Department for
Business, Energy
& Industrial Strategy

SCIENCE & INNOVATION AUDITS

Wave 2 Summary Reports

September 2017

Foreword

I am very pleased to welcome the publication of the second wave of Science and Innovation Audits. The Government's Industrial Strategy recognises the role science, research and innovation plays in driving productivity and growth. We have committed to the biggest increase in public science and innovation funding for nearly 40 years, providing £4.7 billion to 2020. Our new Industrial Strategy Challenge Fund is backing areas where the UK has the potential to use its research strengths to become a global industrial and commercial leader in new and innovative technologies.

The Industrial Strategy also has an important focus on places, recognising that the challenges and opportunities different places face depend on local knowledge, commitment and leadership. In my 'One Nation Science' speech in 2015, when I announced Science and Innovation Audits, it was with the ambition that we could develop better ways to identify and build on areas of greatest potential in every region. One major benefit of the approach we have taken is that the SIAs have brought together consortia and provided a focus for stronger collaborations between the parties involved.

The SIAs are forward looking, examining what the opportunities may be in the locality for their chosen sectors and how those opportunities could be best exploited or pursued. This second wave of 8 SIAs, together with the first 5 published last November add to our understanding of UK capabilities and crucially identifying data gaps and needs; this is an important part of this open policy making process, where stakeholders come together to tackle challenges.

Each SIA has delivered their individual reports, backed by strong evidence and partnerships that show their current dynamism and emerging strengths to a global audience. As we leave the European Union, it is evident that local science and innovation strengths will play a vital role in the UK's success in international trade and attracting inward investment.

Joseph Johnson
Minister of State for Universities, Science, Research and Innovation

Introduction

We are putting the UK's strengths in science, research and innovation at the heart of our Industrial Strategy. Research and innovation leads to new products, services and better ways of doing business and is key to driving economic growth and UK competitiveness.

The UK is already world-leader in science and research, but we must make sure that we maintain our leadership and competitiveness, and make the UK the most innovative country in the world. We are also looking to support science and innovation strengths in places across the UK to ensure innovation can drive local growth. The Science and Innovation Audits (SIAs) are helping to build the evidence base of where our key strengths are.

The SIA process brings together and supports local consortia of business, universities, research and innovation organizations, Local Enterprise Partnerships (LEPs) and their equivalents in the Devolved Administrations.

The SIA process will broaden and deepen our understanding of areas of potential globally competitive advantage across the UK. With independent analytical support, the consortia examine key science and innovation strengths in their regions to provide evidence of their potential to build and develop world-leading products, services and technologies.

The reports combine national data sets with an "on the ground" view based on local data, knowledge and experience. The analysis examines an area's strength in science and innovation and relates these to a national and international context. This evidence will help underpin future investment decisions, foster local collaboration and strengthen future bids for local investment from public and private sources.

This document collects together the summary reports from the eight consortia who undertook the second wave of SIAs:

- Bioeconomy of the North of England.
- East of England
- Glasgow Economic Leadership.
- Innovation South
- Leeds City Region.
- Liverpool City Region Plus.
- OffShore Renewable Energy consortium
- Oxfordshire Transformative Technologies Alliance.

These consortia represent a range of approaches to scale, geography and sectors, and have undertaken the SIA process in these different scenarios. We have worked in partnership with consortia, and with analytical support from Technopolis, to develop the SIA methodology. This work will continue as we continue the process into wave 3 in order to create an evidence base that will inform future work locally, regionally and nationally.

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Summary Report

August 2017

THE BIOECONOMY IN THE NORTH OF ENGLAND

A Science and Innovation Audit Report sponsored by the Department for Business, Energy & Industrial Strategy

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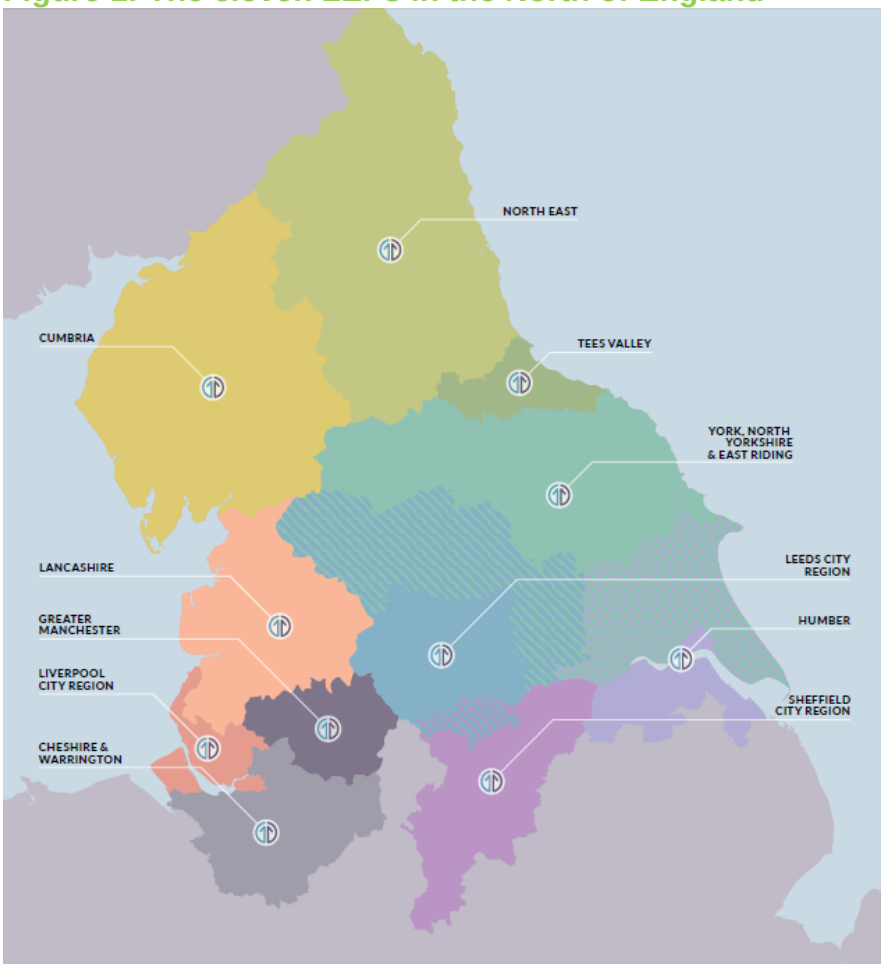
Introduction

In autumn 2015, the UK government announced regional science and innovation audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identifying mechanisms to realise their potential. One such consortium in the North of England has assessed regional strengths and opportunities in the bioeconomy. This summary report presents the results, which include a broad-ranging analysis of the North of England's bioeconomy capabilities, and highlights the challenges and substantial opportunities for future economic growth.

We are pleased to have the opportunity to present the case to the UK government that the North of England has the facilities, specialised research and innovation capability, and industrial capacity to deliver a world-leading bioeconomy based on agri-science, agri-technology and industrial biotechnology with the potential to alleviate pressing societal challenges. This is a substantial economic opportunity for the region; one that is rooted in its existing process industry infrastructure and skills, its research and innovation expertise (which includes world-class universities), its proven capability in technology translation, and its strong connectivity through good logistics, supply chains and networks.

The SIA consortium is led by the University of York and includes small and large companies, universities, agricultural colleges, the science skills body Cogent Skills, translational organisations working between research and industry, and Local Enterprise Partnerships (LEPs). The geography of the audit is covered by the 11 LEP areas shown in Figure 1.

Figure 1: The eleven LEPs in the North of England



National and International Context

The challenge

Over the next 30 years, the world population will exceed 9 billion and the global economy will quadruple, with people becoming increasingly affluent. Almost 70 per cent of the population will live in urban areas. Food and energy demand will double, with renewable sources including biofuels and bioenergy accounting for 10 per cent of commercial supplies. Pressure on the environment and competition for land will intensify as demand for food and animal feed increases. Climate change mitigation will require the cultivation of crops for energy and the production of bio-based ingredients to displace petrochemicals. The bioeconomy will have a major part to play in the transformation of global systems to meet these challenges.

The opportunity

Agri-tech and industrial biotechnology provide technological tools to address these issues by improving agricultural resilience, securing food supplies and offering non-petrochemical routes to industrial feedstocks. Agri-tech involves bioscience and bioengineering approaches to improving agricultural productivity by reducing crop and livestock inputs and developing improved crop varieties. Industrial biotechnology harnesses plants and microbes to create novel foods, products and materials, as well as sustainable feedstocks for the agri-food and chemicals industries. It also adds value to waste streams.

The bioeconomy

This summary report adopts the following definition of the bioeconomy: “The bioeconomy is the production of biomass and the conversion of renewable biological resources into value-added products, such as food, bio-based products and bioenergy”.[i] Healthcare and therapeutic applications of industrial biotechnology are considered beyond the scope of this report, but the authors note that the biomedical sector involves similar underpinning expertise and is an important adjacent economic sector in the region, with the potential for technology crossover.

It has been estimated that more than half of total agricultural output and 35 per cent of chemicals and related industrial output will depend on biotechnology by 2030.[ii] In recognition of the importance of the bioeconomy, at least 26 nations have introduced specific strategies to address it,[iii] and several countries have taken active steps to promote it. For example, since 2002, the US BioPreferred programme has required federal agencies to purchase bio-based products preferentially.

The combined bioeconomy of the UK, including upstream, downstream and induced components, is estimated to generate £220 billion in gross value added (GVA) (2014 figure) and to employ more than 5 million people.[iv] Excluding agriculture, the UK’s bioeconomy is the third-largest in the European Union after Germany and France. The UK is a leading country in the key areas of research and innovation that underpin the bioeconomy, and ranks first globally in terms of ‘quality’ of research, as measured by field-weighted citation.[v]

Our vision for 2030

The consortium's vision is one of an integrated and innovation-driven product, process and service bioeconomy in the North of England. This will have the necessary critical mass to compete in the multi-trillion-pound global market for sustainable food, feed, chemicals, materials, consumer products and energy. Using advanced land management strategies and technology-enabled precision agriculture, the region's farms will cultivate diverse crops for food and non-food markets. Agricultural products, by-products and urban waste will be processed at regional biorefineries to produce foods, animal feeds and high-value chemicals and materials, at the same time returning carbon and nutrients to the soil. Established chemicals clusters will have undergone a substantial transition to use locally produced and imported biomass feedstocks for the production of bulk bio-based chemicals. By 2030, the region will have gained global recognition for the production and conversion of biomass. Its international profile will attract inward investment into productive, knowledge-based businesses sustaining high-value jobs.

Key Strengths

Science and innovation
The North of England has extensive research capability in the science that underpins the bioeconomy. It is comparable with the UK as a whole – a global frontrunner – and, in many regards, outperforms the rest of the country. The region is particularly distinctive for its success in winning funding for translational research, which is at a level well above the national average.

Assets and capabilities
There are over 16,000 companies providing absorptive capacity for innovation in the bioeconomy of the North of England. Collectively, they have an annual turnover of more than £91 billion and employ around 415,000 people. By turnover, food and drink represents around one-third of the regional bioeconomy, and chemicals make up one-quarter. Large companies predominate in food and drink, chemicals and utilities.[vi]

The close links between industrial biotechnology and the chemicals sector is particularly relevant to the region, where the process industries are a major employer. The bulk chemicals industry is located around the estuary ports where crude oil is imported, and biomass-processing companies are also starting to use seaborne logistics to import raw materials. The size of the opportunity can be gauged from a recent report that concluded 40 per cent of Italy's chemical industry could make the transition to bio-based production.[vii]

The N8 Research Partnership[viii] is one of the major science and innovation assets of the North of England, with proven collaborative skills in agri-food research. Other universities in the region have bioeconomy-relevant capabilities, including the consortium partners Sheffield Hallam University and the University of Hull.

Technology translator organisations are a major differentiator and unique strength for the North of England. These bodies have capital equipment and dedicated expertise with which to support business innovation. They include Fera Science Ltd (Fera) in Yorkshire, which supports a range of aspects of agri-food innovation, including the safety and integrity of food supply chains 'from field to fork'. The Centre for Process Innovation (CPI) on Teesside, home to the National Industrial Biotechnology Facility, and the Biorenewables Development Centre in York have both expertise in process development and the capability to scale up processes from the laboratory to full production. In addition, the Unilever–University of Liverpool Materials Innovation Factory brings high-throughput automation to the development of new, bio-derived consumer products.

The North of England has a distinctive set of bioeconomy assets, including world-class science, applied research excellence, translational expertise and industrial capacity. These can be mobilised to build economic value from agri-tech and industrial biotechnology, and fully exploit the bioeconomy to deliver jobs and economic growth.

Talent

Concentrations of skilled people working in the process and manufacturing industries are a strong basis for building a competitive advantage in bioprocessing. The region holds 38 per cent of the UK's chemicals industry workforce, 31 per cent of the polymers industry workforce,[ix] and 36 per cent of apprenticeships[x] relevant to the bioeconomy. Six land-based colleges, including three of the five largest providers of land-based qualifications in England, are in our region and the universities in the North of England provide a quarter of the UK science, technology, engineering and mathematics graduates.[xi]

Growth opportunities

The products that will create future growth in the bioeconomy include advanced biofuels and bio-based jet fuels; biochemical building blocks and bio-based plastics; novel foods; high-value chemicals from novel crops; functional foods and nutraceuticals; and novel crop varieties that are resistant to pests, diseases and climate-related stresses. It has been estimated that industrial biotechnology, biofuels and bioenergy could reduce global greenhouse gas emissions by 1.0–2.5 billion tonnes of carbon dioxide per year by 2030.[xii]

The consortium's ambition is to double the size of the transformative bioeconomy in the North of England in GVA terms from £12.5 billion now to £25 billion in 2030. This will happen primarily through industry responding to economic drivers, but will be facilitated by specific interventions to catalyse growth and remove barriers.

The opportunities to achieve this include:

- making the transition in the chemicals industry to become significantly bio-based
- academic collaborations with major innovation-active companies, such as Croda and Unilever, and encouraging more large companies to pursue open innovation
- supporting disruptive innovators to thrive in the region and bring new products and services to market
- supporting the scale-efficient food- and feed-processing industries to establish competitive advantage in bioeconomy products (e.g. by producing protein from non-animal sources).

Gap analysis and proposals

As stated, the key ambition is to double the size of the transformative bioeconomy in the North of England by 2030. The SIA has identified the main strengths and weaknesses regarding this goal. Combining this analysis with the vision for 2030, feedback from consortium members, primary research with industry participants in the region, and an understanding of what has been critical for success in other regions around the world, gives a clear view of the gaps that need to be filled (see Table 1).

Table 2: Summary of gaps and proposals

Current state We have……	2030 state We want to be…..	Next steps
Strong sector-specific research and a differential strength in translating research into innovation, but this is not fully coordinated	Strategic and joined up in our approach to innovation, accelerating new products and processes to market	Establish a single-entity 'Northern Bioinnovation' to own the vision and coordinate innovation support for businesses in the regional bioeconomy
Used European Union economic development funding to accelerate innovation via short-term applied research projects with our open access innovation centres	Providing a comprehensive 'innovation to market' support service to industry, through integrated, self-sufficient applied research and scale-up centres funded by large businesses, and providing public sector support for market access for small- and medium-sized enterprises	Provide a five-year innovation support programme managed by Northern Bioinnovation, including the following components: • innovation research projects • skills development • capital grants to support innovation
No real cluster of innovation activity based around commercial-scale processing of biomass	Driving economic activity and innovation through bioclusters, providing a focal point around which publicly funded support can be channelled to assist early stage insurgent companies developing disruptive technologies	Establish the first biocluster as an advanced bio-manufacturing park based around a central biomass process such as sugar production and provide demonstration facilities for new added-value processes using secondary product streams
Joined-up applied research capability in agri-food that combines the work of eight universities	World-leading in our connected industrial biotechnology and agri-food applied research, offering scale and single point of contact benefits to industry	Extend the collaborative 'N8 AgriFood' approach to industrial biotechnology and challenge universities to develop a pipeline of technologies that can be commercialised within the bioeconomy
Transport bottleneck east–west across the Pennines	Able to move substantial quantities of biomass around the region as part of a high-capacity transport network	Begin the process of planning the logistics implications of an economy using much larger quantities of biomass
Regional, non-sector-specific venture funds providing seed funding to emerging businesses	Allowing insurgent bioeconomy companies to access £10–30 million of capital to establish production facilities	Investigate the formation of a substantial (£100 million plus) bioeconomy venture fund for the region
An uncertain policy framework for biofuels and bioenergy, and no equivalent renewables incentives for using biomass for higher-value products	Operating under a policy regime that actively promotes the replacement of petroleum-derived products with biomass-derived products, and gives the process industries a reason to change their supply chains	Government review of the policy framework for biorenewables and adoption of an equivalent of the US BioPreferred programme

Networking and Collaboration

The advance preparation and conduct of this SIA spanned a period of more than 18 months. One of the strengths that the consortium has been able to draw on is the existing network of organisations, each of which has a stake in the bioeconomy of the region. The consortium has grown to incorporate partners from across the North of England and has been able to build on and benefit from specialist knowledge from partners that would not have been available without the catalyst of the audit process.

More specifically, the consortium has:

- Engaged partners in the land-based colleges and provided grounds for further and higher education stakeholders to work together on skills mapping and training delivery in the bioeconomy through the analysis of skills in the region, carried out by Cogent Skills.
- Widened and deepened relationships between universities and industry partners; consortium workshops have been a feature of this audit, and have been instrumental in sharing perspectives about what works in innovation and where bioeconomy priorities should be set.
- Allowed consortium members to benefit from a wider national and policy perspective. Some members sit on national bodies, such as the Industrial Biotechnology Leadership Forum and the Chemistry Growth Partnership, which have interests aligned with the vision of the audit. The audit took place in parallel with the consultation on the UK government's industrial strategy, and information has been passed in both directions to help inform the report and consultation processes.
- Generated a large amount of valuable information that is now available to the consortium and other interested stakeholders. This includes size and location information for more than 16,000 companies working in the regional bioeconomy. Individual LEPs have a good understanding of their business base, particularly the larger players, but can benefit from this new information. This is provided in a format that was not previously available, extends knowledge across the region and can be used to identify potential supply chain partners for both commercial and innovation purposes. The consortium intends that all of its members and partners will make use of this data source.

The process of delivering the SIA is only the beginning of broader collaboration in the bioeconomy of the region. We intend that the information presented within the report, and the network of innovation providers involved, should be used as a basis to create a common innovation platform across the region acting in support of LEPs and other strategic bodies.

The connections among the universities and leading translational organisations, such as Fera and CPI, have developed substantially throughout the audit process and there is strong commitment to working together in further technology development. One of the most significant outcomes of the audit was recognition of the importance of the role played by translational organisations in ensuring that new inventions and innovations reach the market, and the value placed by industry on their assistance. These relationships will be demonstrated in more cohesive and better targeted proposals for research and innovation activity to the research councils and Innovate UK.

There is a strong case to support inward investment in biomass-processing industries, and we believe that such industries will find a hospitable environment in which to conduct business. We are determined to build on substantial investments by large incumbent organisations with incentives and technical support that will provide opportunities for insurgent companies to invent and commercialise genuinely new products and processes. A clear signal of intent will be the establishment of an advanced bio-manufacturing park in the North of England, dedicated to the development of new technologies for the bioeconomy.

Full report

The full report, The Bioeconomy in the North of England: A Science and Innovation Audit Report Sponsored by the Department for Business, Energy & Industrial Strategy can be downloaded at: www.york.ac.uk/research/the-bioeconomy-in-the-north-of-england-sia/

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i Bauen, A. et al. (2016) Evidencing the Bioeconomy, Capital Economics, TBR and E4tech.

ii OECD (2009) The Bioeconomy to 2030: Designing a Policy Agenda: Main Findings and Policy Conclusions, Organisation for Economic Co-operation and Development International Futures Project.

iii Bioökonomierat (2017) International Bioeconomy Strategies, http://biooekonomierat.de/en/international0/

iv Bauen et al. (2016) Op. cit.

v Bauen et al. (2016) Op. cit.

vi Information collected by Kepier and Co. during the conduct of this audit

viiIl Bioeconomista (2016) In EU5 the bioeconomy is worth €1.27 trillion and employs 7 million people, https://ilbioeconomista.com/2016/01/12/new-report-in-eu5-the-bioeconomy-is-worth-e1-27-trillion-and-employs-7-million-people/

viii Durham University, Lancaster University, University of Leeds, University of Liverpool, University of Manchester, Newcastle University, University of Sheffield, University of York.

ix Office for National Statistics (2017) Labour Force Survey, four quarter average, October 2015–September 2016.

xSkills Funding Agency (2016/17) Apprenticeship Starts by Region and Sector Subject Area. SSA's selected of relevance to the bioeconomy were science, maths, engineering, manufacturing, agriculture, horticulture and animal care.

xi Higher Education Statistics Agency Student Record 2014/15.

xii World Wide Fund for Nature (2009) Industrial biotechnology: More than green fuel in a dirty economy? Quoted in Chambers, G. et al. (2015*)* Biotech Britain: An Assessment of the Impact of Industrial Biotechnology and Bioenergy on the United Kingdom Economy, Capital Economics, TBR and E4tech.

The East of England Science & Innovation Audit

A Science and Innovation Audit Report sponsored by the Department for Business, Energy & Industrial Strategy

July 2017

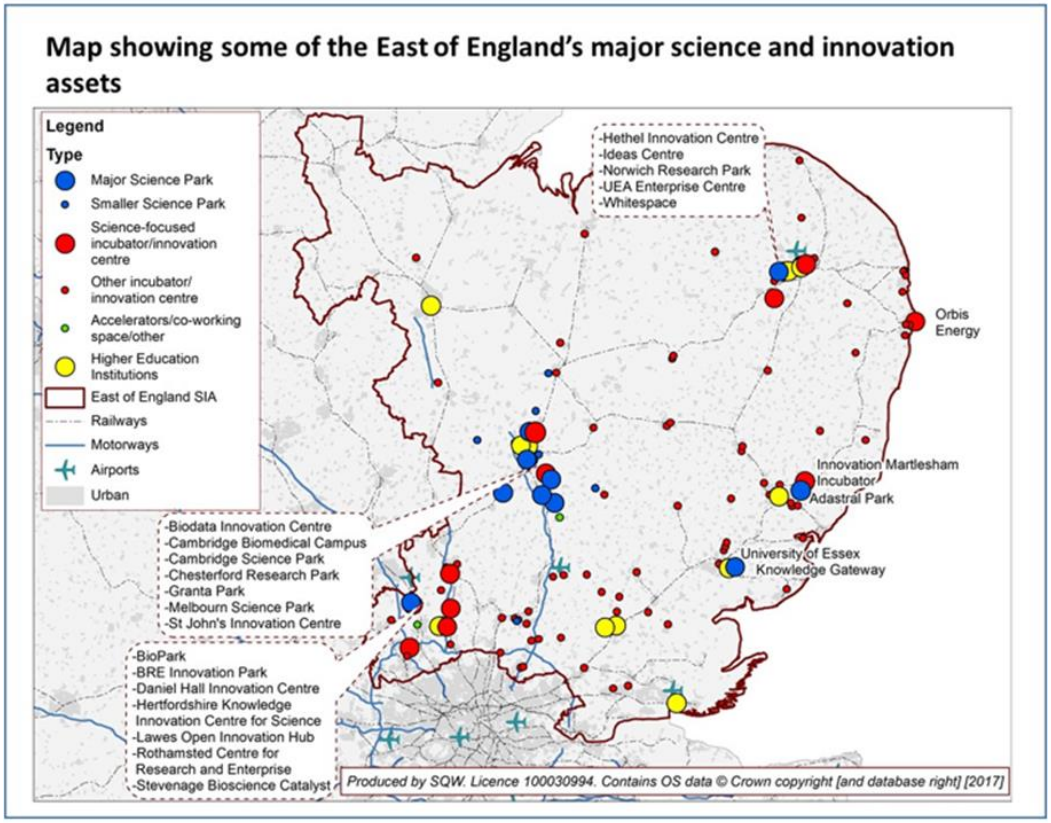
"The East of England Science and Innovation Audit has been a really significant piece of work creating a core data set on which an ambitious ' industrial strategy' can be formulated; its importance especially for the life-science sector cannot be overemphasised. What it reveals is a deep, vibrant and concentrated cluster with determined intent to translate world class research into products and services that will ensure sustained global impact. The connected nature of this ecosystem makes it a key engine of growth for the UK economy: delivering science into protectable and investable ventures, propelling quality start-ups to scale-ups and accelerating ambitious scale-ups to be the independent global players of the future; and with additional direct benefits for the health of UK patients. It is perhaps at its most exciting at the interfaces where biology combines with the physical sciences, where medicine melds with data science and where entrepreneurs and investors interact openly with uncompromisingly excellent researchers. The output of the Audit is impressive but the true asset is its people and here it only hints at future potential that this talent pool can create".

Dr Andy Richards CBE
Life-science entrepreneur and investor

Introduction

In Autumn 2015, the UK Government announced regional Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential.

The East of England[1] – defined in relation to four Local Enterprise Partnership geographies[2] – is home to some of the UK's **foremost scientific research strengths** and **innovation capabilities**. These are vested in a dynamic private sector and across world class universities and research organisations. They are being animated through more-or-less formal networks (of entrepreneurs, investors and researchers) which are now well-established within a distinctive and world class **innovation ecosystem**.



The immediate focus of our SIA is **four Themes**: **Life Sciences, Agri-tech, Advanced Materials and Manufacturing (AM&M) and ICT**[3].

From within these Themes, the region has grown some of the world's most influential businesses – ranging from ARM Holdings and HP Autonomy to MedImmune. It also continues to attract substantial investment in *"the next generation"* of early stage businesses: it is, for example, estimated that over £500m has been invested in Life Sciences companies on Babraham Research Campus over the last two years alone. In addition, the region is attracting the interest of the corporates. Major recent investors include Huawei, Google, Apple, Microsoft, AstraZeneca and Pfizer.

1 The East of England defined here is not the same as the (old) Government Office Region with the same name. Some data are only available at the level of GORs and where that is the case, tables/charts/maps are labelled accordingly

2 Greater Cambridge Greater Peterborough Enterprise Partnership; Hertfordshire Local Enterprise Partnership; New Anglia Local Enterprise Partnership; and that part of South East Local Enterprise Partnership which is north of the River Thames

3 These were chosen because they were considered by the Consortium to be particular strengths of the East of England that might usefully be examined through the Science and Innovation Audit. The case for them was made in an Expression of Interest and supported by BEIS

However our Audit is not just about individual Themes. Instead, it is about the opportunities which are unlocked by processes of convergence. As one of well over 200 stakeholders that contributed to our Science and Innovation Audit explained:

> *"I believe the active investors here – who are coming from all over the world – are investing in artificial intelligence, big data software, machine learning and then into the life sciences, bioinformatics and medical technology, and bringing it all together"*
>
> *"The focus here, in the universities and in the business communities, on artificial intelligence, machine learning and robotics, combined with genetics and genomics, presents huge possibilities. Connecting that up in a small place like this could be dramatic"*
>
> *East of England SIA stakeholder consultations, March/April 2017*

Our Vision

We will build on our position as the leading UK region for science and innovation for the benefit of people within the region, the UK and internationally.

