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

NORTH WEST COASTAL ARC™

Department for Business, Energy & Industrial Strategy

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Membership of the North West Coastal Arc™ Partnership

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Contents

Executive Summary

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 North West Coastal Arc™ (NWCA) Partnership for Clean and Sustainable Growth was formed in 2017 to focus on our strength in science and innovation for Clean and Sustainable Growth. This report presents the results which include broad-ranging analysis of the NWCA Clean and Sustainable Growth Partnership's capabilities, the challenges and the substantial opportunities for future economic growth.

The 2017 UK Industrial Strategy White Paper recognizes that Clean Growth is not simply a challenge but a very significant opportunity to increase productivity, create jobs and scale-up earning power right across the country. In 2014 the global market for low carbon products and processes alone was worth $US3.4 trillion and this is predicted to rise to in excess of $US8 trillion by 2025. In the UK, employment, turnover and GVA in this sector are all growing rapidly (12%, 25% and 28% respectively between 2010 and 2013) and are predicted to grow by 11% per year between 2015 and 2030 – 4 times faster than the rest of the economy. This could deliver between £60 billion and £170 billion of UK export sales by 2030.

This SIA provides the evidence base to demonstrate that the NWCA is exceptionally well-positioned to lead globally in developing both the innovations and the skilled people that will drive forward the economic and environmental benefits of Clean and Sustainable Growth. The NWCA partners share a collective vision of translating world-class research via innovation for Clean and Sustainable Growth to create regional economic value.

We have structured this audit around three prime capabilities in 'science and technology' research and innovation, namely Environmental Industries Technologies & Services, Future Energy Systems and Advanced Manufacturing, Chemicals and Materials. We have also included a fourth 'enabling' capability representing acceleration points for innovation and productivity across each of the prime capabilities. These include co-location of business, support for collaborative research and demonstration capabilities. These complement the technical innovation strengths and act to amplify the translation of research quality into new products and processes for the global market place.

Based on the top 1% of cited publications, the collective research leadership of the partnership is globally leading in Environmental Industries, Technologies and Services, and exceptional in the Agronomy and Crop Science, Plant Science and Waste Management sub-disciplines.

The NWCA's outstanding research excellence in Aerospace Engineering and Materials and Chemistry, particularly Metals & Alloys and Polymers & Plastics is very strong against global comparators. In terms of cross cutting and complementary research capability, the region has outstanding research excellence in Statistics, Probability and Uncertainty, Decision Science, Data Science, Management Science and Management of Technology and Innovation.

Over the course of the audit the underpinning logic chain was developed and refined to link challenges and opportunities with the region's existing activities and assets and ultimately the potential for new assets and activities to drive economic, social and environmental benefits. At the heart of that logic chain (Table 1) are five key opportunities emerging from the collective vision of research and innovation for Clean and Sustainable Growth that has crystallised as partners have worked together to deliver this audit.

The implementation plan defines the mechanisms by which the outcome of this audit will be put into practice. Partners will work together to deliver that plan, and so empower the region as a whole to work collectively to drive forward the economic, social and environmental benefits provided by Clean and Sustainable Growth. The learning, innovation assets and benefits developed as a result of the audit can then be applied across the UK to increase productivity, create good jobs and scale-up earning power right across the country and so maximise the nation's competitiveness in this fast-growing global market.

Five key opportunities emerging from this Science and Innovation Audit

1. Communicating the economic importance of Clean and Sustainable Growth

NWCA partners will 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. Communication activities will be an initial priority.

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

The audit has identified specific opportunities for a more 'joined-up' approach to the region's existing research, development, demonstration and co-location facilities. These include research and innovation into hydrogen-based energy systems, below-ground energy resources and 'place-based synergies' focused on the role of NWCA's uplands and coasts supporting the region's urban areas.

