Department for
Business, Energy
& Industrial Strategy

SCIENCE & INNOVATION AUDITS

Wave 3 Summary Reports

March 2019

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Foreword

I am very pleased to be able to welcome the publication of the third wave of Science and Innovation Audits; the largest group and one that flexed the parameters of the SIA process with a handful of the consortia using untested geographical formations. These 12 SIA reports, together with the 13 already published, enhance our understanding of the UK's strengths and crucially help us to identify the way forward to build on these. This is an important task; convening stakeholders to produce robust evidence and form strategies to address the challenges they see.

All the SIA consortia have delivered reports that are forward-looking and backed by strong evidence that demonstrates their region's existing and emerging strengths to a global audience. They are delivered by partnerships with the drive and determination to grow their economies through investment in science, research and innovation.

Research and development (R&D) is fundamental to improving future living standards, as well as tackling some of the greatest challenges and opportunities, such as those identified in our Industrial Strategy Grand Challenges.

The UK is already ranked as one of the most innovative countries in the world and has a world-class research base and the SIA reports showcase these strengths. We want to grow to be the world's most innovative economy and in the Industrial Strategy we have committed to reaching the target of 2.4% of GDP investment in R&D by 2027, and 3% in the longer term.

Meeting the 2.4% commitment will transform our economy. It would increase public and private R&D investment by as much as £80bn over the next 10 years and see a transformative change in innovation through R&D by businesses in all sectors from sustainable construction and aquaculture to manufacturing and cyber security.

Reaching this target will require concerted effort across the science, research and innovation ecosystem, by both government and business and I have no doubt that the SIA partnerships in every part of the UK will play their part in meeting that challenge and to benefit of their local economies.

Chris Skidmore

Minister of State for Universities, Science, Research and Innovation

Introduction

Under the Ideas Foundation of the Industrial Strategy, the third challenge is to build research and innovation excellence across the UK. We need to capitalise on the existing strengths in R&D and foster the local ecosystems that can support sustained growth.

Since the Science and Innovation Audits (SIAs) were launched in 2015 BEIS, alongside the SIA consortia, have worked to deepen the understanding of the Science Research and Innovation (SR&I) capabilities and comparative advantage around the UK. Through the SIA process we have supported increased collaboration in places, enabling better focussed strategic thinking about how the UK's strengths can be built upon.

The reports and partnerships resulting from the SIA process are an integral part of delivering the Industrial Strategy. The SIAs help address the central aim of productivity, earning power and regional growth by identifying the opportunities and barriers affecting the other foundations of people, infrastructure, and business environment. The SIAs also support the development of Sector Deals; the Grand Challenges; and the Ideas foundation of Local Industrial Strategies (LIS) by using, and building on the networks, evidence and recommendations that have been formed. LIS in turn are facilitating the increase of SRI activity across England, helping to meet the 2.4% R&D target and boost local economies.

The SIA process brought together local consortia of business, universities, research and innovation organizations, Local Enterprise Partnerships (LEPs) and their equivalents in the Devolved Administrations. The SIA reports combine national data sets with 'on the ground' views based on local data, knowledge and experience. This SIA process is helping to underpin future investment decisions, foster collaboration and strengthen future bids for local investment from public and private sources.

The publication of the twelve 'wave 3' SIA reports brings to twenty five the total number of SIAs. These reports, both individually and as a set, put both places and government in a better position to respond to the challenges set out in the Industrial Strategy, particularly around economic growth and productivity.

These twelve reports are:

- Applied Digital Technologies in Advanced Manufacturing
- Cyber Resilience Alliance
- Innovation for Sustainable Airports
- Knowledge Quarter London
- MAXiMAR: Maximising The Marine Economy in The Highlands and Islands
- North West Coastal Arc Partnership for Clean and Sustainable Growth
- North West Nuclear Arc
- Northern Powerhouse Chemicals and Process Sector
- Northern Powerhouse in Health Research
- Precision Medicine Innovation in Scotland
- The South Wales Crucible
- Upstream Space

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Science and Innovation Audit partners:

North East Local Enterprise Partnership
TEES VALLEY COMBINED AUTHORITY
CATAPULT High Value Manufacturing
cpi
DIGITAL CATAPULT CENTRE NORTH EAST & TEES VALLEY
Durham University
FIRST FOR PHARMA
NORTH EAST AUTOMOTIVE ALLIANCE
North East England Chamber of Commerce
Sunderland Software City Regional innovation. World-class connections.
ZERO CARBON FUTURES

Introduction

The focus of this Science and Innovation Audit (SIA) is the application of digital technologies in advanced manufacturing in the North East of England.

The North East has a population of 2.6 million individuals[1] and over 74,000 businesses[2]. In 2016, the region produced £50.7 billion of goods and services[3]. The region includes a mix of cities (Newcastle, Sunderland and Middlesbrough), urban and rural areas, with economic activities concentrated around the coastline and rivers.

The chosen theme of the SIA reflects the importance of manufacturing to the North East economy and the opportunities that our region's growing digital sector provides to support the manufacturing sector to adopt digital technologies. This has potential to lead to future co-creation between the sectors to develop new products and services.

The approach of the Science and Innovation Audit is closely linked to the concept of Industry 4.0. Based on the original proposition set out by the German Government[4], Industry 4.0 refers to the next stage in manufacturing that uses new, digital and real-time approaches to production to meet demand for more complex, individualised and digitally enabled products. The focus of Industry 4.0 is on advanced manufacturing on process improvements to help businesses become more productive and deliver new products.

[1] Data from Population estimates- local authority based by single year of age (Nomis). Data for 2016

[2] Data from UK Business Counts (Nomis) Data for 2017

[3] Data from Regional Gross Value Added (balanced approach) (ONS). Data for 2016

[4] https://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Industrie-4-0/Industrie-4-0/industrie-4-0-what-is-it.html

Manufacturing plays a key role within the North East economy, accounting for 14.3% of the region's GVA[5] and 10.6% of employment[6]. In 2017, the North East exported £12.9 billion of goods, including £7.4 billion of machinery and transport and £2.8 billion of chemicals (including pharmaceuticals)[7]. The North East's manufacturing firms are concentrated in a number of specialist, high value advanced manufacturing sectors. The SIA has focused on three of these:

- Automotive manufacturing
- Chemicals manufacturing (including bulk chemicals, specialty chemicals, polymers and plastics, and materials)
- Pharmaceutical manufacturing.

The Government Office for Science (2017)[8] identified a range of technologies – including batteries; algorithms and machine learning; quantum security of the Internet; and robotics and autonomous systems – that are generating (individually and in combination) opportunities to create applications for businesses, governments and individuals. These digital technologies sense, detect and measure what is happening and use the data this generates to produce insights and drive changes. These technologies have real potential to improve productivity within the North East's advanced manufacturing businesses with key opportunities including:

- Connected factories
- Connected supply chains
- Virtual reality and augmented reality.

The approach set out in this SIA draws on the importance of proximity to support the successful integration of new technologies. Whilst digital businesses are able to transcend geographic boundaries, there is also evidence that proximity to clients can increase opportunities for innovation. In particular, where there is a requirement to share commercially sensitive information around challenges or opportunities a level of trust, often through previous work or knowledge is advantageous. This does not mean that proximity is always required or sufficient alone but that in these circumstances it makes a positive contribution.

The key partners involved in the SIA are North East Local Enterprise Partnership (LEP), Tees Valley Combined Authority, Digital Catapult North East and Tees Valley, CPI, Zero Carbon Futures, Sunderland Software City, High Value Manufacturing Catapult, North East Automotive Alliance, First for Pharma, Durham University (on behalf of the North East's five universities) and the North East England Chamber of Commerce. Through the industry bodies, key private sectors companies have been engaged in and informed the process.

Vision

The vision for the SIA is:

To deploy the North East's potential to be at the forefront of the next manufacturing revolution by enhancing the routes to develop and integrate digital technologies into manufacturing process improvements. Through this we will position the North East as the ideal place to articulate, develop and adopt digital approaches to manufacturing to support long-term UK export competitiveness in high-value, advanced manufactured goods particularly focused on automotive, chemical and pharmaceutical sectors.

[5] Data from Regional Gross Value Added (balanced approach) (ONS). Data for 2016

[6] Data from Business Register and Employment Survey (Nomis) Data for 2016

[7] Data from HMRC Regional Trade Statistics (HMRC). Data for 2017.

[8] Government Office for Science (2017) Technology and Innovation Futures 2017.

Key strengths

As outlined earlier, the North East has specialisms in a number of manufacturing industries - automotive, chemicals and pharmaceutical. A selection of key businesses within these three industries are given below.

Automotive manufacturing	Chemicals manufacturing	Pharmaceutical manufacturing
Nissan	AkzoNobel Performance Coatings	Accord Healthcare
Komatsu	Applied Graphene Materials	Aesica Pharmaceuticals
Caterpillar	Banner Chemicals	Arcinova Biosignatures Fujifilm
Cummins	Biffa Polymers	Diosynth Biotechnologies,
Calsonic Kansei	CF Fertilisers	GlaxoSmithKline Glythera
Gestamp-Tallent	Chemoxy International Ltd	High Force Research
Unipres	Conoco Philips Dupont Teijin Films	MSD
Vantec Europe ZF-TRW	Exwold Technologies	Orla Protein Technologies
R-Tek BorgWarner	Fine Organics	Piramal Healthcare
AVID technology	Greenergy International Ltd	Sterling Pharna Solutions
Hyperdrive	High Force Research	Wasdell Merck Sharp
	Huntsman Chemicals	& Dohme Limited
	INEOS	
	Johnson Matthey	
	Kilfrost	
	Lotte Chemical UK	
	Lucite International	
	Micropore	
	Procter and Gamble	
	Plaxica	
	SABIC Pertrochemicals	
	Thomas Swan	

Source: Compiled by SIA consortium members

The sector is supported by a strong science and innovation base:

- The automotive manufacturing industry in the region is supported by the North East Automotive Alliance (NEAA), the largest automotive network in the UK. The International Advanced Manufacturing Park (IAMP) will offer a high quality, integrated location for advanced manufacturing, with a strong focus on automotive manufacturing adjacent to existing manufacturers.
- Other assets in the region include, the High Value Manufacturing Catapult, the Automotive and Manufacturing Advanced Practice Centre at the University of Sunderland and Zero Carbon Futures and the planned Centre for Sustainable Advanced Manufacturing.The chemicals manufacturing industry is supported by the North East Process Industry Cluster (NEPIC), an award winning membership organisation. Key assets in the region include the Materials Processing Institute, TWI and the Technology Futures Institute and the Centre for Process (CPI) Innovation Graphene Application Centre. The assets and opportunities for the broader chemicals industry is more fully set out in the chemicals and processing SIA.
- The pharmaceutical manufacturing industry is supported by First for Pharma, which brings together some of the world's largest pharmaceutical and biologics manufacturing companies alongside smaller companies to support the development of a regional pharmaceutical manufacturing ecosystem. The sector is supported by the CPI National Biologics Manufacturing, CPI National Formulation Centre and the Newcastle Laboratory. The region also has a number of wider life science assets (including the Academic Health Science Network North East and Cumbria, National Innovation Centre for Ageing, Centre for Ageing and Vitality and Centre for Life). These are important to the pharmaceutical manufacturing industry, with the North East being one of the few locations that can provide an end-to-end translation environment ('bench to bedside').
- Looking at the design, development and application of digital technologies, the region's key assets include:
- The Digital Catapult Centre North East and Tees Valley, led by Sunderland Software City, delivers interventions to grow the region's digital economy.
- The National Innovation Centre for Data has been established to help improve organisations' utilisation of data through a programme of collaborative projects. It received an investment of £15 million from Government in 2017, which has been matched by Newcastle University.
- Advanced Research Computing at Durham University brings together researchers from different disciplines to undertake transformative research, focused on (but not limited to) High Performance Computing (HPC). Advanced Research Computing has been awarded status as an Intel Parallel Computing Centre and an NVIDIA CUDA research centre.
- The region has a vibrant range of networks that support the digital sector (including Digital City, Digital Union, Dynamo, Sunderland Software City and Thinking Digital) and a number of start-up and co-working spaces (including BOHO, Immersion Labs, Sunderland Fab Lab and VRTGO Labs/Proto Lab). Other assets include Stellium, the Urban Observatory and the HMRC Digital Delivery Centre.

The importance of advanced manufacturing and the application of digital technologies have been identified by both the North East LEP and the Tees Valley Combined Authority and are prioritised within their strategic documents. This strategic commitment provides a strong basis for action in the region.

Strategic focus on advanced manufacturing and digital in the North

North East LEP	Tees Valley Combined Authority
Areas of opportunity • Tech North East – Driving a digital surge • Making the North East's future – Automotive and medicines advanced manufacturing • Health Quest North East – Innovation in health and life sciences • Energy North East – Excellence in subsea, offshore and energy technologies **Enabling services** • Financial, professional and business services • Transport and logistics • Education	**Innovation Strategy key growth sectors** • Advanced manufacturing • Process and energy • Healthcare • Digital **SEP cross cutting theme** • Circular Economy

Growth opportunities

Automotive manufacturing

The key drivers of this market are:

- Demand for more connected supply chains, with potential impacts on costs, speed and reliability[9].
- Requirement amongst automobile original equipment manufacturers (OEMs) to future-proof manufacturing processes[10].
- Rapid expansion in global connectivity, including cloud computing, big data and analytics and smart sensors[11].
- Changing consumer markets and government regulation, with electric and autonomous cars being developed in response to changing demand and legislation[12].
- Increasing labour costs, leading to increasing interest in the use of robotics and other machinery[13].

In terms of the size of this market:

- The market for automotive robotics was estimated to be worth $5.07 billion in 2016 and forecast to grow to $8.44 billion by 2021[14].
- The market for connected cars is forecast to grow dramatically from its current value of $30 billion to $170 billion in 2020[15].
- The automotive industry's revenue from Internet of Things- related activity is forecast to be $23.6 billion by 2025[16].
- The gains to the UK automotive industry from digitisation are estimated to be £6.9 billion per year by 2035, with this increasing GVA by £8.3 billion per year[17].

The UK is not currently seen as a leader in digitisation of automotive manufacturing – but is thought to have the factors in place that would allow the market to develop rapidly[18]. Within the UK, the Nissan plant in Sunderland is seen as a good example of the adoption of digital technologies[19].

Chemicals manufacturing

The key drivers of this market are:

- Mitigating supply chain risks, with Internet of Things technologies seen as offering opportunities (e.g. to track logistics, monitor changes in temperature and humidity, etc.)[20].
- More efficient management of data, with potential for this to generate valuable insights[21].
- Safety management, with technologies enabling greater control of manufacturing and delivery processes and the development of alternative processes (e.g. use of drones for safety checks)[22].
- Growing international competition[23]

A number of estimates have been made about the potential size of this market including:

- The materials handling robotics market is forecast to be worth more than $3.4 billion by 2019, with a subsequent annual growth rate of 9%[24].
- The Internet of Things chemicals market was valued at $3 billion in 2016, with this forecast to increase to $4.7 billion by 2025[25].
- The chemicals software market is forecast to grow at a annual rate of 11% between 2018 and 2022[26].

Currently there is no evidence on the UK or North East's share of the global market in digitisation for the chemicals manufacturing industry.

[9] World Economic Forum (date unknown) Building a digital automotive industry.
[10] Berger, R. (date unknown) The Car Factory of Tomorrow is Digital.
[11] World Economic Forum and Accenture (2016) Digital Transformation of Industries: Automotive Industry.
[12] ARC Advisory Group (2017) Mercedes Moves to Smart Manufacturing.
[13] KPMG (2017) The Digitalisation of the UK Automotive Industry.
[14] Global Newswire (23 January 2018) Global Automotive Robotics market 2017-2021: $8.44 Billion Industrie 4.0 And Made in China 2025 Industrial Plan Opportunities.
[15] Grant Thornton (2017) India's Readiness for Industry 4.0: A Focus on Automotive Sector.
[16] Statista (2018) Internet of Things: Automotive Segment Revenue Worldwide in 2014 and 2024.
[17] KPMG (2017) The Digitalisation of the UK Automotive Industry
[18] Grant Thornton (2017) India's Readiness for Industry 4.0: A Focus on Automotive Sector
[19] Ibid
[20] EY(2016)ChemicalsinEurope–thewayforward–balancingtheequationwithcustomizedinnovationandstrategy.
[21] Deloitte (2016) Industry 4.0 and the chemicals industry: Catalysing transformation through operations improvement and business growth.
[22] ARC Insights (2017) Industrie 4.0 in the Chemicals Industry; and Deloitte (2016) Industry 4.0 and the chemicals industry: Catalysing transformation through operations improvement and business growth.
[23] ARC Insights (2017) Industrie 4.0 in the Chemicals Industry
[24] Modern Materials Handling (30 March 2016) Global material handling robotics market to exceed $20 billion by 2019.
[25] GME (7 January 2018) Internet of Things in Chemicals Market Size, Share, Analysis – Forecasts to 2025.
[26] Research and Markets (2018) Global Chemical Software Market 2018-2022.

Pharmaceutical manufacturing

The key drivers of this market are:

- Tackling counterfeiting, with digital technologies providing opportunities to reduce counterfeiting in both the supply chain and in end-use products[27].
- Product traceability, with growing complexity in supply chains and greater data collection making this more important[28].
- Increase in use of individualised medicines, with intelligent machines, the Internet of Things and data analytics being critical to ensuring robustness and stability of these smaller batches[29].
- Increased regulation, with businesses increasingly being asked to provide continuous product monitoring[30].
- Recognition of efficiency gains that can be secured from digitisation[31].

Significant growth is forecast for this market:

- The market for Internet of Things software and services in the pharmaceutical industry was valued at $420 million in 2015 and is forecast to grow to $2.5 billion by 2020[32].
- The market for pharmaceutical robots was valued at $130 million in 2016 and is expected to grow to $430 million by 2025[33].
- The market for data analytics for the pharmaceutical industry is forecast to grow by 15% per annum between 2016 and 2021 (from a value of $1.3 billion in 2016)[34].

Similar to chemicals manufacturing, there is no evidence on the UK or North East's share of the global market in digitisation for the pharmaceutical manufacturing industry.

Gap analysis

The SIA has identified a range of assets in the North East in relation to both applied digital technologies and advanced manufacturing. Given the potential size of the market for applied digital technologies in advanced manufacturing, this gives the North East a strong opportunity to develop its digital sector whilst ensuring the ongoing competitiveness of its advanced manufacturing sectors.

There remains some uncertainty on the extent to which North East digital companies are currently working with advanced manufacturing companies in the region and vice-versa. It is clear however from engagement to date that there is scope for more intensive and structured support to enable solutions development and technical update of digital technologies in advanced manufacturing.

[27] Medical Futurist (date unknown) What the Hell is Blockchain and What Does it Mean for Healthcare And Pharma?
[28] Veeva (data unknown) Pharma 4.0 – time to rethink manufacturing and quality; and Pharmaceutical Manufacturing (2016) Creating Value from Smart Manufacturing.
[29] Veeva (data unknown) Pharma 4.0 – time to rethink manufacturing and quality.
[30] PharmOut (date unknown) Pharma 4.0 – How Industry 4.0 Impacts on Pharma.
[31] Markarian, J. (2016) The Internet of Things for Pharmaceutical Manufacturing.
[32] GlobalData (20 March 2018) IoT software and services in the pharmaceutical sector will be worth $2.4 billion by 2020.
[33] Grand View Research (2017) Pharmaceutical Robots Market Size Share Industry Report.
[34] PRNewsWire (10 October 2016) Commerical Pharmaceutical Analytics market to Provide over USD 1.5 Billion Revenue Post 2016.

Key ambitions and proposals

Through the SIA process, the partnership has worked to develop a programme to accelerate the adoption of digital technologies within advanced manufacturing businesses in the region, including actions that will help overcome the barriers to uptake. The evidence base suggests that the digitisation of manufacturing is a major opportunity with potential implications for North East export competitiveness. The UK and more specifically the North East are well placed to take advantage of this opportunity. This is particularly true when applied to existing manufacturing strengths such as those in automotive, chemicals and pharmaceuticals.

Despite this advantage the sectors are fast moving and there is a need to continually improve to stay ahead of competitors. Alongside increased competitions, changing market demand for complex and integrated products mean there is a need for manufacturers to make use of new technologies to remain competitive and the partnership's ambition is to facilitate this.

The process undertaken for the Science and Innovation Audit including the gathering of data, consideration of global market trends and engagement of key partners have identified areas of opportunity and potential barriers to uptake that will benefit from additional focus, particularly around:

Raising awareness and understanding of digital technologies

- Developing a shared language across the advanced manufacturing and digital sectors to better articulate the opportunities applied digital technologies offer to their advanced manufacturing and barriers to uptake.
- Raising awareness of the opportunities, potential and importance of the application of digital technologies for advanced manufacturing.
- Improving senior managers within advanced manufacturing businesses understanding of the scope and value of digital technologies and supporting them to act as champions for digital technologies within their organisations.

Skills and Training

- Enhancing current provision to ensure the digital skills required by the advanced manufacturing and digital sectors in the North East are available. This includes the development of skills of those joining the labour market for the first time, the current advanced manufacturing and digital workforces and those reskilling.
- Building on existing programmes to provide opportunities for teachers to spend time in the digital and advanced manufacturing sectors to raise their understanding of the skills needs of these sectors, including the importance of digital skills. This will enable them to bring this knowledge and understanding into the curriculum.
- Making use of digital technologies (including virtual reality and augmented reality) to undertake training and skills development within advanced manufacturing (for example, to train workers in advance of a roll-out of a new production line).

Facilities and networks

- Upgrading and expanding test and demonstration facilities to allow prototyping and testing of new approaches and techniques (including the Centre for Sustainable Advanced Manufacturing).
- Supporting cross-sector innovation sharing success and awareness so that other businesses are made aware of the potential benefits whether this is from a digital business perspective of engaging with manufacturers or vice-versa.

Business support and growth

- Tailored and active support to understand and access near-to-market opportunities for both the digital and advanced manufacturing sectors for prioritised support.
- Supporting businesses to utilise digital technologies to improve real-time information regarding their supply chains. With changing formulations and source materials this is also highlighted in the chemicals audit and processing science.

Partners have been engaged through a set of workshops to develop projects which support delivery of the vision. Nearly 30 actions were proposed as responding to the challenges and opportunities identified by the Science and Innovation Audit for Applied Digital Technologies. These have been assessed and prioritised by SIA partners, with areas of overlap brought together into a series of ambitions. These will be further developed by the partnership, putting the SIA into practice and enabling the North East to achieve the identified potential.

Action Plan

In considering how best to deliver these ambitions, a wide range of projects were considered. Potential funding routes for each project has also been considered with scope for significant industry participation and input alongside public interventions. Whilst we understand that there is not an automatic or guaranteed link between the work of the Science and Innovation Audit and any particular funding route, there is a clear potential for potential investment in key elements of the action plan through the Industrial Strategy Challenge Fund and Strength in Place funding alongside other public and private sources. This investment is required for long-term competitiveness to be maintained across the advanced manufacturing sectors and to place North East and UK firms at the forefront of a global market with very significant potential for expansion and growth.

Each of the approaches undertaken underneath the ambitions is essential to deliver productivity improvements and economic growth. The projects focus on building the physical and virtual infrastructure needed to support the integration of digital technologies into areas of manufacturing strength. To achieve this we have included activities to support process innovation, the components required to enable new integrated products, specifically around small batteries, and the skills, finance and test/demonstration facilities required. In each case, developing and adopting these enhance existing regional strengths but together represent an effective, strategic and step change supported by a raft of wider initiatives and sector specific projects. The proposals will be integrated into the wider local ecosystem of business, and research required to be successful.

Complete and ensure uptake of the Centre for Sustainable Advanced Manufacturing (CESAM) across manufacturing sectors.

Through the CESAM project a new hub for the implementation of digital technologies into advanced manufacturing can be developed. From its initial development as a response to the needs of the automotive manufacturing sector, CESAM has the potential to expand to meet the needs of all of the advanced manufacturing sectors that have been examined in this SIA, providing a hub of expertise and test and demonstration facilities to trial and appraise technologies prior to roll out.

Programme of support to enable business to understand and engage with the digitalisation of manufacturing process.

The gap in understanding of the opportunities and scope of digitalisation of the process industries and embedding this into the broader business support provided required a greater focus on these activities. This requires mentoring, 1-2-1 and seminar approaches alongside other supports to facilitate uptake and integration of the new technologies and approaches.

Digitalisation and digital manufacturing leadership and skills programme.

To develop a cross-sector network and structure to identify, refine and develop digital-led solutions for business requirements. This will be supported with further work with universities, schools, colleges and other skill providers to tailor programmes and short courses to meet skills demand. This will include up- and re- skilling across different age groups to provide lifelong learning. A programme of leadership across businesses to embed and understanding of the potential and value of the application of digital technologies at the plant management level.

Improved networks for cross-sector solution development.

To expand from the current provision to bring together a tailored approach to networking between digital and advanced manufacturing. This will draw on good practice in Sunderland Software City and other local partners where to ensure there is a strong and consistent understanding of opportunities, challenges and potential and a shared language.

Identify areas of technology opportunity and deliver supporting infrastructure.

A number of specific technology areas have been identified as being relevant to the digitalisation of manufacturing and relevant local strengths. To support the embedding of the digital technologies the appropriate supporting infrastructure to develop, test, demonstrate and roll-out these technologies is required. Through the process to date opportunities have been around on-board technologies for automotive and for personalisation and smart-packaging for pharmaceuticals.

Networking and collaboration

By its nature a SIA, focusing on the integration and application of technologies and techniques from one area (digital) to another (advanced manufacturing) and by drawing together partners across sectors (automotive, pharmaceutical and chemicals) has shown potential for new collaborations and improved networks.

Through the partnership the beginnings of a longer-term alliance of interested and engaged partners is being built to support practical delivery of the resulting actions. This has been supported through two primary routes:

- A Steering Group was established for the SIA with representatives from key sector bodies, universities and LEPs brought together to facilitate the development process. This has enhanced the connections between partners and led to new insights and relationships.
- Through the partner workshops that brought together the wider partners to develop the work plan. A further workshop is planned for September to initiate the process of moving the SIA

partnership to a longer-term approach. It is anticipated that this will be cross-sector to provide maximum connections and opportunities but will also facilitate smaller- scale activities between specific elements of the partnership.

In supporting this, we are able to build on existing relationships and mechanisms to support interaction including the Innovation SuperNetwork and the growth hubs. These provide routes to continue and expand engagement.

The delivery of the SIA has brought together a new set of partners to support the delivery. This is intended to be a starting point for long-term development and actions. As part of the process we have therefore established a route and process for undertaking the next steps in developing and delivering the proposed interventions and actions.

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CYBER RESILIENCE ALLIANCE

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

Department for Business, Energy & Industrial Strategy

Review led by:

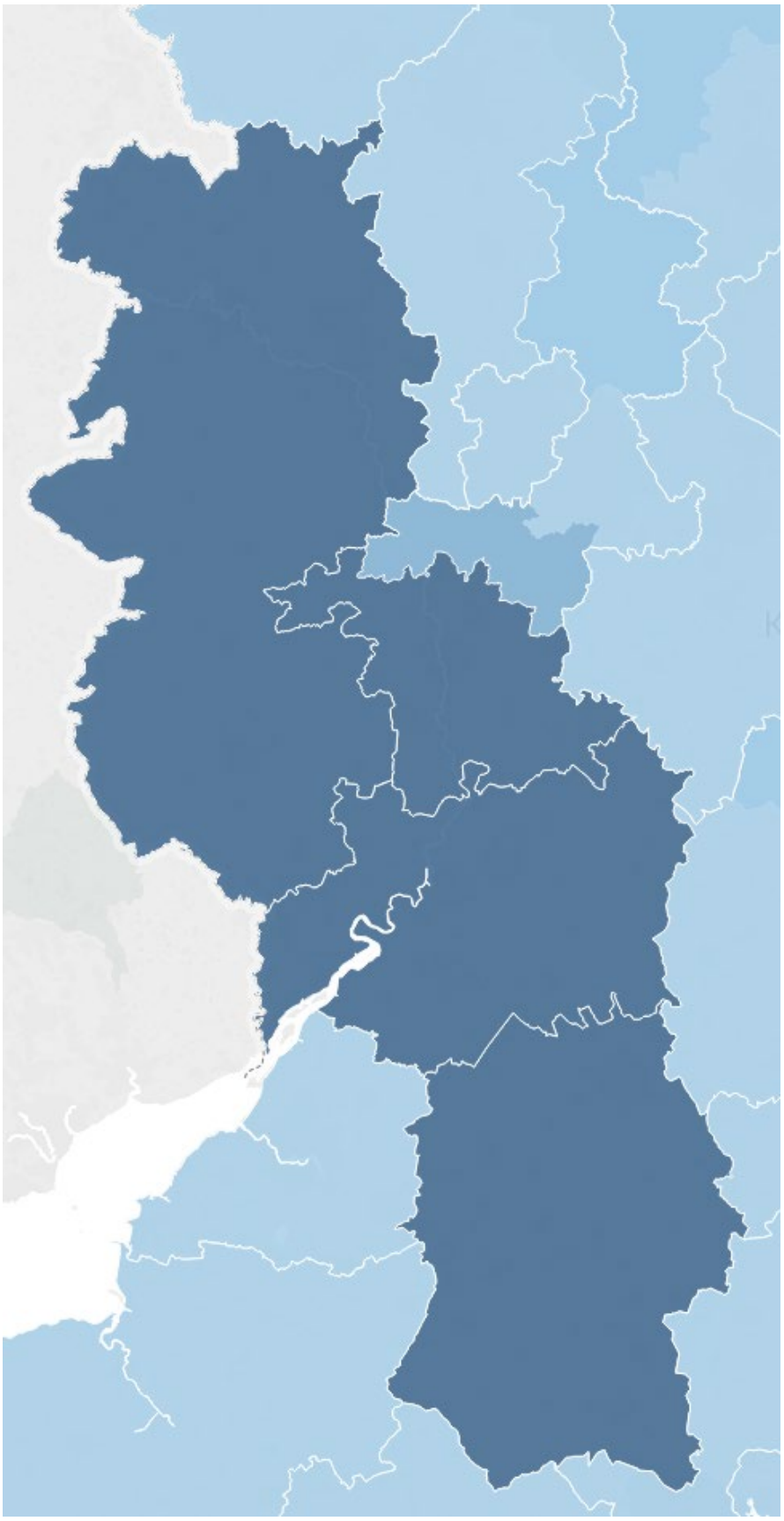
Worcestershire Local Enterprise Partnership

gfirst LEP growing gloucestershire

Swindon & Wiltshire Local Enterprise Partnership

The Marches Local Enterprise Partnership Herefordshire - Shropshire - Telford & Wrekin

Skylon Park



RSM

Introduction

The UK is a globally leading digital economy, and our prosperity is reliant upon our ability to secure our businesses, data and networks from cyber threats. The Cyber Resilience Alliance region[1] consists of some of the UK's brightest minds and cutting-edge technology addressing cyber security challenges every day. As cyber-attacks become more frequent and more damaging, our region offers the talent and resources that lead the way in supporting the UK's efforts to be one of the the most secure, capable, and cyber resilient countries in the world.

We are home to over a hundred businesses and organisations (and growing) active in cyber security product and solution development including large names such as Northrop Grumman, BT, Raytheon, BAE Applied Intelligence, Lockheed Martin, and Nationwide Building Society; highly regarded cyber security firms such as Anomali, Anon AI, and Titania; and rapid growth in innovative start-ups including PixelPin and Ripjar.

Outside of London, we are the UK's leading region in cyber security, with an estimated 5% UK market share, despite having 3% of the UK's population. However, our close-knit community has historically been rooted in securing the UK: during World War II the UK Government moved its radar technology to Malvern; which now holds the UK's largest cluster of cyber security firms. In 2001, QinetiQ, a major defence and security firm, was established through the privatisation of the Defence Evaluation and Research Agency (part of the Ministry of Defence), alongside the creation of the UK's Defence Science and Technology Laboratory (Dstl) in Porton Down. Over 5,000 of our community work in GCHQ in Cheltenham at the heart of UK security matters, and we also host the Ministry of Defence Joint Cyber Unit based in Corsham, and the Special Forces in Herefordshire.

This Science and Innovation Audit has helped to bring together our community of business, entrepreneurs, academics, policy practitioners, and defence, security and cyber expertise in a new way: to identify common strengths, challenges and opportunities for growth.

We are particularly strong in public administration, defence, security, health, and manufacturing. These are all industries that not only require cyber security solutions, but will actively drive the need for innovation, new products, and growth in the industry.[2]

Our people are ambitious and determined to cement the Cyber Resilience Alliance region as a leading place for UK and global cyber security practice helping to grow the region, secure the UK's assets, and to support cross-sectoral and cross-boundary initiatives that can create innovative, world-leading and secure products and services in the UK economy.

We have the skills, infrastructure, and resources in place to continue growing the sector, but we recognise the challenges ahead. That's why we are investing heavily in infrastructure, skills and talent, research and knowledge transfer, and focusing our efforts in making the region the leading location for cyber security firms outside London.

[1] Worcestershire, Gloucestershire, The Marches, and Swindon & Wiltshire LEPs.

[2] The UK Cyber Exports Strategy identifies the six most promising sectors for UK cyber security exports in 2018 (Government, Financial Services, Automotive (and Autonomous Vehicles), Energy and Critical National Infrastructure, Health, and Infrastructure)

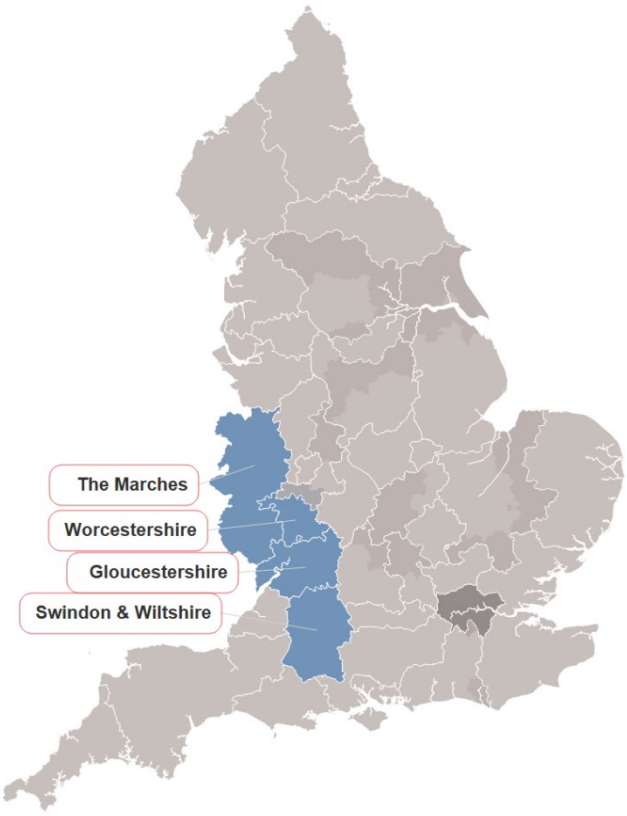
Context

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

In Gloucestershire (GFirst), Worcestershire, The Marches (Shropshire, Herefordshire, and Telford and Wrekin), and Swindon and Wiltshire Local Enterprise Partnerships (LEPs), the **Cyber Resilience Alliance** was formed in 2017 to focus on our strength in cyber security. This report presents the results which includes broad-ranging analysis of the Cyber Resilience Alliance's capabilities, the challenges and the substantial opportunities for future economic growth.

The Region[3]

The Cyber Resilience Alliance region consists of four Local Enterprise Partnerships (LEPs), stretching from north of Shrewsbury to south of Salisbury (over 180 miles). The region spans more than 5,200 square miles (10.4% of England's total geography), with 2.59 million residents, of which 1.58m are aged between 16-64 (3.8% of the UK's working age population). At its heart, it includes the urban settlements of Worcester, Cheltenham, Gloucester, Hereford, Telford, Swindon and Shrewsbury which are well-connected to the rest of the country via strong rail links and the M5 motorway corridor that runs from Birmingham through to Bristol (through the centre of Worcestershire and Gloucestershire LEPs).



The region is synonymous with UK defence and security and is home to some of the world's largest defence firms (BAE Systems Applied Intelligence in Gloucester, Babcock in Swindon, and Lockheed Martin in Wiltshire). as well as the UK's highest levels of public security (Ministry of Defence in Corsham, Special Forces in Hereford, and GCHQ in Cheltenham).

Within the Cyber Resilience Alliance region, we recognise the considerable **concentration of cyber skills within the population[4], largely due to proximity to GCHQ which in recent years has also encouraged a wide range of spin-outs and investment from cyber security organisations.**

The key to industrial success in the future is not just establishing cyber businesses. It is also about embedding cyber skills and principles of 'secure by design' into the existing industrial

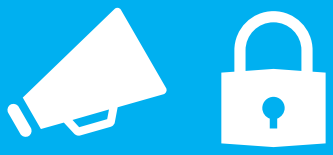
[3] See Section 3: Introduction to the SIA Region

[4] See Section 4 Strengths and Innovation, and Section 5.2 Size and Scale of the Cyber Resilience Alliance Sector

infrastructure. This will provide competitive advantage, and increase opportunities for employees to develop skills that make them and their business more attractive in a global market. We also recognise that skills being currently developed could be vulnerable to future automation, with a need to ensure there is a route to maximise high value skills and increase resilience moving forward.

This audit is therefore structured to test two main hypotheses:

1. There is a strong **concentration of skills in cyber security within the region, which can be used to embed cyber resilience through a wider industrial base,** including making a strong contribution to the growth of the UK's cyber security sector directly, and supporting industries within which their demand for secure solutions will incubate, support and grow the region's economy.



2. **Sustainable business needs to be competitive and trusted. Do traditional businesses do enough to understand and embrace cyber resilience, and how can they best invest accordingly?**

The Audit will identify opportunities to build linkages between the strong regional cyber security expertise and the wider community.

Vision

To maximise the opportunities of the cyber security sector in the Cyber Resilience Alliance, we set out the following evidence-informed vision for the region.

Firstly, we want to double the size (measured by employment) of the cyber security sector in the region, aligning the potential of our people with high-value employment into firms that can be global leaders.

Current: 5,000 Cyber FTEs (2018)

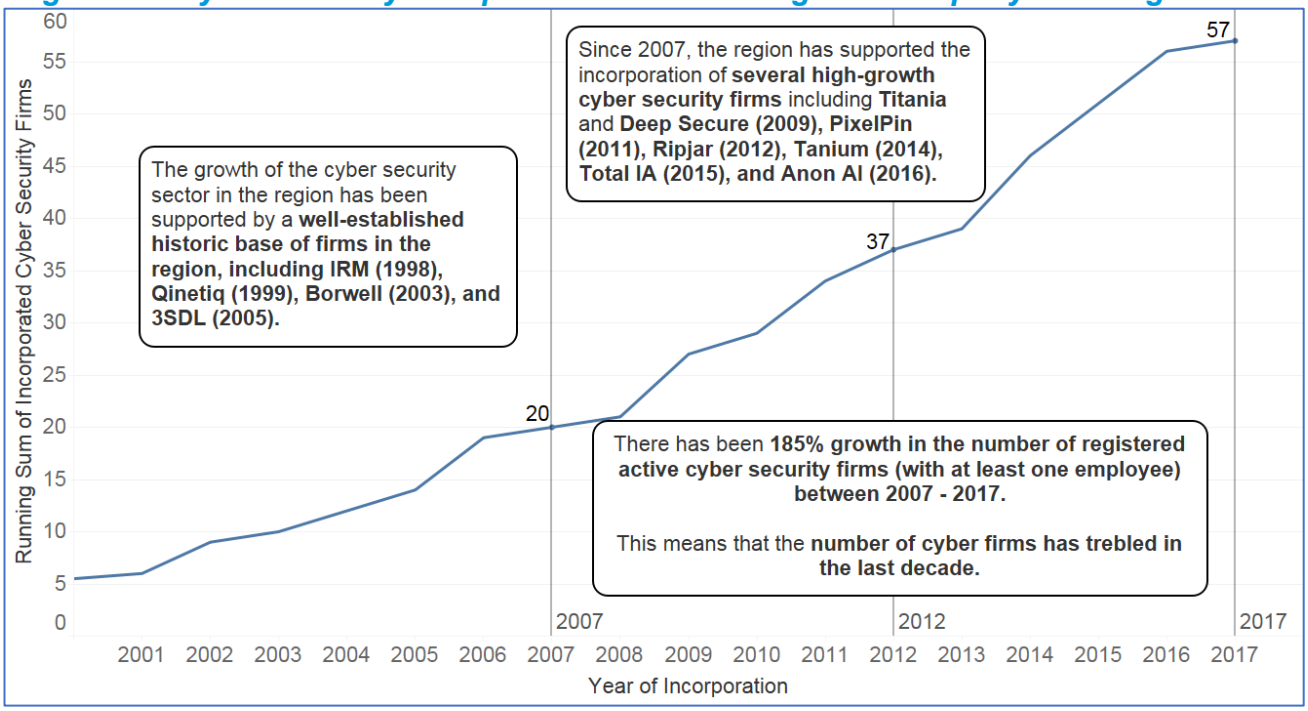
Target: 10,000 FTEs by 2025

We will plan interventions in line with anticipated and sustainable growth (approximately 10% per annum).

By 2025, we aim to have 10,000 (FTEs[5]) employed in the sector.[6]

Secondly, this Science and Innovation Audit has confirmed many of the propositions set out within our Expression of Interest: the region is particularly strong in cyber security with respect to the number of firms (more than fifty cyber security firms[7]), and over a hundred organisations and firms actively shaping cyber security products, services and development. As a result, we want the region to be known nationally and internationally as **the UK's largest cluster of cyber security activity outside London.**

Registered Cyber Security Companies within the Region: A Rapidly Growing Sector…



Source: Bureau van Dijk

[5] Full Time Equivalent staff

[6] See Section 5.3 Employment Estimates and Projections

[7] DIT (2018) Cyber Security Export Strategy identifies c. 800 cyber security firms in the UK.

Thirdly, with this recognition, we want to ensure that the region continues to promote an entrepreneurial start-up culture & attracts new investment. As a result, by 2025, we estimate that the region's sector will contain more than one hundred active cyber security firms – and with further investment and support, this figure could be even higher, particularly given the attractiveness of the region (competitive operational costs for business, a growing talent pool, and strong clusters of cyber innovation). Further, we will endeavour to identify opportunities for firms in manufacturing, defence, automotive, financial services and other sectors to embrace cyber security as a core component in product development.

This aligns to the findings of this Audit that nominal R&D expenditure has increased within the West Midlands and South West since 2008 at twice the national rate (grown 43% between 2008-14 compared to 21% across the UK). In recognition of the rapid growth in BERD[8] in the region, and the potential for disruptive technologies to require cyber security solutions (particularly in advanced manufacturing and automotive), we will support cyber security firms to identify UK supply chain opportunities that can further grow R&D expenditure in the region, improving the quality and value of our strong manufacturing base.

Finally, we recognise there is a long-standing productivity gap in the region. GVA per capita in the region is £22,804 (2015). This means that productivity is 10% lower than the UK's GVA per capita (£25,351). Tech Nation (2017) identify an average advertised digital salary of £36,236 in Worcester and Malvern. Further, there is also a nationally recognised 'cyber dividend' with regard to salaries. Technopolis analysis indicates that in the last six months of 2017, median advertised salaries in cyber security in the region ranged from £45,000 (Tewkesbury) to £82,500 (Worcester) – with a national median of £57,000 per annum.

With regard to productivity and earnings, there is clear potential for growth in the cyber security sector to improve the region's GVA per capita, and support efforts to narrow the productivity gap over the next decade.

Further, the Audit set out to explore how the expertise within the region could be utilised to best develop talent and embed cyber resilience within firms across industries. There are strong initiatives in the region to achieve these aims, including (but not limited to) the Cyber Club, the Malvern and West of England Cyber Security clusters, and the IASME consortium[9]. Our vision for the region is to embed cyber resilience through the promotion of initiatives that encourage wider investment in cyber security products and processes across all industries.

