smart energy market is estimated to be worth \$220 billion by 2020.

Business and Skills

The business, academic, public, and community and voluntary sectors are all active in this sector. There are several key businesses working in clean energy in the West of England. DNV GL (formerly Garrad Hassan) is the world's leading renewable energy consultancy and employs more than 370

staff in Temple Quay. Bristol-based companies design almost 30% of the world's energy from wind today.

Bristol-based companies are also developing and installing solar energy solutions. Aura Power specialises in renewable energy solutions, particularly in solar energy and have based their headquarters in Bristol. Aura Power developed one of the first Enhanced Frequency Response (EFR) battery storage projects (Nevendon 10 megawatt (MW)), and the 15MW Lockleaze battery storage project was the largest in the UK when it was energised in June 2017. Other companies such as Ecocetera in Bristol and Solarsense in North Somerset provide solar panels.

Key electricity suppliers are working to improve their sustainable, clean energy provision. Western Power Distribution, who are the West of England's main electricity Distribution Network Operator, is one of the leading operators for innovation, support for vulnerable customers and community engagement. The gas distribution network operation Wales and West Utilities is also actively involved in exploring options for decarbonising heat.

Thrive Renewables provide sustainable energy equipment and solutions for individuals and businesses and are based in Bristol. OVO Energy also have their HQ in Bristol and are a national company that has been awarded Energy Supplier of the Year, for three consecutive years by the uSwitch Energy Awards and has been recognised for its fairer, more customer-friendly approach. Pure Planet in Bath offer 100% green energy through an app-only system, and Bristol Energy aim to deliver non-profit, affordable, renewable energy.

Many of the region's law firms, planning consultancies and engineering consultancies have strong renewable energy and energy teams, serving national markets as much as local ones. Examples include law firms Renew Legal, TLT and Ashfords and energy consultancy firm ESOS Energy. The presence of Triodos Bank's UK headquarters in Bristol is also a key asset for the region.

The West of England is also home to other companies such as GENeco, a food waste management and renewable energy company.

The West of England has two of the country's most successful community energy enterprises, Bristol Energy Co-op and Bath and West Community Energy. Together with locally-based businesses like Thrive Renewables, they are working to enable wider community ownership of renewable energy generating assets. This is part of a wider network of community energy operations, supported to work together by Regen's community energy support programme based in Exeter who also work closely with Community Energy England.

Enablers of Growth

The West of England has strengths in several areas that have enabled growth in the clean energy sector. These strengths include smart energy, including the associated digital skills and academic expertise in power systems engineering and economics at University of Bath and big data analytics at University of Bristol, and low carbon local and neighbourhood planning. There is also significant electric vehicle take-up, network integration and smart charging in the West of England, as well as some associated engineering R&D.

The West of England also has strengths in heat networks, fuel poverty alleviation and low carbon finance and legal structures. Many of these capabilities have been in place for several decades across the region, with Bristol in particular, building a reputation as a centre for excellence in sustainable energy.

The West of England is home to several collaboration hubs and community energy approaches which have enabled growth in the clean growth sector, including the Bristol City Green Capital and the Bath Sustainable Tech Hub. The West of England region has also seen some of the largest investments in waste re-processing and energy recovery in the UK, and innovation in this area of activity is among some of the most exciting developments happening in the sector globally from companies like GENeco in Avonmouth.

There are also a number of specialist companies, which work collaboratively and remain connected to other hubs in the wider South West to promote growth in the clean energy sector. The Local Authorities in the West of England have played a part in enabling growth in clean energy, by running multiple active energy programmes.

Historically, clean energy was a focus of the previous Government Office South West region, of which the West of England was central. A strategy was developed to capture the economic benefits from the growth of this sector back in 2002. Whilst much of the expertise came from the West of England area, including the Centre for Sustainable Energy and the regional universities, individual pioneers in the sector were also key to the growth of the industry as a whole. The West of England has, as a result, developed several key strengths, including financial and advisory services, energy engineering and spatial planning and has continued to benefit from the expertise of key entrepreneurs in the sustainable energy sector across the region.

Furthermore, the West of England has become a hub in itself, in part because of the ambition of Bristol City Council, expressed through the policies and plans adopted by the council and the success in securing funding, developing programmers and marketing the city as a green city. Recently Bristol City Council has undertaken an extensive energy programme including the development of a licensed energy supply company, Bristol Energy, which is owned by the Council, and a support programme for community energy activities in the city. Bristol City Council has also taken a leading role on energy amongst the national Core Cities group.

Bath & North East Somerset Council provide energy saving advice and support for its residents through the Energy@Home programme and have also established a strong partnership with Bath and West Community Energy, one of the UK's leading community energy co-ops. Furthermore, Bath & North East Somerset Council have explored the challenges of retrofitting heritage buildings to meet modern carbon emission standards without compromising heritage characteristics.

South Gloucestershire also provide local home energy advice through the Warm and Well service and North Somerset Council have played important roles in recent years, supporting energy efficiency advice services and insulation and heating grant programmes.

The Centre for Sustainable Energy suggests that the region's high quality public sector energy management capabilities could provide a test-bed for the development of innovative smart demand management services, which could then be offered to the commercial buildings sector, through such initiatives as Business West and Bristol Green Capital Partnership.

The Science and Innovation Audit highlights several clusters of industrial and R&D activity across the South West and South East Wales region (SWW) that have enabled growth of the clean energy sector. The report highlights:

- A corridor of technical expertise in hydrogen / fuel cells specialism and capacity along the M4, from the Hydrogen hub at Swindon through to Cardiff

- A Nuclear Hub in the region, including the SW Nuclear Research Hub Bristol-Oxford, Hinkley Point C in Somerset, Somerset Innovation Centre in Bridgwater and EDF Exeter and Plymouth offices.
- The SWW region is unique in the UK with all marine renewable resources accessible from ports and infrastructure. There is an important wider geographical linkage across to Southampton, which is reflected in the development of the South Coast Marine Cluster.
- There is an emerging cluster of excellence and good practice in underpinning technologies related to distributed energy systems and smart grids, which will have relevance across many new energy technologies.

The Science and Innovation Audit recognises that these clusters have developed in response to an extensive, vibrant and internationally recognised capability, assets, university and research activity in the region and builds on a broad environmental goods and services sector, alongside regional priority sectors in environmental futures, agri-food / tech, energy, digital, water, low carbon and high value manufacturing.

It recognises that over a quarter of the UK's major environmental research organisations have a base in the South West and South East Wales and there are almost 2,000 scientists working in relevant areas and 25,000 enterprises in the region based in sectors relevant to the theme, with 153,000 jobs.

Barriers to Growth

There are several barriers that may prevent future growth of the clean energy sector in the West of England. The business, academic, public, and community and voluntary sectors are all active in this sector, though efforts are not always joined up to make the most efficient use of resources and focus for collaboration. It is suggested that continual improvements to integration of expertise across the diverse elements of the energy sector could yield exciting opportunities as the market for clean growth expands globally.

Another barrier to growth of the clean energy sector is that it is unclear how rewards for innovation and action in clean growth will be earned in future. As a result, it is recognised that there remains insufficient market pull to stimulate the 'spontaneous' creation of the new business relationships and innovation test beds, which are critical to delivering national and international commitments in clean growth.

The Science and Innovation Audit highlighted the huge opportunity for the wider South West and South East Wales region to lead development of new technology and innovation that will be required to live sustainably and address global environmental challenges. In particular, the Audit identified two areas where the region has the potential to be globally competitive: Environmental Risk and Data, and Sustainable Technologies and Development. These are, critically, underpinned by the need for better integration of Digital Innovation capacity also developing in the West of England.

There is a risk that a failure to act quickly and to establish a clear locus for regional action will leave the West of England in the wake of other regions in establishing a leading sector for smart energy (notably, in terms of stated ambition, London and Greater Manchester). The emerging smart energy market, which is still at relatively early stages with many remaining uncertainties, will not, by itself, pull the West of England into a leadership position, in spite of the region's many strengths in this field.

Relation to Other Deep Dives and Grand Challenges

Greenhouse gases come from nearly every part of our economy, particularly transport, buildings, agriculture, industry and waste. As such, also of importance to clean growth is the overlaps with other sectors and ways of working which improve productivity and reduce emissions, including;

- Reducing the need to travel and improving productivity through smart technology
- Improving low carbon transport opportunities, particularly through the development of electric vehicles and associated infrastructure, as well as alternative fuels
- Productivity improvements through advanced manufacturing
- Greenhouse gas savings and circular economy gains through recycling and the use of more sustainable materials.
- Productivity improvements through agricultural and industrial innovation which reduce greenhouse gas emissions.

Where clean energy, low carbon innovation or environmental research interacts with other key sectors, opportunities for clean growth can be identified. The region's digital technology strengths will also be important in contributing to future growth of smart energy systems.

The increasingly rapid take up of electric vehicles is pushing the national policy focus from creating demand for electric vehicles to developing and managing the orderly growth of charging infrastructure, the introduction of smart charging services (including, potentially, from local suppliers) and the optimisation of its impact on the local electricity network and wider system. The region has a Local Authority-led electric vehicle project (Go Ultra Low West) and the UK's leading Distribution Network Operators on electric vehicles (Western Power Distribution).

The region enjoys significant electric vehicle related R&D capabilities at its universities, for example the Institute for Advanced Automotive Propulsion Systems and FLOURISH research programmes as well as consultancy and research skills, such as the University of the West of England and in the local offices of national consultancy companies, on public attitudes and transport planning.

Inclusion

Action to improve energy efficiency in domestic properties and to increase the affordability of energy should have a positive impact on the region's levels of fuel poverty. The National Institute of Care and Health Excellence (NICE) published guidance in 2015 which demonstrated a link between a wide range of health conditions and living in a cold home. The guidance calls upon agencies to work together to reduce the risk that someone would have to live in a cold home, particularly through improvements to the energy performance of the home. 1 in 9 of the region's households – more than 52,000 households - are in fuel poverty according to the official 'Low Income, High Costs' definition for England.

Supporting Evidence

1. South West and South East Wales Science and Innovation Audit, 2016
2. Allied Market Research
3. The Clean Growth Strategy

Composite Materials

Definition

A Composite Material is when two or more separate materials are combined to make a new material that has distinct, and enhanced, physical or chemical properties from the individual materials. For the purpose of this deep dive, the Composite sector includes processing and applications of composite and other advanced material technologies, including additive manufacturing.

The sector is split between organisations who develop Composite Materials to supply other industries and those that use Composite Materials for industry applications. Therefore, it is both an application and an enabler.

Geographical Reach

The West of England has an unrivalled regional strength in Composites both within the UK and globally. There are several internationally recognised research and innovation institutions based in the region as well as a number of globally leading composites-using companies, especially in advanced manufacturing & aerospace sectors.

Academic competition in composites comes mainly from Nottingham University, which jointly leads the Engineering and Physical Sciences Research Council's Advanced Manufacturing (Research) Hub with the University of Bristol. Manchester, Cranfield, Southampton and Imperial all have research strength in composites but host smaller teams than the University of Bristol. The West of England is home to the National Composites Centre (NCC), which is the accepted lead centre for composites within High Value Manufacturing Catapult. The Advanced Manufacturing Research Centre at Sheffield, Warwick Manufacturing Group, and to a lesser extent the Advanced Forming Research Centre at Strathclyde all have some composites capability, but again none are as large, or as broad in capability, as the NCC. The University of Bath and UWE also host research and teaching capabilities in composites.

The West of England is strong in product engineering with composites, especially for Aerospace, although other regions do have good capability, especially the North-West, where the long history of military aircraft development has built up a strong cluster of engineering and composite manufacturing companies. Other regions are good in other sectors, such as Solent which has a leading leisure marine manufacturing industry.

The region, particularly through the NCC, and its extensive networks in sector leadership groups and industry shaping companies, is highly influential in shaping many sectors' approaches to the take-up of composites materials. There is a clear opportunity to develop the knowledge, skills and existing supply chain companies in the region to service other sectors as they adopt the technology.

Research, innovation, design and systems integration in the West of England is influencing nationally and internationally and shaping strategy at a national level. This is enabling UK industry to be globally competitive and encouraging inward investment.

In Numbers

Growth and employment in the West of England:

- Between October 2017 and October 2018, 274 jobs were advertised
- The number of employees in composites has increased between 2 and 4 times in the last 10 years

Growth and employment nationally:

- The UK has the opportunity to grow its current £2.3bn composite product market to £12.bn by 2030

Growth and Employment globally:

- The composites market is projected to grow from USD 72.6 Billion in 2016 to USD 115.4 Billion by 2022, at a CAGR of 8.1% between 2017 and 2022
- The Aerospace industry is unlikely to be a major contributor to global growth of composites in the next 5 years, although it is likely to be a major driver again by the mid 2020's
- Automotive vehicles are currently less than 1% Composite Materials but markets forecast that this could grow to 6-8% within the next 10 years, representing circa 20% CAGR

Business and Skills

The West of England has an unrivalled regional strength in research & innovation in composites due to the engineering demand in the region which predominantly comes from the aerospace and advanced engineering sectors. The region is believed to host the largest research and technology development capability outside of China.

There is a strength in associated education & skills, and the Universities of Bristol, Bath, and West of England all include composites in their engineering courses. The City of Bristol college undertakes some composites training and colleges in Gloucester, Weston and Yeovil, in the regions adjacent to West of England all provide composites training.

The most sought after specialized skills for jobs in composites are mechanical engineering, manufacturing engineering, test engineering, materials science, high value design, systems engineering and structural analysis including finite element analysis. Baseline skills such as project management, research, communication, problem solving, teamwork and collaboration are also required for a large proportion of these jobs.

The majority of jobs in composites are at very high level and this high-end bias is due to the nature of the local organisations which typically employ large numbers of PhD or equivalent experts in the field. At manufacturers such as GKN, the manufacturing staff are typically higher technician level as the complexity of the manufacturing requires a great deal of knowledge and expertise. However, the composites industry will also impact on non-technical disciplines such as public procurement, business management, financial investment and economics. There is a potential to develop these wider reaching skills and sectors to build on the composites strength in the region.

Five of the largest employers of composites expertise in the region are GKN, Airbus, National Composites Centre, Rolls-Royce and University of Bristol. These five organisations alone employ circa 1650 people on composite technology related roles. These employers are thought to represent between 60% and 80% of the local job market, implying a total number of composites jobs in the region of 2000-3000.

Airbus develops all its technology and product solutions for the wings of its civil airliners at Filton, supporting the manufacture which is undertaken at Broughton in North Wales. Airbus in South Gloucestershire hosts the company's wing research, engineering and test resource and associated facilities. These are unrivalled in Europe let alone nationally. Rolls-Royce bases its composites technology development for aero engine fan blades and cowlings at Patchway in South Gloucestershire and sees composites as a key differentiator for their future. GKN Aerospace has significant research, engineering and manufacturing operations in the region and are a global aerostructures supplier which is key to the Airbus and Boeing supply chain.

These anchor businesses promote growth in the region and invest in further assets. Airbus have invested £70m into the Airbus Wing Integration Centre, which houses circa 500 airbus engineers. GKN are also planning to establish a fourth Global Technology Centre in South Gloucestershire in 2020-21 and Rolls-Royce has a University Technology Centre at the University of Bristol and Dresden, and has established a global Composites Technology Hub in South Gloucestershire which will create 120 jobs by 2019.

There are also a number key anchor companies who use world leading composites in close proximity to the region including, Leonardo Helicopter at Yeovil, GE Dowty Propellers, and Safran Landing Gear in Gloucestershire.

As well as the organisations listed above there are a significant number of other organisations working in composites. Many of these are supply chain organisations to the five above, often resource and/or engineering services supported through companies such as Atkins at Aztec West and Assystem at Emersons Green, as well as more traditional aerospace supply chain manufacturers such as Ipeco at Clevedon. Furthermore, there are a number of companies in the region supplying low-cost composites materials and products such as Matrix Composites Ltd and users of composites such as Bailey's Caravans.

Enablers of Growth

The University of Bristol opened the world leading Bristol Composites Institute (BCI) in March 2017, which builds on the success of the Advanced Composites Collaboration for Innovation and Science. The BCI comprises 200 staff and associates across leading academics, Doctoral Students and industrial researchers.

As well as the University of Bristol's very large team at the BCI, there also important teams of researchers and educators in composites at University of Bath, University of the West of England and at City of Bristol College.

The globally leading National Composites Centre (NCC), is the lead centre for composites within the UK's High Value Manufacturing Catapult. The NCC has over 400 staff, industry researchers and engineers and has had over £100m of public investment in cutting edge facilities, equipment and capability generation. This includes a £37m investment in ten new capabilities, which will ensure the NCC is the world leader in automated deposition of composite materials. The NCC is already a strong enabler of aerospace companies, as well as many other sectors, including automotive, rail, construction, marine, renewable energy, medical and sporting goods in the West of England, nationally and internationally. The NCC can become the gateway for the West of England to access the wider capabilities of the rest of the High Value Manufacturing Catapult.

The West of England Aerospace Forum is one of the largest regional aerospace and defence associations in Europe and members include the NCC, the University of Bristol, the University of Bath and key aerospace companies in the region. The Forum supports and connects its members and provides access to key decision makers both in industry and government. Key organisations in the West of England are also part of national networks such as Composites UK, the Composites Leadership Forum and the Aerospace Growth Partnership. These organisations are key for linking industry, academia and government to help set a strategy for the industry and are often heavily influenced by organisations in the West of England.

Additional strengths in the region that support the application of advanced materials include the High Performance Computing (HPC) and advanced simulation capability, including AI, represented by

the Centre for Modelling & Simulation (CFMS), creative sectors, robotics and automation, and the wider network of companies in these fields. Having these leading capabilities locally brings additional strength to the development of advanced materials and their applications using multiscale modelling and simulation at all levels. These interactions, and the NCC's strength in digital design, help meet the needs of manufacturers and lead to a situation where the region is almost uniquely placed to provide manufacturing and functional demonstrators to validate digital design and manufacturing.

The West of England has the strongest Composites Technology development and related civil aerospace manufacturing capabilities in the country. There is an opportunity to use this foundation to further grow, and diversify on, this foundation, creating a "Composites Valley" cluster, that will capture more than an equal share of the 8% global CAGR.

There are opportunities for the West of England composites engineering to be integrated with electrical propulsion, autonomous operations and system level optimisations. Rolls-Royce and Airbus are 2 of the 3 partners in the E-FanX project with Siemens to develop electrical propulsion/ systems for civil applications. The University of Bath's Institute for Advanced Automotive Propulsion Systems centre has expertise in thermal management and systems integration which could have implications in auto and aero sectors.

The real strengths of the region are in technology development, system integration and product engineering. There is a significant opportunity to use these capabilities in wider applications of composites than just aerospace, looking at new and exciting opportunity areas such as autonomous electric vehicles and personal air transport.

Barriers to Growth

There are several key barriers to growth of the composites materials industry in the West of England. The local land and employment costs are too high for many businesses and there is a skills shortage, especially in advanced design and advanced manufacturing skills. This is especially a barrier for lower value-add activities such as low-cost manufacturing and key assets could be built in neighbouring areas if costs remain high.

Funding is also a barrier to growth of the Composite Materials sector. Funding from central government is needed to support growth and future development of the research and technology assets. Additional funding from key businesses in the region, new anchor businesses, including those from outside aerospace industries and major assets is also needed for the region to remain at the cutting edge of capability and have the capacity to support a wide range of industrial companies. This may be promoted if the region attracted more customers of key businesses. By investing in, and promoting the region's strengths, the West of England has potential to continue to grow as an internationally leading region in Composite Materials.

Labour availability is a challenge for any company looking to grow or start composites activity. Despite the West of England having many people with these skills the demand remains high, so some companies look elsewhere.

It is a combination of the above barriers that makes the West of England less attractive as a region than other, often cheaper locations. This is demonstrated by the choice of McLaren to locate in Sheffield over Bristol. The West of England needs to focus on its technology and engineering strengths and find ways to provide lower cost manufacturing capacity.

There are several potential threats to the composites industry in the West of England. It is important not to take for granted the current strengths in the region in order to mitigate the impact of these threats in the future and maintain the leading composites sector.

Brexit brings great uncertainty to most of the industries that use composites and the impact of Brexit on the composites sector is unknown. It is unclear if the UK will remain a competitive place to do business for manufacturers, in particular aerospace manufacturers, which are highly international. There is also a risk that Brexit will impact the skills resource in the UK. The composite sector is heavily dependent on experts from the EU and further afield.

Furthermore, Brexit might affect the cost of imported Composite Materials. The high-value composites industry is highly dependent upon the supply of high performance and commercial grade carbon fibres at competitive prices. None of these materials are manufactured in the UK and a significant risk that the import cost may become prohibitively expensive and that product manufacture could be relocated close to the raw materials supply.