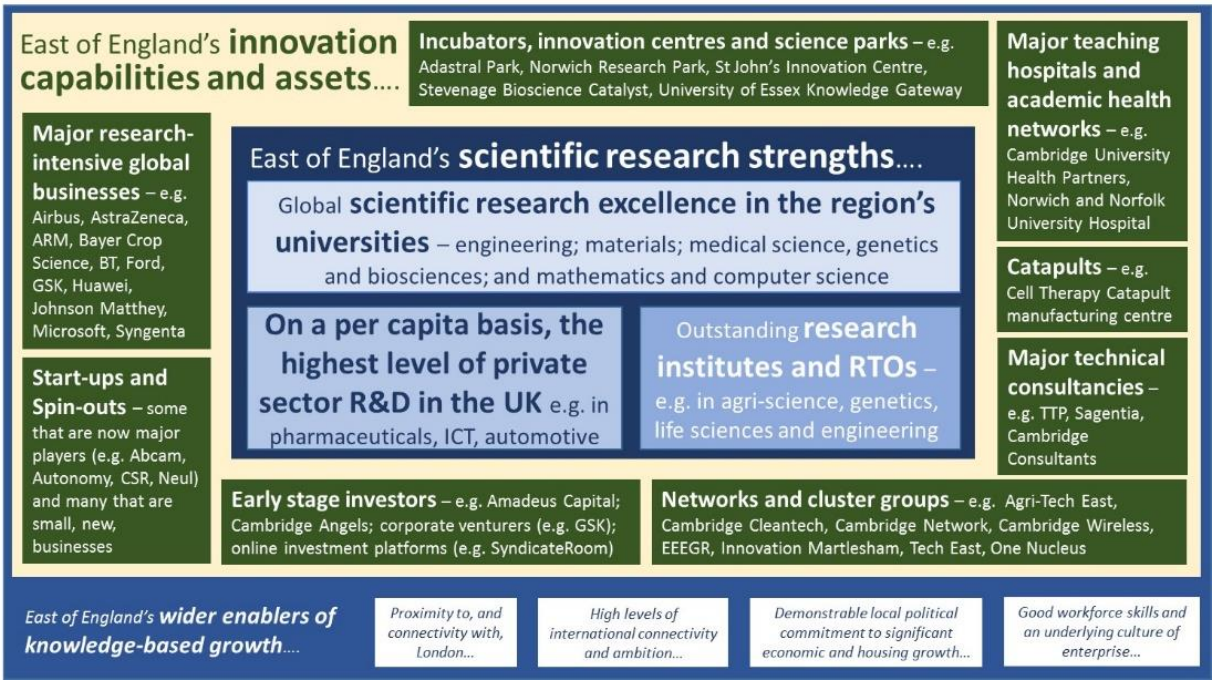
We will achieve this by **accelerating the process of convergence**. Already open innovation is a defining feature, but remaining boundaries between disciplines and institutions will dissolve. Researchers, entrepreneurs and investors – and, in Life Sciences, clinicians – will work alongside end-users (whether patients, industry or customers) on a daily basis. This will **enable and accelerate a process of translation, which will be fuelled – across the piece – through the creative and extensive use of data**. The outcomes will be economic impacts of national significance – and societal benefits that will be enjoyed worldwide and will, literally, be life-changing.

Our strengths

Our Vision is ambitious. However, it is entirely achievable. Our confidence is founded on the strength of our scientific capabilities and innovation assets. **These are impressive when considered individually, but they are outstanding when placed in the context of our innovation ecosystem as a whole**. Some of the building blocks within this are set out in the graphic below. But the "blocks" are less important than the "wiring" – literally, what "makes the whole greater than the sum of the parts".

This is defined, first and foremost, by the **people working within and across our innovation ecosystem**. These people – whether researchers, entrepreneurs, investors or clinicians – constitute some of the world's best talent. They are our strongest asset, alongside the people working with and to them.

The East of England's scientific strengths and innovation capabilities which define the Innovation Ecosystem



Beyond this, particular strengths found **across our four Themes** include:

- **Our ability to both attract and grow talent**: Our universities generate a pool of outstanding graduates and post-graduates, many of whom are quickly employed within our innovation ecosystem, whether by major research-intensive private sector businesses (like GSK and BT); or within small, vibrant start-ups and spin-outs; or as entrepreneurs in their own right. At the same time, our businesses, research institutions, universities and hospitals provide a magnet for talented people from around the world.
- **The strength and depth of our networks:** Cambridge has been described by serial entrepreneur, Andy Richards, as a "*low risk place to do high risk things"*, mainly because of the nature of our informal and formal networks. Our places – such as Cambridge, Norwich, Colchester, Ipswich and Stevenage – are big enough to bring scale but small enough to ensure a depth of relationships with which large cities cannot compete. These are animated more formally and more broadly through outstanding networking organisations, some of which are now well established (e.g. One Nucleus, Eastern Academic Health Science Network, Cambridge Network, Cambridge Wireless, Agri-Tech East, Cambridge Cleantech) whilst others are quickly emerging (e.g. Tech East, SyncNorwich, Innovation Martlesham). These complement each other and they provide invaluable connectivity across our innovation ecosystem.
- **Our ability to generate and attract investment:** Linked closely to the strength of our networks is the vibrancy of investment processes. Within the East of England, there is a growing body of serial entrepreneurs-cum-investors, who provide both early stage investment and a good deal of wisdom and know-how; effectively, they propagate both knowledge and wealth within the ecosystem. The region has its own cadre of locally-based angel investors and venture capitalists, and it also attracts a good deal of interest from the London-based investment community. Increasingly, the East of England is a destination for international investment, both through multinational companies (such as Apple, Google, Huawei) and through global investors.

- **Our support for highly innovative early stage business:** Our network of science parks, innovation centres, incubators and accelerators is second to none. It includes locations which are seen as exemplars around the world (e.g. Cambridge Science Park, St John's Innovation Centre, Norwich Research Park, Wellcome Genome Campus, Adastral Park); more recent ventures which have very quickly become recognised parts of the national innovation infrastructure (e.g. Stevenage Bioscience Catalyst, BioPark, Cambridge Biomedical Campus, Rothamsted Centre for Research and Enterprise (RoCRE)); and some very new and exciting ventures which are really still emerging (e.g. University of Essex Knowledge Gateway, University of Suffolk's Waterfront Innovation Centre, and Future Business Centre, Peterborough). In all cases, these are far more than property schemes. They are nurturing business, encouraging open innovation and providing a material input into the region's networking strengths described above.
- **Our industrial "lineage":** The history of our regional economy is not that of a manufacturing powerhouse, founded on 19th century technologies. This makes the region really quite distinctive. Our history in relation to intensive arable agriculture and horticulture, particularly on land that itself had to be reclaimed, conveys something of our ingenuity. Beyond that, our region benefitted from the growth of major knowledge-based businesses in the early 20th Century that have created an enduring legacy in terms of skills and aptitudes – aerospace in Hertfordshire and automotive in Essex are two examples. We have industries which are changing profoundly, but not in the sense of structural decline; restructuring processes are instead premised on knowledge, ideas and connectivity – core features of our innovation ecosystem.
- **Our locational advantages and international outlook:** The East of England abuts London to the south, and our relationships with London are increasingly strong ones. These are evidenced through flows of people, ideas and money – in both directions. They have been accelerated through major – and highly complementary – investments in London. The location of the Francis Crick Institute and Alan Turing Institute are especially notable in relation to our four Themes. The East of England has the physical capacity to commercialise knowledge to a level that London cannot, and this in itself is a substantial asset and strength[4]. In addition, we are well placed in terms of connections to Oxford and the wider Golden Triangle (infrastructure issues notwithstanding); and to the Midlands and North (on the East Coast Mainline, A1(M) and A14 especially). Crucially, we also have an exceptional location for international connectivity, through both ports and airports.
- **Our research assets:** The final piece in our innovation ecosystem relates to the depth and breadth of our research excellence which is, simply, outstanding. The UK Research Councils (BBSRC and MRC especially) and the major charities (notably Wellcome Trust and CRUK) have invested substantially in our research base. We are home to the Sanger Institute, the Babraham Institute, the Laboratory for Molecular Biology (LMB), the Earlham Institute, the National Institute for Agricultural Botany (NIAB), the John Innes Centre, Rothamsted Research and – from 2018 – the Quadram Institute (on Norwich Research Park). Across research fields that are absolutely germane to Life Sciences, Agri-tech and ICT, these are conducting world-leading research that is changing the way disease is understood and data are used, *and* they are enabling the two to be brought together to unlock world-changing possibilities. Alongside the research institutes are our universities. The University of Cambridge is consistently among

4 For a discussion of the relationship between the East of England and London in relation to science and technology see "*Mapping London's Science and Technology Sectors",* Final Report to the Greater London Authority by SQW, October 2015

the top 5 on worldwide university rankings and it has a huge depth of research excellence across all four of our Themes. The University of East Anglia, University of Essex, Anglia Ruskin University and University of Hertfordshire also all have world class specialisms, and they have been recognised in these terms in national comparative reviews, such as that conducted by Lord Witty. Finally, we would flag the scale, depth and excellence of the research conducted within our businesses: GSK, BT and Microsoft Research, for example, undertake prolific research, increasingly moulding the innovation ecosystem which surrounds them.

Growth opportunities

All four of the Themes which provided the focus for our Science and Innovation Audit are defined around growth opportunities in national and international markets. As "sectors", all four are relatively large on conventional metrics compared to UK averages, particularly at a sub-regional scale. Considered narrowly as "sectors", growth prospects are inconsistent. They are strong in Life Sciences, Agri-tech and ICT and more modest in relation to Advanced Materials and Manufacturing – although we consider AM&M to be of foundational importance to the other Themes (even if the pace of investment and growth is slower).

However, we are not identifying "growth opportunities" in linear sectoral terms. Instead, we are seeing them through the lens of our innovation ecosystem and its ability to adapt and respond to societal challenges and imperatives – both those that emerge through the market and those where government, in some capacity, intervenes. These growth opportunities are difficult to define very precisely, but they are real ones – and they are ones for which the East of England is uniquely well equipped because of accelerating processes of convergence within and across our innovation ecosystem.

This means that we can respond to and (to a degree) precipitate five overarching growth processes that are driving market opportunities in the UK and internationally, and which transcend individual technologies and sectors:

- **Cost savings and imperatives relating to productivity**: Among public sector service providers and across the private sector, there is a relentless imperative to reduce input costs. The adoption of robotics in Agri-tech will reduce the requirement for manual labour and the East of England is in the vanguard in terms of quickly-emerging responses. More generally, in the context of population growth worldwide, there is a need for more productive, nutritional and environmentally sensitive crops; new molecular techniques will be vital to achieving this, and through the work of organisations like the John Innes Centre, NIAB, Rothamsted Research and the University of Cambridge, the East of England is tremendously well-placed. In the healthcare domain, there are huge cost pressures of many different forms. In terms of preventing illness, the potential of the microbiome is enormous and – particularly on Norwich Research Park – the region has outstanding (and growing) assets. Future screening programmes could well rely on innovation in the region in the sphere of medical devices; Cambridge-based Owlstone Medical, for example, is developing a breathalyzer for disease with the overall mission of saving 100,000 lives and $1.5bn in healthcare costs.
- **Precision, stratification and personalisation**: Linked fundamentally to the imperatives for cost savings and efficiency is a raft of different opportunities relating to precision and personalisation. Through Agri-tech, the region is well-placed to apply, and benefit from, new technologies in precision and smart agriculture, including the application of robotics, sensors and diagnostics to increase the efficiency, speed and precision of applying fertilizers and pesticides, and of harvesting. There are also substantial opportunities in the Life Sciences. Many diseases are much better understood now than they were two decades ago (in part because of the impact of the human genome project in which Cambridge-based scientists

played a crucial role) and this is unlocking substantial advances in personalised medicine. Our innovation ecosystem is world-leading in this context, partly because it has been able to bring together fundamental medical research (including in relation to cell and gene therapy) with the possibilities of data, the day-to-day interests of clinicians and – increasingly – the potential linked to medical devices. The result is huge advances in stratified and personalised medicine and far more effectively tailored treatments. These are improving health outcomes and they represent a substantial opportunity across global healthcare markets which are growing quickly. There are challenges too – not least regulatory ones – but the region's innovation ecosystem is uniquely well positioned to respond.

- **Cleaner and resource-efficient solutions**: A third overarching opportunity relates to the imperative for solutions that are environmentally efficient. Again, this manifests itself in many different ways. The East of England is a dry region and innovative Agri-tech businesses are finding ways to reduce the use of water in commercial agriculture and horticulture. The East of England is also a fast-growing region and substantial house building is planned. In this context, there is an imperative for far more sustainable building materials and approaches to construction; again, the region has world-leading expertise and solutions are ensconced within the AM&M Theme (through, for example, Hertfordshire-based BRE). Also within AM&M are the region's substantial capabilities linked to offshore renewable energy. All of these different elements are regional strengths which are genuine assets because of the wider market opportunities linked to them.
- **Disruption**: We consider that there are exciting possibilities linked to disruptive innovation. By its nature this is unpredictable and it will redefine markets, creating substantial opportunities in the process. Our innovation ecosystem has a depth of research excellence and an increasing agility in applying it – through convergence – that will mean that we are uniquely well placed both to initiate disruption and to respond to it. The convergence of Life Sciences with all sorts of data analytics is starting to effect profound changes and the East of England's innovation ecosystem is leading the way. Numerous examples could be cited – from GSK's collaboration with Google to, for example, the Centre for Therapeutic Target Validation (CTTV, now called Open Targets), an open innovation consortium based on the Genome Campus at Hinxton which is committed to sharing data across the scientific community.
- **Global profile, confidence and "brands"**: Finally, we consider that there are growth opportunities that present themselves because of the global recognition that our innovation ecosystem has already generated. "Cambridge" is a global "brand" and a substantial asset in these terms. Equally, around the world, investors associate "Adastral Park" and "BT Martlesham" with pioneering research; "Babraham" and "Hinxton" are no longer (just) "villages in rural Cambridgeshire" but global shorthand for path-breaking Life Sciences research and the life-changing possibilities it creates; and "Norwich Research Park" and "Stevenage Bioscience Catalyst" are synonymous internationally with research excellence and open innovation. Add to this both key individuals (e.g. Hermann Hauser) and companies (e.g. ARM, GSK and AstraZeneca) and the strength of the region's brands is simply phenomenonal. This is not marketing spin, but a source of global profile and confidence. And this in itself is creating growth opportunities. Crucially, it represents a further stimulus for the growth of the region's innovation ecosystem.

Gap analysis

At the start of the Audit **two overarching challenges** were, however, identified – **commercialisation** and **collaboration**. Through the Audit, these were examined rigorously. Four Theme-specific hypotheses were tested through both primary research and secondary evidence, and in all four cases, the hypotheses were supported. **To continue to be world-leading, the challenges must be addressed at the level of the East of England innovation ecosystem as a whole**.

Translation and convergence are – by definition – statements of "process". They are on-going, relentless and demanding, and the bar is set high and rising. The East of England is competing with the most effective ecosystems in the world – some of which are reasonably well known and understood (Silicon Valley, Boston (Massachusetts)) but many of which (particularly those emerging quickly in the Far East) are not. Against this backdrop, there is no room for complacency – or for local politics within the region, or for resourcing squabbles with UK Government. **The East of England innovation ecosystem is world-leading, but it needs to continue to evolve rapidly – and it must be empowered and resourced so to do**.

In accelerating translation and convergence, there are **four main "gaps"**. **These are defined with a view to the ecosystem's future evolution, not simply its current form**.

Unlocking investment in the process of convergence

The investment process is integral to the commercialisation journey and it is, by definition, risky. The innovation ecosystem in the East of England is better than most in terms of early stage investment; Cambridge, in particular, benefits from a vibrant local investor community, and it attracts the interest of investors world-wide. But the challenges are not "solved" and indeed, some are becoming more acute as the process of convergence accelerates.

The issues were noted particularly within the Life Sciences Theme – although they were also observed elsewhere. Open sourcing – and the use of big data – is a major driver of innovation and it is underpinning and accelerating processes of convergence. There are major opportunities relating, for example, to the convergence of clinical patient data, deep/machine learning, communication technology and connected medical and wellness devices, and the region has huge assets and capabilities in this sphere. However, the process of convergence may well not generate intellectual property in a form that can be easily protected through patents. For investors – who may be sector specialists with limited knowledge of convergence interfaces – this creates uncertainty and risk. Solutions need to be found.

Providing skills – particularly relating to data

Across all four Themes, there are major – and similar – skills shortages. The extent and nature of the challenge was summed up by one business consultee from within the AM&M Theme (in this case an automotive business):

> *"I would look beyond automotive. What are the most valuable skills going forward? Software skills, data management skills, automation skills, robotics, artificial intelligence, machine learning. Bringing users to new services through a smart compelling interface… There is a really hard set of computational skills to bring…"*

East of England SIA stakeholder consultations, March/April 2017

Digital technologies are pervasive. Their application is the essential underpinning of the innovation ecosystem. But without sufficient people who are "*educated in real computer science"*, innovation will falter and business growth will stall. The issues are acute already. Moreover, given the global nature of the higher-level skills pool, the risks linked to Brexit are obvious and immediate.

Enabling co-location and clustering

A third finding which was shared across all Themes surrounded the value – and innovation capacity – that is generated through co-location and clustering. Particularly in Life Sciences, there is much to be gained through physical proximity: silos need to be broken down and scientists from different disciplines need to work alongside clinicians, entrepreneurs, investors and patients on a daily basis. Tacit knowledge needs to be generated and shared, particularly against a backdrop of open innovation. Serendipity needs to be engineered.

These observations need, of course, to be contextualised – and they run up against various constraints. First, whilst much value can be generated through physical clustering, considerations relating to Green Belt are also important. Second – and related – even if land can be found, not everything can or should happen in the same physical space. Wider approaches to collaboration across the innovation ecosystem, some of them virtual, need to be developed.

Nevertheless, insofar as the strength of the East of England's innovation ecosystem rests with localised clusters in which proximity is central to translational processes, those clusters need to be equipped to grow appropriately. Equally, where there is *potential* for clustering around knowledge-rich assets (and a specific emerging opportunity is the new Quadram Institute in Norwich), appropriate physical provision should be made to unlock a future growth dynamic. The relationship between the innovation ecosystem and "place" is intrinsic and critical. It needs to be recognised fully in these terms such that the ecosystem as a whole can evolve optimally.

Increasing connectivity

Finally, the importance of connectivity must be acknowledged. Across a relatively large geographical region, the innovation ecosystem will not function well if connectivity (both within and beyond it) is poor.

This observation bites at various levels. At the most mundane, it is very important that broadband connectivity is consistently good. Anticipating emerging gaps in relation to the medium-term evolution of the innovation ecosystem, the issue of digital connectivity needs also to be considered at a more profound level. Looking ahead, data will be transformational across Life Sciences, Agri-tech and AM&M, and within the ICT sector itself. Huge volumes of data will need to be generated, captured, stored, protected, transmitted and used. The region needs a digital infrastructure that can cope – and, indeed, it needs a digital infrastructure that can help to realise the full transformative potential.

Key ambitions/proposals

Eight key interventions…

To start to fill these gaps, **eight key interventions** have been identified. These fall into two groups, reflecting their intervention focus and route to impact:

- three interventions are, in principle, **region-wide ventures which are concerned with building hard and soft infrastructures and capacities for sustained innovation**, particularly in relation to data
- five interventions are focused on **specific clusters and/or sectors with the aim of accelerating convergence and/or translation**.

All eight interventions are grounded in rigorous evidence and endorsed fully by the Science and Innovation Audit Steering Group (and its constituent members) and by GCGP's Science Innovation and Industry Council (which has overseen the whole exercise). The table below lists the interventions and provides a very brief description of them. It also shows how they map onto the principal "gaps" identified above.

Table: Priority interventions identified through the Science and Innovation Audit

Key "gaps" to be addressed in unlocking the full potential of the East of England's Innovation Ecosystem → Priority interventions…	Unlocking investment in convergence	Providing skills, particularly in data	Enabling co-location and clustering	Increasing connectivity	Brief description....
A: Building hard and soft infrastructures and capacities for innovation across the East of England					
Building Innovation Capacity	✓	✓			Cross-cutting venture to build innovative capacity, particularly among SMEs in the ecosystem
East of England Innovation	✓	✓		✓	Initiative to encourage technology transfer, particularly for SMEs outside the main clusters
Smart Enabling Technologies Testbed	✓			✓✓✓	Infrastructure project to achieve high speed and high capacity connectivity
B: Cluster and/or sector-specific ventures to encourage convergence and/or translation					
Centre for AgriFood automation	✓	✓		✓	Venture to provide a regional resource in automation, at Holbeach
MedTech Hubs	✓		✓✓✓		Project to accelerate the development of emerging Hubs and to build synergies
Microbiome Hub	✓		✓✓✓		Innovation Centre anticipating the opening of the new Quadram Institute, on Norwich Research Park
Precision medicine cancer ecosystem	✓		✓✓✓		Radical new approach to precision medicine, building on foremost science
Cell & Gene Therapy R&D Centre	✓		✓✓✓		Provision adjacent to the Cell and Gene Therapy Manufacturing Centre, at Stevenage Bioscience Catalyst

…plus a wider response in relation to crucial skills issues

Alongside the eight interventions, there is an overarching requirement to address **major issues relating to skills – particularly those relating to data science and computer science**. The Audit found shortages across all four Themes – and the scale of the problem is such that unless addressed, it will stymie business growth.

Partners within the East of England are already seeking to address the surrounding issues. But whilst local initiatives and a series of bilateral arrangements between individual businesses and HEIs/FECs are important, they are unlikely to be sufficient, particularly given the systemic nature of the challenges. At this stage, we do not have a fully developed "solution" (and hence there is no specific intervention/business case), but we are committed to working towards one, preferably in dialogue with government.

…within an overarching commitment to the East of England's innovation ecosystem

The eight interventions – and the more systemic skills project – will all need to be delivered as part of a wide-ranging and long term commitment to the East of England's innovation ecosystem, both from within the region and from UK Government. Regional partners are fully committed to seeing this through. It is important, also, that a partnership is formed with UK Government to drive the wider venture forward. Across the East of England's world class innovation ecosystem, much will be achieved as a result.

Networking/collaboration

The East of England's innovation ecosystem is defined around networking and collaboration – and much evidence of this is presented within our main report. The process of completing the Science and Innovation Audit has put this under the spotlight – and helped further to build on it.

…networking/collaboration within the region

The East of England is a big region. However we benefit from highly effective networks which are central to all four of our Themes. None of these map directly onto the "East of England" in a rigid, boundary-driven, sense and nor would we expect them to: some are localised around specific geographical clusters, while others have a broader geography which extends across boundaries to follow functional economic footprints. This fluidity and flexibility is what makes them work.

Key networks which are of crucial importance to our Themes and have a strong regional footprint include, *inter alia*:

- in **Life Sciences** – One Nucleus, Eastern Academic Health Science Network, M11 Health Enterprise Forum, and MedCity
- in **Agri-tech** – Agri-Tech East, the Eastern Agri-tech Growth Initiative, FramFarmers and Anglia Farmers Network
- in **AM&M** – East of England Energy Group (EEEGR), New Anglia Advanced Manufacturing and Engineering (NAAME), and a series of Manufacturing Clubs (e.g. St Neots, Huntingdon, Peterborough)
- in **ICT** – Cambridge Wireless, Tech East and SyncNorwich.

In addition, there are some key regional networks that are cross-sectoral in character. Two important examples are Cambridge Network and Cambridge Cleantech.

As well as more-or-less formally constituted networks, there are numerous examples of collaboration within the region; indeed, these are integral to our whole innovation ecosystem and they are reported throughout our Science and Innovation Audit report. There are many examples of individual companies collaborating with one or more of the region's universities; BT, for example, works with the University of Essex, University of Cambridge and University of East Anglia.

But more than that, we are seeing growing levels of collaboration across parts of the innovation ecosystem that a decade ago would have been quite separate. One very important example is the growing depth and scope of relationships across Life Sciences between hubs in Cambridge and along the A1(M) Corridor. Stevenage Biomedical Campus is located on the site of GSK in Stevenage and it has pioneered approaches to open innovation; a research team from the University of Cambridge is located on site. GSK itself is very active in various initiatives based on Cambridge Biomedical Campus.

It is engaged in many different collaborative research projects, not least with the European Bioinformatics Institute (EBI) and Wellcome Trust Sanger Institute. Heptares – a spin out from the Laboratory of Molecular Biology (on Cambridge Biomedical Campus) – was initially based at BioPark (in Welwyn Garden City) before moving to Granta Park (near Cambridge), in part because it had out-grown BioPark and in part because it entered into major collaborative agreements with AstraZeneca and MedImmune. There is therefore a very substantial underpinning of local collaboration across the innovation ecosystem; much of it is "hidden from view" and difficult to measure but it is, nevertheless, central to its functionality.

…networking/collaboration across the UK

Businesses, universities and research institutions – and the individuals that run them – are engaged in significant networking and collaboration at a national scale.

Amongst the more formalised examples are:

- in **Life Sciences** – the BioIndustry Association, and the network of Catapults (noting that the Cell and Gene Therapy Catapult's advanced manufacturing facility is being developed at Stevenage Biomedical Campus).
- in **Agri-tech** – collaborations across BBSRC's Research and Innovation Campuses – which span Life Sciences and Agri-tech – recognising that of the five that exist nationally, three are in the East of England (Babraham Research Campus, Norwich Research Park and Rothamsted Centre for Research and Enterprise); and a substantial interest in the national network of Centres for Agricultural Innovation (Agrimetrics, Centre for Crop Health and Protection (CHAP), Centre for Innovation Excellence in Livestock (CIEL) and Agricultural Engineering Precision Innovation Centre (Agri-EPI)).
- in **AM&M** – engagement in national networks and associations, such as the Engineering Employers Federation and the Motorsport Industry Association. Again, there are extensive links across the national Catapult network; OrbisEnergy, for example, works closely with the Offshore Renewable Energy Catapult. In addition, the national Association for Innovation, Research and Technology Organisations has strong representation in the East of England including, for example, from TWI and BRE, both of which work across the UK (and internationally).
- in **ICT** – national research collaborations which are intrinsic to our region. For example, the University of East Anglia, University of Essex and the University of Kent joined forces to form the Eastern Academic Research Consortium (Eastern ARC), a significant new force in research collaboration and training. Our businesses such ARM, BT, Google and Huawei have extensive research networks with universities and industry across the UK.

In addition, we consider that the East of England's innovation ecosystem is an engine of enterprise which benefits the UK as a whole. There are many examples of companies which have emerged from the region's innovation ecosystem but have based some or all of their down-stream production activities elsewhere in the UK, generating jobs in other regions. One example is Raspberry Pi which was formed in Cambridge in recognition of the need to build interest and expertise in fundamental computing skills; it is working with Sony's manufacturing plant in Pencoed, South Wales, to manufacture its boards. Another example is Metalysis. Its expertise derived from within AM&M in the East of England, and it is now creating jobs in Yorkshire.

Case study of Metalysis – a company created from the East of England's innovation ecosystem and now generating jobs elsewhere in the UK

Metalysis is a company that is based in South Yorkshire. It is commercialising a revolutionary process for the cleaner/greener, more efficient production of metal powders.

The process was invented by Prof Derek Fray's research group in the Department of Materials Science and Metallurgy at the University of Cambridge. The FFC (Fray, Farthing and Chen) process is based on a solid state reduction process that takes place at a lower temperature and requires less energy than conventional methods of metal production. Details of the process were initially published in 2000, and early development work was undertaken in Cambridge.

Metalysis was set up to commercialise this game changing technology. Although initially operating in the Cambridge area, Metalysis moved to one of the UK's areas of primary metal production, South Yorkshire, in 2005. It has grown subsequently and now employs around 65 people. It is an example of the East of England's innovation ecosystem creating employment elsewhere in the UK.