[8] Business Expenditure on Research & Development. See Section 4.2 Research Strengths and 4.3 Innovation Strengths and Growth Points

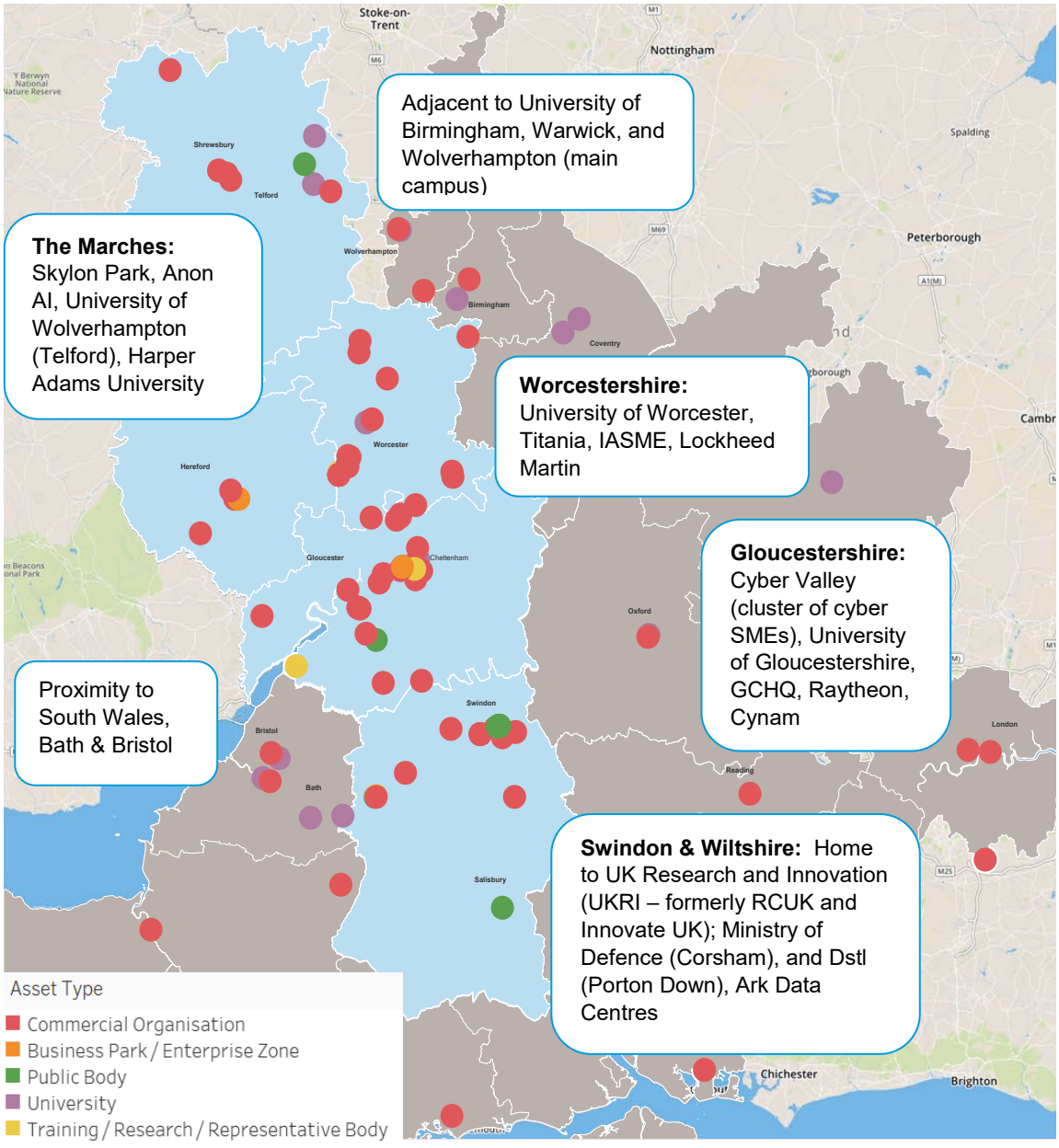
[9] See Section 5.5 Local Science and Innovation Talent

Long-term, it is our ambition that the Cyber Resilience Alliance Region is recognised as a world-leading cluster, and there are many opportunities for our businesses and organisations to embed and promote cyber resilience globally, and to lead within cyber security export markets.

Key Strengths

The Cyber Resilience Alliance region is host to strong research collaboration between government, universities, research institutions, and businesses. Despite a relatively small working age population (1.6 million), the Cyber Resilience Alliance is highly regarded with several internationally recognised cyber security clusters (Malvern, Worcester, and Cheltenham in particular).

Map of the Cyber Resilience Alliance Business, Commercial, Public, and Academic Assets:



Source: RSM, CRA Market Intelligence

The region is particularly strong in…

Research:

The SIA area has an LQ[1] of 2.2 for cyber security projects led, demonstrating that the area is twice as likely as the national average to have organisations leading publicly-funded cyber security research. This indicates that **Cyber Resilience Alliance area has above average concentrations of cyber security research.**

R&D Investment:

Within the Cyber Resilience Alliance, there is evidence that government, business, higher education institutions, and non-profit organisations are increasing expenditure in research and development. As shown in Section 4.3, nominal R&D expenditure has increased within the West Midlands and South West since 2008 at twice the rate nationally (grown 43% between 2008-14 compared to 21% across the UK).

Commercial Activity:

Within the UK itself, London is recognised as a cyber security hotspot, with more than two hundred cyber security firms estimated in the city, and many more vying for cyber security talent to support the operations and development of financial services, legal services, media and telecommunications etc.

However, the Cyber Resilience Alliance Science and Innovation Audit has enabled an overview of the firms and organisations active within the region and provides an evidence base that the region hosts **the second largest cluster of cyber security activity** outside of London.

Further, the region has a prominent defence and security community, which directly supports the growth and sustainability of the cyber sector. As a result of this community rooted in security, the region is a hotbed for cyber security innovation in the UK.

Infrastructure that supports innovation:

The region is focused upon developing its entrepreneurial and innovation support network, with emphasis on high-tech, cyber, digital and manufacturing industries. The region is home to a wide range of universities, research institutes and councils, public sector organisations, businesses, and incubation and innovation spaces active in developing the cyber security sector. This Audit has identified over a hundred assets and organisations active in supporting cyber security product and service development. Further, the region is in close proximity to several world-leading businesses, universities and research institutions active in cyber security, advanced manufacturing and automotive technologies.

Opportunities

The cyber security sector clearly presents several opportunities in the region, not just for economic growth at the sectoral level, but also through securing the crucial technological developments across wider society. Ultimately, cyber security is about embedding trust in society, economy and technology, and the Cyber Resilience Alliance region will provide the expertise to support wider transformational advancement in the UK.

There are clearly opportunities that arise from automation, Artificial Intelligence (AI) and Machine Learning, and within securing the rapid roll-out of Internet of Things (IoT) devices across the country.

Opportunities for R&D, Product Development and Enhancing Productivity:

In recent years, there has been a concerted effort on behalf of manufacturing to increase investment in research and development in the region. Given the opportunities that arise from automation, Artificial Intelligence, and machine learning for firms across the region, there are also core opportunities for the region's cyber security sector to benefit from commercial partnerships to secure these technologies.

This increased investment in transformative digital technology in the region, combined with world-leading secure solutions, will generate considerable opportunity to enhance productivity and living standards in the region.

Opportunities for Resilience:

As stated, the most recent DCMS Cyber Breaches Survey (2017) indicates that 34% of businesses have no spend on cyber security, and that four in ten experienced some form of breach last year. We will seek to further develop initiatives to tackle gaps in cyber resilience in the region e.g. funding for advice, Cyber Security vouchers, Cyber Club etc.

There is clear opportunity for the region to act as a regional testbed for initiatives that support cyber resilience to be scaled up to national level (evidence informed pilots and interventions).

Domestic and Export Growth Opportunities for the Cyber Resilience Alliance:

As identified in the UK Cyber Exports Strategy (DIT, 2018) – our region has an established, expert and innovative sector made up of companies across a full range of capabilities.

UK cyber security exports are set to grow to £2.6bn by 2021, and will be primarily driven by governments, financial services, automotive, energy and Critical National Infrastructure, healthcare and infrastructure.

Gap Analysis

Whilst the cyber security sector has demonstrated rapid expansion and growth in the region in recent years, there remain gaps that are restricting the growth and potential of the sector, and present challenges for the future sustainability and talent flow in the industry.

Within cyber security, these gaps impact not only the sector directly, but impact the UK's capacity to defend its national infrastructure and provide an adequate cyber response function regarding national security. Within the region, given the concentrated presence of cyber security

businesses and critical national infrastructure, there is a fundamental need to address these gaps and to ensure a sustainable model for the growth of UK cyber security.

This audit has identified the following core gaps that must be considered in future interventions to support the sector within the region.

Development of Skills & Talent:

"We are struggling to attract people with the correct experience and skillsets in cyber security." (Gloucestershire SME involved in IT infrastructure security)

Several of the SME cyber security firms in the region consulted throughout this Audit process highlighted the significant gap in the region regarding a skills shortage. As reflected in Section 5.4, there are hundreds of unfilled vacancies in the region within cyber security. This is for several reasons, including:

- The **perception that the City of London has the 'pull' to attract some of the nation's best talent, leaving other parts of the UK with more limited potential for recruitment.** This highlights the need to showcase the Cyber Resilience Alliance region as attractive to live and work in;
- A **perceived gap within the skills accredited** (Level 7+) and the **applied and commercial skills required by businesses;**
- **Demand for labour considerably exceeds supply**: this is creating a labour market with salary costs potentially prohibitive to new innovative start-ups (e.g. salaries in the region of £50,000+ for staff with one to two years' experience);
- The current provision of skills and talent (formal university / higher education, and conversion courses and training schemes) offers a strong model to address many of these gaps, with the Universities of Gloucestershire, Worcester and Wolverhampton taking welcome steps to grow the talent pipeline; however, given the sector's robust growth, there is a gap between what is needed and what can be produced.

Consultees did note, however, that the Cyber Resilience Alliance region is not the only cyber security cluster vying for cyber security specialists, commenting on the need for the region to vie with talent across the entire UK.

Provision of Facilities and Infrastructure: Reflect the Breadth & Diversity of the Sector:

This Audit has identified the wide range of funding and infrastructure initiatives across the region and wider UK for cyber security. The region is host to several of the UK's leading examples of cyber security incubation and acceleration including the Wyche Innovation Centre, and the national GCHQ Cyber Accelerator programme. There are also several planned investments in cyber security infrastructure over the next few years to support sectoral growth including the Cheltenham Cyber Park, and the Marches Centre for Cyber Security. However, several consultations in the region have indicated that within the sector, investment in infrastructure has focused upon schemes supported by government and security agencies. Whilst this is welcome in growing the sector, it is viewed that there are gaps in:

- **Availability and Affordability of Grade A Office Space (all sizes):** As set out by Savills, cyber security firms are set to take up to one million sq. ft in office space across the UK by 2022. Given the demand within the sector, combined with the need for firms to ensure working space that complies with their respective standards and accreditation (ISO 27001, Cyber Essentials etc), many consultees have identified the perceived shortage of high quality office space at all levels (for small to large teams), and the prohibitive costs associated with office rental. Increasing the supply, particularly around clusters, will relieve increasing office costs, and also enable collaboration between adjacent firms – thereby supporting the region's ambition to rapidly grow the sector.

- **Provision of Product Testing and Validation Labs:** One essential process within the industry is testing products and services to provide greater assurance to consumers of the overall validity of the product being offered. As such, there are several testing labs/facilities across the UK, providing CTAS and CHECK testing accreditations which identify any weaknesses utilising publicly known vulnerabilities and common configuration faults. However, joining these schemes can be prohibitively expensive for SMEs, and take up is therefore viewed not as high as it could be with the provision of support.

NCSC has released several certified product schemes which test the validity of cyber security products and services, providing greater assurance to consumers of the reliability and effectiveness of the products they purchase, including Commercial Product Assurance, Commercial Evaluation Facilities, Commodity Information Assurance Services, Tailored Evaluation, and TEMPEST and EMS (see Appendix J).

However, some consultees argue that there is a gap that exists for an independent body to provide testing and validation labs in the region. This would enable private firms to test their products in a space that would not necessitate a standard approach i.e. sharing all relevant code or IP with a national body (see Proposal 1 – National Cyber Lab).

There is also a perceived gap that internationally – investment in UK cyber security is often conflated with London, and that the region will need to invest in a coherent vision, brand and message to promote the area as a highly attractive location for living and working.

Key Ambitions and Proposals for Growth

To best tackle the gaps within the region's cyber security sector, and to take advantage of the opportunities provided by technological transformation, this section sets out our key proposals and suggested interventions for the region.

Across the four Local Enterprise Partnerships, we estimate a financial commitment to the sector over the next five years in the region of £80m (£16m per annum)[10]

Proposal 1: Innovation, Research & Development | Investing in Infrastructure

To further enable innovation and encourage continued investment in Research and Development (R&D) in the region, the Cyber Resilience Alliance propose:

1. **Promoting Existing Infrastructure Expenditure:** The region must ensure that recent proposed investments are maintained and supported; however, these must also receive investment to join-up initiatives across the region e.g. to identify the best possible incubation space for new firms depending upon their capability, capital and ambitions. Any fragmentation of cyber security infrastructure in the region may cause a disjointed approach to seeking investment for the region**.**

2. **New Infrastructure: 'National Cyber Lab':** The Audit has confirmed the initial requirement for exploring the feasibility and potential investment in a 'new specialised data centre with a flexible cyber range and dirty lab to offer organisations the chance to engage and use these facilities in the development of cyber technology and cyber defence' which can be industry-driven.

   Given the proximity of government schemes and NCSC validation facilities, this could be scoped to become a centre of national significance e.g. a National Cyber Lab, with potential sites across the wider region – linking into wider infrastructure in the region e.g. Berkeley C11 Cyber Security Centre testing labs for University of Gloucestershire students, and the launch of UK Cloud's UKCloudX[11] service in the region (a dedicated facility which provides High Assurance cloud provision for defence and government). Membership of this centre would not only allow access to the sites but also access the subject matter experts and a collaborative environment where partnerships could be formed to chase the larger programmes and research funding. It would further allow access to cyber skills from the traditional industrial base. This could provide the potential for international recognition of the cluster (having industry-led testing facilities with international standards to encourage product exports). This would reflect a significant financial commitment by the region to supporting the cyber security centre.

[10] See Annex A (Business Cases) for further detail and rationale.

[11] See https://ukcloudx.com/

3. **Sustained Investment in Aligned Technology:** Increased investment and adoption of innovative technologies in the region e.g. Worcestershire 5G test bed, provides regional firms with significant gains in productivity, but simultaneously requires cyber security support given the proliferation in devices and data. This provides real opportunity for sectoral growth – where the Cyber Resilience Alliance is a technological world-leader, **being a world-leader in securing these technologies is a natural extension.**

Proposal 2: Encouraging Sustainable Demand:

We will support interventions that promote the growth of the cyber security sector through domestic and export sales, and through the provision of innovative new products and technologies.

We identify the following mechanism to support this proposal:

4. **Encouraging Regional Demand**: It is the view of this Audit that the region is home to world-leading and innovative expertise. However, there remains a view by regional stakeholders that London is considered internationally as central to the UK's cyber security activity.

It is therefore crucial to provide a narrative that encourages growth at the regional level, through:

- **Highlighting the strengths, offer and capabilities of the region's cyber security expertise** through investment in suitable marketing, and schemes such as 'Meet the Buyer', Knowledge Transfer Partnerships, and sharing examples of how cyber security in the region can benefit a range of sectors e.g. agri-food, manufacturing and automotive. This could include sponsoring cyber security clusters within the region to engage with wider sectoral groups (automotive, aerospace, manufacturing, agri-food);
- Utilising the existing Local Enterprise Partnership structures to **identify opportunities to bring together cyber security firms and businesses in need of secure solutions;**
- Promoting a **marketing narrative emphasising the strengths of the region as a suitable location for cyber security investment and employment**, including space, affordable housing, high living standards, transport access and infrastructure, availability of talent, and **close proximity to bodies of national significance** in cyber security (GCHQ, MoD) and Academic Centres of Excellence in Cyber Security and active cyber security universities.

Proposal 3: Improving Skills and Talent:

For any sector to be successful, it requires a sufficient and skilled workforce. The cyber security sector has experienced considerable skills and talent shortage in recent years, and this has been reflected within remuneration levels and the extent of unfilled vacancies within the sector.

However, there is substantial demand within the sector, that can facilitate high-value employment within the region where the skills and talent are invested in sufficiently to a) increase supply of labour and b) increase the skills being requested by industry. The Cyber Resilience Alliance therefore propose to:

5. **Facilitate Workforce Planning in the Cyber Security Sector for the Region**: We propose within the Cyber Resilience Alliance to establish a working group to monitor labour supply and demand in the region to enable targeted investment and interventions. This will need to consist of regional decision-makers involved in education (across all levels), business, government and the third sector.
   Further, there is compelling evidence within the region that reskilling and lifelong learning initiatives work well in meeting labour shortages and encouraging new talent into the sector. Indeed, the region's strength in national defence and security provides cyber security as a natural career progression for many of our long-term serving personnel and provides new perspective and innovation in the sector. We will seek to encourage initiatives that encourage neurodiversity in the sector (such as the Community Cyber Operations Centre), that attract younger talent to get involved in cyber security (e.g. Cyber Schools Programme), and those schemes that seek to move people away from potential cyber-crime into security roles.

6. The Cyber Resilience Alliance is a prime location for innovative approaches in encouraging new talent into the sector, and **we will monitor and seek to support funding requirements accordingly given the potential for significant increases in regional productivity as a result of increased sectoral employment**.

7. Finally, the Cyber Resilience Alliance is home to several university accredited courses in cyber security. There are also several universities adjacent to the region that offer courses in cyber security including University of Warwick, University of Birmingham, University of Bristol, Bath Spa, and University of South Wales – demonstrating the importance of neighbouring institutions. There has been considerable growth and interest in cyber security courses in the region. **We propose that the region has potential to become home to one of the UK's first 'Centres of Excellence in Education within Cyber Security',** similar to the EPSRC accredited Academic Centres of Excellence in Cyber Security Research (or the National Security Agency (NSA) /Department of Homeland Security (DHS) Centers of Academic Excellence in Cyber Defence program[12]) - which receive international acclaim, yet focus on how to teach cyber security in an applied format of benefit to employers in the region such as Raytheon, BT, Lockheed Martin and QinetiQ and support 'life-long learning' in the region.

Proposal 4: Focused Marketing & Sector Targeting:

The Audit has also validated that cyber security clusters work where there is a clear awareness of the anchor-driven strengths to encourage talent and investment to flow into the region. Within the Cyber Resilience Alliance, there is national and international recognition that cyber security activity is strong; however, there is a risk that this can become disjointed through recognition of several smaller clusters contained within e.g. Malvern, Gloucestershire, Cheltenham, and Wiltshire etc. Indeed, the geography of the region can also often mean that the West Midlands and South West can be assumed to mean 'Birmingham' and 'Bristol' respectively; which presents a challenge to the region regarding being known on the map.

[12] https://www.nsa.gov/resources/educators/centers-academic-excellence/cyber-defense/

This evidences the need for the Cyber Resilience Alliance to establish a unified consortium, brand and approach to attract investment and talent.

We propose to:

8. **Sustain a Cyber Resilience Alliance representative body,** combining representation from each of the four Local Enterprise Partnerships (government, business and academia), to promote the sector. The management and governance of this body could be agreed in consultation with local, regional, and national government bodies.
9. **Establish a Cyber Resilience Alliance website / dedicated support** to demonstrate how a start-up / SME / large multinational can do business in the region (e.g. access to space, labour, grants and loans, R&D tax credits, university / research support) to ensure coherency;
10. **Establish formal Cluster Partnerships,** potentially 'twinning' the Cyber Resilience Region with comparable initiatives in the United States or other countries with prominent or emergent sectors (e.g. Israel, China, or Brazil);
11. **Marketing:** Promote the region as a high-growth location with a growing and talented labour supply, with support from LEPs to invest, start and grow – where firms will be surrounded by other world-leading innovative firms and public bodies (drawing upon the Midlands Engine Cyber momentum).
12. **Intelligent sectoral targeting:** The Cyber Resilience Alliance will identify and track firms active in sectors aligned to the four LEPs growth priorities (manufacturing, agri-food, professional services) in addition to export potential (Government, Financial Services, Energy and CNI, Healthcare, and Infrastructure), and will identify their respective approach to cyber security (spending, research, relationships with regional suppliers etc.).
13. **Enhancing Opportunities for Investment:** We will explore opportunities to bring more events, and conferences (and specialist VC investors) to the region to showcase the talent and expertise of the region.

Networking and Collaboration

The consortium delivering this audit brings together a wide range of academic, research, innovation and commercial strengths in the fields of cyber security and economic development.

It is led by Worcestershire Local Enterprise Partnership with support from Gloucestershire, Swindon & Wiltshire and The Marches LEPs, and has focused on the needs of the research and business community within cyber secuity, through concentrating on the economic impact, exploitation, and investment potential of cyber capabilities and capacity across the region, while taking cognisance of academic teaching, and IP generation as underpinning elements.

Throughout this process, the Science and Innovation Audit received written or verbal evidence from over sixty leading members of business, academic and public bodies. These contributions are greatly appreciated by the Cyber Resilience Alliance, and have been an valuable call to action for the region.

The Cyber Resilience Alliance have also utilised this exercise to promote collaborative and joint-up initiatives across the region in cyber security and beyond. This includes:

- The Cyber Valley marketing initiative being supported by the Midlands Engine Cyber necessitating close co-operation between Skylon Park, Marches LEP, and Worcestershire LEP who have been leading the initiative. This also means that the trade partnership within Cyber Maryland are aware of the Cyber Resilience Alliance concept, and collaboration being undertaken to grow the region;
- Cheltenham will host the National Cyber Awards 2018 in November, supported by the Cyber Trust, Cyber Security Challenge, and GFirst LEP. This event rewards those who are committed to cyber innovation, cyber crime reduction and protecting the citizen online, and has been supported through relationships developed as a result of this SIA.
- The four Local Enterprise Partnerships involved within this exercise are committed to work collaboratively to identify, share and learn from interventions and infrastructure investment in the region. This means sharing ideas, innovation and working space to give companies in the region the best opportunities to grow.

Further, the Cyber Resilience Alliance will work as closely as possible with other SIA regions to identify opportunities to grow the wider UK cyber security sector. It is considered that this SIA is particulary complementary to the Midlands Engine SIA (Wave 1), Innovation South (Wave 2), Oxfordshire Transformative Technologies (Wave 2), and Applied Digital Technologies, South Wales Crucible, and Upstream Space SIAs (Wave 3).

Innovation for Sustainable Airports

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

Sustainable Airports

Summary Report

Department for Business, Energy & Industrial Strategy

Brunel University London

Introduction

At a national level, the UK has the biggest aviation market in Europe and the second largest in the world, with London having the busiest airport system of any city in the world. The prosperity of the UK is critically dependent on the health of the UK aviation sector. Aviation adds £52bn to the UK's GDP, supports substantial inward investment and almost one million jobs.[1] With 42,000 airports in the world, and world air passenger numbers set to double over the next two decades, there are substantial opportunities for innovative UK businesses that can support sustainable airports.

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 focus on analysing place-based strengths and identify mechanisms to realise their potential. In the Thames Valley and West London, a consortium was formed in 2017 to focus on our strength in Sustainable Airports. This SIA differs from others completed in waves 1 & 2 in that it takes a whole ecosystem approach around a specific business, London Heathrow Airport. In doing so, we view Heathrow as both an 'Anchor Business' for the 400 businesses that come together to operate Heathrow and their supply chains, and as a 'Connectivity Institution', enabling people and products from across the UK to connect with the emerging economies within Asia and South America.

This SIA has focussed on four themes; Sustainable Construction, Big Data and Cyber Security, Operational Excellence and Intelligent Mobility; and tested the hypothesis that:

Science and innovation excellence supporting 'Sustainable Airports' within our study area can be boosted to drive further innovation in the UK, and to enable global exploitation.

Our consortium, led by Brunel University London, includes partners representing the LEPs, SMEs, universities, research organisations, business & trade organisations, industry, and local and national government. Heathrow Airport Ltd and all the partners are committed to advancing the opportunities that have been identified. The Sustainable Airports SIA Study Area is illustrated by the map on the cover page. This report presents the results which include broad-ranging analysis of **West London and the Thames Valley's** capabilities, the challenges and the substantial opportunities for future economic growth.

To create a world leading research and innovation ecosystem, focussed on the needs of sustainable airport development and operation, anchored in the West London and Thames Valley area, driving UK economic growth and productivity

[1] *Working together for a thriving aviation sector*, speech by the Rt Hon Chris Grayling MP, https://www.gov.uk/government/speeches/working-together-for-a-thriving-aviation-sector

Our Vision

INNOVATION FOR SUSTAINABLE AIRPORTS
SCIENCE AND INNOVATION AUDIT

OUR STUDY AREA

Heathrow is the largest hub airport in Europe, with 476,000 aircraft movements annually, an exemplar in the 'industry' as the world's most efficient 2-runway airport, because of the systems, processes and culture that support Heathrow's daily operation. Our study area of West London and the Thames Valley, includes 5 LEPS which are, Buckinghamshire Thames Valley, Enterprise M3, Hertfordshire, London and Thames Valley Berkshire.

HEATHROW

Heathrow is the UK's most important port, with a total trade value of £128bn in 2017, 30% of the UK total

TOTAL BUSINESSES	AVERAGE EARNINGS
145,000	2.6% Higher than the national average

8.99% Percentage of the total workforce employed in science, research, engineering & technology professions	Compared to the national average of 5.6%, which contributes to the higher productivity of the study area.
52% Proportion of the population employed in science, engineering and technology	In comparison to 43% nationally, based on Nomis official labour market statistics

MARKET OPPORTUNITY

The global aviation industry is growing significantly with the International Air Transport Association predicting a near doubling of air passengers from 3.8 billion in 2016 to 7.2 billion passengers in 2035.

There are 42,000 airports across the world and currently over 400 major construction projects going on, with between 20 and 30 new airports under construction. It is estimated that £1trillion in airport infrastructure projects are planned or under way.

£24.6 billion
Global airport spend on cyber security and cloud services in 2017

£52bn
Added to the UK's GDP by aviation, supporting substantial inward investment and almost one million jobs

96% of airports
Planning major programs of Cyber Security investment and Cloud Services over the next 3 years

RESEARCH AND INNOVATION STRENGTHS

Heathrow acts as an Anchor Business for more than four hundred businesses that operate the airport (employing 76,500 people), and hundreds more across the UK in their supply chains. As the only UK hub airport, Heathrow connects UK businesses to global economies and opportunities.

- Four medium-sized research intensive universities are clustered around Heathrow, with a powerful combined research power:

- Brunel University London
- Royal Holloway University of London
- University of Reading
- University of Surrey

Brunel's Engineering and Design capabilities are ranked amongst London's biggest and best.

- These universities are involved in a range of international research partnerships, including 175 Horizon 2020 research projects worth £156M, and with over 40% of their EU funding (by value) in ICT and transport.
- 230 research organisations in the study area

BRE
A world leading multi-disciplinary building science centre with a mission to improve the built environment through research and knowledge generation. Their Innovation Park - features over 300 construction innovations and emerging technologies being evaluated and attracts thousands of visitors from around the world every year.

DIGITAL TECH CLUSTER
The Thames Valley digital technology cluster comprises 7,800 digital technology companies, the highest concentration in the UK, employing 56,300 digital technology specialists and generating 600 new start-ups per annum.

RECOMMENDATIONS INCLUDE

- Innovation/Research Centre for sustainable airports
- An Airport Habitat Lab
- A West London Connected Autonomous Vehicle Cluster
- Export Strategy for sustainable airport technologies
- Research Cluster on Sustainable Construction
- Smart, sustainable, scalable supply chains
- Develop activities to meet innovation skills gaps
- The use of Heathrow as a demonstrator for multi-modal mobility as a service

Our Key Strengths

The study area around Heathrow airport already enjoys strong economic performance in comparison with the rest of the UK, with a Gross Value Added (GVA) of over £100bn.[2] The study area is characterised by 3 complementary, but distinct, highly productive economies. The Thames Valley and Berkshire has a strong base of corporate headquarters and technical and scientific research specialisms, Buckinghamshire and Hertfordshire's economies are driven by entrepreneurial SME and Micro business capabilities and the West London area is more typical of a capital city with a younger demographic, a more cosmopolitan and international workforce and established sector specialisms in industrial logistics.

Heathrow is both an 'Anchor Business' and a 'Connectivity Institution' providing a focus for businesses and growth.

Heathrow acts as an Anchor Business for more than four hundred businesses that operate the airport (employing 76,500 people), and hundreds more across the UK in their supply chains.[3] This includes businesses across a breadth of digital creative, technology and infrastructure areas that present huge opportunities for growth and technology exploitation. The Heathrow employment site generates 1.5% of UK GDP and in February 2017, Heathrow Airport Ltd launched Heathrow 2.0, a plan for sustainable growth.

Heathrow is the UK's most important port, with a total trade value of £121bn in 2017, 30% of the UK total.[4]

As a Connectivity Institution and Britain's only hub airport, Heathrow plays a vital role in supporting the UK's economy. Its importance in linking British innovation to the rest of the world cannot be underestimated. Nowhere is this more critical than across the Cambridge, Milton Keynes, Oxford Growth Corridor (CaMKOx) which adjoins this study area in Buckinghamshire and has been highlighted as a region which could provide Britain's equivalent to Silicon Valley.

The study area has world leading science and research capabilities.

There are 230[5] research organisations in the study area, and four medium-sized research-intensive universities are clustered around Heathrow to the west of London: Brunel University London, Royal Holloway University of London, University of Reading, and University of Surrey. If combined, these four universities would rank as the 3rd university in the UK for research power, with the 4th largest volume of world leading and internationally excellent activity.[6]

[2] Data compiled by Technopolis available at: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgvaibylocalauthorityintheuk

[3] Business Case and Sustainability Assessment – Heathrow Airport Northwest Runway. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/440315/business-case-and-sustainability-assessment.pdf

[4] Data derived from HM Revenue and Customs Regional Trade Statistics. Available at: https://www.uktradeinfo.com/Statistics/RTS/Pages/default.aspx

[5] Data compiled by Technopolis based on Digital Science's GRID (Global Research Identified Database, accessed September 2017). Available at: http://grid.ac/

[6] Data derived from REF2014 submissions and results. Available at: http://results.ref.ac.uk/DownloadSubmissions/ByForm/REF1

Brunel's Engineering and Design capabilities are ranked amongst London's biggest and best, including the National Structural Integrity Research Centre focusing on building structure and materials. Both Royal Holloway University of London's Information Security Group and Surrey University's Centre for Cyber Security have been recognised as one of the 14 UK Academic Centres of Excellence in Cyber Security Research and the University of Reading has a number of strengths in environmental sciences, construction and the built environment that support the creation of sustainable airports. Although some 20 miles outside of the study area, the new £65 million Digital Aviation Research and Technology Centre (DARTeC), which will be built at Cranfield University, will provide digital aviation technology research facilities unprecedented in Europe.

BRE is a world leading multi-disciplinary building science centre that developed the first bespoke standard for airport terminals to assess, recognise and encourage construction sites managed to reduce resource use, energy consumption and pollution. Morgan Sindall Construction, with staff based at Heathrow, link with supply chain partners to lead UK innovation in sustainable airport construction and maintenance.

The region also benefits from the presence of the Transport Systems Catapult and the Transport Research Laboratory, both involved in research, development and innovation in intelligent mobility. Conigital are scaling up their Midlands Connected Autonomous Vehicles Cluster (M-CAV) by replicating with a West London CAV, and establishing an International CAV.

TRL has recently been awarded £19.2M by the UK Government to develop a Smart Mobility Living Laboratory in London.

The Thames Valley digital technology cluster comprises 7,800 digital technology companies, the highest concentration in the UK, employing 56,300 digital technology specialists and generating 600 new start-ups per annum.[7] The Digital Catapult, based in central London, supports and promotes digital innovation in the UK. Their focus is on artificial intelligence, augmented and virtual reality and future networks such as 5G. Helios aviation consultancy (Hampshire) has specific expertise in airport Cyber Security, along with the related standards and policies, and led the major SESAR Cyber Security study "Addressing Airport Cyber Security" in 2015.[8] The London Cyber Innovation Centre[9] is a new £13.5M cyber innovation centre in the Queen Elizabeth Olympic Park (10 miles east of our 'Study area'). It will spur the development of cutting-edge technology and help to develop new talent through up to 2000 UK jobs in cyber security.

[7] http://www.thamesvalleyberkshire.co.uk/getfile/Public%20Documents/Data/International/Digital%20Tech%20Sector%20Proposition%202017.pdf?inline-view=true

[8] https://www.sesarju.eu/sites/default/files/documents/news/Addressing_airport_cyber-security_Full_0.pdf

[9] https://www.plexal.com/cybersecurity/

Given the significance of the noise impacts in the locality, Heathrow Airport Ltd has made significant investment to become an innovation leader that understands, and manages the noise envelope across the estate, and in the surrounding communities. The Noise Action Plan (NAP) sets out proposed actions to enable Heathrow to operate within defined limits,[10] and work closely with the community on a range of interventions. The range of measures and assessments have set Heathrow apart in this expertise area with transferable knowledge for other airports and sectors.

Growth Opportunities

There are currently over 400 major construction projects going on at airports worldwide, with between 20 and 30 new airports under construction.[11] It is estimated that £1 trillion in airport infrastructure projects are planned or under way[12] within a timescale that continues (in some extreme cases) for four decades into the future. These range from new terminals on green field sites, to new runways, pier or satellite extensions and refurbishments. 'Building' connections with Innovate UK's Core Innovation Hub for the construction sector and the Transforming Construction Challenge Fund will enable the sustainable airports construction supply chain to export and exploit these opportunities.

Air passenger numbers are predicted to increase from 3.8 billion in 2016 to 7.2 billion passengers in 2035[13]

The SITA Air Transport IT Trends Insights (2017)[14] report states that 96% of airports surveyed are planning major programmes of Cyber Security investment and Cloud Services over the next 3 years.

Global airport spend on cyber security and cloud services reached £24 billion in 2017

The Future Aviation Security Solutions (FASS) programme[15] will improve aviation security by investing £25.5 M over 5 years in innovative science and technology.

The UK's Cyber Security Export Strategy,[16] provides a vehicle for UK cyber security companies to showcase their capability to find and secure export opportunities.

The Global Supply Chain Optimisation project GEMSTONE[17] completed by Brunel University, in collaboration with Caterpillar and Intel, won Caterpillar's Chairman's Innovation Award 2016 for innovation impacting business results. This demonstrated how the application of real- time data solutions to complex supply chains can achieve global efficiencies which deliver huge productivity gains and demonstrable competitive advantage.

[10] https://your.heathrow.com/wp-content/uploads/2017/01/Heathrow2.0.pdf
[11] https://en.wikipedia.org/wiki/List_of_airports_under_construction
[12] https://centreforaviation.com/insights/analysis/usd1-trillion-for-airport-construction-globally---but-its-not-enough-capa-database-356495
[13] http://www.iata.org/pressroom/pr/Pages/2016-10-18-02.aspx
[14] https://www.sita.aero/resources/type/surveys-reports/it-trends-insights-2017
[15] https://www.gov.uk/government/groups/future-aviation-security-solutions-programme
[16] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693989/CCS151_CCS0118810124-1_Cyber_Security_Export_Strategy_Brochure_Web_Accessible.pdf
[17] https://sites.google.com/site/brunelsupplychainopt/home

The market for CAVs in the UK (specifically, for road vehicles with CAV technologies) is estimated to be worth £28bn in 2035, capturing 3% of the £907bn global market.[18] There would be an estimated 6,000 direct UK jobs in the production of CAV technologies, with a further 3,900 indirect jobs created in the supply chain for these technologies. 70% of these jobs are estimated to be in software related industries, where our capabilities are strong.

Challenges, Opportunities and Proposals

The SIA highlights the importance of this sector to the UK economy. However, four main challenges have been identified, which if addressed would ensure that the research and innovation excellence in the region is harnessed to guarantee that innovative technologies for future airports are developed, and then translated into increased productivity, increased exports and economic growth. The four challenges are:

- The connection between the research base and industry supporting innovation in sustainable airports could be stronger and more diverse, leading to higher productivity
- The economic competitiveness of our study area means that space for businesses to grow is at a premium
- There are no incubators or accelerators specific to our themes which relate directly to sustainable airports within our study area
- There are significant higher-level skills shortages to grow innovation in particular themes, e.g. Cyber Security for Aviation.

There are also barriers to innovation at airports, inherent to the operation of the airport, such as the regulatory environment, high safety standards and the difficulty of trialling something safely without affecting the efficiency of the airport. These barriers can be overcome to some extent through the facilitation of co-innovation across the whole supply chain, as well as infrastructures such as innovation centres embedded in the airport estate or digital twins to experiment with innovation away from the airport.

The SIA identified the following strategic and theme specific opportunities:

OPPORTUNITY 1

Establishing a Research/Innovation Centre to work with all stakeholders to co-create research programmes addressing future sustainable airport challenges. It could use the airport as an innovation test bed, ensuring the airport and its supply chain partners establish the UK airports sector as leaders in global sustainability. Once successful the Research Centre and incubators would strengthen the case for an Enterprise Zone for Sustainable Airports, providing opportunities for SMEs developing the innovation technologies emerging from the Centre to expand whist remaining in the region.

[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642813/15780_TSC_Market_Forecast_for_CAV_Report_FINAL.pdf

OPPORTUNITY 2

Developing collaborative incubation and innovation facilities close to Heathrow, the natural meeting point of regional economic geographies, which will support wider collaboration, and provide space for micro businesses to grow.

OPPORTUNITY 3

Supporting and developing the provision of higher apprenticeships and graduates in areas of skills shortage such as big data, cyber and construction. This would include establishing a doctoral training centre to produce a cohort of researchers, able to work in universities or industry, attuned to the research challenges of sustainable airports.


Sustainable Construction

OPPORTUNITY 4

Consortium partners establish a formal Research Cluster on Sustainable Airport Construction & Maintenance – SEGRO, Brunel, BRE, Morgan Sindall and Heathrow focussed on the particular needs of the region.


Big Data

OPPORTUNITY 5

Develop open models for data analytics, that are trusted or validated by a body or community which would be particularly beneficial to sustainable airports. These models when used by businesses will enable export opportunities (e.g. the ACI ACRIS Semantic Model).[19]


Cyber Security

OPPORTUNITY 6

Cyber Security for Sustainable Airports could be a key offer for the UK Cyber Security Export Strategy. Targeted effort could co-create huge export opportunities for UK businesses.

[19] https://www.slideshare.net/SegunAlayande/aci-acris-semantic-model-airport-ecosystem-knowledge-management

OPPORTUNITY 7

Given the importance of logistics and transport to the region, we recommend the research and innovation partners come together to develop best practice in the development of smart, sustainable, scalable supply chains. This would bring together cutting edge technologies from big data, cyber and operation excellence to create tomorrow's supply chains for smart circular economies.

OPPORTUNITY 8

Develop a 'living lab' with Heathrow communities, businesses and CAV experts to explore Mobility as a Service (MaaS) solutions in the context of sustainable airports.

Networking and Collaborations

The process of carrying out this audit has led to new collaborations, plans and opportunities. This is what our collaborators had to say:

"Since publishing Heathrow 2.0 in 2017 we have been intensively focussed on the role of collaboration in identifying solutions to the sustainable innovation challenges our industry faces. The SIA has made a real difference to extending our networks with the business community, industry, government and academia and as a consequence has proven to be one of our most important tools in accelerating progress. The ideas and connections it has brought forward will have a lasting impact."

Matt Prescott, Interim Director, Heathrow Centre of Excellence for Sustainability, Heathrow Airport Ltd

"SIAs are designed to encourage investment in R&D by mapping places of potential global competitive advantage and identifying routes to realise that potential. TVB LEP is a consortium partner to three separate SIAs, including this one on sustainable airports. That involvement has been invaluable in helping us inform our asset base as we continue to lead the process of developing a Local Industrial Strategy for Thames Valley Berkshire."

Tim Smith MBE, Chief Executive, Thames Valley Berkshire LEP Ltd

"*The SIA has raised the profile and momentum for Intelligent Mobility initiatives in West London. As a result we have started to form a 'West London Connected & Autonomous Vehicle Cluster' in partnership with West London Business. We have already expanded our ecosystem and generated good business leads as a result. It has given Conigital a great platform to voice its opinion and share its vision on the future integration of Intelligent Mobility in 'real world' scenarios. We look forward to further collaborations and joint initiatives with our SIA partners."*

Monique Seth, Conigital

"Participation in the SIA has developed significant insight into emerging airport sustainability options and opportunities. The outcomes will better equip SMEs to focus on developing transformative solutions in Cyber Security and Big Data amongst other areas. Continued collaboration between universities and business will help make this happen."

Olu Odeniyi, Former Chairman & CEO Maidenhead and District Chamber of Commerce

"Working with the SIA and its partners, Morgan Sindall has developed strategic relationships and contacts who will work with us in the future. Innovation is a behaviour that needs to drive our thoughts, approach and delivery. It needs to be the lifeblood of how we work – our heartbeat. The relationships established through the SIA will help us achieve this goal."

Amanda Soundararaj, Proposal Manager, Aviation, Morgan Sindall

"The increased focus that this SIA has delivered on Heathrow Airport as an 'anchor business' has been extremely useful for BRE. The collaboration to connect more research with impact is a key priority for us, and the opportunities created by the SIA will support our aim to increase the dissemination of our world leading research for active skills development."

Deborah Pullen MBE, Group Research Director, BRE

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The primary authors of this report have been Brunel University London, ICE blue, Conigital and Olu Odeniyi (Former Chair and CEO Maidenhead and District Chamber of Commerce). Our Science and Innovation Audit Consortium has also provided significant input, support and advice.

The full report is available to download from the above web address.

Consortium Partners

Knowledge Quarter London

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

Introduction and context

London's Knowledge Quarter (KQ) is defined as the area within a 1-mile radius of King's Cross station (Figure 1). It hosts what is arguably the most dense concentration of scientific and knowledge-based organisations anywhere in the world, creating an 'incubator for the UK'. In recent years the KQ has seen substantial improvements in the public realm, associated with redevelopment of former railway lands to the north of St Pancras and King's Cross. On-going developer and investor interest in the area in part reflects its location at the heart of a vibrant global city. However, the KQ is also a magnet for businesses because of its highly-skilled workforce, linked to institutions that undertake world-leading scientific research. The quality of place-making and the burgeoning cultural offer aids recruitment and retention of these staff. Key to the KQ's success is an integrated transport network, i.e. fast connections to other parts of London, the wider UK, mainland Europe via Eurostar, and the world beyond, through London's airports. This provides ready access to a huge pool of skilled labour. These factors combine to give the area a competitive advantage over other cities[1].

Figure 1: Map showing London's Knowledge Quarter and the surrounding area

[1] Sarah Yates, *Knowledge Capital: Making places for education, innovation and health.* New London Architecture (2018).

With no signs to demarcate its borders, or identify its buildings as part of the UK's largest cluster of 'knowledge houses', the KQ remains one of the country's best kept secrets. In order to investigate the area's strengths in science and innovation, and how they are being harnessed to create skilled jobs across the UK, a group convened by Knowledge Quarter Ltd. — a body linking over 90 knowledge-based organisations in the KQ — conducted a Science and Innovation Audit of the KQ. This took place between November 2017 and June 2018. The Steering Group for the Audit consisted of representatives from: the British Library; Camden Council; City, University of London; Knowledge Quarter Ltd.; The Royal Veterinary College; and University College London. Its work was assisted by SQW Ltd. and Technopolis Ltd., the latter under contract to BEIS. The Group also received support from an Advisory Group drawn from industry, regional and national government, and other innovative cities and city-regions across the UK — the wider 'KQ Alliance'.

The Audit chose to focus on five areas of established or nascent expertise in the KQ, namely:

•Emerging Infectious Diseases, including Antimicrobial Resistance (AMR)

•Musculoskeletal Pathology Associated with Ageing

•Dementias

•Digital Collections — Archiving, Curation and Publishing

•Machine Learning, a form of Artificial Intelligence (AI).

For convenience in the Main Report, the first three of these specialisms are grouped together under a single Life Sciences 'umbrella'.

The Audit examined three **hypotheses**:

i)That an exceptional concentration of scientific research and other knowledge-based organisations in the KQ can have a positive effect on innovation and economic growth elsewhere in the UK;

ii)That place-based 'network brokers' (including but not limited to, Knowledge Quarter Ltd.) have an important role to play in catalysing relationships between businesses, universities and other organisations; and

iii)That close proximity in an urban setting facilitates open innovation between knowledge-based organisations.

Each hypothesis was tested by data from structured interviews, questionnaires, workshops and desk-based research, including an analysis of interdisciplinary collaborations across the KQ, and national/international benchmarking studies around each of the five specialisms.