The presence of a leading aerospace industry in the West of England is both an opportunity and a threat. Whilst the expertise and associated knowledge infrastructure is an attractor for inward investment, there is a risk that a single decision over “the next project” location could start a new trend of relocation, potentially overseas. Previous experience shows that once companies start to relocate, it can be hard to stop and is usually permanent. One key decision by Airbus, GKN or Rolls-Royce could have very serious medium to long term impacts on aerospace, and composites in the region. It is critical, therefore that the West of England works closely with its key aerospace manufacturers to ensure the region remains competitive for all future project decisions.

Relation to Other Deep Dives and Grand Challenges

Composites technology is key enabler of competitiveness and productivity in many other sectors. As already discussed aerospace is a beneficiary of composites technology, regionally, nationally & globally. Automotive is likely to be equally dependant on the technology in the future and it is clear how composites directly relate to the Future of Mobility Grand Challenge.

Composite Materials are also increasingly used in offshore wind, tidal and wave energy which will enable clean growth in the region and beyond. Wind Energy, especially offshore wind energy generation could not happen without composites and innovations in materials used in wind turbines are increasing their power output.

Composite Materials are increasingly being used in rail, aerospace and other transportation methods. Composites products are typically lighter and more aerodynamic than corresponding metallic ones which in transportation products, directly reduces the energy required and hence reduces emissions. Composite products also need far less through life maintenance than traditional materials, last longer and have a lower environmental impact during manufacture and at end of life. Other examples of where composites are reducing transport emissions are in the construction industry, where significantly lighter weight products mean that 2 – 5 times as many parts can be transported on one vehicle.

Composites are highly suited to smart structures/products and integration into the Internet of Things. Embedding sensors and integrated communication devices is far easier in composites than in most other materials. These capabilities further enhance the efficiency and capability of composites structures over those made from conventional materials and demonstrate the possibilities of Composite Materials to develop clean growth in the West of England and beyond.

Other innovations in low carbon, composite technology include Life Cycle Analysis, low energy processing, especially “Out of Autoclave” processing of Composite Materials into products, using bio base materials for resins and fibres and end of life and recycling initiatives. These help improve the sustainability of products and there is opportunity for future development.

Composite materials is a high growth sector and there is the opportunity for skills development and increased employment. This will range from highly skilled jobs to technician & manual jobs in emerging sectors as well as numerical analysis, simulation, and engineering jobs, which could provide high value jobs for the disabled. A dedicated training and re-training programme will be needed to meet the forecast skills demand, but there is an opportunity for inclusive growth, offering jobs to a variety of skill levels.

End products of Composite Materials will also enable inclusive growth, for example Composite Materials are used in prosthetics and other medical / lifecycle enabling devices such as robotics. Collaboration with BRL and the medical schools could create an opportunity in robotic exoskeleton suits, providing controlled strength and stiffness to weakened and unstable individuals, allowing aging people to walk without frames and paraplegics to manage walking without wheel chairs.

Supporting Evidence

- Global market forecasters “Markets and Markets”
- Composites Leadership Forum’s UK Composites Strategy 2016

Connected and Autonomous Vehicles

Definition

Connected vehicle technologies allow vehicles to communicate either with each other or the world around them; fully autonomous vehicles are vehicles where a driver is not necessary. There are five levels of autonomy described by the Society of Automation Engineers (SAE): these range from Levels 1 and 2, which are effectively driver assistance requiring a human to monitor the environment (and available on new cars today), through to Level 5 full automation.

At present, the automotive sector is focused on Research & Development and trialling, and implementation of Level 1 and 2 technologies. Automotive manufacturers are making rapid technological progress and claim that they will be able to produce increasingly automated vehicles at Level 4 by the early 2020s.

The Connected and Autonomous Vehicle (CAV) sector facilitates the development and roll-out of CAVs, including trialling technologies, future mass roll-out, supply chain and manufacturing of CAVs. CAVs include personal, public, goods, agriculture, construction, manufacturing, and freight transport and drones. The focus of this report is on personal, and to an extent, public transport. The CAV sector is supported by a series of enabling technologies including AI, control systems, sensors, cyber security and traffic management and is an application of these technologies.

Geographical Reach

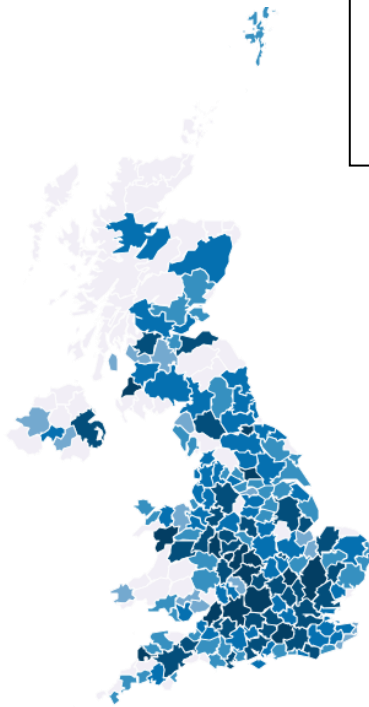
The CAV sector is developing across the UK, with a strong focus on the M1, M40 corridor between London and Birmingham, which was identified as the geographic priority for CAV by Innovate UK. There are also strong clusters of activity in Oxfordshire and Warwickshire.

The West of England is consolidating and extending its position as a centre of excellence for the safe trialling and testing of connected vehicle technology and autonomous vehicle technology. Most partners involved in the West of England projects are located within the region, including the local authorities, Universities and research and development (R&D) assets. Project Managers (AECOM, Atkins), First Group, Burges Salmon all have a strong presence in the region but have a wider geographic presence. Organisations in the West of England are involved in six Innovate UK collaborative UK projects, working with partners across the country. Nevertheless, development activity in the West of England is a fraction of the overall activity taking place in the UK.

The unique selling points of the West of England are focused on higher-level technology and knowledge activities rather than large-scale manufacturing. In the medium-long term, the West of England could provide supply chain expertise for CAVs into manufacturers in the West Midlands and elsewhere in the UK. Together with propulsion and materials expertise, the West of England has a strong range of innovation and research assets that will be important in the future competitiveness of the UK automotive industry.

The CAV sector is rapidly evolving at a worldwide level, and several other countries are rapidly developing their CAV capabilities. The Netherlands has passed legislation allowing testing of autonomous vehicles without a driver in the car, and Singapore, Japan, South Korea and the United Arab Emirates are also considered to be highly advanced in preparing for CAV adoption.

In Numbers



Map of demand of jobs in the CAV sector in the UK.
 Employment Figures are based on annual Population Survey data from 2016, and Travel to Work area calculations are based on areas effective from April 2011 (Office for National Statistics)

Growth and employment in the West of England:

- Between November 2017 – November 2018 240 jobs were advertised in CAV-related roles.
- Bristol has a much higher demand than the UK average for jobs in the CAV industry
- Bath has an average demand for jobs in the CAV industry
- Mean salary of advertised jobs was £33,400 and the median was £31,100

Growth and employment nationally:

- £250M of R&D projects funded by the UK Government nationally as of May 2018
- The Government is ensuring that legislation will not be a blocker to CAV testing, development and adoption, for example through the Code of Practice for Testing of Automated Vehicle Technologies (2015) and the Automated and Electric Vehicles Act (2018).
- The overall economic and social benefit of CAVs could be £51 billion per year, creating 320,000 jobs in the UK by 2030.

Business and Skills

People enter the CAV-related sector from several routes and typically come from numerate and analytical, engineering, systems, transport planning and project management backgrounds. Technical specialisms of CAV employees are varied and depend on the discipline of work.

It is important that the skills system plans for future change and development of CAV, particularly in terms of disruptive change in the wider automotive sector, including developing multi-disciplinary capabilities for educating, training and developing the CAV workforce of the future. A CAV MSC is currently under development by BRL for delivery in Autumn 2019.

Between November 2017 and November 2018, 240 jobs were advertised in the CAV industry in the West of England. Of these jobs, the top skills that employers sought, ranged from specialised computing skills such as Python and software engineering, to more baseline skills such as teamwork, collaboration, budgeting, project management, communication, planning and problem-solving skills.

The top occupations being advertised were programmers and software development professionals, engineering professional and IT business analysts, architects and systems designers.

As CAV technologies become more widely adopted there will be a need to change the skills provision in the area, for example training for businesses to undertake new forms of MOT for CAVs including software and sensors and training for councils using new ITS systems. There is also a potential that CAVs will affect jobs such as bus and lorry drivers in the medium-long term and there is an opportunity to provided training to those workers who are at risk.

The West of England has several key anchor businesses. Large engineering firms such as AECOM and Atkins have a presence in the region and are working on CAV projects, providing expertise in R&D project management, intelligent mobility and consulting. Aerospace companies such as Airbus provide expertise in human state monitoring and cyber-security and BAE Systems have provided Wildcat vehicle and sensor integration, performance testing and subsystem evaluation to CAV projects. Insurance company AXA is also an anchor business to the CAV sector, providing skills in risk analysis and expertise on the liability implications of CAVs and companies such as Burges Salmon offer advice on legal and regulatory issues of CAVs. Fusion Processing's technology underpins many of the UKs most significant CAV projects, including Gateway, VENTURER, INSIGHT, CAPRI, synergy, CAV-Forth and others.

Other businesses working in the CAV industry in the West of England include Designability, Five AI who are bringing together AI, engineering and mobility to deliver a fully autonomous shared transport service, T&VS and YTL Group.

Enablers of Growth

The growth of the CAV sector in the West of England has been enabled by several factors, including the proximity to expertise in enabling technologies, as well as access to government funding for projects.

The West of England has strong capabilities in enabling technologies for CAVs, including R&D capabilities in propulsion technologies, through the Institute of Advanced Automotive Propulsion Systems, IAAPS and automotive materials testing, through the National Composites Centre, NCC. There are also connectivity capabilities for example the Bristol is Open Network and a leading AI sector in the region. The biggest strength of the region and the greatest area of potential is the ability to unite these enabling sectors to collaborate on one key goal.

The Bristol Robotics Lab is jointly run by the University of West of England and the University of Bristol and is one of the key assets in the West of England that brings together various technologies to collaborate on CAV technologies. It is also home to the West of England Robotics Network. The Bristol and Area Autonomous Technologies and Systems group (BAATS) is organized by Business West and is another network that brings together different sectors to work on CAV technologies.

There are six different Innovate UK funded CAV projects that involve at least one organisation, but typically a consortium of organisations from the West of England that are collaborating:

1. VENTURER is a project to assess road users' responses to CAVs and understand blockers to large-scale adoption of CAVs
2. FLOURISH aims to better understand consumer demands, including implications of an aging society, cyber security and wireless communications
3. CAPRI is a project to design, develop and test new autonomous and connected pods on-demand, culminating in an on- road public trial in the Olympic Park in London
4. ROBOPILOT is developing and demonstrating autonomous driving functionality for new

- electric delivery vans
5. MULTICAV are trialling self-driving vehicles at Milton Park, the business and science hub near Didcot
 6. CAV-Forth, a trial autonomous bus on a route near Edinburgh across the Forth Bridge, which is due to start in Spring 2019

Through commercialisation of CAV R&D capabilities in the region, there is the opportunity to develop new markets and capabilities and a West of England CAV cluster that benefits from agglomeration of economies. This cluster could provide a strong supply chain and testing capabilities for the automotive sector in the West Midlands.

Barriers to Growth

It has been demonstrated that there are leading CAV capabilities in the West of England, however, the region was not recognised as the major location for CAV development in the UK. The Government has instead chosen to focus investment for CAV test bed infrastructure on the M1/M40 'red box' corridor between London and Coventry. This could prevent organisations in the West of England from securing necessary funding to capitalise on potential capabilities in CAV. Initially this caused uncertainty in the West of England, though this has lessened, and it is now time for the West of England to make a case for investment in the region.

There is also a lack of co-located space for the development of the CAV industry, both in terms of office space for start-up and scale up companies in the region, but also in test site space, which would require significant initial investment. Test sites in the UK include the Millbrook proving ground in Bedfordshire, HORIBA MIRA in Nuneaton, Smart Mobility Living Lab in London, and UK Central CAV Testbed in Coventry and Birmingham.

There are also challenges to the CAV industry that will be faced across the UK, not just within the region.

There is uncertainty related to the CAV industry, particularly around international and national technology standards which could lead to the design of inadequate solutions. There may also be a reluctance of some companies to share technological advances. Ultimately, these issues could deter potential investors and limit the growth of the CAV industry in the UK.

A future challenge to the industry will be the ability to transition from CAV R&D to the commercialisation of real-world technologies. One reason for this is the public apprehension around CAVs and uncertainty of future adoption rates. Nevertheless, there is significant investment in CAV R&D through Government funded projects and industry.

Relation to Other Deep Dives and Grand Challenges

As previously mentioned CAVs are supported by several enabling technologies in the West of England and are heavily linked to other deep dive areas including robotics, AI, quantum computing, medtech, composites, propulsion and creative digital. It is the collaboration of these different sectors that has enabled the growth of the CAV sector and is what makes the West of England different to other areas in the UK.

CAVs will contribute towards new forms of mobility including Mobility as a Service and is therefore a key component of the Future of Mobility Grand Challenge. Mobility solutions that are consumed as a service under a single intuitive mobile app have the potential to radically transform the transport system. There is a strong potential for the West of England to act as a testbed for Mobility as a Service.

CAV also has potential to link to the other 3 Grand Challenges. Older adults with ageing-related impairments are recognised as being able to benefit greatly from the introduction of CAV technology. The FLOURISH project focuses on the needs of this group within society and demonstrates how CAV can contribute to the Ageing Society Grand Challenge.

It is through the ageing society and the provision of alternative mobility options that CAV technologies could make the biggest impact on social inclusion. Mobility as a Service solutions could transform the transport system and there is a strong potential for West of England to act as a testbed for these services. The introduction of driverless vehicles will make public transport more cost-effective and open up new routes. This could link areas of employment deprivation to employment at the east and north fringes of Bristol and the Avonmouth and Severnside area.

Development of a Future Mobility Zone would help ensure that plans for CAVs are underpinned by investment in sustainable travel. The Government is allocating £90m to set up Future Mobility Zones in England, through a bidding process, which will trial “new transport modes, services, and digital payments and ticketing”. This shift in transportation in the region will also reduce air pollution and promote clean growth. CAV technologies will introduce more efficient, safer and cost-effective ways for businesses, visitors and commuters to travel.

Supporting Evidence

- KPMG (2015) Connected and Autonomous Vehicles – The UK Economic Opportunity. Available at: <https://www.smmmt.co.uk/reports/connected-vehicles/> [Accessed 18 November 2018]

Creative Digital

Definition

The Creative Industries were defined in the Government's 2001 Creative Industries Mapping Document as "Industries which have their origin in individual creativity, skill and talent and which have potential for wealth and job creation through the generation and exploitation of intellectual property". This definition includes Advertising & Marketing, Architecture, Crafts, Design, Film TV Radio & Photography, Software, Music Performing & Visual Arts, Publishing, Museums Galleries & Libraries.

There are significant overlaps of creative industries with both cultural and digital sectors. This deep dive focuses on Advertising & Marketing, Architecture, Crafts, Design, Film TV Radio & Photography and Publishing, with less emphasis on Software, Music Performing & Visual Arts, Museums Galleries & Libraries, recognising that these areas are covered in other areas of deep dive research and/or the Cultural Strategy.

Geographical Reach

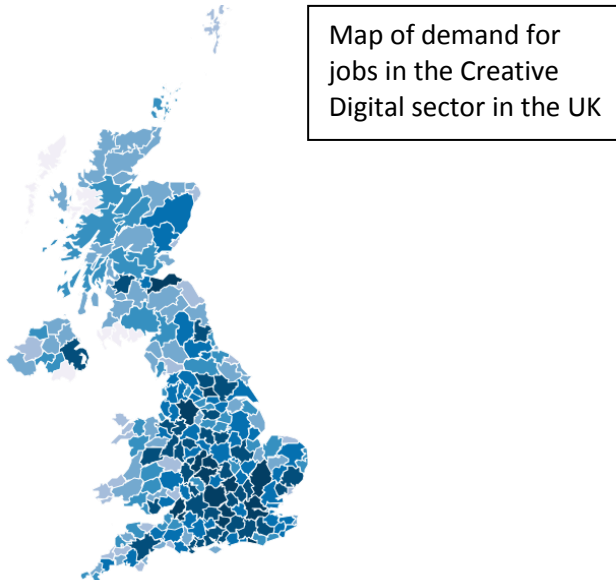
The Government Industrial Strategy Creative Sector Deal describes the West of England as a "*globally significant, high-growth creative cluster*".

The Creative Industries sector in the West of England is described by Nesta as one of the top 5 creative clusters in the UK. It is focused particularly in Bristol and is highly connected with London and the South East. More locally the agility of the creative workforce allows a positive expansion of opportunity, connecting the West of England ecosystem into Cardiff, particularly in content production.

A key differentiator of the West of England creative economy is its international reach. The local sector is a major exporter and co-producer and key markets include US, Europe and China while key co-producers include Canada, India, Europe and Singapore.

The UK Creative Industries have been the fastest growing industrial sector for the past decade and this is reflected regionally with the West of England seeing a 27% growth rate as digital technologies have been embraced. The ability to combine creativity and technology is a significant strength and Bristol is one of only two cities outside London which feature in the top 10 for both Creative and High-Tech clusters, according to Nesta.

In Numbers



Growth and employment in the West of England:

- 20,219 jobs advertised in Creative Digital from December 2017 and December 2018
 - This doesn't fully capture Freelance workers, which account for 42% of creative workers in the South West
- Mean salary of jobs advertised = £45,200
- Bristol has a higher than average demand for jobs in Creative Digital compared to the UK
- Key West of England Film and TV companies report a 65 - 80% export
- 27% growth in value of Creative Industries in the South West since 2010

Growth and employment nationally:

- Creative Industries national exports are £37Bn per annum
- Total GVA £101.5Bn in 2017 and has grown nearly twice as fast as the economy since 2010
- Fastest growth sector in UK economy

Business and Skills

There are over 4,500 undergraduate students in the West of England studying courses related to Creative Digital, including Creative Computing, Film and Screen Studies and Media Communications at Bath Spa University, Digital Media and Audio and Music Technology at UWE and Film and Television at the University of Bristol. There are an additional 750 postgraduate students in the region, completing either masters or PhD courses in similar subjects to those above.

There are very few apprenticeships in Creative Industries both nationally and in the West of England, with creative businesses saying that the current apprenticeship model is incompatible with specific industry practice. The local sector is currently seeking to articulate a more appropriate model of inclusive pathways into industry.

Jobs in the Creative Digital sector require specialised skills in imagination, design thinking, digital technologies and a wide range of creative and cultural experiences as well as core skills in resilience, problem-solving, team working and communications on multiple platforms. Many creative jobs are highly resistant to automation with the blending of creative and software skills becoming more essential and valuable. Software integration is vital across the sector.

There are almost 6000 Creative Digital firms in the West of England region. Nationally, the vast majority of businesses in the sector are small or micro enterprises and it is important to note that

the industry employs a significant number of freelance and self-employed contractors; therefore, a clustering effect is vital in supporting continued industry growth.

Key anchor businesses based in the West of England include: Aardman, BBC, Channel 4, Immediate Media and Future Publishing as well as companies such as Plimsoll, Silverback, Icon, BDH, Kinneir Dufort, Yogscast, Rocketmakers, Great State (E3), Mubaloo, Sift, and Films@59. These businesses span a range of disciplines including film & TV production and post production, content distribution, publishing, design and advertising.

There were 20,219 jobs advertised from December 2017 and December 2018 in the Creative Digital sector. The top industries recruiting these jobs were higher education, computer programming and consultancy and the most common job titles were software development engineer, business development executive and .net developer.

Enablers of Growth

Creative Industries are a major growth sector internationally and the UK is a global leader, with huge potential to grow exports, however, this is a very competitive sector. Bristol and Bath has been identified as one of 3 UK regions (outside London) that have international growth potential and particular strengths in the West of England are the fusion of hardware, software, content and user experience. It is a globally significant creative cluster which has enormous potential for continued growth and greater synergy with higher education research and other industrial sectors.

One way that the creative sector in the West of England has been able to grow and diversify over the last 20 years is through embracing digital technologies. This has been promoted through some key assets including research and education at the 4 Universities in the region as well as through organisations such as the Watershed / Pervasive Media Studio, Games Hub, Bottle Yard Studios, VR Lab, Architecture Centre, Spike Island, KWMC, The Guild and The Stable. These organisations have helped bridge the gap between creative and high-tech industries in the region, leading to innovations in the Creative Digital sector.

Accelerating innovation and adoption of new technologies such as VR, AR, AI, Voice Activation and 5G is one way that the growth in this sector could be further promoted. This will add value to other sectors in the region, for example health, mobility, engineering design/visualisation, and robotics.

As previously mentioned, there is a large, skilled freelance community in the West of England and this has encouraged innovation and growth in Creative Digital. A mobile workforce encourages collaboration and knowledge sharing between companies.