(Source: Based on evidence provided to the East of England Science and Innovation Audit)

…networking/collaboration around the world

The region's innovation ecosystem is intrinsically networked internationally. It draws in the best international talent and it is attracting international investment of many different forms. There are many specific examples of international networking and collaboration. These include:

- in **Life Sciences** – substantial international networks, some of them animated through One Nucleus (e.g. links to BioJapan). There are also many examples of international inward investment (e.g. the establishment of the Spanish firm, Aglaris, at Stevenage Bioscience Catalyst) and collaborations (e.g. the US firm, Biogen, is one of the major partners in the collaboration with GSK, EBI and the Wellcome Trust Sanger Institute linked to open data).
- in **Agri-tech** – many international research collaborations in which the region's universities and research institutes are involved. For example, the John Innes Centre has formed a partnership with two institutes of the Chinese Academy of Sciences to establish the Centre of Excellence for Plant and Microbial Science (CEPAMS) in Shanghai, and Rothamsted Research has collaborations in more than 58 countries and collaborative Centres in China, India and Brazil.
- in **AM&M** – significant international collaborations, some of them facilitated by Horizon 2020 (or before that, Framework Programme 7). One example is ECOWindS (European Clusters for Offshore Wind Servicing). In addition, Research and Technology Organisations like TWI and BRE are operating across the world.
- in **ICT** – significant international inward investment, much of it following earlier collaborations. Examples include Huawei's acquisition of Cambridge-based Neul and the Centre for Integrated Photonics at Adastral Park; and Apple's acquisition of VocallQ.

How the process of the Science and Innovation Audit has itself added value

The different forms and processes of networking and collaboration outlined above are well established and on-going, and they are integral to the mechanics of the East of England's innovation ecosystem. They are also the motive force in relation to the accelerating process of convergence – and it is that process which defines, fundamentally, our assets, our opportunities and our vision.

All of this has been given additional focus and impetus through the process of the Science and Innovation Audit in early 2017. Its added value has been recognised and applauded across the region. It has included, specifically:

- the dialogue between key investors, entrepreneurs, scientists and businesses from across Life Sciences which has been further energised through six round table events/workshops involving well over 100 stakeholders
- the insights generated through the two-day Hot House which was organised by BT at Adastral Park to define opportunities relating to the use of data and as part of the ICT Theme
- a re-energised dialogue between four Local Enterprise Partnerships focused specifically on the opportunities relating to science and innovation
- links to the Wave 1 Midlands Engine SIA (principally through the contribution of Cranfield University to our process) and to the Wave 2 Innovation South SIA (as South East LEP has been part of both the Innovation South consortium and that for the East of England)
- an on-going dialogue with other Wave 2 SIA consortia, notably those in Leeds City Region (around medtech) and Oxfordshire (particularly in relation to satellite applications and their links to Agri-tech); and in relation to the Offshore Energy SIA.

Department for Business, Energy & Industrial Strategy

GLASGOW ECONOMIC LEADERSHIP

Scottish Enterprise

Glasgow CITY COUNCIL

Forewords

Foreward from the Chair of Glasgow Economic Leadership **Professor Sir Jim McDonald**

The Central Belt with its major cities of Glasgow and Edinburgh is Scotland's main population centre - a compact and connected innovation region which is home to some of the UKs most research–active universities and to a growing translational infrastructure focussed on responding to market demand and anticipating disruptive change.

Scotland's challenge, recognized by the Economic Strategy of Scottish Government, is to achieve substantial increases in productivity, exports, and job creation. This audit focusses on the Enabling Technologies Sector in Scotland, its potential to accelerate young companies – particularly in photonics and quantum sensing - and its potential to produce step changes in the productivity of the manufacturing base and in the management of key infrastructure assets such as the power grid and our water network.

The Enabling Technology sector is relatively small in the Scottish Economy producing 1% of GVA, but it produces 10% of Scottish exports and invests 25% of Scottish BERD. Our regional innovation system has developed remarkably over the last 15 years, from research pooling to innovation centres, Fraunhofer and Catapults, creating a young but effective Triple Helix support structure.

With further investment this system can build a vibrant internationally competitive photonics and quantum sensing cluster. Through Technology Integration our Enabling Technology sector can help the digital transition of manufacturing in highly specialised application areas including Forming and Forging, and Industrial Biotechnology, creating thousands of jobs. And it can support our Infrastructure sectors – particularly energy - to make big performance improvements through sophisticated sensing and control systems.

The outcomes of this report, written with the support of Scottish Enterprise, are fully aligned with the Scottish Government economic strategy and its Manufacturing Action Plan. This report gives strong support to the creation of the National Manufacturing Institute for Scotland, and highlights a set of exciting growth opportunities for manufacturing and services in Scotland and through the UK.

Foreward from the Chair of Technology Scotland **Dr Allan B Colquhoun**

Technology Scotland has been deeply engaged with the development of this Science and Innovation Audit. The Audit report has identified the strengths of our Enabling Technologies cluster including its contribution to exports and Business Investment in R&D, its strong links to the excellent research base, and the benefits of investment in links between industry and research. Most importantly the report seeks to start a process to create the environment for a step change in the growth of our Enabling Technology companies and help drive the digital transformation of our manufacturing and infrastructure sectors. The Audit has set out opportunities and actions which will help our sector companies individually and collectively and Technology Scotland will play its part in building on this exciting collective vision.

About Us

This audit has been undertaken by a consortium that brings together a unique combination of research strengths and expertise in the field of enabling technologies, coupled with strong economic leadership, support and direction. The consortium is led by Glasgow Economic Leadership[1] and includes Glasgow City Council, Scottish Enterprise, the Universities of Strathclyde, Glasgow, and Heriot-Watt, NPL Scotland, Fraunhofer Centre for Applied Photonics, Technology Scotland, and the Scottish Innovation Centre for Sensors and Imaging Systems (CENSIS).

1 http://glasgoweconomicleadership.com/

Introduction/Context

In autumn 2015 the UK Government announced regional Science and Innovation Audits (SIAs), to catalyse a new approach to regional economic development. SIAs enable consortia to focus on analysing regional strengths and identify mechanisms to realise their potential. In the Central Belt of Scotland a consortium was formed to focus on our strength in enabling technologies. This report presents the results which includes broad-ranging analysis of the Central Belt of Scotland's capabilities, the challenges and the substantial opportunities for future economic growth.

The Region

The Central Belt is by far the most important economic, employment and innovation region in Scotland, with a concentration of high value, highly skilled jobs, but productivity (both for the Central Belt and Scotland more generally) is not as high as it could be.

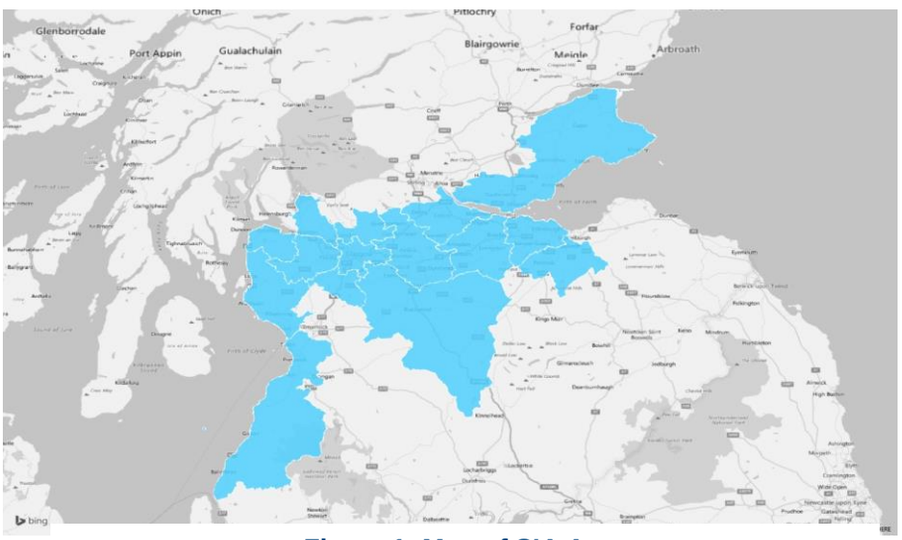


Figure 1: Map of SIA Area

Business investment in research & development (BERD) is recognised as a leading indicator of future productivity. Scotland's general BERD performance is only around 60% of the UK average (where BERD is measured as a proportion of GDP), and BERD within manufacturing (a significant sector for Scotland) also lags the UK average[2].

The Scottish Government has recognised the need to boost productivity to ensure long term growth within the manufacturing sector – and a key means of achieving this will be the adoption of innovative enabling and emerging technologies.

Enabling Technologies

There are many accepted definitions of enabling and emerging technologies, but essentially they can be defined as technologies that improve productivity and efficiency in existing industries, and new technologies that could have significant commercial impact. We believe that by their very nature, these are the key to unlocking productivity improvements, accelerating the UK's global competitiveness, and increasing exports. In this report, reference to "enabling technologies" can be taken to mean any combination of the following, applied in an industrial setting: quantum; sensors, sensor systems and photonics; electronics; robotics and autonomous systems; industrial biotechnology; advanced/smart materials; software and data analysis; communications including satellite; and monitoring and control.

2 A Manufacturing Future for Scotland, Scottish Government

Our Vision

To capitalise on the full range of opportunities the enabling technology sector has to offer our Audit considers how existing and new enabling technology companies in the Central Belt can be developed, accelerated and anchored. Our main focus is on high growth enabling technology companies, and our expertise in the creation and application of photonics and quantum enabled devices.

Within Scotland, both manufacturing and infrastructure are large sectors in terms of turnover and output. However, our manufacturing sector in particular demonstrates relatively low BERD and exports. Our audit considers how, through the adoption and integration of enabling technologies, there is scope to deliver a step change in productivity and competitiveness.

Broader Context

Our vision is in keeping with the Scottish Government's economic strategy and addresses several themes within the Manufacturing Action Plan for Scotland which was launched in 2016. It also aligns with Glasgow's Economic Strategy 2016-2023[3], which aims to make Glasgow the most productive major city economy in the UK through a focus on key sectors, innovation and productivity.

At a UK level, our vision addresses several of the principles and areas of focus outlined in the UK Government Industrial Strategy Green Paper, particularly the "balancing productivity" agenda across UK regions.

The UK National Infrastructure Commission (NIC) will explore which emerging technologies have the most potential for improving infrastructure productivity, and we expect that at least some of the NIC's findings, as yet unpublished, will endorse our vision.

3 https://www.glasgow.gov.uk/CHttpHandler.ashx?id=36137&p=0

Key Strengths

The Central Belt excels in terms of research quality and intensity in subjects that support enabling technologies, and also in successfully exploiting these technologies through the creation of new companies[4].

The Central Belt's universities have a research base of exceptional quality, with an average research power that is 20% higher than the UK average. The Research Excellence Framework (REF2014) shows the audit area demonstrates a particular concentration of excellence and power in those subjects that are most relevant to the enabling technologies.

Table: Key Enabling Technology strengths by University

Technology Area	University					
Photonics	University of Edinburgh	University of Glasgow	Heriot Watt University		University of St. Andrews	University of Strathclyde
Micro/nano electronics	University of Edinburgh	University of Glasgow				University of Strathclyde
Advanced materials	University of Edinburgh	University of Glasgow			University of St. Andrews	University of Strathclyde
Industrial Biotechnology	University of Edinburgh	University of Glasgow	Heriot Watt University			University of Strathclyde
Advanced manufacturing	University of Edinburgh	University of Glasgow	Heriot Watt University			University of Strathclyde
Nanotechnology	University of Edinburgh	University of Glasgow	Heriot Watt University	Napier University	University of St. Andrews	University of Strathclyde

Source: Analysis conducted by Scottish Enterprise in 2015

In addition to the Central Belt's discrete strengths within these disciplines, REF2014 also shows that our HEI's demonstrate a 15-year track record of successfully collaborating in order to achieve greater research excellence and greater international competitiveness.

We also have a unique set of translational assets that are already creating economic impact at regional, UK and international level.

Table: Key translational assets by technology area

Technology Area	Key Translational Assets		
Photonics	Fraunhofer Centre for Photonics	James Watt Nanofabrication Centre	LiFi Research and Development Centre
Advanced Sensors	CENSIS	QuantIC	
Micro/Nano electronics	James Watt Nanofabrication Centre	Scottish Microelectronics Centre	
Advanced Materials	Thin Film Centre University of the West of Scotland		
Industrial Biotechnology	IBioIC	Scottish Association for Marine Science	James Hutton Institute
Advanced Manufacturing Technologies	Advanced Forming Research Centre	Continuous Manufacturing and Crystallisation	Centre for Innovative Manufacturing in Innovative Manufacturing in Laser-based Production Processes
Nanotechnology	SAFENANO		

4 Examples of relevant company spin-outs from Edinburgh, Glasgow, Heriot Watt & Strathclyde provided in Appendix B.

There are around 400 companies engaged in enabling technologies in Scotland, employing in the region of 15,000 people with around 90% of these based within the audit area. This strong company base is a significant contributor to Scottish research. It represents 17% of all Scottish R&D spend, and has a world class BERD figure of £200M (5.0% of turnover). Analysis conducted by Scottish Enterprise breaks this down further by key technology areas[5].

Table: Employment and economic data for key technology areas in Scotland

Technology Area	GVA Estimate (£M)	Employment Estimate	Companies
Photonics	300	4,000	45
Advanced Materials	180	3,000	40
Micro/nano electronics	250	2,500	45
Industrial Biotechnology	61	1,100	43
Nanotechnology	20	200	10

Source: Analysis conducted by Scottish Enterprise[6]

Growth Opportunities

The data collected during this audit strongly supports our vision, demonstrating that:

- There is an opportunity to develop a high growth cluster of enabling technology companies within our audit area, based around the consortium's assets.
- These companies, with expertise in the provision of high quality, premium price services to end user companies, have the potential to create new supply chains for Industry 4.0, underpinned by advanced sensing, measurement and manufacturing technologies.
- The consortium's engineering and physics based research excellence in measurement science provides an opportunity to accelerate the audit area's emerging company base in photonics and quantum enabled devices, which has the potential to be globally recognised.
- The audit has helped substantiate our assertion that there is potential to capitalise on the adoption and integration of enabling technologies to markedly increase productivity in the manufacturing and infrastructure sectors.

5 Smart Specialisation: Scotland's Key Enabling Technologies, Scottish Enterprise Report, 2014

Gap Analysis

The Central Belt has strong and relevant research base assets, a collaborative ecosystem that is mature compared to most UK regions, and a unique set of translational assets. However, we have identified several gaps in our innovation landscape, which need to be addressed if the Central Belt is to deliver the types of productivity gains we hope to achieve from the growth opportunities noted above. These gaps are:

- **Technology Integration Facilities**

Within the region there needs to be a better understanding of the range of support mechanisms available, alignment of goals, and the ability to take a sector-agnostic, end-to-end system level approach to addressing industry problems, as identified by Innovation Centres in the region[6]. Significant investment is therefore required in more industry-led *technology integration* facilities that work across traditional sector boundaries. This will ensure that we have the ability to rapidly identify and link developing technologies (at TRL 3-5) and trial these in pre-competitive environments, in order to accelerate productivity gains for relevant sectors.

- **Technology Demonstration Facilities & Larger Scale Test Beds**

Existing demonstrator facilities need additional infrastructure to support the diversifying demand-led needs of industry, with no demonstrator facilities available in some sectors [7]. Significant investment is therefore required to create new and extend existing *sector-specific technology demonstration facilities.* These would focus on technologies at a more developed stage of readiness (TRL's 5-8) so that industry sectors such as manufacturing and infrastructure can demonstrate, prototype and validate new technologies in a realistic setting and scale.

- **Developing and maintaining appropriate skills**

Underpinning any successful economy is its skilled workforce. Indeed the main barrier to the increased adoption of enabling technologies is likely to be the skill set of the workforce, without which growth will be vulnerable to stalling.

- **Stimulation of the Scottish Investment Market with International Risk Capital**

Attracting UK or International specialist investors with a focus on the types of emerging, growing companies we focus on in this audit would markedly assist the long term economic productivity and international competitiveness of the audit area.

6 See Appendix C for further feedback from key Translational Assets.

7 See Appendix C for further feedback from key Translational Assets on challenges and barriers that they face when trying to support industry demand.

Key Ambitions/Proposals

The technologies we focus on in this report have the potential to act as enablers across every single one of the UK's 8 Industrial Strategy challenge areas[8]. They will assist in closing the overall productivity gap (between high performing UK based industries and their less productive counterparts, and also between the UK and substantially more productive countries such as France and Germany – where niche industrial manufacturing positively thrives).

We envisage, with the investments noted above driving the pervasive adoption of enabling technologies, and with the full benefits of Industry 4.0 adopted by manufacturers, it would be possible to achieve a 3.0% per annum ongoing increase in productivity within our manufacturing sector, which if sustained would represent an effective doubling of our existing productivity levels. This is further supported by a recent SAS report that indicates that the application of Bid Data and the IoT within the UK could result in a 2.7% per annum increase in GDP[9].

In relation to infrastructure, we believe the deployment of the latest enabling technologies, providing smart electric grids, smart water and sewage networks and smarter buildings, for example, can lead to a step change in productivity, such that a similar 3% target is ambitious but achievable.

Due to the overall size and structure of the Central Belt's economy, an equally important prize will be the accelerated development of clusters of high growth companies. Significantly growing the size of the enabling technologies sector will be a challenge, but the opportunity is clear. We believe there is realistic scope to double the size of our enabling technologies company base over the next 10 years in terms of jobs, turnover and GVA, (effectively an average annual growth rate of 7.2%), and in doing so, create a world leading position in quantum and photonic enabled devices.

- **High Value Technical Services**

This Audit has established that successfully developing the central belt's enabling technology capabilities and integrating those into widespread industrial applications will inevitably create opportunities for specialist companies to emerge. The offerings of such specialist companies and services will support the increased use of information and data intensive technologies by large, industrial end users. The trajectory of an emergent company base, that delivers high end enabling technology services, and supplies international markets, could be comparable to the growth of the offshore technical services industry in Scotland.

- **High Value Quantum- and Photonic-Enabled Devices**

The research base and translational assets of the Central Belt provide outstanding potential for the development of specialist companies creating new devices and products based on Quantum and Photonic technologies. The success of existing companies like Cascade Technologies Ltd, Coherent (formerly Microlase Systems Ltd) and MSquared Lasers Ltd, demonstrates that designing and "product-ising" such devices can provide a solid basis for sustained growth.

8 https://www.gov.uk/government/news/business-secretary-announces-industrial-strategy-challenge-fund-investments

9 https://www.sas.com/content/dam/SAS/en_gb/doc/analystreport/cebr-value-of-big-data.pdf

Key Proposals

The proposed interventions noted below will contribute significantly to accelerating industrial productivity in the audit area, with particular emphasis on manufacturing and infrastructure.

I. **Establishing headquarters and/or nodes of UK Catapult centres (or similar models) within the Central Belt.** If there are future UK Catapults in sensor systems/industrial data/digitisation (or investments backed by the industrial strategy challenge fund), the audit area would be well placed to fully exploit such opportunities and create economic impact. Other specific examples could include establishing a node of the Compound Semiconductor Applications Catapult or the Energy Systems Catapult within the audit area.

II. **Investing in the creation of a new and large scale systems integration centre, or "virtual foundry", to facilitate the rapid combination and testing of quantum and photonics technologies**. The resulting devices and systems being developed would combine capabilities in quantum and photonics with other enabling technologies in order to address opportunities and challenges identified by industry. We envisage this as a facility (or facilities) that would be co-invested (at the very least) by UK Research and Innovation (UKRI), and Scottish Enterprise.

III. **Co-investment by UK and Scottish Governments in the proposed National Manufacturing Institute for Scotland (NMIS), as part of the UK High Value Manufacturing Network.** The proposed Digital Factory 2050 (DF2050), positioned within NMIS, will provide a critical collaborative physical environment and proving ground for the demonstration, development and acceleration of cutting edge manufacturing technologies. Using advanced sensing, measurement, data acquisition and analysis systems, the DF2050 will demonstrate the concepts of Industry 4.0 in a practical, relevant and tangible way.

IV. **Further strategic investment to extend the scope and linkages of the existing Power Networks Demonstrator centre (PNDC)**. Such an investment would firmly anchor the PNDC facility within a bigger UK National Smart Energy Institute. Within this broader proposition, the PNDC would function as a critical hub for the UK's demonstration system for smart grid technologies, with a unique combination of academic and translational institutes, including the energy systems catapult.

V. **Creation of a scale-up demonstrator for Industrial Biotechnology processes.** This type of large scale facility would complement the Central Belt's existing academic assets and the Industrial Biotechnology Innovation Centre (IBioIC). It would demonstrate the feasibility of exciting industrial biotechnology developments across a variety of markets. It would also support the cluster of regional SMEs who are already working to realise Scotland's National Plan for Industrial Biotechnology, which targets a £900M turnover in Scotland by 2025.

VI. **Training and fostering entrepreneurial leaders**. These leaders will form start-up companies and lead their growth. The audit geography is rich in proven initiatives addressing this from the purely educational, such as Strathclyde's Hunter Centre for Entrepreneurship, to the relatively well developed enterprise support infrastructure such as the University sector's Enterprise Campus, Converge Challenge processes, and the Glasgow City Council's Tontine House accelerator.

VII. **Co-ordinate CPD type interventions to ensure we support our industry leaders.** The Central Belt plays a lead role in many UK Centres for doctoral training[10], providing an obvious platform for

10 Appendix E provides a summary of current CDTs that Consortia members are leading.

the higher-level, multi-disciplinary and industry-informed skills that will be vital for sustainable growth. However, it is important that this post-graduate training is balanced with continued professional development (CPD) type interventions to ensure we support our industry leaders, putting them in a strong position to deliver the step change in business performance and process required to fully capitalise on the opportunities set out in this audit.

VIII. **Development of complementary FE-based programmes.** Scottish Funding Council sees FE Colleges as a key component of the innovation system, and is working closely with the FE sector to enhance its role. An exemplar of this approach is the collaboration between the IBioIC and three regional FE Colleges to address the skills shortage within the Industrial Biotech sector. This could be extended across other relevant Innovation Centres.

IX. **Work-based learning programmes.** While the introduction of the Apprenticeship Levy has started driving training activity, there is a need to also change workplace and management culture to enable more sophisticated use of work-based learning programmes.

X. **Create funds specifically to provide access to the range of investment size that is currently problematic.** Early stage, growing companies within the Audit Region have limited access to investment capital in the range of £2M-£20M. The Scottish Investment Bank (SIB) has issued a tender for a review of the feasibility of a “secondary fund” to help maximise private sector investment into Scotland. To help realise the ambitions of the audit, the Audit Consortium will need to work with the region’s existing Angel Investment Syndicates, SIB and other UK Investors to ensure that routes to access such investment capital are opened and other funds raised, once demand is validated.

XI. **Link Consortium members more “intelligently” with global specialist VCs.** More needs to be done to identify and engage with sophisticated (lead and co-lead technology-specific) international investors. EIE (Engage Invest Exploit) is Scotland´s premier technology investor showcase. More EIE type activities could help to intelligently link growing companies with global specialist VCs investing in enabling technologies. There is also the potential for government agencies to co-develop a plan for promotion of the Central Belt as a hotbed of opportunity for investment in growth companies in enabling technologies.

VISION

- Double the size of our existing enabling technology asset base over the next 10 years
- Create an internationally recognised cluster of enabling technology growth companies in the Central Belt
- Use our enabling technology assets to increase productivity by 3% per annum within the manufacturing and infrastructure sectors

OPPORTUNITIES

- Develop a high growth cluster of enabling technology companies within our audit area, based around the consortium's assets.
- Create new supply chains for Industry 4.0, underpinned by advanced sensing, measurement and manufacturing technologies.
- Use research excellence in measurement science (particularly in quantum and photonics technologies), to accelerate emerging company base in photonics and quantum enabled devices
- Ensure adoption of enabling technologies acts as a positive catalyst on investment and productivity within manufacturing and infrastructure sectors.

GAPS

- Sector agnostic technology integration facilities – complete solutions
- Sector focused technology demonstration facilities
- Skills at all levels
- Financing

PROPOSALS

Sector agnostic technology integration facilities – complete solutions

- Establish headquarters and/or nodes of UK Catapult centres (or similar models) within the Central Belt
- Invest in the creation of a new and large scale systems integration centre, or "virtual foundry", to facilitate the rapid combination and testing of quantum and photonics technologies

Sector focused technology demonstration facilities

- Co-investment by UK and Scottish Governments in the proposed National Manufacturing Institute for Scotland (NMIS), as part of the UK High Value Manufacturing Network
- Secure further strategic investment to extend the scope and linkages of the existing Power Networks Demonstrator centre (PNDC)
- Create a scale-up demonstrator for Industrial Biotechnology processes

Skills – at all levels

- Training and fostering entrepreneurial leaders
- Co-ordinate CPD type interventions to support our industry leaders
- Development of complimentary FE-based programmes
- Work-based learning programmes

Financing

- Create funds specifically to provide access to the range of investment size that is currently problematic
- Link Consortium members more "intelligently" with global specialist VCs

Networking/Collaboration

The consortium delivering this audit brings together a unique combination of research and innovation strengths and expertise in the field of enabling technologies, coupled with strong economic leadership and economic development expertise.

The consortium, through its members, and working in partnership with industry, other HEIs in Scotland and the UK, and Government agencies, has the skills and assets to leverage real improvements in productivity and competitiveness, in the audit area and beyond. Consortium members have a track record over 10-15 years of creating translational assets in partnership with industry and Government that are already starting to demonstrate an impact on the Central Belt's productivity, and that are regularly cited as UK-leading in the context of impact. The collaborative ethos among the consortium members, other universities in the Central Belt, the Scottish Funding Council and key UK funders such as EPSRC, BEIS and Innovate UK is a distinctive feature that assists us.

Throughout the audit process we sought to engage with as many stakeholders as possible. Technology Scotland and Scottish Enterprise were essential in ensuring the range of diverse business and industry viewpoints were captured and integrated into the audit's findings and conclusions. Both these organisations, together with Scottish Funding Council, BEIS, UKRI, and most importantly of all our large cohort of engaged industry partners, will be essential in making the persuasive investment business cases we now need to make in order to secure the technology integrator and technology demonstrator assets identified in our gap analysis, which in turn will drive the 10 year plus vision that we have presented for the contribution of enabling technologies to UK productivity, driven from Scotland's Central Belt.