To enhance the region's existing assets, an International Centre of Excellence for Clean and Sustainable Growth would act as a gateway for stakeholders to access to the NWCA's existing prime capabilities, targeting the challenges and opportunities at the interaction of the Clean Growth Strategy and 25 Year Environment Plan. 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 would be developed alongside public engagement facilities.

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 higher education institutions in order to develop SME internationalisation support programmes across the higher education partners.

4. Training regional talent to support and lead Clean and Sustainable Growth

Consultation with business and other stakeholders highlighted a gap in training at all levels relevant to Clean & Sustainable Growth. Improved integration and connectivity across the region's further education and higher education providers would create a 'skills escalator', for example through a virtual Clean Growth Training Academy.

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

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.

This audit has proved the strength of the NWCA partnership and shown a real commitment by each of the organisations involved to create a Strategic Alliance, develop an action plan for the first 12 months and convene an implementation group to drive progress.

Since the formal submission of this SIA in July 2018, the Intergovernmental Panel on Climate Change (IPCC) published a special report[32] on the impacts of global warming of 1.5°C above pre-industrial levels. The report makes clear that limiting warming to 1.5°C would prevent many of the risks associated with a 2°C rise.

The IPCC report states that to limit global warming to1.5°C *"....would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems. These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options."*

This conclusion of the IPCC report further reinforces a major outcome of this audit in highlighting the urgent need for Clean and Sustainable Growth that addresses the needs of all sectors and industrial systems.

The SIA consortium is led by Lancaster University and includes all the region's LEPs (Cumbria, Lancashire, Cheshire, Liverpool City, Stoke-on-Trent and Staffordshire), the North Wales Economic Ambition Board and the Mersey-Dee Alliance, together with companies of all sizes, and across a wide range of sectors. It 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 (LMJU), University of Central Lancashire (UCLAN) and Wrexham Glyndwr and other national research assets, together with Blackpool and The Fylde College.

Table 1

Logic chain for North West Coastal Arc™ (NWCA) Partnership for Clean and Sustainable Growth Science and Innovation Audit

What are the challenges and opportunities?	What assets does the SIA build on in the region?	What new activities or assets could be developed?	What will these new assets and activities unlock?	What will be the result in the long term?
Industrial Strategy highlights weak UK productivity performance and clean growth as a grand challenge. 25 Year Environment Plan requires significant acceleration of decarbonisation. Misconception of the nature and need for Clean and Sustainable Growth beyond 'low carbon energy'. No integrated national centre of excellence to develop, test and showcase such technologies.	Complementary research strengths across the region. Demonstrable track record of business-driven innovation. Northwest is ranked first for employment in the clean growth sector in England. Unique set of place-based assets.	**A connected ecosystem of research, innovation and demonstration facilities across the NWCA geography.** Creation of an **International Centre of Excellence for Clean and Sustainable Growth** including the expansion of demonstrator facilities.	Increased IP commercialised from wider sectors (e.g. aerospace) used for clean growth applications. NWCA assets and facilities across the geography mutually accessible to researchers, innovators and industry. SMEs/Corporates all linked, to develop new products and services for global marketplace.	Substantial improvements in NWCA economic growth rebalancing relative UK productivity performance. International Centre of Excellence for Clean and Sustainable Growth established as a gateway for business to access NWCA prime capabilities and demonstrator sites. NWCA known as globally leading for Clean & Sustainable Growth through Eco-Innovation.
Skills shortages at all levels associated with clean growth requiring cross-disciplinary skills.	Complementary teaching and training strengths of regional higher education and further education providers.	A new **collaborative Training Academy for Clean & Sustainable Growth** attracting, creating and retaining talent within the NWCA. **Enhanced leadership & entrepreneurial behaviour programmes** enabling start-ups to become scale-ups.	Relevant STEM skills and talent attraction and retention programmes at all levels. Training to enhance leadership driving innovation and entrepreneurialism in SMEs.	World-class student/ research/ industry talent attracted to the NWCA and the 'eco-innovators' of the future retained within the region. New models of shared provision for training across the NWCA, including better collaboration across FE and HE providers and increased engagement with Degree Apprenticeships.
Sub optimal support for overseas expansion and not easily visible.	Universities have extensive and complementary, international partnerships and infrastructure, but this is currently under-utilised to support trade.	**Enhanced and "joined-up" leverage of university's international reach.**	Successful SME internationalisation support programmes across higher education institutions.	NWCA make a significant contribution to increases in UK trade figures through clean growth export opportunities.
Clean growth resources and programmes are fractured i.e. they tend to be project based and targeted around specific physical locations.	Broad-based and successful collaborations across the region have been established despite the current fractured funding models.	**New flexible funding mechanisms** to support SME focused R&D. **National Open Innovation IP Bank for Clean Growth** to support increased commercialisation.	R&D activities operate at appropriate and transformational scale across LEP boundaries. Increased investment in supporting expansion of clean growth and sustainable cross-sector start-up and scale-up SMEs.	New mechanisms secure the enduring success of the NWCA in driving Clean and Sustainable Growth, and the resulting economic, social and environmental benefits.