Key strengths of the KQ

Whilst a handful of venerable institutions in the KQ, such as the British Museum (founded in 1753), The Royal Veterinary College (1791) and University College London (1826), have long histories and deep associations with the area, the wider KQ is far from static. The most visible sign of this is the transformation since 2006 of the area to the north of King's Cross and St Pancras stations[2], mostly through private sector investment within a supportive planning framework. Accompanying this transformation, there has been substantial developer interest and investment in new scientific institutions, notably the £650-million Francis Crick Institute which opened in 2016. Looking ahead, even greater investment is likely. This will include the British Library Extension, due for completion in 2023, and the multi-billion-pound redevelopment of the area around Euston station, associated with the arrival of High-Speed 2 (HS2) in 2026[3].

Latterly the KQ has been considered as an innovation district[4] — an "enclave that merges the innovation and employment potential of research-oriented anchor institutions, high-growth firms, and tech, and creative start-ups in well-designed, amenity-rich residential and commercial environments"[5]. While it possesses all of these assets and more (including national museums and libraries), the KQ defies easy categorisation; as noted by Sir Richard Lambert in his Foreword to this report, the KQ was not 'planned' in the same way as archetypal innovation districts such as 22@ (Barcelona), MIT Kendall Square (Boston) and Kista (Stockholm), but over two centuries has woven itself into the fabric of London's streets.

Data gathered by the Audit has confirmed that the KQ is internationally leading in each of the five specialisms, as measured longitudinally by data on: the number and value of research grants awarded (publicly-funded research collaborations); number of highly-cited publications; number of patents awarded; number of drug discoveries; and number of start-up companies, including university spin-outs. The KQ's strengths are concentrated in specialist centres and institutions:

- In *Emerging Infectious Diseases and AMR*, the leading actor is the **London School of Hygiene & Tropical Medicine** (LSHTM), with University College London (UCL), The Royal Veterinary College (RVC) and the Francis Crick Institute also featuring strongly;
- In *Musculoskeletal Pathology of Ageing*, and *Dementias*, the main player is **UCL** (hub of the new National Dementia Research Institute), including its eight research hospitals, with the **RVC** also being a significant actor in musculoskeletal research;
- In *Digital Collections (Cultural, Heritage and Scientific),* the field is dominated by the **British Library** and **British Museum**, with the Wellcome Trust and UCL also housing collections of international importance; and
- In *Machine Learning / AI,* the main actors are **UCL, City, University of London** and the **Alan Turing Institute** (the National Institute for Data Science); while on the innovation side, **DeepMind** (part of Alphabet, Google's parent company) and **Benevolent AI** emerge as front-runners in the KQ — and indeed internationally.

[2] King's Cross Central Limited Partnership, *Overview: King's Cross* (2017).
[3] Greater London Authority, Transport for London and London Borough of Camden, *Euston Area Plan* (2015).
[4] Kat Hanna, *Spaces to think: Innovation districts and the changing geography of London's knowledge economy*. Centre for London (2016).
[5] Bruce Katz and Julie Wagner, *The rise of Innovation Districts: A new geography of innovation in America.* Brookings Institution (2014).

As a result of growth in these specialisms, between 2003 and 2013 some 42,000 new employee jobs in science and technology were created in Camden and Islington, such that by 2015, one-third of the 352,000 employee jobs in Camden fell into this category — the highest concentration of any local authority area in the UK[6]. These jobs made a substantial contribution to the output (gross value-added, GVA) of the two boroughs, which in 2015 was £43.4 billion. To place this in context, the City of London had a GVA of £46.7 billion in the same year, whilst the cities of Birmingham and Manchester had a *combined* GVA of £41.8 billion[7].

The knowledge 'spill-over' effects of the KQ on the wider UK economy (Audit Hypothesis 1) are not captured so readily by available statistics. Nevertheless, evidence obtained from the Audit suggests that these effects are likely to be considerable. This is mainly through the supply of highly-skilled graduates, postgraduates and postdoctoral researchers (in total, circa 30,000 per year), many of whom go on to work outside the KQ; but also through the founding of highly innovative businesses, which settle elsewhere in London or other parts of the UK. Two such businesses are described in Box 1 (overleaf).

It is not possible to quantify the long-term impact on the UK economy of start-ups such as these — and there are many more examples that could be quoted. However, data collected during the Audit show that the KQ's universities have been responsible for spinning-out more than 100 small businesses in recent years. On the basis that many of these firms are already contributing to the creation of skilled jobs and GVA *outside of the KQ* (thus reinforcing the idea of the KQ as 'an incubator for the UK'), we can say that *Hypothesis 1 is supported by the available data*.

Box 1: KQ outside the KQ — some examples

- **Achilles Therapeutics Ltd.** (https://achillestx.com/) — a Life Science spin-out from the Francis Crick Institute and UCL Cancer Institute (part of the UCL Hospitals' Biomedical Research Centre) in 2016, Achilles is developing novel cancer immunotherapies that target truncal (clonal) tumour neo-antigens – unique flags to the immune system that are present on the surface of every cancer cell. It has raised £13.2 million to develop these therapies. Following its move to become part of the emerging cell and gene therapy cluster at Stevenage Bioscience Catalyst in 2017, Achilles now employs 25 staff.

- **Hazy Ltd.** (https://hazy.com/) — a AI spin-out from UCL's Centre for Computational Statistics and Machine Learning, Hazy has created a secure data sharing system that helps businesses to track and manage who has access to their data. An automated data anonymisation tool being developed by the company will allow privacy to be optimised for each use case. In May 2018, Hazy won the Microsoft Innovate.AI prize (valued at US$1 million), and is backed by Microsoft's venture fund. The company is headquartered in Shrewsbury, with an office in 'Tech City', east London.

[6] Gordon Douglass and Jonathan Hoffman, *The science and technology category in London.* GLA Economics Working Paper No. 64 (2016).
[7] Greater London Authority, *Economic Evidence Base for London 2016*, GLA Economics (2015).

Gap analysis

The KQ's success has placed multiple pressures on its infrastructure: local housing is in short supply and extraordinarily expensive (in 2016, the median house price in Camden was 19.6 times the median salary of workers in the borough[8]); commercial property prices have sky-rocketed; and employment sites are under pressure, including from conversion to residential use under Permitted Development Rights. Alongside these 'space' issues, the local transport system is congested, leading to disruption and delays at peak times; electricity 'brownouts' are becoming more common; and telecommunications networks (legacy broadband fibre and 4G) are overloaded.

The Audit has identified the following 'gaps' in the innovation ecosystem in the KQ, all of which are space related:

- **low availability and high cost of appropriate commercial sites and premises**. To illustrate this, the US pharmaceuticals giant Merck (known in Europe as MSD) announced in November 2017 that it intends to site its new UK Discovery Centre in the KQ. By 2020, this Centre is expected to house 950 staff including 150 researchers. Thus far, MSD has been unable to find suitable premises.

- **a dearth of innovation space, especially wet-laboratory space for Life Sciences start-ups and small businesses**. Established in 2001, the London BioScience Innovation Centre (LBIC, owned and operated by the RVC) on Royal College Street is the only large innovation facility in the KQ. Since opening it has run at, or close to, full capacity, with a waiting list of potential tenants.

- **a lack of suitable move-on space** in the KQ for companies wishing to expand their operations and/or take on additional staff.

- **a lack of business accelerators for start-ups and other small firms**. Mapping of physical space showed few examples in the KQ area, compared to adjacent clusters such as 'Tech City'. One example is BaseKX on Camley Street, north of St Pancras (Figure 1). Opened in 2015 and operated by UCL in conjunction with Camden Town Unlimited, it assists start-ups in the technology and creative sectors.

These gaps were also noted in a London-wide report commissioned by MedCity[9]. It appears that since that report's publication in March 2016, progress towards addressing them *within* the KQ has been slow (but see sections 4 and 5).

[8] Volterra Partners LLP, Camden Enterprise District: Securing Camden's inclusive growth. Volterra (2017).
[9] MedCity, Planning for growth: Demand *for healthcare R&D space in London.* Creative Places (2016).

The Audit also revealed that **open innovation** initiatives have yet to make major inroads in businesses in the KQ. This is despite the high density of the KQ and the activities of network brokers. Addressing this is a challenge not only in the KQ, but across the UK — especially in the Life Sciences[10]. It is early days, but there is evidence of progress in the KQ with, for example, the Alan Turing Institute's recent (May 2018) announcement that it plans to work with University College Hospital on the application of machine learning algorithms to large data-sets obtained from A&E patients[11]. In a further example of data sharing, since 2013 clinicians from the UCL Hospitals' Biomedical Research Centre have been working with other NHS Trusts in London, Oxford and Cambridge to create an inter-institutional 'safe haven' for metadata that can then be harnessed for clinical research and population health science[12]. On this basis, *Audit Hypothesis 3 is partially supported by the available data*, and further effort is needed to champion open innovation in the KQ.

Opportunities for growth

Due to the area's science strengths, the KQ Steering Group believes that continued growth needs to happen in the KQ, in order for it to happen elsewhere in London and the wider UK. More specifically, the Group has concluded that **the potential for growth is greatest in the Life Sciences (Audit themes 1 to 3), paired with exciting new developments in Machine Learning / AI (theme 5).** The opportunities fall under two of the Industrial Strategy's 'grand challenges':

i. Ageing Society — musculoskeletal pathology associated with healthy ageing (theme 2); gene and stem cell therapies; research into different types of dementia (theme 3); and

ii. AI and the Data Economy — applications of machine learning (theme 5) to large data-sets in the Life Sciences / healthcare, in order to accelerate drug discovery; use of AI diagnostics to screen for the early stages of disease (linking themes 1 and 5); and computer vision — the application of 'deep learning' to extract meaning from images (theme 4).

There is an exciting opportunity for these two challenge areas to come together in the **British Library Extension**[13], which will comprise 75,000 square-metres of innovation space on a 2.8 acre site between the Library and the Francis Crick Institute. The Extension will house the headquarters of the Alan Turing Institute and provide more space in which to display the Library's extensive digital collections. It will also offer laboratory space for a cross-section of businesses, large and small, that wish to locate within the heart of the KQ. Farther west along the Euston Road, the **HS2 / Euston station redevelopment** (Phase 1: 2019-33[14]) has the potential to provide substantial science and/or innovation space, either above[15] or alongside the southern terminus of HS2.

[10] Shelford Group of English NHS Trusts, *Submission to the House of Lords Science and Technology Committee on the Life Sciences Strategy and Sector Deal*. NHS / Shelford Group (2018).
[11] See: https://www.turing.ac.uk/media/news/revolutionising-healthcare-with-ai-and-data-science-uclh-and-the-alan-turing-institute-announce-breakthrough-partnership/
[12] See: http://www.nihr.ac.uk/about-us/how-we-are-managed/our-structure/systems/research-information/health-informatics-collaborative.htm
[13] See: https://www.bl.uk/projects/building-the-future
[14] See: https://hs2ineuston.commonplace.is/schemes/proposals/hs-2-euston-station-design-development/details
[15] Nicolas Bosetti, Kat Hanna, *Ideas above your station: Exploring the potential for development above London's stations*. Centre for London (2017).

Alongside these major construction projects is a new investment by LSHTM in epidemiology and public health (linking with Audit theme 1). **TP2**, a dry-laboratory facility being built on Tavistock Place, is scheduled for completion in 2020.

In relation to opportunities for growth in AI and the Data Economy, including the development of privacy and ethics surrounding the use of public data, **Google** is creating a 11-storey, 81,000-square-metre 'land-scraper'[16] adjacent to King's Cross station. Due to open in 2020, this building and another premises nearby will accommodate up to 7000 staff, providing a new headquarters for Google's UK operation. The site is close to Google's existing home at 6 Pancras Square, which also houses **DeepMind**'s 300 London-based employees and YouTube Space, a hub for creatives. **Facebook's** anticipated move to a 65,000-square-metre site to the north of Granary Square, behind King's Cross station[17] raises the exciting prospect of a new AI / Data Economy hub at the heart of the KQ by 2024.

There are also an increasing number of instances in which the KQ's strength as the home of unique digital collections (theme 4 of the Audit) is being harnessed to benefit the UK economy. The work is at an early stage when compared to Life Sciences, but there are some exciting initiatives in this space. One example is a collaboration between the University of Oxford's Visual Geometry Group and researchers at the British Library, which aims to apply next-generation computer vision methods and tools to large collections of digital images, including prints, paintings, stamped images, photographs and film[18]. The objective of this project is to produce methods that can analyse, describe and search image and video content with human-like capabilities; and thereafter to be able to apply these methods to industry and across academic disciplines, with the result that "everything visual should be describable and searchable"[19]. This offers tremendous potential to create 'tech' start-ups — based anywhere in the UK — that make use of open source tools developed by the project.

Networking and collaboration

Complementing current and proposed growth in the KQ is *growth outside the KQ, but linked to the KQ*. The largest such development is a nascent innovation district at **Stratford** in east London, only 7 minutes by high-speed train from St Pancras. This district, lying within and adjacent to the Queen Elizabeth II Olympic Park, is to be known as the East Bank[20]. It will host government agencies including new offices for HMRC and Transport for London, a £13.5-million cyber innovation centre (known as LORCA, the London Office for Rapid Cybersecurity Advancement) and major cultural organisations (BBC Music, Sadler's Wells East, V&A East, with a link to the Smithsonian Institution), alongside housing and retail space.

[16] See: http://www.heatherwick.com/project/google-kings-cross/
[17] See: https://www.architectsjournal.co.uk/news/frank-gehry-lined-up-to-design-facebooks-new-kings-cross-base/10027866.article
[18] See: http://blogs.bl.uk/digital-scholarship/2018/05/seeing-british-library-collections-through-a-digital-lens.html)
[19] See: http://www.robots.ox.ac.uk/~vgg/projects/seebibyte/
[20] See: http://www.queenelizabetholympicpark.co.uk/the-park/attractions/east-bank and https://www.internationalquarter.london/

Importantly for the KQ, the East Bank development includes a new campus for UCL, complementing its existing site (shared with Loughborough University London) at Here East on the Olympic Park. UCL will join Birkbeck, University of London, another KQ resident, which since 2013 has had a base at University Square Stratford. The first new building on the UCL East Campus will be Marshgate Phase 1, a 33,500-square metre research and teaching facility, due for completion in 2022. Stratford offers an abundance of grow-on space for knowledge-based organisations, at a build cost per square metre that is very low when compared to the KQ. This has led UCL to move elements of civil engineering and architecture — two of its most 'space-hungry' schools — to Stratford. The same logic may yet tempt other KQ residents to establish a presence there, whilst retaining their sites in the KQ. To this end, Knowledge Quarter Ltd. is in regular dialogue with the London Legacy Development Corporation (LLDC, the Mayoral development authority) in order to understand how the KQ and Stratford can develop their respective 'offers' in ways that are mutually supportive.

Knowledge Quarter Ltd. is also engaging with Imperial College at **White City** in west London[21]. The new 11.5-acre campus places a strong emphasis on multi-disciplinary research and innovation with application to the Life Sciences. Under construction or recently completed are: a 26,000-square metre Molecular Sciences Research Hub, due to open this year; a 13-storey Biomedical Engineering Research Hub due for completion in June 2019; and i-Hub, a 20,000-square metre Translation and Innovation Hub which opened in 2016. The White City development has the advantage of being close to two research hospitals (Hammersmith Hospital and Queen Charlotte's & Chelsea, respectively), providing the critical 'ABC' community (i.e. academics, businesses and clinicians) much beloved of innovation district developers. Like the KQ, White City Campus has a strong community development ethos that includes a commitment to citizen-led innovation[22]. This may help it form a natural bond with the KQ. That said, whilst the two districts are fewer than 6 miles apart, travelling between them takes 35 minutes by tube — a fact that could yet stifle collaborations (compare with the 7-minute overground journey from St Pancras to Stratford).

Farther afield, but only 20-25 minutes by train from King's Cross and with growing links to the KQ, is an emerging cluster in gene therapy, stem cell therapy and tissue engineering (linking to Audit themes 2 and 3). This consists of the Cell & Gene Therapy (CGT) Catapult's £55-million Cell Manufacturing Facility on GSK's open innovation campus at **Stevenage** in Hertfordshire, which opened in April 2018[23]; the CGT Catapult's network of industry partners — several of which are based at the Stevenage BioScience Catalyst (SBC), on the same site; the Advanced Therapies Division of the National Institute for Biological Standards and Control, which is co-located with the UK Stem Cell Bank at **Potters Bar**[24]; and the RVC, which has a campus at Hawkshead Lane, Potters Bar. Whilst this cluster is focused on human medicine, the CGT Catapult's interests complement those of the RVC, which is developing stem cell therapies for equines and companion animals.

[21] See: http://www.imperial.ac.uk/white-city-campus
[22] See: http://www.imperial.ac.uk/white-city-campus/community/the-invention-rooms/
[23] See: https://ct.catapult.org.uk/manufacturing-centre
[24] See: http://www.nibsc.org/science_and_research/advanced_therapies.aspx

Opportunities for collaboration between the Catapult, companies based at SBC, and the RVC are being pursued through joint bids for funding, and will be boosted by the opening of a Veterinary Vaccinology and Cell Therapy Hub on the RVC's Hawkshead campus in summer 2020 (see reference 1).

At national level, Knowledge Quarter Ltd. is part of a newly-formed network of nascent innovation districts chaired by the LLDC and including Manchester, Liverpool, Leeds and Glasgow; whilst at international level it is working with innovative cities and city-regions in Europe, the USA and Asia to share good practice. This includes acting as host for visiting delegations, undertaking 'ambassadorial' visits overseas and, prompted by the Audit, contributing to technical debates on the role of urban innovation districts in creating sustainable economic growth (for example, in June 2018 the RVC and UCL gave a presentation on 'what works in the KQ' at the University-Industry Innovation Network conference in London). These activities are comparatively low-key at present and could with benefit be expanded as part of efforts to make the KQ 'brand' more widely known inside and outside the UK.

The process of carrying out the Audit has undoubtedly strengthened collaboration *within* the KQ, particularly between the Steering Group members, but also between innovative small firms in the KQ, that hadn't previously been aware of one another's existence (some of these firms met for the first time during the thematic workshops). The Audit has also helped to formalise relationships between the KQ and external actors such as the GLA and the LLDC, whilst creating new 'soft' connections with MedCity, Tech Nation, HS2 and Imperial White City. At the same time, some hoped-for relationships failed to get off the starting blocks, because no individual champion emerged to engage with the Audit process (this is perhaps inevitable given the large and diverse set of organisations in the KQ). This failure demonstrates that new connections can only be made if all parties are open to the possibility, and serves to highlight the importance of 'network brokers' in joining the dots between organisations — a role that in the KQ is undertaken by Knowledge Quarter Ltd. and a handful of highly motivated consultants. A KQ-wide survey conducted as part of the Audit revealed that these brokers, most of whom have been active only for a short time, are starting to have a genuine catalysing effect on collaborations. *Hence, Audit Hypothesis 2 is supported by observations made during the Audit.* That said, the Audit found that the scale of brokerage activity is modest, in keeping with the small number of brokers active in the KQ. Brokerage activity will need to be ramped-up considerably (and be complemented by in-work enterprise skills training — see section 7) if we are to fully exploit the KQ's potential as an 'incubator for the UK'.

A vision for London's Knowledge Quarter

The KQ Steering Group has drawn up a list of priorities for the short, medium and long term.

In the short term, the Group believes **it is important for the KQ's 'premium brand' and profile to be better communicated and promoted worldwide, with attendant benefits for the whole of the UK**. The KQ represents a world-class resource for the UK in terms of innovation and research commercialisation, yet it remains largely invisible in wider London and UK narratives. This is to significantly under-play (or even mis-represent) the area's assets, especially in respect of international investors. The Steering Group is keen to work with BEIS and/or the Department for International Trade in order to correct this anomaly.

Over the medium term, the Group's vision is to sustain and harness fully the disruptive potential and impact of the KQ's scientific and knowledge-based assets. This will be evidenced through processes of open innovation, with both economic impacts and wider social benefits, which will improve lives nationally and internationally. Processes of research commercialisation will be central to this, which means that the KQ must continue to be a place where very early-stage businesses can be nurtured (with appropriate finance, physical provision, and supportive networks). The Steering Group recognises that scale-up and growth may need to occur outside the KQ**. Its vision is that this process should be actively supported and encouraged by organisations and individuals based in the KQ, thereby delivering direct economic benefits to locations outside of central London.**

At the same time, we want those who are resident within the KQ to benefit fully and more equitably from the growth process, insofar as it can be accommodated there. Currently there are substantial local pressures, particularly in relation to housing (availability and cost) and congestion. Many of the jobs generated in the KQ in recent years are 'low pay' in character and the risk is one of increasing polarisation in income[25]. Thus, whilst Camden is ranked eleventh from top in the UK in terms of local authority areas with the highest proportion of wealthy households, levels of deprivation in some parts of the borough (e.g. Somers Town) and in Islington are similar to those in Hackney, Newham and Tower Hamlets, the local authority districts in the UK with the highest percentage of households living in poverty[26].

How might this inequality be addressed? A spatial plan for the KQ's development, covering the next thirty years ('KQ 2050'), would help to create a long-term vision for sustainable growth to which all interested parties can subscribe. The purpose of this Plan will be to:

- give coherence and legibility to long-term aspirations for the area, in which the possibilities surrounding science and knowledge are a central feature (in this respect, the Plan will resemble a 'local industrial strategy' for Camden and Islington, but with the benefit of a longer timeframe);
- provide a 'script' that can be shared widely, including internationally ("this is what the KQ will be like");
- build investor awareness and confidence in KQ, and in the process, help both to accelerate the delivery of major schemes and 'unlock' key sites, including those that form part of the NHS estate[27];
- provide a high-level framework within which infrastructure investment priorities might be meaningfully identified and advanced; and
- set out the scale of the social mission to deliver genuinely inclusive growth for residents of Camden and Islington and the constructive role of industry, investors and institutions in meeting the challenge.
- If realised, the plan will provide a long-term framework for development processes within the KQ, and govern its relationship with strategic partners outside the KQ. It will exist within the framework of the London Plan and, whilst it will not have statutory planning status, it will influence the evolution of Local Plans in Camden and Islington.

[25] Neil Lee and Stephen Clarke, *A rising tide lifts all boats? Advanced industries and their impact upon living standards.* Resolution Foundation (2017).
[26] Danny Dorling and Bethan Thomas, *People and Places: A 21st-century atlas of the UK.* Policy Press (2016).
[27] Sir Robert Naylor, *NHS property and estates: Why the estate matters for patients.* Department of Health (2017).

Key ambitions and actions arising from the Audit

Creating a spatial plan for the KQ will be the main follow-on activity for the Steering Group's successor body over the next few years. In support of this high-level commitment, Steering Group members will seek to advance several more immediate projects within the KQ, including:

i. nurturing and growing a **UK-wide network of innovation districts**, to ensure that these districts secure the investment and policy support necessary to maximise their success [Lead institution: *Knowledge Quarter Ltd.*]
ii. **building the brand of the KQ**, as a route to securing international profile and investment in innovation across the wider UK [Lead institutions: *RVC and Knowledge Quarter Ltd*.].
iii. creating effective mechanisms by which to nurture **strong(er) ties between institutions** within and beyond the KQ, using a 'network of network brokers' to champion the benefits of open innovation [Lead institution: *Knowledge Quarter Ltd.*].
iv. developing the **start-up / small business ecosystem in the KQ**, including: training for early-career researchers and small businesses in enterprise skills and market awareness (e.g. emerging sectoral trends and major disruptive innovations; innovation demand and supply), and providing enhanced access to finance. To do this at scale — and thereby make a real impact on the wider UK economy — will require leadership, funding and coordination between key organisations and individuals responsible for delivery of the training [Lead institutions: *UCL and City, University of London*].
v. **unlocking the NHS estate**, working with colleagues in NHS Estates and the NHS Trusts to provide new wet-laboratory space in central London [Lead institution: *Camden Council*].
vi. creating a **'digital content hub'** to encourage innovation around the KQ's unique digital collections. This hub will bring together a range of actors including technology companies, digital content holders, designers and artists [Lead institution: *British Library*].
vii. launching **KQ visas** in order to secure the labour supply following Brexit [Lead institution: *Knowledge Quarter Ltd.*].

Resources for these projects will be sought locally and at national level — for example through proposals to UKRI[28]. Various arms of central government could assist organisations in the KQ to deliver each of the projects listed above, not necessarily by providing funds, but by exercising their convening power. This will enable certain strategic conversations to take place more quickly and/or facilitate conversations that, without government's intervention, might not take place at all.

[28] UK Research and Innovation, Strategic Prospectus: Building the UKRI strategy. UKRI (2018).

Conclusions

The Audit of the KQ has identified the main strengths and weaknesses of the KQ, tested three hypotheses, mapped the KQ's principal collaborations and networks, and started the process of creating a long-term spatial plan for the area ('KQ 2050'). This plan will aim to **accelerate the development of the KQ as an 'incubator for innovation' that supports the economic prosperity of the wider UK**. In addition, seven projects have been identified that will facilitate the plan. Each of these projects has been assigned a lead institution(s) from the KQ.

Importantly, the Audit exercise has demonstrated to Steering Group members that a small, dedicated group of people can achieve a surprising amount in a short space of time, by working in partnership. The key to continued success will be placing 'KQ 2050' at the forefront of strategic thinking by national government on science and innovation; and thereafter, mobilising the strength of *all* stakeholders in the KQ to help deliver this vision.

MAXIMAR: MAXIMISING THE MARINE ECONOMY IN THE HIGHLANDS AND ISLANDS

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

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

SUMMARY REPORT

imani DEVELOPMENT
global vision, local knowledge

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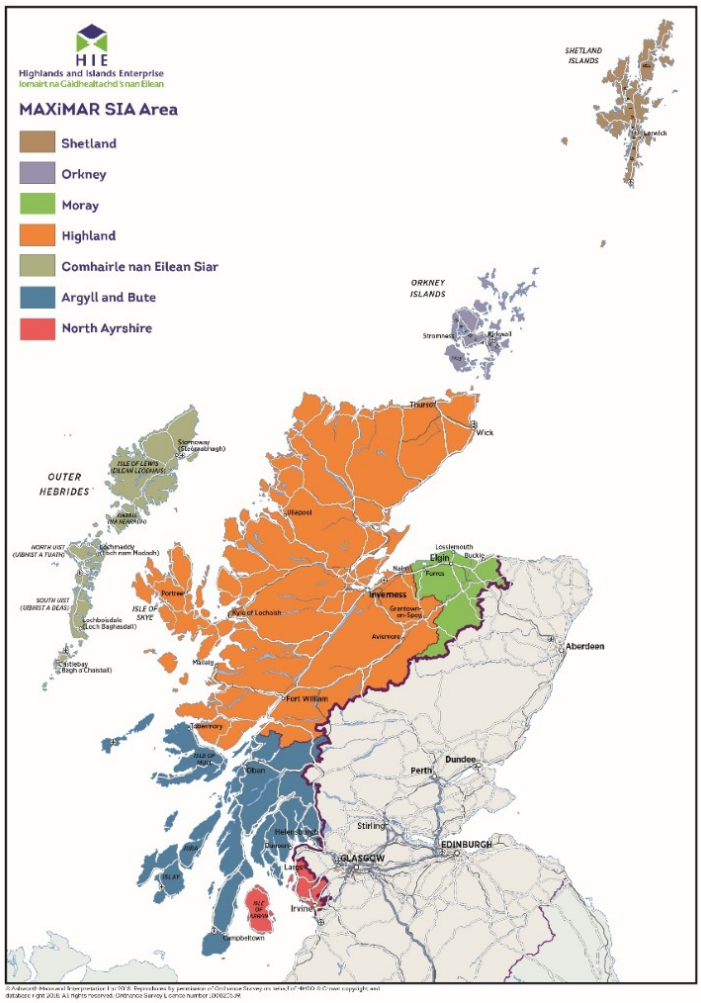
Summary

At just over 40,000km^2, the Highlands and Islands region stretches from Shetland in the north to Campbeltown at the southern tip of Argyll, and from the Western Isles to Moray in the East. In 2016 the total population for the Highlands and Islands SIA region was just over 625,000.

It is a largely rural and sparsely populated area. With a population density of around 12 people per km^2, in comparison to 129 per km^2 in the rest of Scotland, the region has the lowest population density in the UK, and one of the lowest in Europe. Of the total population, 61% are of working age (aged 16-64). This is lower than the 63% UK average and reflects the difficulties faced by the region in attracting and retaining young people.

In total there were just over 300,000 jobs in the Highlands and Islands region in 2016. Reflecting the concentration of population, over 40% of these were based in Highland local authority area.



Introduction and 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 local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential. In the Highlands and Islands, a consortium was formed in October 2016 to focus on our strength in the marine economy. This report presents the results which includes broad-ranging analysis of the Highlands and Islands marine economy capabilities, the challenges and the substantial opportunities for future economic growth.

There is worldwide recognition of the potential of the marine economy, for example for food security, for clean energy and to provide new solutions and a wide range of applications. It also has an enormous contribution to make to the circular economy agenda. The Highlands and Islands has an outstanding marine environment and contains almost two thirds of the UK's coastline and coastal waters. It is home to world class marine science and innovation.

The focus of the SIA is on aquaculture, wave and tidal energy and marine biotechnology which are the most highly innovative sectors in the marine economy. They offer the greatest growth potential and the opportunity to accelerate economic growth through strategic, focussed effort built on technological innovation.

- **Wave and tidal energy:** Scotland is the global leader of wave and tidal energy innovation, with the world's first commercial scale projects in development[1] and excellence across the supply chain. By harnessing the marine power of the Highlands and Islands region the UK will be able to position itself at the forefront of one of the untapped global clean energy industries of the future.
- **Aquaculture:** The Highlands and Islands is the largest aquaculture region in the UK, and the third largest salmon producer in the world[2], with the best premium for its produce. The increasing demand for fish protein is being driven by global population growth and rising affluence in developing countries. There is tremendous scope to increase sustainable production through the development and application of new science and technology.
- **Marine biotechnology:** The pristine marine environment, described as '*a huge and diverse 'underwater forest'* is an extremely valuable but currently underused resource in the Highlands and Islands. It presents a huge growth opportunity with a diverse range of innovative applications in high growth, high value sectors such as health and life sciences, and energy.

Combining wave and tidal energy, aquaculture and marine biotechnology into a marine economy strategic framework will add value to each sector as well as to the region, and the UK overall. Investing now will secure Scotland's long-term position as a global leader in this field. The SIA demonstrates how the marine economy will take a place-based approach to deliver against the themes of the UK Industrial Strategy[3] and the Foresight Future of the Seas report.[4]

It articulates the strategic opportunities for the marine economy and shows that innovators, infrastructure, capabilities and ideas are concentrated in the region. It also confirms that the region has the capacity to provide the necessary skills and assets for sustainable growth.

[1] http://www.orkneymarinerenewables.com/crown-estate-leasing-round
[2] http://marineharvest.com/globalassets/investors/handbook/salmon-industry-handbook-2017.pdf
[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-_version.pdf
[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693129/future-of-the-sea-report.pdf

Vision

With our unique marine environment and our collective strengths in science and innovation, we will work collaboratively to accelerate the economic opportunities of the marine economy to benefit the Highlands and Islands, Scotland and the UK. In doing so, we will protect and respect the communities that are the custodians of this world-class resource.

Key strengths

The Highlands and Islands has a rich base of marine economy science, innovation and capabilities across a number of institutions and in industry. This, combined with its natural marine assets, makes it an unparalleled destination and resource for research, and the development of new ideas. The activities in the region act as a catalyst for new, often disruptive technologies.

There is a commitment to, and strong examples of, clustering and collaboration, cross-sectorally, and between industry and research. The region has an established and strong science and innovation infrastructure with a high degree of specialism in the marine economy. As a result, it has a global reputation for research excellence and has attracted significant funding, along with world-class talent.

It is an enterprising region with a highly qualified workforce and a significant concentration of marine-economy based businesses. Growing the marine economy will increase the supply of higher value jobs and activities and will be a key component in realising UK growth ambitions. It will deliver economic and social benefits to the Highlands and Islands and help to support the sustainability of fragile communities.

Growth opportunities

The three sectors that comprise the marine economy are at different stages of development but for each, there is significant and demonstrable potential for growth. Though the sectors will grow at different rates, evidence points to a **total value of the marine economy in Scotland of £5bn by 2035.** Estimates suggest this is an approximate seven-fold increase on current values.

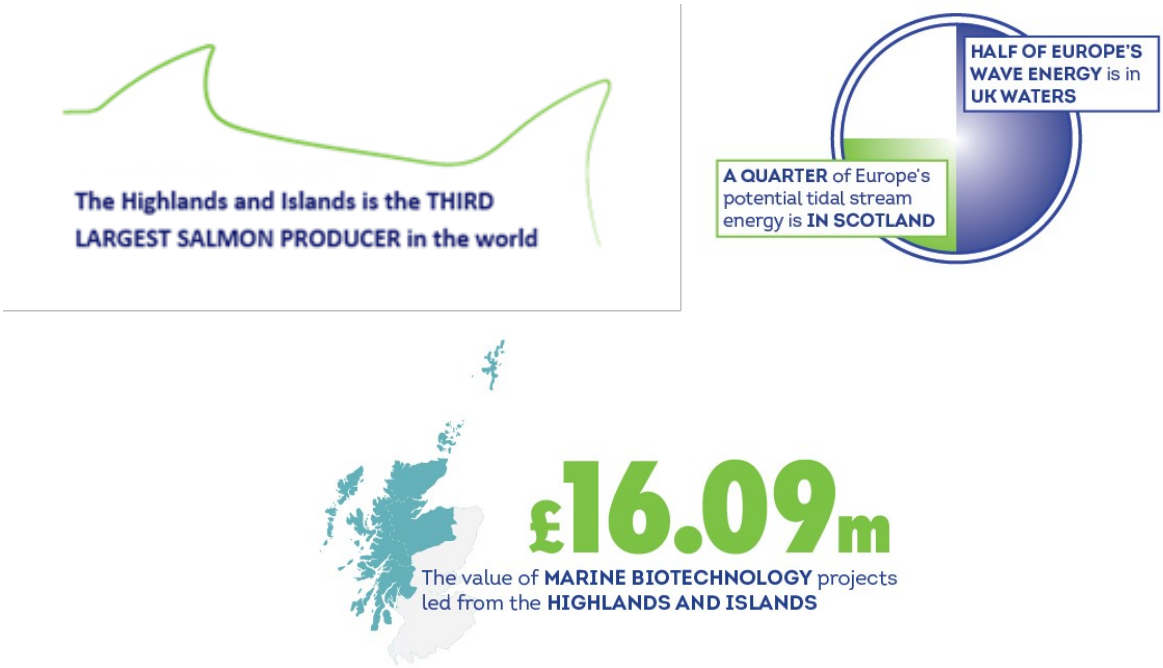
In **aquaculture**, the scale of the salmon industry drives much of the innovation investment, both for expansion (new cage design, smolt (young salmon) production, sites in more challenging locations) and tackling challenges (disease control). The industry in Scotland aims to double the value of production by **2030 to £3.6bn**. Key to achieving the expansion will be tackling the issues through science and innovation.

Wave and tidal energy is moving into a new phase of innovation where it is seeking to commercialise and export knowledge, to 'capture the value' of new device innovation and systems learning to date. Current estimates indicate a potential value to the UK of **£800m by 2035**.

In **marine biotechnology**, significant applications are in early development and could impact across a range of high profile and important areas such as energy, human health, and food production. The potential value to the Highlands and Islands is expected to be **£600m by 2030**.

But it is not just the Highlands and Islands that will benefit, the marine economy in the region drives activities in, and impacts on, other parts of Scotland and across the UK. It also supports an extensive and diverse supply chain generating economic benefits and providing a wide range of employment opportunities.

Interdisciplinary capacity and the recognition of translational research opportunities are key to accelerated progress in the marine economy. The relatively small size of Scotland and the existing channels of communication make this more readily achievable. Smart technology in terms of unmanned vehicles, miniaturised sensors, data capture and pre-processing, and the handling of large datasets are core abilities that translate across each sector. Examples already include environmental and oceanographic monitoring, survey and planning.



Gap analysis

There is undoubtedly enormous potential for the development of the marine economy in the Highlands and Islands. However, if the benefits for the UK are to be maximised and the economic benefits realised, there are some clear challenges that must be addressed. Failing to do so will inhibit growth and have a negative impact on the economic and social health of the Highlands and Islands. There is currently a lack of clear routes to commercialise innovations and new technologies; there are some skills and gaps that will need to be addressed to make sure there is an adequate workforce to fuel sector growth; and current planning and regulation is working against innovation, commercialisation and expansion. There are some good examples of cross sector science, innovation and operational activities. However, there is enormous scope to make much, much more of this by catalysing, clustering and capitalising on the wide range of the known and currently unanticipated opportunities.

With these gaps and issues in mind, four hypotheses of the MAXiMAR SIA were developed to provide a holistic and systematic framework to address the challenges in terms of:

- Having the mechanisms in place to support the commercialisation of the marine economy science and innovation assets and so realise the economic potential for the region, for Scotland and for the UK.
- Implementing a planning and regulatory framework that supports and encourages innovation and development, balanced with environmental sustainability and the needs of different user groups.
- Identifying opportunities and developing marine economy clusters in science, innovation and operations building on the strong networks and relationships in the region.
- Making sure that the right skills, education and workforce development opportunities, science and infrastructure are in place to fuel marine economy growth.

This is all achievable, it is within our grasp and there is the determination amongst the stakeholders across Scotland to work together to ensure that the opportunities are maximised.

Targeted Opportunities

The Targeted Opportunities have been developed with industry, education, the public sector and other key stakeholders working collaboratively. They address the particular challenges for the marine economy in the region. They are based on identified need, rather than being developed to target particular funding streams, however, they align with regional, Scottish and UK policy objectives. They will also be aligned with the developing Regional Deals in the Islands (Orkney, Shetland and the Outer Hebrides), Argyll & the Isles, and Moray. By driving these forward, the marine economy will contribute to the transformation of food production and clean affordable energy. Marine biotechnology also has a potential role in helping to meet the needs of an ageing population through innovations in human health.

Overarching the opportunities is the proposition that the marine economy should be developed by taking a whole-sector approach, for example to strategic planning, science and innovation, operations, funding and problem-solving. There is a great deal of intelligence, knowledge and experience in each sector. However, it is largely kept within each sector and in many cases, within individual institutions. Integrating the three sectors and adopting a strategic approach for the marine economy will enable this knowledge to be better shared between industry, academia and the public sector. Importantly, the community will form the fourth element of this quadruple helix so that the marine economy works *with* communities where possible and appropriate.

Flowing from the SIA will be a strategic plan for accessing funding for science, innovation and growth of the marine economy. There will also be opportunity to support and influence the development of a Sector Deal for the Marine Economy. We have developed four Targeted Opportunities; the first has three strands flowing from it.

1: REGIONAL CLUSTER MODEL FOR MARINE INNOVATION, TECHNOLOGY AND SKILLS

The case

Industry has expressed a need for access to high quality, state-of-the-art facilities, equipment and wider infrastructure to drive enhanced R&D and aid clustering, close to the marine environment. A number of key locations in the region host research and technology organisations which already support this, but they are not currently sufficiently resourced. There is a strong case for a major cluster development incorporating technology and sea-trial testing facilities and industry support mechanisms. It will incorporate enhanced marine training and skills development provision which will scale up training provision in the Highlands and Islands, and will align with other training providers across Scotland. There is an opportunity to develop an innovative partnership model that builds on the combined existing infrastructure to better meet the needs of industry, grow innovation in the sector, extend and expand the skills base, and attract new business to the region. A key element will be a pilot test site to explore the potential for, benefits of, and associated risks of clustering marine economy activity across the sectors, for example, use of drones and robotics in areas that offer different marine characteristics. New approaches would be developed, deployed and monitored, and lessons learnt and applied in the region and further afield.

The regional cluster model would create the conditions to maximise innovation and support growth of the marine economy. It would facilitate collaboration and cross-sectoral working, provide a route to market for innovation and research, encourage entrepreneurship and business development. It would also add value to the existing innovation-supporting infrastructure.

Underpinning the regional cluster model will be three critical strands:

- 1a: Workforce development
- 1b: Blue economy infrastructure investment plan
- 1c: Science, research and industry: scale and alignment

1a: Workforce development

There is potential to better exploit and facilitate cross-sectoral working, training and development, as well as workforce movement between sectors. There is also a need to understand current and emerging skills gaps and training requirements. This requires scaling up the provision of education and learning in the Highlands and Islands to anchor skills development in the region, align need with opportunity, and address both replacement and expansion demand in the labour market. This, along with upskilling the existing workforce to keep pace with new processes and developments is a key issue identified by industry and public sector partners, and one that the current skills system is not meeting. It will capitalise on the activities and partnership working of the network of marine training centres across Scotland.

1b: A marine economy innovation infrastructure plan for Scotland

Mapping the existing infrastructure to better understand current provision, and how it aligns with need will be critical in developing a targeted and proactive plan to ensure appropriate infrastructure is in place to develop and grow the marine economy science and innovation opportunity. This will be integral to the regional cluster model and will be driven by industry needs. It will identify the infrastructure, equipment, facilities, incubation and soft-landing space required across the three sectors, and include costed proposals targeting appropriate funding opportunities. The economic impact of a well-researched innovation infrastructure investment plan will be measured in terms of employment, productivity and GVA over a 30-50 year period, and this planned approach will accelerate realisation of the economic and social benefits generated by the marine economy.

The required capital investment will link to existing regional strategic infrastructure such as the European Marine Science Park, European Marine Energy Centre and the Orkney Research & Innovation Campus.

1c: Science, research and industry: scale and alignment

Marine economy research undertaken in institutions is often not well-aligned with the current and emerging needs of industry. There is a perceived imbalance between science that focuses on environmental factors and that which focuses on technology, process and product development. The current scale of research taking place in the region is also insufficient to meet the needs of the sector and so needs to be increased as well as better aligned. Academic research, located in close proximity to industrial activity, is a proven requirement. The regional cluster model will be central to delivering this. Two key components are required to ensure proper alignment of the science and research base in the region – ensuring it is industry-driven and ensuring that there is capacity to broaden the research activity. Both have been identified as key to accelerating the use of new technologies across the three sectors.

This will require growing the number of principal investigator and post-doctoral opportunities in the region at the various innovation sites, and providing collaborative challenge funding to encourage industry engagement and ensure focus is on the right industry challenges.

2: ROUTES TO MARKET

The case

The marine economy in the MAXiMAR SIA region has enormous potential with an international reach. However, each of the three sectors faces challenges in terms of realising the potential and commercialising innovation.

The Highlands and Islands has the potential to produce large quantities of **wave and tidal** energy and contribute significantly to the development and provision of clean energy to UK and international markets. New technology is being developed and tested in the region

and there is a need to optimise its value. However, the dated infrastructure to get the energy to market is inhibiting production, innovation, testing and development. There are four elements to this opportunity: connecting the production areas to the National Grid; providing a range of 'routes to market' support mechanism for example through Contracts for Difference, time limited enhanced fee tariffs and/or through the tax system; bringing activities that need power to the source, rather than relying on the power being routed to the activities; capturing the potential of hydrogen production from wave and tidal as a power source.

Marine biotechnology is the least developed of the three sectors and has enormous largely untapped potential. Despite its assets, the UK trade balance for marine biotechnology is negative and worsening as a result of persistent failure to remove the barriers and challenges to commercialisation of marine biotechnology science and innovation. The Targeted Opportunities in in the SIA will be an important toolkit for addressing some of the barriers i.e. planning and regulation and an innovation cluster. However, specific mechanisms will be established to support marine biology enterprises to develop and take their products to market. It will include specialist scale-up support and support to access financial investment and de-risking strategies.

Aquaculture is relatively well established as a sector and very well established in the region, with many large vertically integrated producers. However, small scale innovative companies and entrepreneurs in Scotland face structural and geographical barriers to access the Scottish market. They frequently have to take their innovations overseas and sell them into competitor markets. This impacts on the companies and means that the UK and the sector in Scotland is losing the benefits of the innovations and potential gains in efficiency and productivity, and subsequently losing global market share. Increasing the active support for collaboration between the small innovators and the larger companies will raise awareness of the innovative work and opportunities, leading to joint projects. In addition, financial mechanisms to temporarily reduce the cost to larger companies of testing new innovations would help to remove some of the barriers.

This opportunity and the objectives and activities within it will increase the economic value of the Scottish marine economy. It will allow more enterprises to commercialise their innovations and increase the number of enterprises active in the market. It will also help to exploit international markets

3: REFRESHED PLANNING AND REGULATION FRAMEWORK FOR THE MARINE ECONOMY

The case

A highly successful process for the planning and regulation to support the deployment of wave and tidal machines in our coastal waters in Scotland is already being implemented. Learning from this and applying new approaches across the wider marine sector could be advantageous.