The West of England has potential to be strongest creative cluster outside of London, attracting business, talent and investment. Bristol was recently chosen as the location for a Channel 4 Creative Hub after open competition between 27 cities across the UK. This new investment brings with it the potential to build on the production communities in the city and develop talent across the region. This decision is very promising for the region and will hopefully encourage future inward investment, both for start-up and scale up companies.

Networks and creative hubs are vital to create connectivity, knowledge exchange and community in a fast moving and flexible industry. It is this connected clustering effect which has encouraged innovation and growth in Creative Digital, sustained a fluid mobile workforce and encouraged collaboration and knowledge sharing between companies.

Having an active and innovative cultural and creative sector makes a huge contribution to Place Making and the Quality of Life in the West of England, important to all growth sectors for talent recruitment and retention.

Barriers to Growth

There are several barriers to growth of the Creative Digital sector in the West of England. There is a lack of available and affordable, suitable workspace, especially for start-up and scale-up companies. There is also a lack of affordable housing in the region as well as a limited number of performance and showcase spaces, such as music venues. This lack of space is reducing the pipeline of start-up organisations and talent and more support is needed for open access spaces to develop diverse talent and ideas, including showcasing and performance spaces.

There is insufficient support for innovation and R&D in the region which will constrain growth if it is not accelerated. While the new Bristol + Bath Creative R&D programme will inject new innovation support, there is a need to build capacity for longer term support. Stronger, better resourced networks are needed in the region, alongside investment in innovation and peer to peer mentoring to support innovation and R&D.

There is a lack of diversity in the creative workforce which will weaken the competitive position and limit talent supply. There are some strong initiatives but there is a need to scale up and join up across the region to encourage diverse workplace skills development and to re-invent the ineffective apprenticeship model for the creative sector.

Although the West of England has been identified as a potential region for high growth internationally, it still has a low international profile which limits investment and sales. Increasing visibility and highlighting the regional strengths in key international markets could further promote growth in the region.

The local transport issues are also creating a barrier to growth of the Creative Industries in the West of England. Increased and sustained investment in place making is needed to ensure the region maintains its competitive position in talent attraction and retention.

Relation to Other Deep Dives and Grand Challenges

Creative Industries impact across all sectors and have significant collaboration potential with 5G, IOT, Immersive, AI and Robotics sectors. Through partnership driven innovation with these sectors, Creative Industries will develop capacity for adoption of new technologies and capacity to respond creatively to emergent customer behaviours and expectations. This will promote growth and development in the West of England and enable the region to position itself at the forefront of the future digital economy.

Inclusive Growth

There is a huge opportunity to engage young people from all communities through Cultural and Creative Industries and reduce social exclusion in the region. This could provide skills in creative, communication and collaboration, which are essential core skills for most industrial sectors. Despite the growing interest of young people from all communities there are limited opportunities to gain the necessary experience to enter the creative workforce.

As previously mentioned, the creative workforce currently is not very diverse and there is a movement to diversify. The arrival of Channel 4 will help to catalyse this long-term movement through increased focus and profile. There is a pressing need, and a major opportunity, to re-invent apprenticeships for the creative sector which is so heavily dominated by small and micro businesses.

Social inclusion in the creative sector could be promoted by increasing the visibility of the sector to school age groups, improving career advice and guidance and providing more support for those starting their first job or starting freelance work.

Clean Growth

In terms of clean growth, the sector has an early adopter, activist workforce with potential to lead clean growth initiatives locally and nationally. This could be done through content production to develop strong narratives of change and locally commissioned environmental festivals which promote the key messages.

Supporting Evidence

- Creative Industries Economic Estimates January 2016
- AHRC 2017
- DCMS Employment Stats June 2018
- Growing the UK's Creative Industries 2018
- DCMS Sectors Economic Estimates 2017 (November 2018)
- UWE: Go West: Film TV and Animation in Bristol
- McKinsey: Industrial Revolutions
- SQW: Bristol-Bath Innovation Cluster
- NESTA Creative Nation 2018
- NESTA UK's Geography of Creative and Hi-Tech Sectors
- Industrial Strategy Creative Sector Deal 2018
- Creative Industries Federation: Growing the UK's Creative Industries 2018

Cyber Security

Definition

Cyber security covers the range of activities that an organisation needs to do to manage their digital risks, and includes steps to identify risks, protect data and infrastructure, and detect, respond to, and recover from, cyber security attacks. The cyber security sector is usually thought of as those specialist companies that provide products and services to help companies with these activities, but in terms of skills and job mobility there is little difference between those employed in specialist companies and those employed on these activities inside any company.

It has been difficult to collect data on companies that have cyber security functions as part of a wider business and there is much better data on those employed in specialist cyber security companies.

Cyber security is an enabler technology for the wider digital economy and technologies such as AI, IoT, 5G and autonomous vehicles requires cyber security challenges to be addressed.

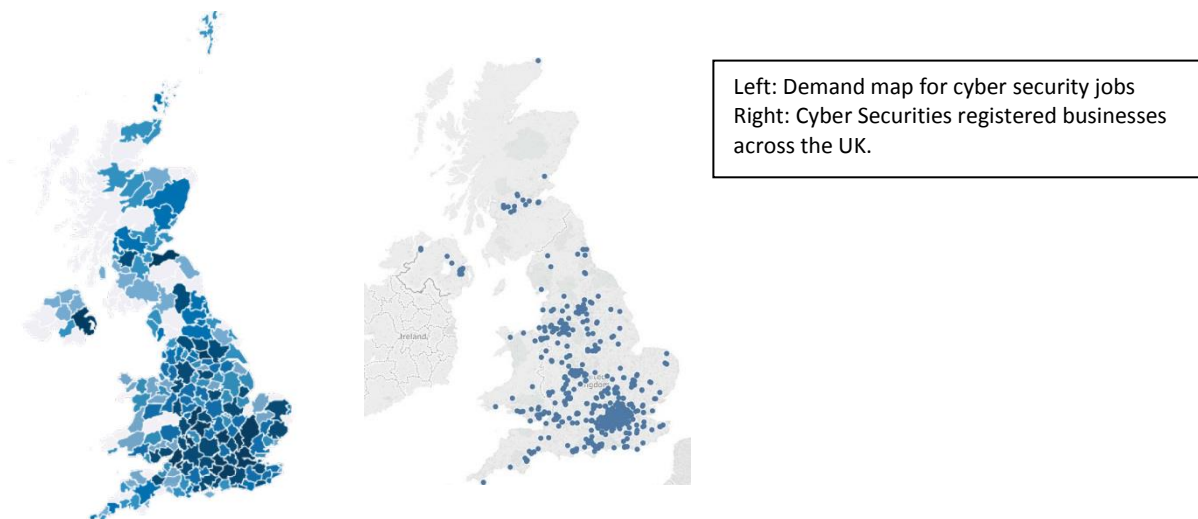
Geographical Reach

Cyber security capability, specialised companies, and opportunities are spread across the country, with a greater accumulation around London and the South East.

There is no leading cyber security region in the UK, and there are no companies that dominate globally or nationally. Relative to the rest of the country, outside London and the South East, the West of England does well for small and mid-sized companies, has very strong academic capabilities, strong capability within companies, and benefits from being close to Cheltenham.

In terms of international perceptions, the West of England benefits from being adjacent to Cheltenham and GCHQ and is seen as part of the much larger region rather than standing alone. The UK has a strong position in cyber security, but is not generating the number of start-ups that are typical of the US or Israel.

In Numbers



Growth and employment in the West of England:

- 1755 job postings in cyber security from September 2018 to August 2018
- Bristol has a higher demand for cyber security jobs than the UK average
- Mean salary of these jobs is £64,900
- Top 3 industries for these jobs were: legal and accounting activities, computer programming, consultancy and related activities, and telecommunications

- The most common occupation of these jobs was information technology and telecommunications professionals
- South West specialist companies are 6% of UK workforce, although note the South West is identified as having 10% of UK economic activity in cyber security

Growth and employment nationally:

- UK specialist cyber security companies employ between 31,300 – 40,000 people
- The UK has 846 businesses, with a total revenue of £5.7Bn
- GVA was estimated at £2.3Bn for 2016
- Average revenue per employee was £181,000 and GVA per employee was £75,000
- Cyber security exports by UK firms was £1.8Bn in 2015
- Number of active specialist companies has grown by 50% nationally from 2012 to 2017
- Over 100 new businesses have registered in the same time frame

Business and Skills

Cyber security covers a wide variety of job roles and skills. The skills required range from highly technical skills in chips, applications, and system architectures, to understanding the psychology of grooming and phishing, to training others to work in a safe way. Less skilled jobs in monitoring and reporting threats are also available.

It is likely that a deep understanding of how technologies work, coupled with understanding of how users engage with the technologies and how they might be deceived or manipulated in some way, will be a highly sought-after combination of skills for the majority of cyber security jobs.

Cyber security capability and teaching is growing across UK universities, with many now offering specialist degrees or units within more general computer science courses. This is true of the West of England. The University of the West of England offers both an undergraduate degree in Forensic Computing and Security and a master's degree in Cyber Security. The University of Bristol offers a specialist master's degree in the Mathematics of Cyber Security.

Apprenticeships are new in cyber security with pilot schemes currently undergoing an evaluation.

The South West has 1780 employees working in a 65 specialised cyber security companies, 31% in large companies, 36% in medium companies, 26% in small companies, and 7% in micro companies. The South West has the highest number of small, medium and micro companies registered as cyber security anywhere outside of London and the South West.

Cyber security jobs inside other companies are very hard to estimate but for large companies could amount to 8 - 10% of IT staff.

It is estimated that there are 18 specialist cyber security companies in the West of England LEP with 352 employees, a revenue of £29m and a GVA of £13m in 2016.

Amongst the large companies, HP's Research Labs have worked on cyber security in Bristol since the 90s and it is now their main area of research locally. They are the company's global centre of expertise in cyber security and they develop and advise on the security technologies HP adopts in its' PCs, printers, and 3D printers, together with the associated online services. They are well connected with both universities internationally and the industry more generally, and like the local universities they also have an international reputation. With their move to Bristol's city centre in early 2019, they will be much more accessible to local small and medium companies.

In addition to the large companies a great deal of specialized consulting is provided by many small companies such as Logiq Consulting, who carry out the risk assessments and reviews of security architectures that organisations don't always have sufficient specialist capability to deliver internally. Cyber security is an attractive area for investors, and cyber security start-ups are in the mix in any tech incubator, not least SETsquared in Bristol.

Another important part of the glue is those companies such as BMT in Bath who offer a wide variety of design and engineering consultancy and are also developing cyber security capability. They understand how to couple cyber security with other emerging digital technologies, and see new opportunities at the intersections.

Whilst no one of these small businesses is of itself an anchor, collectively they attract similar businesses. There are also several key specialised businesses located outside the West of England boundaries, including GCHQ in Cheltenham, MOD in Corsham and other companies in Newport and Cardiff.

Enablers of Growth

It is the quality of the environment as a digital place to be that is probably the most significant factor in whether a cyber security company would be attracted to the area. Very dedicated specialist start-ups might look to set up close to Cheltenham, but companies in the intersection of cyber security and something else, and those looking to scale-up, will look as much to tech hubs such as the West of England as they round out their mix of staff with other digital skills.

As well as the strong tech cluster and skills base on the region, several key assets have enabled growth in cyber security in the West of England. For example, both GCHQ and the MoD are internationally significant local assets.

The University of Bath and the University of Bristol have strong research groups with international reputations. The Heilbronn Institute for Mathematical Research based in Bristol is a partnership between GCHQ and the University of Bristol and offers post-doctoral fellowships in mathematics many of which are tackling difficult cyber security challenges. The national Cyber Security Body of Knowledge (CYBOK) identifies the content for professional training for cyber security is led by the University of Bristol.

Networks, meetups, and events, focused on cyber security have come, and been replaced with others, but have run in the region since the mid-90s. Attendees are a mix from all sizes of company and organization and illustrate that “cyber” is very much an identifiable subculture within the wider digital culture. In addition, cyber security has been a topic at many other digital events including Bristol Cyber Security Meetup and Bristol and Bath Cyber.

Cyber security has seen consistent growth in the region since the mid-90s, and with continuing high-profile breaches and an increased appetite for greater regulation, there is no indication this is slowing down.

Barriers to Growth

Cyber security is a very dynamic sector, adversaries and new types of attacks can render cyber security techniques obsolete overnight. Consequently, there is a constant interest in innovation and new technologies. This can impact significantly on smaller companies who may not be able to keep up with the industry and may struggle to retain an edge as they scale up.

That said, there are also several barriers to growth of larger cyber security companies as well. There is a lack of trust between nation states regarding cyber security which will prevent companies becoming globally leading. Every nation wants to protect themselves whilst also having cyber influence on other states and consequently, no company will receive the required levels of trust globally to become internationally leading.

Furthermore, there is a national desire for “strength in depth” and not being dependent on single mechanisms to provide “the” solution. This will make it hard for any single company to dominate at the national level but provides an opportunity for small and medium sized companies to grow their businesses and for the West of England continue to encourage and support the growth of these businesses, in particular hybrid businesses linked with cyber security and other tech sectors.

One way to encourage the growth of smaller businesses is to celebrate local strengths and increase the profile of cyber security in the region, encouraging bigger players to recognize the achievements of the smaller companies. Cyber security is often hidden from view and promoting the work of

smaller companies and will help in making the West of England the preferred region to grow a cyber security business.

Contribution to our vision and/or grand challenges

Currently cyber security is not strongly dependent on other activity and much of the community can be quite insular. However, as previously mentioned, one of the strengths of the region is linking cyber security businesses with the wider tech hub, and these links are growing. With increasing levels of cyber-crime, terrorism and warfare, cyber security has already become an essential enabler for much of the wider digital economy and growth in technologies such as AI, IoT, 5G and autonomous vehicles, requires cyber security challenges to be addressed.

Cyber security is rapidly becoming an important application area for AI, however, there is a risk that advances in AI will disrupt cyber security jobs that are centred on monitoring, detecting attacks, and then responding to them.

As it stands, cyber security does not encourage social inclusion. The workforce is predominantly white, middle-class UK nationals and jobs in defence or intelligence often require a security clearance. Clearly, more needs to be done to make cyber security more inclusive and accessible. Both DCMS and NCSC are keen to see much greater diversity and inclusion in cyber security. Initiatives that couple local strengths in social enterprises, with the local ability to deliver cyber security training, and with employers willing to take on a more diverse workforce will address a nationally identified need.

To the extent that green growth depends upon instrumented infrastructures, or being more efficient in how information is captured and used, cyber security can clearly play a supporting role.

Supporting Evidence

- DCMS's UK Cyber Security Sectoral Analysis (June 2018)

Fintech

Definition

Fintech – companies that mainly develop or utilise digital technology in the delivery or creation of financial services products. Also in scope is the application of blockchain technology in all sectors. Within financial services, reg-tech refers to the use of technology to serve the interests of the regulation of financial markets and related transactions. Also considered has been the use of technology in the delivery of recruitment services.

Geographical Reach

Fintech activity is evident across the West of England including all four unitary authorities but is most apparent in Bristol including it is Northern Fringe and in Bath. The subsector is also evident proximally in Cardiff, Newport and Swindon but this activity is discontinuous with that in the West of England.

Approximately 34,000 staff are engaged in the West of England Financial Services sector and about 7,000 in tech. While there will be some considerable overlap between the two cohorts, it is not possible to be precise as to how many staff are engaged in fintech. Some companies such as Hargreaves Lansdown would regard themselves as exclusively fintech but will still engage the majority of staff in generic roles that would be equally excluded from this enumeration in companies where fintech represents a discrete line of business.

The Financial Services industry is wide in its reach and therefore the potential for growth is equally great in insurance, investment advice, custody, clearing, banking, settlement, blockchain, apps, websites. The list is long and the scope extremely wide. Anecdotally, much of the FS industry, behind the scenes, is still based on paper or manual processes and therefore the opportunity for automation is huge. Among those canvassed in this regard, there was unanimity that the scope for fintech globally is immense. The technology is translatable globally so for the right solutions, the market is vast.

TheCityUK: The South West has already been identified by the Government as a Financial Centre of Excellence. Within the region, Bristol is home to the largest cluster and its diverse industry offering – coupled with a burgeoning fintech community – marks it out as an alternative industry centre to London. There is strong potential for Bristol and the South West for further growth driven by global trade. It is estimated that FRPS exports for the region were valued at £4.6 billion in 2016, a 19% increase of the 2015 figure of £3.8 billion. Despite its success, the West of England at present is not leading nationally / internationally in respect of fintech – in the UK the majority of activity to date has been centred around London, but the West of England does though have a bright fintech scene, which is growing.

The West of England and Bristol have a thriving entrepreneurial blockchain community. This includes innovative product and servicing companies such as WeOwn, Dovu and Acorn amongst others. These companies also support a growing supply chain ecosystem including specialist marketing agencies and social media freelancers, technology providers, data visualization teams, software development firms, legal, finance and tax specialists. Bristol's entrepreneurial infrastructure, such as the University and UWE incubator hubs, as well as commercial workspaces such as the NatWest Accelerator, Runway East and The Engine Shed are helping to nurture the community by hosting events, talks and a number of start-ups with workspace.

In Numbers

Growth and employment in the West of England:

- Approximately 33565 people are employed in the Financial Services sector in the West of England according to TheCityUK. Approximately 7000 are employed in tech in the West of England according to Tech Nation. The extent of the crossover is unknown.
- It is estimated by TheCityUK that FRPS export from West of England grew by 19% from £3.8bn to £4.6bn in 2016

SOUTH WEST FINANCIAL AND RELATED PROFESSIONAL SERVICES EMPLOYMENT											
City / Town	Financial Services					Related Professional Services				Total	% of City/Town Employment
	Banking	Insurance	Fund Management	Other Financial Services	Total	Accountancy	Management Consultancy	Legal Services	Total		
Bristol	7,000	6,250	350	4,465	18,065	5,000	3,500	7,000	15,500	33,565	11.3

Growth and employment nationally:

Nationally, employment in the financial services sector has remained stable over the past 17 years according to ONS statistics with major drop following the 2008 recession and recent trends showing that pre-recession levels of employment might be reached around 2021

A Burning Glass report on scale and density of fintech skills requirements put both the Bristol and Bath labour markets in fifth position behind London, Manchester, Edinburgh and Birmingham with London as might be expected ahead of the leaders by a wide margin. In terms of density of requirement Bristol ranked fourth among the top five with London Edinburgh and also Reading having a higher proportion of job adverts focused on the likely keywords. Of those employment opportunities where the advertisement quoted an expected salary the median was £40,000 and the mean £48,400.

Business and Skills

The breadth of the sector means that the required skill set can vary hugely from role to role. There are instances of best practice, and these are being led locally by institutions such as the Bristol Business School at the UWE or the University of Bristol, which have developed sector specific course offerings in partnership with industry. While as expected a variety of generic skills are seen as a prerequisite – IT, good people skills, resilience, strong communication skills both written and oral, teamwork, pragmatism, and business acumen. Within fintech specific skills would include full stack software development, analysis, innovation, legal and compliance, finance, cloud, AI/AMR, cyber, blockchain and distributed ledger. The required skills scheduled above are considered unlikely to change in the short term, and it appears unlikely they will change in the medium to longer terms. They will be core to the majority of fintech businesses.

Enablers of Growth

It would be true to say that the West of England has only come to recognize its pre-eminence in fintech since 2015 when a number of informal networks including Bristol Fintech and BrisTech were established to support development of and in the subsector. The major players are Hargreaves Lansdown, NatWest, Lloyds, Funds Library, Altus, Parmenion, and MoneyHub. Undoubtedly, fintech has thrived and grown to this position because of a number of factors:

- Advance incubation facilities in the West of England - SETSquared, Engine Shed, NatWest, UWE, University of Bristol.
- Strong tech community
- A long and established history of pre-eminence in Financial Services
- Strong support network of other professional services companies

Barriers to Growth

Blockchain

Lack of clarity means that many blockchain companies are advised to legally incorporate in non-UK jurisdictions where the legal position is clearer. This is unnecessarily driving UK-based teams offshore. It also adds unnecessary cost and bureaucracy to the start-up firms, who would much prefer to incorporate in the UK. Lack of clarity over national regulatory position of cryptographic assets, blockchain and DLT in the financial services industry.

Additionally, the lack of clear regulatory position is a significant barrier to adoption by larger enterprises. Whilst many innovative and tech forward companies are adopting Distributed Ledger Technology in various forms, the perceived lack of regulatory clarity remain a barrier to closing deals with biggest firms. Managed and flexible workspace is already making a difference in fintech – such developments whether public and private sector-led should be encouraged and supported.