Forewords

Mark Knowles
Head of Low Carbon at Liverpool City Region Local Enterprise Partnership

Liverpool City Region is leading the development of hydrogen deployment in energy and transport systems. In May 2018 the HyNet project launched and will see the first large scale deployment of hydrogen into the gas grid displacing up to 20% of the methane currently in the system. The City Region wishes to link hydrogen and marine power systems to deliver sustainable energy vectors for our power, heating, transport and process requirements. The City Region's designation as a Centre for Offshore Renewable Engineering is recognition of our continued potential in the low carbon and renewables sectors.

The Clean Growth sector contributes over £2bn to Liverpool City Region's economy employing over 22,000 people in 1,400 companies. It is probably the most important of our Industrial Grand Challenges as it needs to be delivered throughout every aspect of our lives. We will need everything from small step changes to disruptive innovations in the energy we use, products we buy, food we eat, and modes of transportation, along with improving how goods are manufactured, delivered, used and recycled. In Liverpool City Region alone Clean Growth is being stimulated through the £3.5bn being invested in Liverpool Bay, the exploitation of commercial opportunities in environmental goods and services through collaborative projects such as the Low Carbon Eco-Innovatory, the development of sustainable materials through the Materials Innovation Factory, converting existing rail stock to create the UK's first hydrogen powered trains, and our work in delivering sustainable urban solutions through Sensor City.

This SIA is building on the Northwest's strengths as a hub of world-class universities, research institutions, business networks and industry and we fully support this report and are committed to continuing our collaborations with our SIA partners on this critical agenda. Our coastal location combined with the high level of interconnectivity between partners places us in a unique position to harness the growth potential of embracing renewable energy and a low carbon economy. Delivering transformational Clean and Sustainable Growth is therefore a key driver in the region to create new opportunities for the wealth of talent within the North West Coastal Arc and in supporting the re-balancing of the UK economy.