There is important learning from countries such as Norway and Iceland on developing and implementing proactive planning and regulation that supports sustainable development. A strategic, refreshed framework is key to facilitating innovation, research and development, taking an active management approach, through a process of survey, deploy and monitor, supporting a collaborative approach between regulator(s) and science, innovation and industry.

This will require the acceleration of decision-making and reduced costs from a refreshed regulatory framework agreed to the public and private sector. This would lead to the faster realisation of economic benefits generated by the industry, as well as increased productivity through a reduction in unnecessary regulatory costs.

4: A REGIONAL MARINE ECONOMY PROSPECTUS

The case

The Highlands and Islands has very strong, and in many ways unique marine economy research capabilities, opportunities and assets. It also has a global reputation for some of its activities and products, but crucially there is a lack of informed knowledge and detailed understanding, worldwide, about its marine specialisation. There is also a lack of an accurate understanding about the research and career opportunities offered by the marine economy in the region amongst both local residents and those living, working and studying out with the Highlands and Islands.

The prospectus will help the region promote itself globally to a range of audiences. It will also be a tool for individual organisations, including industry partners, to use.

This will help to attract new research and innovation, inward investment, new enterprises, business growth and in talent recruitment and retention.

Networking and collaboration

The SIA process has been enormously valuable for consortium members and wider stakeholders. It has enabled new and better linkages, communication and networking between sectors. Partners have come together at consortium meetings as well as at thematic workshops which involved broader participation, including by industry leaders. Strong new relationships have been established.

Through the SIA, Highlands and Islands Enterprise (HIE) has established a closer relationship with Marine Scotland, the Scottish Government body tasked with the integrated management of Scotland's seas. HIE now has a deeper understanding of Marine Scotland' skills, expertise and policy and how the Scottish Marine Plan aligns with the region's economic aspirations. This relationship will continue in the long term and is an extremely valuable outcome of the process.

As a result of the SIA, there is a much greater awareness of shared challenges and cross-sector synergies in marine economy science and innovation. As well as new relationships, existing relationships have been galvanised, with new activity and focus. These new and strengthened links are anticipated to make a substantial difference to the marine economy and the sectors and organisations within it.

Developing the SIA has provided an opportunity for partners to understand and think about science and innovation outside of their individual sectors and organisations and how what is happening in one sector relates to their own sector and work. Consortium members have expanded their knowledge and understanding of complementary sectors and have identified where collaboration in science and innovation, as well as at operational level, can add significant value. The consortium members and other partners have jointly identified cross-sector benefits and how each sector can support and work with others and achieve synergy. There is now a much greater understanding of how the three sectors can work collectively within the framework of the marine economy. Importantly, there is commitment and enthusiasm amongst all partners and a sense of ownership of the shared goals.

Consortium members have substantially broadened their networks and contacts, particularly their reach in to related but separate sectors. There are examples where members have invited individuals they have met during the process to join formal networks, e.g. an economist from one organisation has been invited to join another's technical network. This would not have happened without the SIA.

The development of the SIA has supported members in their own work and in their organisations. The learning, along with the SIA report, are already being used by partners to inform strategy and planning. This is likely to increase steeply as the SIA is launched and implemented. As an example, the information captured in the audit will be used to inform the strategic direction of the pan-Scotland Business University Leaders Forum. This group was recently established, bringing together strategic leaders to identify significant opportunities for Scotland. Consortium members also acknowledge that the SIA has been very helpful in preparing the Islands Deal bid. Another academic partner reported that their internal strategies and organisational change have been consolidated because of the process and being part of the SIA consortium has led to a growing confidence in their strategic direction.

As a result of relationships established through the SIA process, Heriot Watt University is working with other consortium members to explore opportunities for jointly supporting a new

Chair in Energy Systems. The University and other SIA partners, including HIE, have developed a collaborative partnership to explore options and opportunities for the academic community to support marine economy growth in Orkney. Principals, Vice Principals and researchers have met, along with HIE, have been meeting regularly and a plan is being developed that is likely to attract project seed funding.

Just as encouragingly, the European Marine Energy Centre (EMEC) has engaged with a number of stakeholders in the marine biotechnology sector – a completely new territory for EMEC and something that would not have happened without the SIA. This will offer some exciting new innovations and developments for clustering, joint working and the circular economy. The initial focus of the discussions have been around how the hydrogen produced by EMEC from excess renewable energy could be applied in the marine biology sector. It could be used for processing natural molecules to deliver a range of high value products and benefit both sectors. Early stage conversations are underway between EMEC, Xanthella and other enterprises to explore this along with other opportunities for cross-sector collaboration and clustering.

Another innovative idea that has flowed from bringing partners together to prepare the SIA is the concept of combing hydrogen with seaweed and algal derived products into the production of bio-propane. Renewable powered electrolysis produces oxygen and heat as waste products and EMEC has been discussing with the Industrial Biotechnology Centre (IBioIC) how this could be used in marine biotech processes if plants are co-located.

Consortium members and partners have been exploring how EMEC's wave and tidal test sites could be used as a growing site for marine biotech species. They have also been considering how power generated in the sea and hydrogen produced from renewable energy can support future developments and operations in marine biotechnology and aquaculture. Partners have developed a clear understanding and fresh ideas of the potential synergies between a move into offshore and higher-energy environments for fish farming and the application of wave and tidal energy as a source of power. There is also scope for EMEC to become involved in modelling environmental conditions to test fish farm infrastructure and equipment such as cages and moorings.

EMEC and the private enterprise, Scottish Sea Farms, are exploring whether hydrogen powered fuel cells could replace diesel generators on their salmon farms, with both parties interested in a test project on Eday. It is very unlikely that this cross-sectoral, research-to-industry relationship would have been established without the SIA.

The waste products from electrolysis (heat and oxygen) could also demonstrate the case for a co-located onshore fish farm, although this is still in the concept stage. Wave power for supporting offshore fish farms is a key area of opportunity and a long-term match. However, the generation technology still needs a few years of development to become cost competitive and so for this opportunity to be realised.

Although some early conversations have taken place, the partners recognise that this is only the beginning. There is a commitment to better integrating ideas, innovation and goals and for public, private and research stakeholders to work together. We are confident that the new and strengthened relationships and the deeper and broader understanding of the marine economy will continue to deliver substantial benefits. We are in no doubt that the SIA will prove to be a game-changer for the marine economy, for the Highlands and Islands and for the UK.

Closing remarks

The SIA has been an extremely helpful process and has highlighted the opportunities for the marine economy and the challenges that the public sector, industry and academia will work together to address. New relationships have been established and existing partnerships galvanised. Through it, we have a very clear, evidence-based understanding of the marine economy and a definitive and agreed agenda to develop it in cross-sectoral partnership. We will work collectively for the long term to realise the ambitions of the SIA and respond positively to the changing context which we will undoubtedly face. We will advance science and innovation to benefit people in the Highlands and Islands, businesses and the wider economy. However, the reach of the SIA's benefits will go far beyond our geographic boundaries, to Scotland, the UK and internationally.

Developing the SIA has demonstrated our combined ability to think innovatively, challenge assumptions and be confident in the unique opportunity that we have in the Highlands and Islands. We are now ready to realise that opportunity.


Department for Business, Energy & Industrial Strategy
imani DEVELOPMENT
ekosgen
HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean
HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean
EMEC
THE EUROPEAN MARINE ENERGY CENTRE LTD
wave energy SCOTLAND
University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean
IBioIC
HERIOT WATT UNIVERSITY
UK | DUBAI | MALAYSIA
SAMS
Scottish Government
Riaghaltas na h-Alba
gov.scot
marinescotland
Marine Alliance Science Technology Scotland
Scottish Aquaculture Innovation Centre
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL
UNIVERSITY of STIRLING

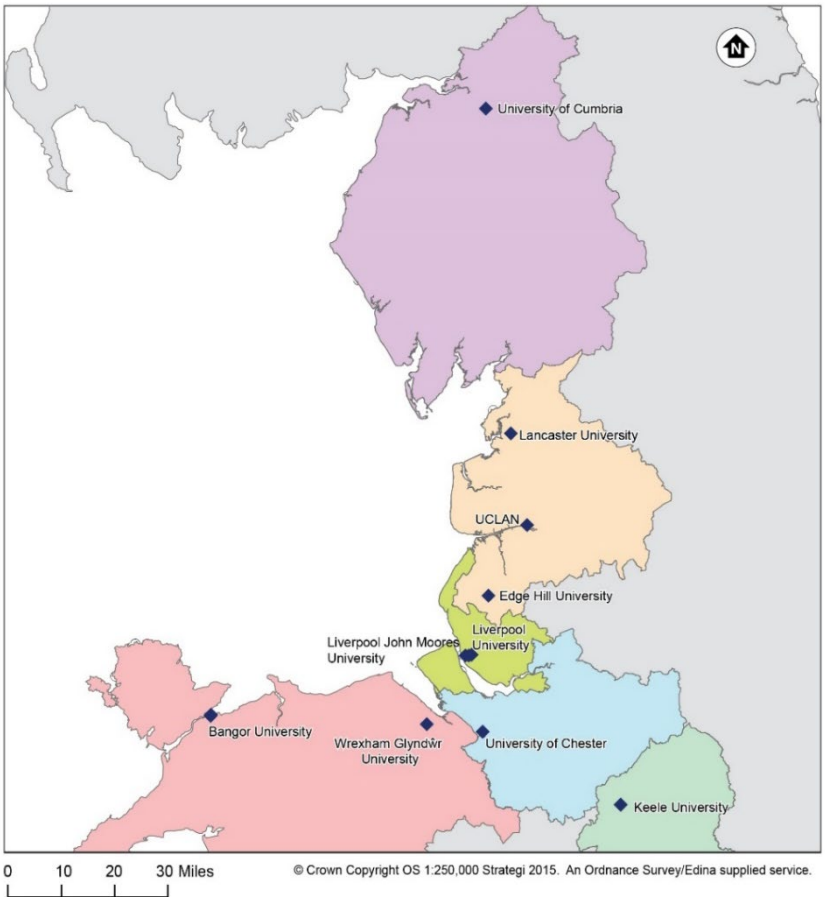
North West Coastal Arc Partnership for Clean and Sustainable Growth

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

A Geography for Clean and Sustainable Growth

The North West Coastal Arc Partnership for Clean and Sustainable Growth brings together the complementary research strengths of ten regional universities, (Lancaster, Liverpool (both members of the N8 partnership), Bangor, Chester, Cumbria, Edge Hill, Keele, Liverpool John Moores, Wrexham Glyndwr and University of Central Lancashire), together with Further Education at Blackpool & The Fylde College. Additional research capacity is delivered from the Centre for Ecology and Hydrology (at Lancaster and Bangor), the National Oceanographic Centre at Liverpool. The consortium also includes all regional LEPs, the North Wales Economic Ambition Board. Mersey Dee Alliance, our strong regional communities of eco-innovative SMEs and large industry players with international reach, including Unilever and the North West Aerospace Alliance.

Map of the geographical area covered by our consortium.



Introduction and context

The 2017 UK Industrial Strategy White Paper[1] recognises that Clean Growth is not simply a challenge but a very significant opportunity to increase productivity, create good jobs and scale-up earning power right across the country – accordingly clean growth is highlighted as one of four grand challenges in the Industrial Strategy. The Government's Clean Growth Strategy[2] (2018) highlights that technological and environmental innovation is driving new high value jobs, transforming industry and creating new companies. This conclusion is equally clear in estimates of the international opportunities for Clean Growth. In 2014, the global market for low carbon products and processes alone was worth $3.4 trillion and this is predicted to rise to in excess of $8 trillion by 2025. In the UK employment, turnover and GVA in this sector are all growing rapidly, which could deliver between £60 billion and £170 billion of export sales by 2030. Clean growth is also a priority in the 2016 Northern Powerhouse Independent Economic Review (IER) and across all of the strategic plans of the region's LEPs and North Wales Economic Ambition Board.

Clean Growth is also inseparable from the aims of the Government's 25 year Environment Plan (2018) to protect the climate and environment upon which we, and future generations, depend. For that reason, **this Science and Innovation Audit (SIA) refers to 'Clean and Sustainable Growth' rather than simply 'Clean Growth' to emphasise that opportunities are not limited to the energy sector**. Meeting the changing patterns of demand in global trade will need new products, services and technologies- 'eco-innovations'- across multiple sectors. It is these Clean and Sustainable Growth solutions that are needed to deliver the objectives of both the UK Industrial Strategy and the 25 year Environment Plan.

Our expression of interest defined the fundamental hypothesis of this SIA: 'The NWCA will realise its potential as a global market leader for low-carbon and sustainable products, processes and services through greater networking, integration and connectivity across the whole of the region's research base and business community, beyond that which exists in our current networks'.

This SIA has tested that hypothesis, and provided the evidence base to demonstrate that the Northwest Coastal Arc (NWCA), by bridging across disciplines and sectors, and from discovery to implementation, is exceptionally well-positioned to lead globally in developing both those solutions and the skilled people that will drive forward the economic and environmental benefits of Clean and Sustainable Growth.

Our vision

The NWCA partners share a collective vision of translating world-class research via innovation for Clean and Sustainable Growth in order to create regional economic value. That vision has been emerging and evolving for several years and this audit has confirmed that the vision emerges from four powerful foundations.

Our first foundation is our industrial assets that exist across multiple sectors, not least the low carbon sector for which the Northwest of England is ranked first for employment, set against clear additional opportunities for significant further economic growth, not only across our region, but also the wider North and the whole of the UK. Our second foundation is the unique

[1] HM Government Industrial Strategy

[2] HM Government Clean Growth Strategy

geography and natural assets of the NWCA as a natural test-bed for Clean and Sustainable Growth solutions. The third foundation is the substantial base of significant human and infrastructure assets in science and innovation. Our fourth foundation is our experience in demonstrating the power of business-driven collaboration with the science and innovation base and our long-standing, successful partnerships in addressing the challenges and opportunities in the global market for low carbon goods and services (for example the award-winning Centre for Global Eco-Innovation).

Key strengths

The NWCA has pioneered a vision of eco-innovation for Clean and Sustainable Growth in which many research activities and business challenges transcend traditional disciplinary and sectoral boundaries. An analysis of research excellence and regional key business sectors has led to the identification of three prime capabilities within this audit, **Environmental Industries Technologies & Services (EITS)**, **Future Energy Systems (FES)** and **Advanced Manufacturing, Chemicals and Materials (AMCM).** In addition, we identified an enabling capability in **Cross-cutting research and innovation for Clean and Sustainable Growth.** This enabling capability draws on strengths across disciplines and enhancing collaboration with industry and supports the translation of research excellence across the three prime capabilities into new products, processes and services for Clean and Sustainable Growth**.**

The region's strength in depth in the research base supporting EITS, FES and AMCM is enhanced by both underpinning research and significant cross-cutting knowledge exchange and business collaboration assets. In summary, we have innovation strengths in depth in three highly distinctive, complementary areas:

i. Business-led understanding of the demand for a wide range of eco-innovative goods and services. Our industrial partners, from SMEs to large industry players with international reach, are committed to sharing and identifying the commercial opportunities that will arise from a deeper understanding of the eco-innovation market place as well as specific innovation needs and skills demands. The strength of the wider consortium is connecting these corporate businesses with the wider community of eco-innovative SMEs, building on our significant existing networks.

ii. Complementary strength in the core research and innovation disciplines for low carbon and eco-innovation. In terms of research and innovation infrastructure, the audit has identified sixty internationally significant research units across the whole NWCA, many developed jointly between academia and industry. It is notable that more than half of these identify as undertaking research that cuts across at least two of the three capabilities identified in this SIA, one line of evidence for the inherent connectedness across research and innovation for Clean and Sustainable Growth. However, at present, this infrastructure has been developed by individual universities and their local research users. There are only a few exceptions where facilities and activities are joined-up across the region.

iii. Specific regional strength in long-term SME eco-innovation capacity-building and evidenced delivery of business benefit. A key strength here is the nationally award winning Centre for Global Eco-innovation. Since 2012 CGE has been established and grown using ERDF-funding (£30M). CGE was initially a partnership between Universities of Lancaster and Liverpool, but since 2016 has expanded to include Cumbria, Chester, Liverpool John Moores University and University of Central Lancashire. CGE has proven

power and capacity to stimulate collaboration between eco-innovative business (especially SMEs) and the region's research base by supporting the development of new low carbon/eco-innovative products, processes and services for global markets and a new generation of eco-innovation entrepreneurs and academics. At the heart of the Centre are innovative SMEs seeking to address global challenges, including energy, water, natural capital, resource efficiency, food, and waste, to deliver economic, social and environmental benefits. From this foundation, the SIA is the key next step in growing the approach, broadening and deepening our existing network of successful collaborations to ensure that we secure our competitive advantage ahead of competing regions around the globe.

Growth opportunities

It is clear that between now and 2030 a number of 'mega trends' will drive change in future global markets. These include 'innovating to zero' as resources become scarcer; compliance with climate change obligations to reduce emissions of greenhouse gases, which drives the shift to low or zero carbon systems; adapting to climate change (especially around extreme weather events) and, in an age of rapid urbanization, upgrading poor drinking water and waste water infrastructure, and feeding the world's growing population. Clean and Sustainable Growth encompasses all these drivers.

Products, processes and services for Clean and Sustainable Growth offer significant opportunities for exports into the growing economies of China, India, the Middle East and Africa. The 2015 Goldman Sachs report '*Unlocking UK Productivity: Internationalisation and Innovation in SMEs*' highlights the importance of SME engagement with the global market place and innovation as key to driving productivity and shaping the future growth trajectory of the UK economy. It also notes that only 20% of SMEs are exporters, with only 5% classified as 'persistent exporters'. Key barriers are identified as: gaining access to networks; navigating unfamiliar business environments; procedural obstacles; understanding overseas environments; finding the management time, confidence and resources to pursue opportunities.

The NWCA universities have significant 'on-the-ground' presence in key export markets. These already provide opportunities to showcase leading-edge technology, serve as an intermediary to bring together innovators and funders, to support international commercialisation opportunities for SMEs, and to streamline international technology transfer and knowledge exchange. However, while the activities of NWCA partners in this sphere are significant they are currently entirely unconnected. This audit highlights the further clear scope for increased collaboration with our regional corporate partners to exploit their international market presence and global supply chain opportunities for Northwest SMEs looking to trade internationally.

Gap analysis

The SIA has confirmed the NWCA's strength-in-depth in terms of nationally and internationally leading science, innovation and industrial capabilities across the region. Those assets include not just research infrastructure but also strength in depth in the human assets of highly skilled researchers and technicians, and the innovative, forward-looking mind-set of those in our business community. The region's capabilities map well on to the intersecting priorities identified in the UK Industrial Strategy White paper, the Clean Growth Strategy and the 25 year Environment Plan. We start from a position of strength and our priority now is to build on that strength to secure the region's global leadership in delivering eco-innovative products, services

and technologies- the solutions needed to deliver Clean and Sustainable Growth in the coming decades.

The audit has highlighted five broad gaps that limit our ability to connect current capabilities with future market / application opportunities. As detailed below, of these five gaps, three were anticipated in the hypotheses defined in our expression of interest, and two more emerged from the consultations undertaken during the audit itself. These gaps, in turn, highlight the opportunities that will enhance the region's capabilities and leadership.

Gap A. Poor understanding of the opportunities from Clean and Sustainable Growth.

We began with the hypothesis that *'… current regional (and UK) strategies will be considerably enhanced by a deeper understanding of the scope and market potential for the full spectrum of products, processes and services required for global sustainable growth (i.e. those beyond low carbon energy generation)'.*

The audit confirmed a widespread misconception of the nature and need for Clean and Sustainable Growth. In our consultation with more than 100 businesses and other stakeholders, many of those we interviewed were unclear how 'Clean and Sustainable Growth' was relevant to their own planning, both in business and local/regional policy. This highlights a major disconnect between thinking 'on the ground' and global and national policy drivers, including the UK Industrial Strategy, the UK Clean Growth Strategy and the UK 25-year Environment Plan. The complementary resources, skills and experiences of all NWCA partners, universities and businesses of all sizes have the power to voice this need to a wide audience, and so support not only the technical innovations needed for Clean and Sustainable Growth but also the awareness and behavioural change needed for its successful implementation.

Gap B. Lack of connectivity across the region's assets for research, development and demonstration for Clean and Sustainable Growth

Our over-arching hypothesis referred to the need for *'greater networking, integration and connectivity'*, which applies across all elements of the audit, but we further hypothesised that *'valuable, additional mechanism(s) may be identified to optimize synergies across the NWCA's unique mix of large companies and SME business assets, skills and research.'*

Inputs from businesses and stakeholders recognised lack of connectivity between sectors, and the audit has highlighted the remaining challenge of improving connectivity between academic disciplines. Both are a legacy of 20th century models of thinking that must change if we are, collectively, to meet the challenges of Clean and Sustainable Growth. The audit also identified the power of universities to act as catalysts to 'join-up' currently unconnected sectors, for example by supporting 'open innovation' through CGE and other cross-cutting activities. Yet the audit made clear that we have only started this journey. The audit has drawn out our distinct 'capabilities', but also the inherent integration at the heart of Clean and Sustainable Growth.

A specific 'valuable*, additional mechanism …. to optimize synergies across the NWCA*' identified through the audit was a 'joined up' approach to demonstration facilities. Businesses and stakeholders clearly identified this need for 'test-bed' facilities. The region is already growing a powerful range of demonstration facilities. However, there has been little consideration to date of the power of 'mutual access' to researchers, innovators and industry from across our geography and partners.

Gap C. A substantial skills-gap at all levels in sectors relevant to Clean and Sustainable Growth

Our original hypothesis also detailed that *'… the region's HEIs have specific role in attracting and training the skilled people and eco-innovation talent needed by the region, and providing these people with the experience and opportunity to stay in the region and contribute to its growth'.* Our consultation with more than 100 stakeholders, including extensive input from industry confirmed that the 'skills agenda' was very high on the priorities of businesses and our wider stakeholder community. Our audit highlights two particular aspects to this skills gap, (i) apprenticeships and (ii) widening the skill-set of STEM graduates.

Gap D. Limited use of the partner's international networks to maximize shared benefits.

The audit identified the scale and diversity of international research and innovation connections of NWCA university partners. These international campuses, partnerships and 'commercialisation' offices represent an important bridge for two-way business innovation supporting Clean and Sustainable Growth. However, as with UK-based facilities each institution's connections remain 'silo-ed'. While that may be entirely appropriate for teaching activities, it may constrain opportunities for taking a more coordinated approach and integrating these facilities in order to scale-up impact and business opportunities across NWCA partners.

Gap E. Poor integration in funding research and innovation in Clean and Sustainable Growth

This gap emerged from discussions across partners involved in the Centre for Global Eco-Innovation (CGE) and related projects. Phase 1 of CGE (2012-2016) was a single project that allowed Lancaster University and the University of Liverpool to work with SMEs from across the region then covered by a single regional structural funds (ESIF) programme. A migration to sub-regional LEP-based division of resources meant that as the network of CGE partners expanded in phase 2 (2016-2020), each of the four new projects were evaluated and funded separately by Cheshire, Cumbria, Lancashire, and Liverpool City Region. This has resulted in operational inefficiencies to programme development and delivery and unnecessary multiplication of administrative effort. There was a very clear view from our consultations with stakeholders, businesses and LEPs, and well as from universities, that this detracted from the ability of the project to support business and deliver its economic and environmental targets.

Key ambitions and proposals

The five gaps noted above lead directly in to the five opportunities described below.

Opportunity 1. Communicating the economic importance of Clean and Sustainable growth

There are immediate opportunities in both '*Green Great Britain Week*' outlined in the Clean Growth Strategy and the proposal in the 25 Year Environment Plan specifically to make 2019 a '*year of action for the environment*'. This represents an excellent opportunity for NWCA partners to work together to use the outcomes of this audit to highlight the immense benefits of Clean and Sustainable Growth for the economy and people, as well as the environment. In the medium-long term, the recently announced feasibility study for a £60 million 'Eden Project of the North' based in Morecambe Bay could be a unique and transformational opportunity for the region. One route forward, drawing on expertise and examples from across the NWCA, **could be to integrate an internationally-leading gateway for education and the engagement of the public around Clean and Sustainable Growth** as part of "Eden Project of the North",

complementing the opportunity for new research, development and demonstration facilities (Opportunity 2).

Opportunity 2. Improving connectivity between the region's assets for Clean and Sustainable Growth

One key message from this audit is that Clean and Sustainable Growth must cut across business sectors and academic disciplines. Responding to that message might use multiple approaches but the audit has identified the opportunity to develop a single point of focus– for example an International Centre of Excellence for Clean and Sustainable Growth. **A Centre of Excellence would act as a gateway for stakeholders to access the NWCA's existing prime capabilities, targeting the challenges and opportunities at the interaction of the Clean Growth Strategy and 25 Year Environment Plan.** Again, the proposed 'Eden Project for the North' offers a unique opportunity to develop new research, development and demonstration capacity, serving the whole of the NWCA partnership, both its research base and business communities, and developed alongside public engagement facilities (Opportunity 1). The aim would be to scale-up to a new level the NWCA's ability to support our corporates and SMEs to develop and show-case new Clean and Sustainable products, processes and services for global trade through collaboration across the regional research base.

Opportunity 3. Enhanced support for connecting business to global markets.

The audit has identified the opportunity to take a **more coordinated approach to leveraging the international campuses and technology transfer facilities of the region's universities in order to develop SME internationalisation support programmes** across the HE partners. This ambition will need to start with discussions between our universities, but will ultimately require the involvement of regional global corporates and key government agencies including DIT. As a first step, we will share the SIA with DIT trade and export staff with two aims. First, to help identify UK companies that could export goods and services into growth markets. Second, to assist DIT to develop a strong inward investment offer for innovative business developing the products, services and technologies needed to meet the demands of the global market for Clean and Sustainable Growth. Indeed, the opportunities here are relevant to businesses across all sectors.

Opportunity 4. Training to support and lead Clean and Sustainable Growth

The wider concerns around the 'skill gap' led to the identification of two issues, apprenticeships and widening the skills sets of STEM graduates. By working together, we can ultimately develop and secure the currently unfulfilled potential of regional talent to support and lead Clean and Sustainable Growth. **Improving integration and connectivity in training offers relevant to Clean & Sustainable Growth across FE and HE providers to provide a 'skills escalator' could be developed through a virtual Clean Growth Training Academy**. Such a training academy might start with pre-degree apprenticeships but extend through to include the collaborative development of relevant skills programmes within degree and other formal programmes and through CPD. The aim is to attract world-class talent to the region and retain the 'eco-innovators' of the future within the NWCA.

Opportunity 5. Freedom and flexibility in supporting industrial R&D for Clean and Sustainable Growth, particularly in SMEs.

The vast majority of the innovation assets, physical and revenue, identified in this audit have been/are supported by European Investment and Structural Funds and it is critical that emergent funding streams enable the continuation and evolution of HEI-SME innovation support programmes. A clear conclusion from the audit is that achieving our aspirations of significantly increased SME R&D for Clean and Sustainable Growth requires funding mechanisms (for example the multiple mechanisms of government investment highlighted in the Clean Growth Strategy) that operate at an appropriate and transformational regional scale across individual LEP boundaries.

Table 7.1 Next Steps: a plan for implementing the opportunities identified by this Science and Innovation Audit

June 2018	Draft report submitted to BEIS.
July 2018	Initial “awareness raising” flyer prepared to ensure audiences within the region and beyond are aware of the expected publication of the SIA in the Autumn (e.g. for use at the EIC Eco-Innovation conference.
Late summer-early Autumn 2018	Discussions between all partners leading to formal terms of reference for the North West Coastal Arc Alliance for Clean and Sustainable Growth, formalising the relationships developed through the partnership preparing this SIA.
Autumn 2018	Next steps post publication – a discussion meeting with BEIS. October 2018.
	Final Clean and Sustainable Growth SIA published and formally launched.
	Regional launch of SIA and the North West Coastal Arc Alliance for Clean and Sustainable Growth.
	“Clean and Sustainable Growth Roadshow” by all Alliance partners to communicate the key outcomes and recommendations of the audit “on the ground” in all the sub-regions of the NWCA.
	Partner representatives on alliance steering group agreed, and times/dates of monthly meetings of the steering group agreed until July 2019.
	Planning for Alliance communications under the ‘2019 Year of Action for the Environment’ begins.
Winter 2018-2019	Steering group leads a scoping exercise to review work-streams. The current proposal is that the work-streams will be based on Opportunities 1-4 above, but that Opportunity 4 in particular might generate multiple work-streams.
Early 2019	Initial alliance communications and engagement activities under ‘2019 Year of Action for the Environment’ (continues through the year).
	Final work streams agreed, including decisions on which partner leads which work-stream.
Spring 2019	Work stream carry out their activities.
Early summer 2019	Work-streams assessments and recommendations submitted to Alliance Steering Group
Late summer 2019	Steering Group agrees priority actions.
Autumn 2019	Planned Centre for Global Eco-Innovation Conference will provide a public-facing platform to communicate further steps.

Networking and collaboration

Our SIA collaborative activities with partners represents a shared manifesto and springboard for action on Clean and Sustainable Growth. We assert that a focus on establishing the NWCA as the exemplar region, both nationally and internationally, will make a significant and sustained positive impact on our productivity performance, drive significant growth and play a major role in rebalancing the national economy.

The strength of the partnership process enabled through this audit has shown a real commitment by the organisations involved to create a strategic alliance, develop an action plan and convene an implementation group to drive progress. But our Manifesto represents only the starting point for action on Clean and Sustainable Growth.

Across the North West Coastal Arc Partnership, there are internationally leading innovation strengths and assets within the science and industrial base. If they can be coordinated at scale, there is the potential to accelerate the understanding, realisation and implementation of eco-innovation nationally and internationally, enabling both Clean and Sustainable Growth and substantial productivity improvements. We have an agreed implementation plan for the first twelve –eighteen months after the submission of this audit.

In addition to the specific implementation plan of the audit, the collaborative working and improved mutual understanding of capabilities across all partners has led to new developments, listed below, that would not have occurred had the audit not taken place.

1. During the course of this audit our discussions with Centre for Ecology and Hydrology (CEH), which has research stations at both Lancaster and Bangor, revealed that CEH colleagues, completely independently of this SIA, were exploring the creation of a powerful Research Alliance at the Land-Sea Interface across the North West Coast. Discussions have begun with potential partners including the National Oceanographic Centre, Lancaster University, the University of Liverpool and Bangor University. The independent development of this “parallel vision” is, in our view, a testament to the power and timeliness of this audit and of our founding hypotheses. The thinking emerging from CEH has been integrated in this audit and discussions on aligning the NWCA ‘alliances’ are progressing positively.

2. This audit has coincided with rapid progress in planning for the Eden Project North in Morecambe Bay, a transformational project to develop an internationally significant visitor attraction, centre for environmental and related research and for public engagement with science. The proposal is for the Eden North project to become a recognisable global icon of ‘wellbeing, wonder and curiosity’. It would combine research, innovation and outreach and transform the local and broader regional economy. The proposals now incorporate opportunities identified through this audit, above all the concept of integrating both an internationally-leading gateway for education and the engagement of the public around Clean and Sustainable Growth and an International Centre of Excellence for Clean and Sustainable Growth within the Eden Project North development. The project (supported by Lancashire Enterprise Partnership, Lancashire County Council, Lancaster City Council and Lancaster University working with the Eden Project) is currently undergoing a series of detailed feasibility studies.

3. Even whilst we were awaiting the outcome on the Expression of Interest, we originally submitted for this SIA, the partnership was actively seeking opportunities for further collaborations, building on those that drove the collective buy-in to pursue the audit in the first place. A prime example of this was the submission of an application to HEFCE's first Connecting Capabilities Fund during 2017. All of the SIA partners (excluding those from Wales due to the funding rules) together with Manchester and Manchester Metropolitan universities, came together to develop a CCF proposal. At the heart of the proposal was a collective drive to work together to improve knowledge exchange and commercialisation between the research base and SMEs. Though the bid was ultimately unsuccessful, the drive across the partnership remains and has directly informed this SIA.

4. As a direct result of this audit, the University of Bangor has recognised the many points of synergy and complementarity between its activities and those of Lancaster University. This has led to discussions on forming a strategic alliance between the two institutions.

5. During 2017, Lancaster led a consortium bid 'MENTOR' to the NERC RISE Programme with partners that included CEH, the University of Cumbria and United Utilities. The focus was on improved management of the region's water resources that are central to the regional economy of North West England. In 2013, United Utilities supplied 630bn litres to 6.9m customers and 200,000 businesses, the latter adding £140bn of gross value to the UK economy. The management of the region's water is also fundamental to tourism and the wider visitor economy, including across the Lake District National Park and the Morecambe Bay coasts. The Lake District is the most visited tourist attraction outside of London, bringing in 21% of total UK tourist income, equating to 2% of UK GDP. MENTOR was co-designed to act as a catalyst to realise the full potential of NERC-funded research at Lancaster University and CEH to deliver regional benefits. The bid was unsuccessful but the partnership is committed to the value and impact of the proposed work, which is now being repurposed towards other place-based funding streams.

6. Starting in October 2016, the Global Challenges Research Fund Collective call (Growing research capability to meet the challenges faced by developing countries) is funding RECIRCULATE, a 4-year, £7M programme with partners in sub-Saharan African. Led by Prof Nigel Paul at Lancaster University, RECIRCULATE emerged from the learning obtained from working with SMEs and multiple university partners in the Centre for Global Eco-Innovation. RECIRCULATE will use that learning to facilitate new partnership-based approaches to develop capacity to harness Clean and Sustainable Growth opportunities that support the sustainable use of water for food, energy and sanitation. This audit, which has been concurrent with the first year of RECIRCULATE, has supported further synergies. For example, staff from the projects partners (in Ghana, Nigeria, Malawi, Botswana, Zambia and Kenya) have already visited Liverpool John Moores University and Chester University to learn more about their approaches to eco-innovation for Clean and Sustainable Growth. We anticipate that the further learning obtained from the audit will continue to inform RECIRCULATE's research in to the best approaches for collaboration between universities and businesses to drive Clean and Sustainable Growth in sub-Saharan Africa.

The North West Nuclear Arc

Introduction and Context

The North West Nuclear Arc (NWNA) is defined by the area shown in Figure 1 below. The NWNA sweeps down from Carlisle through Lancaster and Preston, then continues to Manchester where it turns westwards to Liverpool and crosses the border into North Wales, finishing in North West Wales, where on Anglesey there is an ideal site for new nuclear build and in Trawsfynydd for potential deployment of advanced nuclear technologies. The region includes an eastern corridor that crosses the Pennines to include the world class experimental facilities, universities and companies operating in South Yorkshire, and also embraces the Northern Powerhouse. In terms of Local Enterprise Partnerships (LEPs), the area includes the North Wales Economic Ambition Board, Liverpool and Sheffield City regions, Cheshire and Warrington, Cumbria, Greater Manchester and Lancashire (Figure 2).

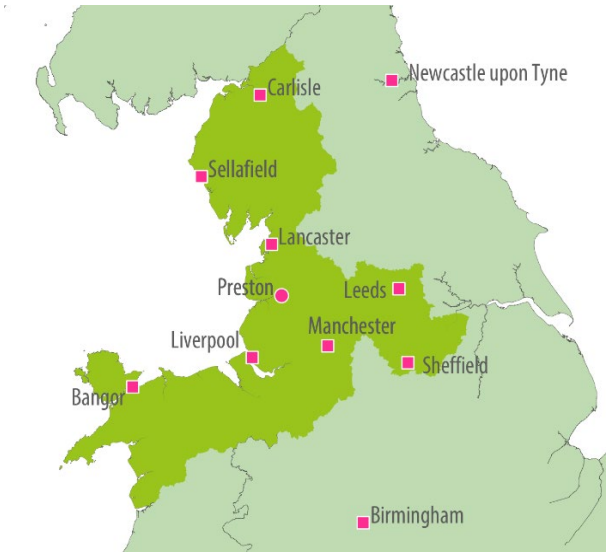


Figure 1: The audit region (dark green)

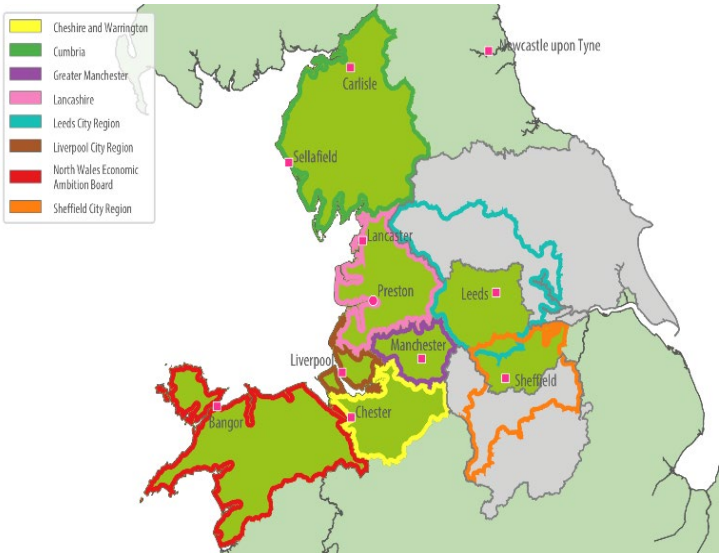


Figure 2: The boundaries of the LEPs

The area encompasses a significant proportion of the UK's existing civil nuclear Research Development & Innovation (RD&I) and operational capability and is a major area for potential large new nuclear deployments (Wylfa and Moorside). The current capability and mix in the NWNA is unique in the UK in terms of Higher Education Institutions (HEIs), Tier 1 and 2 companies, regulators, decommissioning and new build, as well as specialist facilities providing an arena for technical innovation, and technology transfer. The region will be very important in the implementation of the Nuclear Sector Deal with the decommissioning, cost reduction and skills targets all deliverable within the NWNA.

Nowhere else in Europe is so much nuclear expertise so concentrated, with unparalleled access to a world-renowned skills base and pioneering expertise in nuclear research and development. Hundreds of companies and investors in the nuclear industry – including global leaders such as URENCO, Westinghouse, Sellafield Ltd, EDF Energy, and National Nuclear Laboratory (NNL), which already benefit from the geographic proximity and easy connectivity to build more efficient

and reliable supply chains, readily access customers across the UK, and access a pool of highly-skilled people attuned to the specific needs of the nuclear industry.[1]

Key strengths and assets include:

- RD&I: both facilities and research expertise with depth and breadth, which includes the universities of Lancaster, Liverpool, Manchester, Leeds, Sheffield and Bangor.
- Decommissioning and Clean Up (DCU) expertise at Sellafield Ltd
- Waste disposal at the Low Level Waste Repository
- Major facilities including the National Nuclear Laboratory, Wood Group High Temperature Facility, Science Technology Facilities Council (STFC), Nuclear Advanced Manufacturing Research Centre (NAMRC), Cammell Laird
- National agencies:
    - Office of Nuclear Regulation,
    - National Decommissioning Authority (NDA),
    - Environment Agency & Natural Resources Wales
- People – expertise and skills, covering a range of education levels across Higher Education (HE) and Further Education (FE).
- Good mix of industry organisations and an established supply chain.

The purpose of the Science and Innovation Audit (SIA) is to determine exactly what is available, and to present a vision of how to build on the strengths in the region, (S2) in order to capitalize on growth opportunities (S4). Through the audit: gaps have been identified (S5); proposals for future actions (S6); networking and collaboration opportunities (S7).

The Vision

The Hypothesis is *that it is possible to re-engineer the nuclear sector, driving 30% reductions in cost and time, without compromising safety and security,*[2] *and that the NWNA is uniquely positioned to maximise the opportunity for the UK*. The vision for the NWNA is that it can bring about lasting economic benefits and prosperity through innovation in the sector, working in partnership with Industry, academia, regional government and local communities to transform the UK‘s nuclear industrial capability and enhance its global presence.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/595853/Nuclear_in_the_Northern_Powerhouse_LR.pdf

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665473/The_Nuclear_Sector_Deal_171206.pdf

Innovation is taken to be: 'activity that is new in its context, such as implementation of a new or significantly improved product, service or process, a new marketing method or new organisational methods' - at the local and regional level (BIS, 2014b).

Based on the strengths in the NWNA region, the area can support the full spectrum of nuclear activities including:

- manufacturing,
- supply-chain and operational capabilities
    - fuel enrichment and management,
    - fuel fabrication and manufacturing,
    - reactor decommissioning,
    - waste management,
    - new reactor design,
    - research, development and engineering expertise,
    - skills and training capability and
    - regulatory and safety expertise.

To deliver the vision will require investment in facilities and people, but more specifically in bringing the assets together in 'Innovation Partnerships' to ensure that the UK is in a position to deliver the innovation and change required to realise the full potential and create a long term sustainable future for the UK's nuclear sector on a global basis.

As the scope and proposals vary across the different activities in civil nuclear, the market has been classified into four market segments in line with the recent ETI Nuclear Cost Drivers Report[3]:

- Large Light Water Reactors (New Build)
- Decommissioning and Clean Up (DCU)
- Advanced Nuclear Technologies
    - Small Modular Reactors (SMRs) - Generation III water-cooled small modular reactors, which are similar to existing nuclear power station reactors but on a smaller scale,

[3] https://d2umxnkyjne36n.cloudfront.net/documents/D7.3-ETI-Nuclear-Cost-Drivers-Summary-Report_April-20.pdf?mtime=20180426151015

- Generation IV advanced modular reactors, which use novel cooling systems or fuels to offer new functionality (such as industrial process heat).

In the NWNA SIA, we show how all these sectors can be enhanced with the key focus on DCU and Generation III+ technologies.

Key Strengths

The results of the SIA show that nowhere else in Europe is so much nuclear expertise so concentrated, with unparalleled access to a world-renowned skills base and pioneering expertise in nuclear research and development. The NWNA is one of few regions in the world with a nuclear industry covering the full life-cycle.

Physical Assets

There is a wide range of physical and innovation assets within the region, with over 20 facilities providing research support to academic and industrial activity in the region including university laboratories, the National Nuclear Users Facilities (NNUF), National Nuclear Laboratory, private facilities and public-private partnerships, as can be seen in Figure 3.

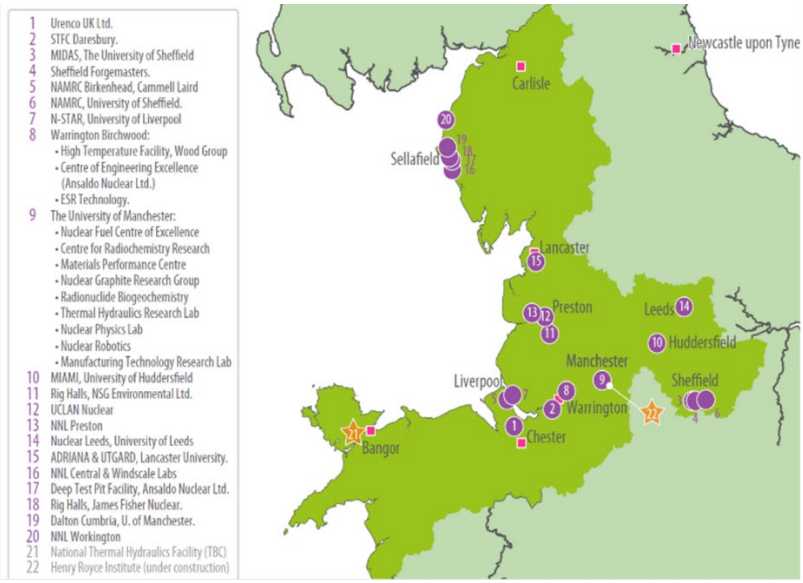


Figure 3: Map of the research facilities within the North West Nuclear Arc

There are the science and innovation sites, that include Westlakes, Birchwood, Trawsfynydd and the Menai Science Parc, where there are hubs of activity related to nuclear and innovation. Trawsfynydd has been identified as an ideal site, already licensed for nuclear, for deploying First of a Kind (FOAK) modular reactors.

There are various industry networks set up, including the Centre for Nuclear Excellence (CoNE) based in Cumbria. CoNE is supporting the nuclear sector to capitalise on the nuclear opportunities in the UK and globally. A key initiative that CoNE has been developing with partners is establishing an Innovation Partnership to create a vibrant marketplace for innovation, a key recommendation of this SIA.