Skills availability

A priority for industry is ensuring a sustainable supply of skilled workers with the necessary technical skills. Bristol benefits from its proximity to world leading universities but future skills pipeline will be a priority. There is an onus on industry, further and higher education organizations and policymakers to ensure that Bristol provides a career long offer to people wanting to work financial and related professional services, not simply entry level or graduate jobs. For more established firms, access to talent is difficult. IT staff are in demand across many sectors, and although there are 34,000 people employed by Financial Services firms, there is not the degree of specialism that London enjoys.

Ecosystem

London houses the centre for financial services in this country, and therefore many of the ancillary services too. For start-ups in this area, access to these services, along with funding, is limited.

Relation to Other Deep Dives and Grand Challenges

The West of England can aspire to become the main fintech hub outside London. The West of England could further build its position as a leading industry centre of excellence for financial and related professional services. According to TheCityUK locally there is the opportunity for the FRPS industry to carve out a distinct industry offer. The fintech and start up community within the city is a particularly exciting area with enormous growth and potential. This was underlined by the fact that Bristol was identified as the most productive UK tech eco system (with turnover per person standing at £320,000). This would be based on a number of factors. Potentially it could strengthen its credentials as:

- A magnet for high quality skills and talent, with industry offering attractive reasons to work in the city coupled with an excellent quality of life offer and world-leading tuition.
- A specialist financial and related professional services sector, offering services complementary to London.
- A well-connected hub, both digitally and in terms of physical infrastructure, that has strong links and partnerships with other UK and international business clusters.
- Support systems in place to help firms scale-up quickly, access finance and receive business support services.

Blockchain

With the correct support, Bristol could become a hub for blockchain fintech companies, similar to the “Crypto Valley” in Zug, Switzerland which would be a good model to emulate. In terms of benefits to the region it would offer excellent jobs, both in terms of the number of roles available and the breadth of roles available (IT, developers, data analysts, legal, financial and accountancy professionals etc.). This would bring the parallel benefit of increasing the mass of the tech ecosystem and support economic growth generally.

Inclusive Growth

TheCityUK's interaction with its members – locally and at national level – show the industry 's desire for 'inclusive growth' that supports a range of stakeholders across communities, the education system and local business. Institutional offerings are aimed to reduce baseline costs and increase automation, arguably meaning less manual-processing and therefore a reduction in low skilled work. Opportunities for employment will come at the more highly skilled end – IT, development etc.

Working with Bristol Pound we will be able to offer a cryptographic platform for social enterprises and other good causes to directly interact with supporters and investors. Social ownership and inclusion projects are ideal use cases for funding and asset management on blockchain.

Clean Growth

Blockchain v1.0 solutions (e.g. Bitcoin) running Proof of Work consensus have huge energy requirements. The vast majority of this power is being consumed by mining farms in China with a significant environmental impact. Newer Distributed Proof of Stake consensus solutions such as those being created by WeOwn in Bristol do not have this wasteful energy consumption model. Thus, a significant reduction in energy consumption, hardware production and CO2 emissions globally.

Supporting Evidence

- Burning Glass analysis
- ONS employment statistics
- <https://www.thecityuk.com/assets/2018/Reports-PDF/b408b7220a/Enabling-growth-across-the-UK-2018.pdf>

5G and Internet of Things

Definition

5G is the fifth generation of mobile communications, following on from 4G, 3G and 2G. 5G aims to supersede the performance of 4G with, for example, higher data rates, reduced latency and higher systems capacity. The Internet of Things (IOT) is the interconnection of everyday objects via the internet, enabling these objects to send and receive data. Full Fibre investment and delivery is also directly relevant to 5G and IOT.

5G and IOT are enabler technologies that provide a platform of connectivity, investment and skills to facilitate development and distribution of technologies.

Geographical Reach

Bristol is one of a several leading centres of 5G/IOT research in the UK and the West of England was announced as one of six winners for the first phase of the 5G Testbed and Trials. Other areas include Liverpool, Bedford, Orkney and Somerset, and Worcestershire. Additional significant centres for 5G/IOT development include the 5G Innovation Centre in Surrey and the West Midlands LEP, which was selected to be the UK's first multi-city 5G testbed, as part of the Urban Connecting Communities Project.

In Numbers

Growth and employment in the West of England:

- 3592 jobs in 5G/IOT advertised in the West of England between November 2017 and November 2018
- 96% of these jobs were based in the City of Bristol, which has a much higher demand for jobs in 5G/IOT than the UK average

Growth and employment nationally:

- Nationally 5G and IOT are valued at £118bn per annum, and account for 16% of UK economy
 - This is expected to grow significantly over next 10 years
- In 2020, the impact of mobile on UK GDP will be £112bn, rising to £164–198bn per annum by 2030

Growth and Employment globally:

- 5G's deployment will fuel sustainable long-term growth in annual global GDP. Between 2020 to 2035, the total contribution of 5G to global GDP is predicted to be equivalent to an economy the size of India today, the seventh-largest economy in the world.
- It is estimated that mobile will contribute \$4.6 trillion to the global economy by 2022 (5% of GDP), up from \$3.6 trillion in 2017 (4.5% of GDP).
 - This will be mainly due to productivity gains

Business and Skills

Skills needed for 5G and IOT jobs include advanced skills in telecommunications, computing and cybersecurity. Digital transformation skills such as leadership, consultancy, business process re-engineering and project management are also sought-after skills in this industry. In the longer term, it is likely that there will be a greater need for skills in automation, machine learning and AI. There were 265 business in the West of England working in 5G and IOT in 2018; this figure has grown by 32.5% since 2010, which is significantly higher than the UK average growth of 17%. In the West of England, 85% of businesses were micro-businesses, 9% were small businesses, 4% were medium sized businesses and 2% were large businesses, with the medium businesses showing the fastest growth since 2010. Wholesale of electronic and telecommunications equipment and parts and wired

telecommunications activities were the most common types of business. The West of England employs 5000 people in 5G and IOT which accounts for less than 2% of employment in this sector across the UK.

The West of England is home to some new and scale-up businesses which are driving innovation in 5G/IOT including Zeetta Networks, Blu Wireless and GDS Digital. Among major network companies, EE have a centre for R&D and network management in Aztec West in South Gloucestershire, and Huawei also have an R&D centre in Bristol, and these companies act as key anchor businesses. Vodafone has chosen Bristol as one of their first 5G pilot locations. There are also several key industries and companies in the region that are driving innovation and adoption of 5G/IoT technologies, including utility companies such as Western Power and OVO, transport companies such as First, and health and social care providers.

Enablers of Growth

The growth of 5G / IoT technology in the West of England has been supported by several key assets and programmes. DCMS awarded one of six testbed 5G projects to the West of England Combined Authority for Smart Tourism for delivery in 2018/2019. This project is accelerating the development of 5G technologies and involves over 20 partner companies.

Several organisations in the West of England, including High Tech Bristol and Bath CIC, SETSquared, Engine Shed, and the University of the West of England, won the Digital Catapult's IOT UK Boost programme in 2016/17. This programme acts to address barriers to entering the IOT marketplace through experimentation and innovation in various industry areas. It also works to roll out Low Power Wide Area Networks (LPWAN) across the UK. Collectively the cohort generated £76k in investment, reached £160k in revenue and created 15 jobs and 11 partnerships, enabling and promoting further growth in the area.

The University of Bristol is home to the Smart Internet Lab which is undertaking international research and development and has strong links with industry. Other assets that have enabled growth of 5G and IOT technologies in the region include: Bristol is Open, Bristol Operations Centre and Bristol VR Lab. In 2017 Bristol was recognized in the UK Smart Cities Index 2017 as the UK's leading Smart City which has further promoted growth of 5G/IOT technology. There are also several networks in the region which enable growth of 5G and IOT technologies, including High-Tech Bristol & Bath, Techspark and the Assisted Living Action Network.

Furthermore, Vodafone and EE have announced intentions to deploy 5G services to Bristol in their early stages of UK rollout which will catalyse the development of 5G and IOT technologies and application in the region.

Barriers to Growth

There are several barriers to the growth of 5G and IOT technologies in the West of England. Currently, there are challenges in deploying 5G and full fibre across the region, and current 5G technologies are not scalable to the whole region. This could result in some areas being left behind and increasing deprivation. Furthermore, 5G deployment is not considered to be a priority by all partners and this could limit the adoption of 5G and the development of applications of 5G, including IOT. Coordination will be needed among network users to enable investment that makes the best use of the technology.

There is a lack of current investment in infrastructure for 5G development and deployment. There is an opportunity for the public sector to lead in the deployment of 5G and become a key anchor tenant. Currently, the investment, innovation and deployment of 5G technologies is uncoordinated and the lack of an anchor tenant is a key driver of this. Whilst there are several incubators acting to

encourage 5G technologies, coordinating the approach of these organisations could help drive this technology further.

There are also considerations around the technical and security standards of 5G and IOT technologies. These include cybersecurity matters in relation to providers (e.g. Huawei), countries, cities, organisations and individuals and the future development and agreement of standards. Without agreement of these standards, the growth of 5G and IOT technologies will be limited.

There are insufficient skills in the region to meet the demand. If this technology is to continue to grow, then more digital and STEM skills need to be available. Finally, organisations are limited by the lack of available and affordable office and work space in the West of England, especially in central Bristol. This is particularly a concern for start-up and scale up companies and prevents some companies from locating to the region.

Relation to Other Deep Dives and Grand Challenges

5G and IOT technologies are enablers of other technologies being developed in the region. For example, they enable significant growth in Digital Health, Autonomous Vehicles, AI and have potential to be linked with all 4 of the Grand Challenges.

5G and IOT technologies can help provide inclusive growth to the region, utilising digital connectivity to support businesses and citizens and deliver local services. The adoption of 5G will increase local economic activity, including improved productivity, innovation and creation of new businesses as well as jobs associated with the deployment of network infrastructure. Furthermore, 5G will bring improved access to public services, such as personalised healthcare, online services and smart cities. Ubiquitous internet access through reliable broadband connectivity, with better and more affordable services is key to maximizing the inclusive growth potential of 5G. Immediacy of access to public services such as adult care, telemedicine, and important local information and data will help ensure that 5G availability and growth contributes to inclusion. This will require private sector investment across the region.

Digital services and applications are key to engage communities and individuals, gaining additional commercial value and improving the public service offering. Availability and services “on the move” and in “high-traffic” locations will also improve the transport experience, productivity and inclusive opportunities. Specific initiatives for digital inclusion including IT education and skills for key locations and groups will also help maximise the opportunities for inclusive growth.

The adoption of 5G and IOT will also provide clean growth through the delivery of real time information and a series of sensors which will improve traffic and parking flows and improve air quality in the West of England. 5G internet will also help mobilize the development of autonomous vehicles, linking it to the Future of Mobility Grand Challenge.

Supporting Evidence

- DCMS Next Generation Mobile Technologies: A 5G Strategy for the UK (March 17)
- UK 5G Testbeds and Trials (June 18)
- Future Telecoms Infrastructure Review DCMS July 18
- OFCOM’s Approach to Future Regulation July 18
- Tech Nation Report
- ‘Commercial Case’ component of the Treasury Green book assessment
- ‘Centre for Cities’ report
- MIT Technology Review, 2017

Food and drink manufacturing

Definition

Food and drink manufacturing involves the processing of agricultural and fishing products into food or drink for humans or animals. Processing can take several different forms depending on the type of product being manufactured. Examples include the slicing of produce, the pasteurisation of milk, the roasting of nuts, the slaughter of animals and the curing of meats. Food processing also includes adding components to food, such as ingredients that extend shelf life or vitamins that improve nutritional quality. Similarly, the manufacturing process for beverages will slightly differ based on the type of drink produced. This could include the distilling of alcoholic beverages, the fermentation of non-distilled alcoholic beverages, the production of malt and brewing of beer.

Food and drink does not qualify as manufacturing where the processing is minimal and does not lead to a real transformation, such as the sale of fresh seafood by fishmongers or raw agricultural produce by grocers.

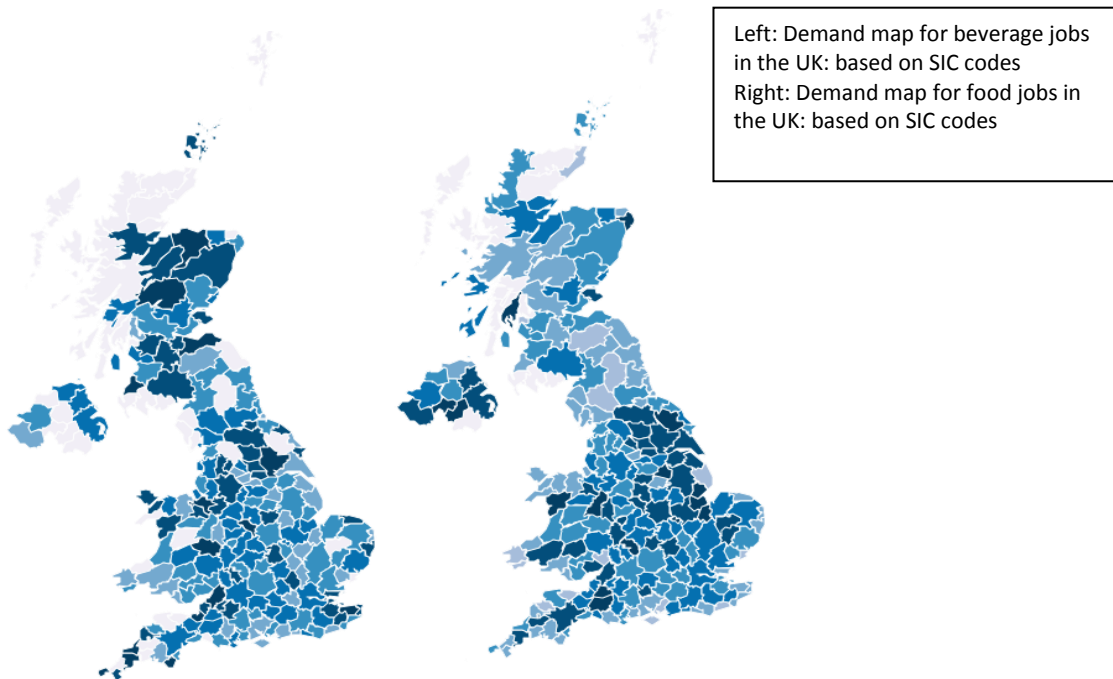
Geographical Reach

Food and drink manufacturing businesses can be located in both rural and urban areas and are widespread across the country. Investment and R&D in food manufacturing in the West of England has applications to the food and drink sector nationally and much wider applications into digital technology, health and life sciences.

The food, beverage and agriculture industry has experienced exceptional growth in recent years and continues to expand rapidly. This can be attributed to several factors, including changing consumer demographics, rise in disposable income, advances in health care, increases in global population, urbanisation, and growth of the global retail and distribution network.

The industry yields significant value from exports on an annual basis, with export figures worth more than £22bn in 2017. There is scope to build on this performance too, as currently only 1 in 5 manufacturers export. Notable opportunities remain in Europe despite the uncertain trade outlook, as well as in emerging markets.

In Numbers



Growth and employment in the West of England:

- 135 Food and Drink Manufacturing companies in the West of England in 2017
 - 67 % of these companies are micro-businesses
- 3,800 people were employed in Food and Drink Manufacturing companies in the West of England in 2017
- 822 jobs advertised in Food Production and 212 jobs advertised in Drink Production between January 2018 and December 2018
- Bristol has a higher than average number of jobs advertised in this time for Food Production
- Bristol and Weston-super-Mare have a much higher than average number of jobs advertised in this time for Beverage Production and Bath has a higher than average demand
- The average salary for jobs advertised in Food Production was £34,700 and £22,000 for Beverage Production

Growth and employment nationally:

- Food and Drink Manufacturing contributes £28.8bn to the economy
- The Food and Drink Industry is the biggest manufacturing sector in the country, larger than automotive & aerospace combined.
- The Food and Drink Sector is the 14th largest sector, contributing 1.6% to total UK GVA
- Between 1997 and 2015 the sector's GVA grew by 27% making it the fourth fastest growing UK manufacturing sector by GVA over that time period, ahead of total manufacturing which grew by 13% over the same period.
- Total Food and Drink export figures were worth more than £22bn in 2017.
- In 2017 there were approximately 6,700 micro, small and medium sized enterprises (SMEs) in the Food and Drink Sector with turnover of around £18bn and 120,000 employees.
- Around a third of the SMEs in the food sector are manufacturers of bakery products.
- In 2015, the sector employed 392,750 people.
 - The largest employment sub-sector was the Bakery (24.9%), followed by the Other food products (22.6%) and Meat and meat products' (19%).

Growth and Employment globally

- Global revenues for Food and Drinks almost doubled from \$8.3tn in 2004 to \$15.1tn in 2014, a compounded growth rate of approximately 7% per year.

Business and Skills

Jobs in the food and drink manufacturing sector are highly varied and consequently, cover a wide range of skills. There is currently a shortage of engineers in the food and drink industry, even though this is an area of growth. Key roles in engineering include controls engineers, maintenance engineers, engineering managers and automation engineers. There is also an increasing emphasis on sustainability and traceability of food which has opened up jobs roles such as new product development managers, process managers, new product development food and drink technologists, packaging specialists and development chefs who can reformulate existing products to extend life cycles, reduce sugar and salt.

Skills in compliance and quality assurance are also sought after in the food and drink industry with key roles like technical managers, quality assurance managers, hygiene managers, health and safety managers and technologists becoming highly sought after. Furthermore, lean manufacturing and continuous improvement techniques are increasingly being adopted by food companies, creating roles in production management, production planning, shift management and team leadership. Skills are also sought after in purchase and procurement of products.

As a result of the wide range of skills needed in food production, there is a huge range of relevant further and higher education courses, from engineering and mechanical engineering to physical sciences to businesses studies and management courses. The food and drink industry has developed a number of industry specific apprenticeships up to degree level in order to help fill the skills gap.

There were 35 beverage production businesses in the West of England in 2017, of which 30 are micro companies and five are small companies. Most of the micro companies were based in Bristol City Council and 20 of the companies were manufacturers of beer. 300 people were employed in beverage production in the West of England, with 200 working in the manufacture of cider and other fruit wines. Key beverage businesses in the region are breweries Bath Ales, Wickwar and Butcombe Brewery and cider makers, Thatchers.

There were 100 food production companies in the West of England in 2017, of which 70 were micro-businesses, 20 were small and five were medium businesses. 3,500 people were employed in food production industry and 1,250 of these people worked in the manufacture of bread, fresh pastry goods and cakes. Major bakeries in the region include Warburtons Bakery and Hovis, and this figure will also include multiple micro and small bakeries.

Other key anchor businesses in the region include Create Flavours that develop and produce natural and synthetic flavourings and TasteTech, a leading manufacturer of controlled release flavourings. Kerry Ingredients produce food to go and chilled and frozen ready meals and there are three major producers of dairy products (Yeo Valley, Marshfield Ice Cream and Lye Cross Farm) in the region. Other key companies include Cocoa Libre who produce dairy-free, wheat free, nut free and gluten free chocolates, Pukka Herbs and Pieminister.

The West of England is also home to companies that are developing new ways to grow and produce food, including LettUs Grow, who design irrigation and control technology for indoor, vertical and glasshouse farms.

Enablers of Growth

Growth in the food and drink industry has recently been enabled by growing trends in public food consumption. Free-from products, including vegan and gluten free products, have seen significant growth recently and are predicted to continue to grow by 10% from 2017 to 2018. It is also predicted that more food and beverage manufacturers will launch more “natural” and “functional” products as the consumption of natural beverage products that can deliver nutritional and functional benefits was projected to grow at a rate of 10 percent, in terms of volume, from 2017 to 2018.

There is a new generation of modern convenience food and drink companies emerging as manufacturers respond to healthy eating priorities, quests for foodie-inspired flavours, interests in personalisation and competition from speedy delivery services. These products have clear benefits for public health and there is an opportunity to link the food and drink manufacturing industry with lifescience and medtech industries.

Food tech is likely to be largest disruptor to the food and drink industry as it bridges the gap between food, health and the medical system, plant-based proteins, innovative ingredients, food safety and traceability, and new approaches to consumer engagement to meet the growing need for safe, traceable, nutritious foods. Food tech can be applied to the food value chain from farm to plate to waste bin and covers all aspects of production, transportation and storage, processing, marketing, distribution, consumption and disposal.

Another area of potential growth and innovation, closely linked to food and drink manufacturing are developments in alternatives to plastic packaging, with early stage developments currently underway in edible packaging, nanotechnology, smart packaging, anti-microbial packaging, water soluble, self-cooling and self-heating packaging.

There is also a huge opportunity for automation to enable growth in food and drink manufacturing by improving productivity, process capability, boosting competitiveness and enhancing product quality in the food and drink industry. It should be noted that there is a recent trend for SMEs in the West of England towards producing high quality premium, artisan, niche and ‘handmade’ products that might mean automation and the use of new technology needs to be introduced in the right way to improve quality but maintain brand credibility.

These recent trends in food consumption are driving growth in the food production industry nationally. There are also two key regional initiatives will enable further growth of the Food Production sector in the region.