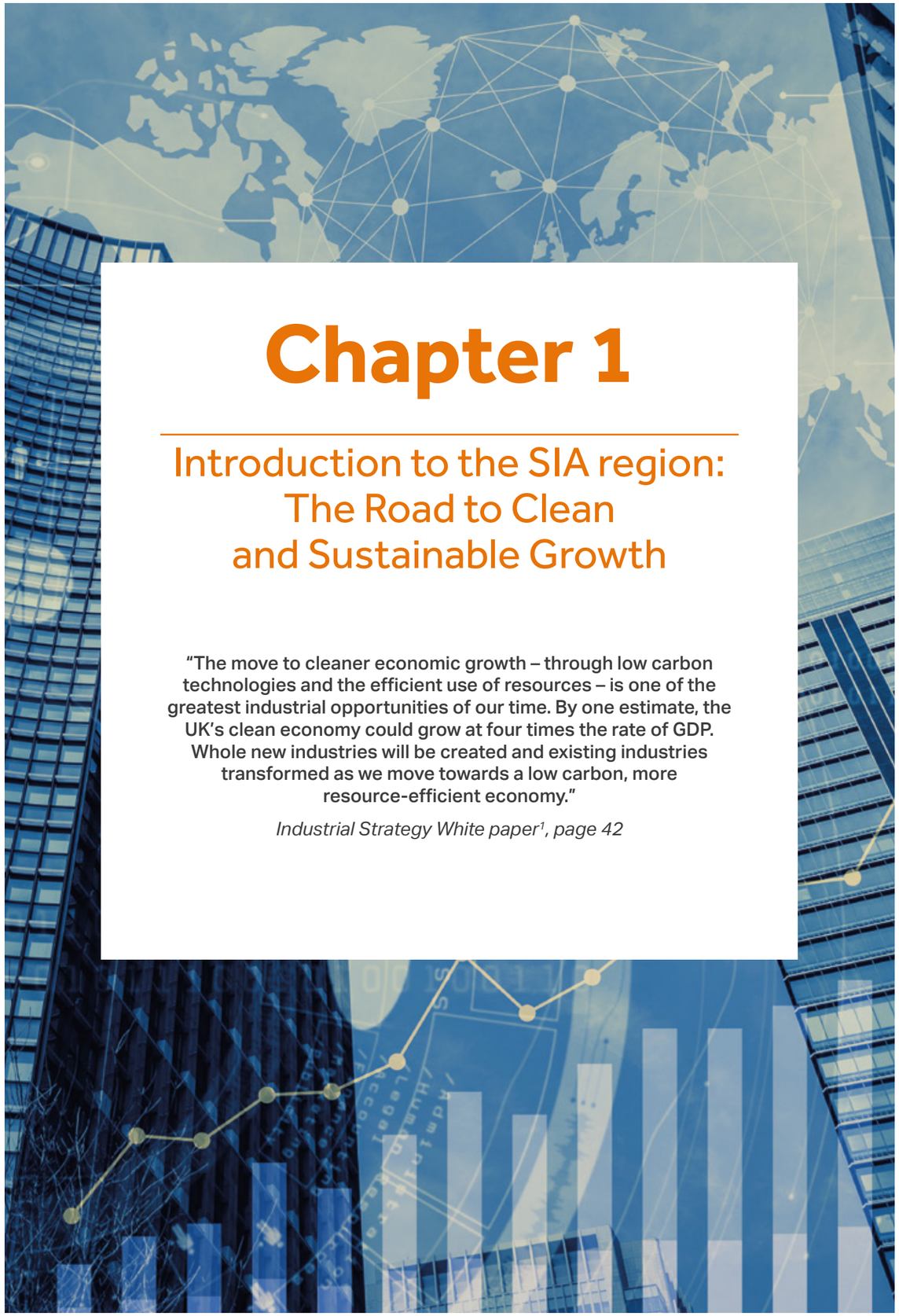
Professor Mark E Smith
Vice Chancellor, Lancaster University

The UK Clean Growth Strategy and 25 Year Environment Plan recognise that there are tremendous opportunities to deliver a low carbon future and grow new global market opportunities from the development of innovative solutions. Clean Growth is one of the four Grand Challenges set out in the emerging Industrial Strategy. The North West Coastal Arc hosts the unique set of assets (people, technology and place) to exploit those opportunities to become world leading in the development of low carbon and other eco-innovative products, services and technologies to support the global drive for Clean and Sustainable Growth. Those assets include not just research and innovation 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 focus for this SIA in the North West Coastal Arc emerges from the region's specific business and natural assets, and their strong interface with its research and innovation assets. We have excellent universities, research organisations, key industrial clusters and underpinning assets supporting environmental technologies, future energy systems and advanced manufacturing and materials. We are particularly well organised to lead and to grow opportunities for Clean and Sustainable Growth. We have pioneered the development and impact of the award-winning Centre for Global Eco-innovation® in the North West, which has delivered both business growth and significant positive environmental impact through business driven R&D collaborations with our universities.