People & Skills

Nowhere else in Europe is so much nuclear expertise so concentrated, with unparalleled access to a world-renowned skills base and pioneering expertise in nuclear research and development. However, the workforce is ageing, and the Nuclear Workforce Assessment predicts there could be shortage of up to 40,000 workers by 2036 (Figure 4).[4] Maintaining the population of nuclear Subject Matter Experts is an explicit priority in the forthcoming Nuclear Sector Deal, and availability of High Level Skills and subject matter experts, is identified as 'of particular concern' in the Nuclear Skills Strategy.

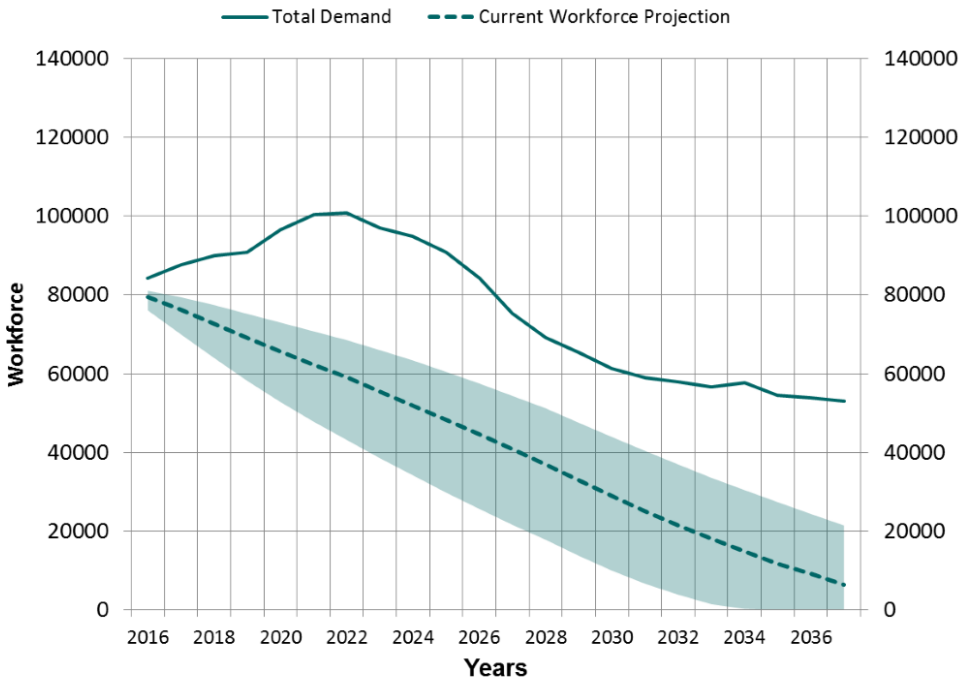


Figure 4: Demand and Projection of current workforce, the current workforce projected (dotted line) on the basis of retirement at 65 and an additional 4% general attrition.

The North West Nuclear Arc uniquely houses 15 nuclear skills providers, both HE and FE, which can provide specialist training across the full range of skill levels 1-8, and already has Centres for Doctoral Training (CDT) programmes which can support the development of the subject matter experts. Refreshing the workforce also provides the opportunity for diversification, in particular, in addressing the gender balance.

Knowledge Base

The evidence illustrates the significance of the NWNA's knowledge base. The NWNA universities account for 46% of the EPSRC Nuclear fission spend (£46.5m), and the NIRAB report on the UK Civil Nuclear Research & Development (R&D) Landscape estimated that 44% of university researchers are within the NWNA. Analysis of grants and publications demonstrates that research in the NWNA spans the whole spectrum of nuclear related activities (Figure 5), with an impressive track record of working internationally, crucial in establishing global markets for new products, and securing the UK's position in global markets.

[4] NSSG: Nuclear Workforce Assessment 2017

This is overwhelming evidence that the NWNA is the single most 'nuclear' research intensive region in the UK, and a sound basis on which to foster innovation.

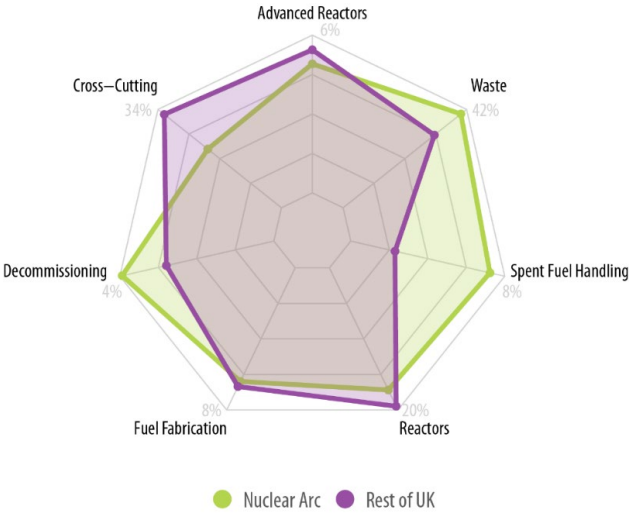


Figure 5: Radar plot showing the research mix for academic publications inside the NWNA and the rest of the UK.

Business Environment

There are >235 companies in the nuclear industry in the NWNA, contributing over £5bn to the UK economy. These companies provide 1 in every 64 jobs in NWNA totalling an estimated 30,000 jobs, accounting for nearly 40% of the 78,000 people directly employed in nuclear in the UK (Figure 6).[5]

Figure 6: Map of employees in the nuclear industry categorised by county as described in the NIA UK Jobs Map.

[5] The Nuclear Industry Association Jobs Map, Summer 2017

Growth Opportunities

A number of potential growth opportunities have been identified, which are:

- increasing the UK's share of global DCU related services,
- developing and building capability for some, or all of the components for SMRs,
- developing and building capability for Advanced Modular Reactors (AMRs),
- providing an attractive environment and regulatory regime for innovation in nuclear.

Further work will be required to assess the global market for both SMRs and AMRs and, within it, the opportunity for the UK. A competition to carry out feasibility studies into AMRs has been initiated although at the time of writing the SIA, the results have not been published.[6] The NWNA Consortium will need to take account of these decisions in taking future actions.

Consideration of regulation and its impact on innovation, suggests that the UK's goal-based regulatory system could possibly be more open to innovation than the more prescriptive process employed elsewhere. The 'enabling regulation' approach seeks to change the relationship between regulators and duty holders, and has been shown to accelerate programmes and enhance risk reduction. Bringing about gains through innovation will require change in organisational and individual culture, relationships and behaviours.

In order to capitalise on these opportunities, it is evident that there has to be cultural and organisational change. There is a view that many of the organisations operating in the UK are ex-government and by their nature need cultural change to improve their commercial appetite.[7] The sector has been slow to adapt to technical change, such as fully exploiting digitisation in the sector, and there is scope to build on the experiences and innovation in other sectors, such as aviation, oil & gas, pharmaceuticals, and off-shore wind.

In order to stimulate cultural and organizational change, and bring about long term economic benefits, these are some of the lessons that should be reviewed:

- ensure that technologies and techniques used for new nuclear build draw on best practices deployed in mainstream, non-nuclear, major construction projects, such as London 2012 and Crossrail.[8]
- 'import' technologies deployed in other sectors, including robotics, digital innovation
- standardise and modularise components: the off-shore wind sector transitioned to modular build and factory-based assembly of mass-produced units that can be manufactured and shipped to sites for installation, not custom-built, to speed up delivery times and lower direct costs. Engineering solutions standardised and deployed at scale enables non-recurring engineering costs to be absorbed across a higher number of units.
- 'innovation through collaboration' - cost and risk sharing across the public sector, focus on accelerating commercialisation of new products, at scale, within rapid timescales.
- De-nuclearise elements and remove the 'specialness' of nuclear, where possible such as in other high hazard, highly regulated, high profile industry and demystify it.

[6] https://apply-for-innovation-funding.service.gov.uk/competition/80/overview

[7] http://www.ey.com/Publication/vwLUAssets/ey-report-creating-confident-investors-and-competitive-advantage-for-the-uk-nuclear-supply-chain/$FILE/ey-report-creating-confident-investors-and-competitive-advantage-for-the-uk-nuclear-supply-chain.pdf

[8] http://learninglegacy.independent.gov.uk/themes/design-and-engineering-innovation/index.php

- Complete design fully before moving into construction for either new build or decommissioning to avoid escalated costs relating to retro design and fix while on site.

Gap Analysis

Some of the gaps in capability and capacity have been documented in an National Industry Council (NIC) 'Future Capability' review, and suggested ways of addressing some of the challenges are set out. From this SIA, the gaps can be grouped under a number of headings:

- Reduced and insufficient level of investment in RD&I (see graphs),
- Lack of larger scale facilities to test and demonstrate key reactor components and systems,
- Access to national facilities that do exist are constrained (processes and business models),
- Emerging skills crisis,
- Lack of Innovation incentives and programmes,
- Too few collaborative spaces.

The fall in investment in RD&I is quite clearly illustrated in this diagram below taken from 'How to Make Nuclear More Innovative'.[9] And the impact of this reduction in the number of patents filed by US, UK and EU, compared to Asian countries in latter years can be seen in Figure 4.

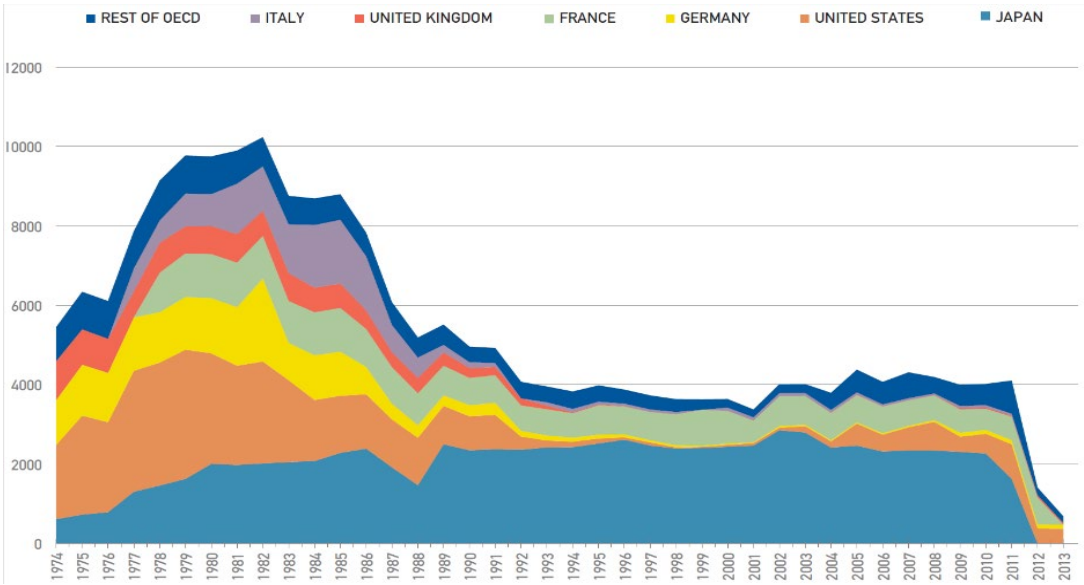


Figure 3: Total R&D spending on nuclear fission in OECD countries (million 2013 USD). Data from the OECD Stat Library.

[9] https://thebreakthrough.org/images/pdfs/How_to_Make_Nuclear_Innovative.pdf

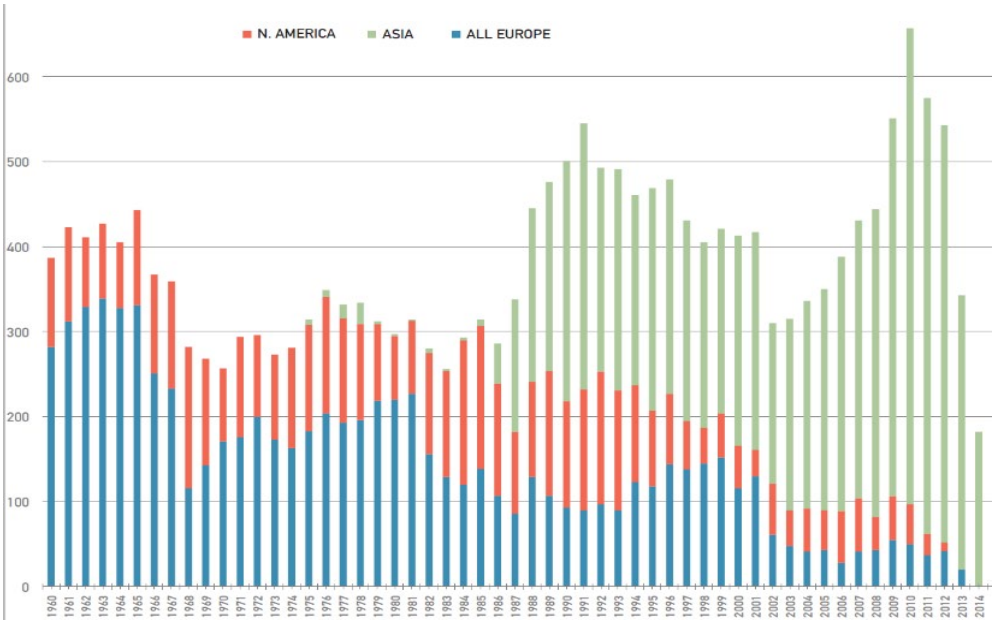


Figure 4: Nuclear patents in OECD countries. Note the shift from the United States, France, and Germany to Japan and Korea. Data from the European Patent Office's PATSTAT database.

This reduction in funding naturally impacts on the UK's ability to compete globally. With less funding available it is critical that investment is targeted much more, and that decisions are taken on which reactor technologies are to be supported going forward. Then academia and industry can work together to capitalise on the opportunities.

A notable gap, in the UK not just NWNA, is the lack of larger scale test facilities to demonstrate key reactor components and systems, such as a thermal hydraulic test facility. Further work is required to review the type of facilities required in the future; ideally the mix of facilities should be technology agnostic to support a spectrum of research allowing the development of modular reactors, GigaWatt (GW) scale reactors and all aspects of the fuel cycle.

Whilst some national testing facilities and laboratories exist, it has been found that gaining access can be difficult, and time consuming. This is in part due to procedural hurdles, but also due to the business models deployed at sites, where prioritisation is often driven by the need to generate commercial income to cover costs. Occasionally research takes place at facilities overseas as it can be easier to gain access, but already this is becoming increasingly difficult in the light of Brexit.

Around 30,000 people are estimated to be employed in nuclear related jobs (both direct and indirect) in the NWNA area, many of which are highly skilled. However, with the planned expansion in nuclear, there will be a significant skill shortage, and initiatives are needed quickly to attract talented people into nuclear related fields. This needs to take place at a sufficient pace to not only meet the expected expansion of the industry but also to compensate for natural losses due to retirement from an ageing workforce. The mix of high level skills required going forward provides an opportunity for the NWNA to develop a single training pathway with enhanced CDTs, Level 7 and 8 Degree Apprenticeships, Accelerated Speed to Competence

and refreshed Nuclear Technology Education Consortium (NTEC) (short, fat structure; Continuous Professional Development (CPD) focus), supported by further educational vocational courses and the National College for Nuclear (NCfN).

It is fair to say that where there have been substantial funded programmes, the UK has typically developed world class solutions, such as in fusion or the DCU arena. The overriding conclusion being that the existence of a sustained major programme, creates a market which stimulates the relevant industry and academia partners which results in the UK capability in that area. Recent initiatives include Fit4Nuclear (NAMRC), Gamechangers, and Innovus, (which has now finished). However, the level of funding is generally considered to be inadequate, and insufficient to stimulate the level of activity required.

Whilst maybe not a 'gap' per se, the perspective on and perception of risk could be having a negative impact on innovation in the nuclear sector. There is a definite lack of awareness (amongst the public) and a lack of objective risk measurement and comparisons. There a number of 'risk types' (and a need to distinguish between risk from a health and environmental perspective, and risk in the commercial and contractual context.

Proposals for capitalising on these opportunities, are set out in the next section.

Key Proposals

The findings of the audit, with conclusions and recommendations can be found in the full report.

As stated earlier the key proposals aim to change organisational and cultural change to reduce time and costs. There are a number of mechanisms that may need to be put in place to help create the environment in which nuclear can thrive. Some of these include:

- ensure zero emissions and reliability taken into energy market decision making and energy mix mandates
- having mechanisms for securing longer-term investment that optimise option appraisal over longer time horizons
- optimise risk-taking
- offer tax incentives for innovation
- develop a UK programme to maximise and incentivise learning for new build (and other programs) based on best in World (see ETI report conclusions). Government support should be dependent on application of cost reduction approach.
- Integrate skills provision (all the way to Level 8) and remove academic/vocational divide; work-based qualifications; consortia of providers working together.
- Investment in testing facilities, need to investigate what is feasible

In order to address the many facets of innovation and bring about change in organisational and individual culture and behaviours, the proposal is to set up a Nuclear Innovation Partnership, with two hubs, one in Cumbria and one in NW Wales, that can create a marketplace for innovation in NWNA, which:

- fosters more collaboration,
- overcomes barriers to innovation,

- deploys innovation from other sectors – eg aviation, oil/gas, shipbuilding etc and other technologies such as robotics and digital,
- supports the development of AMRs,
- Creates a business environment where innovation thrives and entrepreneurship, investment and economic growth are driven by visible and diverse opportunities for local companies; small, medium and large,
- provides customers and suppliers of innovation with greater opportunities and capacity to develop, buy and sell innovative products and services,
- works with business and community stakeholders to create a market for technical, business and social innovation, supporting innovators and problem holders to solve real world problems.

The 'Marketplace for Innovation' diagram at the end of the section illustrate the vision, strategy and high-level goals to be achieved by 2030 in the Cumbrian innovation Partnership. The NW Wales innovation partnership goals are being formulated. By bringing together key accountable leaders, the Innovation Partnerships will work to facilitate market push and customer pull for innovation. It will:

- map and segment the market for nuclear innovation, identifying strengths and capabilities,
- create visibility of immediate and long term innovation problems,
- work with Tier 1s to put in place effective procurement structures and practices that facilitate the rapid delivery of initial ideas, prototypes and the effective partnerships needed for the delivery of selected solutions,
- speed up the flow of ideas and solutions and create a culture of innovation by putting problem holders and innovators together, through formal and informal means, to stimulate conversation and the sharing of ideas, increasing serendipity and creative collisions,
- build on and promote existing regional and national innovation programmes.

Components may include:

- **Innovation solutions cell**: to support joint problem solving between Tier 1 and supply chain innovators. mixed teams of people outside of their normal environment and culture into a supported, dynamic solutions-focussed environment, with clear tasks, objectives and limited timescales. This facility will provide the IT, workshop and prototyping facilities, along with the work spaces needed. It will include the neutral space and social facilities, support and development services needed to successfully bring people together for collaborative working.

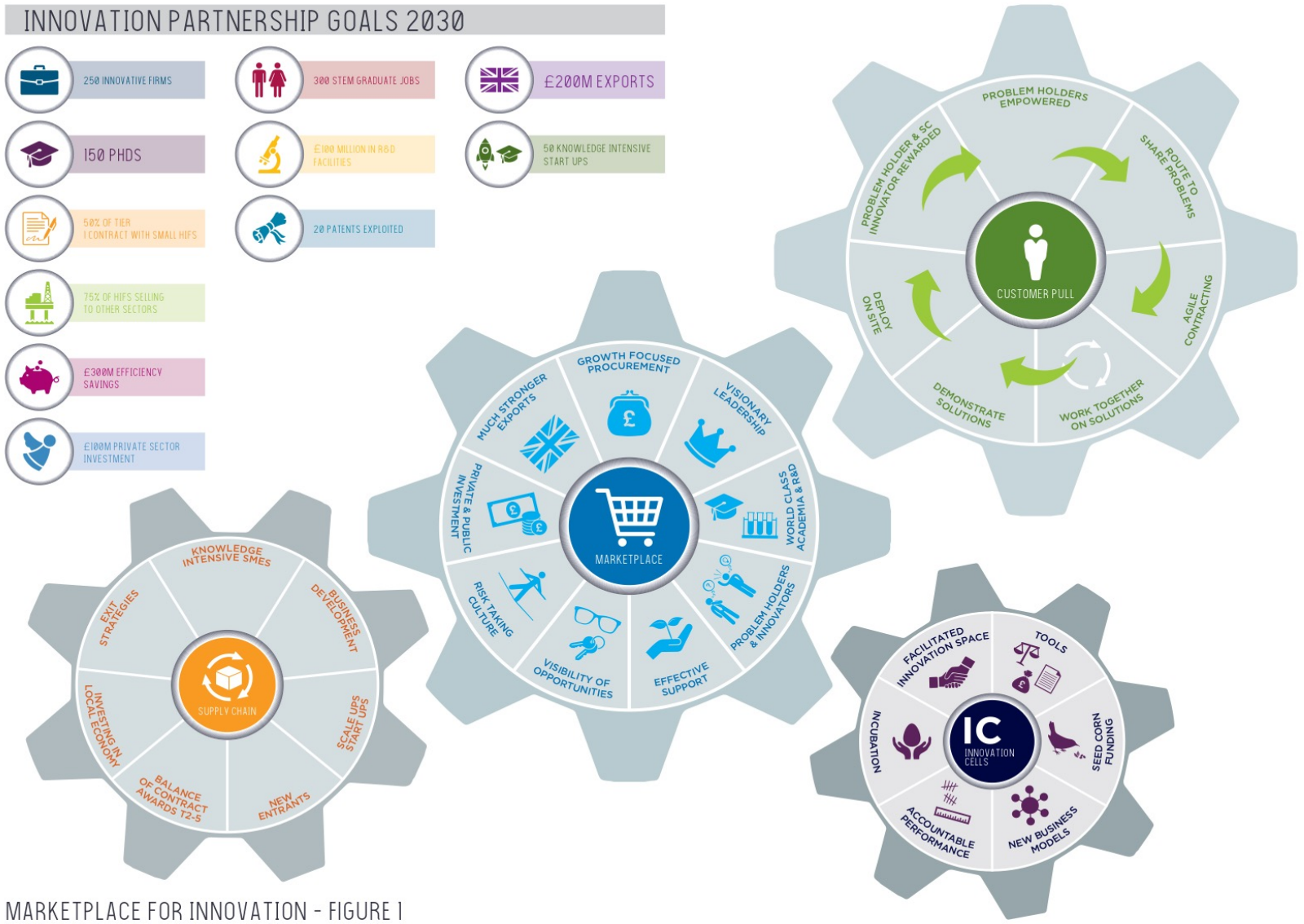
- **Incubator cell**; provide space and support to start-ups, spin-outs and patent exploitation around the nuclear supply chain. Marketing, business development, networking, seedcorn funding.

- **Social innovation cell**: to work with public, private and third sectors to support participatory innovation projects aimed to tackle big and 'difficult to solve' local issues. Offering support for and by community leaders and activists, initiating projects comprised of innovators and users to generate ideas for social innovation be that problem or opportunity focussed.

- **Research and Technology cell;** led by technologists and academic institutions, this cell will develop the concept of an R&D hub and link to the nuclear sector deal's place component. This group will enable technology transfer from the research environment into real world application and commercialisation. It will provide access to the research and technology community, to academic experts, laboratories and skills.

- **Innovation skills cell**; this cell will develop and disseminate new 'soft' problem solving skills and capabilities from the Innovation Partnership drawing upon expertise and resource from design, creativity, the arts and business & management from HE, FE and industry best practice; develop an innovation and creativity 'tool box' and set of practices.

The funding model needs to be developed, but the Innovation Partnership will require focussed dynamic leadership, and will depend on support from Tier 1s within the sector and a sponsor or group of sponsors and start-up funds for a pilot phase.



MARKETPLACE FOR INNOVATION - FIGURE 1

Networking/Collaboration

The North West Nuclear Arc Consortium has the ability to act as a catalyst and co-ordinator to develop a strategy and action plan to create a vibrant and dynamic marketplace for innovation around the nuclear related activities in NWNA, with industry, communities and academia working together to create a shared and cohesive goal for nuclear innovation.

This has been made possible through the SIA process which has strengthened the relationship between the three main partners (Bangor University, The University of Manchester and National Nuclear Laboratory). It has allowed a diverse group of people from the public and private sector to come together with the objective of identifying the capabilities within the nuclear industry in our region and identifying potential ways in which to build on those.

The NWNA collaboration has facilitated between cross-border discussions between devolved, local Government and LEP partners which have identified similarities between Cumbria and North West Wales, allowing for the innovation partnership proposal to be developed further for both regions.

The academic and industrial partners have met in a network spanning from Cumbria to Anglesey with the aim of developing the recommendations included in this summary report and the main SIA through the Strength in Places fund. This will be followed by public sector meetings within the arc. The SIA has provided the platform to foster these connections and pursue a communal goal of revitalising the nuclear sector and its potential within our region.

The North West Nuclear Arc Consortium, which was identified in the recently published Nuclear Sector Deal, will continue to work together upon submission of the SIA and, for example, will be submitting an Expression of Interest (EoI) to the Strength in Places fund. Much of the evidence base for this EoI is from this Science and Innovation Audit which has identified the 2 Innovation Partnership hubs in Cumbria and North West Wales.

The NWNA consortium will host the Science and Innovation Audit report and act as a communication platform for the sector within this region.

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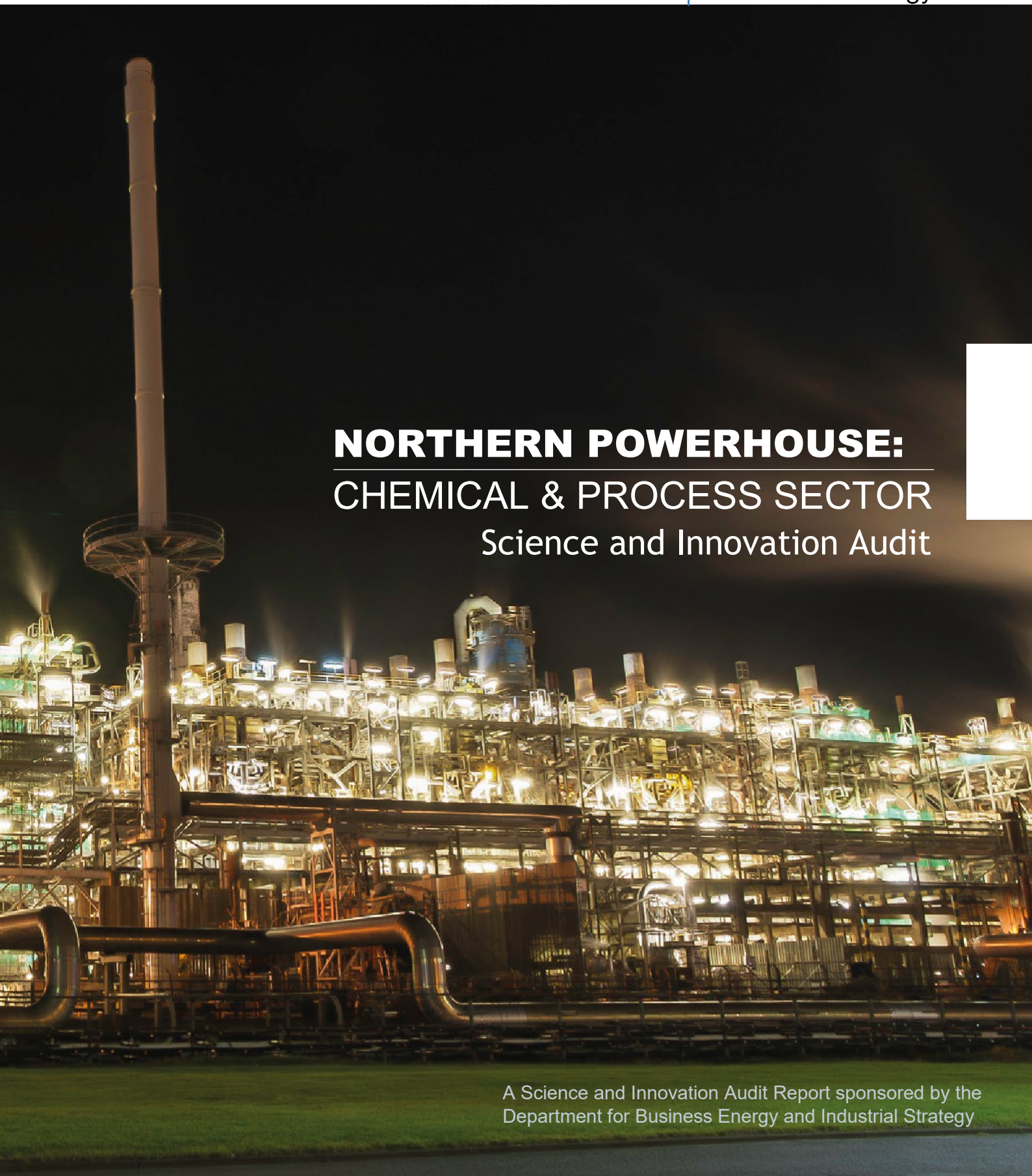


NORTHERN POWERHOUSE:

CHEMICAL & PROCESS SECTOR

Science and Innovation Audit

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

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.

This Science and Innovation Audit has been developed to identify the global competitiveness of the chemicals and process sector across the Northern Powerhouse (NPH). The SIA has reviewed for the first time, the pan Northern Powerhouse chemicals and process sector industrial proposition and the continuing fitness of purpose of the associated regional innovation ecosystem.

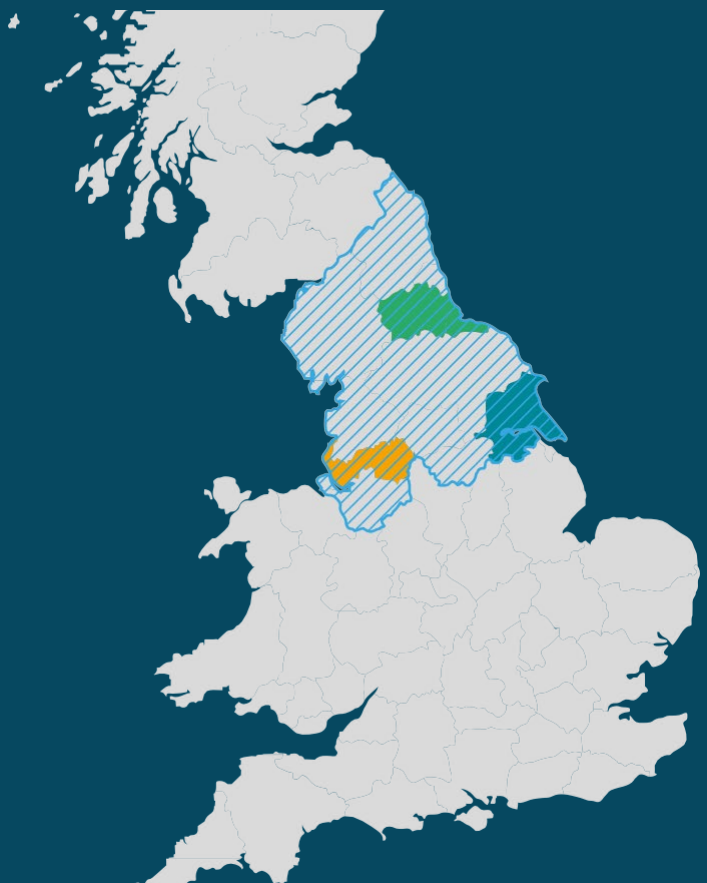
The SIA recognises the maturity of the sector and existing support structures and seeks to future proof its global competitiveness by identifying emerging technological opportunities and their consequential requirements on the regional innovation ecosystem

Geographic Coverage

The audit geography is the Northern Powerhouse which covers all 11 North of England Local Enterprise Partnership (LEP) areas. The area is shown in Figure 1

Allowing for overlap of these areas means the effective Science and Innovation Audit geographic area comprises the three North of England regions (North East, North West and Yorkshire and Humber) plus the Sheffield LEP districts that lie within the East Midlands region.

Figure 1: The SIA region comprising the LEP areas; North Eastern, Cumbria, Tees Valley, York, North Yorkshire and East Riding, Lancashire, Leeds City Region, Liverpool City Region, Greater Manchester, Humber, Sheffield City Region and Chester and Warrington.



Tees Valley & Durham

Total GVA £21,312m
Sector GVA per employee £154,000
Average Wage £37,543
Location Quotients 3.7
163 establishments

Humber

Total GVA £18,378m
Sector GVA per employee £215,000
Average Wage £35,923
Location Quotients 4.1
192 establishments

Liverpool & Cheshire

Total GVA £60,196m
Sector GVA per employee £449,000
Average Wage £35,923
Location Quotients 3.0
373 establishments

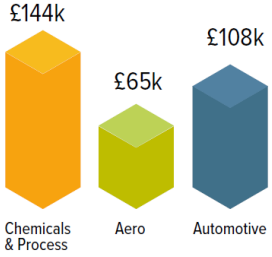
Northern Powerhouse

The Chemical and Process Sector

The chemical and process sector encompasses the range of industries in which raw materials are processed through chemical conversions to give finished products. The Sector inputs to a range of chemistry using industrials in sectors such as aerospace and automotive through the provision of coatings, adhesives, rubbers and plastics, as well as providing intermediary ingredients to the pharmaceutical, cosmetics, agrochemical, personal care, paint, and home care sectors.

Whilst the upstream chemicals and process sector accounts for approximately £28bn, 15.8% of manufacturing output, it has a downstream impact on approximately £212bn or 90% of the UK manufacturing sector. The sector accounts for 140,000 employees, 6% of UK manufacturing workforce. Workers in this sector make a significant contribution to the UK economy with an average GVA per employee of £144,000, significantly higher than both the aerospace (£65,000/ employee) and automotive (£108,000/ employee) sectors[1].

Scale of Sector



GVA Per Employee

International context

Global chemical sales in 2016 were led by China (€1,331bn), USA (€476bn) and Germany (€185bn). The UK continues to be a significant player in the global chemicals market, presently ranked 10th with €60bn sales[2].

The most significant growth has been in the emerging markets in China, India and Brazil. The global market is expected to grow by a further 3% in the next 20 years as Asian and Middle Eastern demand and capacity continues to grow. By 2030, Asia is expected to account for almost two thirds of the global chemical industry market[3].

Demand for chemicals, particularly intermediate and finished goods, continues to expand both in Britain and globally. However, what is in question is the UK's ability to meet both indigenous and export demand, as increasing competition from both East (e.g. China) and West (e.g. USA) is driving down revenues and making it harder for UK- based firms to compete in the global marketplace.

The chemicals and process sector has traditionally had a very strong export orientation, presently representing 18% of UK export trade. Figure 3 (overleaf) shows an upward trend in trade over the period 1996 to 2017[4]. 2013 was the first unfavourable imbalance in trade for the chemicals and related products sector. This fall can largely be attributed to a number of Astra Zeneca products going off patent in 2011/12[5].

The reduction in exports has been across the board including price sensitive sub sectors such as the manufacture of organic chemicals, pharmaceuticals and fertilisers and nitrogen.

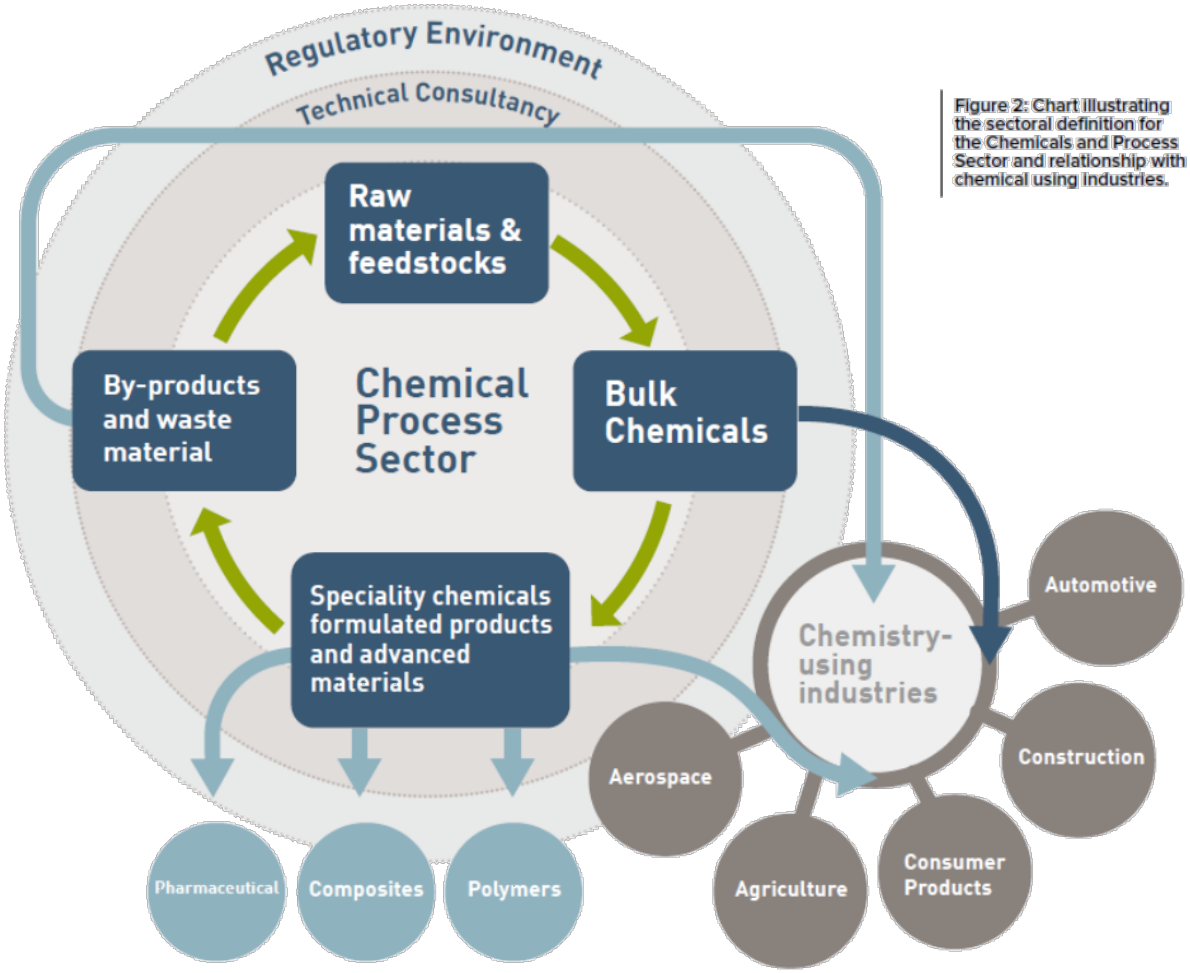


Figure 2: Chart illustrating the sectoral definition for the Chemicals and Process Sector and relationship with chemical using industries.

Export Activities by Country

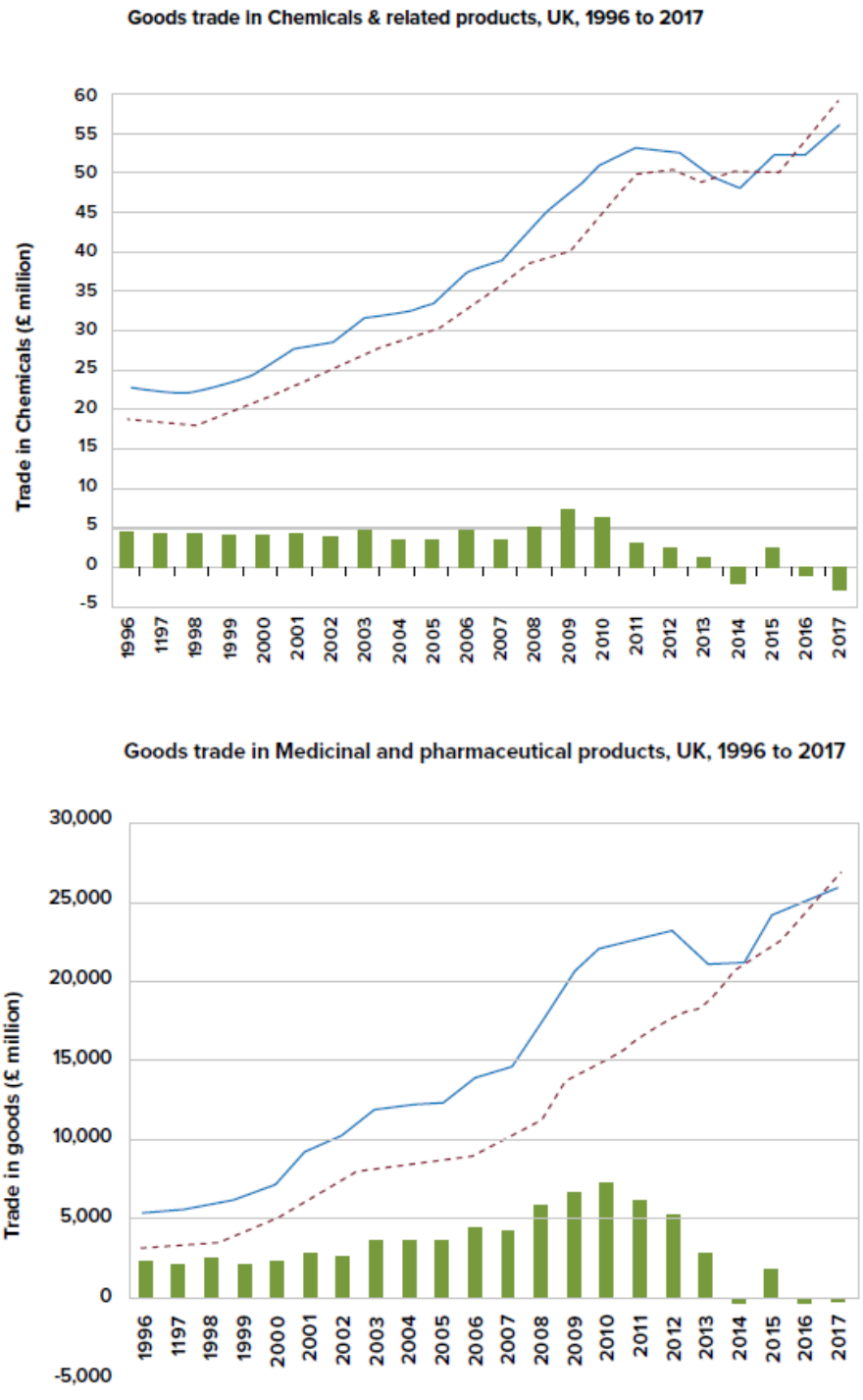
Country	Sales (Billion €)	Population (Million €)	Sales per head of population (€)
China	1,331	1,415	941
US	476	326	1,460
Germany	185	82	2,256
Japan	140	127	1,102
South Korea	113	51	2,216
France	70	65	1,077
India	76	1,354	56
Taiwan	63	23	2,739
Spain	63	46	1,370
UK	60	66	909
Brazil	59	210	281
Netherlands	55	17	3,235
Italy	52	59	881

Net Trade for Chemical Products

The reduction in exports has been across the board including price sensitive sub sectors such as the manufacture of organic chemicals, pharmaceuticals and fertilisers and nitrogen.

The UK chemical sector is facing a challenge of diminishing cost competitiveness due to increasing costs related to energy and feedstocks particularly in relation to lower value intermediary goods. The knock-on effect of reduced production of these goods leads to greater fragmentation of existing supply chains and a diminished export orientation across the sector. This decline in export orientation may have a causal effect on the level of innovation activity undertaken and be a consequence of reduced indigenous investment in Research and Development and Innovation.

Figure 3: Net Trade for the Chemicals and related products 1996-2017.



Sector characteristics

The chemicals and process sector across the UK and particularly in the Northern Powerhouse is mature, both in the technology being used and also the sectoral age profile. There are relatively few new business start-ups and the churn rate is low (i.e. few company closures). In addition, the sector is highly concentrated 6.

- **The top four large firms account for 16.5% of total sector employment, 38% of turnover;**
- **The top seven large firms account for 23% of total sector employment, 41% of turnover.**

Overall the chemicals sector has a higher proportion of mid-sized businesses (£25-£500million annual turnover) 7 than the economy as a whole. Most mid-sized companies are indigenously owned and generally compete in terms of price.

The proportion of SMEs is at variance to the wider economy in which there are circa 88% micro and 98% small enterprises compared to circa 12% micro and 30% small enterprises for the chemicals sector. There is also greater variance in the composition of the sector by scale than between sectors, with the pharmaceutical sector having the greatest preponderance of micro enterprises, which reflects the higher number and proportion of new starts within this subsector.

The sector has a high proportion of mid-sized and large-scale companies, with the former generally delivering intermediate goods to the latter for subsequent exporting. There is a significant proportion of the larger companies under international ownership with, in some cases, a perception of "branch plant" status with higher value adding functions such as headquarters and research bases sited overseas.