The Food Works^{SW} centre is a food and drink innovation centre at Weston-super-Mare that is due to open in 2020 and is driving growth in food production in the region. The centre will provide 10 food-grade business units, product development facilities and a business engagement centre that will serve as a focal hub for food and drink businesses across the region and will offer specialist technical and business support.

In 2015 North Somerset Council successfully bid to the Department for Environment, Food and Rural Affairs to become one of 17 Food Enterprise Zones (FEZ) across the country. The FEZ and related Local Development Order (LDO) comprise a 10-acre site which forms part of a much wider 35-acre employment site within Weston Business Quarter on the outskirts of Weston-super-Mare. The Local Development Order provides a simplified planning process to support the improvement of the food supply chain in the South West, linking farmers and producers at the very start of the food chain to food development and manufacturing, but also encouraging links to distributors and retailers. This

will not only bring increased sustainability to the food supply chain process, but will also attract new business to the area, create new jobs, and increase economic activity. North Somerset already has a strong food and drink Sector, but the LDO will create a significant opportunity to support growth ready SMEs, through The Food Works^{SW} which forms Phase 1 of the FEZ site.

Barriers to Growth

One of the biggest barriers to growth of the food and drink industry is the lack of skills. Nationally, 40,000 of the industry's ageing workforce are expected to retire in the next ten years and 140,000 new workers are required by 2024 to fill the looming skills gap, which is especially an issue for technical and scientific jobs. Companies such as Thatchers and Yeo valley have resorted to pushing salaries up for technical jobs in an attempt to attract and secure the right skills.

The demand for workers, both skilled and less skilled, currently exceeds supply. Within the existing workforce, occupations suffering significant skill gaps include production workers, managers and the traditional craft sectors. Poor image and profile of work in the industry is exacerbating recruitment difficulties. In particular, there is a need to address the shortage of food scientists and technologists.

Furthermore, there is a great uncertainty regarding future access to EU workers, who are highly-valued and make up 32.5% of the industry's skilled and high-skilled workforce. This uncertainty has potential to inhibit the growth of the food and drink industry.

In the West of England, a large percentage of food and drink businesses are located in rural areas and face a multitude of barriers that is hampering their growth potential – poor connectivity in terms of broadband and mobile, accessibility in terms of attracting employees, size which can limit apprenticeship opportunities and ability to share apprentices, added to the fact that the profile and perception of industry is poor despite a wide range of skills and opportunities. Opportunities for many micro and small businesses to connect and network are limited, which The Food Works^{SW} hopes to address.

Whilst the food and drink sector was chosen as one of the first eight sectors in 2014 to take part in Department for Business, Innovation and Skills Trailblazer initiatives, to develop an apprenticeship standard for food and drink engineering, there are still a low number of apprenticeships in the industry and further work is needed to develop this programme. The sector suffers from an image problem, especially when compared to other manufacturing sectors such as automotive or pharmaceutical which are often perceived to be more exciting, innovative and better paid sectors. The food and drink industry is rarely mentioned as part of the West of England tech cluster and consequently there is a lack of awareness and understanding of the career opportunities in the food and drink sector.

Another barrier to growth of the food and drink industry is the limited access to finance for investment, particularly in new technology and automation. There is significant scope to improve not only the production process through increased automation, but also the development and introduction of new products, for example to seek alternatives to standard animal sources of protein and other free-from products and develop smart and bio-degradable packaging solutions. There is currently insufficient government support into these R&D facilities to promote growth, or such support is poorly communicated.

In the West of England there is also a lack of specialist food and drink support to guide businesses through R&D, new product development, factory layout and packaging and distribution. Business support is often too generic and new mentoring and accelerated growth schemes still lack specialist knowledge necessary for food industry. This is especially true for new technological challenges facing

the food and drink industry and a large proportion of SMEs in West of England are unaware of technology changes or unwilling or unable to invest in new technology. Without intervention, the region's producers will continue to underexploit advances in technology and innovation in a sector that needs to respond to increasing pressure from the government and public, to meet changes in policy, legislation, health and market trends.

Another barrier to the growth of the food and drink industry in the West of England is the lack of food-grade premises for SMEs and grow on space. The Food Works will, to some extent, address this issue, and phase 2 and 3 of the Food Enterprise Zone will be critical to support this food and drink cluster. However, there is a risk that the area might lose business to other regions due to a lack of food grade premises.

Relation to Other Deep Dives and Grand Challenges

Food and drink manufacturing has potential as an application of key enabler technologies such as advanced engineering and robotics. More companies are adopting automation in processing plants as the sector looks to evolve and move towards systems of batch production and fully automated production lines, allowing food to be produced quicker, with less waste and greater precision. The introduction of systems such as APRIL, a fully automated robotic system that can mix, load and manufacture ingredients on an industrial scale, with the capability to lower costs and reduce food wastage is one example of this. This has a clear connection to automation and robotics.

The food and drink industry also has applications of technologies such as blockchain, which presents potential for brands and retailers to be transparent with consumers about every aspect of product manufacturing to allow full traceability. Some businesses have already adopted this approach. Furthermore, there are close links between the food and drink industry and lifesciences, especially with the growing trend for healthier, natural foods.

There is an opportunity to improve the collaboration and share expertise and 'know how' between food and drink manufacturing and other industry sectors such as manufacturing, engineering, life sciences, medtech and robotics. Food tech represents a key opportunity to embed new technology across the food and drink supply chain and more closely link and apply advances within the region.

Clean growth:

Food and drink manufacturing creates the following opportunities in clean growth:

- **Redistribution:** opportunities for surplus food that is fit for human consumption to be redistributed to commercial organisations or charities such as FareShare. If not suitable for human consumption, investigate then could be used as animal feed. This is already being done by Thatchers and Bradley juices.
- **Recycling:** Where redistribution is not possible, anaerobic digestion is growing in popularity, for example Wyke farms.
- **Packaging solutions:** Opportunities to look at reducing weight of packaging, using modified atmosphere packaging or improved seal integrity to reduce the risk of food waste. Returnable packaging involves re-usable transit packaging to reduce secondary packaging waste. Improvements to packaging design and materials to reduce the carbon impact of packaging.
- **Improvements to supply chain communications:** Opportunities for manufacturers to work more closely with suppliers and customers to reduce instances where ingredients and product are out of specification or too close to their sell-by date.
- **Technical improvements:** Walking the production line can often identify problems between various parts of the process, for example in cases of machinery performance problems

- Waste: Increasing consumer interest in food waste prevention will be a global trend. Process and packaging innovations that extend shelf life, making use of unavoidable food waste.
- Water minimisation

Supporting Evidence

1. Growth in Food and Drink manufacturing, Deloitte 2018
2. FDF Economic contribution and growth opportunities, June 2017
3. EEF July 2017 Food and Drink Bulletin
4. Defra Food and Drink statistics Pocketbook
5. Business population estimates, 2016
6. Annual Business Survey (ONS), 2016
7. Mintel 2018 Global Trends
8. Grant Thornton Food Manufacturing May 2017
9. Scale Up institute
10. WRAP -Waste reduction in processed food sector.10. Food Engineering Dec 2017.

High Performance Computing and Cloud

Definition

High Performance Computing (HPC) is where the amount of physical computing resource needed to solve a problem, is several orders of magnitude greater than a standard computer. HPC is typically run on a general purpose or dedicated supercomputer. Cloud technology is where computation processing occurs remotely over the internet rather than through a direct connection to a server. This typically means the user and the server are not co-located and that multiple people can use the resource simultaneously.

Historically cloud and HPC were 2 distinct technologies, however, recent advances in cloud infrastructure mean that high performance supercomputers can now be accessed remotely via the cloud and hence, the 2 technologies are heavily linked.

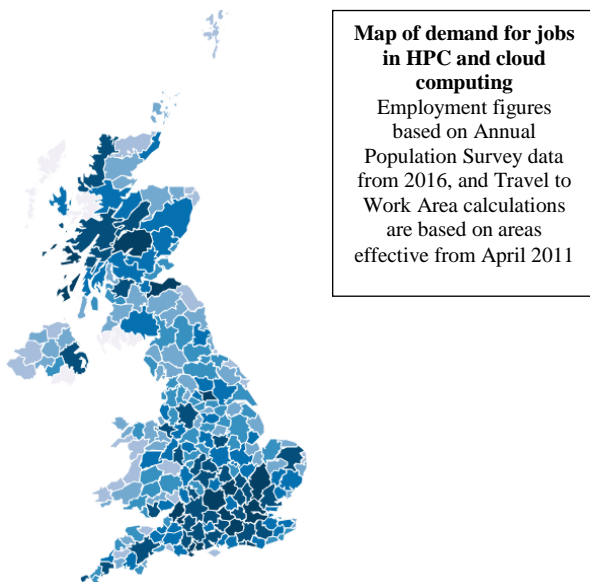
Cloud and HPC are enablers of other industries, applications and technologies.

Geographical Reach

Bristol has recently been chosen by several companies as a base for cloud technologies, for example Oracle, Huawei and Cray. This is due to the leading technical capability, capacity and resources available in the area.

Within the UK, the South West has a leading capability in HPC. The UK's strongest supercomputer is in the Met Office in Exeter, which is also within the global top 20 supercomputers. However, overall the UK significantly lags behind countries such as the USA, China and Japan in terms of raw power.

In Numbers



Growth and employment in the West of England:

- Between November 2017 and November 2018 4463 job postings were made in HPC and cloud industries
- Demand for these jobs in Bristol is higher than UK average
- Mean salary for these jobs is £37,200

Business and Skills

The University of Bath, the University of Bristol and the University of West of England all offer both undergraduate and postgraduate courses related to computer science, including an undergraduate course in Computer System Engineering and masters in Human Computer Interaction offered by the University of Bath. However, most HPC and cloud computing jobs do not necessarily require a computer science related degree and it is very common for graduates with other degrees, such as physics, mathematics or even languages to start a career in HPC and cloud.

The market to attract the top graduates is highly competitive and the growth of skills in the region has been driven by anchor businesses such as Cray and Just Eat who have attracted people to the region. The potential for people to move between businesses within the region has enabled the growth of skilled workers in to develop.

Cloud technology is quickly becoming ubiquitous across most businesses and there is a vast user base of cloud in the region. Whilst this is uniform across the country, the West of England also has activity in developing cloud technologies, including companies who develop cloud infrastructure and companies who produce bespoke applications that are run on the cloud.

Oracle are a flagship example of a company that develops cloud infrastructure and came to Bristol specifically to build their cloud development team. As an anchor company, they have promoted the growth of cloud computing in the West of England.

Cray Inc. are a supercomputer manufacturer who have based their European headquarters in Bristol and act as an anchor business in HPC in the region.

There are also small, medium and micro companies based in the region that develop applications of HPC and cloud technologies, including Interactive Scientific who are based in Bristol and access supercomputers over the cloud to visualize scientific concepts, and Zenotech who are building HPC and cloud services that have been used to model multiple wind turbines, an application that has been marketed globally.

Enablers of Growth

Historically the West of England has been a significant user and developer of technology spawning companies such as INMOS & Meiko who in the 80's led the development and application of microelectronics for parallel computing. This community of engineers has provided the platform for further growth and expert resource for other companies in the region. Whilst HPC technologies can now be accessed remotely, companies who are developing this technology require proximity to companies that develop applications of HPC to understand their requirements. Therefore, HPC companies such as Cray are attracted to the region. Having both HPC and cloud-based organisations in the region creates the opportunity for unique innovation which further attracts more organisations and spin offs to the area.

Large businesses such as Cray and Oracle also attract skilled workers to the region which promotes further growth and encourages new businesses to locate in the West of England. People are constantly having to evolve their skills as latest technologies are developed and progressed. There is now a diverse range of skills in the region embedded on 20 years of software development, that are willing and able to transition when needed. This large talent pool has put the West of England on the global map as an option for large tech companies to locate to.

Several nearby assets have promoted growth of HPC and cloud technologies in the region. The universities are developing world leading technologies, for example the University of Bristol has, in conjunction with the Met Office and Cray, developed the ISAMBARD supercomputer to support the

future global weather prediction needs. The Centre for Modelling and Simulation based in Bristol and Bath Science Park is a leading independent research organisation that conducts high value design studies in support of advanced engineering companies using their open access HPC capability. Furthermore, the West of England is situated close to the Supercomputer housed at the Met Office in Exeter and GCHQ in Cheltenham. Proximity to these assets is an important factor for companies deciding where to locate their business.

Another key enabler of growth in HPC and cloud technologies in the region is the large number of active incubators, co-working spaces and early stage launch spaces in Bristol, such as Engine Shed, SETSquared and Future space, that have helped start-up companies in the region. These organisations provide cheap accommodation, coaching and investment opportunities to start-up and small businesses to help them grow, and has led to a well-established early stage ecosystem in the Bristol.

Barriers to Growth

There are several barriers to the growth of HPC and cloud technologies in the region. Firstly, the number of home grown skills is not sufficient to meet the current demand in the region. Not enough children and young adults are encouraged to pursue a career in computer technologies, because they are not aware of the opportunities available to them and the companies that operate locally. This has resulted in a mismatch between the skills available in the region and the vacancies in HPC and cloud organisations.

Whilst apprenticeships are one way of overcoming this barrier, small and micro companies are put off by apprenticeships as they require a significant time investment to train. Companies with few employees do not have the necessary capacity to train apprentices and often would rather hire graduates who require less time to train.

Another barrier to growth in the region is the mismatch between support provided for start-up companies when they first start and support for continued growth, particularly after a company graduates from a start-up incubator. Often companies cannot become small or medium sized because they do not have the needed support. A main contributor to this is the lack of affordable office space especially if companies want to be located close to similar companies, particularly in central Bristol. Commercial landlords typically require long term leases to be signed and start-up companies are unable to commit to this. Companies such as DeskLodge and Runway East have alleviated this pressure slightly by providing affordable and flexible office space in central Bristol. However, there is still a need for further support for companies wishing to grow.

Another barrier to growth in HPC and cloud computing is access to venture capital funding. The majority of VC providers are based in London which encourages companies wishing to attain larger sums of funding during their early stage development to locate to London. Furthermore, the VC funding cycle means lots of companies get tied into repayment deadlines and end up selling their company early to repay the funds.

Relation to Other Deep Dives and Grand Challenges

The main application of HPC technology in the West of England is for modelling and computational fluid dynamics (CFD) for the aerospace industry. This could lead to more efficient and cleaner air transport, wind turbines and other renewable technologies, thus linking to the Clean Growth Grand Challenge and vision of the Local Industrial Strategy. Other applications of HPC are modelling for immunology and molecular visualization, linking HPC with the Ageing Society Grand Challenge and medtech industries.

Clean Growth

HPC and cloud technologies have more potential to be carbon neutral than most other technologies. For example, Apple's data centres are all carbon neutral. By housing data centres in locations such as Nevada, Apple have utilised solar energy to power its data centres.

Cloud technologies are also reducing the need for consumers to constantly replace computers with the latest device. This means the number of new devices and supercomputers being built is declining and the need for new materials is reducing.

Locally, Yellow Dog are doing similar things for the animation and financial sectors; increasing efficient use of underutilised existing resources rather than building more physical devices which will be poorly utilised.

Inclusive Growth:

Cloud technologies are becoming wide spread, but there are still opportunities in this area that the West of England can employ. Nearly every current application can be moved onto the cloud and there is huge growth in the adoption of cloud services. This will require both high end skills but also more basic digital programming skills. By upskilling people, this could provide an opportunity for inclusive growth in the region.

There are also examples such as DotWorks and others using AI to drive recruitment beyond CVs and qualifications to traits, capabilities and potential, and it is hoped this will allow more people to realise their potential in the workplace and careers.

Cloud technology helps to democratise access to some leading-edge capabilities, for example, most modern devices now include voice recognition. This technology relies upon both cloud and HPC. As such, more and more members of the community benefit. As these technologies are made available via remote access services, even small development teams can now incorporate voice recognition into apps, for example, meaning a small team can develop leading edge apps, not just the IBMs of the world.

Supporting Evidence

1. National Industrial Strategy – Building a Britain Fit for the Future (2017)
(<https://www.gov.uk/government/topical-events/the-uks-industrial-strategy>)
2. <http://www.weforum.org>
3. Bristol Bath Innovation Cluster: SQW Report October 2018
4. UK Government Industrial Strategy Green Paper: West of England Response
5. West of England Strategy – West of England Combined Authority Discussion Paper
6. South West England and South East Wales Science and Innovation Audit, 2016

Immersive Technologies

Definition

Immersive Technologies include virtual reality, augmented reality, haptics as well as video games development and video streaming based on video games. Companies can be split into those that specialise in immersive, creating and distributing their own content or applications to customers and participant companies who use immersive skills, tools and techniques.

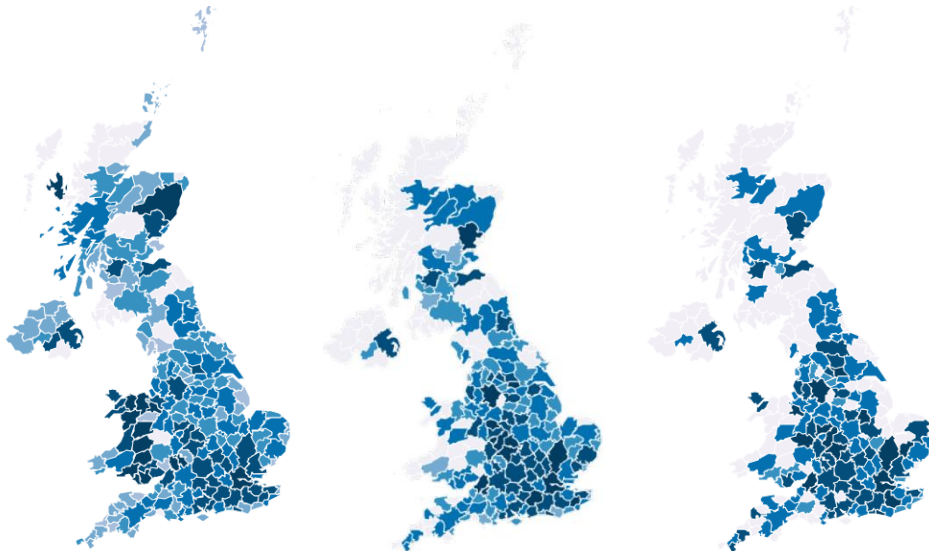
Geographical Reach

Immersive, games and streaming all have activity in the West of England region, however each of these are global industries and companies in the West of England link with national and international businesses and customers.

Bristol is known internationally as a hotbed of Immersive development and is often highlighted as the key to the industry after London and ahead of Manchester, Newcastle and Brighton. While this is true, other areas in the UK are catching up on the specialist side or on the participant side, where film, TV, games, engineering, health and training companies are incorporating the technology. Bristol is also leading in video streaming and games development and hosts with the UK's largest video streaming company, Yogscast, which is completely unique and has no competitors of its size within the UK. Bristol is also in the top 5 cities for games development in terms of job postings.

The UK is well respected in these industries and seen as a good place to do business due to various video games and R&D tax breaks. The US, particularly San Francisco, LA, Austin and New York have greater concentration and activity than the UK. As these industries sell globally and are not tied to any location and countries like China and India are rapidly become key competitors as the skills become more widespread and economically costs go further for development.

In Numbers



Demand map for jobs advertised in Immersive (left), Video gaming (centre) and video streaming

Growth and employment in the West of England:

- Approximately 1300 jobs were advertised in Immersive Technologies, video gaming and video streaming between November 2017 and October 2018.
- The demand for these jobs in Bristol is the same as the UK average

- Mean salary for advertised jobs were £39,200 (immersive), £42,200 (video gaming) and £28,900 (video streaming)
- Average income for a video games developer was £53k
- 300-400 people involved in the immersive industry in the region
- 250 people in the Games industry in the region
- 100 people in video streaming and eSports in the region,
- Export value of immersive in the South West estimated at £75m.

Growth and employment nationally:

- The Immersive market in 2017 had £660m turnover combined in the UK
- 50.6k job postings in 2018 nationally
- Games industry employs 46,380 people nationally, providing a GVA of £2,821 million to the UK
- The UK games industry is worth £2.7bn in total to the British Economy
- Video streaming and e-sports employs 280 nationally, with £18.4 million GVA during 2016
- Video streaming and eSports have a combined export value of £18.4m
- Up to 500,000 people employed in participant companies, with a £60 billion turnover across the UK

Business and Skills

Many FE colleges provide courses on games development and video production, as part of renewed focus on STEM and STEAM, and are now beginning to set up Immersive courses as the technology becomes more available. Specific colleges include Filton, South Bristol, Digitech Studio School, and a new £5m digital campus set up by Access Creative College in Broadmead.