We start from a position of strength and this audit lays the foundations for accelerated action on Clean and Sustainable Growth, understanding and exploiting our particular strengths through collaboration and strategic investment. The act of producing this report has built common purpose across our partners and a commitment for this audit to become a manifesto for action.

Our priority now is to secure the region's global leadership in developing eco-innovative products, services and technologies - the solutions needed to deliver Clean and Sustainable Growth in the coming decades and drive growth across our key regional business sectors. We are committed to building and coordinating our alliance to ensure the UK brings forward the R&D driven innovation to make the Clean Growth Strategy a reality and to make a significant contribution to the delivery of the Industrial Strategy.



Chapter 1

Introduction to the SIA region: The Road to Clean and Sustainable Growth

"The move to cleaner economic growth – through low carbon technologies and the efficient use of resources – is one of the greatest industrial opportunities of our time. By one estimate, the UK's clean economy could grow at four times the rate of GDP. Whole new industries will be created and existing industries transformed as we move towards a low carbon, more resource-efficient economy."

Industrial Strategy White paper[1], page 42

1.1 Background to this audit

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 how technological and environmental innovations are 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. It is also evident in the 2016 Northern Powerhouse Independent Economic Review[3] (IER) and across all of the strategic plans of the region's LEPs and North Wales Economic Ambition Board (Annex 1).

International opportunities for Clean and Sustainable Growth

The World Bank (2014) currently estimates the global market for low carbon products and processes alone as being worth $3.4 trillion and predicted to rise to in excess of $8 trillion by 2025[4]. In the UK employment, turnover and GVA in this sector are all growing rapidly (12%, 25% and 28% respectively between 2010 and 2013) and is predicted to grow by 11% per year between 2015 and 2030 – 4 times faster than the rest of the economy. This could deliver between £60 billion and £170 billion of export sales by 2030[5]. Capturing part of this global opportunity for Clean and Sustainable Growth can play a key role in our Industrial Strategy, building on our strengths to drive economic growth and boost earning power across the country.

Clean Growth is also inseparable from the aims of the Government's 25 Year Environment Plan[6] (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 the global marketplace will need new products, services and technologies- 'eco-innovations'- across multiple sectors. It is Clean and Sustainable Growth solutions that are needed to deliver the objectives of both the UK Industrial Strategy and the 25 Year Environment Plan. This SIA provides the evidence base to demonstrate that the Northwest Coastal Arc (NWCA) 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.

The NWCA partners (Annex 2) share a collective vision of translating world class research via innovation for Clean and Sustainable Growth to create significant regional economic impact. That vision has been emerging and evolving for several years and has developed on four powerful foundations. Our first foundation is our industrial assets across multiple sectors, not least the low carbon sector for which the Northwest of England is ranked first for employment, with clear additional economic opportunities for further growth in business and employment across our region, the wider North and the whole UK. Our second foundation is the unique geography and natural assets of the NWCA as a natural test-bed for Clean and Sustainable Growth solutions (Figure 1.1). The third foundation is a substantial base of significant science and innovation assets (Annex 3).

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 and co-operation in addressing the challenges and opportunities in global markets for low carbon goods and services (for example the award-winning Centre for Global Eco-Innovation, page 20).

The 2016 Northern Powerhouse Independent Economic Review (IER)

The IER, commissioned by Transport for the North highlights that the North of England is home to 16m people, and 7.2m jobs, and generated an economic output of around £290bn of Gross Value Added (GVA) in 2015, about one fifth of the UK's total. The IER went on to note '… persistent gaps in GVA per capita and productivity performance compared to the rest of the UK'. By using Smart Specialisation Principles the IER identified four 'Prime' capabilities at a pan-Northern level that perform well on productivity and can compete at a national and international scale. Relevant to this SIA, these include Advanced Manufacturing and Energy, in particular low carbon technologies.