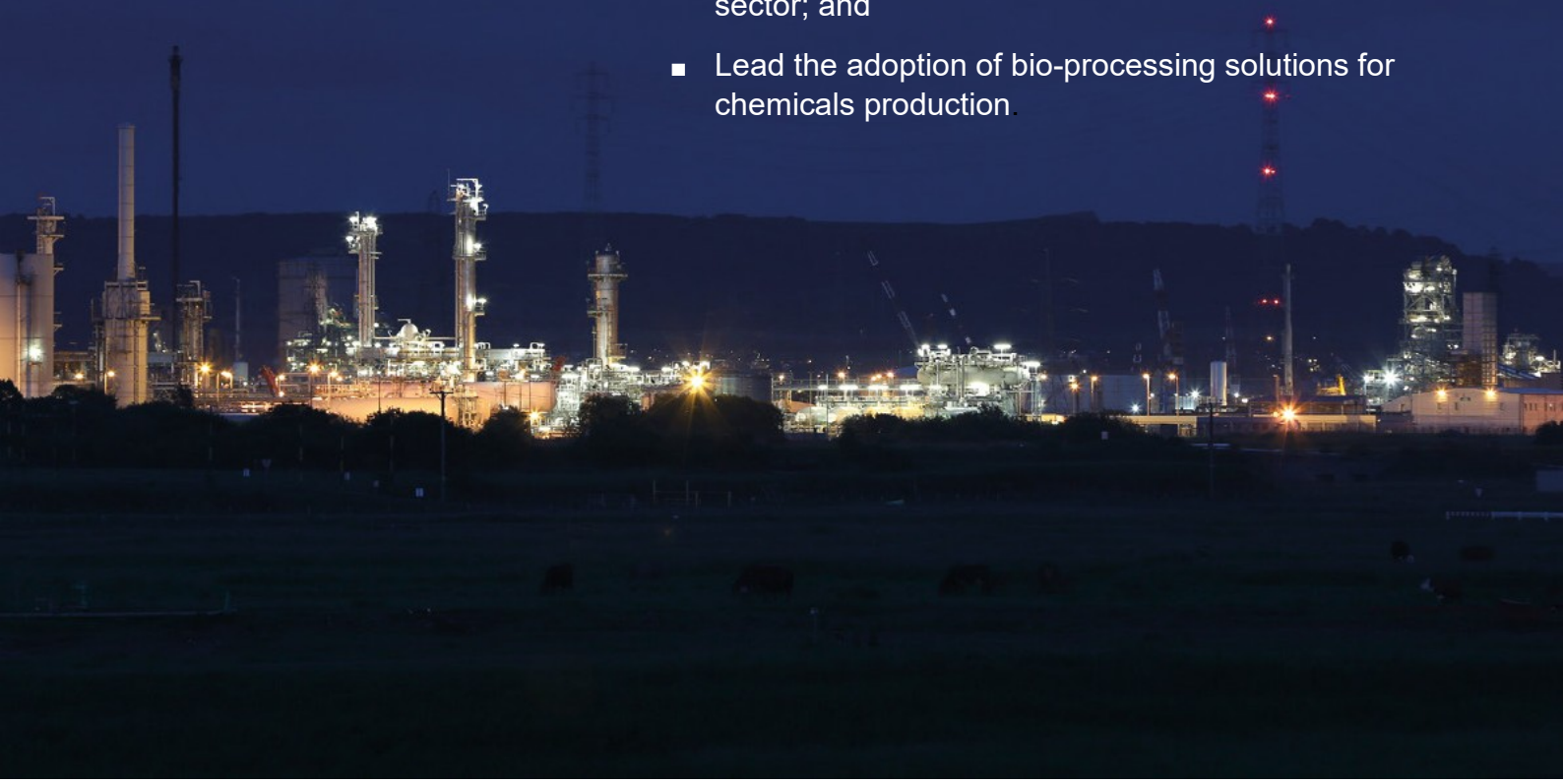
Whilst large firms account for over two-thirds of turnover, the mid- sized firms also make a significant contribution (26.4%) to turnover for the sector, however they only contribute around 4% of R&D expenditure 6. The low level of R&D spend within the mid-sized and small enterprises suggests an imbalance within the sector, skewed towards the larger firms. This has highlighted the need to encourage greater take up of innovation, in particular by mid-sized enterprises, with interventions being tailored to meet their specific characteristics.

Our Vision

"To ensure that the Northern Powerhouse contributes to the successful delivery of the Strategy for Chemistry Fuelled Growth that by 2030, chemistry using industries will increase their contribution to the UK economy from £195 billion to £300 billion".

Our vision is that over the next 12 years, the Northern Powerhouse chemicals and process sector will:

- Be the most competitive location, by building upon its existing highly efficient bulk chemicals infrastructure, further driving down costs through accessing (existing and emerging) affordable feedstocks and utilising nascent technologies;
- Regain lost export markets and re-shore the production of high value intermediary goods and R&Di functions of locally based global concerns;
- Diversify into new geographic and sectoral supply chains;
- Deliver more knowledge transfer between industry of all size and ownership structure and the regional innovation ecosystem to enhance productivity and ensure global competitiveness;
- Be a globally recognised centre for the application and testing of industrial digitisation and circular economy solutions to the chemicals and process sector; and
- Lead the adoption of bio-processing solutions for chemicals production.



Key Strengths

Strong and connected clusters

At £13.40bn GVA, the NPH contributes 48% of the UK's chemical production and is by far the largest region in terms of output for the sector. In addition, the sector contributes 26.5% of all NPH manufacturing GVA, compared with the UK average of 21.2% [8].

The Northern Powerhouse chemicals proposition is based upon three strong clusters interlinked by strong East-West supply chains and associated pipeline connectors of key raw materials:

- Tees Valley and County Durham;
- Humber LEP area; and
- A combination of Cheshire and Warrington and Liverpool City Region LEP (Cheshire and Merseyside).

These sub areas have a location quotient of 3.4, compared with
1.8 across the NPH as a whole against the average of 1 for the UK as a whole.

The region has a strong tradition in exporting, dominated by the large companies and supplied by largely indigenously owned mid-sized and smaller companies.

Highly trained and responsive workforce.

The NPH employs 44% of the UK Chemical and Process sector work force 9. The NPH Universities provide a quarter of the UK science, technology, engineering and mathematics graduates representing a significant opportunity to meet local demand for professional talent.

In 2016/17, 39% of all chemical sciences apprenticeships were started in the NPH 10. The demand for apprenticeships is high. Data from the Working Futures report 11 shows a trend towards a more highly skilled workforce both within the NPH and nationwide.

Centres for Doctoral training (CDTs) represent strong vehicles for engagement with industry and also train postgraduates as future employees within the sector. There are presently 9 Centres for Doctoral Training (CDTs) in support of the sector with a further 6 under application.

An asset rich innovation ecosystem

The effectiveness of the innovation ecosystem of the NPH was assessed using the following key variables: perspectives of academic research quality, University engagement with industrial base, business R&D spend, Government innovation support, Intellectual Property filed and Research and Technology Organisations' (RTO) activity.

The NPH region contains 32 higher education institutions with 522,000 students[12] and includes the N8 research partnership of eight research intensive Universities (Durham, Lancaster, Leeds, Liverpool, Manchester, Newcastle and York)[13]. While the Northern Powerhouse is a comparatively small region, it has a number of individual academic institutions which have international status and continue to attract significant UK and foreign research investment.

The leading academic research institutions within the SIA area demonstrate strong research quality across all six sub-sectors of the chemical and process industry with particular strengths highlighted in materials sciences, chemical synthesis, chemical measurement, atmospheric physics and chemistry[14]. This high-quality research on an individual institutional level indicates that there is strength in depth across the chemical process sector within the SIA area that should be utilised to deliver innovation and further enhance the region.

Figure 4 presents the analysis of research quality (as measured by the field weighted citation index) across the key innovation needs identified across all six chemical and process sub-sectors against publication quantity for the Universities within the SIA. The combined scale and quality of research outputs if deployed collectively would outstrip larger national comparator institutions several- fold.

There is a northern cluster of nationally and internationally important Catapults and other National Innovation Centres that support the chemicals and process sector. The key players are the Centre for Process Innovation (CPI), the Materials Processing Institute, TWI, the Royce Centre and Materials Innovation Factory. Driven by the needs of industry, these innovation centres work closely with academia and industry to foster and encourage innovation in key areas. The innovation strength of the chemical sector is reflected in the predominance of patents filed on chemical sector technologies, which represents 38% of all patents filed in the NPH. The NPH exhibits a particularly strong specialisation when compared with the rest of the UK in basic materials chemistry, macromolecular & polymer chemistry, materials metallurgy, surface coating and technologies[15]

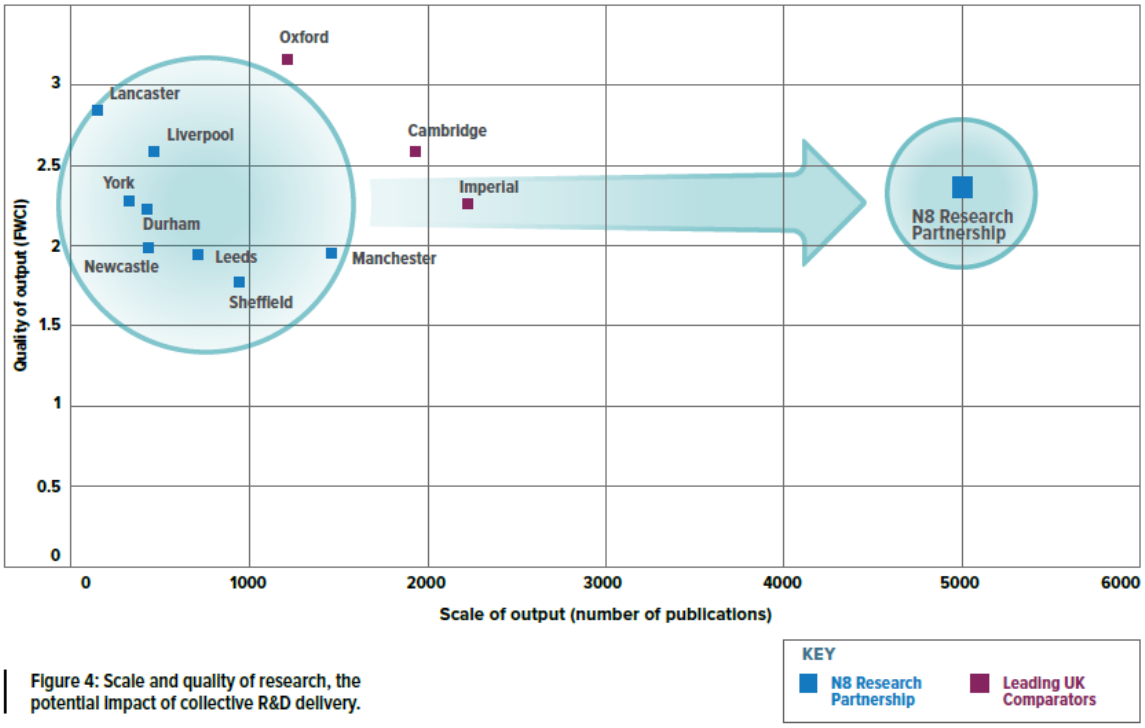


Figure 4: Scale and quality of research, the potential impact of collective R&D delivery.

Growth Opportunities

The SIA has identified a number of growth opportunities:

- Increase in demand in global markets for intermediate and higher value adding goods
- Use of nascent technologies and new energy feedstocks
- Increased demand for reshoring and use of circular economy solutions
- Opportunities for the use of industrial digitisation
- Opportunities to utilise sectoral free trade zones in conjunction with block chain solutions
- Opportunities to use Northern Powerhouse international networking
- New models for commercialising technologies: public/private partnerships and associated financing mechanisms
- Significant opportunities for scale and growth particularly in mid-sized companies through supply chain/export diversification.

Benchmarking against best practice in international comparator regions*, as illustrated in Figure 5 assumes that if cumulatively delivered, the Northern Powerhouse vision has the potential to contribute £23bn of additional output to the UK economy, dependent on the following components and interventions:

- **New feedstocks** could increase output by **30%**
- **Industrial digitisation** could increase output by **20%**
- **Supply chain diversification** could increase output by **10%**
- **Circular economy** could increase output by **10%**
- **Skills development** could increase output by **5%**

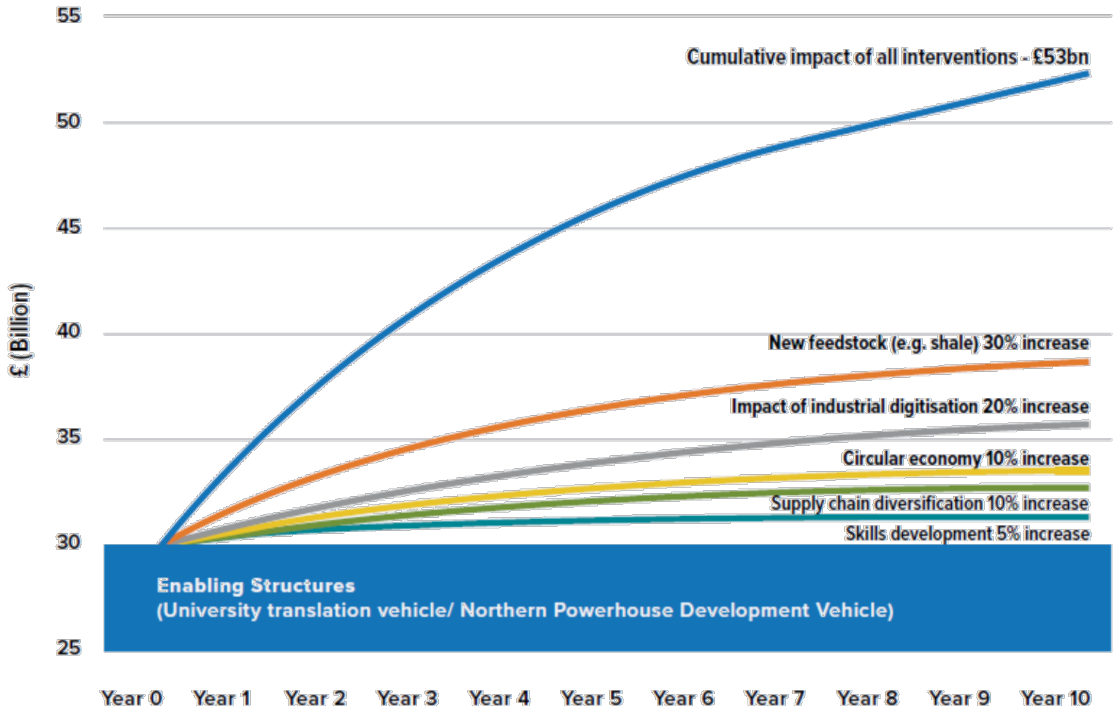
Strong enabling structures are proposed to deliver this vision including the development of:

- Northern Powerhouse Development Vehicle.

A coordinated University translation vehicle, working closely with the RTOs and industry.

* Rheinhessen-Pfalz; Antwerp- Rotterdam; Geleen; Gulf Coast (USA); Singapore; and Busan (formerly Pusan) South Korea

FIGURE 5: GROWTH TRAJECTORIES OF POTENTIAL INTERVENTIONS



Gap Analysis

We have utilised TOWS (Threats, Opportunities, Weaknesses and Strengths) analysis to develop workable solutions to the opportunities/challenges identified in the SIA. Table 1 summarises the key conclusions:

Table 1: TOWS analysis of opportunities and challenges

Internal Strengths and External Opportunities (S-O)- how can they use the strengths to benefit from existing external opportunities?	**Internal Weaknesses and External Opportunities (W-O)- how can they use opportunities to overcome the organisation's internal weaknesses?**
Need to match local research strengths to emerging global demand for R&Di; and Increasing global demand for chemicals, with enhanced opportunities for reshoring due to levelling out of costs in Far East.	High feedstock costs, opportunity to use circular economy solutions; and Fragmented supply chains, opportunity to use circular economy and industrial digitisation to promote local sourcing.
Internal Strengths and External Threats (S-T) how can they benefit from their strengths to avoid or lessen (potential) external threats?	**Internal Weaknesses and External Threats (W-T)- how can they minimise weaknesses and thus avoid potential threats?**
Loss of management and leadership skills in region: Address perceptions of lack of critical mass within the sector and overcome denudation of higher value-added functions; and Increased R&Di being undertaken out with of the region, need to highlight the research proposition of Northern Powerhouse and also attract private sector R&Di back into the region.	Address local of local intermediaries, develop capacity and growth ambition of local management; and Too few new entrants, development of patient/risk capital to promote start-ups.

Key ambitions/proposals

In response to the findings the following proposals have been developed:

Develop a unique selling point for the Northern Powerhouse in conjunction with associated mechanisms and institutions to promote the region and ensure global competitiveness, including a Sectoral Free Trade Zone Proposition;

Masterplan for Northern Powerhouse development, building the capabilities and skills to deploy the following supports:

- **Development of new feedstocks;**
- **Impact of industrial Digitisation/Sectoral Free Trade Blockchain Solution;**
- **Supply chain consolidation and diversification;**
- **Impact of the circular economy; and**
- **Development of a programme of support for leadership training/talent attraction and retention.**

Building upon these proposals, Table 2 sets out an ambitious action plan to deliver major growth to the sector.

Action Plan

Table 2: Proposed Action Plan

Intervention	Implementation
Acting at Global scale	**NPH Chemicals and Process Sector Development Vehicle:** Augmenting existing sectoral representative bodies, it will be tasked with delivering an enhanced business support function, including but not limited to: supply chain /export diversification and foreign direct investment. Success will be enhanced added value being delivered within the NPH.
Unifying the innovation ecosystem	**Technology translation:** Creation of an innovation delivery system to valorise the academic research base and maximise the economic impact on the sector. Establish an integrated science and technology innovation network (a 'knowledge-based growth hub') integrating with the innovation scale-up of CPI and the other specialist Research Organisations in the NPH. This to provide a strong, agile translational interface accelerating the translation of University research into Industry, closely coordinating with the N11 local enterprise partnerships and science/business parks to drive infrastructure provision in support of relevant inward investment. **Accelerate Technology Commercialisation:** This would require new venture capital funding to commercialise research and provide finance for emerging companies and initiatives to promote clustering and sharing between the public and private sectors.
Increasing productivity through new feedstocks, the use of nascent technologies and decarbonisation	**Resource Efficiency: Develop new feedstock base for chemical industry:** Consider the options that (existing and emerging) affordable feedstocks (e.g. hydrogen, carbon dioxide, shale gas) may give the North. Recognise the opportunities that the bio-economy presents to feedstock and product development as well as the strength of companies in the NPH. This would require feasibility studies and a roadmap for industry development, as well as aligning the different stakeholder interests. **Accelerate the move towards industrial digitisation.** Northern chemicals sites could provide testbeds for the trialling of industrial digitisation and 5G solutions to address issues related to fragmentation. **Develop the circular economy proposition to mitigate feedstock concerns.** Northern chemicals sites could provide a base for new industries. This would require active engagement with the players developing these industries, as well as the development of a number of pilot / demonstrator projects.
Consolidating and diversifying supply chains	**Programme of support aimed primarily at mid-sized chemical companies,** including provision of skills, innovation and networking support for diversifying supply chains.
Delivering skills to meet sector ambition	**Programme of support to develop talent across the NPH.** Development of an integrated training and skills programme, primarily focused on the coordinated delivery of apprenticeships, including: recruitment, training and placement across the region. This will be primarily aimed at mid-sized businesses across the region. In addition, work with existing knowledge providers to impart specialist leadership and technical training driven by industry. This will in large part be driven by emerging technological absorptive incapacity in, for example the circular economy and industrial digitisation. The integrated model would address the issue of emerging fragmentation across the sector and will therefore significantly benefit both business and individuals if cross-company apprenticeships could be supported.

Networking & Collaboration

The SIA has been delivered though a core project delivery group led by the Tees Valley Combined Authority (TVCA). This group comprised representatives from the TVCA, Durham and Teesside Universities, North East Process Industry Cluster (NEPIC), Centre for Process Innovation (CPI), Materials Processing Institute (MPI) and TWI, with representation from Innovate UK and the BEIS appointed SIA consultants, Technopolis.

An initial desk-based review of secondary research identified a number of gaps in existing knowledge of the sector within the Northern Powerhouse, which in line with the original hypotheses, necessitated extensive primary research including: Stakeholder Interviews; International benchmarking against six comparator national and sub-national entities; and 3 Stakeholder workshops. The SIA has networked extensively though close consultation and engagement with

- HEI Research institutions: 15 Universities formed the core consortium. including the N8 research partnership of the eight research intensive Universities within the NPH (Durham, Lancaster, Leeds, Liverpool, York, Manchester, Newcastle and York) and also a further seven key additional NPH Universities with strong links to the chemicals and process sector including Teesside, Bradford, Chester, Huddersfield, Hull, and Northumbria and Sunderland.
- Economic Development agencies: The project delivery lead, Tees Valley CA has liaised with the 11 LEPs that reside within the NPH, with close engagement with the locations of the key chemical clusters in the Humberside LEP and Liverpool City Region LEP respectively.
- National Innovation Centres: CPI, MPI, TWI and the Royce Centre and Materials Innovation Factory through their Manchester and Liverpool University leads.
- Sectoral bodies, NEPIC has acted as the lead coordinating sectoral body, working with counterparts in Chemicals NW, HCF-CATCH and YCF. Input on the important pharmaceutical intermediates sub-sector has been provided through the First for Pharma organisation.
- The Chemistry Growth Partnership (CGP) has been consulted in the audit through engagement with their secretariat, the Chemistry Industries Association. Alignment has also been through CGP Board member, Paul Booth's Chairmanship of the SIA project delivery group. The SIA has coordinated its evaluation of the key innovation themes with the work undertaken by the Innovation Committee of the Chemistry Growth Partnership on key priorities for innovation and investment and indeed has undertaken further analysis for the CGP on a UK wide assessment of key innovation parameters as supporting evidence for the sector deal proposal currently being prepared for Government.
- Industrial consultation has been through the sector bodies and also through one to one interviews with businesses conducted as part of the stakeholder interview activity.
- Other key consultees have included Innovate UK, the KTN, EPSRC, the Smart Specialisation Hub, and the BEIS chemical sector team.

The SIA has built upon the learning in the SIAs in Waves 1 and 2. Several common themes run through these audits in particular, the importance of coordinated innovation and business support; strategic investment and access to finance; and recognition of the sector identity through a single body. These closely align with the conclusions arising from our work.

There are very clear technological linkages in particular with the work of the Applied Digital SIA in the application of digitisation to the chemicals and process sector and both working groups have closely collaborated in developing their conclusions and actions and have agreed to continue to work collaboratively as they move into implementation phase post-completion of the audit.

The SIA has identified the Circular Economy and resource efficiency as strong enablers that cut across the key sub-sectors as a means of reshoring activity and driving growth. This is showing close alignment with messaging on the importance of eco-innovation and clean growth within the North West Coastal Arc Clean Growth SIA. Both groups have been in preliminary discussions and will seek to continue dialogue on coordinated and collaborative interventions post- completion of the audit phase

Full report

The full report; The Northern Powerhouse Chemicals and Process Sector: A Science and Innovation Audit Report sponsored by the Department of Business, Energy and Industrial Strategy can be downloaded from www.teesvalley-ca.gov.uk/research-intelligence/sia

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The Northern Powerhouse in Health Research - A Science and Innovation Audit

Executive Summary

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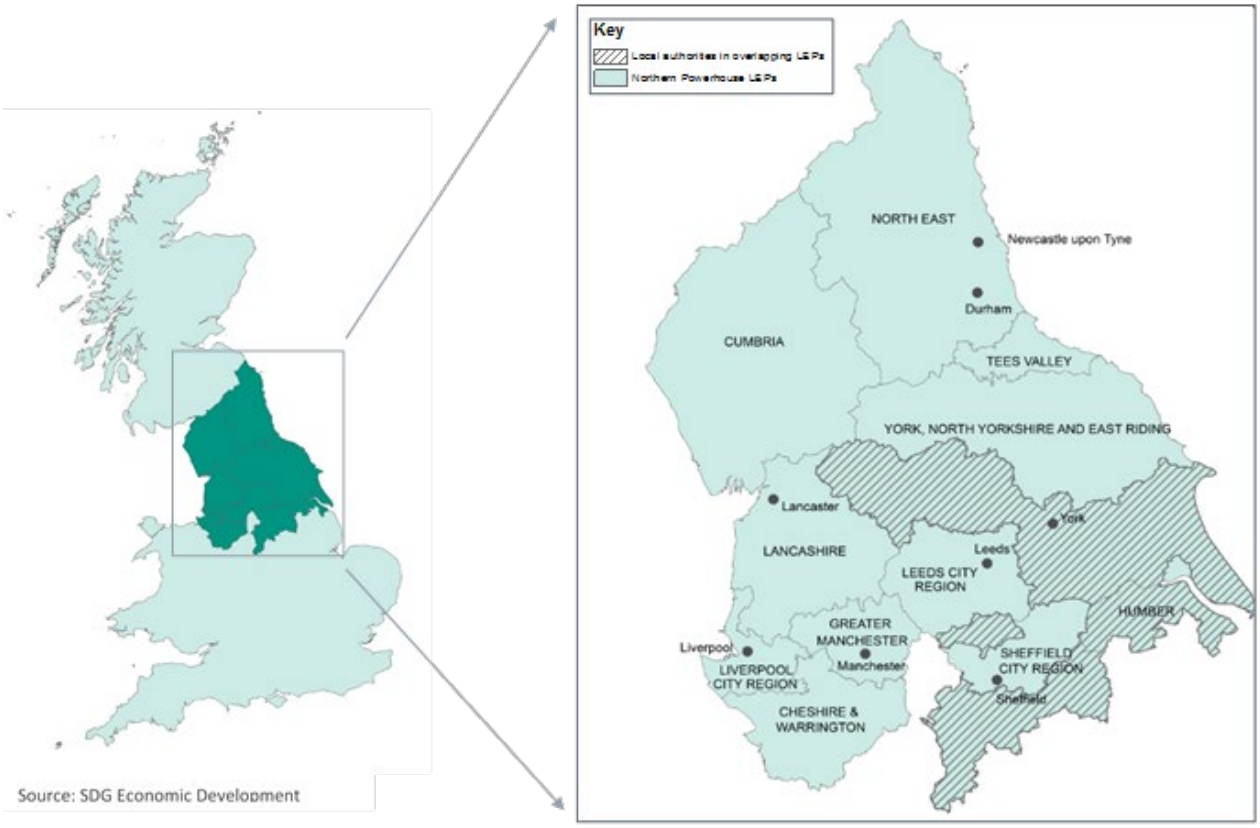


Introduction

This Science and Innovation Audit (SIA) reviews the tangible and intangible assets in the North of England for:

- **Data for Better Health and Wealth,** which is *the ability to develop and implement Learning Health Systems*[1] where progress in Science, Informatics, and Care Culture come together to generate new knowledge as an ongoing outcome of the care process, and deliver continuous improvement in Health and Healthcare; and
- **Precision Medicine,** which is the search for, and application of, the right treatment, at the right dose, to the right patient, at the right time.

At its core, this SIA seeks to exploit the North's potential to drive real-world clinical research across the North's 16m population, drawing on the area's expertise and knowledge in Health and Life Sciences. By working with place-based communities, supported by initiatives such as #Datasaveslives and Connected Health Cities, and pioneering assets such as the Great North and Leeds Care records and the Salford Lung Study, the North is in prime position to diffuse and embed digitally-enabled Precision Medicine research and application at scale, for the benefit of UK citizens and the national economy.

Our Vision

Our aim is that this SIA can play a vital role in progressing the Life Science Industrial Strategy and the proposed Northern Life Science Industrial Strategy Sector Deal.
Our vision is that over the next 10 years, the North of England will:

- Be a globally recognised centre for applied Health Innovation with strengths in (i) **Data for Better Health and Wealth**, and (ii) **Precision Medicine**;
- Be one of the world's most connected and networked regions for Applied Health Innovation – attracting significant levels of public, private, and voluntary sector investment, based on a track record of excellence in applied Health Innovation;
- Apply pervasive Health Innovation by bringing together unique combinations of assets and expertise with which to conduct research;
- Nurture locally applied Health Innovation talent in terms of research, clinical practice, entrepreneurship and business management, and attract and retain Health Innovation talent from around the world; and
- Become a healthier and more economically productive place in which to live, narrowing the North's health and productivity gaps compared with the South of England.

Context

Our Place and Partners

The footprint for our area is built on the eight city regions of Durham, Lancaster, Leeds, Liverpool, Manchester, Newcastle, Sheffield, and York. The research-intensive Universities in each of the cities form the N8 Research Partnership. The Life Science businesses in the North work collectively through the membership organisation Bionow. Four Academic Health Science Networks (AHSNs)[2] and 11 Local Enterprise Partnerships (LEPs) operate in the SIA's geography.

Our Economy, Population, and Health

The North of England is an integral part of the UK economy, with a population of c. 16 million generating approximately one-fifth of national output. While we have areas of outstanding productivity, such as Cheshire and Warrington, in 2015 GVA per filled job in the SIA footprint was 87 per cent of the UK average (£44,078, relative to £50,830).[3] In the way that our productivity varies by place, so do inequalities among our citizens. On the one hand, this puts many challenges on Health and Social Care providers – the chance of dying under the age of 75 is more than 20 per cent higher in the North than in the South of England[4] – but in the context of this SIA this rich diversity of socio-economic and ethnic background at the level of the North is a major 'testbed' for the UK as we look to understand how we use Learning Health Systems and Precision Medicine to improve the delivery, efficacy, and value of 21st century Health and Care.

As such, the North's c. 16 million population, with a steady and high burden of disease, provides a unique setting to progress applied health research in our two SIA themes, facilitating an environment ideal for Precision Medicine clinical trials at scale. Such new activity will build on already strong foundations – for example, the NPiHR's footprint delivers more clinical trials than London, Oxford and Cambridge combined (30 per cent relative to 26 per cent in 2016-17).[5] Our area is also home to three of the top ten hospitals for the number of clinical trials[6] and we have clinical research networks which, in combination, can recruit from across the North and all levels and providers of care. So, we are well positioned to reap the benefits to be gained from Data for Better Health and Wealth to promote Learning Health Systems and extend the use of Personalised Medicine.

To do this, we require appropriate access to data, both at the level of the individual as well-defined cohorts with shared characteristics. In addition, data on environmental and civic factors are required to understand the actual (or potential) efficacy of a treatment in a place-based context. There is a gap in our infrastructure in relation to understanding these environmental and civic factors, which we aim to fill, but more support and investment are needed to make this a reality.

Against this background, we propose a two-pronged approach to tackling the productivity gap between the North and South. First, we will grow, attract, and retain high value-adding businesses in the North's Health supply chain by providing excellent support for research, trials, and business growth. And, second, we will contribute to labour productivity by improving generational health outcomes in the workforce through the increasing efficacy of treatments that Learning Health Systems and Precision Medicine will enable.

Our Research Funding

Between 2007 and 2017, organisations in the NPiHR's footprint led:

- 1,320 projects (18 per cent of all projects in the UK, and c. 17 per cent of all funding) in areas related to **Data for Better Health and Wealth**; and
- 1,582 projects (c. 17 per cent of all projects and c. 14 per cent of all funding) in **Precision Medicine**.[7]

Research by the UK Clinical Research Collaboration shows that, in 2014, our three Northern regions received 13.5 per cent of funding from 64 funders of health research, this against the North having about 25 per cent of the UK's population.[8] Of 20 Biomedical Research Centres (BRCs) nationally, we have four in the North (Leeds, Manchester, Newcastle, and Sheffield) – some £816 million has been allocated to BRCs, of which the North has received just 7 per cent.

Our SIA is focused on ensuring the appropriate recognition of our research excellence, arguing that by improving radically our capacities, capabilities, and expertise in exploiting Data to promote Learning Health Systems and Precision Medicine, we can become still more investable to health research funders and contribute further to the UK's thriving Life Science sector.

Accordingly, over time, we aim to raise the North's share of national Health Research funding to 20 per cent. This will be done through the better coordination of our Health Innovation assets at the level of the North and by working with funders to ensure that, through the quality of the research and application we undertake, more resources are made available for testing and validation as well as for the take-up of innovation in relentlessly improving healthcare systems.

Key strengths

Data for Better Health and Wealth

In relation to **Data for Better Health and Wealth**, our SIA process has identified:

- The North of England's combination of clinical and research assets, expertise, and networks mean that it is placed ideally to drive the use of data to promote the speedy introduction of innovation;
- Our clinical assets, in relation to Data, include six Acute and two Mental Health NHS England Global Digital Exemplars, which are internationally recognised for their efficient delivery of exceptional care through world-class digital technology. Our digital maturity scores an average of 18 percentage points higher than the UK averages across the three main assessment areas: Capability, Enabling Infrastructure, and Readiness;
- Our research assets include, but are not limited to, the High Performance/Cognitive Computing facility at Hartree (including access to IBM's Watson engine), plus the University of Liverpool's Department of Biostatistics, the Liverpool Health Data Science Network, the Centre for Health Informatics, Computing and Statistics at the University of Lancaster, the Centre for Biostatistics at the University of Manchester's Faculty of Biology, Medicine and Health, the Health eResearch Centre in Manchester, University of York's expertise in Biostatistics and Computing science (including the York Cross-disciplinary Centre for Systems Analysis and the Biostatistics Research Group at Newcastle University's School of Mathematics, Statistics and Physics), the National Institute for Smart Data Innovation in Newcastle, and the Leeds Institute for Data Analytics (LIDA);
- The Research Excellence Framework 2014, shows excellence in Computer Science and Informatics at the Universities of Lancaster, Liverpool (who was ranked first for 3* and 4* outputs), Manchester, Newcastle, Sheffield and York;
- Our research expertise, as measured by SciVAL, indicates that, while the *volume* of academic papers produced in the North has scope to grow, the *quality* of that research we undertake is already of international standard;
- Our networks include Connected Health Cities, which unites local health data and advanced technology to drive research and service provision, and has developed the necessary protocols and approvals to share health data at both volume and geographic scale;
- This combination of world-class assets, knowledge and networks, plus our excellent track record in recruitment to trials, means that the North plays a leading role in novel trial designs, including 'change of practice trials', for example, the world-leading Salford Lung Study, and trials within cohort studies, such as the Born in Bradford Better Start Innovation Hub.
- The North is ideally placed to conduct Real-World Clinical Trials – clinical trials are already a regional strength for the North, with six major academic clinical trials units across the footprint, including one of the largest in the UK at Leeds;

- The North also has significant clusters of digital health businesses, particularly in its city regions (notably Leeds, Liverpool, Manchester, Newcastle and Sheffield); and
- Collaboration between business, clinicians and academics is growing. For example, Connected Health Cities is supporting the development of long-term, trust-based relationships between clinicians and researchers and over 70 businesses by establishing a Pre-Competitive Collaboration Consortium focused on data.

Precision Medicine

In relation to **Precision Medicine**, the SIA found:

- The NPiHR's footprint's assets include, but are not limited to, the Genomics England's NHS Genomics Medical Centres (in Leeds, Liverpool, Manchester, Newcastle and Sheffield), the National Institute for Health Research, four NIHR Biomedical Research Centres, NIHR Medtech and In-Vitro diagnostics co-operatives (in Leeds, Manchester, Newcastle and Sheffield), InnovateUK's Medicines Discovery Catapult and the Antimicrobial Resistance Centre (both at Alderley Park), the UK Pharmacogenetics and Stratified Medicine Network, the Wolfson Centre for Personalised Medicine, the Medical Research Council's Centre for Drug Safety Science, The Centre of Excellence in Infectious Disease Research (Liverpool), expertise in economic evaluation at the University of York's Centre for Health Economics and other groups in the region, the Stoller Centre (Manchester), and the Medical Research Council's Stratified Medicine Consortia (n3) (in Manchester and Newcastle). We also benefit from two (of three) InnovateUK-funded Advanced Therapies Treatment Centres (ATTCs), which are facilitating the development, commercialisation, and adoption of Cell, Gene and Tissue Engineered Therapies (Innovate Manchester's Advanced Therapy Centre Hub (iMatch), the Northern Alliance Advanced Therapies Treatment Centre (NAATTC);
- In terms of specific areas of expertise, the Research Excellence Framework 2014 shows academic excellence in Allied Health Professions, Dentistry, Nursing and Pharmacy at the Universities of Lancaster, Bradford, Leeds, Manchester, and Sheffield; in Psychology, Psychiatry and Neuroscience at the Universities of Lancaster, Newcastle, and York; in Public Health, Health Services and Primary Care at the Liverpool School of Tropical Medicine compares favourably with that of leading institutions in the UK and world-wide;
- International collaboration is a vital part of innovation in Precision Medicine. Universities in the NPiHR's footprint demonstrate high levels of international collaboration with over 60 per cent of papers containing at least one international partner, a rate comparable to the UK's best research institutions;
- Collaborative working (between sectors as well as across borders) is vital to the success of innovation in Precision Medicine, supported by multidisciplinary centres that complement our themes e.g. the Maths in Healthcare at Liverpool and the recently funded £2 million EPSRC grant at Lancaster. The NPiHR's 'soft' infrastructure supports collaboration within the North, and between the North and the rest of the world;
- In terms of business, the NPiHR's footprint has nationally significant and complementary clusters of Life Science business. The North is home to over 12, 450 Core Biopharma companies (around 20 per cent of all UK Biopharma firms), employing 21,500 over people (18 per cent of all UK employment in the sector); and around 21,700 Medtech companies (around 22 per cent of all UK Medtech companies), employing over 28,500 people (23 per cent of all UK employment in the sector).[9]
- The North West is strong in therapeutics at Alderley Park and has a core Biopharma and Medtech service and supply chain; Yorkshire and the Humber is strong in core Medtech and Digital Health; and the North East, which has a significant cluster of 17 major pharmaceutical

companies including Allergan and AstraZeneca, is strong in Biopharmaceutical service and supply, and core Biopharmaceutical; and
- There is also a well-established and growing diagnostics cluster in the North, including the Abtek Biologicals Mast Group in Liverpool, QIAGEN in Manchester, and Mids Medical at Sci-Tech Daresbury.

Growth opportunities

Bringing together Data for Better Health and Wealth and Precision Medicine

As is clear from the above, the North of England has internationally competitive and globally connected clinical, research, and business assets and capabilities in relation to **Data for Better Health and Wealth** and **Precision Medicine** as separate domains. But if our two themes combined effectively, their assets and strengths can form a uniquely attractive offer to researchers, clinicians, and businesses working on the effective use of data to drive innovation in Precision Medicine. In other words, our two themes in synergy equip the North to develop as a global centre for ***applied* Precision Medicine**.

A wide body of stakeholders across our SIA's footprint were asked to think creatively how such synergetic expertise in *applied* Precision Medicine might take form practically. The following specific proposals were offered:

- **Real-World Clinical Trials –** building on the platform developed by North West Electronic Health (as well as strong capabilities across the wider Northern footprint), which has 1.4 million patient records, and a unique, secure, and safe method for managing pseudonymisation and re-identification for Real-World Evidence, and from which the North can establish a novel, world-leading unique platform. Liverpool and Leeds Clinical Trials Unit are other examples of building strengths with established e-trial platforms and experience across multiple studies including comprehensive strengths in clinical trial design. Utilising the combined strengths of real-world data and adaptive clinical trial design, the NPiHR SIA partners are positioned to conduct robust and unbiased evaluations of Precision Medicine technologies and methods, with prior consent, to being monitored pre-disease to enable longitudinal studies. Recruiting people for clinical trials using live data for identification and accessing data at the point of care would underpin this;
- **Ageing** – building on age-related assets across the North, such as the National Innovation Centre for Ageing (NICA), the NPiHR footprint has the potential to lead a number of pan-Northern population health-based initiatives, including scaling the activities of the five Active and Healthy Ageing (AHA) Reference Sites, which are now working together through the AHA North initiative on areas such as Falls Prevention, Frailty, and Bone Health. Ageing is, of course, one of the four Grand Challenges set out in the UK Industrial Strategy;
- **Anti-Microbial Resistance** (AMR) – building on assets and expertise, particularly those in the North West, the North is well-placed to lead Precision Medicine research into AMR which, posing a significant threat to current treatment practice, has huge market potential. The key area for development here is both the support for a dedicated AMR cluster in the North West, as well as a national clinical trials platform for AMR that could be established first in our SIA geography;
- **Predicting future health needs in the population** – linking such findings to (a) the most effective treatments, and (b) preventive measures/treatments.

Gap analysis

Stakeholders identified a number of challenges specific to **Data for Better Health and Wealth** and **Precision Medicine**, along with challenges related to our ability to bring the two themes together.

Data for Better Health and Wealth

The issues to address, if we are to make the most of the opportunities arising from Data for Better Health and Wealth, are:

- World-wide skill shortages in Bioinformatics (and the underpinning skills, such as Statistics and Mathematical Science), Pathology, Microbiology, Genome Sequencing, Health Economics, and Clinical Trial Methodologists;
- The need to encourage more and deeper cross-discipline working, as a means of using skill and expertise sets in new and novel ways;
- Improving access to finance to enable firms to scale-up, as well as the need to build the business management skills of growing businesses; and
- Optimising the synergies, linkages, and connections with other relevant SIAs elsewhere in the North and the wider UK (such as the emphasis given to High-Performance and Cognitive Computing in the Liverpool+ SIA, and Applied Digital Technologies in the Oxfordshire SIA).

Precision Medicine

The issues to address, if we are to maximise the health and economic benefits of the North's potential in **Precision Medicine**, include:

- A lack of pan-regional fully joined-up infrastructure to conduct real-world precision trials at scale;
- Insufficient funding and support for scale-up businesses in Precision Medicine (notwithstanding the good work already being done e.g. at Alderley Park);
- The slow adoption and application of innovation in the NHS, due to, among other things, conservative procurement processes, cultural issues, and crucially a lack of engagement by clinicians (often due to wider NHS pressures), with the latter meaning that researchers and companies tend to push products from a technology perspective, and in ways which are not always aligned with the patient pathway/Health and Care system;
- A workforce that has not been sufficiently trained in the skills required fully to exploit the opportunities offered by Precision Medicine, including cross-team working and entrepreneurial and business management skills; and
- Optimising the synergies, linkages, and connections with other relevant SIAs elsewhere in the North and the wider UK (such as Scotland's SIA focused on Precision Medicine Innovation, and Medical Technologies in the Leeds City Region SIA).

Gaps in our capacity to bring our two themes together

Figure 1 illustrates the interaction between the two themes, the specialisms in which the NPiHR is well-placed to build international and commercial collaborations, and the enabling factors which, if strengthened, will drive our growth. The SIA process identified five 'enabling factors' that determine our ability to innovate at scale and speed, and which inform our proposed 'targeted opportunities' described below. These are:

- Clinical and academic excellence in knowledge;
- 'Hard' and 'soft' enabling and supporting infrastructure;
- Arrangements for large-scale consent to support Real-World Clinical Trials;
- Skills and understanding of Precision Medicine to support learning health systems; and
- NHS regulation and procurement to support the adoption and diffusion of innovation at scale.