The local universities also offer several relevant courses, including a number of undergraduate courses on games development and video production and a masters in VR at UWE. Bath Spa have a new campus which features motion capture, film studio and games development courses and the University of Bath have the CAMERA department, which has motion capture facilities and works with researchers, students and commercial companies. The University of Bristol has a 3rd year project on games development as part of their computer science course, which has strong links with investors and publishers through Bristol Games Hub and Bristol VR Lab.

The industry currently takes up very few apprenticeships as most companies are too small to take on the overhead of an apprentice.

Jobs in immersive and gaming are typically highly skilled and specialised skills sought include software development, social media, javascript, software engineering, project management, photoshop and c++. Core skills in planning, budgeting, team work, creativity and communication as also highly sought after. The skills required for these technologies are constantly changing and these roles also require continuous on the job training to keep up with technology. There is also an economy of 'bedroom' training, as graduates and untrained young people study online.

There are approximately 80 – 90 specialised companies working in Immersive Technologies in the West of England. These vary in size from companies such as SN Systems and Ultrahaptics that have over 100 employees; companies such as Yogscast, Auroch Digital, nDemic Creations, and PQube with over 20 employees; and companies with fewer than 20 employees such as Opposable, Lofi Games, Ground Shatter and BDH Immersive.

There are also participant companies in the region including media, training, education, advertising, health, tourism, architecture and engineering. Examples include Aardman, Airbus, Atkins, Rolls-Royce and BAE; however, these companies are harder to count and size.

Of the jobs advertised in the region in 2018, common job titles were software development engineer, architectural technician, digital content creator, business analyst and sales executive and the top industries that were recruiting were higher education, computer programming, consultancy, motion picture, video and television programme activities and business support service activities.

Enablers of Growth

Until 4 or 5 years ago, the South West was generally under-represented in Immersive Technologies. Since then there has been an influx of assets and businesses in the region that have promoted further growth and put the West of England on the map.

In 2013, the Bristol Games Hub formed which catalysed the growth in game development in the region. The Bristol Games Hub was set to create a gravity point for video game development in the region. It is a co-working space that has grown over four years, housing a mix of individual entrepreneurs and freelancers. It has supported growth in resident companies such as Lofi Games, Ground Shatter, Meteor Pixel, large Visible Machine, Toxic Games, and larger companies such as Pqube moving into the grow space from London to access the talent pool.

By acting as a central point for a community of over 1,000 games developers, designers and researchers, the organisation has attracted successful companies to the region, including Ndemc Creations, created a vibrant digital talent pool in the city which has benefited companies incorporating games and games technology into the business (for example Airbus, Atkins and Aardman), and has raised the region from being a complete void for games developers to the place which is now in the top 5 employment regions for games development. While other initiatives have been set up in other UK and international cities, the Bristol Games Hub is the largest independent games hub in the world, the only larger Games development space is the Dutch Game Garden in the Netherlands.

In 2015 Bristol became an early hotspot in the Immersive industry by hosting the SouthWest VR conference. This later developed into the VR World Congress, a 3-day event in the city centre attracting over 750 attendees from a broad business audience. This conference promoted investment into Ultrahaptics, and the opening of the Bristol VR Lab.

The Bristol VR Lab was set up by UWE, the University of Bristol, Watershed and Opposable Games to assist a new generation of VR, AR, haptic and other Immersive businesses get traction in the rapidly evolving digital market. It has now attracted 14 commercial residents, generally very early stage start-up businesses, and researchers from UWE and UoB.

There have been 23 training, workshop and talk events run, with a total of about 760 unique attendees, and the hosts have held meetings and provided business support to over 100 corporates, small businesses and start-ups, and people keen to get into the industry. The BVRL has been supportive in creating the South West Creative Technology Network, a £6.5m program to bring together universities and industrial partners, and the Bristol & Bath Creative R&D programme that sits within the AHRC Creative Clusters research programme.

Video streaming as an industry is approximately 8 years old, during this timeline Bristol has hosted the UK's largest video content producer Yogscast, which has grown rapidly over the last 7 years to have a core staff of 15 based in Bristol, and now forms a network of 55 content producing teams,

which usually consist of 1 to 5 content producers. Yogscast have online viewer numbers far larger than terrestrial TV audiences, and a dedicated fan base that attend conferences and game shows to meet the video streamers.

Based in Bristol, the company is the only one of this scale within the UK, with most of their competitors being based in the US. Video streaming is a high growth industry which can be made more accessible for new generations, Yogscast have always had ambitions to open a video streaming academy but have been unable to find time and resourcing outside of the core business.

Barriers to Growth

One significant barrier to growth of immersive industries is investment. Several of the key assets in the region need more investment to continue to grow. The Bristol VR Lab and the Bristol Games Hub need investment to move from co-working spaces to research spaces and incubators.

For events like VR world congress to continue in the region, further investment is needed. The region is also restricted by a lack of a large conference centre that could host audiences of 1000 – 2000.

Skills shortages are also a major barrier to growth to this sector and is limiting the investment of large video games and immersive employers. Currently small companies and organisations like the Bristol Games Hub and Bristol VR Lab are constantly called upon to provide training & regional development, however, they are too small and under-invested to fulfil this role unsupported. The lost opportunity of not being able to provide such training or regional development has reduced the growth of the region in these areas over the last five years.

Without support, companies and employers will move to other cities both nationally and internationally. This is being seen anecdotally with young developers moving from the Bristol Games Hub to other regions for work.

Relation to Other Deep Dives and Grand Challenges

Digital skills learned in immersive sectors go on to provide skills and products to almost every other sector in the UK; these include media, training, education, advertising, health, tourism, architecture, engineering, hardware, manufacture, retail, journalism, defence, automotive, data, telecommunications, energy, electronics and finance. Digital skills are critical to the future of engineering and manufacturing through high value design and automated or data-enabled industry, and these are strongly represented in the West of England.

The sector is extremely relevant for 5G technology, with most use cases highlighted covering video streaming, immersive and games technology.

Inclusive Growth

There is a huge possibility for social inclusion through Immersive Technologies as digital skills have little barriers to entry the industry supports anyone who is interested to be involved. Furthermore, many solutions exist for the less abled. However, most companies in Immersive are quite small and can only provide limited support, recruitment and training opportunities to new generations. Investment in a centre that enables education of the technology to new audiences could help promote social inclusion in this area. There are also potential innovation opportunities for Immersive Technologies. Providing a unique view of the context and application of inclusion (or exclusion), could make a huge difference to people's perception on inclusion.

Clean Growth

Immersive itself does not promote clean growth except through industries that employ Immersive Technologies to design, plan or visualise products and services related to clean growth. That said,

Immersive Technologies do not have a significant negative impact on the environment and require relatively low levels of manufacturing. Immersive industries also allow for clean work and life patterns, for example working from home.

Supporting Evidence

- The Immersive Economy in the UK, Immerse UK & Innovate UK
- Screen Business report, BFI, SPI & Nordicity

Life Sciences

Definition

The Life Sciences Industrial Strategy states that “‘Health Life Sciences’ refers to the application of biology and technology to health improvements, including biopharmaceuticals, medical technology, genomics, diagnostics and digital health”.

The information provided in the medtech deep dive focuses on medical technologies and digital health. This document covers the other areas of the Life Sciences that have not been represented, including therapeutics, diagnostics, genomics and targeted therapies.

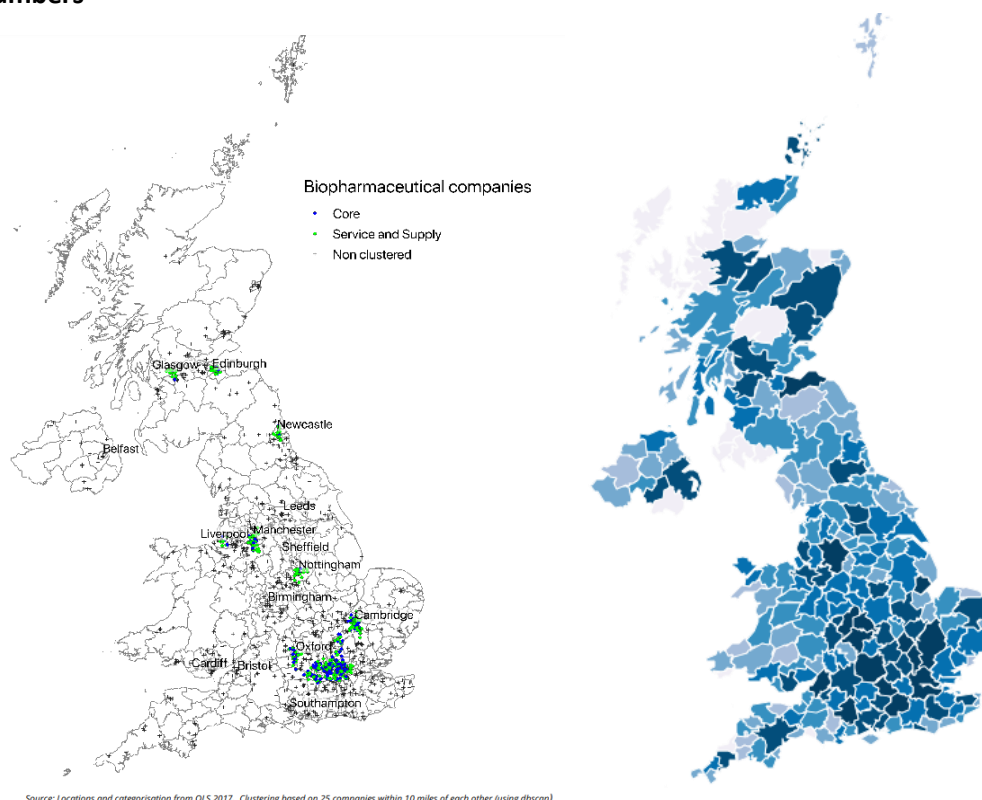
Geographical Reach

The West of England has a world-leading research base for the areas that feed directly into new therapeutics, diagnostics, genomics and targeted therapies and a modest, but rapidly growing industrial Life Sciences sector.

London, Oxford and Cambridge form a ‘golden-triangle’ that is traditionally strong in the Life Sciences field. Due to local investment in infrastructure which allowed this ecosystem to form, the ‘golden-triangle’ will likely remain leading and this growing strength in the West of England can be seen as complementing the ‘golden-triangle’.

The Life Sciences are international in nature and should be one of the least-affected sectors in a post-Brexit scenario.

In Numbers



Left: Map of Biopharmaceutical companies in the UK

Right: Demand map of job vacancies in the UK in Life Sciences

Growth and employment in the West of England:

- 1288 jobs were advertised in the Life Sciences sector in the West of England between January 2018 and December 2018
- The demand for jobs in Bristol was the same as the UK average for Life Sciences jobs
- The demand for jobs in Bath and Weston-super-Mare was much lower than the UK average
- The mean salary of advertised jobs was £33,800
- 2700 employees across the sector
- Academic research base employs 1560 people
 - 900 people at the University of Bristol
 - 540 people at the University of Bath
 - 120 people at the University of the West of England

Growth and employment nationally:

- The Life Sciences sector currently generates £64 billion turnover nationally
- 233,000 people are employed as scientists and staff in the Life Sciences sector.
- On indexed output per hour, pharmaceuticals exceed the output of other major sectors such as communications, computing, electrical and optical, transport, manufacturing, professional services, and financial services
- In 2015 the UK's biopharmaceutical sector consisted of 1,857 companies, generating £41.9 billion turnover and employed 113,000 workers
- 42% of biopharmaceutical companies have less than 5 employees and 10 % have over 250 employees
- UK is 3rd in the world for start-ups but 13th in the world for scale ups

Business and Skills

The University of Bristol, the University of Bath and UWE all offer relevant undergraduate and postgraduate courses, including Biological Sciences, Veterinary Science, Physical Sciences, Medicine and Dentistry, Agriculture and related subjects. In 2016, the total number of undergraduates starting a course related to Life Sciences was 10,410, with 55% them at the University of Bristol. In the same year 570 students started a taught postgraduate degree and 1,365 started a research postgraduate degree. For all types of courses, the University of Bristol had the highest number of students. Around 11% of these students gain employment in the West of England after they graduate

Weston college offer laboratory technician apprenticeships, however, this is typically not a sufficiently qualified course for most of entry level jobs. Due to the level of pre-requisite knowledge, entry level jobs often require a Masters or a Doctorate level qualification.

Due to the region's research strengths, there are large numbers of people in the region who are highly skilled in Life Sciences.

Between January 2018 and December 2018, 1288 jobs were advertised in the Life Sciences sector in the West of England. Of these jobs, the top skills that employers sought, ranged from specialised skills such as molecular biology, to baseline skills such as teamwork, collaboration, research and organisational skills. The top employers were the University of Bristol, the NHS and the University of Bath.

The majority of Life Sciences companies operating in the region are based in translational research facilities. Unit DX is a privately funded lab space that opened in May 2017 and is now home to 26 companies, 9 of which operate in the life science sector. These companies are: Folium Science, FluoretiQ, Invivo Clinical, Carbometrics, Zentraxa, Vitamica, Imophoron, Cytoseek, Innaxon

Therapeutics. Future Space is another collaborative space that opened in September 2016 and has 4 tenant companies operating in the Life Sciences.

There are an additional 9 companies based in Bristol and Bath and a further 5 in Gloucester and the surrounding area. 42% of the companies in the region are spin up or start-up companies from either the University of Bristol or the University of Bath. A further 4% are industrial start-up or spin out companies and the remaining 54% are companies that re-located to or expanded in, the region.

Typical jobs in these companies are in applied R&D, product development and prototype testing and scale-up processes. The jobs range from management roles, highly skilled scientific roles and junior technical roles.

Enablers of Growth

The West of England historically has lacked the facilities and reputation to have a leading Life Sciences cluster. Recently, rentable lab space has become available from places such as Unit DX and Future Space. This has opened up space for spin off and start-up companies and has catalysed the Life Sciences sector growth in the region. These spaces also provide hubs for informal networks simply through the presence of an ecosystem, running events relevant to the sector and providing the opportunities for collaboration.

Translational research facilities have also shifted the culture in Life Sciences, encouraging SME's to translate technology from research institutions. The facilities in the West of England are highly popular and successful and Unit DX was recently awarded Best Sector Support Organisation by the Oxford BioScience Network (OBN).

The laboratory facilities inside of the golden triangle are becoming full, and the West of England is seen increasingly as an attractive place for people to move to. It has a good quality of life and is cheaper for young entrepreneurs than places like London. The ease of hiring highly qualified and skilled personnel on competitive salaries compared to Cambridge, Oxford or London also makes the West of England an attractive alternative.

BrisSynBio is another facility that has nurtured the translation of research into 4 companies (Zentraxa, Cytoseek, Imophoron, and Alpha Nanopore) with a further 2 in the pipeline. The success of BrisSynBio sees it being incorporated into a much larger project, the Bristol Biodesign Institute which will coordinate research, training, innovation and public engagement in biodesign research across biotech, agritech and Life Sciences at the University of Bristol.

These changes have resulted in the West of England meeting a critical mass which has attracted others into the region and increased investment from companies operating in the Life Sciences field. There has also been an increase in the number of 'home grown' companies being created from local research institutions.

The region has also attracted international media attention, for example, the recent sale of Ziylo Ltd to Danish pharmaceutical company Novo Nordisk for up to \$800M which was a result of research translated from the University of Bristol. This acquisition is of international significance due to the magnitude of the purchase price and the comparatively early stage of Ziylo (pre-revenue) at the time of acquisition. The resulting worldwide media coverage increased the profile of Life Sciences in the West of England and will enable further growth.

As previously mentioned, the University of Bristol, the University of Bath and UWE all have world-leading research departments in Life Sciences. Together with the translational research facilities, these have led to a number of spin up companies which are working to translate academic research

into commercial products. Other assets in the region that have promoted growth in Life Sciences are: GW4, Synthetic Biology Leadership Council, Synthetic Biology for Growth network, Bristol Health Partners, All-Party Parliamentary Group for Life Sciences and West of England Academic Health Sciences Network.

The sector has experienced rapid growth in the last few years and this growth is forecast to continue due to several factors, including further investment in university led incubation and entrepreneurial training programmes, funding from UK government into priority sectors and encouragement from UK government to translate more research into commercial enterprises.

Further growth in Life Sciences in the region could be promoted by making use of the laboratory space in Avara that is not currently in use and opening up wet lab space in Bristol and Bath Science Park or similar facilities that are built in the future.

The growth of the Life Sciences sector in the region will have a sizable ripple effect on the rest of region, benefitting the economy, increasing employment opportunities, social engagement & outreach and regenerating industrial areas.

Barriers to Growth

The recent success of the Life Sciences sector has predominantly been promoted by the translational research facilities. These facilities need to grow and sustain their success if the sector is going to continue to develop. Unit DX is already at capacity and an expansion is currently being looked into to meet the immediate demand for laboratory space. This expansion is only likely to meet the market demand for 18 months at most and is not a long-term solution for the region.

More appropriate lab space needs to be found in a suitable timeframe to meet the demand of the growing sector. Life Sciences companies almost never build their own lab spaces for various reasons (cost, gaining building leases, funding runway, primary focus being the science etc.) and therefore they rely on external facilities being present for them to grow. Currently Unit DX is privately funded; however, expansion will only occur if it is financially viable. Without assistance from local government the development of Life Sciences in the region may decline as companies run out space.

It is also important that research facilities are located in close proximity to the research base as this is where innovations come from. Building scientific facilities on the outskirts of a city when your target demographic are young entrepreneurs and graduates who typically live in the city and require access to the services and benefits of being in a central location simply will not work.

In the past, the lack of appropriate translational research facilities has led to a drain of scientific companies from the region; examples include:

- Glythera (now called Iksuda) a University of Bath spin out which relocated to Newcastle
- Azellon Cell Therapeutics a University of Bristol spin out which relocated to London
- Apitope a University of Bristol spin out which relocated to Cardiff
- Revolymer a University of Bristol spin out which relocated to North Wales

Without local government intervention and support for the wet laboratory side of the Life Sciences, the region will continue to miss out on opportunities.

Another barrier to growth is that previously, consultation of the 'Health and Life Sciences' sector in the West of England has been weighted towards the health technology and digital health sectors. As such, a full picture of Life Sciences is not always portrayed of the region's strengths, assets and opportunities. Consequently, the region has seen significant investment in facilities that are suitable

for those operating under the 'health' umbrella but these are not necessarily suitable for those operating in the 'Life Sciences'.

Relation to Other Deep Dives and Grand Challenges

The life science sector has been realised by the sector's collaboration with the local high-tech sectors, such as AI, high performance computing and quantum. The Engine Shed based cloud computing company, Oracle, have in the last 12 months heavily expanded into the Life Sciences sector and are working collaboratively with several research institutions. One example is the modelling of protein-drug interactions using high performance computing.

Commercially relevant Life Sciences are also highly interdisciplinary and sectors of particular relevance include pharmacologists that rely on synthetic chemists to make the drugs/compounds and medical practitioners who rely on physicists to design and develop optical detection equipment used to identify bacterial strains. Such examples demonstrate the need for the fields of 'health and Life Sciences' to be developed together in the region.

The health benefits of a strong Life Sciences sector will benefit everyone in both the West of England and the UK, especially with the current ageing society. There is opportunity to link Life Sciences with health tech and digital health to improve social inclusion in the region and develop leading technologies.

Inclusive Growth:

The Life Sciences sector often provides niche, highly skilled jobs for cutting edge projects which attracts a diverse range of people who are willing to travel to where the opportunities are. There is an opportunity to showcase these skills to primary and secondary students to attract more people to this sector. This can be done both by direct exposure such as site visits by the students, school visits by the scientists or through internship programmes, prizes and scholarships and by developing enterprises that are viewed as 'employers of choice' by virtue of their behaviour and ethos. There are several outreach events in the region, for example, 800 local school children have attended hands on outreach events at Unit DX in the last 18 months.

The ONS's job multipliers highlight that employment in the scientific sector enables employment in other sectors such as law and other professional services, supply chains, property etc.

Clean Growth:

Life Sciences are energy and resource hungry, however the innovations that result from these fields do lead to incremental steps in cleaner/greener technology. For example, Imophoron are developing a vaccine delivery platform for chikungunya and dengue (and a few others) that does not require the vaccine to be stored at -20°C all the way from the laboratory to wherever in the world the point of administering the vaccine is, their platform is stable at room temperature, this results in the delivery being cheaper and therefore more people will have access to said treatments. Other examples include reductions in hazardous medical waste and reductions in energy consumption.

The products developed by the Life Science sector will also contribute to health improvements for society as a whole, which itself will be a great environmental benefit.

Supporting Evidence

- The Life Sciences Industrial Strategy
- Life Sciences Sector Report
- Life Sciences Sector Deal
- Smart Specialisation Hub, Benchmarking the Life Sciences Sector in the UK, December 2018

Medtech and Digital Health

Definition

Medtech is the development and/or production of medical technology products, from single-use consumables to complex hospital equipment. Digital health is the production of digital products for hospitals and consumers, including products such as hospital information systems and mobile medical devices and apps. For the purpose of this report, medtech and Digital Health are considered as applications of technologies.