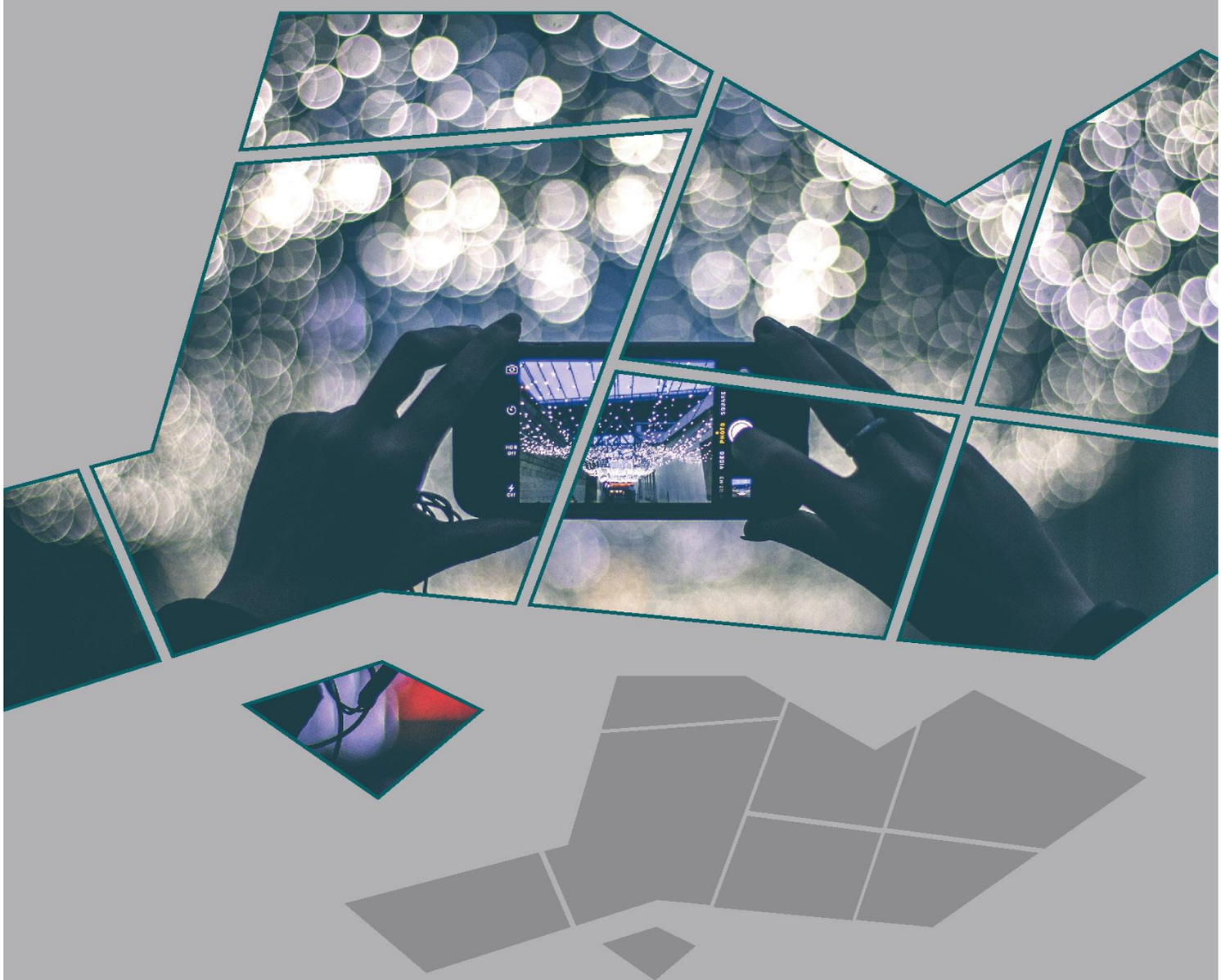
Finally, the outputs of our audit and the plans that we will implement subsequent to it, are directly complementary to the outputs of at least three other SIAs. Our findings complement the Edinburgh City wave 1 Audit in "Enabling a World-Leading Regional Digital Economy through Data Driven Innovation", by providing routes to *industrial* application and productivity via improved and pervasive use of industrial data and measurement. Our Consortium is already working with Edinburgh to ensure we capitalise on these synergies.

Our findings also complement the quantum elements of the wave 2 audits from Innovation South and Oxford. Our audit's findings focus on the potential in the Central Belt for rapid integration of quantum and photonic technologies with other enabling technologies (at relatively low TRLs 3-5) into prototype devices. Through our demonstrators, this will support major strides in technology adoption in industrial monitoring, process control, asset management, imaging/ visualisation and digital manufacturing (at higher TRLs 5-7). The same capacity for integration of quantum technologies into composite devices at low TRLs will also complement the Oxford audit's aspirations in respect of quantum computing and the Innovation South audit's aspirations in quantum supply chain.

INNOVATION SOUTH - A POWERHOUSE OF WORLD CLASS STRENGTHS IN DIGITAL ENABLING TECHNOLOGIES

A SCIENCE AND INNOVATION AUDIT REPORT SPONSORED BY THE DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY

SUMMARY REPORT
2017



Department for Business, Energy & Industrial Strategy

INNOVATION SOUTH
SWITCHING ON OUR FUTURE

1. INTRODUCTION

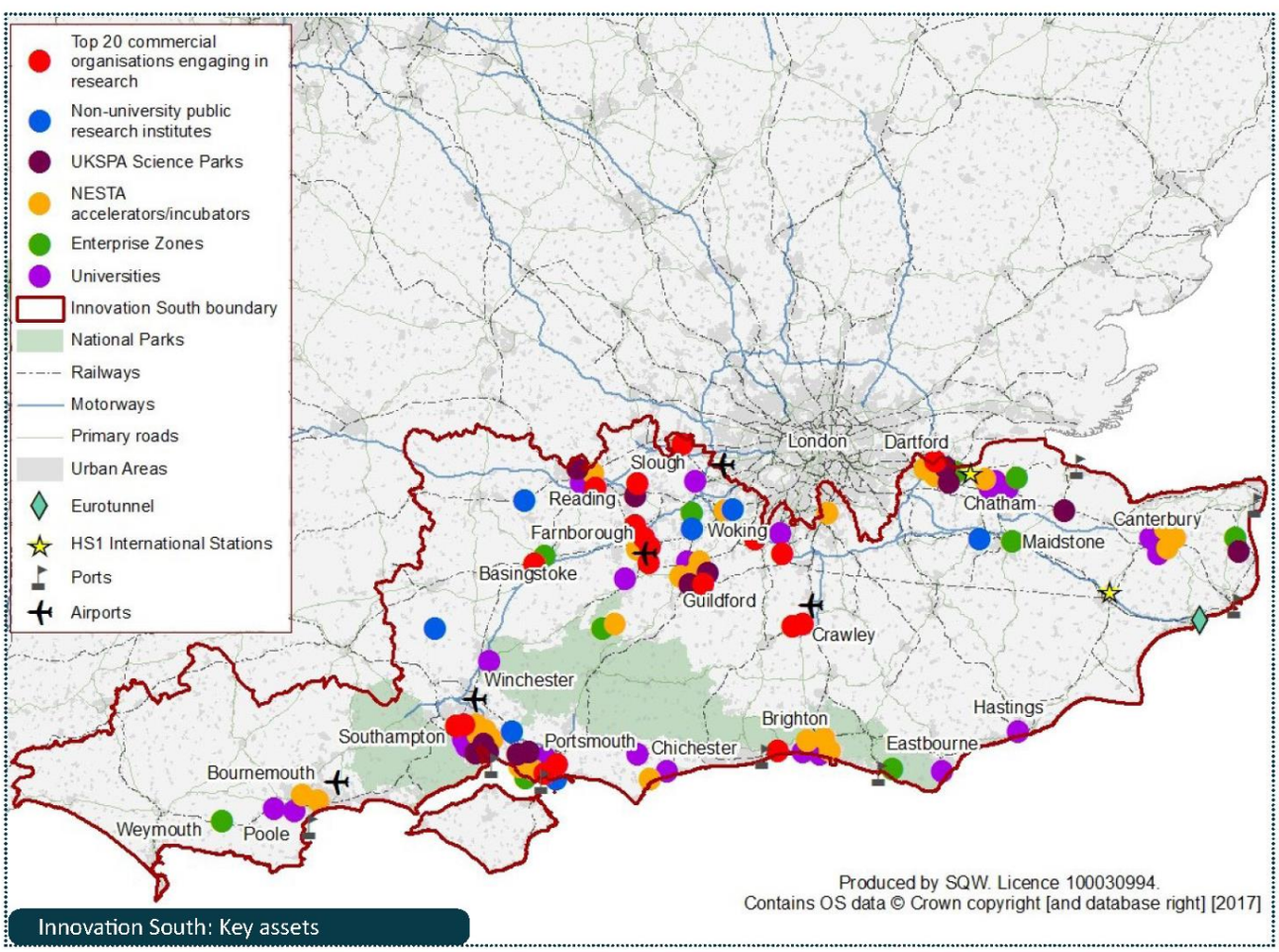
The UK has a world-leading digital economy and a proud history of digital innovation. Innovation South is key to that – a globalised region, with high- value, digitally-enabled innovation; a powerhouse of research strengths; a strong commercialisation culture; and dynamic businesses and industries to match. In the story of the UK's digital success, a significant chapter belongs to Innovation South.

In Autumn 2015, the UK Government announced regional Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential.

The specific focus of this Science and Innovation Audit report is the region's capacity to commercially exploit its excellence in a portfolio of five mutually supportive digital enabling technologies[1].

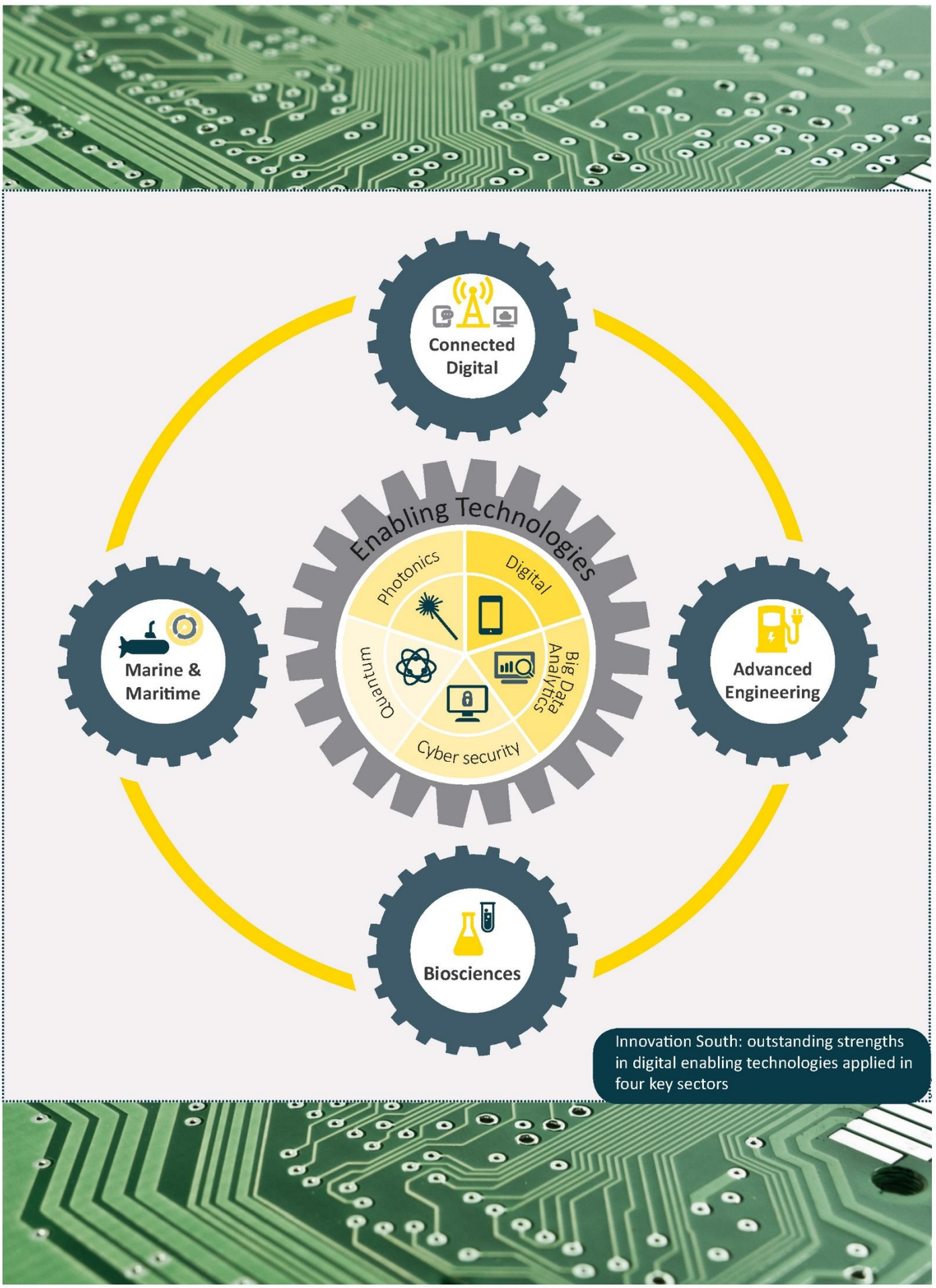
The Audit tests the hypothesis that while others may share strengths in individual technologies, Innovation South stands out for the number and breadth of digital enabling technologies, and their widespread application. These are underpinned by world class research, supported by centres of excellence in digital creativity and adopted by a successful stock of regionally-based, innovative businesses in four high-tech sectors: Connected Digital, Marine and Maritime, Bioscience, and Advanced Engineering.

The Innovation South Consortium – which has completed the Audit – embraces well over one hundred organisations spanning the region's eight counties[2] and its private (both corporate and SME) and public sectors. All are committed to using the findings from the SIA and advancing the opportunities that are identified.



Innovation South: Key assets

[1]Digital Communications ; Cyber Security; Big Data Analytics; Photonics; Quantum



Innovation South: outstanding strengths in digital enabling technologies applied in four key sectors

2. INNOVATION SOUTH – OUR VISION

OUR VISION IS TO:

- showcase and maximise Innovation South's world leading and world class industrial and scientific strengths across a range of Digital Enabling Technologies
- demonstrate how investment in science successfully translates into innovation in four of the region's stand out sectors, in a high performing Innovation South economy, and take that further still
- champion Innovation South as a global region - intrinsically resilient and equipped to face the challenges of competing in international markets
- extend partnerships to ensure areas of outstanding performance are not isolated, localised "hotspots" but region-wide excellence
- demonstrate Innovation South is a UK-wide national asset, whose strengths and collaborations impact in other regions - with ambition for more
- implement effective mechanisms to help maximise and realise the vast potential of these strengths, for the benefit of both Innovation South and the whole UK.

3. INNOVATION SOUTH – OUR STRENGTHS

THE REGION - INNOVATION SOUTH IS A GLOBAL REGION AND A NATIONAL ASSET

The region has a total economic output of £225.3 billion – around 13.7% of national output. Two National Parks and many Areas of Outstanding Natural Beauty earn the South's reputation for an excellent quality of life. More than one in ten people in the UK live here - a population of over 8.6 million and 5.3 million are of working age.

High skilled, high tech and dynamic in

Compared to the national average, Innovation South's workforce is, in general, more highly qualified; the proportion of those working in science, research, engineering and technology is higher; average earnings are greater; and in parts of the region, productivity levels are much higher.

It is a dynamic region for business growth. Across most of the area, the concentration of start-up enterprises and the incidence of high growth firms are well above England's average[3].

International connections are excellent, access to Heathrow, Gatwick, Southampton and Bournemouth airports and international rail via Ebbsfleet and Ashford. The region's ports (including Dover and Southampton) and Eurotunnel via Folkestone are also significant.

Proximity to London is important. Whilst congested, road and rail links are good and provide access to a highly valued sources of customers, finance and skilled labour. However, unreliable and inadequate transport systems, coupled with high housing costs, are a persistent obstacle to maximising the region's potential. Although there are regional variations, the South's digital infrastructure is better than the rest of the UK's.

The South: 'internationalised'; impressive foreign

The South's economy has an international focus. International corporations have chosen to locate their UK and European headquarters here. Export performance is strong[4]. The South East region, including most of Innovation South, attracts foreign direct investment and has the largest share of FDI projects in the UK outside London[5].

[3]Technopolis core data

[4]The best available evidence is Government's figures for the standard 'South East' region- the nearest approximation to Innovation South. It excludes Dorset and includes Bucks; Oxfordshire; Milton Keynes. Department for International Trade (2017), Regional Goods Export Data accounted for £37.8 billion in exports in 2015, 14% of the UK's total exports. The region's share of the UK's exporters is just over 18%.

[5]Over the five years to 2016, the South East region accounted for 1,029 FDI projects, around 11.5% of the UK total, according to Department for International Trade (2016), FDI projects by UK region for 2011/12 to 2015/16. Note, as in note 5, the South East region is the nearest geographical approximation for some data produced at regional level

The region is a powerhouse of world leading

Innovation South has 16 universities[6] **- a powerful diversity including Southampton, the UK's number 1 for engineering, and Surrey's internationally renowned 5G Innovation Centre**. High profile research institutions include the Atomic Weapons Establishment and TRL, the Transport Research Laboratory in Berkshire.

According to analysis of publicly-funded research and innovation activity involving business (e.g. Intel and Microsoft) and universities, the South 'punches above its weight' in winning backing for Digital Enabling Technologies innovation projects[7].

The region is entrepreneurial and has a strong

Businesses are emerging from the region's universities and research institutions to commercialise research. For example, at Surrey Research Park, technology firms such as Surrey Satellite Technology Ltd (SSTL) and Detica (now BAE Systems Applied Intelligence) began as start-ups making use of university research, and have since grown into major internationals.

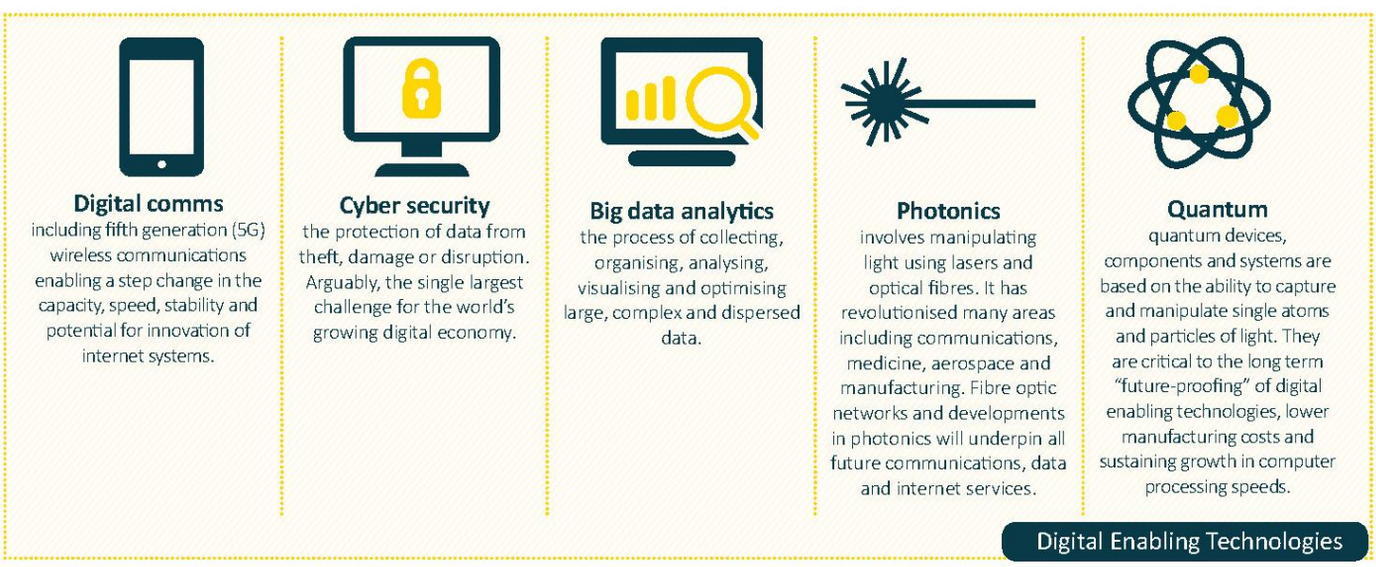
Business expenditure on research and development in the Innovation South area is high. According to 2015 figures, the wider South East, including most of Innovation South, enjoyed the highest corporate research investment of any nation or region in the UK[8].

Major research and development facilities in Innovation South include those operated by QinetiQ, Ordnance Survey Ltd, IBM, BAE Systems, SSTL, Ricardo, Thales UK in Reading, Fujitsu and Oracle.

Dynamic business growth is being encouraged by support for innovative enterprises. SETsquared[9], "the Global #1 University Business Incubator"[10], is a stand out example. Sussex Innovation[11] runs a number of incubation hubs across the South, and Growth Hubs, supported by the LEPs, add to the large and extended family of Innovation South business support organisations.

INNOVATION SOUTH: STRENGTHS IN DIGITAL ENABLING TECHNOLOGIES – DRIVING AN ECONOMIC, CULTURAL AND SOCIAL REVOLUTION

The Innovation South region is home to world-leading research strengths and innovation capabilities in five powerful Digital Enabling Technologies (defined below).



[7]Technopolis (2017), Innovation South: Analysis of research activity and main collaborations. For example, while institutions in the Innovation South area participated in just under 14% of all UK projects funded by the Research Councils, Innovate UK and European research programmes, they were engaged in 19% of cyber security projects.

[8]Again the 'South East' is the nearest available approximation to Innovation South (see 5 above). The South East accounted for the highest for any region or nation in the UK- a total expenditure of about £4.7 billion which is 22.5% of UK business expenditure on R&D in 2015

[9]http://www.setsquared.co.uk

[10]UBI Global Top University Business Incubator and Accelerator World Rankings 2015. UBI Global provides access to business incubation data & networks

5G Digital Communications: World-Leading

> *"The development of 5G presents a significant economic opportunity and this world-leading centre will position the UK at the forefront of research into the next generation of communications technology"* Science Minister Jo Johnson, opening the 5G IC, 2015

The 5G Innovation Centre (5GIC), based at the University of Surrey, is the largest open innovation centre for 5G development worldwide. Partners include international corporates[12]. In 2016, 5GIC was recognised by G7 nations as a global leader driving the growth and promotion of a digitally-connected world[13].

It is a valuable asset not just for the South but for the whole UK. Plans are underway to create regional and national test beds connected to the 5GIC core network. They include: Digital Greenwich (London); NE LEP (Northern Powerhouse); and Worcestershire LEP (Midlands Engine).

Within the region, partnerships include investigations with Airbus and Portsmouth University to create a Satellite/5G and Big Data Innovation Centre; work with Enterprise M3 LEP to extend the 5GIC existing network of SMEs; and a DCMS-commissioned 5G network and mapping tool, involving Bournemouth Council, Dorset LEP, Ordnance Survey and the Met Office, ahead of the national roll-out of 5G.

Cyber Security: A global Industry; An Innovation

In the UK, three of the fourteen universities now recognised by Government as Academic Centres of Excellence in Cyber Security Research are in Innovation South: Royal Holloway, University of Southampton, and University of Surrey.

Royal Holloway Information Security Group
Founded in 1990, the Royal Holloway Information Security Group (ISG) is a GCHQ/EPSRC recognised Academic Centre of Excellence for Cyber Security Research (ACE-CSR). It hosts one of only two UK, National Cyber Security Centre (NCSC) supported Centres for Doctoral Training in Cyber Security (CDT), and its MSc in Information Security (launched 1990) is recognised by GCHQ/NCSC.

Big Data Analytics: Big Business; Deep

As our use of digital devices has exploded so has the volume and complexity of data being collected. Exploitation of this Big Data has many potential commercial gains, and expertise in the South goes broad and deep. It includes the University of Reading's Institute of Environmental Analytics and partnership in Agrimetrics, the world's first Big Data Centre of Excellence for the whole food system; Royal Holloway's specialisms in machine learning - British Gas is among its partners; and the University of Portsmouth's Institute of Cosmology and Gravitation. IBM at Hursley and QinetiQ; the Open Data Institute and Dame Wendy Hall, Regius Professor of Computer Science at Southampton, who is jointly leading a government review of the UK's world-leading Artificial Intelligence technology add to the region's private sector/academic mix of capabilities in Big Data.

Photonics - world-leading pioneers among research excellence in lasers & optical fibres; transformers of billions of lives

There is a concentration of photonics research expertise at several Innovation South universities and it is particularly distinctive for its impact on everyday life and wider society. Researchers at the University of Southampton's Optoelectronics Research Centre (ORC) have been making ground- breaking discoveries in photonics throughout the centre's four decades. A device that led to the rapid expansion of the internet was developed in the 1980s, for example, and its numerous industry partners include BAE Systems, BMW, VW and Volvo. The Universities of Surrey, Kent and Sussex also have significant research strengths in photonics.

[12]Key partners include EE, Huawei, O2, Vodafone, HEFCE, Enterprise M3 LEP, TEOCO Corporation, BBC, BT, Cobham, Anite, Ascom, Digital Catapult, Fujitsu, Rohde & Schwartz, Samsung, Roke, McLaren Applied Technologies, Ofcom, Imagination Technologies, ITRI, MYCOM OSI, Three and Ordnance Survey.

[13]See G7 Opportunities for Collaboration – available at http://www.japan.go.jp/g7/_userdata/common/data/000416960.pdf. Also see notes from G7 ICT officials meeting, Brussels, 2nd December 2016 (meeting convened by Japan G7 Presidency. Chaired by Vice Minister Shigeki Suzuki and moderated by Yoichi Iida Director for International Research and Policy Coordination)

Quantum

> *"You don't need to understand the details of the underlying physics…Quantum devices could enable us to see around corners, map hidden underground hazards, and easily solve problems that would stump any existing supercomputer."* [14]

The pursuit of quantum technologies is a national priority and universities across Innovation South are stepping up to the challenge, namely Southampton, Sussex and Royal Holloway. All are key collaborators in one or more of the four Quantum Technology Hubs.

The University of Sussex is leading work with Google and Aarhuson on a breakthrough in developing a quantum computer; Southampton University is important in developing the industrial capacity and supply chain for quantum products and has particular expertise in the commercial exploitation of the technology with regional partners, the Government's Defence Science and Technology Laboratory (Dstl) and National Physical Laboratory (NPL), the UK's National Measurement Institute.

The University of Surrey has close working links with the National Physical Laboratory (NPL). Together they formed the NPL South hub and aim to expand the quantum industry, and subsequent development of new products, as led at the Advanced Quantum Metrology Laboratory, currently under construction, in Teddington.

APPLYING DIGITAL ENABLING TECHNOLOGIES ACROSS FOUR KEY SECTORS

Strengths in the Connected Digital Sector - A National Success

The digital economy is a UK success story and the outstanding performance of the Connected Digital sector in Innovation South is essential to that. The South has a major concentration of large corporates, including international businesses such as Fujitsu, Huawei, Microsoft and IBM, with UK/European Headquarters in the Thames Valley, Surrey and Hampshire. These are major employers, ensuring the South's position as a globally- significant and globally-connected region.

Clusters of digital companies are achieving national and international acclaim: the gaming sector in and around Bournemouth, Brighton, and Guildford, is the "Hollywood of Videogames"[15]. Around half the UK games industry is in London and the South.

The "prize" of a Digital Catapult located in Brighton is testimony to the area's innovation culture. The South has growing credentials in the Internet of Things (IoT) and the closely linked "Internet of Place". In the South, the application of digital technologies across a raft of sectors and services, e.g. FinTech & HealthTech, is spearheading the digital revolution.

Strengths in Digital Enabling Technologies in the

Innovation South, home to the Navy at Portsmouth and the UK's number one vehicle-handling port at Southampton, is a major contributor to the UK's marine and maritime industry, which, national estimates suggest, is similar in scale to pharmaceuticals and notably bigger than aerospace.[16]

Digital Enabling Technologies are driving fundamental change, especially: robotics, sensors, big data analytics, smart ship autonomous systems, cyber and electronic warfare, human computer interaction, communication[17]. The notion of "high value digitally enabled design" is also key as many of these drivers need to be integrated into complex systems requiring multidisciplinary design tools, often enabled by high

In both marine science and maritime engineering, the cross-disciplinary Southampton Marine and Maritime Institute (SMMI) and the National Oceanographic Centre are especially important. There are many other research centres too. A Marine Robotics Innovation Centre has been established and innovative SMEs are playing a crucial role in the commercialisation

The role of large commercial companies is

[14]" The Quantum Age- Technological Opportunities " Govt Office for Science
[15]https://www.theguardian.com/technology/2014/jun/04/guildford-uk-video-game-industry-ubisoft-little-big-planet-hollywood [16]Maritime Growth Study – keeping the UK competitive in a global market, Department for Transport, 2015
[17]Identified by Southampton Marine & Maritime Institute, and based on Global Marine Technology Trends 2030, QinetiQ, Lloyd's Register, University of Southampton, 2015

significant – including Sunseeker International (in the leisure market), Lloyd's Register (a classification society) through to BAE Systems (in defence-related maritime systems). The RNLI, based in Poole, drives innovation in search & rescue.