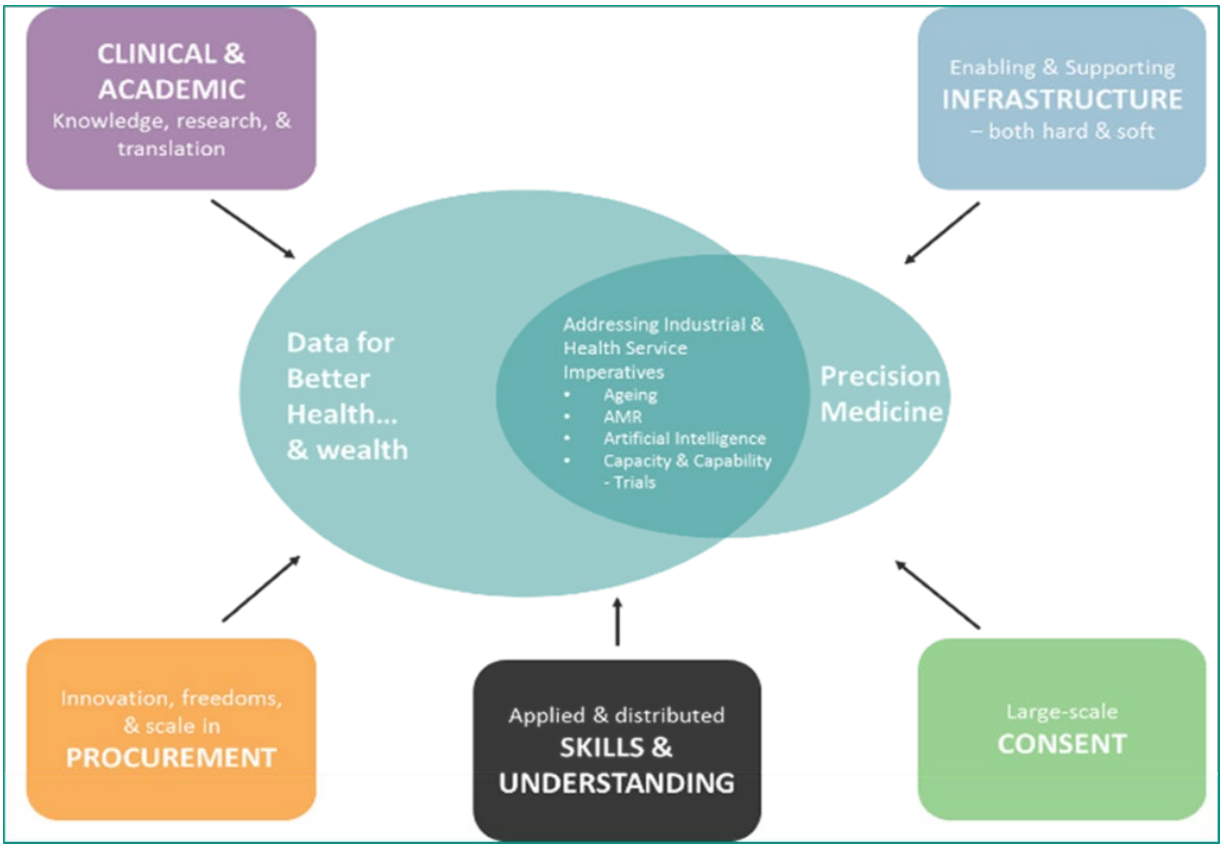


Figure 1: Enabling factors, interactions and synergies between Better Data for Health and Wealth and Precision Medicine
Source: SDG-Economic Development

Key proposals

The specialisms, enabling factors, and the issues and constraints highlighted by stakeholders have informed our development of 'targeted opportunities'.

Our Targeted Opportunities

Given our established strengths and our analysis of the challenges and barriers to growth, we have identified six targeted opportunities that will enable us to stay ahead where we lead, and to achieve excellence in new and growing markets. These comprise our 'asks' from this SIA:

Extending Connected Health Cities

- The Health North/Connected Health Cities (CHC) initiative is creating a world-leading partnership using large-scale data to drive public sector reform in health and social care;
- The original CHC funding was for the pilot of the project, and was linked to potential future scale-up capital;
- An extension to CHC will enable the development of almost 16 million consented population based on the Great North Care record, and its various sub-regional equivalents, that will complement the UK Life Sciences Industrial Strategy. The latter seeks, among other things, to improve the speed and efficiency of UK clinical trial capabilities and to support collaboration between the NHS and industry for the benefit of patients;
- CHC also has significant export potential, with existing requests from Australia, USA, Canada, Brazil, Turkey and Singapore for international relationships based on the platform being demonstrated through CHC; and
- The funding requirement over the next five years, based on experience to date, is estimated at **£25 million capital, and £75 million revenue**.

Extension of the Northern Health Science Alliance (NHSA)

- The NHSA performs a vital animateur and coordinating role working with Universities, Academic Health Science Networks and NHS Teaching Hospitals, plus engaging with business;
- It currently handles around 35 private sector enquires a year, translating around 90 per cent of these into formal R&D projects; and
- The funding requirement for NHSA over the next five years, based on experience to date and expectations of future demand, is estimated at **£3-5 million revenue.**

Development of a Centre for Civic Computation

- This will involve co-locating physical and digital facilities with the CHC data analytic centres at a regional science park(s) across our SIA geography. The latter are able to accommodate industry partners, so optimising the opportunities for clustering, as well as ensuring activity is visible to the public and thereby helping to build public trust in the increasingly sensitive and high-profile 'personal data' domain;
- The CCC will drive regional and national growth by working closely with CHC, entrepreneurs, and existing businesses to develop digital health products and services. It will establish a programme in Civic Data Science research alongside a Centre for Doctoral Training, addressing an acute need in the rapidly expanding Digital Health and allied Digital Civic segments; and develop a cohort of Computing and Mathematics Fellows;
- The precise form of the asset needs to be worked through, but it could take the form of a single facility for the North, a network of nodes across the North, or the North leading as part of a national collaboration in civic computation. Links to, and synergies with, Health Data Research UK will be key; and
- The funding requirement over seven years is estimated at **£10-15 million capital and £25-40 million revenue** – based on benchmarking with other Centres.

Development of a Precision Medicine Academy

- An **Applied Precision Medicine Academy** (APMA), focussed on delivering coordinated training and knowledge transfer across the North, will build on partners' outstanding track record in innovative clinical academic training (this includes the Modernising Scientific Careers Programme under Health Education England, the NIHR National Dean for Training (Liverpool), the National Lead for Training in the NIHR Infrastructure, NIHR Infrastructure National Training Forum Chair and NIHR Rare Disease Training Lead (all in Newcastle)); and
- Further work is required to determine the scale of the Academy and the breadth of Allied Health Professional courses that it will cover. Initial estimates indicate **annual running costs of around £2-4 million a year.** In the first instance, **an estimated £75,000 is required for a Concept Feasibility Study** – based on previous similar feasibility studies.

Development of Real-World Clinical Trials

- The NHSA and the team at North West eHealth (NWEH), which ran the Salford Lung Study, plus the wider Northern platform will scale-up the North's offer on Real-World Clinical Trials. Wider expertise will be drawn in from other centres of specialist clinical trials expertise, such as the UKCRC's Clinical Trials Research Centre (Liverpool) and Clinical Trials Research Unit (Leeds). Similarly, the Wolfson Centre for Applied Health Research Medicine is seeking to research Health Inequalities in the Leeds-Bradford area;
- This opportunity is complementary to, and supportive of, the Life Sciences Industrial Strategy, which aims to establish two to five regional innovation hubs providing data across regions of three to 5 million people. The NWEH and the broader Northern platform is a

ready-made regional innovation hub, able to take forward work identified in the Life Sciences Industrial Strategy; and

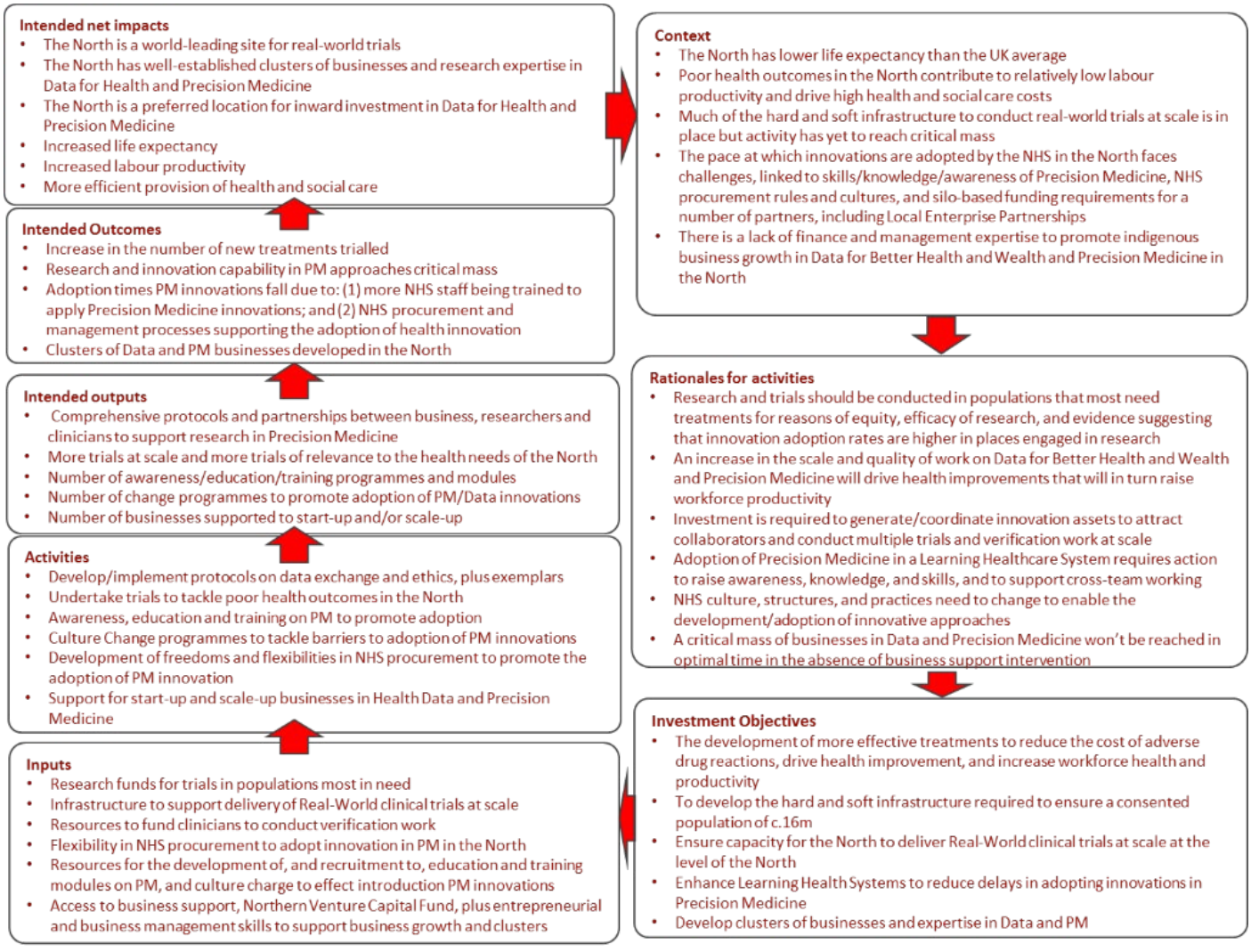
- The funding requirement for this is estimated at **£20 million over five years**, which, based on our experience of partnership working to date, will unlock at least twice as much in private sector investment.

Freedoms and flexibilities in Procurement and Funding

- The NHSA, working in partnership with NHS Trusts, AHSNs, and the newly developing NHS Northern Procurement Hub will explore fresh ways for the North of England to procure innovation at scale, with the aim of identifying any procurement barriers to the introduction of pan-Northern innovation procurement. The estimated cost of a **Scoping Study for this opportunity will be £100,000** – based on the need for specialist procurement expertise and the scale of the processes to be reviewed; and
- The NHSA will work with researchers, businesses and LEPs to prepare a Business Case for LEPs which have prioritised the Life Sciences to have the freedom to support work to develop and validate new products, processes, and services delivered to the NHS. Based on previous work, the **estimated cost of this case-making activity is a further £140,000.**

Figure 2 provides a logic model which summarises our overall approach.

Figure 2: NPiHR SIA Logic Model



Source: SDG-Economic Development

Networking and collaboration

Producing the SIA

This is a partnership-led and -built document, drawing on the rich and diverse mix of Health, Care, Business, Academic, and wider intermediary agencies across the North of England's Data, Health and Care, and Life Science communities. The Northern Health Science Alliance has coordinated these activities. The Alliance itself is an independent not-for-profit company limited by guarantee. Its governance structure includes the eight leading research-intensive NHS teaching hospitals, the N8 universities, and the four northern Academic Health Science Networks.

All of the AHSNs, and the seven of the North's LEPs that are prioritising Life Sciences for sector development, have participated actively in the production of this SIA, and will be key partners in its delivery and execution. These partners ensure, and will demand, a high level of place-specificity to the implementation of our SIA. In particular, the North's AHSNs have for a number of years been working collaboratively across the North to share know-how, expertise, and capability. Accordingly, the North is one of the best networked UK regions in having AHSNs collaborating at scale. Our AHSNs have a proven track record of joint working, and collaborating, with partners in industry, in particular around the validation and uptake of novel products and devices. Our AHSNs also work on a single Innovation Pathway[10] aligned to the North's agreed research areas, ensuring they leverage the combined 'power' of the North's NHS Trusts.

The SIA process specifically facilitated discussions which led to identification of the synergies to be developed from the interactions between Data for Better Health and Wealth and Precision Medicine, the specialisms in the North that are most likley to yield results, and the enabling factors which need to be strengthened if we are to maximise the impact of the SIA. The debates, initiated by the SIA, led to the development and refinement of our targeted opportunities.

Delivering this SIA

The SIA process has also focused partners' minds on next steps. In the initial phases of delivering the recommendations and suggested outcomes from this SIA, the NHSA will act as the governing body in the first instance. However, to reflect the full breadth of the North's health innovation economy the NPiHR will establish a Leadership Steering Group to support the implementation and delivery of the SIA's recommendations and next steps. The NPiHR joint leadership steering group which will involve members from the NHSA, regional trade bodies, such as BioNow and LEPs, as well as directly involving the senior leadership from relevant companies to guide and inform the implementation of the SIA outputs. The NHSA is in the process of agreeing the governance model for the NPiHR SIA Leadership Steering Group with relevant stakeholders.

The NHSA is grateful for all the thinking, advice, data, wider evidence, and constructive challenge that partners have offered this last six months. Our thanks go to all those who participated.

Department for
Business, Energy
& Industrial Strategy

Precision Medicine Innovation in Scotland: Accelerating Productivity Growth for Scotland and the UK

Science and Innovation Audit Report
sponsored by the Department for Business,
Energy and Industrial Strategy
Report 2018

Introduction

1. 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. In Scotland, a consortium was formed in 2017 to focus on our strengths in PM. This report presents the results which includes a broad-ranging analysis of Scotland's capabilities, the challenges and the substantial opportunities for future economic growth.
2. This SIA report has been developed by an impressive consortium comprising public and private sector partners from across Scotland, as well as a number of leading international actors involved in PM globally. Whilst the consortium has been led by the University of Glasgow, the SIA process has very much been characterised by a genuine "Team Scotland" approach, with support, commitment and real insight from industry (both large and small), academia, NHS Scotland, Scottish Enterprise, Scottish Government and the health charities sector operating across the country.
3. The SIA Steering Group includes a wider range of national and international experts from industry, academia, NHS and Government. These include: Professor Dame Anna Dominiczak, Vice-Principal and Head of College of Medical, Veterinary & Life Sciences at the University of Glasgow (Chair); Dr Victor Dzau, President of the US National Academy of Medicine; Peter Silvester, Senior Vice President of Thermo Fisher Scientific; Dr Menelas Pangalos, Executive Vice President of AstraZeneca; Dr Ken Sutherland, President of Canon Medical Research Europe Ltd; Dr David Sibbald, Chair of the Stratified Medicine Scotland Innovation Centre; and John Brown, Chair of NHS Greater Glasgow & Clyde Health Board and NHS Tayside Health Board. A full list of the SIA Steering Group members is included in Annex A.
4. Over recent months, partners have enthusiastically joined together to progress this SIA, ensuring that it provides a robust, balanced and granular assessment of Scotland's PM strengths and emerging prospects for growth. The evidence suggests that the further development and adoption of PM will potentially be transformative for the Scottish and UK life science clusters, developing expertise and know-how that can be exported around the world through new technologies, products, services and behaviours. Indeed, one of the key drivers for the audit has been a recognition across consortium members that Scotland is extremely well positioned to unlock the exciting and substantial productivity growth opportunities associated with PM.
5. The growth and development of Scotland – and indeed the wider UK's - PM ecosystem and associated digital and life science clusters, is only one of the economic benefits. Implementation of PM will help our NHS to generate significant savings at a time when it is struggling to meet increasing demand from an ageing population. Analysis conducted by health economists at the University of Glasgow reveals that PM generated innovations could help deliver billions of pounds of healthcare cost savings. Furthermore, more effective targeted treatments and better prevention of disease will create a healthier and more productive UK workforce.
6. The SIA has ensured we are fully cognisant of the nature and scale of the challenges in translating our research and clinical excellence into a globally significant PM business cluster in Scotland. A review of the evidence collated through this SIA work confirms that most of the key elements of our ecosystem are already in place – and we are well on our way to creating a healthier and wealthier Scotland.

What is Precision Medicine?

7. According to the WISH Precision Medicine Forum, Precision Medicine is defined as:

> *"the tailoring of medical treatment to the individual characteristics of each patient… to classify individuals into subpopulations that differ in their susceptibility to a particular disease or their response to a specific treatment… [allowing] preventative or therapeutic interventions [to] be concentrated on those who will benefit, sparing expense and side effects for those who will not"*[1].

8. Precision Medicine offers business, clinical and social opportunities for a range of stakeholders. It is not only of interest to scientists and medical professionals, but provides a clear space for industry, academia, health charities, the NHS and governments to collaborate to tackle the significant healthcare challenges that we face. There are a number of key market and technology drivers of change impacting on the PM opportunity, including an ageing population, increasing costs of healthcare and the emergence of new technologies (which are converging rapidly) allowing us to develop better, more targeted and tailored healthcare solutions for both economic and patient benefit.

The SIA area

9. This PM SIA covers the whole of Scotland. The opportunities to grow the PM cluster in Scotland will build on existing clinical, research and commercial expertise in the four major cities (Glasgow, Edinburgh, Dundee and Aberdeen). Scotland is already widely recognised as one of the key life science clusters in Europe[2], and as demonstrated in a Wave 1 SIA, the Edinburgh city region is a global centre of excellence for computer science and informatics. Through this SIA process, we have started to explore how best to leverage the expertise set out in the Edinburgh City Region SIA on Data Driven Innovation and develop new collaborative action areas designed to unlock new synergies and associated growth opportunities for the benefit of Scotland and the UK's life science industry as a whole.

10. The core approach that the consortium has adopted in undertaking this SIA has been to demonstrate the scale and nature of the PM opportunity to the whole of Scotland. Whilst Glasgow and Edinburgh boast a wide range of clinical medicine expertise, Dundee has strengths in drug discovery and Aberdeen also has genuine expertise in bio-pharmaceuticals. The role of NHS Scotland is also critical in scaling-up the PM cluster - both as a key innovation partner and customer - and its remit covers the whole of the country. Indeed, as Scotland's fully integrated healthcare provider, NHS Scotland works closely with industry, academia and the health research charities sector. It provides co-ordinated access to clinical investigators and patients through a single point of contact for industry, accessible clinical research support infrastructures, and streamlined and timely clinical trial approvals.

1 World Innovation Summit for Health (WISH) (2016) Precision Medicine, A Global Action Plan for Impact – Report of the WISH Precision Medicine Forum
2 See for example: Science Business/Sanofi (2015), 'The leading life sciences clusters in Europe'

Our vision

11. The high calibre SIA consortium of public and private partners from across Scotland and international experts are committed to helping Scotland become a global centre of excellence for the implementation of PM over the next 10 years. In order to achieve this vision, the SIA focuses on four main opportunity areas:
    - The £1bn Queen Elizabeth University Hospital (QEUH) campus in Glasgow is acting as a focal point for Scotland's wider ecosystem for PM, delivering substantial clinical and economic benefits to Scotland and the UK
    - Driving increased awareness and adoption of PM, as well as the strengthening of our innovation ecosystem, will accelerate productivity growth and improved patient outcomes
    - Enhancing Scotland's leadership role in the advancement of PM will help to speed up the adoption of PM, providing an internationally significant UK exemplar, attracting Foreign Direct Investment (FDI) and delivering competitive advantage for the UK
    - Scotland's PM strengths have the potential to add significant economic value by complementing and synergising with other major UK innovation initiatives; including those in adjacent sectors most notably drug discovery. Specifically we will build on existing close relationships with the UK based European Lead Factory and the Medicines Drug Discovery Catapult. PM will lead to much better understanding of molecular mechanisms of diseases and therefore is prime source of feedback new druggable targets.

Key strengths

12. In recent years, Scotland has built up strong foundations, which support the development and diffusion of PM focused approaches to healthcare. Major investments have been made at the new £1bn Queen Elizabeth University Hospital (QEUH) campus in Glasgow, including the Stratified Medicine Scotland Innovation Centre (SMS-IC), the Clinical Innovation Zone

ReproCELL Europe is headquartered at the West of Scotland Science Park in Glasgow. It is a contract research services company that works with 19 out of the 20 major global pharmaceutical companies.

ReproCELL invested in Scotland in 2015 when it acquired Biopta, a spinout from Glasgow Caledonian University. A new company ReproCELL Europe was then created in 2016, merging Biopta and another acquisition, Reinnervate. ReproCELL Europe currently has 23 employees, with 19 in Glasgow and 4 in County Durham. Its annual turnover is around £1.5 million and 90% of sales are exports.

Working with NHS, academic and industry partners at the SMS-IC has helped ReproCELL to improve the selection of patient stratification criteria based on a combination of genomics and associated functional data from studies in human tissue samples. The project was a key factor in ReproCELL's decision to buy Biopta and has also been successful in showcasing the opportunities of industry, academia and the NHS (the triple helix model) working together in the area of Precision Medicine.

and the Imaging Centre of Excellence. This is the first clinical-academic-industry campus worldwide designed around the clinical implementation of PM and it is one of the jewels in the crown of Scotland's burgeoning ecosystem for PM. In 2016, the UK's first 7-Tesla MRI scanner in an acute clinical setting was installed at the ICE and the 7T scanner is one of only 75 worldwide and one of the first with the capability for use in clinical practice.

13. We have a well-established Scotland-wide *Ecosystem for Precision Medicine*, centred around the SMS-IC and which is funded by the Scottish Government and industry. The combination of world-class clinical research, high quality patient data, patient samples, a single healthcare provider (NHS Scotland), and large cohorts of patients with chronic disease differentiates Scotland from other life science clusters. Scotland is already widely recognised as a key location for hosting clinical trials and has strong relationships with the global pharmaceutical industry.

14. Scotland's investment in PM has been recognised internationally. In a report for the World Innovation Summit for Health (WISH), Dr Victor Dzau (President of US National Academy of Medicine) highlighted Scotland as an exemplar in terms of cross sector collaboration and the important roles being played by SMS-IC, the Scottish Genomes Partnership, Generation Scotland, and Glasgow Polyomics[3].

15. The strength of the PM ecosystem was also recognised by AstraZeneca, when SMS-IC was invited to join its Global Genomics Initiative. In addition, Professor Andrew Biankin, at the University of Glasgow, has led on the formation the International Cancer Genome Consortium (ICGC) Accelerating Research Genomic Oncology (ARGO) project, which is analysing biospecimens from at least 100,000 cancer patients worldwide with standardised methods and high quality clinical data.

16. Scotland's key strengths in PM are summarised in Table 0.

Thermo Fisher Scientific Inc. is a global leader in serving science, with a total revenue of more than $20bn. It supplies instruments, equipment and software, as well as services and consumables to help conduct research, solve complex analytical challenges, improve patient diagnostics, deliver medicines to market and increase laboratory productivity. Around 850 of Thermo Fisher's 70,000 global employees are based in Scotland: 700 at Inchinnan near Glasgow, 100 in Perth, and 50 who are field based. Thermo Fisher generates approximately $1bn revenue from Scottish customers.

In 2015, a new £14m facility was opened to use Thermo Fisher's proprietary technology to manufacture dry media powder, which is then used to manufacture a range of drugs. One of only two such plants in the world, products from Inchinnan are used by customers across the Europe, Middle East and African (EMEA) markets. These customers then develop drugs that can be used to treat targeted groups of patients. The company was also a founding partner in the SMS-IC.

3 Dzau et al (2016), Precision Medicine, A Global Action Plan for Impact -Report of the WISH Precision Medicine Forum 2016

Table 0: Scotland's key strengths in Precision Medicine – an overview

Scoland's unique strengths and key assets		Globally significant PM research base	Expanding PM business base
• **Queen Elizabeth University Hospital (QEUH)** – The new £1 bn hospital campus opened in 2015 and is the largest acute hospital in the UK. It is home to major specialist services such as renal medicine, transplantation and vascular surgery, with state-of-the-art critical care, theatre and diagnostic services • **Imaging Centre of Excellence** -located in the QEUH campus, the centre hosts a ultra high-field 7T MRI scanner, a 3T MRI scanner and a 320 multi-slice CT scanner and houses clinical academic and industry personnel dedicated to the development and deployment of next generation imaging • **Stratified Medicine Scotland Innovation Centre (SMS-IC)** - based within the Clinical Innovation zone at QEUH, SMS-IC set up in 2013 and has partners from 4 Scottish NHS Health Boards, 4 Scottish Universities and 2 industrial partners in informatics- Aridhia Ltd- and in genomics with ThermoFisher Scientific Ltd	• **Quality of Scotland's electronic health records** –among the world's best and include a Community Health Index (CHI) number, which was introduced over 30 years ago and uniquely identifies a person on the index. Data on Scotland's entire population is captured routinely at all points of contact with the health service, meaning patient demographics and clinical information can be accessed and used in clinical research and trials. • Scotland has the ability to bring together real patient data, historic data and patient samples, as well as unique patient databases such as SHARE and Generation Scotland • **Single healthcare provider NHS Scotland** – NHS Scotland is made up of only 14 regional health boards and patient records and regulation is consistent across Scotland.	• **Scotland's universities produce world-class research and perform well across various international rankings** – five of Scotland's universities are in the world's top 200 ub tge categories of clinical, pre-clinical and health, life sciences and computer science[4] • The quality of research from the four SMS-IC partner universities in PM-related subjects is higher than in other key university groupings in the UK[5] • **Key figureheads driving Precision Medicine in Scotland** –Professor Dame Anna Dominiczak, Vice-Principal and Regius Chair of Medicine and Therapeutics at the University of Glasgow, and Professor Andrew Morris of the University of Edinburgh and the Farr Institute have been at the forefront of developing the PM Ecosystem in Scotland • **SMS-IC projects showcasing Scotland's expertise** – demonstrating the applicability of PM in a range of chronic diseases, and including large multinational consortium projects	• **Growing life sciences cluster** Scotland is one of the largest life science clusters in Europe. It employs over 37,000 people across 700 organisations, and contributes around £2bn in annual GVA for the Scottish economy. There has been significant growth in the sector with GVA increasing 45% between 2010 and 2015, and employment growing by 16%[6,7] • **Regarded as one the best locations for the development and clinical trials of treatments and therapies** – high number of trials taking place compared to other countries with eight out of the top 10 global CRO's located in Scotland • **Increasing number of businesses involved in PM** – including Canon Medical Systems, Aridhia, Fios Genomics, Pharmatics, Sistemic, Destina Genomics, Biopta (ReproCELL), BioClavis, ThermoFisher Scientific and Arrayjet • Overall, it is estimated by Scottish Enterprise that there are currently **around 230 companies undertaking PM related activity in Scotland[8]**

Scoland's unique strengths and key assets		Globally significant PM research base	Expanding PM business base
• **MRC Molecular Pathology Nodes** – two of the six UK nodes are based in Glasgow (the UK's largest) and Edinburgh. The nodes provide infrastructure and expertise to deliver PM in a wide range of disease areas • **NHS/ University Clinical Research Facilities** and accredited **Clinical Trials Units** – coordinated facilities in Glasgow, Edinburgh, Dundee and Aberdeen bringing together university and NHS Scotland research expertise • **NHS Research Scotland** –encourages researchers to bring studies to Scotland, and invests in nationwide clinical research infrastructure • **NHS Scotland Biorepositories and Safe Havens** – a network of four regional biorepositories for tissue samples and health data 'safe havens' located in Glasgow, Edinburgh Dundee and Aberdeen.	• **Continuing prevalence of chronic disease in Scotland** – these diseases include heart disease, stroke, cancer, diabetes, chronic inflammatory and autoimmune diseases such as multiple sclerosis. In addition, Scotland has a very stable population, which also helps with longitudinal health monitoring • **Significant Scottish Government support for PM** –major investments in SMS-IC, facilities at the QEUH campus, and funding for the Scottish Genome Partnership	• In 2016, **SMS-IC joined AstraZeneca's Global Genomics Initiative**. Other partners include the University of Cambridge, the Wellcome Trust Sanger Institute, Genomics England, Human Longevity Inc. in the USA, Columbia University in Canada and Finland's Institute for Molecular Medicine • SMS-IC partners are looking to enhance Scotland's expertise in bio-informatics, next generation sequencing, data assimilation, biomarker identification and diagnostics development • **Complementary expertise in health economics** – University of Glasgow's Health Economics and Health Technology Assessment team (HEHTA) is at the forefront of developing robust economic models on the effectiveness of PM, and the University of Aberdeen Health Economics Research Unit won the Queen's Anniversary Prize for sustained research excellence	• **Strengthening links between life science companies and Scotland's emerging data and informatics sector –** strong strategic focus on health informatics in Edinburgh and Glasgow, making links with Edinburgh City Region SIA • **Supportive business environment for start-ups and growth companies** – support for firms provided by Scotland's enterprise agencies (Scottish Enterprise, Scottish Development International, Highlands and Islands Enterprise, Skills Development Scotland, Scottish Funding Council) and through private sector investors (e.g. Epidarex Capital) • Broad range of business accommodation tailored to life science and technology rich companies – with key concentrations of sites in the Glasgow and Edinburgh areas (Clinical Innovation Zone, BioCity, BioQuarter)

Source: Precision Medicine in Scotland SIA Consortium

4 Times Higher Education World University Rankings
5 Based on SQW analysis of SciVal citation impact scores 2014-17 – SMS-IC universities were compared with N8 Research Partnership, Russell Group and Golden Triangle
6 Sciences in Scotland (2017), Life Sciences Strategy for Scotland 2025 Vision - Accelerating Growth, Driving Innovation
7 The Office for Life Sciences also produces data on the life sciences sector across the UK. The latest data in the 'Strength and Opportunity 2017' report estimates there are just over 15,000 jobs in Scotland in the biopharma and medtech sub-sectors. The SIA consortium agreed that the wider Scottish Government definition of the life sciences cluster was more appropriate to use for the purposes of this Audit
8 Analysis undertaken by Scottish Enterprise

Growth opportunities

17. There are several market and technology drivers of change impacting on PM including an ageing population, increasing healthcare costs and the emergence of new disruptive technologies. Changes to regulation, approvals processes, new business models in the pharmaceuticals sector, and growing demand for non-invasive and personalised treatments are also important contextual developments for PM.

18. The global PM market value was estimated at almost $43bn in 2016 and this figure is projected to rise to around $134bn by 2025, so it is a prize worth pursuing for both the Scottish and wider UK economies[9]. However, there are significant global challenges in implementing PM in terms of data privacy, the integration of health datasets, regulation, and evidencing impact. Despite these hurdles, the SIA evidence suggests that Scotland has the complementary expertise in clinical research, computer science and informatics needed to create substantial economic opportunities from exploiting PM.

19. More specifically, there are three main areas of economic opportunities from investing in PM in Scotland:

    - It will create new business opportunities in a range of sectors including life sciences, data analytics and informatics, and over 200 Scottish firms are already involved in this area.
    - Implementing PM will help our NHS to generate significant savings at a time when it is struggling to meet increasing demand. Initial analysis by health economists at the University of Glasgow demonstrated how PM -generated innovations could help deliver billions of pounds of health savings across Scotland.

More effective treatments and better prevention of disease will create a healthier and more productive UK workforce.

Gap analysis

20. The development of this SIA has involved extensive consultation with 45 public and private sector organisations from across Scotland. These in-depth discussions have been used to clarify the existing PM related strengths of Scotland and helped partners to identify where more can be done. The main gaps and solutions are as follows:

    - **Limited integration of - and exploitation of potential synergies across - Scotland's expertise in clinical medicine and data science, both in terms of research projects and commercial activities. This is a major missed opportunity for the UK**

9 Frost & Sullivan (2017), Global Precision Medicine Growth: Opportunities, Forecast to 2025. Strategies and Tactics for Accelerating Growth in a Transforming Market

> **Develop a more strategic partnership between clinical medicine and data science capabilities,** including machine learning and artificial intelligence (AI) and the opportunities enabled by new 5G data networks – building on the work of SMS-IC and Datalab, and other joint research projects, PM offers a major opportunity for closer collaboration between the Universities of Glasgow and Edinburgh, along with NHS Scotland, industry and the major health research charities

- **Low levels of entrepreneurship in Scotland, compared to other parts of the UK, and a relatively limited number of start-ups to date targeting the PM opportunity**

  > **Embed a more pervasive culture of enterprise and attract more VC Funds to support the commercialisation effort** – we need to promote the PM opportunities for new tech start-ups, celebrate the successes that we have in Scotland, and ensure that growth finance is available (on attractive terms) for investable propositions

- **Inconsistent messaging across Scotland about the scale and nature of the business growth opportunities linked to PM** for start-ups, existing SMEs, and potential inward investors. This has resulted in a lack of clarity and general awareness amongst the business and investor communities

  > **Create PM champions within NHS Scotland, academia and the Scottish Government,** to work together and with the enterprise agencies and industry to drive demand/investment and raise the profile and awareness of PM related opportunities. A clearer demand statement from NHS Scotland and the Scottish Government would accelerate the development, adoption and mainstreaming of PM in Scotland

  > Complementing the previous action area, **better PM promotion to the SME base and potential inward investors** – the partners involved in developing this SIA are committed to working with different sectors and investors to articulate the scale and nature of Scotland's offer and the exciting market opportunities associated with PM

- **Insufficient promotion of Scotland's existing key PM assets and centres of excellence** – there needs to be greater clarity on the PM offer and the major investments in new facilities over recent years. A more coherent, powerful and compelling narrative is needed around the PM ecosystem in Scotland and its key differentiators

  > Encourage **stronger collaboration between key PM assets and centres of excellence** (e.g. the Clinical Innovation Zone at QEUH, BioCity and the Edinburgh BioQuarter etc.), with support from Scottish Enterprise, ensuring a fully integrated offer combining both hard and soft enabling infrastructures

- **Lack of clarity on the skill-sets required to grow and develop the PM cluster in Scotland**

  > Invest more in targeted PM and bioinformatics and AI for Health skills development programmes – the integration of different skill-sets will be key to developing and maximising Scotland's PM opportunity

Key ambitions and investment proposals

21. Building on the evidence and feedback from SIA Steering Group members and framed by the potential high-level benefits outlined above, we have identified the following key action areas for Scotland to maximise its existing and emerging strengths in PM:

- **Integrate complementary regional strengths in Data and PM** – Scotland now has a potentially transformational opportunity to combine the regional strengths in Data Science and PM, particularly in Edinburgh and Glasgow, to accelerate the implementation of PM and achieve long-term economic impacts for Scotland through NHS savings, a healthier and more productive workforce, and growing Scotland's PM focused business base
- **Develop the QEUH as a 'living lab' to realise the potential of PM and drive economic growth** – the new hospital campus provides an exciting and timely opportunity to pilot the adoption of PM within the UK's largest health board. This will enable the scalable Real World implementation of PM, demonstration of savings to the NHS and patient benefit by the use of health economics, and accelerating the growth and development of the flagship PM cluster in Scotland, creating high value jobs in Govan, an area of historic high unemployment and disadvantage
- **Create next generation clinical decision support tools or 'clinical cockpits'** – these tools will be developed by making use of Scotland's enviable access to large databases of relevant patient data (with governance through Scotland's Safe Havens) to allow the relevant models of population based precision pathways of care to be built. They will also involve clinicians to guide the design and development of these next generation clinical cockpits, and will utilise advances in AI. These tools will be applicable elsewhere in the UK and by other global care providers
- **Develop SMS-IC as a gateway to 'Scotland's Ecosystem for PM'** – broadening out the initial work undertaken by the SMS-IC, to develop tools for PM such as omics, imaging, and digital pathology, work with the NHS on the regulatory aspects and implementation of PM, strengthen the application of health economics and build stronger links with global pharmaceutical and diagnostics firms.

BioClavis is a personalized diagnostics spin-out of US based BioSpyder Technologies. In early 2018, BioClavis set up at the Queen Elizabeth University Hospital (QEUH) campus in Glasgow supported by a £3.4m R&D grant from Scottish Enterprise. The parent company BioSpyder was set up in 2011 and developed a novel product for targeted sequencing called TempO- Seq™, a transcriptomic/ genomic platform technology. It has five employees in Glasgow.

BioSpyder considered a range of locations around Europe (in the UK, Ireland, Germany, Switzerland, Netherlands) but soon realised the QEUH in Glasgow was the best location for setting up BioClavis. The first key attractor was the scale and quality of clinical data and samples that they would be able to access. QEUH has one of the largest pathology laboratories in the UK and Europe, and a large biorepository, which is networked to others across Scotland. The company also saw the networking infrastructure as a real asset of Glasgow, specifically the integration of industry, academics and clinicians at the Clinical Innovation Zone.

Networking and collaborating

22. The development of this SIA has been shaped by an open, inclusive and wide-ranging programme of stakeholder engagement and consultation. This has included consultations with 45 stakeholders, in-depth case study research to showcase examples of PM excellence and knowledge exchange on the ground, regular meetings with the SIA Delivery Team, as well as continuous 'check and challenge' provided by the high-level SIA Steering Group.
23. We are at the start of an exciting process to scope, define and implement the key growth opportunities for Scotland in the context of a rapidly evolving and highly competitive global PM landscape. Informed by these SIA findings - and indeed the two previous Scotland SIAs, which focused on enabling technologies and data driven innovation - consortium partners are now much better equipped to focus their effort and investment on those niche areas where Scotland is either currently leading the world or has the potential to do so over the next 10 years.
24. The process of developing this SIA has increased the profile and understanding of Scotland's areas of comparative advantage for both internal (Scottish) stakeholders and wider UK and international partners. There is now a clearer understanding of the PM opportunity within the Scottish Government and its agencies. The SIA foreword provided by Scotland's First Minister reflects this strong policy support, and plans are being developed for Scotland to host an international 'Summit in Precision Medicine', to showcase Scotland's highly differentiated and internationally significant PM focused capabilities.
25. Importantly, our consortium is confident and bold enough to know that competitor areas elsewhere in the UK and beyond are also moving fast in relation to PM innovation and adoption. Therefore, we are already using the SIA process and audit report to help us demonstrate to others where and how Scotland can contribute to this exciting global agenda.
26. Indeed, we have a long and proud history of collaborating with the best and we will continue to do this where there are clear complementarities and strong alignment with our strategic objectives. For instance, constructive discussions with the Northern Powerhouse have already taken place and these are giving rise to new partnerships, collaborative ideas and areas of joint working. The partners involved in SMS-IC have also been using the SIA process to highlight Scotland's opportunity and explore new collaborations with partners in Finland and British Columbia in Canada.
27. Encouragingly, the SIA process has energised partners, strengthening their commitment to realise our vision and provided an opportunity for them to foster new relationships across the ecosystem. It has enabled us to shine a spotlight on Scotland's impressive and internationally recognised PM related capabilities. Informed by robust evidence, we have identified a number of targeted new investment propositions designed to complement our existing activities and take us towards our long-term goal of translating Scotland's well-established scientific excellence into innovation-led inclusive growth. Many of the pre-requisites for success are in place, but this SIA report has revealed some important gaps which we are determined to fill so we can grow a large and dynamic cluster of exporting frontier firms.

SUMMARY REPORT
DECEMBER 2018

SOUTH WALES CRUCIBLE
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THE SOUTH WALES CRUCIBLE

A Science and Innovation Audit Report

Sponsored by the Department for Business, Energy & Industrial Strategy

INTRODUCTION

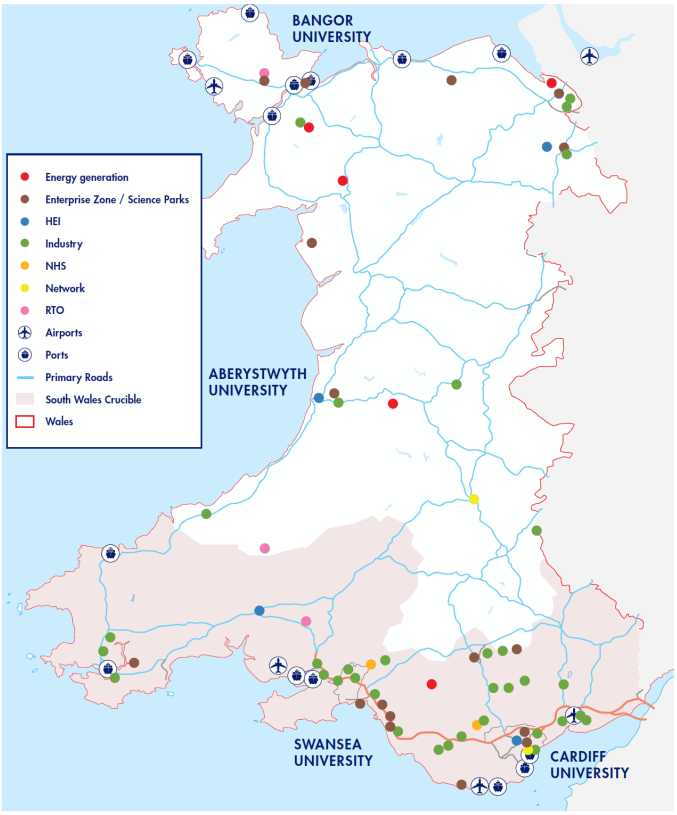
1. In Autumn 2015 the UK Government announced regional Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential. The South Wales Crucible consortium was formed in 2017 to focus on our strengths in steel innovation, smart manufacturing, health innovation, agri-food tech, digital technologies and sustainable energy. This report presents the results which includes broad-ranging analysis of the South Wales Crucible area's capabilities, the challenges and the substantial opportunities for future economic growth.

2. The South Wales Crucible SIA consortium includes world-leading universities (Swansea, Cardiff, Bangor and Aberystwyth), research centres of excellence, internationally significant firms. The consortium is supported by the Welsh Government and aligns with Wales' two City Deals and the proposed Growth Deals for Mid and North Wales. Importantly, although rooted in South Wales, the reach of our SIA consortium extends across all of Wales, including key science and innovation assets in places as diverse as Deeside (focused primarily on automotive and aerospace), Bangor (energy) and Aberystwyth (agri-tech). Additionally, it has strong links to leading sectors, clusters, universities, Research and Technology Organisations (RTOs), science parks and innovation districts across the wider UK and globally.

3. The process of developing the South Wales Crucible SIA was a highly collaborative and engaging one. Weekly meetings were held between theme leads to provide an open forum for discussion and to allow the synergies between the themes' different capabilities to be identified and clearly articulated. The emerging evidence was robustly tested through an extensive programme of business and wider stakeholder consultation. In total, over 70 organisations have contributed formally to this process and many more informally.

4. The core geography for our SIA covers the 14 local authority areas that make up the Cardiff Capital Region and Swansea Bay City Region. However, each thematic area of our audit has a slightly different spatial footprint to reflect the underpinning distribution of science and innovation assets across Wales. For example, our Health Innovation theme focuses on the academic, clinical and business strengths in South Wales, whilst our Agri-Food Tech theme looks pan-Wales to reflect our dispersed primary production base.

Figure 1: The South Wales Crucible geography



Source: Produced by SQW 2018. Licence 100030994. Contains OS data © Crown copyright [and database right] [2018]

OUR VISION

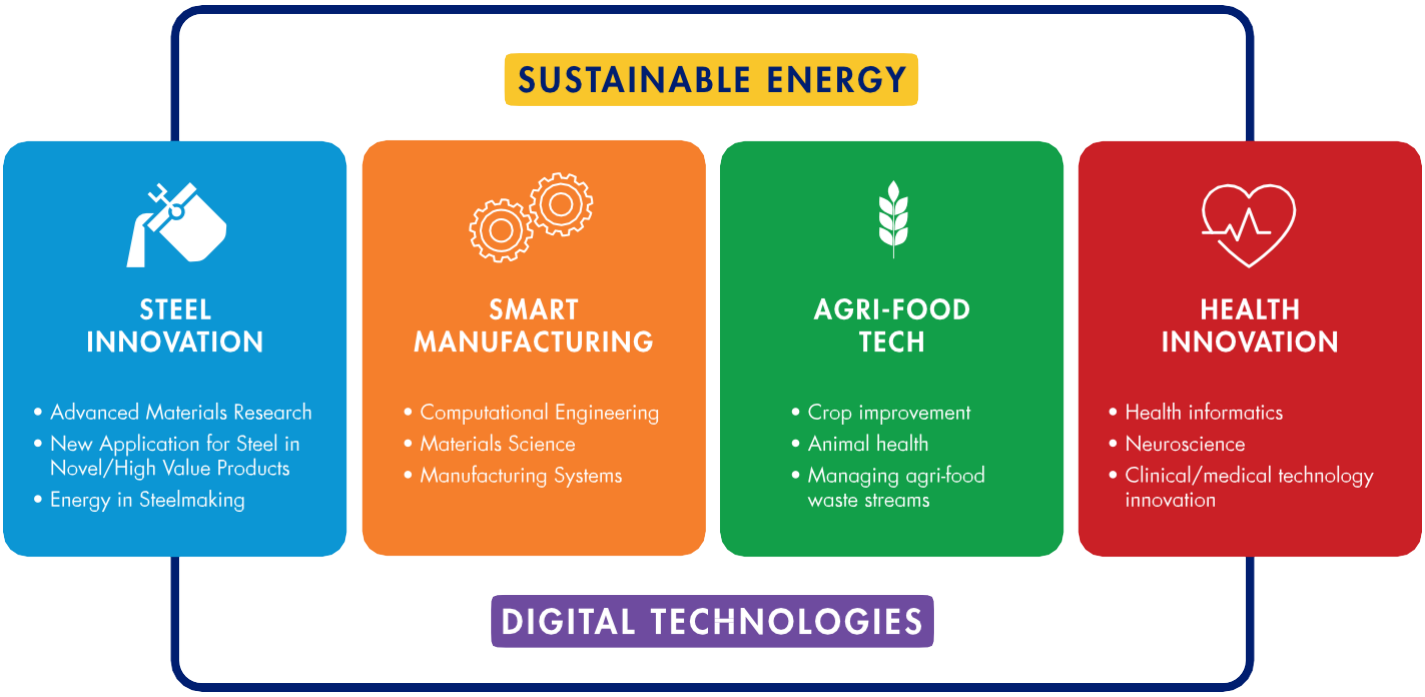
5. Both our long-standing and emerging world- class research and innovation strengths have shaped the SIA hypotheses, which are framed by four core thematic capabilities of steel innovation, smart manufacturing, health innovation and agri-food tech. These themes are underpinned by two enabling competencies of digital technologies and sustainable energy – with the latter being particularly important for our steel innovation and smart manufacturing agendas.