Geographical Reach

Medtech activity in the West of England forms part of a wider local ecosystem and is closely associated with activity in the M4/M40 Corridors and South Wales. The South West region (including the West of England, Devon and Cornwall) accounts for approximately 5% of employment national, representing 206 business sites and turnover of £997M. The South East region is the largest medtech region in the UK, contributing a turnover of £5BN and accounting for almost one quarter of medtech employment nationally.

With regards to Digital Health, the greatest concentration of companies are in London, Yorkshire and Humber and the South East, accounting for 64% of employment and £840M turnover. However, no region has a dominant position yet at this relatively early stage of development. USA and China lead the global market place for value of digital health companies and funding. US digital health start-up companies have received 75% of global private investment since 2013, followed by India (4%), China (3%) and the United Kingdom (3%).

In Numbers

Growth and employment in the West of England:

- Approximately 4000-5000 people are employed in the medtech and Digital Health sectors in the West of England which represents approximately 3% of the national workforce (not verified)
- There are 178 medical technology companies (including digital health) in the West of England. The top 5 areas of activity are: assisted living; diagnostics; medical electronics; and clinical management and hospital infrastructure/services
- There are 435 Health and Life sciences companies in the wider West of England AHSN region which includes Wiltshire, North Somerset and Gloucestershire, of which 350 are SMEs
- There has been a 25% increase in digital health companies in 3 years. National growth is 15% over the same period for medtech and around 30% for digital health. The growth in the West of England is roughly in line with the national average.
- 43 new businesses or sites formed since 2015 in the West of England

Growth and employment nationally:

- Medtech is the UK's largest life science sector in terms of employment. Medtech employment grew at 4.4% in 2017, with overall turnover also increasing at a rate of 3.9%.
- The Department of Health plan to invest around £4.5BN in the digital transformation of services by 2020
- UK exports of medtech products had a value of \$3.8BN in 2016.

Growth and Employment globally

- The global medtech industry is expected to grow at close to 6% per year (CAGR) between 2017-2024, with global sales forecast to reach \$595BN by 2024
- The global market for the digital health sector is estimated to reach £150BN by 2020, growing at more than 20% a year.

Business and Skills

The Life Sciences Sector Industrial Strategy highlights the lack of access to a skilled workforce as a key barrier to growth of this sector, citing specifically digital health and data science, clinical trials, manufacturing regulatory and engineering as specific shortages. The sector deal skills plan makes the suggestion to 'Create an apprenticeship scheme that focuses on data sciences, as well as skills across the life sciences sector, and train an entirely new cadre of technologists, healthcare workers and scientists at the cutting-edge of digital health.'

It also suggests that 'The Government should establish Institutes of Technology that would provide opportunity for technical training, particularly in digital and advanced manufacturing areas.'

With the UK exiting Europe there is a clear threat to the supply chain of talent from the EU and some estimates suggest up to 26% of the workforce the health and life sciences may be EU nationals.

The Skills Gap is exemplified by businesses such as Mayden a high growth digital health company based in Bath who have developed their own in house skills academy to meet the demands of their current growth trajectory.

Since it was set up in 2015, over 40 new software developers have graduated from Mayden academy and all of these have gone on to be offered developer roles in less than three months after graduation. Mayden Academy is now expanding, and is set to train a further 40 developers in 2019 with plans to continue on its current growth trajectory in future years. The course will become even more accessible in 2019, with the introduction of software developer apprenticeships, run in conjunction with Bath College.

Chris May, Founding Director of Mayden, said " The West is a leading centre of technology in the UK, yet tech businesses all over the region are struggling to find software developers fast enough to match their growth. We set up Mayden Academy to solve our own recruitment problem. We ended up offering a job to all six students who graduated from the first cohort, and have continued to take academy graduates as and when Mayden has needed them. We are delighted to now be able to help other software companies in the West and beyond with their developer shortages as the academy scales up and produces more and more skilled and "business ready" software developers.

The University of the West of England offers 7 undergraduate courses and 6 postgraduate courses that support medtech and Digital Health sectors, including Biomedical Science, Medical Ultrasound and Robotics. There are currently 10,498 students in the Faculty of Health and Applied Science at UWE.

The University of Bristol is expecting a decision on a Centre for Doctoral Training in Digital Health and Care, which would start in October 2019 and are considering a taught Masters in Digital Health which would start in October 2020.

In 2015, there were 178 core medtech companies and 35 Digital Health companies identified in the West of England. Based on the 2018 estimates this has now risen to 221 medtech and 55 digital health companies which represents roughly a 25% increase in 3 years. The vast majority of companies in the West of England are early stage or scale up stage SMEs, with very few corporates. Where larger corporates do exist, they are divisions of associated sectors e.g. medical division of Renishaw and the UK headquarters for EPIC healthcare systems.

Despite the absence of major anchor companies, the growth of the companies in the West of England is considerable with 43 new businesses or sites formed since 2015, mirroring the level of the growth rate of the sector across the UK.

Enablers of Growth

One key enabler to the growth of the medtech and Digital Health sectors is the research excellence and support provided by three of the local universities: the University of Bristol, the University of Bath and University of the West of England. These universities have research excellence in biomedical sciences and engineering as well as mathematical modelling and data analysis which support the medtech and Digital Health sectors in the West of England. Major projects based in these universities, such as the SPHERE project, propel R&D in the region and offer unique facilities for technology development that may result in spin off and start-up companies.

Science and technology focused incubators such as UnitDX and SETSquared have also supported growth of medtech and life science companies across the region. The Universities are also heavily linked with initiatives and organisation in the region. The University Enterprise Zone which is located at the UWE campus in Frenchay has created 95.5 jobs, with a GVA of £4.9M in just 2 years. Within the UEZ Bristol Robotics lab which is jointly run by UWE and the University of Bristol has several projects and initiatives linked to medtech and Digital Health associated with assisted living. Similarly, the Health Technology Hub and Institute for Biosensor Development supports companies developing technology to enable new diagnostic systems to enable people to be monitored and treated at home, keeping patients out of hospital. At the University of Bath, the Biosensor Network brings together international academic and industrial partners to carry out research in biosensor development and the CAMERA Centre provides state of the art facilities for developing motion analysis including rehabilitation after injury.

The University of Bristol is also home to world-leading birth cohort studies, charting the health of 14,500 families in the Bristol area, Avon Longitudinal Study of Parents and Children which attracts considerable research activity and investment from life science companies. There has also been significant activity regionally through the NHS to link up data resources including the Local Health and Care Record Programme and Digital Global Exemplars are nationally leading. These are now attracting inward investment and seeing the growth of local businesses such as Bristol based System C/Careflow who are expanding locally working with the local NHS.

There are several networks in the region that have enabled growth including, the Assisted Living Action Network, MedilinkSW, and the West of England Health and Life Sciences Innovation Exchange. Furthermore, initiatives such as Bristol is Open and the Bristol Ops Centre make up the country's leading smart city network and are now providing a test bed for innovation in health and social care.

Barriers to Growth

Stakeholders felt that the biggest barriers for growth in the medtech and Digital Health sectors was the lack of coordination of different networks and no clear or consistent strategy. A strategy is needed to link the West of England with neighbouring areas and allow the region to fully reach its potential, especially in the Digital Tech market. Similarly, a coherent strategy around healthy and active ageing is needed to provide the West of England with the opportunity to bid for national test bed programmes such as the Innovate UK healthy ageing programme.

Whilst there are several different networks established in the medtech and Digital Health sectors, there is no one clear coordinating group. Such a group would align the different activities occurring in the region and allow the West of England to compete on a national and global scale in health and life sciences.

Finally, the West of England region lacks a major anchor medtech or Digital Health company which could limit future growth and investment in the region.

Contribution to our vision and/or grand challenges

There is significant overlap between medtech, Digital Health and the Ageing Society Grand Challenge. The ageing population is a key driver for medtech and Digital Health and the Global Elderly and Disabled Assistive Devices Market was valued at \$14 billion in 2015 and has been projected to expand at a CAGR of 7.4% to 2024. A key strength in the region is the existing ecosystem of activity around healthy and active ageing for example through voluntary organizations and social enterprises such as Bristol Ageing Better and VOSCUR which has brought together over 200 organizations interested in reducing isolation and loneliness among older people. The West of England comprises one of the highest densities of social enterprises in health and care in the UK, employing around 3,000 people and with an estimated turnover just short of £200m.

This sector also links heavily to the AI and Big Data Grand Challenge. Key activity in the West of England that demonstrates this partnership is centred around the Health Tech Hub, Bristol Robotics Laboratory and SPHERE IRC. For example, Bristol Robotics Laboratory has recently partnered with several regional care and retirement home providers such as Extra Care and St. Monica's Trust to trial companion robotics and smart sensing technology.

The Department of Health plan to invest around £4.5 billion in the digital transformation of services by 2020 and this provides a major opportunity for medtech and Digital Health sectors to use data-driven technologies and AI. Having a joined up Local Health and Care Record system such as the nationally designated Local Care Record programme such as the One Southwest programme is seen as an enabler for applying to become a Digital Health Innovation Hub which is a key future delivery mechanism for the industrial strategy.

There is also an opportunity for medtech and Digital Health to influence the Future of Mobility Grand Challenge, for example the partnership between AGE UK Bristol and Uber, which is a way to link local shops to those with restricted mobility due to age via an innovative voucher scheme.

Digital health and connectivity have a significant impact on reducing the need to travel, while this has not been audited across the sector as a whole there is strong local evidence that this has a major impact. For example, in one community care organisation in North Somerset where this has been evaluated the implementation of a connected digital workforce via connected digital records has reduced the total number of claimed travel miles by 17% in the first year of its implementation. This organisation is one of the smaller providers but still recorded over 80,000 business miles. Multiplied across the entire health sector (the largest employer in the west of England) the impact of digital health data and mobile working is expected to be very significant. In addition, digital consultations, which are likely to be available at scale over the next few years, will equally impact the travel patients and family members will need to make.

Supporting Evidence

- Strengths and opportunity 2017, Office for Life Sciences
- Med City Map
- Life Sciences Industrial Strategy
- Health & Life Sciences in the WE-LEP area: Discussion paper, West of England AHSN, 2015
- Evaluate Med Tech Report 2017, Outlook to 2022, Executive Summary
- United Nations, World Population Prospects
- NCUB: Human Factor in Digital change
- Growing the AI industry in the UK, Independent report
- Department for Health and Social Care policy paper: The future of healthcare: our vision for digital, data and technology in health and care, 2018

Propulsion

Definition

Propulsion systems are machines that use thrust to push objects forward. The propulsions industry includes:

- Advanced engineering for internal combustion engines and systems efficiency
- Electric machines & power electronics as related to light duty transport vehicles
- Lightweight vehicle and powertrain structures
- Energy storage and energy management
- Intelligent personal transport

Geographical Reach

Both automotive and aerospace propulsion industries have research and development activity in the West of England that reaches nationally and internationally in manufacturing and maintenance. There is limited manufacturing in automotive and aerospace in the West of England and some manufacturing falls outside the West of England region. Marine research and development in the region is limited to the defence industry and consultancies that work with transferable technologies from Light Aero/ Auto Propulsion Systems. Therefore, there is a limited impact within the region, the UK or internationally.

Recent funding from the UK Government in propulsions technology has been awarded to other areas of the UK, and there is a lot of investment going into low and zero carbon research, particularly in the West Midlands. The National Propulsion Test Facility is a recent £30m investment by Government and industry in a facility for space technology testing in Westcott, Buckinghamshire, and the Advanced Propulsion Centre is a 10 year £1bn investment by the UK government in Coventry.

The propulsion sector, in particular personal transportation, is in a period of unprecedented change both nationally and globally. The move towards lower carbon transportation is evident in national strategy as well as globally with many nations declaring similar strategy or intent particularly with the 2015 Paris Climate Agreement.

Two of the most important issues that are currently shaping the automotive industry globally are fuel economy and emissions. As also indicated in recent research¹, despite the promise of new, cleaner technologies, the automotive sector still believes downsizing the traditional internal combustion engine is likely to yield the best results in the short- to medium-term. Furthermore, when it comes to alternatives, fuel cells have moved ahead of battery electric systems to become the number two priority for investments until 2020. All these mean that a large array of technology opportunities are competing to provide market and economic advantage in all these areas. Therefore, the leading systems efficiency and integration research taking place in the region is well placed to have global impact when implemented in production vehicles.

Within aerospace, the pace of change is somewhat slower. The gains to be had here lie in light-weighting, fuel efficiency and novel fuels. The real change for aerospace is in light aircraft where a range of companies are producing electric-taxi-style aircraft for intra-city transportation in the world's congested mega-cities such as Dubai and Los Angeles. At the 2018 Farnborough Air Show over 200 electric aircraft were launched, demonstrating the wealth of competition in the market.

In Numbers

Growth and employment nationally:

- Britain is the fourth largest vehicle producer in Europe, making 1.6 million vehicles in 2014. Approximately 4 in 5 cars produced in the UK (78%) are exported, to more than 100 countries.
- The UK motor vehicle manufacture industry contributed £12 billion to the economy in 2014 and employed 142,000 people.

Business and Skills

The local universities have strong engineering departments that offer undergraduate and postgraduate courses in subjects relevant to Propulsion Systems. UWE offers courses in Aerospace Engineering and Automotive Engineering, the University of Bath offer courses in Aerospace Engineering, Mechanical Engineering, Integrated Design Engineering, Chemical Engineering, Electronic and Electrical Engineering, Mechanical and Automotive Engineering and Engineering Design. The University of Bristol also offers similar courses including Engineering Design, Engineering Mathematics and Aerospace Engineering.

Whilst it is common for graduates to move into the propulsion industry from engineering degrees, other elements of propulsion systems attract graduates from other disciplines. For example, Mathematics and Computer Science degrees are required for advanced simulation roles and a Psychology degree is required to understand driver behaviour.

A range of high-tech engineering skills are required across the board for this sector, covering aerospace, electrical, mechanical and chemical disciplines. The integration of electrical propulsion systems into mechanical systems will require propulsion engineers of the future to have a skillset straddling traditionally separated disciplines. This could be enhanced to include other disciplines such as mathematics to supply the increasing need for simulation to develop systems of the future. The required skills are not likely to change in the short term but new education avenues must be explored and the scale needs to increase to satisfy increasing demand. The pace of change is likely to increase as demand from industry rises.

The 2016 Science and Innovation Audit for the South West and South East Wales identified a digital and advanced engineering automotive and hydrogen corridor running from South Wales to Swindon with businesses in WECA a key touch point en route.

Within the West of England Airbus, Rolls-Royce and GKN are the major players in aerospace R&D and manufacture. GE is also a key anchor business in maintenance, manufacturing and R&D, and Ricardo is a key business in automotive powertrain R&D and light weighting. BMT, with an office in Bath, is an automotive and aerospace consultancy.

The Institute for Advanced Automotive Propulsion System (IAAPS) is opening at the Bristol and Bath Science Park in 2020 and will become the region's most significant commercial automotive offering. IAAPS already has an industry partnership cohort and will seek to draw large companies such as Jaguar Land Rover and McLaren into the region as anchor clients, leading their R&D programmes from within the West of England.

Enablers of Growth

The region's universities have been major enablers of growth in propulsion systems technology in the West of England. The University of Bath has a strength in automotive and aeronautical engineering, production, regulation, materials, fuel (both renewable and non-renewable), energy storage & management, artificial intelligence, big data management and manipulation, business

management, economics, policy change & delivery. The University of Bath is also home to several leading institutes and research centres which are driving innovation and enabling growth in propulsion technologies in the West of England. The Powertrain and Vehicle Research Centre conducts research focusing on improving efficiency and emissions from diesel and petrol engines. The Institute for Mathematical Innovation assist businesses and other organisations in analysing big data and solving complex problems using mathematics as well as a related doctoral college, and the Institute of Coding is a Government-funded consortium of more than 60 organisations that is led by the University of Bath. The Institute of Coding aims to fill the UK's digital skills shortage and attract underrepresented groups into the sector by developing and delivering industry focused, higher education across the UK. Furthermore, IAAPS will support collaborative research with the automotive industry, becoming a global centre for excellence that will provide new apprenticeships, Masters & PhD studentships over the first 5 years of operation.

The University of Bristol also has a strength in enabling technologies, for example robotics (through the Bristol Robotics lab, which is a jointly run by the University of Bristol and the University of the West of England) and composites through the National Composites Centre.

There are also several networks in the region that have enabled collaboration and growth in Propulsions, such as the Bristol and Area Autonomous Technology and Systems group (BAATS) and iAero, a collaborative partnership of aerospace stakeholders in the South West of England. The Automotive Industry Club is an established network, formed by the University of Bath, which works in collaboration with regional Universities and LEPs to run regular events that are fruitful for organisations contributing to propulsion technology innovation.

Barriers to Growth

The main barrier to growth in this sector is a skills shortage in high-tech engineering and in particular the blend of electrical, mechanical, automotive and aerospace disciplines required for the future of propulsion technology. The impact of the skills shortage is to limit the ability of industry to realise the pace of development required to remain at the forefront of propulsion technology. This could drive R&D offshore to the likes of Germany or America.

Whilst there are already some key anchor businesses for propulsion systems in the West of England, there is still room to attract further businesses to the region and build this sector locally. This is especially true for non-aerospace industries which are less prevalent in the region. IAAPS at the Bristol and Bath Science Park are seeking to draw large companies such as Jaguar Land Rover and McLaren into the region as anchor clients, leading their R&D programmes from within the WECA region. There is also a need to encourage further collaboration between SMEs with large companies and academia to realise the vision of smaller up-and-coming companies.

The West of England has potential to be “real-world” test bed of ground and air-based trials of new propulsion systems but the current regulations are currently creating a barrier to this.

Relation to other deep dives and grand challenges

Propulsion system technologies cross over with regional technology capabilities including:

- Big data collection and management and manipulation to deliver vehicle and powertrain design optimisation and testing for real world driving and vehicle development for the median user.
- Data processing and wireless communication management of data for the system-to-system integration needs of electrified vehicle and electrified autonomous vehicle simulation, manufacture and management.

- Smart energy system creation and monitoring (data) for effective harvesting, grid-upload, grid management and extraction of energy to meet electrified transport demands.
- Economic and policy impact of electrified vehicle adoption, inclusivity, accessibility and market growth.

This sector is to some extent co-dependent on the clean growth activity and connected and autonomous vehicles (CAV) sector as the move to electric drive via roads and air coincides with the move to increased autonomous behaviour. CAVs will need propulsion to be more efficient, lightweight and greener, to enable them to become a viable reality. These three technology areas will become increasingly interconnected as low-emission autonomous vehicle controllers become the consumer of the powertrain's service.

Propulsions systems are an integral part of the Future of Mobility Grand Challenge, which is an indication by the government that investment in propulsion technology is part of a global trend that will put the UK at the forefront of key changes in the world.

Inclusive Growth

Propulsion Systems provide opportunities for training a skilled workforce and educational opportunities for a broader workforce through apprenticeships and via collaboration with Bath College. Growth of the propulsion systems industry will lead to increased productivity and growth, providing job opportunities locally through the connected SME community and Bristol and Bath Science Park.

Social inclusion could be promoted through improving the service offering for populations relocating to the region to meet the employment demand and through investing in localised collaborations between institutions that broaden the educational offering within commutable distances of existing capability and infrastructure.

Clean Growth

Propulsion systems offer possible benefits in automotive council roadmaps as a clean growth product. Bath hosts the low emission vehicle research Centre (CLEVeR), a £2.4 m facility connected with the Powertrain Vehicle Research Centre which provides opportunity to develop clean growth in the region.

Clean growth could be promoted in the region through an alliance with the Automotive Council UK, capitalising on the Advanced Propulsion Centre hub and spoke model and encouraging collaborators nationally and internationally.