Solent University's Warsash Maritime Academy has a global reputation in international marine and offshore oil and gas industries, earned over 70 years. Its deck officer training exploits highly sophisticated digital simulators for ship operations. The ambition to bring the America's Cup home and the location of Land Rover BAR (Ben Ainslie Racing) in Portsmouth are generating new opportunities for science and innovation in the powerful technology behind "spectacle" events such as high level competitive yachting.

Strengths in Digital Enabling Technologies in

The profound influence of Digital Enabling Technologies on the development of health & social care, medical data, devices, pharmaceuticals, and agrimetrics plays to Innovation South's strengths in Big Data Analytics and Security, 5G, Advanced Engineering and Robotics. Increasingly, advanced data analysis has reduced the cost – and pushed forward the boundaries – of drug discovery. At Discovery Park near Sandwich[18], this has opened up new opportunities for Bioscience in the wider South East[19] is seeing strong growth in Med Tech SMEs, in particular. The South East boasts one fifth of the UK workforce (compared to 6% for London and 11% in the Midlands).[20]

Around 500 businesses[21] across Innovation South are in Med Tech and Biopharmaceuticals, in disciplines ranging from medical imaging to oncology. Prosthetics and Orthotics is a regional specialism supported by many Med Tech enterprises and the Institute for Life Sciences at the University of Southampton. The global company, Blatchford, based at Basingstoke, developed the first commercially available microprocessor controlled prosthetic knee. Innovation in the use of digital technologies to improve care and hospital/GP information systems, is a regional strength. University Hospital Southampton achieved national recognition in 2016 as an IT Centre of Excellence and Global Exemplar for Clinical Informatics development. The Kent, Surrey and Sussex AHSN[22] is participating in one of five national 'test bed' initiatives, sponsored by NHS England, to assess the potential for new technology in health and social care, and devices have been tested at the 5G Innovation Centre. The University of Southampton will be a core partner in the new Rosalind Franklin Institute[23].

Technologies to control bacteria and pest threats, and the of use of data and connectivity to ensure safe, efficient and sustainable food production are also being exploited in Innovation South by organisations such as the University of Reading's Agrimetrics, the global life science company, Bayer, Syngenta, a global agribusiness, NIAB-EMR, an internationally-significant centre for fruit research, and the Pirbright Institute, a world leading centre of research excellence in virus diseases of farm animals and animal/human virus transfer, one of eight National Institutes of Bioscience.

Strengths in Digital Enabling Technologies in

The South has high-value, innovation-intensive engineering. Its advanced engineering capabilities are at the centre of the UK's defence and aerospace sector, where the UK has a strong comparative advantage.

World-class and outstanding research strengths in Advanced Engineering go deep and wide across the region. In general engineering, Southampton university is the UK's highest ranked university by research power. It also comes top for research power in electrical and electronic engineering, metallurgy and materials. The University of Surrey is second. Five Innovation South universities are ranked in the top 20 nationally in relevant research areas (Greenwich, Portsmouth, Southampton, Surrey and Sussex). Four more are in the top 30[24]. Innovation South is the chosen base for several major engineering corporates.

[18]See case study at Box 6-4
[19]Official South East data do not reflect Dorset. These statistics do include the rest of Innovation South, plus Oxfordshire, Bucks and Milton Keynes
[20]UK Medical Technology Sector Strength & Opportunity 2015 compiled by UK Govt
[21]Office for Life Sciences (2016), Strength and Opportunity 2016: The landscape of the medical technology and biopharmaceutical sectors in the UK database estimates 430, which compares with around 260 in Oxfordshire. The University of Southampton Institute for Life Sciences counted 557.
[22]Academic Health Science Network
[23]https://www.epsrc.ac.uk/newsevents/news/rosalindrranklininstitute/
[24]More details in 7.11 of main Audit report

There are many aerospace & defence companies around Farnborough. Ricardo, in Shoreham supplies the McLaren Formula One team, based in Woking[25] and there is an array of specialist engineering SMEs using Digital Enabling Technologies. At Bournemouth Aviation Park, for example, there is a concentration of aerospace and advanced engineering firms, including Cobham, Meggitt and Magellan Aerospace.

Advanced engineering is increasingly dependent on the use of digital technologies to maintain competitiveness in the global marketplace. The South's strengths in engineering research are closely connected with, and regularly inseparable from, strengths in Digital Enabling Technologies. For example, Innovation South research organisations are at the cutting edge of the revolution in transport underpinned by the introduction of connected and automated vehicle technologies. TRL (the UK's Transport Research Laboratory) based at Wokingham is examining how automated vehicles will improve transport systems. Thatcham Research, located near Newbury, is the motor insurance automotive research centre, and engaged with manufacturers (particularly Volvo) in developing standards for automated vehicle safety, operation and repair. Ricardo plc, has strengths in systems for autonomous vehicles, through Ricardo Agent Drive, in simulation software to test complex driving situations for autonomous road vehicles.

4. LOOKING FORWARD: GROWTH OPPORTUNITIES, CHALLENGES, GAPS – AND AMBITIONS/PROPOSALS

The commercial application of Digital Enabling Technologies is the key to innovation and future success. It is also clear, from the results of this Audit, these technologies and their application are a specialism for Innovation South, putting the region in an excellent position to support national growth, global competitiveness and to step up to economic challenges ahead.

The SIA highlighted five areas where the potential of this substantial region could be improved, released and maximised. In all cases, these reflect specific elements of the region's scientific specialisms and innovation assets coupled with its distinctive economic character and potential:

OPPORTUNITY 1 KNOWLEDGE-TO-MARKET ACCELERATOR

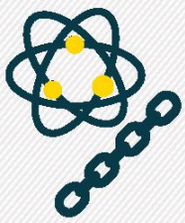
Enhancing collaboration between business, industry, universities, & other research expertise to maximise the commercial application of digital enabling technologies and ensure Innovation South is among global leaders in innovation in the digital, marine, health and life science and advanced engineering sectors.

OPPORTUNITY 2 LINKING INNOVATION HOTSPOTS

Complementing the first opportunity by enhancing, replicating and expanding the South's excellent "innovation hotspots" (e.g. SETsquared, Wired Sussex and SinC) to develop a more powerful innovation network across the South driving new growth, underpinned by digital enabling technologies.

[25]See Case studies of Ricardo (Box 7-1) and McClaren (Box 7-4) in main

OPPORTUNITY 3 QUANTUM SUPPLY CHAIN INITIATIVE



Helping to build capacity and presence in the development of products using quantum technology in readiness for significant commercial demand. This project will not only improve the supply chain for current research into quantum technologies, but will also develop the industrial capacity needed to support the production of the first quantum products once the technologies are market-ready. The strength of defence-related activities in the region will provide an important foundation for this project.

OPPORTUNITY 4 DEVELOPING SME ENGAGEMENT WITH THE 5G INNOVATION CENTRE

Building the capacity and reach of the 5GIC even further, unlocking a new generation of high growth digital businesses in the South and other UK regions, fit for a global competitive market. This opportunity complements 1 & 2, and extends these facilities to SMEs and companies across the South and in other UK regions.

OPPORTUNITY 5 ADVANCED & SPECIALIST SKILLS IN DIGITAL TECHNOLOGIES

Securing a supply of high calibre digital talent which will be critical to realising the significant growth potential of applying digital enabling technologies. Fresh thinking is required to address the needs and responsibilities of employers, and ensure competition between providers does not frustrate the end goal. This project will champion and promote career opportunities linked with digital enabling technologies, provide a clearer skills evidence base which can be used by industry bodies, universities and further education, and offer a brokerage service, linking SMEs with new entrants to industry from the region's universities and further education colleges.

5. NEW PARTNERSHIPS IN INNOVATION AND GROWTH

- *"Without the SIA process, I wouldn't have*
- *been aware of the capabilities that*
- *Universities in the Southern area have*
- *around our key themes. Even the diverse*
- *location of the meetings, highlighted key*
- *strategic themes (e.g. 5G Innovation Centre*
- *in Guildford) that other groups had that we*
- *might be able to use. I have been invited to*
- *Royal Holloway to visit the Cyber/Big Data*
- *department, as a direct result of using SIA in*
- *a networking capacity. This could foster*
- *future work or collaboration between Industry*
- *and Academia"* Matt Albans, BAE Systems

Conducting this Science & Innovation Audit has presented a great challenge, but an even greater opportunity, to unite this, extremely large, area of Southern England for the first time around a single endeavour and achieve results in just a few months. There are many conclusions to draw, but one message prevails: **there is huge potential for Innovation South to be greater than the sum of its parts.** The comments below speak for themselves. As of June 2017 a series of meetings have taken place with BEIS , regional LEPs and the Innovation Strategic Steering Group to discuss a) developing the profile of the Innovation

South region and b) implementing the opportunities identified by the SIA . There is clear support and ambition to do both. Next steps include involving all these stakeholders in decisions about geography, delivery and funding going forward.

Innovation South has initiated early conversations with other SIAs about potential partnerships: Leeds on Med Tech, Glasgow on Quantum, and Oxfordshire on transformative technologies. South East LEP has a direct interest in two Audits: East of England and Innovation South. These linkages are set out in more detail in Annex E of the report.

"Representing TRL in the development of the SIA has been excellent both in terms of discovering the innovative activities taking place across the region but also being able to share our thought-leading research to create the future of transport. Our work is about producing a transport system that is safer, cleaner and more effective. Increasingly, this requires an in-depth understanding of transport as one part of a complex, interdependent set of social, technical, economic, environmental, communications and energy systems. To be able to forge connections with organisations working in the Innovation South region across these sectors has been excellent and enables collaboration that delivers better outcomes for transport and for the UK" Dr Nick Reed, Academy Director, TRL

"As a direct result of new introductions during the SIA I am working with a Consultant Surgeon at the University Hospital of Southampton to explore how Enterprise M3 LEP and the hospital can support significant growth in high level digital and technology skills" Sue Littlemore, Enterprise M3 LEP

"The SIA has proved to be a great forum to bring together various leading initiatives within the region…the SIA has given [impetus] to the concept behind the formation of a Satellite Innovation Hub to be based in Portsmouth as a joint initiative between Airbus, Portsmouth University and the 5G Innovation Centre" Keith Robson, CEO, 5GIC, University of Surrey

"A couple of the universities reached out to us for potential engagement with their apprentice scheme, for a possible hackathon and the third for a contact for Amex cyber security" Jaime K Lee Choon , Amex

"I've made valuable new contacts in BAE and Airbus which I expect to take forward. I've also been able to discuss the SIA activity with senior contacts in Thales offline, who are involved in maximising their SME supply chain. I discussed the potential collaborative outcome of the report with them and they were insistent this is going to be of value and reflects a broader issue that Primes have. It has been very useful from a Growth Hub perspective to make new contacts within the universities, particularly Royal Holloway..TRL…and Portsmouth / SetSquared..." Mel Redding, JuMelia Ltd. & Enterprise M3 Growth Hub Champion

"I think that in general the workshop Digital Enabling Technologies is quite effective in terms of knowing the Government is working very hard on collecting evidence of the key assets in the region and in return hopefully more investment/opportunities will be brought to the region which I personally wasn't aware of before the workshop" Dr Taihai Chen, Director & IC Design Engineer, AccelerCom Ltd, Workshop attendee

"As a University we are very keen to follow up on the findings of the audit and to provide leadership and support in delivering digital enabling technologies to allow further impact in the region through the four industry sectors identified, as well as more broadly… My engagement with the SIA process has also allowed me to see more clearly how the Southern region benefits from a particularly strong and diverse capability in digital technologies, supported by a wide range of higher education institutions and being exploited by companies ranging in scale from the micro-start-ups to multinationals across several key industry sectors. It has been a great pleasure to be involved and I look forward to implementation of the recommendations from the audit for the benefit of the South and the UK more widely" Professor Mark Spearing, Vice President (Research & Enterprise), University of Southampton

Opportunities and Growth: Medical Technologies in the Leeds City Region

Summary report

A Science and Innovation Audit Report sponsored by the Department for Business, Energy & Industrial Strategy

July 2017

Introduction

In autumn 2015, the UK Government announced Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to analyse regional strengths and identify mechanisms to realise their potential.

In the **Leeds City Region**, we focused on our strengths in **medical technologies**. This summary report provides an overview of the results, highlighting substantial opportunities for future economic growth.

Vision

The UK will be the best place in the world to develop and launch innovative medical devices and diagnostics – contributing to a substantial increase in economic growth and productivity, reduced healthcare costs and improved patient outcomes.

Our ambition is to deliver successful innovation through concentration, convergence and smart specialisation in a single geography, the Leeds City Region, aligned with national centres of excellence in science and technology and substantial growth in an already established UK-wide network of academic, clinical and industrial collaboration. Taking advantage of projected growth in global medtech markets, we will increase UK economic output, productivity and exports. Investments in clinical evaluation and multidisciplinary skills will be supported by strong strategic leadership and continuous innovation across the value chain.

Leeds City Region

In terms of Gross Value Added (GVA), Leeds City Region[1] represents the largest economic area in the UK outside London and the South East, generating £65bn GVA[2].

A **population of 3 million**, of whom 1.9 million are of working age (2015), and **over 120,000 businesses** (Business Counts 2016), make the Leeds City Region an economy of international significance[3].

Leeds City Region is at the heart of the UK's advanced manufacturing and engineering industry, and **over 140,000 manufacturing jobs** are based in the region[4].

With **nine higher education institutions** and **14 further education colleges**, the Leeds City Region represents **one of the largest concentrations of education facilities in Europe**. Its universities are home to over **115,000 students**[5] (HESA, 2015/16), training around **40,000 graduates each year**. These graduates feed into the largest science,

1 11 local authorities: Barnsley, Bradford, Calderdale, Craven, Harrogate, Kirklees, Leeds, Selby, Wakefield and York, alongside North Yorkshire County Council
2 https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/gvaforlocalenterprisepartnerships
3 https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds#tabrespop
4 (ONS Business Register and Employment Survey, 2015)
https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds
5 https://www.hesa.ac.uk/data-and-analysis/key-tables

research, engineering and technology workforce for any LEP outside of London (101,000 people in 2015)[6].

Leeds City Region has a strong tradition of excellence in science and research. The region is home to **two members of the Russell Group of research-intensive universities**: the University of Leeds and the University of York.

The Leeds City Region had the **highest number of staff submitting to REF2014 in STEM disciplines for any LEP outside of London**[7]. The combined research power of the Leeds City Region universities puts the region third overall, just behind the University of Oxford and research power leader University College London.

However, the Leeds City Region faces a number of economic challenges:

Productivity levels, although comparable to other northern cities, are significantly lower than the national average[8]	**The rate of employment remains below the national average**[9]
The proportion of people with higher level skills and qualifications in the Leeds City Region is lower than the national average.[10]	Data from HESA (Destination Survey) suggests that only around 40% of students at Leeds City Region universities who entered employment took up a job in the region following graduation[11]

The nature of the regional business environment is complex. While there is clustering around large corporates and multi-nationals in the finance and food and drink sectors, this is not the case for manufacturing, tech or digital companies in the region. **Micro-enterprises make up more than 82% of the Leeds City Region business base**[12]. On the one hand this **diversity and agility** is a strength.

However, the region's business base is also highly **fragmented**. This represents a significant challenge to the effective delivery of strategic support for economic development, innovation and global competitiveness.

Extending our strengths is crucial if we are to realise the region's full economic potential. This Science and Innovation Audit focuses on medical technologies, one of the most promising sectors for growth in the region.

6 ONS Business Register and Employment Survey: https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds

7 Data available from http://smartspecialisationhub.org/observatory/ Staff submitted to REF 2014, HESA, 2013/14

8 GVA per hour worked indices; Local Enterprise Partnerships, 2004 – 2015 https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/datasets/subregionalproductivitylabourproductivitygvaperhourworkedandgvaperfilledjobindicesbylocalenterprisepartnership

9 https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds#tabrespop

10 In 2016, 31% of the LCR's workforce had achieved NVQ4+ qualifications, compared to 38% in the UK overall (ONS Annual Population Survey (2016) https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds#tabempocc

11 http://www.activeinformatics.com/wp-content/uploads/2016/03/Leeds-City-Region-Labour-Market-Analysis-2016-2017_1.pdf

12 UK Business Counts (2016) https://www.nomisweb.co.uk/reports/lmp/lep/1925185551/report.aspx?town=leeds#tabjobs

Key Strengths in Medical Technologies

8.9% of medtech patents submitted by UK inventors have originated in the Leeds City Region[13].

The Leeds City Region hosts a distinctive concentration of **over 250 businesses specialising in medical technologies**, complemented by **over 200 digital and technology businesses operating in the health and social care space**. It hosts some of the **leading medical device manufacturing companies** in the UK, including the Global Development and Technology Centre for DePuySynthes, a Johnson & Johnson company, RSL Steeper, Brandon Medical, TPP and EMIS.

Analysis of data from the Business Register & Employment Survey, 2015[14] shows that the Leeds City Region has the **largest workforce in medtech-related industries outside of the South-East**. A location quotient (LQ) of 97 suggests employment concentrations are broadly in line with the national average, but this is misleading because the Leeds City Region has high degrees of specialisation. Over a third of employment in the sector in the Leeds City Region is in the **manufacture of medical instruments**. With a **location quotient of 138**, this subsector also reflects a **high degree of specialisation**. The sector has seen **strong growth** in the Leeds City Region in recent years, with average employment growth of 4% p.a. between 2009 and 2015. This growth rate is matched only by the Greater Cambridge area among the main centres of medtech employment, and far outpaces the national picture, where employment has been largely static over that time. It also outperforms the Leeds City Region economy as a whole, where employment has increased by 0.7% per annum since 2009.

Allied to growth in medtech is an expansion in digital technology within the Leeds City Region, which now accounts for **22% of digital health jobs in UK**[15].

Alongside a strong medtech business base, the Leeds City Region has established a **world-leading concentration of excellence in research and innovation in medical technologies** in the Universities of Leeds, Bradford, Huddersfield, Leeds Beckett and York. Leeds City Region universities currently attract **8% of EPSRC funding for medical technology research**. Our significant regional strength in medical technologies research is further demonstrated by a field weighted citation impact of 2.05 compared with the wider UK (1.67) and globally (1.29)[16].

13 European Patent Office data, PATSTAT, for the period 2004-2014
14 Business Register & Employment Survey, 2015
15 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/525102/bis-16-237-strength-and-opportunity-2015-UK-medical-and-biopharmaceutical-landscape.pdf
16 Analysis of data from SciVal

The University of Leeds **Institute of Medical and Biological Engineering** (iMBE) was recognised for excellence in medical engineering through the **Queen's Prize in 2012**. The Institute is renowned for its multi-disciplinary work with hospitals, and its collaborative work with industry, charities and other academic institutions around the world. Internationally-leading facilities provide preclinical testing in joint replacement, and mechanical and biological assessment of regenerative devices.

The University of Leeds also hosts a substantial number of **nationally funded medical technology centres of excellence**: £13m EPSRC-funded Innovation and Knowledge Centre in Medical Technologies; £8m EPSRC and industry-funded Centre for Innovative Manufacturing in Medical Devices; £10m EPSRC Centre for Doctoral Training in Tissue Engineering and Regenerative Medicine; the EPSRC national robotics facility; and the Leeds Institute for Data Analytics (with support from MRC and ESRC)

The **University of Bradford** hosts the Centre for Advanced Materials Engineering, which focuses on the development of smart materials for high added-value products aimed primarily at health and wellbeing, e.g. medical devices, biomedical products.

The **Digital Health Enterprise Zone** is a £13m partnership led by the University of Bradford, with investment from BT, City of Bradford Metropolitan District Council and the UK government (BEIS). It works in partnership with the Digital Catapult Centre, Yorkshire. These investments reflect the Leeds City Region's ambition to become the best place in the UK for entrepreneurs to set-up and grow innovative businesses in the digital healthcare sector.

The **University of Huddersfield** hosts the £15m EPSRC, industry and University-funded Centre for Innovative Manufacturing in Advanced Metrology – part of the University's Centre for Precision Technologies, which has an international reputation in precision engineering, and metrology research and development. Advanced metrology is key to the precision manufacture of medical instruments and devices, and is paving the way for advancements in the design and manufacture of traditional medical implants. In December 2016 it was announced that the Centre would host a new £30 million EPSRC Future Metrology Research Hub to help transform UK manufacturing.

NPL Huddersfield is hosted by the University, and specialises in dimensional inspection and measurement of complex components and assemblies, CMM programming, and bespoke measurement training and consultancy.

Leeds Beckett University hosts a state-of-the-art clinical skills suite, which supports specialist clinical skills training and provides opportunities for product development.

The **University of York** has key strengths in life sciences, neuroimaging and enhanced-sensitivity MRI. The Centre for Hyperpolarisation in Magnetic Resonance explores methods that have the potential to revolutionise clinical imaging (£13m funding from Wellcome Trust, Wolfson Foundation, University of York, EPSRC and industrial collaborators). The York Health Economics Consortium is the largest and most active group of health economics research departments in the UK. It meets private and public sector needs in addressing cost v benefit for the health care sector, with expertise in health economics and evaluation for medical technologies.

Research excellence in medical technologies in the Leeds City Region is further enhanced through nationally-funded **partnerships across the UK** – with formal collaborative research contracts with over 45 universities and over 300 industry partners, and a wider network of over 800 industry, clinical and academic members.

Importantly, the Leeds City Region is **leading the way in the translation of medical technologies research**. For example, the EPSRC-funded **Medical Technologies Innovation and Knowledge Centre** brings businesses together with world-class experts from across 35 UK universities to accelerate the development of new medical technology products and services. It aims to bridge the gap between fundamental research in medical technologies and industrial investment by de-risking technologies.

Alongside the region's universities, there is a **unique and influential wider health innovation ecosystem**. The Leeds City Region has distinctive **patient population cohorts** (such as **Born in Bradford**) and the unique "**Leeds Care Record**", which has been developed in conjunction with leading healthcare software companies TPP and EMIS. It is home to four out of **five NHS headquarters**, **13 clinical commissioning groups** and **12 NHS trusts**, including one of the largest NHS Trusts in the country, the Leeds Teaching Hospitals NHS Foundation Trust. The region also hosts the NIHR National Clinical Research Coordinating Centre (NCRCC), which manages the Clinical Research Network (CRN) on behalf of the Department of Health – infrastructure that allows high-quality clinical research funded by charities, research funders and life-sciences industry to be undertaken throughout the NHS.

Growth Opportunities

The global medtech market was estimated to be worth $371 billion in 2015[31], and is forecast to grow to $529.8 billion by 2022[32].

Market growth is being driven by a number of social, economic, technological and political factors:

- an increasing and ageing global population
- lifestyle factors in the developed world, with an associated rise in levels of obesity and the prevalence of diseases such as diabetes, cancer and cardiovascular disease
- increasing wealth in emerging economies, fuelling the adoption of the western lifestyle, progressively increasing the demand for medical devices
- the increasing importance of consumerism as access to the internet provides patients with enhanced healthcare information
- technological developments, including minimally invasive devices, gene editing and proteomics, digitally-enabled healthcare solutions, and handheld diagnostics

31 http://www.marketsandmarkets.com/PressReleases/top-10-medical-device-technologies.asphttp://www.marketsandmarkets.com/PressReleases/top-10-medical-device-technologies.asp

32 http://info.evaluategroup.com/rs/607-YGS-364/images/mt-wp16.pdf

The UK is punching above its weight in this global market place. The **turnover of UK medtech companies has been increasing by 50% per year**, significantly ahead of the international trend, and now totals **£21bn**[33].

There is a clear **opportunity for the UK** to capitalise on the innovative business potential and scientific excellence that fuel this sector. This is particularly apparent in **technology convergence and combined technologies**. Examples include the convergence of medical devices and information technology; artificial intelligence applied to medical devices; combining medical imaging with robotics to automate surgical procedures; digital health; smart drug delivery devices. **Leading tech companies Apple, Google, IBM and Samsung are investing heavily in digital health** initiatives, especially around wearables, life sciences and smartphones.

Leeds City Region has core academic excellence and industry strengths in traditional medical devices and materials, orthopaedics and instrument manufacturing. Combined with emerging strengths in biologics and digital, the region is uniquely well-placed to respond to the opportunities associated with technology convergence.

However, it is important to stress that the rate of change associated with technology convergence is unprecedented. There is an urgent need for the Leeds City Region and wider UK medtech sector to adapt to exploit this opportunity.

Time is of the essence. The convergence of medical technologies has already impacted on almost all medtech sectors. New sectors that have developed out of combined technologies have seen market growth rates between 20-50%[34]. The global digital health market alone ($61bn in 2013) has been forecast to grow to $233bn in 2020, representing a CAGR of more than 20%[35].

Gap Analysis

The UK Med Tech sector is highly fragmented. SMEs with fewer than 250 employees make up 98% of UK medtech companies, and 82% have less than £5m turnover[36].

Despite geographical concentrations of medtech companies – notably in the Leeds City Region, the South East and the Midlands – there is **poor connectivity and clustering** activity, a lack of business-to-business networking and pre-competitive collaboration across the sector, across the region and across the UK. This was recognised in interviews, focus groups and our online survey.

Rapid growth and rapid transformation in the nature of markets, products and technologies generates opportunities and challenges. Future medtech products and services will include

33 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/525102/bis-16-237-strength-and-opportunity-2015-UK-medical-and-biopharmaceutical-landscape.pdf

34 https://www.forbes.com/sites/reenitadas/2016/03/30/top-5-technologies-disrupting-healthcare-by-2020/#14efa20b6826; https://www.weforum.org/agenda/2016/12/seven-global-medical-technology-trends-to-look-out-for-in-2017/ 33; Deloitte Report. 2016 Global Healthcare Outlook. Battling costs while improving care.

35 Deloitte Report. 2016 Global Healthcare Outlook. Battling costs while improving care

36 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/525102/bis-16-237-strength-and-opportunity-2015-UK-medical-and-biopharmaceutical-landscape.pdf

more complex combination devices and increased use of, and dependency on, digital technology. Extensive consultation with the medtech sector reveals that companies need **funding**, the **development of a more entrepreneurial culture in the sector** and **enhanced networking and collaboration** to enable them to embrace these convergence opportunities.

There are significant **skills shortages and changing skills needs** in the medtech sector, both regionally and nationally. There are skills shortages and gaps in specialisms, including medtech, digital, and regulatory, particularly at graduate level and for early career professionals. There is also a significant lack of 'industry ready', graduates with medtech industry experience – SMEs need experienced graduates because they do not have the resources to provide on-the-job training. Companies provided a range of ideas for how these issues could be addressed, including co-development with industry of new educational programmes, companies providing projects for students to undertake, work experience (e.g. through secondments and internships) and industry taking responsibility for education after graduation. Finally, there is a need to diversify the skills of the existing workforce to address the challenges of industry transformation – advanced multi-disciplinary skills are needed to address emerging market opportunities for combined technologies.