6. Importantly, our core themes have not been considered in isolation. The evidence presented throughout this SIA report points towards a need to foster stronger interdisciplinary linkages across and between these areas of excellence so that we can achieve our full productivity potential. By doing so, we will support the UK as it embraces both the challenges and opportunities presented by industrial digitalisation, AI and the data economy, clean growth and an ageing society.

Overview of the South Wales Crucible Innovation Ecosystem

Source: SQW analysis (full references in Annex D of Full SIA Report)

THE SOUTH WALES CRUCIBLE SIA THEMATIC AREAS



Source: SQW on behalf of the South Wales Crucible, 2018

STEEL INNOVATION

A global leadership position for the UK can be secured through the creation of a hub for steel innovation by building on and expanding existing research excellence in the South Wales region, and investing in innovation within the UK steel industry and wider supply chain.

SMART MANUFACTURING

Sustainable Smart Manufacturing will bring a step change in performance for the regional and wider UK economies through enhanced global competitiveness and productivity. In Wales this will be achieved through investment in existing capabilities and key assets in advanced manufacturing to accelerate convergence with digital and energy enabling technologies. This will deliver the most efficient and productive methods for manufacturing sustainably, creating value in new and different ways.

AGRI-FOOD TECH

Accelerated process efficiency, productivity growth and economic sustainability will be delivered through world-class research into improving primary production, specifically through improvements in crops, animal health and the waste streams from the agri-food supply chain.

HEALTH INNOVATION

Developments within data driven life-long health and mental health will be accelerated by the creation of an interconnected test bed for innovative developments in healthcare, drawing on our clear and distinctive strengths in health informatics, neuroscience and clinical/medical technology innovation.

KEY STRENGTHS

7. Our internationally significant strengths identified and evidenced through this audit are summarised below:

STEEL INNOVATION

We have a renowned cluster of steel and metal processing industries, customers and suppliers, all of which are supported by research excellence. Our research is led by Swansea's newly formed Steel and Metals Institute and the Wolfson Centre for Magnetics at Cardiff. TWI Wales at Port Talbot is another key asset. On the industrial side, Tata Steel has five facilities in Wales, whilst Celsa Steel, Liberty Steel and Cogent Power have large operations in the Cardiff and Newport areas. These anchor firms are complemented by anumber of internationally recognised downstream customers including: Sandvik Osprey, a global leader in the production of gas atomised metal powders; Timet, who supply a fifth of the world's titanium; Welsh Government anchor companies Ford and Valero; and the Royal Mint.

SMART MANUFACTURING

Our academic strengths in Computational Engineering and Materials Science are complemented by well-established strengths in Manufacturing Systems in both industry and academia. Demand-led by industry, the EU-backed multi-University ASTUTE 2020 project (Swansea, Cardiff, Aberystwyth, University of South Wales and University of Wales Trinity Saint David) is working together with the Welsh Manufacturing Industry to embed advanced and sustainable future manufacturing technologies through knowledge exchange. As defined by the Welsh Government, the Advanced Manufacturing and Materials industry has almost 3,000 enterprises and employs 86k people across Wales, including multinational firms such as Airbus, Ford, GE Aircraft Engine Services, Panasonic, Renishaw, SONY and Toyota.

AGRI-FOOD TECH

We have globally significant strengths in agri-food tech scientific research, specifically on crop improvement, animal health and managing agri-food waste streams. Our academic strengths are pioneered by the Institute of Biological, Environmental and Rural Sciences (IBERS) at Aberystwyth - one of only two BBSRC institutes embedded in a UK University - which conducts internationally recognised research and delivers a commercial impact, estimated at £365m in GVA terms over 2012/13. Some 88% of Wales' total land mass is agricultural land and on farm employment is up to 54k people, so we also have a diverse primary production base.

HEALTH INNOVATION

We have identified clear strengths in health informatics, neuroscience and clinical/ medical technology innovation. This combines members from our academic, business and clinical communities. Diagnostics is another focus area. On the academic side, the medical schools of Cardiff and Swansea universities host extensive research and innovation strengths. Complementing this, Wales' diverse Life Sciences business base employs around 11,000 people in over 350 companies with a combined £2bn annual turnover. Our clinical assets include the Welsh Wound Innovation Centre – the world's first national wound healing centre.

8. Cutting across these thematic areas of strength, our SIA has also consistently highlighted the importance of our competencies in the underpinning areas of digital technologies and sustainable energy. For example, by exploiting synergies in relation to our big data and health informatics capabilities, as well as lowering the energy input costs for our major steel producers and advanced manufacturers.

GROWTH OPPORTUNITIES

9. Through the SIA process we have identified existing and emerging areas of international science and innovation excellence that have the potential to boost productivity - both for South Wales and the UK as a whole. As highlighted earlier, we have impressive, strong foundations to build on, including research intensive universities, a high concentration of incubators and accelerators, many world-class anchor firms, and strong policy support through the Welsh Government's commitment to driving innovation-led inclusive growth.

10. Through a mix of desk based research, stakeholder consultation and workshops we have identified specific ways in which our thematic and enabling strengths can help us close the region's sizeable productivity gap. These are summarised below:

Steel Innovation The creation of a hub for steel innovation will build on and expand our existing strengths in advanced materials, new applications for steel in novel/high value products, and energy in steelmaking. A more productive, less energy intensive steel industry will enhance our international competitiveness, making the UK steel industry, and its downstream dependents, more sustainable.

Smart Manufacturing When our academic and industrial manufacturing strengths are combined with our underpinning strengths in the enabling technologies of digital and sustainable energy, we have the ability to raise the productivity and long-term competitiveness of our broad base of manufacturing companies. However, in order to realise these productivity gains, we must support our SMEs to invest more in leading edge technologies and advanced skills – particularly in relation to digital.

Agri-Food Tech By translating our innovative process and technology developments into practice, our primary producers can improve their productivity performance. This both increases their exporting potential and also provides higher quality inputs for our large food and drink processing industries, thus boosting their long- term competitiveness and resilience.

Health Innovation By combining our powerful digital health infrastructure and focused life science research institutes, new industry developed products and health service developments can be rapidly piloted and commercialised. Our companies and partner health research charities will benefit from faster access to more comprehensive data on drug/ device performance than is currently available, thus accelerating and de-risking future R&D activities. This will make Wales and indeed the UK, an attractive and distinctive location for foreign investment and high value job creation.

11. By fostering stronger linkages across and between our areas of excellence and our enabling strengths in digital technologies and sustainable energy, we will ensure that our economy is 'more than the sum of its parts.' This will enable us to achieve our full productivity growth potential. For example, the core themes provide digital and sustainable energy innovators with powerful and disruptive drivers to create new demand-led technologies that will be applicable in products, services and sector domains beyond the core thematic areas that run throughout this audit report.

GAP ANALYSIS

12. Whilst this audit has identified an impressive range of science and innovation strengths, it has also highlighted some key areas for improvement within the ecosystem, notably around our persistent productivity gap. We also face difficult challenges on access to skills and both innovation funding and growth finance, including having a relatively low share of UK business R&D expenditure.

13. Although there is a diverse set of challenges within and across our four core themes, there are also some important commonalities. For example, connectivity across parts of our geography is relatively poor and too many barriers exist around some elements of our key translation or commercialisation pathways. For instance, it is still difficult for early stage innovative life science firms to access the right clinicians within the NHS and suitable regulatory support at the right time, whilst many of our manufacturing SMEs do not have the requisite digital and data science skills needed to fully embrace the industrial digitalisation agenda. Addressing these challenges effectively and quickly will be essential if we are to close our productivity gap and maintain our existing areas of excellence.

KEY AMBITIONS AND PROPOSALS

14. The South Wales Crucible has brought many different academic, industrial and government partners from across Wales together to create a powerful new economic grouping to compete internationally and accelerate the growth of our local economies. We already work together effectively, but the audit has brought a sharper focus to our partnership working and this will be maintained over the coming years as we seek to tackle those important grand challenge areas discussed above. By addressing these gaps in our ecosystem and seizing some of the exciting growth opportunities that have emerged through this SIA process, we can make positive and lasting progress towards unlocking Wales' - and by extension - the UK's full innovation-led growth potential.

15. To do so, we will need to make best use of emerging funding opportunities to build on our current strengths and rapidly emerging areas of excellence. Potential funding sources include the Strength in Places Fund, relevant calls under the Industrial Strategy Challenge Fund, and the Growth Deals for both Mid and North Wales, which are currently in development. We are also mindful of the Reid Review and the identified need to give wider access to Welsh innovation funding, partly though potential new innovation hubs across the country, where different parts of the innovation ecosystem can interact and complement one another.

16. The table below shows some of the key ambitions and proposals emerging from this SIA process. Two of these are expansions to projects that have been approved in principle, but have not yet started delivery (The National Steel Innovation Centre and the Factory of the Future). The others are ambitious new proposals which will be further honed and refined over the coming months. As a consortium, we very much look forward to working collaboratively with the UK/Welsh Governments, anchor universities and the private sector to realise these exciting propositions.

Table 1: Proposed action areas for driving UK productivity growth

The National Steel Innovation Centre (NSIC)	
Description	Building on SaMI, and the underpinning regional role cluster of businesses and innovation assets, the NSIC will provide research excellence at Technology Readiness Levels 4-9 in both processing methods and product development. Steel technologists will be co-located with academic and research staff from Swansea and key UK partner universities to support knowledge exchange. Specific areas of expertise will be in low carbon steel making, carbon capture and utilisation/storage, materials processing and characterisation; process and product innovation; energy efficiency and environmental sustainability, all underpinned by the circular economy and industry 4.0 principles. A £23m capital investment has been confirmed for a state of the art new Innovation Centre and specialist equipment, which will be enabled by a £20m investment from the Swansea Bay City Deal, along with £3m from HEFCW. Consultation with industrial and academic partners identifies a requirement for an additional £10m capital investment to be raised to support this project for new equipment and existing equipment upgrades. Resource for future core funding via project grants and competitive RCUK/UKRI mechanisms will also be required to help sustain the centre and support future new staff and research project costs. NSIC aims to have 200 staff by 2025, including Engineering Doctorates and apprentices.
Objectives	• Build on regional excellence to address the current and future challenges of sustaining steel-making capacity in the region and the wider UK. • Create a vibrant multidisciplinary environment equipped with state of the art research equipment to deliver innovative solutions to industry defined demand- led problems across the UK. • Help safeguard around 11,000 steel industry jobs in Wales and a further 20,000 in the UK steel sector, with the potential to create a further 1,000 jobs in the Swansea Bay City Region. • Help to maintain the international competitiveness of the some of the UK's most important industries, which are heavily reliant on steel products e.g. automotive and construction.

	The Factory of the Future
 **Description**	The Factory of the Future and an aligned Active and Intelligent Digital Twin Institute are proposed to be an academia-industry R&D&I hub operating out of Swansea University and using next generation technologies to provide technical solutions for smart manufacturing businesses with state of the art facilities and a multidisciplinary team of experts, hereby building on existing investment in the Bay Campus, IMPACT, the Computational Foundry. The Swansea Bay City Deal will enable a £10m mainly capital investment as seed funding for basic infrastructure, limited purchase of equipment, and employment of an essential team of staff. To enhance the potential for impact, additional capital and revenue funding is required to build on the Phase 1 investments. Securing additional capital funding would enable infrastructure enhancement and future proofing (c.£5m), and the purchase of additional equipment (£2m for an additional first fit-out, and c.£500k per annum thereafter) to add required function. Additional revenue funding (c.£3m per annum) will be required to form a highly effective multidisciplinary delivery support team.
 **Objectives**	• Build on the Bay Campus investment (ASTUTE, IMPACT, Computational Foundry) and the pioneering landscape of the Swansea Bay City Deal Internet Coast (The Factory of the Future) by establishing a multidisciplinary team of engineers and computer scientists in a fully equipped open innovation environment to work on industrial digital technologies such as digital twins. • Create an ecosystem capable of manufacturing innovative products developed within the region, and also attract inward-investing manufacturing demand. • Support local businesses to increase their competitiveness by de-risking and accelerating the uptake of industrial digitalisation technologies using the SBCD Smart Manufacturing Pillar as seed facility and the driver to roll out across the Nation, thus boosting the regional economy and reducing the productivity gap. • Safeguard 158,000 Welsh manufacturing jobs, and maintain or better the c.3% per annum. average GVA growth rate achieved over 2006-2015.

CS Connected and Integrative Semiconductor Materials	
Description	The future focus will be to firmly establish the CS cluster on the international stage. This requires concerted effort to land multiple Foreign Direct Investment (FDI) projects from major international players in the CS supply chain. Currently there are in excess of ten FDI opportunities in play, but there are significant gaps in the collective infrastructure to facilitate customised, persistent FDI projects that critically engage the existing supply chain, and promote indigenous spin out activity derived from the CRD investment. Meeting the objectives defined above will facilitate increased FDI, as well as addressing the skills gap.
Objectives	• Establish the cluster on the international stage – increasing FDI flows. • Expand the cluster and create incubation and acceleration space across the region to support indigenous business growth. • Provision of training to enhance skills across all levels from NVQ to PhD. • Demonstration platforms to showcase the innovation and manufacturing elements of the cluster via a series of CS Accelerator centres in areas such as 5G, Automotive, Data-communications, Power, Energy and Healthcare.
Agri-tech Commercialisation: The Agricultural Futures Innovation Platform (AFI)	
Description	The Agricultural Futures Innovation Platform will be co-located with Aberystwyth University and the extensive agri-food assets in Wales. It will bring together interdisciplinary experts from agriculture, biosciences, veterinary sciences, artificial intelligence and remote sensing/earth observation disciplines to enable food, energy, and chemical supply chains to develop more competitive products and services from agricultural land. Through the Platform, existing jobs will be safeguarded, new jobs will be created through diversification of products and services, and new export opportunities of expertise and zero carbon footprint services (e.g. in digital and remote sensing) will be established. The Platform will have wider impacts for livestock health and welfare. It will also enable the development of responsible and informed ecosystem services and land management, and enable the productive use of marginal land.
Objectives	• Create unique test beds for product and service development from lowland and upland holdings. • Enable economically viable diversification of land use to alternative, post carbon products and services. • Successfully integrate digital, big data and cyber security technologies into agricultural product and service developments of the future. • Train and inspire the next generation of producers and suppliers to adopt step change technological advances into agricultural practices and enable knowledge exchange.

Centre of Excellence for Integrated Diagnostics	
 **Description**	Integrated diagnostics are vital to the future of healthcare in underpinning precision medicine and prudent healthcare. SIA assets relevant to these and other health disciplines will support the "living laboratory" across the South Wales Clinical Innovation Corridor to address healthcare needs and create commercial opportunity. Within this framework the Centre of Excellence for Integrated Diagnostics will consist of a physical centre and virtual network model to maximise flexible engagement opportunities and expand national and international reach. Specific areas of expertise would be supported in measurement technologies, imaging, molecular diagnostics, medical and wearable devices, AI and data driven diagnostics. As with other health innovations developed within the Clinical Innovation Corridor, end-user, NHS and industrial interaction will be key to the Centre's long-term translational research aims and so involvement will be integrated at strategic, operational and research levels to ensure that end-user demand and commercially viable prospects are supported. The establishment of a flagship Centre of Excellence within the Clinical Innovation Corridor and close interaction with the unique NHS Wales structure as a nationally facing test-bed will stimulate further collaboration with industry to deliver economic growth and income as well as delivering patient, health economic and socio-economic benefit.
 **Objectives**	• Interconnecting disciplines: Build on excellent multidisciplinary capabilities by facilitating novel step-change advances in a 'connect the dots' approach. • Collaboration culture: Create capacity for collaboration along the Clinical Innovation Corridor, bringing together industrial (indigenous and inward-investing), academic and clinical researchers and innovators. • Research pipeline and translational support: Improve the translational efficiency and success rates of transferring and integrating devices, technologies and services into clinical settings. • Skills: Improve the interdisciplinary interactions between disciplines. • People: Improve the interaction with end-users to create a more informed development pathway.

Energy Systems Commercialisation Demonstrator	
Description	Building on the FLEXIS consortium of world-leading energy research capability in South Wales, the development of integrated demonstrator sites across South Wales will provide the specialist technical and innovation capacity to maximise the exploitation of a variety of new technologies. The proposed facility will consist of a multi-vector digital twin of the energy system, and a series of interlinked practical demonstrators that will enable the technical and commercial potential of novel technologies to be evaluated. Once tested and de-risked, such technologies can be scaled up to maximise their societal, economic and environmental impact.
Objectives	• Create interlinked demonstrator sites that will support the development of fully integrated multi-vector energy systems to address the challenges of decarbonising energy generation, storage, distribution and consumption. • Build on regional excellence in energy research to address the current and future challenges of the low carbon economy. • Support the upskilling and training needs of the rapidly expanding energy sector.

Source: South Wales Crucible

NETWORKING AND COLLABORATION

17. The process of developing an SIA with such a broad coverage – both in terms of spatial footprint and thematic focus – in six months has been challenging. However, it has provided a great opportunity for the SIA consortium members to engage with different stakeholders across Wales. Our universities, businesses and the public sector, including the NHS, already have a strong track record of collaboration, but through this audit process, new relationships have formed and existing ones have strengthened. By having a clear focus and timetable, partners from different organisations and, crucially, different disciplines have worked directly together for the first time. For example, the weekly meetings between theme leads allowed networks to be formed between energy researchers from one institution and agri-tech specialists from another; something which may not have happened without the SIA. Similarly, digital experts were supported to engage with industry representatives and academics from across Wales' steel innovation agendas. It is this 'cross fertilisation' which has contributed most in terms of stimulating new ideas in response to common challenges and rapidly converging drivers of growth.

18. More broadly, the SIA process has reinforced the importance of building and maintaining effective industry-academia collaborations. All of the universities involved in the SIA already have this at the heart of their institutional strategies, and the SIA has ensured that it will remain in place going forwards.

19. In keeping with the SIA ethos, and as set out above, we are committed fully to improving regional and national productivity by collaborating with partners to build on our existing strengths and to reinforce our emerging areas of excellence. To ensure that our SIA maintains momentum and acts as a powerful catalyst for change, we are planning the following strands of activity:

- Holding a post-SIA publication event and schedule a conference to engage with stakeholders and promote the work of the South Wales Crucible more widely
- Establishing a Steering Group to carry forward our action ideas and recruit further partners to our consortium.
- Ensuring that the SIA report remains a relevant document and is used to help shape regional policy and investment. This may include for example, drawing on evidence from the audit in the Research and Innovation Strategies of our universities, as well as by adding the SIA to the agenda of high-level strategic meetings in Wales e.g. meetings of the Pro Vice Chancellors for Research.
- Forming strategic regional and national links on initiatives with other relevant SIA consortia to improve linkages that will ultimately help the UK to deliver increased productivity and prosperity.

Upstream Space: A Galaxy of Capability

An Audit of Upstream Space Capability in The Oxfordshire-Cambridgeshire-MK-Herts Corridor; M3 Corridor & Solent; Greater East Midlands; Scotland; Wales; and Northern Ireland.

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

SUMMARY REPORT
Autumn 2018

Introduction

The UK has a rich and proud heritage in the global space sector. Since the 1950's UK has been an integral part of both the economic and scientific growth in space systems and space applications. From the early days of experimental satellite manufacture, UK is now producing the heart and essential systems for 25% of the worlds telecommunications satellites in what is now a mature commercial market. UK has contributed significantly as a member state within the European Space Agency, to space science, space exploration and earth observation missions, and is now a trusted prime contractor for global flagship missions such as Exomars Rover, Solar Orbiter and Biomass.

The UK has also embarked on unique and breathtaking adventures of our own, such as the iconic Black Arrow rocket, which flew successfully in 1971, to the Beagle 2, which landed on the surface of Mars in 2004. The re-invigoration of a National programme supporting future 'UK-own' and bilateral opportunities is a cornerstone of the recently submitted Space Sector Deal proposal.

Over the years the UK has had an extraordinary cornucopia of capability, demonstrating world-class expertise in a broad spectrum of fields at every step of the upstream space value chain, that process, that designs, tests, manufactures and launches satellites and spacecraft, and then is able to operate them from Earth. However, in order to realise this, investments of time, effort and finance must be made across the UK's excellent industrial and academic base to ensure that these exciting developments keep pace with our competitors internationally and are effectively aligned so as to offer a sleek, coordinated suite of services and capability to our investors, users and partners.

This audit has, for the first time, brought together stakeholders from across the parts of the United Kingdom with significant critical masses of upstream-space activity to focus on their strengths in and understand where investment and effort may fortify and prepare these assets for the future.

It is worth recognising that this audit is not intended at this stage to be a comprehensive national audit and is broadly confined to the geographic regions represented in the Consortium. It is therefore also recognised that key competencies within some areas are not currently included, but that future maintenance and development of this audit will expand both its geographic and technical scope.

Sky High Aspirations

Since 2000, the UK space sector has trebled in size, and grown at a rate of 8.1%, five times greater than the UK wider economy over the same period, while productivity is over three times the national sector average. Yet this is only the beginning.

In 2010, the Innovation & Growth Strategy (IGS) for Space outlined a challenging and inspirational target of growing the UK's share of the estimated £400 billion[1] global space market by 2030 from 6.5% to 10%. Space already is a UK success story; a strong presence in global commercial markets, a powerhouse of innovation, a bastion of engineering and scientific excellence, and can boast a world-class, highly productive workforce across many areas. As a result, the space sector supports 14% of UK GDP, some £250billion[2], which the Space Growth Partnership aims to double to £500billion, attract £3billion of inward investment, and provide 100,000 new jobs.

To achieve the IGS targets, we must build on the sector's core strengths and established market position, and in addition encourage companies to pursue new commercial opportunities from the UK, which offers an excellent location for space launch into in-demand polar orbits, with a world-leading satellite industry, and reputation for regulatory excellence. While the space industry in the UK is booming, much more needs to be done at pace to capture this intended market share.

The decision to leave the EU creates a particular need for agility. The UK must develop new and enduring international partnerships, while retaining the industrial corporates already embedded within the UK. We must also stimulate investment into UK businesses and attract new inward investment. The focus on facilities, innovation and skills to support rapid, volume production of mid-weight satellites in particular, is highly relevant. This in the context of Newspace trends towards constellations of smaller satellites, UK Launch status & the associated need to develop a robust supply chain, Brexit resilience and specifically the potential requirement to respond to the EU's potential abrogation of the UK's involvement in the Galileo Programme.

The Science & Innovation Audit for Upstream Space will be aligned with the Sector Deal for Space to act as a call to investors to recognise the strength and depth that the UK Upstream Space sector offers – in particular in the context of the highly dynamic and growing space market where industrial and market position will become established in the next few years.

Benefits of Upstream Space

Market forecasts indicate that downstream applications will be the major source of economic growth in the space sector in the coming years[3]. However, strong presence in the upstream sector is essential to secure a 'virtuous circle' of capability across the value chain. The detailed knowledge and competence that comes from upstream engagement underpins the development of standards and operations that are the basis of downstream end user applications.

[1] Space IGS Update, July 2015, http://www.ukspace.org/wp-content/uploads/2015/07/Space-IGS-Report-Update-July-2015.pdf

[2] Satellite Applications Catapult Press Release, 11 May 2018

[3] https://www.gov.uk/government/publications/space-growth-action-plan

For example, mastering the technology for space-based digital payloads allows a direct understanding of satellite operator needs for power and bandwidth flexibility, and being able to optimise this in an upstream design solution can prove decisive in a global competitive environment. Similarly, radar system competence is directly relevant to support delivery user applications related to surveillance, climate change and flood management. The UK is a thought leader in downstream space-based applications, and it has a strong established upstream and emerging innovative capability. Continuing efforts to maintain and build this 'virtuous circle' in the UK will help to grow market position in the face of increasing global competition.

Upstream Space delivers a range of services to both public and private customers and users, bringing scientific and economic benefits and providing critical information to the security, meteorological and environmental sectors.

It provides infrastructure on which modern society depends. From multinational businesses such as Sky and Uber, to local farmers who use satellite data to help manage their crops, the products of upstream space have been developed and exploited to create capabilities that have become a part of everyday life. This will only increase as our understanding of how to use space data improves, enabling us to face ever more complex challenges, both on Earth and beyond.

In the science and planetary exploration domain, Upstream Space is what enables scientific investigation and pioneering. The engineering and manufacturing capabilities that have supported missions such as Rosetta, Mars Express, and Lisa Pathfinder have ensured that the science instruments are delivered safely into space, provided with resources to allow experiments and investigations to continue in the harshest of environments throughout the satellites' lifetime. Having major roles for this kind of mission in the UK allows close links to UK scientists, development of the UK supply chain and the ability to inspire young people through outreach and public media. Finally, upstream space has an almost unique ability to excite and inspire young people – our next generation of scientists and engineers not just in the space sector but across the whole UK economy.

WHAT IS UPSTREAM AND DOWNSTREAM SPACE?

The space sector is divided into two complementary segments. The segment that makes and sends objects (satellites, probes, spacecraft and rovers) into space is conventionally called "Upstream". The segment that uses these objects to deliver products and services on Earth for largely commercial (but also environmental and scientific) exploitation, such as telecoms, is called "Downstream". The upstream segment overwhelmingly consists of space manufacturing: the design, manufacture of spacecraft, payloads, systems, subsystems, and components, and the infrastructure required to launch and operate them from Earth. This Science & Innovation Audit focuses on that **Upstream Segment.**

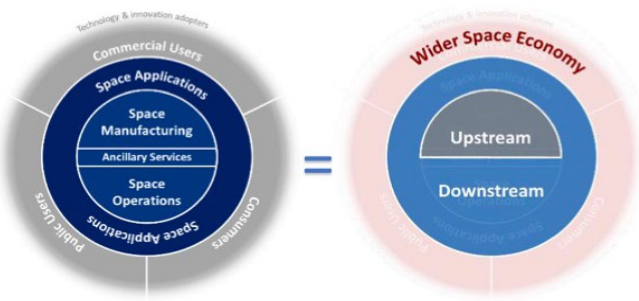


Image 1: where upstream and downstream sit in the wider space economy. Image credit: London Economics.

The Upstream Space SIA Regions

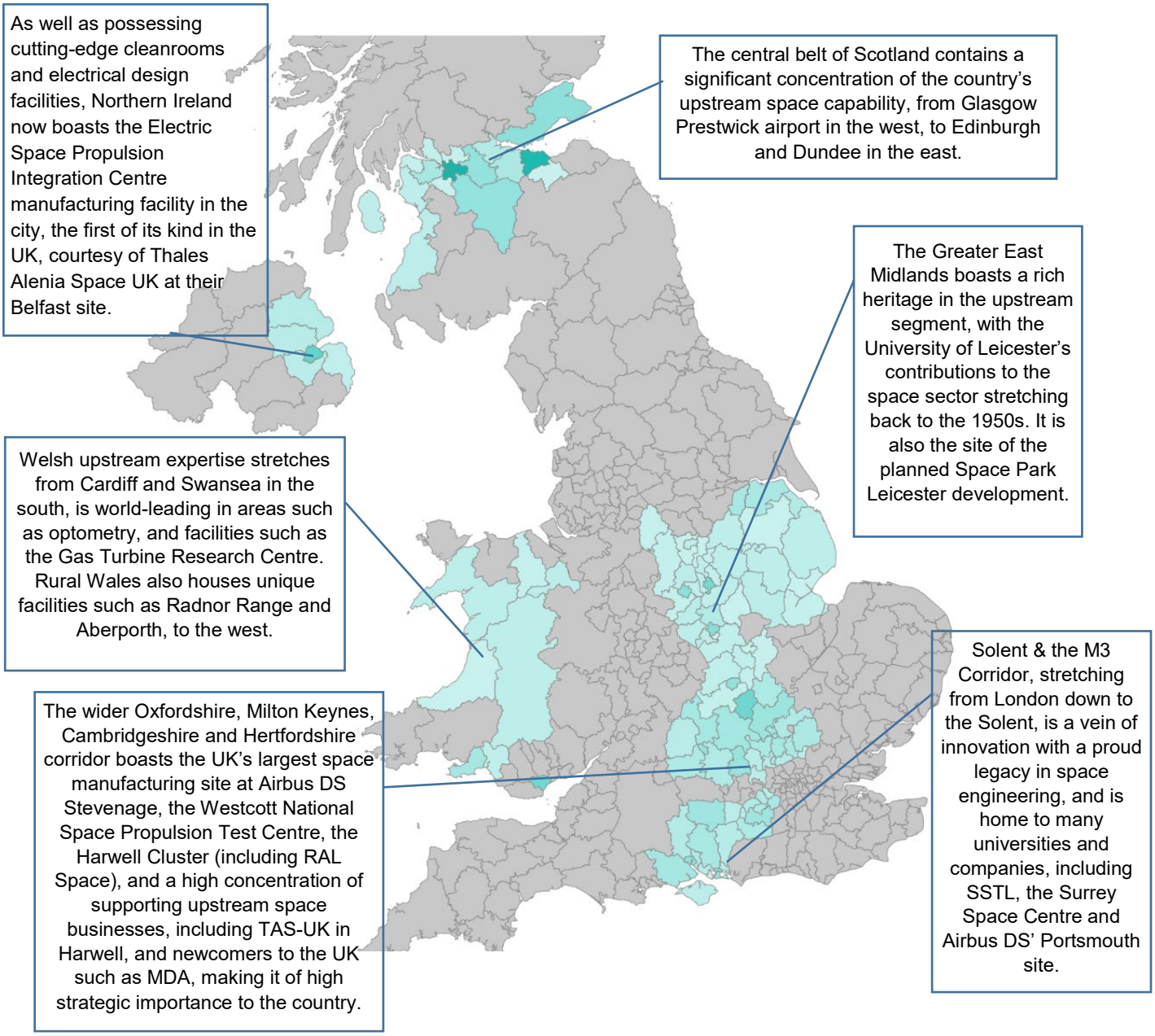


Image 5: Map of the UK, highlighting the regions making up the audited area for the Upstream Space Science & Innovation Audit. It is anticipated that, in future iterations of this report, the geographic breadth of the report will increase to provide a truly national picture of upstream space in the UK.

Our Hypothesis

Upstream Space is a maturing sector which is operating at levels of productivity higher than national average and generating substantive economic value as well as significant contributions to scientific and educational endeavour. The sector is facing a very dynamic market with high potential for growth and a complex external environment in the context of Brexit, global commercial competition and changing European institutional landscape.

As private sector companies continue to gather a foothold in growing upstream markets such as satellite launching, and emerging future markets such as exploration, construction, infrastructure assembly and mining, there is a unique opportunity for engineers, researchers, businesses and investors to get in on the ground floor.

The UK upstream sector has major assets that can contribute towards future success, relying also on cutting edge innovation, business entrepreneurship, export support, skills development and targeted investment to maximise potential of the collective UK effort. The Space Growth Partnership, in its Prosperity from Space strategy, has published proposals aimed at focusing the next steps to build future success. It is an extremely research-heavy sector at the cutting edge of the scientific and engineering arena. It returns value not only to the scientific community, but also economically, and is one of the very few sectors that continually and effortlessly captures the imagination of the public.

Harnessing diversity

The upstream space value chain across the UK has a wide range of diverse capabilities, all of which contribute to a thriving current industry base and help prepare for the future.

The UK Space Landscape created by the InnovateUK-funded Knowledge Transfer Network (http://space.ktnlandscapes.com/) reflects the following space manufacturing ecosystem:

- 1 complete space systems manufacturing organisation
- 40 companies involved with satellite and payloads manufacture
- 29 companies involved with launch vehicles and subsystems
- 19 ground systems and equipment suppliers
- 109 suppliers of materials and components
- 13 scientific and engineering support companies
- 4 providers of scientific instruments

The recent joint working within the Space Growth Partnership has resulted in a number of recommendations encapsulated in their “Prosperity from Space”[4] strategy document including a National Space programme which would complement the European institutional investment and further stimulate the upstream sector.

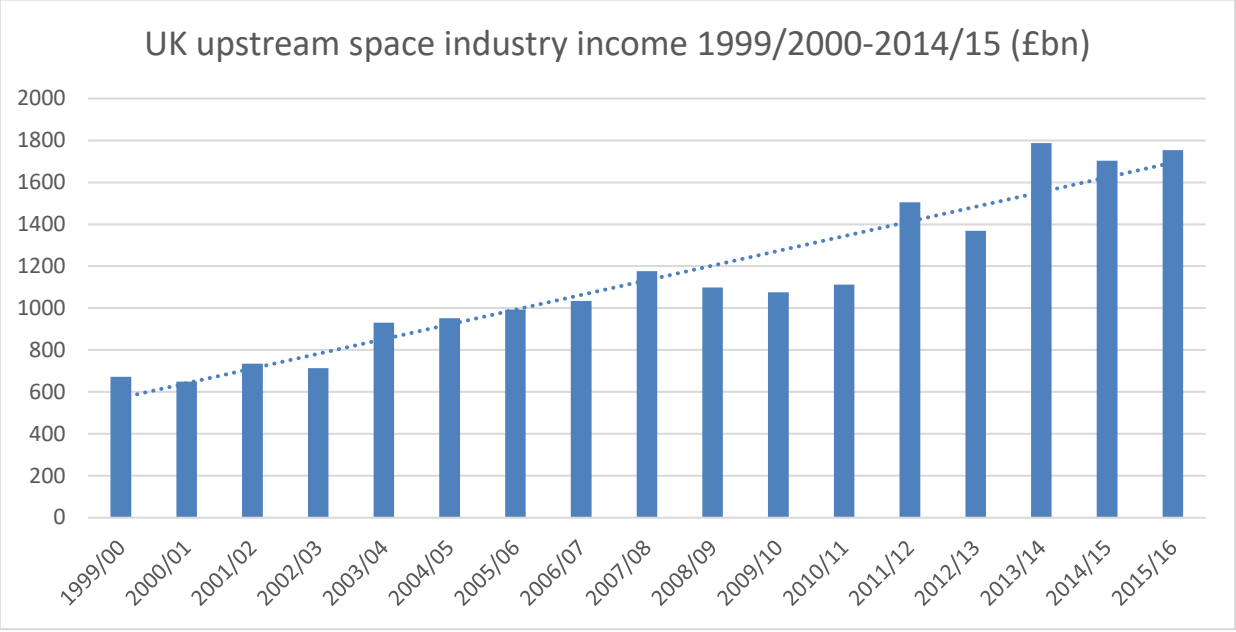
Whilst it is still expected that institutional investment will remain important to the sector as it continues to mature over the coming years, there is clearly increasing appetite for private sector investment in space. This is coming for example from ‘new space’ entrepreneurs and venture capitalists interested in the future commercialisation of space infrastructure, operations and services. The development of an attractive regulatory regime in UK to encourage inward

[4] http://www.ukspace.org/wp-content/uploads/2018/05/Prosperity-from-Space-strategy_2May2018.pdf

investment has been a recent focus – efforts in this direction should be maintained to keep UK competitive advantage vs other space nations.

We therefore believe that every effort should be made to:

- Showcase the economic benefits of Upstream Space to potential inward investors
- Increase investment from both private and public sources to protect new infrastructure, such as test centres and spaceports, and to enable the fundamental and applied R&D activities to continue to thrive
- Continue to build connectivity and mutual support across the whole UK upstream sector, including established global players and the wider 'UK Nationwide Cluster'
- Yet ensure activity at these individual, regional clusters, is doubled down and retains focus. Clusters grow organically, quickly and attract inward investment more effectively.
- Maintain R&D intensity through a dedicated and stable funding base for space manufacturing and ground segmentation technologies, and create the conditions in which companies are able to confidently re-invest in R&D.
- Support the UK's shaping of new markets through improved awareness raising of emerging technologies that will plug the gaps in the UK's value chain and drive down satellite manufacture costs to drive down the cost of downstream services
- Develop unique, strategic, industrially-focused infrastructure, such as the LOCAS (Low-Cost Access To Space) facility, with the potential to anchor business investment, and accelerate UK technical and manufacturing / production capability for 'newspace' markets.



UK Regional Strengths

The UK's greatest strengths are quite simple: the excellence of its workforce, and the excellence and intensity of its research base, and the breadth of industrial capability.

Upstream Space boasts a highly qualified, highly productive workforce in all geographic regions, and is the highest qualified of all sectors in England and Wales[5]. Productivity also is well above the national average. As this full audit focuses on a select few geographical regions, here we offer a summary of their main strengths and concentrations of activities in Upstream Space.

The Greater East Midlands

The Greater East Midlands has a cluster of nationally important space activity. The University of Leicester enjoys worldwide recognition for its international research in space science, planetary exploration and earth observation science. **Space Park Leicester** is being developed as a science and innovation hub. The **University of Nottingham** is a world leader in space-based applications of position, navigation and timing, and hosts the UK national centre of excellence for GNSS. The **National Space Centre** in Leicester is a £60m science visitor centre attracting over 200,000 visitors annually, with over 10,000 students and their science teachers participating in the National Space Academy programmes and other space education initiatives (some of which are globally exported). GEM is also home to Space @ **OU** (Milton Keynes) with the **Centre for Electronic Imaging** (detector for Gaia, Euclid, JUICE), and the proposed **Blue Abyss** test and training centre for commercial aquatic and space research.

Hertfordshire

Hertfordshire has been part of upstream space since the 1960's when the British Blue Streak rocket was built by Hawker Siddeley Dynamics. The company has evolved into **Airbus Defence and Space** (Airbus DS), housed in the same buildings, and today Airbus DS teams focus on the design and manufacture of advanced satellites and systems for telecommunications, earth observation, and navigation and science programmes. Airbus DS builds a quarter of the world's telecommunications satellites and leads flagship ESA projects such as the ExoMars Rover, Solar Orbiter and Biomass. They also support the UK's military satellite communications services to the UK armed forces, including mobile voice, video, internet and broadcast communications. Delivered through the Skynet 5 constellation, these services also meet the needs of other military and government users like NATO. There are over 1200 employees in Stevenage, with more across the UK.

Oxfordshire also boasts one of the most concentrated clusters of upstream space activity in the UK. At **Harwell**, the **Rutherford Appleton Laboratory's Space Science** group (RAL Space) employs around 200 staff working on world-leading research and technology development, space test facilities, instrument and mission design, and studies of science and technology requirements for new missions. RAL Space has been involved in over 200 space missions. The site also hosts the **Satellite Applications Catapult**, as well as a growing industrial base, including sites for **Thales Alenia Space UK**, **MDA UK**, **GMV UK, Neptec,** and many more businesses within the supply chain.

[5] See Chapter 2.5, Full Report

In the M3 Corridor running to the Solent, Portsmouth supports a high-tech defence and advanced manufacturing cluster in aerospace and space, including companies such as **Airbus DS**, **BAE Systems**, **GE Aviation Systems** and **QinetiQ**. The Airbus site in Portsmouth employees over 1000 people and specialises in digital payloads for telecommunication satellites, as well as instruments for spacecraft including low-cost radars. The northern end of the corridor also supports **SSTL**, **Surrey Space Centre** at the **University of Surrey,**, and start-ups such as **Earth-I**.

In the space industry, **Scotland's** central belt undertakes more upstream space activity by volume of craft than other parts of the UK, and Glasgow alone builds more satellites than any other European City[6] thanks to local activities of **Clyde Space** and **Spire**. With respect to the upstream sector, Scotland is home to 23% of the industry in space manufacturing, compared to 17%. The UK space industry has strong presence in Scotland with 18% of the UK space industry workforce based there. It is further supported by the reputable research expertise, with Scotland being ranked as number 1 in the World University Rankings for space sciences. Scottish industry has set out its aspiration to rapidly expand to become a £4 billion industry by 2030 and play host to at least one UK Spaceport, an ambition which was confirmed at the 2018 Farnborough Airshow, where Government Industrial Strategy funding was confirmed for the development of a vertical launch spaceport in Sutherland, on the north coast of Scotland, by **Lockheed Martin**.

Opportunities and Threats

The UK's Upstream space sector is highly productive, commercially and scientifically successful and highly innovative; as such, the space sector plays well as a growth opportunity within the UK Government's Industrial strategy. There are a number of opportunities that UK Government, industry, academics and investors can take hold of, but also various risks that must be mitigated by close collaboration and alignment.

Opportunity 1: The Sector Deal

The recently announced Sector Deal proposes to align strategic approaches to addressing needs in the areas of R&D, industrial growth, skills and workforce development, and regulations. The upstream space sector needs to remain alert as the UK Government agrees a number of sector deals across the UK economy as the technology crossovers between sectors may provide future opportunities.

Opportunity 2: A Growing Workforce

Space-related science & engineering courses yield great economic benefits by preparing the future generation of engineers for the rigours of industrial work. However, leakage to other sectors exacerbates an existing skills shortage. The Space Growth Partnership is formulating proposals to address this skills gap, including industry supporting one million engagements per year with young people at all levels to inspire and encourage them to consider careers in STEM.

[6] www.scotsman.com/future-scotland/tech/glasgow-builds-more-satellites-than-any-other-european-city-1-4354219

Opportunity 3: Growth Potential

Upstream Space in the UK is set to grow and grow quickly due to a combination of new technologies, the completion of an end-to-end value chain within the UK, and greater access to space for customers and operators. There is a unique opportunity for investors to get on board on the ground floor, as startups and established businesses look to enter and broaden their market share in satellites, launchers and ground segmentation markets.

Opportunity 4: R&D Excellence

The UK's Research Base for Upstream Space is uniformly excellent, with some of the world's best-ranked universities. If the requisite funding for future programmes of industrial and space science research is secured, the UK will be able to leverage its excellent research base for long-term benefits. With alternative models of R&D, such as Strategic Research Clusters and ARTES, continuing to be supported, industry can be supporting into researching areas they otherwise might not.

Risk 1: Regulations

The UK does well in UK and European markets, but with the exception of large multinationals, penetration of non-European overseas markets could be improved. Regulators and insurers can help businesses to overcome barriers to entering the market by working closely with Government and industry.

Risk 2: Research Funding Gap

Upstream Space outperforms the rest of the UK when it comes to accessing UK funding, leading and participating in research projects. However, the majority of fundamental and applied research funding for upstream space has come from the EU over the last decade, and Brexit represents a very real and imminent threat to sources of R&D funding for UK academic and industrial researchers. With negotiations for FP9 underway, certainty is crucial if the R&D intensity is to be successfully maintained.

Risk 3: Fragmentation

Because the UK has no centralised research capability in the vein of France, Germany or Italy, we have the benefit of protecting key assets from the vicissitudes of the market, whilst ensuring that technological and political strengths are more closely aligned, allowing for some very long-term investment decisions to be protected from the political winds. Recent investment decisions pertaining to the **National Satellite Test Centre**, and the **National Space Propulsion Test Centre** at Westcott suggest that the UK is taking some steps in the direction of its European counterparts. Building upon this, long term planning and support for UK launch infrastructure, and ground segmentation infrastructure, such as space gateways, control stations and VSATs, is seen as crucial in order to ensure that current UK aspirations and activities provide world-class space services and products for generations.

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