Supporting Evidence

1. KPMG's Global Automotive Executive Survey Who is fit and ready to harvest? 2015
2. 2011 Carbon Plan
3. 2015 Paris Climate Agreement
4. Automotive Sector deal
5. South West England and South East Wales Science and Innovation Audit, 2016

Quantum Technology

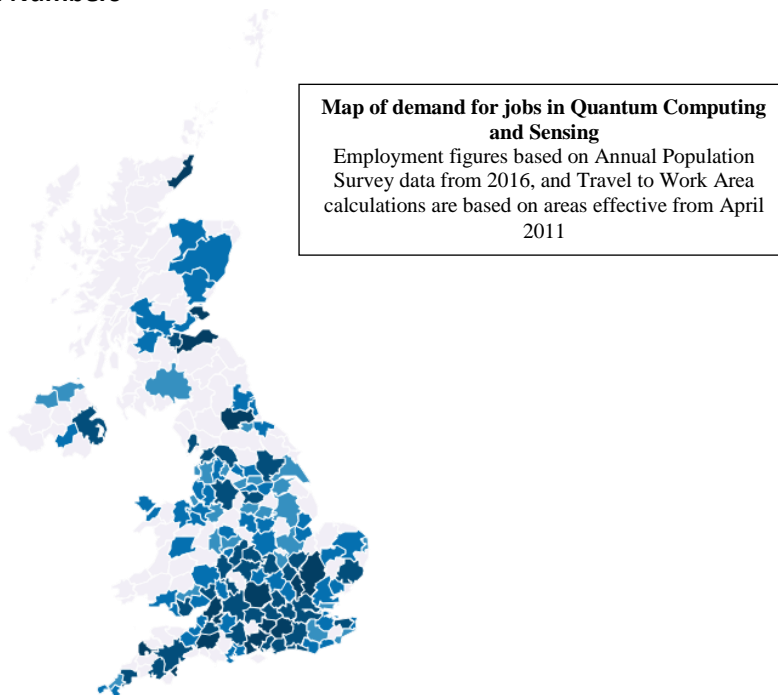
Definition

Quantum Technology is an enabler which will have many applications, including but not limited to timing and positioning, imaging and visualization, sensing and measurement, computing and simulation, and communications.

Geographical Reach

West of England and Bristol in the lead. Bristol is a world leading hub for quantum photonics, quantum computing and quantum computer software for modelling and simulation. It is also a hub for innovation and entrepreneurship in the emerging quantum sector. QET Labs is a global centre for research, development and entrepreneurship in the emerging Quantum Technology industry and is a national and international node for collaboration with industrial and academic world leaders, and the Engineering and Physical Sciences Research Council UK Quantum Technology Hub Network. Quantum enabled technologies will underpin a wide range of sectors, and as a result it is more supportive than dependent.

In Numbers



Growth and employment in the West of England:

- Job adverts
 - Burning Glass analysis shows Bristol to sit in third position behind London and Cambridge only in terms of recruitment volume. Torquay and Paignton has the highest recruitment density – about 100% higher than Bristol albeit at a much lower volume – and Cambridge second at about 80% higher, with Bristol ranking alongside a small number of other locations including Southampton, Oxford, Edinburgh, and Yeovil. No locations exhibit higher densities or volumes than those mentioned. We can thus conclude that the West of England is a significant employer in this highly-specialized field.

- Keywords: Photonics, communications, measurement, sensing, encryption, quantum computing, quantum software, computing, algorithms, innovation, entrepreneurship, start up, spin out, scale up, QT, 5G
- Salary
 - The mean advertised salary, £41,500, and the median is £38,900
- Direct and indirect employment in the sector is thought to total around 540 excluding students and support staff

Growth and employment nationally:

Bristol is a hub at the heart of the world's quantum industry which could be transformational, with far reaching benefits for the city/region, and well beyond. The UK plays a significant global role and thus will benefit accordingly. The WoE is viewed as a world leader in quantum information theory, quantum computing, quantum simulations, algorithms and software.

The UK research council's collective investment in quantum falls under the £300m UK National Quantum Technologies Programme (and a further £315m promised) with a mission to support the translation of revolutionary technology from the lab into the commercial market. However, this is dwarfed by China's US\$10b investment to build/fund the National Laboratory for Quantum Information Science; the USA's US\$1.3b for the National Quantum Coordination Office; and the European Union's €1b flagship initiative in Quantum Technology.

Growth and Employment globally:

New Quantum Technologies will impact upon all major market sectors. This includes the £305.6b semi-conductor industry, the £1.6t world oil and gas industry, along with anticipated implementation in to 5G LTE telecoms base stations around the world to overcome the limitations of GPS timing signals and in to mobile and network telecoms to provide unbreakable information security. Quantum Technologies will lead to major advances in precision timing, sensors and computation, destined to have a major impact on the finance, defence, aerospace, energy, infrastructure and telecommunications sectors.

Business and Skills

The number of quantum businesses which have been established as spin outs and start up from the University of Bristol sits between 15-20. This doesn't reflect though the ever increasing and wide-ranging interest in Quantum Technologies, from high number of industries across range of sectors located in, around, and dependent upon the west of England region. This includes the large industry primes, such Boeing, Airbus, Thales, MOD, Defence Science and Technology Laboratory, BAE Systems and other sectors, for example Hargreaves Lansdown, who see a huge opportunity in the quantum arena and have located their quantum teams in the region. Other key anchor businesses in this space include KETS, QLM, Phaseworks, Beosense, AdvancedDiamondX, DotQuantum, BosonX, Lab2Fabs, SeeQC, SurfaceRF, FluoretiQ and Raycal.

Higher Education

Quantum Mechanics, Quantum Physics, Advanced Quantum Physics, Quantum Computation, Quantum Information Theory, Advanced Quantum Information Theory and Physics with Innovation (BSc) are open undergraduate courses delivered by the University of Bristol as well as 'Quantum in the Summer', an annual week-long summer school summer school, which aims to teach students, aged 16 and over, about quantum mechanics and light. Its 'Quantum Engineering Centre for Doctoral Training' programme offers a unique 4-year training and development experience for those wishing to pursue a career in the emerging Quantum Technologies industry. It will also be providing a 1-year taught masters, Quantum Engineering (MSc) programme in 2019. Bristol leads a UK training and skills hub in QT consisting of a Centre for Doctoral Training in Quantum Engineering and a

Quantum Technologies Enterprise Training Centre (QTEC). University of Bath delivers Advanced Quantum Theory, Quantum Mechanics at undergraduate level.

Further Education

The Quantum Technology Enterprise Centre (QTEC) is a world-leading incubator for quantum-based technology innovators, its vision is to educate and create the quantum entrepreneurs of the future who will be the foundation, pillars, and growth of the UK's Quantum Industry. QTEC provides vocational training and a fellowship bursary, attracting talented QT entrepreneurs from across the world to the WoE region. Together these courses engage with over 200 undergraduates and over 70 postgraduates.

Apprenticeships

The University of Bristol's new Temple Quarter Enterprise Campus (TQEC) presents a huge opportunity to develop and deliver a range of apprenticeship programs to support the emerging quantum sector. There are plans to develop a level 7 MSc degree apprentices (possibly level 8, EngD) for the university and Quantum Technologies could be part of this.

Skills needed

The specific skills for those researching and developing Quantum Technologies to take advantage of quantum properties include maths, engineering and physics. There are entrepreneurial skills required to take quantum to commercialise quantum-inspired technologies and develop the business to take advantage of the emerging quantum market. Engineers and technicians are required to deploy and maintain Quantum Technologies when utilised at large scale. As the quantum sector develops there will be a need to invest in developing all skill sets. Whilst the academic sector has seen relatively good investment in quantum, the innovation and entrepreneurial sector and future workforce are areas which are currently developing most rapidly within the WoE. In the long term, we expect the demand of all skills to increase and eventually stabilise.

Enablers of Growth

WECA region's unique selling point is to have coordinated the innovation system broadly with specific innovation gaps being managed and closed for QT. This differentiates the region from other places which have only treated QT from a technology push perspective.

Other enablers of growth are assessed to include the following assets:

- Quantum Engineering Technology Labs (QET Labs): QET Labs brings together the broader quantum and related activity at Bristol to maximise opportunities for new science discoveries that underpin engineering and technology development.
- Bristol Centre for Nanoscience and Quantum Information (NSQI)
- Quantum Technology Innovation Centre (QTIC): The world's first open access Quantum Technologies Innovation Centre, focusing on taking quantum research from the lab and into the commercial world and positioning the UK as a global leader in the field.
- Quantum Technology Enterprise Centre (QTEC): World-leading incubator for quantum-based technology innovators, its vision is to educate and create the quantum entrepreneurs of the future who will be the foundation, pillars, and growth of the UK's Quantum Industry.
- Quantum Photonic Integrated Circuits (QuPIC): UK quantum device prototyping service, focusing on design, manufacture, test, packaging and rapid device prototyping of quantum photonic devices.
- Bristol Quantum Information Institute: World leading group specializing in theoretical quantum information science and which will underpin future generation of quantum scientists and engineers and the prototypes of tomorrow, from theory to technology.

- Quantum Information Theory Group: Expert group in theoretical aspects of quantum information science, including mathematical underpinnings of quantum information theory, quantum algorithm and computation, and the applications of quantum information theory to other disciplines (e.g. thermodynamics).
- Smart Internet Lab – Quantum Secured 5G: The Smart Internet Lab is a unique interdisciplinary research hub, combining more than 200 digital experts from around the world. We aim to address key limitations of our current internet system, improving scalability, lowering latency and increasing bandwidth
- University of Bath, Centre for Photonics and Photonic Materials: The Centre comprises around 30 academics, postdoctoral researchers and PhD students. Much of the research work is based in state-of-the-art fabrication facilities and extensive optical laboratories, which are equipped with a wide range of laser sources and optical test gear. Extensive numerical modelling of both linear and nonlinear optical effects is undertaken.
- SETSquared Bristol: The World's top incubator for high tech, high growth start-ups providing world leading business development support.
- Unit DX: Science incubator offering specialist facilities with science-focused business support, the incubator has been instrumental in building a new scientific ecosystem in the city.
- Bristol is Open

Barriers to Growth

The recently published House of Commons Science and Technology Committee on Quantum Technologies...

- *that a lack of suitably skilled workers could hinder the future development of the UK quantum industry. The existing training programmes are well-regarded, but increasing and improving the training offered must be a priority going forward. The second phase of the National Programme must also ensure that training is available at undergraduate, technician and apprenticeship level*

Relation to Other Deep Dives and Grand Challenges

Reflecting this, the recently published House of Commons Science and Technology Committee on Quantum Technologies states...

quantum technologies offer the opportunity for significant economic growth and improved capabilities across most industry sectors. The Government Office for Science estimated in 2016 that quantum technologies could grow to be worth as much as the consumer electronics manufacturing sector, then worth £240bn per year worldwide.

The West of England expects to be playing a central role in realising these benefits.

Inclusive growth

The emerging quantum market will provide a range of opportunities for employment across the full spectrum of skills ranging from apprenticeships to post-doctorates. Given that this is an emergent market sector in a post-Brexit UK, then the opportunities for those with connections beyond traditional market areas (EU, USA...) would enable for a more diverse range of businesses to flourish.

Clean growth

The emerging sector can be encouraged to be a green sector from the offset. Quantum Technologies are likely to be more efficient “per bit” than traditional technologies. Further, sensing and imaging technologies, will improve environmental sensing/measuring and interpretation than conventional technologies providing measurements that are more sensitive, accurate and informative.

Supporting Evidence

- Blackett Review (2016), The Quantum Age: technological opportunities, Government Office for Science (Ref GS/16/18)
- House of Commons Science and Technology Committee (2018), Twelfth Report of Session 2017–19, (Ref HC820)
- A roadmap for Quantum Technologies in the UK (2015), Published by Innovate UK and the Engineering and Physical Sciences Research Council on behalf of the Quantum Technologies Strategic Advisory Board (Ref CO004)

See further publications here: <http://uknqt.epsrc.ac.uk/resources/publications/>

Robotics and Autonomous Systems

Definition

Robotics and Autonomous Systems (RAS) are intelligent machines that operate in feedback with the real world by sensing, making decisions and physically acting. Although the machines are becoming more capable and autonomous, cooperation and interaction with humans remains central, from individual to societal scales. RAS includes enabling technologies such as control, AI, materials, smart actuation, vision and perception technologies as well as applications of other sectors, ranging from assisted living to unmanned flight.

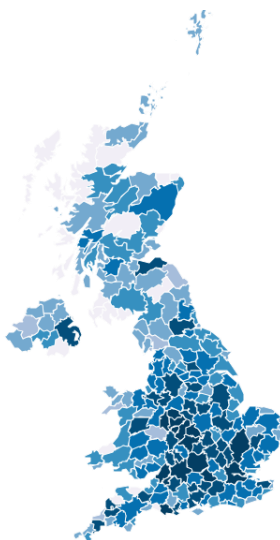
Geographical Reach

Since 2006, the South West has received almost £60M in research funding for robotics themes which is the largest funding for robotics normalized to GVA per capita out of all 12 UK regions. It is estimated that institutions in the West of England account for ~93% of the total funding to the South West.

The West of England RAS sector focuses on adaptable or ubiquitous robotics, that interact with the real world, especially humans and society. This focus is distinct from robotics work found in other regions, which typically serve locally-prevalent user sectors (e.g. offshore in Edinburgh). Internationally, the West of England's impact is through disruptive start-ups, high-value components or systems design/integration. The West of England is also home to a small number of businesses which are internationally leading in very specific areas, for example Shadow robot hands are being used in research labs around the world by leading institutions such as NASA, Siemens, GSK, Hitachi and MIT.

There is evidence of a cluster and community of robotics users and providers operating locally, however, this is part of a wider national and international collaboration and most robotics and automation hardware is manufactured overseas.

In Numbers



Map of demand for jobs in Robotics and Autonomous Systems.
Employment figures based on Annual Population Survey data from 2016, and
Travel to Work Area calculations are based on areas effective from April 2011

Growth and employment in the West of England:

- 1,551 jobs in the robotics field posted in the West of England between December 2017 and December 2018
- Bristol has a much higher demand for robotics jobs than the UK average

- Mean real-time salary for advertised jobs was £40,300

Growth and employment nationally:

- Market for non-military RAS is £70 billion with productivity gains of up to 22% through adoption of RAS in UK manufacturing.

Growth and Employment globally:

- The global impact of advanced robotics is estimated to increase from \$1.7 trillion to \$4.5 trillion by 2025.
- The global market for 'service' robotics is estimated to be \$18 billion in 2020, with a suggested 10% UK market share.

Business and Skills

The University of the West of England and the University of Bath both offer undergraduate courses in robotics / robotics engineering and between 40 – 60 students graduate each year in these courses, set to grow to over 100 as more come on stream. On top of this, other undergraduate courses across the Universities of Bath, Bristol and the West of England contain significant robotics elements for example, Aerospace and/or Automotive Engineering and Computer Science.

University of Bristol and UWE offer joint postgraduate masters and PhD level courses in robotics. Each year around 120 students graduate with a masters in a robotics related field and 30 – 50 graduate with a PhD in robotics. UWE and the University of Bath offer additional masters-level courses in robotics / robotics engineering.

Whilst there are no robotics-specific apprenticeships or further education courses available in the West of England, UWE works with numerous regional local colleges to deliver foundation courses and degree apprenticeships that touch on robotics and automation, for example Mechatronics. Bristol Robotics Laboratory (BRL) offers the ERDF-funded SABRE programme of free workshops and development support for SMEs.

RAS technologies require skills in computer science, engineering and systems modelling and simulation as well as contextual understanding and application-specific knowledge such as hardware specification and selection. For the West of England to continue to develop the “robots in the community” agenda, more multidisciplinary skills are also needed, drawing on social science and business analysis, for example. At present, this expertise is not sufficiently networked with technology developers in the region.

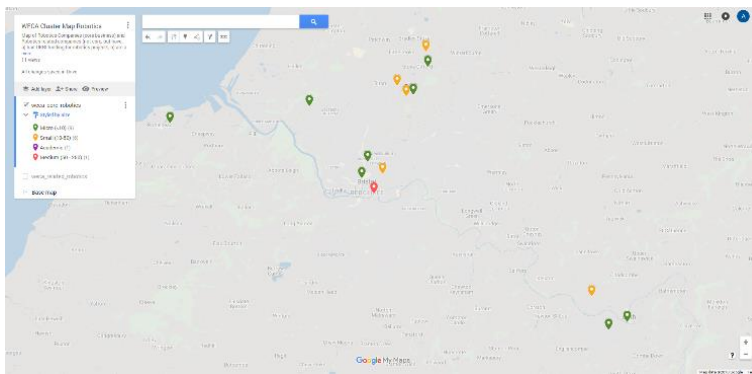
Between December 2017 and December 2018, 1,551 jobs in RAS were advertised in the West of England region. In Bristol, the demand for employees in the robotics industry is higher than the UK average whereas in Bath, the demand is similar to the UK average and in Weston-super-Mare there is a much lower demand than average. Of the advertised jobs, 138 jobs were at Higher Education institutions, with 63 at the University of Bristol and 26 at UWE. Of the jobs advertised, key occupations were programmers and software development professionals and Engineering professionals and the top job title was software development engineer.

The top skills required for the jobs advertised can be split into specialized skills, basic skills and computer skills. The top three of skills required in each of these categories is as follows:

- Specialized skills: robotics, sales and technical recruiting
- Basic skills: communication skills, research and planning
- Computer skills: software engineering, c++ and software development

There are 17 companies in the region whose core business is in robotics, 9 of which are micro-businesses, 6 are small enterprises and 2 are medium enterprises. Altogether there are more than 100 companies who have a strong interest in robotics, either through developing robotics technology alongside other activities or making use of robotics for core applications, who actively participate in local RAS networks.

The primary anchor for the regional cluster is the Bristol Robotics Laboratory (BRL), a partnership between UWE and University of Bristol that performs extensive R&D and training as well as hosting 15 firms in its hardware business incubator and coordinating networks from regional to international scale. BRL also enjoys a leading national and international profile, including frequent high-profile visits from UK government, media, and global industrialists and academics. There are currently no large anchor businesses unique to the sector, although several major regional businesses are moving into the RAS space as users and/or R&D collaborators.



Cluster map of RAS businesses

Enablers of Growth

There are several key assets that are pivotal to the arrival and success of businesses in the region, including the National Composite Centre and BRL. The West of England has a strong entrepreneurial ecosystem that has allowed businesses to develop and grow, including SETSquared, Engine Shed and the BRL incubators.

The Universities (University of Bristol, the University of Bath and UWE) are also key enablers of growth in the region, not just because of the leading research that they undertake, but also due to the high retention rates of students. BRL enhances that potential by combining UWE and Bristol's research into a high-profile critical-mass partnership and providing innovation support.

There are also several key networks in the West of England that enable growth of the robotics industry, including the West of England Robotics Network (WERN) and the Bristol Area Autonomous Technologies and Systems Group (BAATS). BRL hosts a successful "Women in Robotics" network and the international Robohub.org non-profit network was co-founded by a BRL academic. Many of these networks and organisations enable growth by introducing RAS industries to other sectors with potential applications that could overcome major societal challenges. For example, the common enablement of future mobility through RAS, AI and communications and the interactions between sectors such as RAS and manufacturing through the National Composites Centre.

It is often a combination of these assets that leads to growth in the West of England, and many successful companies are formed by graduates of the universities and/or users of local incubator provision. For example, OpenBionics was formed by UWE graduates with help from Future Space and Perceptual Robotics was formed by University of Bristol graduates using the BRL incubator.

International investment has also been an enabler to growth for several companies, including Reach Robotics who have raised over \$7.5M through international investment and OpenBionics who have had \$2.9M of international investment.

Barriers to Growth

The RAS economy in the West of England is based on research and development, with little work in large-scale manufacturing occurring in the region itself. R&D is readily mobile and there is a risk that this sector could move to another region without the support from a major anchor business or large-scale manufacturing. There is also limited capacity for large scale employment without this support.

More enduring critical mass could result from leveraging existing regional assets, for example the RAS anchor institutions and networks, in concert with other sectors. RAS and Connected Autonomous Vehicles (CAVs) enjoy considerable overlap, both in terms of skills foundations and the people and organisations involved. Opportunities in health technology, medical robotics and personal assistance are developing through the UWE Health Tech Hub collocated with BRL. Great regional SME successes have come from the interface between technology and creativity. Future collaborations with major business anchors in manufacturing and aerospace, for example, also offer great promise.

Perhaps the greatest challenge in realising this potential is in alignment of the applications: the region's R&D base and SME community ("the primes of the future") are well-placed to deliver on emerging applications such as CAVs and health tech, but large regional industry anchors are rooted in different sectors. Developing a unifying regional narrative, possibly around the "regional living lab" concept for "systems of systems" innovation, would close this gap. This is especially important if we are to deliver our potential for inclusive and green growth, which is greatly enhanced by robots moving out of labs and factories and into homes, streets, shops and community centres.

Relation to Other Deep Dives and Grand Challenges

RAS technologies are closely linked with various other technologies and sectors in the West of England, especially AI which is an enabler to RAS and heavily complements the RAS development in the region. Telecommunications and connectivity are also enablers to RAS and many RAS applications.

RAS also acts as an enabler to several industries including advanced materials manufacturing and as a result of these collaborations, RAS could contribute to any of the four Grand Challenges, especially the Future of Mobility, Ageing Society and AI and Big Data Grand Challenges.

The West of England is well-placed to lead in the "systems of systems" area and understand how RAS technologies interface at scale with society, including new usage models, adoptions prospects and human interaction. This could contribute to a wider vision within the West of England to integrate multiple technologies and ideas into society.

Supporting Evidence

- UKRI Gateway to Research
- Disruptive technologies, May 2013
- Evidence to Science & Technology Committee, May 2016
- The UK Robotics and Autonomous Systems strategy, RAS 2020, Jul 2014