For companies based in the **Leeds City Region**, the **economic environment remains challenging**. There is a low level of regional investment in R&D[37], an absence of targeted regional and sector specific investments in innovation, and a lack of infrastructure, such as grow-on space. Companies felt that there were numerous organisations in the region that could potentially help the industry, but that the boundaries were unclear and that there is a **need for coordination**.

Engagement between companies and the science base was seen as a real strength in the region. There is a **need to sustain science capacity and capability in the region through centres of research excellence**, aligned to address opportunities associated with technology convergence and future transformation of the market.

A **shortage of funding** was recognised for translation (pull through) research and collaborative funding with industry. Companies cited huge challenges in navigating a discontinuous and disconnected pipeline of support for different stages of the innovation pipeline. Access to the NHS and a lack of support for **critical clinical trial phases** has hampered development.

Companies also cited **poor access to the NHS** and limited ability to **evaluate clinical efficacy and effectiveness**.

Finally, it was noted that the **regulatory environment is complex**. There are **long lead times on product development** and market entry, and there is increasing complexity associated with an increase in the use of precision medical devices. **Companies find the regulatory process for gaining a CE mark complicated**. While most companies used regulatory consultants, these were seen as an expensive external resource. Future planned changes to European and UK medical device regulations are a significant challenge.

37 In 2013, Business Enterprise R&D Expenditure in the Leeds City Region was £440m, which equates to £399 per FTE – significantly below average for the size of workforce: bis-15-345-mapping-local-comparative-advantages-in-innovation-framework-and-indicators-appendices.pdf

Key Ambitions and Proposals

This Science & Innovation Audit of the Leeds City Region medtech sector has demonstrated a concentration of excellence in industry, science and public health.

However, to take advantage of opportunities in a rapidly changing and growing global medtech market, there is an urgent need for strategic intervention, nationally and regionally – to drive medtech innovation and economic growth.

Our proposals:

1. **Clinical evaluation**: a national 'test bed' and early clinical evaluation hub and network for medtech devices (linked to existing NIHR infrastructure) will act as a beacon to attract inward investment into the UK. Early stage clinical evaluations will provide evidence to support regulatory approvals and later stage health technology assessments, increase the precision of clinical adoption and feed back to upstream product developments, and further refine the stratification of patient needs.
2. **Enhanced high level skills:** a medtech skills academy will support people and skills exchange programmes, training new graduate and post graduate engineers, and upskilling existing professionals in the industry, focusing in particular on addressing the needs of SMEs in the medtech sector. The collaborative development of new education and training programmes will deliver highly skilled industry-ready, multidisciplinary graduates/postgraduates, to meet the needs of industry in medtech, digital health, and regulatory science.
3. **Joined up connected and continuous innovation support:** an integrated medtech innovation hub with soft and hard infrastructure, with connected, interactive and collaborative medtech nodes across the UK. A flexible, joined-up and continuous industry-focused research and innovation development programme, providing support throughout the value chain, supporting early stage research, product development, manufacturing, preclinical and clinical evaluation, business development and access to finance (public and private).
4. **Sustainable infrastructure:** grow-on and scale-up space, support for businesses to start and grow, coupled with continued infrastructure investment in national centres of research excellence.
5. **Strategic leadership, providing vision, direction and common purpose**. We have defined a distinctive 'place' for the medtech sector in the Leeds City Region and across the UK, bringing together excellence in medtech science with industry partners and NHS. We will establish a Medtech Sector Council to provide strategic leadership for industry, academia and the NHS, to deliver our vision, the goals defined in our strategic common purpose and the development of our propositions to deliver economic growth in the region and across the UK.

The **next steps** are to work with key stakeholder groups and partners across the UK, the Local Enterprise Partnership, BEIS and the OLS, industry, universities, and the NHS to develop each of the five propositions into business cases and investment plans. Reflecting the scale of our ambition: to grow UK medtech sector economic output by at least £10bn by 2025, investment of £50m per annum is required.

Networking and Collaboration

This Science & Innovation Audit has been led by the University of Leeds, working in partnership with the Universities of Bradford, York, Huddersfield, Leeds Beckett and Leeds Trinity, together with Yorkshire Universities, the Leeds City Region Local Enterprise Partnership (LEP), the National Physical Laboratory in Huddersfield, Innovate UK, SMEs, multinational corporations, the NHS, and key local innovation organisations. We have developed a strong partnership, with clear commitment to driving forward our proposals. It builds upon existing centres of research excellence, strong science collaborations across the UK, and a growing network of 300 industry partners in the Leeds City Region and beyond.

Stakeholders from industry, particularly business leaders attending our focus groups, commented that the process had provided the first opportunity for them to meet, to exchange ideas, and to network. There was genuine enthusiasm and commitment for continued networking and support for developing our proposals for the sector in the Leeds City Region and beyond. This demonstrates the wider value of the Science and Innovation Audit. It also emphasises both the need and the potential associated with pre-competitive networking and collaboration in the sector.

An important outcome has been the definition of a new **Medtech Place**, a connected group of institutions, locations and industry partners for the sector with an agreed **common strategic purpose:**

- Driving economic growth, improving productivity, and increasing exports into a growing global market: supporting innovation and growth in companies that currently export, and increasing the number of companies that export.
- Transforming the sector, addressing the growth in new global markets with new products, through convergence of technologies, enabled by digital technology, data analytics & enhanced evaluation.
- Establishing the UK as a world leader for development, pre-clinical and clinical evaluation of medtech.
- Supporting growth through continuous strategic investments and development along the value chain.
- Supporting evaluation, adoption and efficient use of medical technologies emerging from UK companies in the NHS.
- Improving the effectiveness of medical technology, reducing healthcare costs.

LIVERPOOL CITY REGION +

A SCIENCE & INNOVATION AUDIT SUMMARY REPORT

SPONSORED BY THE DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY

JUNE 2017

Department for Business, Energy & Industrial Strategy

LIVERPOOL CITY REGION COMBINED AUTHORITY

Liverpool City Region Local Enterprise Partnership

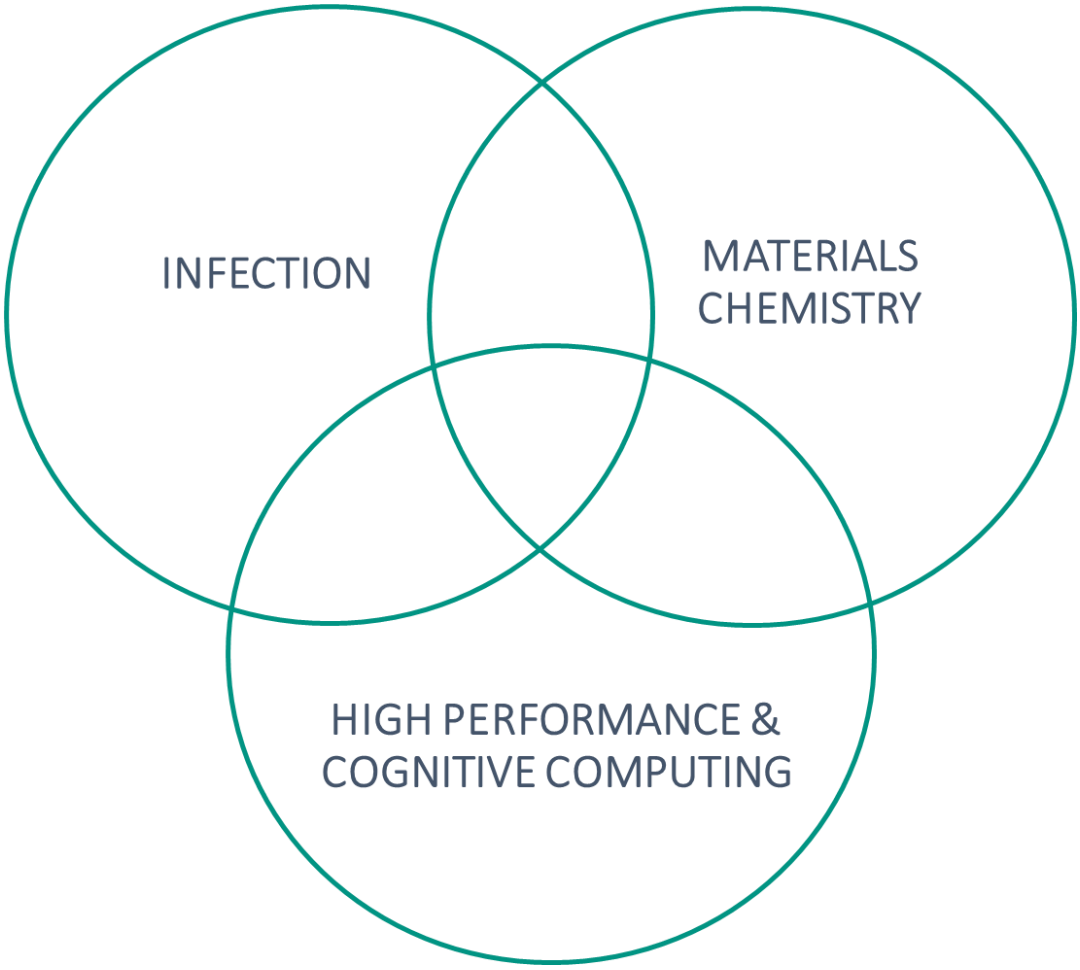
LSTM LIVERPOOL SCHOOL OF TROPICAL MEDICINE

Science & Technology Facilities Council

Unilever

UNIVERSITY OF LIVERPOOL

Liverpool City Council



OUR FINALISED SCIENCE & INNOVATION AMBITIONS:

Infection To consolidate the LCR's position as an international centre of excellence in tackling infectious diseases, and create a cluster of anchor and high growth companies to take advantage of global market opportunities in infection.

Materials Chemistry To apply the LCR's world class materials chemistry capabilities and commercialisation model to provide transformational opportunities for mature UK sectors, create new high-growth industries, and become a recognised global leader.

HP&CC To harness the LCR's world-leading High Performance & Cognitive Computing capabilities to accelerate cross-sector growth and productivity, public sector transformation, and develop a world-class data-centric and disruptive digital technologies cluster.

Innovation Excellence For the LCR to be a national exemplar of place-based and innovation-driven economic growth that supports the UK Industrial Strategy.

Introduction & Context

These are exciting times for Liverpool City Region, and we are at a pivotal moment in our place's history. Faced with major economic, technological, environmental and political changes, the old certainties are passing, and new ways of thinking about and approaching inclusive economic growth are needed. The grand challenges we face cannot be dismissed and are also major opportunities – shifting trade patterns, increased automation as the Fourth Industrial Revolution, driven by data, computing and artificial intelligence, becomes pervasive, and new demographic and health concerns, including anti-microbial resistance present fundamental changes for us. We need to be able to respond to these, both locally for our businesses and our people, and as part of UK rebalancing efforts through, for example, the prospective Industrial Strategy.

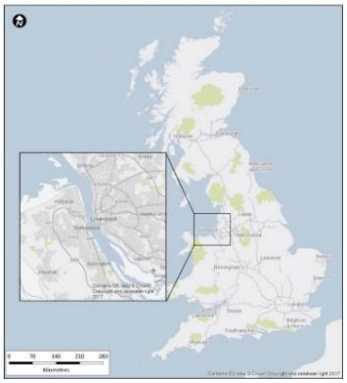


Figure 1: Map of SIA Area

Liverpool City Region is well equipped to respond. We bring:

- A high global profile and an international outlook and connections, which builds on our maritime, trade and industrial heritage;
- Connectivity, with strong connections into our immediate hinterland, including West Lancashire, Warrington, Cheshire, Greater Manchester and North East Wales, as well as global networks developed by our universities, centres of excellence, and businesses;
- Scale and critical mass, based on a functional economic geography employing 600,000 workers, 86% of whom live in the City Region, and generating around £30bn GVA per annum;[1]
- Economic capabilities aligned with those of the wider Northern Powerhouse, namely, Advanced Manufacturing and Materials, Health Innovation, Digital, and Energy;
- An agreed growth plan, *Building Our Future*, to tackle challenges and exploit future opportunities;[2]
- A well-mapped and coordinated innovation ecosystem, with a dedicated Innovation Board and excellent industry links via our other business-led Sector Boards;
- Integrated local governance and resources focussed on Smart Specialisation principles to drive place-based innovation and commercialisation for productivity-based growth; and
- A leading role in the development and prospective delivery of the UK's devolution agenda.

1 Parkinson, Evans, Meegan &, Karecha, 2016, *The State of Liverpool City Region Report: Making the most of Devolution.* University of Liverpool and Liverpool John Moores University. www.liverpoollep.org/wp-content/uploads/2016/01/SOLCR.pdf-Jan-15.pdf

2 Liverpool City Region Local Economic Partnership and Combined Authority 2016, Building Our Future; Liverpool City Region Growth Strategy. https://www.liverpoollep.org/growth-strategy/

- We have the scale, assets, governance arrangements, capabilities, pipeline of investable propositions, and the appetite to play a leading role in the delivery of the UK Industrial Strategy.

Vision

The What . . .?

Liverpool City Region's growth plan*, Building Our Future*, sets the broader context for our Science and Innovation Audit. By 2040, and relative to 2016, we are committed to achieving:

- 100,000 additional jobs;
- A net increase of 20,000 businesses;
- An additional 50,000 people living in the City Region, and
- An increase in the City Region's economy to around £50bn.

. . . and the How?

We are committed to developing our innovation ecosystem to maximise its contribution to the promotion of economic growth. To do this we aim to embed open innovation across the LCR's innovation ecosystem. Our approach to open innovation to date has been based on a close coupling of science and innovation excellence and collaboration between industry and academia. Our approach to developing open innovation in the future will build on this by emphasising the importance of knowledge-sharing supported by state-of-the art computational capability. We will also prioritise co-location of complementary organisations, a process that is already well-established in the Liverpool Knowledge Quarter and at Sci-Tech Daresbury.

Over £2billion[3] of recent and ongoing innovation infrastructure investments in the LCR provide an exceptional platform for innovation-led growth and underlines the deliverability of our ambitions.

In May 2017, our residents elected the first Liverpool City Region Mayor who will control devolved budgets across Transport, Skills, Infrastructure, Planning, Housing, and Business Support (including Innovation). Significantly, the Mayor has taken personal responsibility for the Innovation Portfolio. Devolution gives us more freedom to shape and deliver the economic future of our place; government has defined the role, we will assume responsibility for delivery.

3 Including the £1billion Paddington Village development (1.8m sq. ft, including RCP North); £335million new Royal Liverpool Hospital (opening 2018); £279million new Alder Hey Children's Hospital; £124million Clatterbridge Cancer Centre in the KQL (opening 2018); £64million Materials Innovation Factory (MIF Nexus opening 2017); £25million Life Sciences Accelerator; £20million Bio Innovation Hub; Unilever's £24million Advanced Manufacturing Centre (opening 2017); £15million Sensor City incubator (opening 2017), the £8million "LCR 4.0" manufacturing digitisation project; and the ongoing £35million Sci-Tech Daresbury expansion which builds upon the £113million UK funding for the STFC Hartree Centre and IBM Watson's £200million investment.

Key Strengths

Enthusiasm and assertion can only get you so far in life. In economic development, substantive strength is what carries places and their businesses and people forward. In the Liverpool City Region, we have an established history of building and exploiting complementary strengths in industry and academia – and over 20 years' experience in strategic partnerships driving growth; these strengths reflect the region's long history of vibrant industrial and research communities linked to a port of global significance.

Our City Region's excellence in science and research is coupled closely with innovation excellence and industrial strengths:

- In the manufacture of basic pharmaceutical products and preparations, we have three times the UK average employment, and twice the UK average in local businesses; and
- In the manufacture of chemicals and related products we have well-over twice the UK average employment, and twice the UK average in local businesses – reflecting the City Region's role as part of a leading national cluster.

The findings of the 2014 Research Excellence Framework (REF) highlight our research excellence in Chemistry, General Engineering, Electrical and Electronic Engineering, and Physics, all of which had over 90% of their research outputs classed as world-leading or internationally excellent. Whilst Clinical Medicine as a whole had 71% of its output classed in this top tier, there is world-class research in Infectious Diseases in the LCR; for example, data on literature citations (SciVAL) between 2011 and 2016 shows LCR research in Infectious Diseases is cited more than 2.3 times the global average. Materials Chemistry research is cited nearly 2.5 times the global average. High Performance and Cognitive Computing research in our City Region is cited at over twice the global average rate.

These standout strengths are enhanced by access to high-performance computing via the Science and Technology Facilities Council (STFC) Hartree Centre and the only UK deployment of IBM's Watson cognitive computing platform. This provides a unique and international-class capability to innovate faster, cheaper and at a scale and scope that has not been possible in the past. As we move towards the third decade of the 21st century, innovation in industry, the public sector, and the public good objectives of improved global health will all rest on the ability to use advanced computation and automation in the discovery, testing, application and market introduction of new products and processes.

More widely, our innovation ecosystem is built on co-funded and co-located research and open innovation facilities and asset clusters – most notably concentrated within the Liverpool Knowledge Quarter and at Sci-Tech Daresbury - via which industry and academia work together to exchange know-how, and commercialise research and innovation. This is characterised as the "Liverpool Model", delivering the "Liverpool Advantage", and is best exemplified by the Materials Innovation Factory (MIF Nexus).

Growth Opportunities

Our three SIA themes – Infection, Materials Chemistry, and High Performance & Cognitive Computing – all relate to significant global markets, which are forecast to experience major growth over the next 20 years. Researchers, entrepreneurs, and businesses in our City Region, working with international partners, are well-placed to exploit these opportunities.

Infection Theme

The Infection market falls into three broad categories – Diagnosis, Therapeutics, and Prevention. North America and Europe tend to be the biggest markets, with growth coming from Asia-Pacific, Latin America, the Middle-East, and donor-driven demand in Africa. One of the most significant challenges to be faced in relation to prevention is anti-microbial resistance (AMR)[4]. Antimicrobial coatings and the application of surface science, e.g. on medical devices, are likely to see significant market growth. Global Market Insights research (2016) estimates that the market could potentially treble over the next 20 years to approximately USD$7bn. LCR is well-placed to address this challenge.

Materials Chemistry Theme

The chemicals industry makes vital contributions to UK exports, employment and GVA. The Chemistry Growth Strategy Group estimate the industry value to be £200 billion and highlight the strong potential for a further £100 billion contribution to the UK economy, of which one-third will come through innovation. A specific example of a potential growth area is sensors, an area underpinned by materials chemistry. The market for sensor systems is estimated to be £310 billion globally and is growing at over 10% per annum. The UK sensor industry (impacted on by materials chemistry) is a £13 billion per annum sector supporting 70,000 jobs and producing £6 billion in exports. Around 1.4 million people in the UK are employed in the sensor aligned professions, of which 159,000 are in the North West and 27,000 are in Liverpool City Region (supported by the new Sensor City University Enterprise Zone incubator in the Knowledge Quarter).

High Performance & Cognitive Computing Theme

The markets for High Performance & Cognitive Computing (HP&CC), including those related to Artificial Intelligence (AI), are already large, and set to grow massively over the coming years. Data from American technology specialists IDC Research Inc (2016) indicates that the HPC market will be worth circa $31 billion by 2019, with an expected compound annual growth rate of eight per cent. Similarly, the global CC market's size is expected to reach $50 billion by 2025, (Grand View Research Inc, 2016). In order to make the most of these opportunities, we require constant re-investment with upgrades every four years.

4 Jim O'Neill et al, *Tackling Drug-resistant infections globally* Final Report and Recommendations, May 2016 and Annual Report of the Chief Medical Officer, Volume Two, *Infections and the rise of antimicrobial resistance*, 2011

Gap Analysis

R&D Spending

In 2014, gross expenditure in R&D in the North West in all sectors was £2,557 million (8.3% of R&D expenditure in the UK). The breakdown of R&D expenditure by sector in the North West is in line with UK norms, except for the case of government sector R&D, which is estimated at 1.55% of total R&D expenditure. This is below the Wave 2 SIA average (6.28%) and the UK (at 7.26%).[5] Thus, the North West is under-represented in government sector R&D. We have a strong pipeline of investable proposals offering strong returns.

Infection

Our SIA confirms that our City Region has:

- World-leading assets and expertise, with the largest concentration of translational-focused public sector RD&I infectious diseases expertise in the UK, and leading international science and innovation networks;
- A century-long track record of academic-industry collaboration, and
- An excellent current track record of accessing research funding from national and international sources, including the World Health Organisation and the Bill and Melinda Gates Foundation.

It has highlighted that the City Region must:

- Develop a targeted inward investment strategy that leverages its excellence in research into infectious diseases, and the combination of world-leading facilities and expertise offered by the three Themes – by building on the achievements of and, lessons learned from, the Knowledge Quarter development, in particular the importance of colocation and cluster development;
- Continue to invest in its research assets to maintain its world-leading status;
- Re-double its efforts to attract, develop, and retain the skills and talent required to grow the supply chain in the City Region, and
- Ensure that relevant support regimes, especially access to finance, business support services, and inward investment expertise – are in place, if the growth of a locally based cluster of firms active in the Infection RD&I space is to be realised.

Materials Chemistry

Our SIA work confirms that our City Region has:

- World-leading expertise in Materials Chemistry, and Fast Moving Consumer Goods (FMCG);
- A track record of accessing research funding from national and international sources, and

5 See Appendix 5 of the main report for more detail.

- A unique model for university-industry collaboration - the 'Liverpool Model', which has been developed in partnership with multinationals and their supply chains in several phases over the past 15 years.
- It has highlighted that the City Region:
- Has a significant opportunity to become a globally significant player in both FMCG and other high-value chemical industries and their supply chains, underpinned by academic excellence;
- Should move to exploit the unique and distinctive contribution that the Liverpool Model can make to the LCR+ area by transferring knowledge into other parts of the City Region's Innovation Ecosystem, and
- Must ensure that new open innovation facilities plus relevant support mechanisms, such as access to finance, business support services, and inward investment expertise, are in place to foster opportunities for new Materials Chemistry-related ventures to thrive.

High Performance & Cognitive Computing

Our SIA confirmed that the City Region has:

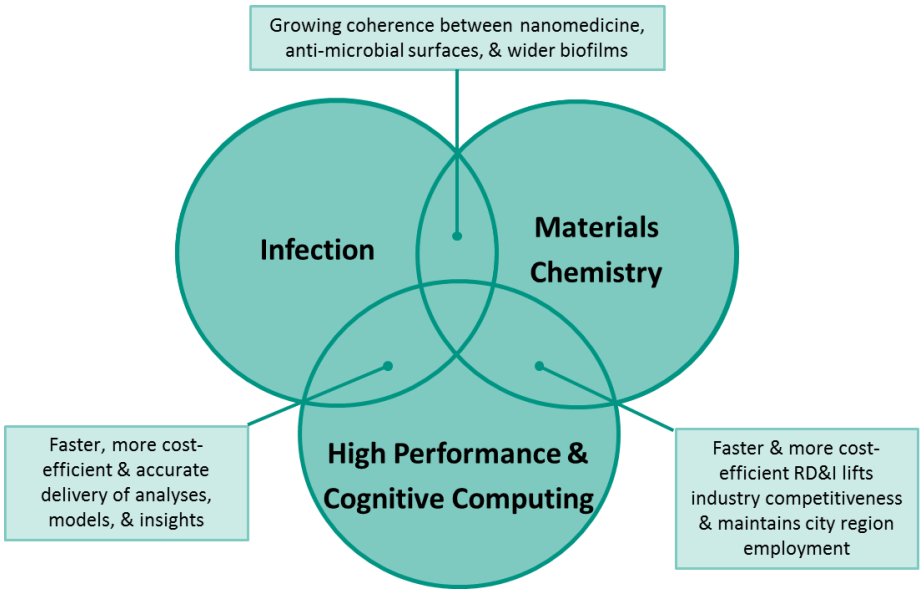
- An emerging cluster of HP&CC capability and capacity, which is already of national class and, in terms of computing power, is international class;
- Achieved a major 'result' in attracting IBM to locate its UK R&D Centre alongside The Hartree Centre, and
- An opportunity for HP&CC in the LCR to be developed both as a 'sector' in its own right, and as a key 'enabling service' for the Infection and Materials Chemistry themes, and the wider economy.
- It has highlighted that the City Region must:
- Broaden its HP&CC activities to include both industry and service sector user bases (in both private and public sectors), and reflect the multi-partner grouping that LCR's HP&CC actors comprise;
- Continue to work to ensure that the different components of its HP&CC offer are integrated effectively;
- Increase HP&CC activity at the business core of the City Region; proposals for a Hartree presence in Liverpool itself, and the proposed Digital Innovation Factory, will be essential for this to happen;
- Ensure strong and vibrant links with centres of excellence elsewhere in the UK and internationally remain a priority, and
- Retain, enhance and maximise the LCR presence of IBM's R&D Centre and Atos, by packing around these prime assets a resilient supply chain of local HP&CC providers and partners.

Key Ambitions & Proposals

Key Ambitions

Our work was informed by an over-arching framework of analysis (Figure 3) and an initial set of hypotheses and ambitions, which we tested and revised.

Figure 3 Our City Region's Science & Innovation Audit at a glance



Our Revised Ambitions:

To consolidate the LCR's position as an international centre of excellence in tackling infectious diseases, and create a cluster of anchor and high growth companies to take advantage of global market opportunities in infection;

To apply the LCR's world class materials chemistry capabilities and commercialisation model to provide transformational opportunities for mature UK sectors, create new high-growth industries, and become a recognised global leader;

To harness the LCR's world-leading High Performance & Cognitive Computing capabilities to accelerate cross-sector growth and productivity, public sector transformation, and develop a world-class data-centric and disruptive digital technologies cluster; and

And, overall, for the LCR to be a national exemplar of place-based and innovation-driven economic growth that supports the UK Industrial Strategy.

Proposals

Our SIA process has initiated and facilitated many large-scale and bi-lateral discussions among institutions and businesses both within the City Region and further afield. These generated ideas and helped to shape existing proposals from partners, and are continuing actively to do so. The tables below summarise the theme-specific proposals. The cross-theme proposals are discussed in Section 7, as examples of how the SIA process added value to existing arrangements and networks.

Infection Theme	
Project Title	Centre of Excellence for Infectious Diseases Research+ (CEIDR +)
Leads	Liverpool School of Tropical Medicine, and University of Liverpool
Partner Organisations	**Core Partners**: Royal Liverpool and Broadgreen University Hospital; Alder Hey Children's Hospital Trust; Liverpool Clinical Laboratories; The Innovation Agency. Affiliate partners: Liverpool Health Partners; Liverpool Knowledge Quarter. **Business**: Collaborative programmes with large pharmaceutical companies with operations within and outside the LCR; locally based companies include Seqirus, AZ/Medimmune and Elanco; plus SMEs including MAST Diagnostics, Perfectus Biomed, Arcis Biotechnology, Biofortuna, Pro-lab Diagnostics and Global Biodiagnostics, Gencoa, Vodus Medical and other digital health companies.
Project Description	CEIDR's first phase (2017-2020) will build a portfolio of projects with collaborating companies. This will catalyse the second phase (post 2020) where we anticipate a new bespoke facility stimulated by increased SME spinouts and demand from collaborating companies for co-location. Three of the exemplar projects are: Discovery and Development of Next Generation Anti-infective Drugs; Discovery and development of vaccines; Consumer products for prevention of emerging arboviral diseases (ZIKA+). Based on the size and scope of Liverpool's Infection capacity, CEIDR is forecast to create 252 gross direct and indirect jobs (138 net additionals) and £42 million in cumulative net additional GVA in the region over 10 years.

Materials Chemistry Theme	
Project Title	MIF (Materials Innovation Factory) Nexus
Leads	Co-leaders University of Liverpool, and Unilever
Partner Organisations	**Core Partners**: University of Liverpool, Unilever and NSG Pilkington. **Affiliate partners (initial):** Croda; Bristol Myers Squibb; ACAL energy; C Tech Innovation; Chemistry Growth Partnership; Ceres Power; Gencoa / Pegasuss; ITM Power; Johnson Matthey; Liverpool Chirochem; Morgan/Ceramtec; National Nuclear Laboratory.
Project Description	The proposed project was developed directly from the SIA process. MIF Nexus will support major companies through access to shared robotic testing, scale-up and proof-of-concept facilities; SMEs through access to synthesis and characterisation services and facilities they would not otherwise afford; start-ups and spin-outs through access to expertise and pump-priming support. It will comprise a Materials Design Engine focussed on academic research of industrial relevance and several Materials Applications Engines specific to industry sectors. The integrated facility will help to de-risk investment in new materials for a wide variety of applications, most importantly in a manner that will facilitate investment in major transformational and potentially disruptive technologies of global significance. This will be achieved by decreasing the levels of investment faced for these high-reward opportunities in a manner unique to this facility. As such, MIF Nexus will create a virtuous circle of cumulative economic impacts based on attracting risk capital able to exploit this unique 'investment ready' translational facility. The facility business model is based on accelerating the development of new advanced materials, creating a commercial capability in materials design that will attract investment, encouraging corporate re-location and, itself, will generate revenue from services provided and funds for re-investment to develop the facility's capabilities over the long-term.

High Performance & Cognitive Computing Theme	
Project Title	'Deep Change'
Lead	Science & Technology Facilities Council (STFC) Hartree Centre
Partner Organisations	The wider HP&CC cluster in the LCR - STFC's Scientific Computing Department (SCD), the Virtual Engineering Centre (VEC), Departments/Schools of Computing at Liverpool and Liverpool John Moores Universities, IBM, and Atos
Project Description	Deep Change is a path-finding three-stage programme designed to embed a pervasive understanding of HP&CC technologies and methods across all parts of the Liverpool City Region economy, and eventually to develop a model for national application. Building on existing HP&CC activity and linked to the LCR Activate project, it will be delivered using the hardware platform expertise of Hartree, the fundamental science capabilities of the Scientific Computing Department, the applied project experience of the Virtual Engineering Centre, the international understanding of HP&CC technologies and the proposed Digital Innovation Factory in University of Liverpool, and the inclusive outreach expertise of Liverpool John Moores University. Deep Change will have three phases; (i) *Discovery*, a broad-based outreach component, designed over a five-year period to benefit 12,500 firms, organisations, and/or individuals, focused on developing understanding of HP&CC technologies and their benefits; (ii) *Accelerator*, identifying from the pool of *Discovery* beneficiaries some 200 organisations (both private and public sector) with potential to engage with HP&CC major vendors (e.g. in Liverpool, IBM UK and Atos in particular) to co-address HP&CC challenges and opportunities; and (iii) *Rising Stars* which, from within the *Accelerator* cohort, will identify and develop 50 organisations with real HP&CC capacities and capabilities to offer expertise, services, and/or products at an international level. The Rising Stars will have the potential to create very significant volumes of higher value-added jobs, contributing directly to our economic well-being. The project will be focused on the City Region but will operate with strong links to another part of the UK and internationally, especially in terms of where other major HPCC vendors are located.

In addition to these theme-specific proposals and the cross-cutting proposals discussed in the next section, our SIA work has additionally shown that we need to:

- Ensure relevant business support regimes, especially access to finance, business support services, and inward investment expertise are in place in order to facilitate inward investment, business start-ups and supply-chain and cluster development;
- Develop and retain strong and vibrant links with centres of excellence elsewhere in the UK and internationally, in order to maintain and enhance world-leading positions in our theme areas, and
- Build on the global reputation of LSTM for supporting the public good by generating new diagnostics, therapeutics and preventative products.

Networking & Collaboration

Networking & Collaboration Process

Science and innovation partners in the City Region are well networked with leading Northern and national industry, academic, and research leaders, not least via the LCR Innovation Board, under whose auspices our work has been conducted. This foundation, with a particular emphasis on business engagement, enabled us to effectively engage partners in the SIA. A major stakeholder event, attended by over 80 people, was held in Liverpool on 7th March, at which attendees discussed overarching issues related to science and innovation in the City Region along with theme-specific matters, and cross-cutting synergies.

Proposals arising from the SIA process

Two cross-thematic proposals – building on existing activity – have been developed.

Case Study 1: Development of a 'Biofilms Innovation and Knowledge Centre'
This proposal builds on the work of the Open Innovation Hub for Antimicrobial Surfaces (OPIHAS), which is already translating internationally leading expertise from University of Liverpool's UK Interdisciplinary Research Centre in Surface Science. OPIHAS partners with global companies such as Akzo Nobel, Ansell, Croda, dePuy Synthes, Smith & Nephew, Scapa, Unilever and Walgreens Boots and many innovative SMEs. It combines physical, biological and clinical sciences to develop next generation anti-infective surfaces and materials that are key in infection prevention and control. OPIHAS already has a demonstrable commercialisation pathway – four patents are filed, and clinical trials are underway for one, and will take place in 2018 for two others. While led by the Infection theme, the new proposal involves cross-theme working with Materials Chemistry and HP&CC, where multiscale modelling will help drive knowledge-based innovation.

Case Study 2: Improving product design and efficacy through optimising placement
Products designed to prevent infectious disease transmission are often tested in artificial systems, or designed to be placed at the point where 'expert' opinion suggests they will have the greatest traction. Products in the development phase or early operational testing often look very promising only to fail when they are deployed in real-life situations. The technology is now available to track the movement of microbes, parasites or viruses over time in three dimensions, alongside tracking human and secondary vector movements. Hence, for example, we can start to track how resistant bacteria enter a hospital environment, how they move around the building and how they are carried by patients, staff and visitors. The data generated from 24hrs of tracking requires several weeks of detailed analysis using traditional technology. We aim to develop an Open Innovation Hub for 3D monitoring linking with the high-speed computing abilities at Daresbury/Hartree, to speed up this process.

Conclusions

Our SIA process has been a rewarding journey. We have collectively built upon existing smart specialisation activity to forensically prioritise the truly world-leading elements of our science and innovation offer and identified a clear and ambitious plan for future development. We have immeasurably strengthened existing relationships, established new external connections, and developed major new ideas. We are excited by what can do for our place, and for the wider UK.

Our audit has taken place within the context of over £2 billion investment in LCR's innovation infrastructure; it coincided with the launch of the UK Industrial Strategy Green Paper and Challenge Fund, and the election of our new Metro Mayor and the establishment of a devolved Single Investment Fund. Taken together, this presents an unprecedented opportunity for the LCR to deliver transformational growth, which we fully intend to grasp with both hands.

LCR+ SIA governance arrangements and key stakeholders

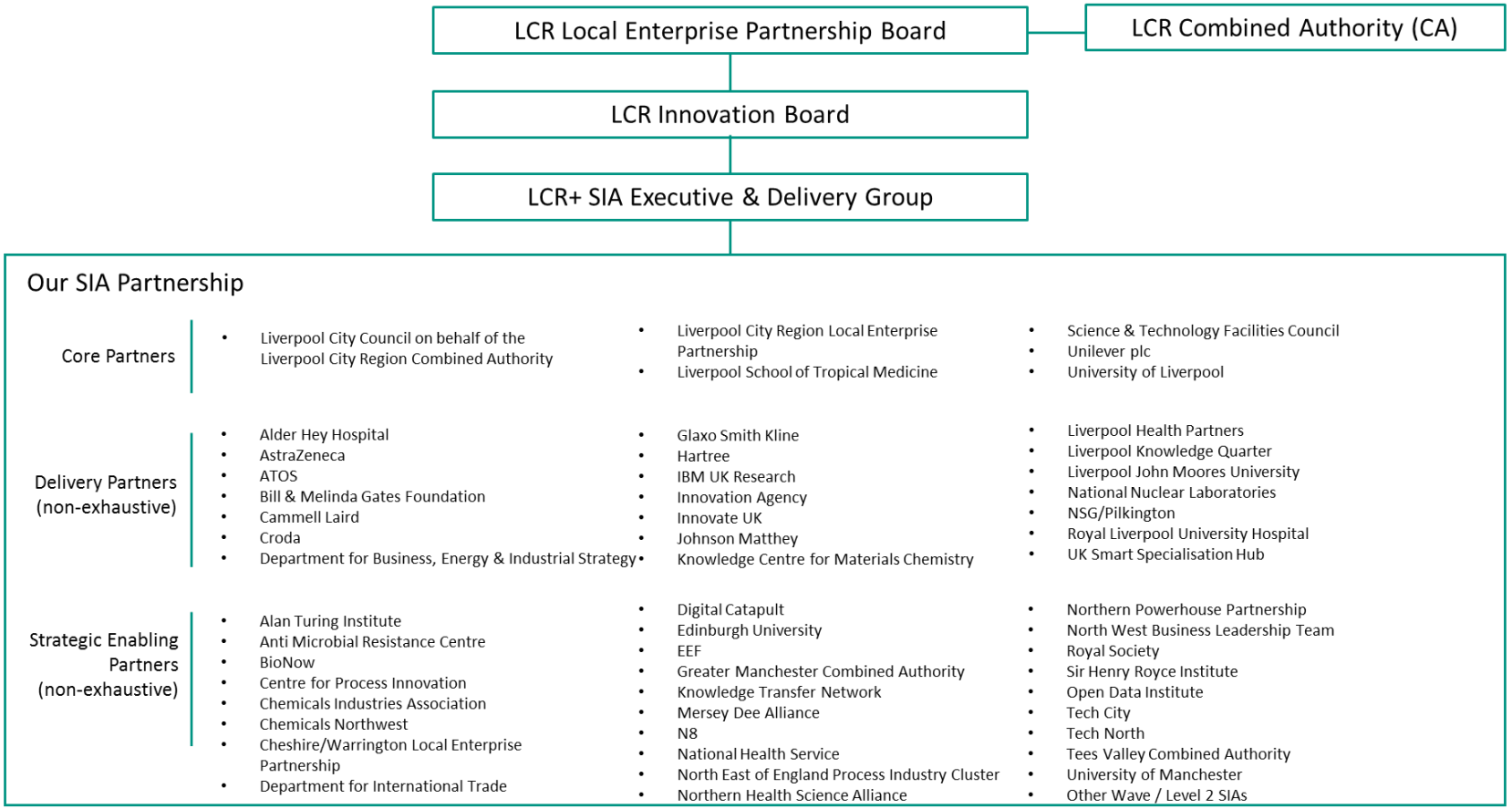


Figure 2: Stakeholder map for SIA

- You can contact us via lcrsia@liverpoollep.org
- The full SIA report, appendices and further information can be accessed via our website www.liverpoollep.org/lcrsia

OFFSHORE RENEWABLE ENERGY

A Science & Innovation Audit

Sponsored by the Department for Business, Energy & Industrial Strategy

Summary Report

The Offshore Renewable Energy SIA Geography

The Offshore Renewable Energy SIA was conducted across the north of England and Scotland by a consortium comprising:

- the Universities of Durham, Hull, Liverpool and Newcastle
- four LEPs (Humber, Liverpool City Region, North-East and Tees Valley Combined Authority), Scottish Enterprise
- the Offshore Renewable Energy Catapult

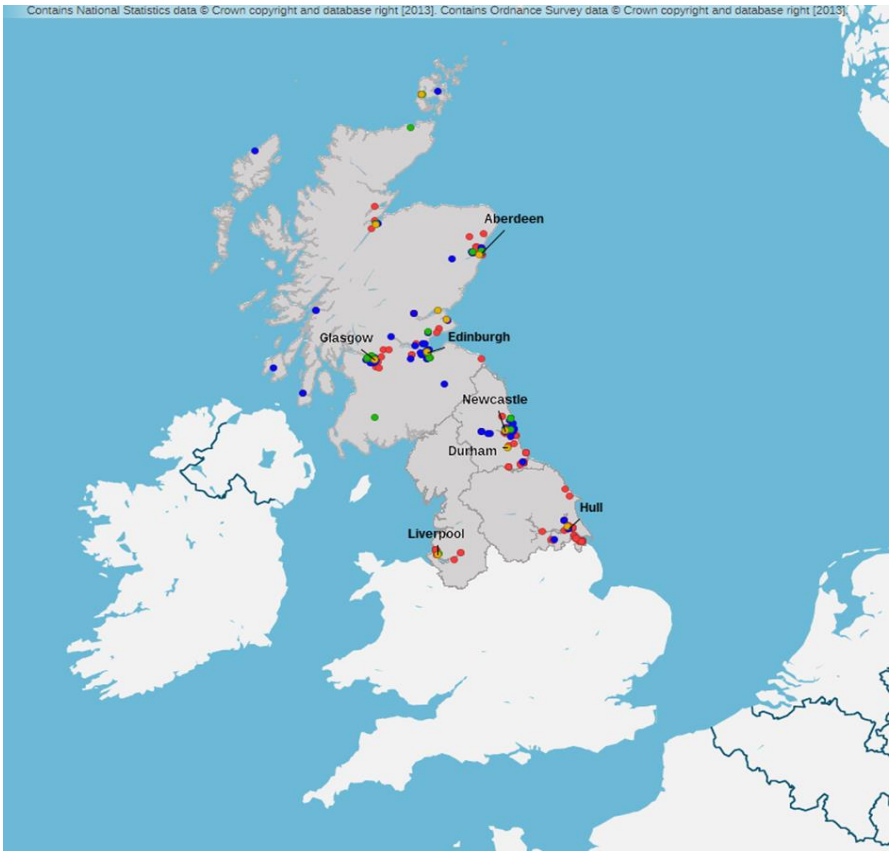


Figure 1: Map of SIA Area

The Offshore Renewable Energy SIA consortium was formed so that it covered a geographically distinct unit of significant activity in this industrial sector - comprising Scotland and the North of England with clear foci around key major ports with their well-developed maritime industries and associated supply chains. The geographical areas included in this SIA are linked through common interest as well as long histories of co-operation and joint enterprise in the offshore energy sector which developed out of their historical maritime activities in the major ports of Northern England and Eastern Scotland.

Local Strategic Economic Plans developed by LEP's within the SIA consortium identify offshore renewable energy as a key economic priority and existing connections between the areas include research linkages, key businesses with multiple locations, the existence of established business networks and the primary locations of the offshore renewable catapult. There are also UK leading local innovation eco-systems in some parts of the territory offering opportunities for dynamic open innovation activities linking technology bases, for example digital and satellite applications and wider energy technology assets.

The partnership believes that there is potential for stronger alignment of these assets and resources, and that the shared coastal location and the focus into similar offshore and coastal sites provided an opportunity for strengthened collaboration through the SIA process.

Introduction

Offshore renewable energy in a number of forms (offshore wind, wave, tidal stream and tidal range) is a crucial part of the UK's energy mix and will continue to play a major role in the meeting of international environmental targets in the long term. The UK economic opportunity in offshore renewable energy is robust and growing. Over £15bn of private sector resource has been invested in commercial offshore wind projects in the UK to date and a further £15-20bn is in the pipeline. The cost of electricity from offshore wind has fallen 32% in the last four years[1], surpassing 2020 cost reduction targets and putting the goal of being the cheapest, large-scale clean energy source within reach. Further cost reductions will lead to deployment of thousands more offshore wind turbines by 2030, allowing UK companies to help deliver value to the UK economy of £4.4bn per year[2], whilst wave and tidal energy technologies are now being trialled at scale. This Science and Innovation Audit focusses on this creative and dynamic sector – analysing the current situation and providing insight into the significant opportunities ahead.

Vision

The vision for the SIA area is that Northern England and Scotland can transform from a majority importer of offshore renewable energy technology to a major UK supply base and, ultimately, an export hub for UK manufacturing and services in this sector. Key to this will be the creations of significant technology clusters which will provide a supportive environment for manufacturing companies (OEM and T1) to design, innovate and manufacture components and systems in the UK in key areas such as:

- Blades
- Bearings and drivetrains.
- Electrical systems
- Cables

In addition, the UK can continue to build a world class knowledge hub for design and delivery of O&M services and technologies including optimisation and control instrumentation, sensors and sensor systems (including environmental sensing), autonomous systems, communications innovations, health, safety, training and simulation (augmented and virtual reality), digitalisation, data, logistics and modelling.

This ambition is supported by the UK government's industrial strategy, which demonstrates the UK's push to enhance its competitive advantage in the offshore renewable energy sector. This will require developing the UK as a global leader in innovation in offshore renewable energy; sustainably reducing the cost of energy across infrastructure design and supply chain through

[1] ORE Catapult Cost Reduction monitoring Report 2016
[2] The Economic Value of Offshore Wind: Benefits to the UK of Supporting the Industry

innovation in the application of sub-sea and marine technologies and efficient deployment of offshore wind technologies.

Key strengths

The SIA team undertook an extensive analysis of a wide range of activities across the broad area of offshore renewable energy. The following key strengths were identified (full details and references in the main report):

1. **Market**

- The UK currently has the world's largest installed capacity of offshore wind (approximately 5.1GW) and construction is progressing or close to beginning on a further 5GW, giving a forecast installed capacity of more than **10GW by 2020**
- The UK is currently a leading market for offshore wind but the opportunities are global, with up to 100GW potentially installed worldwide by 2030, and tapping into this global market (particularly in Asia and the US) will be vital for UK companies to maintain a steady pipeline and stable order books.
- The UK government is fully committed to two Contract for Difference (CfD) auction rounds, with awards for the first of these expected in autumn 2017 and industry expectations are that further commitments will be made, enabling the UK to reach an installed capacity of **30GW by 2030**
- The vast majority of the UK's operating offshore windfarms are readily accessible from ports within the SIA area, which covers both the Irish and North Seas and other European offshore windfarms are also readily accessible from the Humber and Teesside
- Tidal stream energy is at an earlier stage of development than offshore wind but has arguably more potential for primary construction in the UK. Scotland's Pentland Firth is home to the world's first utility-scale commercial tidal stream project, with a **strong pipeline** of consented wave and tidal sites in the SIA area and there are a number of floating wind demonstration projects currently under construction or in development

2. **Academic Research**

- The academic research produced in the SIA area in offshore wind, wave and tidal is world-class in terms of both quality and volume and there are a number of universities in the area with centres of excellence in, or with close ties to, the field of offshore renewables
- Multi-disciplinary, multi-stakeholder hubs including academic, commercial and government organisations have emerged, encouraging transfer of knowledge from related areas of specialism towards implementation and deployment.
- Other academic hubs focus on specific components (e.g. Wind turbine control), allowing deep technical expertise to be developed

3. **Innovation**

There is strong evidence of innovation in the sector but also signs that the potential for enhancing that is at risk without further support.

- The number of wind energy patents filed by inventors in the SIA area has been growing year-on-year since 2005, both in absolute terms and as a proportion of those filed for all

UK-based inventors, demonstrating an increase in developing relevant intellectual property (IP) in the region
- The UK has a strong collection of world-class physical research, innovation, testing and demonstration facilities to support businesses to commercialise new products, services and bring down the cost of producing energy from offshore renewable energy sources. The ORE Catapult plays a key role as an entry point to these capabilities.
- Offshore renewable energy in the UK is supported by a number of industry and/or academic bodies and programmes and the SIA has identified substantial activity from support bodies within the SIA area, including Wave Energy Scotland (WES), Subsea North East, Aura and the ORE Catapult,

4. Supply chain engagement in R&D and collaboration

- The SIA has identified almost 200 individual companies across the SIA with offshore renewable energy as their core business, with a large number currently engaged in publicly-funded offshore renewable energy innovation projects, demonstrating both the importance of innovation to the sector and the ability of companies to access appropriate funding
- The industry-led innovation projects identified include a number of collaborations with academic partners, which highlights the emergence of joint industry-academic clusters and highlights the importance of aligning the research agenda with industry's current and future needs

Growth Opportunities

The offshore renewables sector is undergoing a period of rapid and unprecedented growth both in the UK and globally. This presents strong opportunities for growth and the UK has an opportunity to become a true global leader in this key industrial sector.

- The SIA region has a strong tradition and expertise in heavy industry, including fabrication for offshore oil and gas projects, which can be tailored towards the needs of offshore renewables, particularly in turbine tower and foundation design and manufacture and further linkages between fabricators and port facilities can provide more of a compelling offer to offshore developers, increasing the UK share of major contracts and growing UK GVA.
- The regions covered in the SIA have the potential to create a compelling offer to technology developers within the OEM supply chain through the creation of a supporting environment in which to design, innovate and manufacture in areas such as Blades, Drivetrain components, electrical systems.
- The region can further build on strengths in the O&M space through the creation of knowledge hub for design, delivery and export of O&M services, technologies and knowhow.
- In addition to offshore renewable energy focussed companies, the SIA identified over 500 businesses which have had some involvement in the sector and there is an opportunity for these businesses to grow the relevant expertise, enabling them to enhance this growth industry as well as preserving existing valuable skills and jobs.

- Floating wind concepts are progressing towards commercialisation and ports and supply companies in the SIA region are well-placed to capitalise, particularly in Scotland, where seabed conditions in some areas do not favour fixed-bottom foundations
- Opportunities exist to strengthen the existing links between industry and academia in order to focus funding and resources on research which will address the key current and future industry needs, leading to increased competitiveness for both universities and supply chain companies
- There is a critical mass of digitalisation and high value manufacturing activity in the SIA region, which could be more highly levered into research, development and innovation (RD&I), training and fabrication for offshore renewables through increased cross-Catapult working and collaborations between industry and academia.
- There is a particularly strong opportunity for the development of data services in operations and maintenance of offshore renewables assets. This could be a potentially very strong export activity for the UK.
- The increase in investment in the Humber region could potentially be replicated where offshore renewables activity is due to grow, for example around the Moray Firth, and advance planning for this can allow for planned wind, wave and tidal sites to factor such hubs of expertise into innovation and cost reduction plans.

Gap Analysis

The gap analysis focusses on the ability of the current research, supply chain and skills capabilities to meet the current and future needs of the offshore renewables sector.

- Much of the academic activity relevant to offshore renewable energy cuts across the whole sector and there is space for increased focus on specific technologies and challenges related to the development of the next generation of turbines (such as composites, longer blades, aero-elastic modelling, large bearings, full systems load modelling, reliability issues with turbine scale up amongst others), new O&M technologies autonomous vessels, digitalisation in design and control systems – for offshore wind, wave and tidal
- There is an apparent lack of offshore renewable energy-focussed funding sources available for innovative companies, including Small and Medium Enterprises (SME's), in Northern England compared to Scotland
- The UK's ambition in offshore renewable energy does not appear to be matched by the level of funding made available through research grant funding
- An existing shortage of skilled engineers and other technical professionals is forecast to be compounded in future as demand for higher-skilled workers increases at the expense of a lower-skilled workforce. There is a need for a coherent, demand-led skills road map to establish the future requirements and delivery routes for talent in the sector.
- There is no ring-fenced Contract for Difference (CfD) auction pot for tidal or wave energy, meaning there is currently no clear route to market for innovative companies developing solutions in these maturing technologies.
- Overall the UK lacks for coordination of effort by comparison with for example Germany where the Fraunhofer network provides for more integration of effort and resource.

Key Ambitions and Proposals

The region has the potential to draw together many of the existing facets of the RD&I and skills landscape into a compelling offer for technology developers and project operators. Doing so will create a higher degree of visibility and easier access for developers and innovators into the region. The SIA identified a number of key opportunities that are outlined below:

- A stronger focus on convening engagement between academic research and industry to ensure needs are identified and addressed and appropriate academic and commercial-level funding is made available for the emerging priorities. This could be achieved through a focussed program of innovation support for companies that draws on BEIS place-base funding.
- The SIA, through the linkage to the Industrial Digitalisation review, has identified that there is a clear opportunity in the development of digital technologies for offshore wind – particularly in operations and maintenance of deployed assets and in the design phase of elements such as foundations. This could be driven forward through the Industrial Strategy Challenge Fund.
- There is a need for a systematic investigation of skill requirements and provision across the offshore renewable energy sector - leading to the development of a national skills roadmap for offshore renewables and implemented through partnership working including devolved powers.
- The establishment of a new initiative to support subsea engineering which is a key enabler of offshore renewables. This should involve support for a small number of existing regional clusters of excellence to enable expensive capital testing facilities to be utilised and supported efficiently.

Networking and Collaboration

The process of the SIA has been highly collaborative – both within the SIA consortium and with the wider community. This approach has been very valuable in itself but a number of more specific benefits have emerged.

During the SIA, the consortium team members have undertaken extensive discussions with a number of companies active in offshore renewables. This has included companies of every size and with activities across the full supply chain. These discussions have enabled a very productive exchange of views and information – enabling key issues and ideas to be examined in detail and tested for consistency and feasibility.

Participation in the SIA has also strengthened the collaboration within the SIA consortium members. Links were already good prior to the SIA starting (members had collaborated many times in various configurations through a number of projects involving say two or three members at a time) but the SIA process represents the first time that the full consortium had worked together. Working relationships were quickly established and there has been excellent engagement from all members throughout. It is clear that the relationships within the

consortium have deepened as a result of participation and a significant team ethos has been developed. This is perceived as being a valuable outcome in itself and will likely result in enhanced collaboration in the future across a number of activities and projects.

For the Universities involved, participation in the SIA has reinforced approaches and existing strategies rather than led to radical changes. All the Universities involved in the SIA are committed to offshore renewables but typically have areas of specific focus and excellence rather than attempting to cover all of the potential fields involved in such a multi-disciplinary topic as offshore renewables. Participation in the SIA has provided for the universities very useful insight into the direction of travel of the industry and future needs of the various companies involved. This is extremely valuable contextual information that will feed into future strategies and decisions rather than lead to immediate changes of direction.

The LEPs involved in the consortia have participated strongly with a particular focus on supply chain and skills analysis. This has provided a deepened understanding of those issues and highlighted the need for devolved powers and resources so that LEPs and other regional actors can start to provide targeted support to help the industry develop. At the moment, more generic national actions do not provide the necessary focus and specific activities to ensure optimal outcomes. The dialogue within the SIA process has strengthened the understanding of the LEPs of the regional company base and highlighted the integrative nature of the industry across the full SIA region. This understanding has already fed into development of strategic economic plans and will continue to do so over the next few years.

For the ORE Catapult, the SIA process has reinforced and deepened understanding of where genuine academic strengths are located. This will help identify potential partners for future projects and encourage strategic but focussed links with key academic teams. The collaborative team working inherent in the SIA process has developed improved links with the LEPs and helped firm up key contacts for ensuring that discussions of key innovation challenges reach the right LEP audience. It has also improved understanding of the supply chain on a regional basis and helped highlight specific companies and their innovative activities.

The SIA consortium partners have benefitted from a deeper understanding of the international competition and opportunities as a result of the SIA process. This has highlighted opportunities for growth in the UK economy through exports (both goods and services) that could be enhanced if the SIA cluster is supported to grow over the next few years. The SIA process identified companies developing innovative products and services but at present LEPs, for example, are not able to offer suitable funding instruments to assist those companies enough nor are national funding competitions structured and focussed in a compatible manner. The SIA process through enabling a sector wide understanding has consolidated this view.

Post completion of the SIA report, the consortium sees strong potential benefits in using the information and recommendations as a focus for further networking and collaboration building with industry. That might take the form of focussed meetings that concentrate on a key technology or opportunity and lead to the establishment of new projects.

During the SIA process, industry has also given clear feedback that is struggles to understand university capability and capacity in this field. The analysis of UK research expertise will thus be a very useful resource for industry to identify potential partners for collaborative projects. To support this use, the SIA consortia intend to publish and maintain a detailed analysis of UK research strengths in offshore renewables for initially a fixed period (three years is the current thought) to see if this really represents a useful resource for industry.

Overall, the SIA consortium believe that there have been additional benefits from the networking and collaboration inherent in the SIA process that extend well beyond simply completing the task. The establishment of the team involved and the strong working relationships developed will persist and lead to future partnerships across a range of activities.

Oxfordshire Transformative Technologies Alliance

Science and Innovation Audit

Summary Report

August 2017

Introduction and context

The Oxfordshire Transformative Technologies Alliance SIA focusses on 4 large scale, disruptive, inevitable, digital technologies, for which the UK has great need and world class strength, particularly in Oxfordshire. There is considerable consensus that business sectors and workforces globally will be significantly disrupted by the development and impact of these technologies. We have sought to think beyond 'business as usual' to identify opportunities and strategies to secure the UK's position in a global context as these technologies increase their market share, and their relevance and influence in policy, society and economies.

The technologies are fast-moving and competitive, and offer opportunities which require strategy and cohesive leadership and prioritisation if the UK is to maintain and develop a global position in the science and innovation and markets.
We consider maximising the value of investments through co-location and connectivity between complementary technologies, and delivery mechanisms and connectivity into the supply chain. The national purpose is to maintain and capitalise on the UK's narrow, and otherwise fragile, early mover advantage.

This SIA demonstrates both the scale and quality of Oxfordshire's science and innovation assets, and their potential to support implementation of the National Industrial Strategy, and have lasting transformational impacts on national competitiveness and productivity through 2030.

Place

The geographic focus for the SIA is on assets within Oxfordshire. There are links with three other areas of the UK: the M3 corridor, greater Cambridge, and the north-east of England, for technology development, manufacture and rollout.

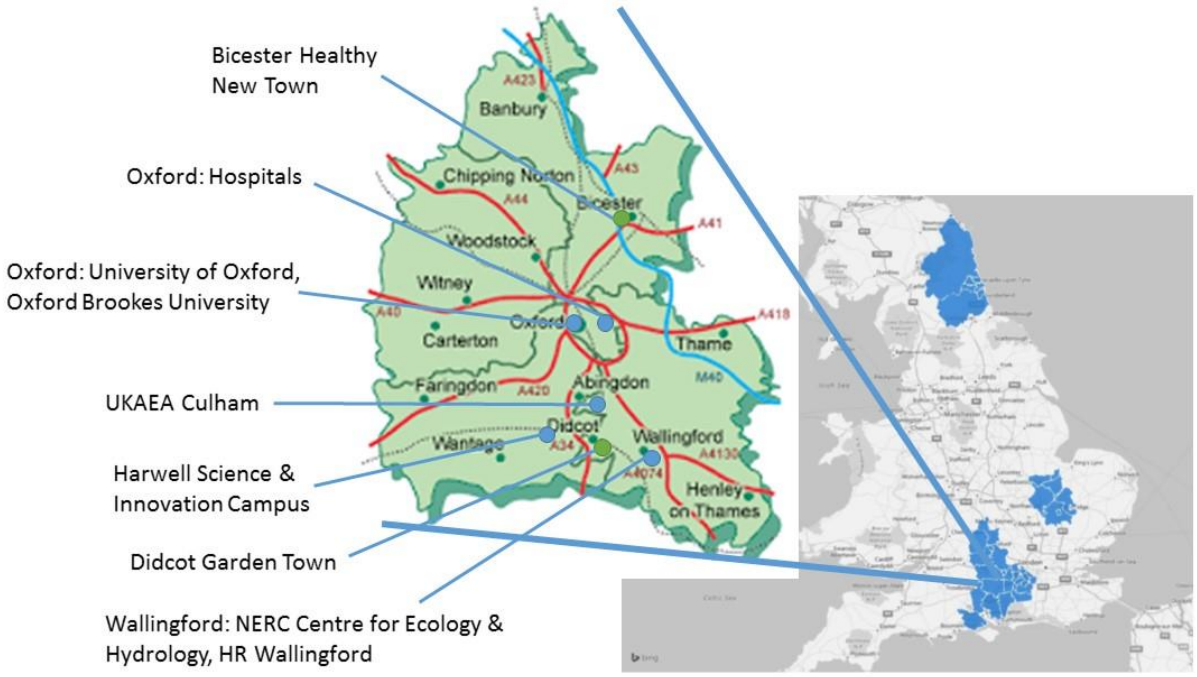


Figure 1: Map of SIA Area

Vision

The core vision of this SIA is for Oxfordshire to be a global leader in the development of transformative technologies that will underpin the future UK economy and provide lasting global competitive advantage.

Convergence of ubiquitous computing power, cloud data storage, and advanced decision making algorithms with mass consumer acceptance of increasingly smart digital devices, will continue to transform society.

The opportunity for the UK is to play a leading role by developing new products and services built on purposeful investment in appropriate skills and strategic support for cross-sector engagement. This will mutually reinforce the growth of these technologies, and their application to a wide range of market sectors. The selected technology areas are:

- Digital Health
- Space-led Data Applications
- Autonomous Vehicles
- Technologies underpinning Quantum Computing

These are not the only themes in which Oxfordshire has highly significant or leading science and innovation capacity in the UK, and internationally[1].

These four technologies were selected because they are specific areas of technology and application development (rather than broad industrial sectors) which, combined, have the potential of driving innovation across many sectors and they share common aspects which make them a cohesive proposition:

1. They are all digital technologies, or are highly dependent on digital technologies. They are all developing rapidly and present long-term opportunities for significant growth and competitive positioning in the global economy.
2. They share co-dependencies, such as cybersecurity and machine learning, which are regional strengths.
3. They will extensively disrupt industry sectors and workforces: integration will require innovative governance. A place-based approach underpins the holistic nature of the opportunities, leading to economies of scale and other potential synergies across the value chain and in new market opportunities.
4. Opportunities for innovation (products and services) exist at the interfaces between these technologies (e.g. vehicle-based health monitors), which are more likely to be identified and exploited quickly if these technologies are co-located and strategized.

[1] Leading strengths in, for example, Sustainability, Biosciences, and High Value Manufacturing, shown in 'Mapping England's Innovation Activity', Smart Specialisation Hub, June 2017. University of Oxford ranks 1st in UK in REF2014 for 12 of the 31 subject Units of Assessment by volume of world-leading research.

5. Their development suits Oxfordshire's highly skilled workforce, with a strategy to deploy the skilled workforce nationally and internationally as new products and services are manufactured and roll out to other regions and countries. A UK growth model would include manufacture at scale in other parts of the UK.
6. Many skills needs are common to all four technologies. A place-based approach creates a value proposition for training and workforce development.
7. The technologies share a development and economic model of having "hardware" (physical components and products), "software" (data and analysis), and data access and consultancy services:

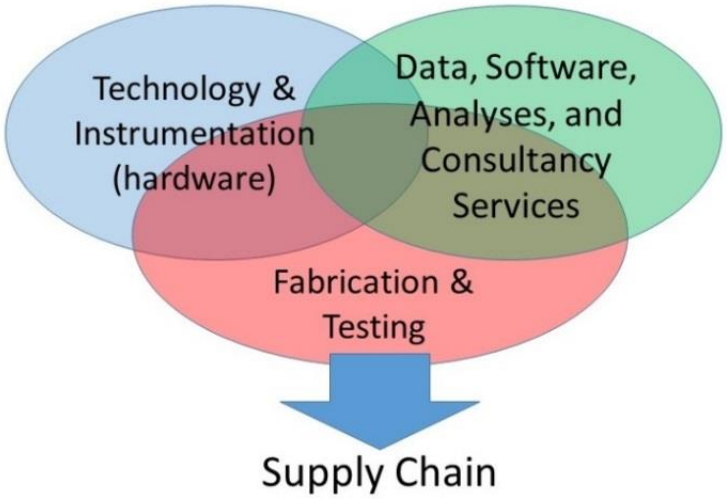


Figure 2: Economic Model

Hardware, software and services are best developed together, to maximise the benefits of test beds, and rollout via Living Laboratories.

These four transformative technologies are at different stages of commercial maturity. Digital health and satellite applications technologies are in the market, and growing. Autonomous vehicles are beginning to be demonstrated. Quantum computers are in early stage research and development, and are part of a larger whole: the ability of the human mind to utilise the brute power of computing.

Human society is on the cusp of a 4th industrial revolution, in which automated systems and data connectivity change possibilities and society. The breadth and depth of research and innovation in Oxfordshire in these 4 transformative technologies should be recognised and supported as a strategic national asset.

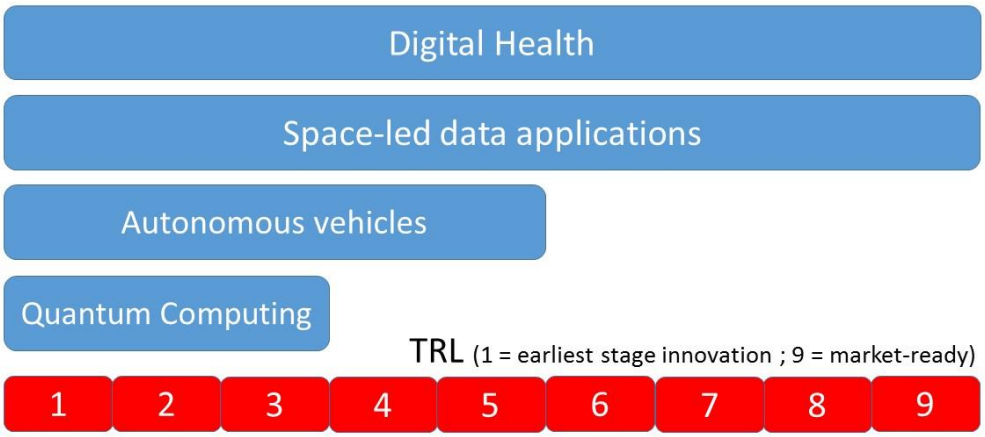


Figure 3 : Technology readiness levels for Oxfordshire Transformative Technologies

The Transformative Technologies

Connected and autonomous vehicles (CAV)

Oxfordshire is best placed to be a Living Laboratory for real world testing of CAV rollout. By retaining the UK's strong global position in Autonomous Vehicle development, revenue to the economy is expected to be at least £51bn by 2030, with 320,000 new jobs, 5,000 serious accidents avoided and 2,500 lives saved.[2]

Oxfordshire is a near perfect test bed. Vehicles can be tested geographically closely to the design, communications, navigations, and analytics facilities and workforces.

The Oxford Robotics Institute kick-started the UK's autonomous cars programme in 2010. Oxbotica was created in 2014 as a spinout of Oxford University, and now leads the UK consortium to develop and launch a fleet of driverless vehicles on public roads in 2.5 years. The research and development continues in conjunction with RACE (Remote Applications in Challenging Environments) at Culham, which provides testing conditions ready for rollout to public highways. New and expanded settlements across Oxfordshire can be living laboratories for the integration of Autonomous Vehicles, demonstrating transport solutions for further deployment nationally and in other countries.

Digital health

Digital technologies can transform healthcare, from prevention, through diagnosis and intervention, to ongoing monitoring.

The UK market for digital health is expected to grow to £2.9bn by 2018, driven primarily by high growth in apps (38%) and analytics (24%)[3]. The UK can do better than present at capitalising on innovation and bringing beneficial technologies to market more rapidly.

The Oxford Thames Valley region has over 160 digital health companies and 430 stakeholders across industrial, academic, NHS and third sector[4]: this region is a potential major growth cluster for developing and demonstrating high income, technology-based healthcare solutions[5]. Creating a closed loop of data and testing along the entire care pathway will vastly smooth the existing pinch points to market.

Developers with an end-to-end patient pathway and test-bed system can speed innovation, demonstration and rollout, and better evidence health benefits and cost systems. This can create 300,000 new jobs (33,000 in Oxfordshire) by 2030 and yield £1.8bn/year in savings[5] to the NHS.

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2 *Connected and Autonomous Vehicles: The UK Economic Opportunity*, KPMG

3 *Digital Health in the UK. An industry study for the Office of Life Sciences*, Deloitte

4 *Digital Health in Oxford and the wider Thames Valley region*, Oxford Academic Health Science Network, Oxford University Innovation and the University of Oxford

5 Existing capacity and excellence makes the region a very strong choice for highly skilled workers and inward investment, and thereby for sector growth for the UK. 1% savings across the NHS through digital health technologies (conservative estimate). NHS budget 2030: £180bn (2017 budget: £123.7bn (source: King's Fund), 3% inflation)

Space-led data applications

The UK space industry's target is 10% of the global space market by 2030. This should mean £40bn/year and 100,000 jobs for the UK.[6]

Space data includes earth observation, satellite positioning and communications. To develop products and services space data is applied with other data sources to create real-world solutions.

Oxfordshire has over 75 organisations, Europe's largest Space Cluster, the Satellite Applications Catapult, world-class research, a rich innovation ecosystem, and international pull.

To at least maintain the UK's global position – and add value in conjunction with CAV and Digital Health's use of location data, and communication – the proposed interventions include a data analytics hub to develop applications, and work with Living Labs as demonstrators for data products, and to boost the value proposition for inward investment in UK Space.

Technologies underpinning quantum computing

Quantum technologies will profoundly change the world, and our lives, by 2030. The UK has a strong, but fragile, global position in the race to develop a quantum computing capabilities.

Oxfordshire leads a consortium of 34 organisations to build a quantum computer demonstrator by 2020, and to stimulate quantum industries.

Establishing a 'Quantum Valley' in Oxfordshire, to build a computer, will create 10,000 UK jobs across the supply chain. Oxford University ranks 1st in the UK for mathematics, physics and engineering[7]. Local companies are engaged, e.g. Oxford Instruments which is providing the cooling technology. Oxfordshire leads extensive high-level training programmes in quantum technologies.

Assembling a functional quantum computer will nucleate new companies, and attract inward investment for the UK.

Global USP: opportunities for innovation at the intersections between technologies, for added value and output

Our global USP is to facilitate innovations at the intersections between these four transformative technologies, situated with Living Lab testing and demonstrators. There is added value in combining these transformative technologies in a highly networked science and innovation setting which is excellent at shared features such as machine learning, cyber security, imaging and sensing.

Development of any one of the four technologies will yield economic and social benefits for the UK. There is a strong opportunity for additionality: more applications and products will arise by focussing the development and test sites of these four complementary technologies in a place of world-leading science – opportunities which investment in any of the technologies independently will not achieve.

[6] *Building our Industrial Strategy: UKspace and Space Growth Partnership Response*, UKspace

[7] REF2014: the Research Excellence Framework, HEFCE

Key strengths

Oxfordshire has long been a world-leading centre for research and innovation across a wide range of technologies and sectors. It contains Oxford University, ranked number 1 in Europe for both research and commercialisation, large government investments (>£2Bn in internationally leading scientific facilities), especially at Harwell and Culham, leading industry clusters in life sciences, scientific instrumentation and motorsport, and the largest investment fund for university spin-outs globally.

Growth opportunities

This SIA is focussed on four themes where rapidly developing digital capabilities are converging but where the industry is nascent and therefore has the greatest potential for growth, anchoring capabilities in Oxfordshire and securing the UK's global competitive advantage. Within the UK context, Oxfordshire will always be a location where new technologies are invented, developed and tested but most full scale manufacture and assembly will occur elsewhere.

The key to success is for the research, innovation and testing of technologies to be clustered such that national supply chains can be developed from this base and for the skills and services supporting this cluster to be of sufficient quality, scale and flexibility to enable the innovation, integration and translation processes.

Oxfordshire has a history of developing hi-tech clusters of this sort and its proximity to London and Heathrow airport together with its connectivity with the rest of the UK and a global outlook make it ideal for developing and commercialising new technologies. The approach requires building three core capabilities in the county:

- Technology & Instrumentation ("hardware"): linked to targeted sectoral goals in Harwell (satellites and quantum), Culham (autonomous vehicles) and Oxford Hospitals (digital health)
- Data & software: to take data analytics and science from the laboratory into practice, including machine learning, vision and imagery techniques, in the context of cyber security and privacy
- Fabrication & test facilities: Living laboratories where solutions can be deployed and tested together in real-world environments, whether at Culham for autonomous vehicles or smart communities at Bicester and Didcot garden towns

Common features required to underpin development include:

1. Digital skills development and attraction of global talent
2. Investment in supply chains which will grow across the UK
3. Consistent strategic funding for growth
4. National networking to strengthen complementary technical capabilities in other regions

Gap analysis

Through consultation with key players in the county and beyond, gaps have been identified which need to be addressed for innovation and growth to flourish:

1. Oxfordshire's principal challenge is to continue to attract and retain the top talent required for world-leading businesses. This requires significant investment in training of engineers (both software and hardware) and addressing critical issues of the cost of living (associated with the largest house price to salary ratio in the UK) and transport constraints.
2. Whilst the region boasts an enviable track record of start-ups, the ability to grow businesses to medium scale and beyond is challenging through lack of facilities and skilled staff and there is a need to grow "unicorns" and attract inward investment at scale from multi-nationals if the county is to rapidly seed the development of the UK's digital economy.
3. With the wealth of research expertise generating new solutions, the principal challenge with new technologies lies in their translation through integration of capabilities and rapid scale-up by testing and demonstration. Good examples exist with the Satellite Applications Catapult and healthcare translational pathways. These require further integration, and new facilities need to be developed for autonomous vehicles and quantum computing.

Key ambitions/proposals

The critical components of the system that require investment in order to maximise national opportunity in Oxfordshire, can be divided into four areas:

1. Hardware development - e.g.:
    - Space: Disruptive innovation centre to translate technologies from other sectors and platforms to accelerate innovation in the satellite sector
    - Quantum: Facility for the building of the first quantum computer
    - Autonomous vehicles: Accelerate fleet design and national testing
2. Data & software - e.g.:
    - Health: Create a data lake to enable development of new applications
    - Space: Geospatial analytics centre to translate new analytics research into tools to address business requirements with a geospatial context
    - Autonomous vehicles: agreeing frameworks to collate and share data to enable new services whilst addressing cyber-security and privacy concerns within regulatory frameworks
3. Test facilities - e.g.:
    - Health: An end-to-end patient pathway and test-bed system for new digital health technologies
    - Autonomous Vehicles: Development of a test facility to provide comprehensive testing of urban, intra-urban and rural services
4. Technology integration:

    Seamless connectivity between data and communications networks for satellites, autonomous vehicles, and aspects of digital health.

Living Laboratories

Within this SIA, the convergence of sectoral thinking was reflected in the over-arching desire to establish world class 'Living Laboratories' delivered with industry where several technologies can be deployed together to address common challenges (e.g. healthy living, efficient mobility, national productivity). These Living Laboratories have many layers: strategic planning and local politics; infrastructure and hardware including seamless networks for transport, housing, hospitals and industry; software systems, data management and system of systems control; integrated solutions that use big data to optimise service delivery to improve productivity within environment constraints; sales opportunities, local, nationally and internationally, to generate jobs and growth; and last but not least, deep and wide engagement with the public.

- This model can be built on existing opportunities with Didcot Garden Town and Bicester Healthy New Town, both of which are undergoing rapid development. Also at small scale in the putative Culham Smart Community.

For broader, more effective, national development and demonstration of these (and other) technologies and solutions, we propose involvement in a platform approach to connect development initiatives (such as Healthy New Towns) nationally. This proposal would integrate these transformative technologies further (for example, with environmental management, air monitoring systems, energy, and/or waste solutions being developed and tested in other Healthy New Towns), and accelerate the production of proven solution sets.

Networking/collaboration

The progression from hardware to software, and thence to Living Laboratories, suggests a movement from technology towards society. Whilst some would see the inevitable conclusion of digitalisation as being the rise of the machines, with artificial intelligence controlling our lives and robots invading our human spaces, our position is more optimistic. We see these new digital technologies as enhancing our lives - the next generation of smarter tools used by smart humans to improve health, mobility and prosperity.

To achieve this we need thorough and comprehensive conversations that engage all of society. This raises the need to network, collaborate, and communicate - perhaps in unprecedented ways - to ensure that our reliance on digital technologies does purposefully lead to improved quality of life for all.

Connecting across the UK, for global strength

The process of producing this SIA has involved close collaboration between members of the core consortium (OxLEP, Oxford Brookes University, University of Oxford, STFC, UKAEA, the Satellite Applications Catapult, Oxford AHSN and Oxford University Innovation) and the involvement of a wide range of industrial partners. In addition an Advisory Group, chaired by the Pro-Vice-Chancellor Research & Innovation at Oxford University and comprising senior representatives of

the business, research and academic communities, has already met twice to advise on the SIA, and this Group will continue to meet in future in order to support and oversee resulting initiatives.

The work on the SIA has also stimulated increased networking between the four themes, and has identified opportunities for Oxfordshire to be *a living lab for the testing and roll out of new technologies*, leading towards a digitally-enabled world where healthcare and transport, as well as numerous other sectors (e.g. agriculture, financial services, energy) are revolutionised through the transformative technologies of satellites and quantum computing. Existing initiatives such as Smart Oxford, Barton Park and Bicester Healthy Towns, and Culham Smart Community provide small scale test beds which can be linked together to form a county-wide network.

To quote one member of the Steering Group: “Part of the process of the SIA for me has been the coming together of elements where I have been working with others and beginning to see how things fit together now and could do in the future”. The diversity, dynamism and tight geographical focus of the Oxfordshire high tech cluster means that interactions between researchers, businesses and residents are made possible by proximity, and the strength of the cluster also means that new ideas are more likely to secure funding and attract the technical and management skills needed to generate economic and social benefits from those ideas locally, nationally and internationally.

The SIA process has emphasised existing links with other SIA technologies, regions, and business sectors. Increased awareness of complementary activities across the UK has identified shared aspirations, and has increased willingness to collaborate for collective benefits and efficiencies. Beyond Oxfordshire, four other LEPs (Thames Valley Berkshire, Greater Cambridge Greater Peterborough, Enterprise M3 and North East) were included in a wider, active grouping because of the strong inter-relationships within the four themes between research and innovation organisations in Oxfordshire and these other areas.

Industrial participants and stakeholders

The production of this report, including its propositions and strategy, has involved intensive collaboration between the 7 members of the core consortium, and the close, dedicated involvement of 33 industrial partners and 18 non-business organisations (listed at Annex A of the full report), most of which have a business representation role and are in regular contact with business regionally, nationally, and internationally.

Examples of links between SIAs, and the importance of the themes to the wider UK economy

1. Agri-tech (East of England SIA) and 'Space-led data applications'

The East of England has a national leadership role in Agri-tech, resulting from the combination of a strong heritage in crop-based agriculture and horticulture and the depth and calibre of related scientific research in the region.

This SIA region is well-placed to apply, and benefit from, new technologies in precision and smart agriculture, including the application of robotics, sensors and diagnostics, to increase the efficiency, speed and precision of applying fertilizers and pesticides, and of harvesting. Precision and smart agriculture rely on the rapid processing of large amounts of data, much of which is gathered from satellites. There is strong complementarity between the OxTTA SIA proposition in space led data applications to dramatically increase the efficiency and environmental performance of agriculture. For example:

- The Satellite Applications Catapult is working with Cranfield University and the Agri-EPI Centre to exploit EO, weather and field data to support the precision management of grassland agriculture.
- Oxfordshire-based remote sensing consultancy Rezatec have been working with British Sugar to develop decision support tools to help optimise sugar production across the supply chain.

2. Offshore Renewable Energy (ORE Catapult, North East LEP, Midlands Engine SIA) and 'Autonomous Vehicles' and 'Space-led data applications'

The full range of satellite technologies are used to support the offshore renewables sector. In particular:

- Satellite communications and positioning are widely used in the building of offshore facilities; companies developing applications for this market have combined datasets such as weather information and sea conditions for use by offshore energy companies.
- Unmanned Autonomous Vehicles including drones are increasingly deployed; organisations including the Satellite Applications Catapult are using data from drones to complement satellite data, with the drones rely on satellite positioning. Through its Centre of Excellence in the North-East, the Catapult is linked into the drone supply chain in the North East and the Offshore Renewable Energy Catapult.

3. Quantum technologies (Innovation South SIA and Glasgow Economic Leadership SIA, in conjunction with Birmingham Hub)

The Quantum Enhanced Imaging (QuantIC) Hub at Glasgow and the Glasgow SIA HEIs are partners in all 4 EPSRC Quantum Technology Hubs. Their Consortium is particularly well-placed to drive productivity from the EPSRC's overall investment.

OxTTA's findings major on the potential in Central Scotland for rapid integration of quantum technologies with photonics, microelectronics, software/ big data interpretation at relatively low TRLs 3-5 into prototype devices that will support major strides in technology adoption (via our

demonstrators) in industrial monitoring, process control, asset management, imaging/ visualisation and digital manufacturing at higher TRLs 5-7. The same capacity for integration of quantum technologies into composite devices at low TRLs will particularly complement the OxTTA aspirations in respect of quantum computing and the Innovation South SIA aspirations in quantum supply chain. It will also provide particular opportunity for rapidly increasing links with the Birmingham-based Quantum Hub in Sensors and Metrology.

These SIAs together illustrate the connected, national nature of the investment needed to drive UK-wide success. Investment in each of these regions will lead to spillover benefits in the others (and beyond), and we hope that these three SIAs, taken together will inform a national strategy for developing a UK lead in quantum computing.

4. Satellite technologies and data (Innovation South SIA)

Innovation South's strengths in satellite data are more widely distributed across a larger geography, including a number of excellent Universities, Pirbright and NPL's South Hub and a very large number of major industry partners and many diverse, and innovative SME clusters, including marine and coastal sectors.

The two regions are therefore complementary with Oxfordshire more intensely research-focussed and Innovation South providing more of a balanced and diverse portfolio between corporate R&D, academic and PSRE research and SME innovation across a much larger economic region. In the space sector, Oxfordshire's focus is downstream on satellite data and national testing laboratories whilst Innovation South's key strengths lie in upstream satellite innovation from Airbus, Surrey Satellite Technologies Ltd, NPL and the Universities of Surrey and Southampton with complementary satellite data analytical capability from the University of Portsmouth.

5. Catapults

Oxfordshire is already linked into the whole Catapult network through the Satellite Applications Catapult, which works across the whole network and on projects with High Value Manufacturing, Transport Systems and Offshore Renewable Energy Catapults.

6. Quantum technologies, AV, and compound semiconductors (South Wales)

Compound semiconductors are essential for the development of quantum computers, autonomous vehicles, electronic propulsion and satellite technology requiring advanced data-communications and energy generation. Oxfordshire has considerable expertise from academia to SMEs and larger companies. We anticipate close collaboration with the Compound Semiconductor Applications Catapult in South Wales, together with the other key facilities in the compound semiconductor cluster: the Institute for Compound Semiconductors, the EPSRC Compound Semiconductor Hub and the Compound Semiconductor Centre.

Investing in R&D in these areas will lead to economic growth within the Oxfordshire region, and will also lead to the expansion of the compound semiconductor industry in South Wales, creating economic growth and increased high-value employment in the region, and related industrial benefits elsewhere in the UK.

Diamond Light Source is the UK's national synchrotron science facility and is part of the Harwell Science and Innovation Campus, Oxfordshire