Innovation for Clean and Sustainable Growth: Eco-innovation

The innovative products, services and technologies needed to deliver Clean and Sustainable Growth are often described as 'eco-innovations'. However, our experience, confirmed by this SIA, is that the term eco-innovation is poorly recognised. As we use the term in this SIA, eco-innovations deliver positive environmental impacts by virtue of their use, manufacture, raw materials, reuse or disposal but, fundamentally, they are commercially successful products, services and technologies that drive growth and exports, and deliver skilled jobs.

The innovative products, services and technologies needed to deliver Clean and Sustainable growth are often described as 'eco-innovations'. However, our experience, confirmed by this SIA, is that the term eco-innovation is poorly recognised.

Figure 1.1

The North West Coastal Arc™: a geography for Clean and Sustainable Growth

The NWCA hosts the unique set of assets (people, technology and place) to exploit the opportunity to become world leading in the development of low carbon and other eco-innovative products, services and technologies to support the Clean Growth Strategy.

The regional focus for this SIA in the NWCA is powerfully based on the region's specific business and natural assets, and their strong interface with its research excellence assets.

The diverse and varied geography of the NWCA presents significant opportunity and 'strength in place' for innovation from concept to demonstrator and from test bed to marketplace:

+ Extensive coastline
+ Largest mountains
+ Record-breaking river flow
+ Highest rainfall

BIS' UK Low Carbon Economy Report

BIS' The Size and Performance of UK Low Carbon Economy report highlights the substantial and sustained growth rate of this sector.

Between 2010 and 2013 the direct low-carbon economy grew by:

12%

in terms of employment

Gross Value Added (GVA) increased by

29%

in terms of employment

and increased by

25%

in terms of turnover

With a compound annual growth rate of

8.7%

and now stands at

£44.9 billion

This is almost nine times larger than aerospace and four times larger than the chemicals sector.

The same report showed that of the 9 regions in England, the Northwest has the greatest employment in the low carbon economy.

(80,500 from a total of 391,700)

Gross Value Added (GVA) in the region was **£130,084m** in 2015 and made up **7.9%** of the UK total. Broken-down by sector, the largest proportion of this value was generated by:

NORTHWEST COASTAL ARC IN NUMBERS

Population count of

6.25m

in 2015, 9.5% of the UK total

At this time

61.7% (3.86M)

of the population were of working age **(16-64)** and **3.04M** jobs were available within the region.

This represents

0.79

jobs per working age individual

Which is slightly lower than the UK average of

0.83

(where 34.06M jobs were available in a population where 63.1% were of working age).

1.2 Key NWCA Clean and Sustainable Growth Strengths and Assets

From our starting point of 'Eco-innovation' in our expression of interest (January 2017) the structure of this SIA has developed through discussion between partners and has been informed by Northern Powerhouse IER[3] and the subsequent publication of three key policy documents: the UK Industrial Strategy White paper[1], the Clean Growth Strategy[2] and the 25 Year Environment Plan[6]. This is complemented by the LEP Strategic Economic Plans (and Welsh equivalents) across our geography, across which Clean and Sustainable Growth is a common strategic priority (Annex 1). As a result, we have structured this audit around three prime capabilities in 'science and technology' strengths and assets (Box 1.3) plus a fourth enabling capability. We recognise the value in dealing with these broad sectors in separate chapters, and the links between our three prime capabilities and the three UK policy documents are summarised in Figure 1.2. We also recognise that activities map on to specific elements of other Science and Innovation Audits, and we have been pro-active in consulting with them to explore these relationships (Annex 4).

However, as we emphasise throughout this SIA, there are strong inter-linkages between all three prime capabilities, and the enabling capability is a vital element in that integration. By connecting our strengths in the science and technology of Clean and Sustainable Growth with complementary strengths in management and decision sciences, the enabling capability addresses needs highlighted in the 'Ideas' chapter of the Industrial Strategy White Paper[1]. For example, that 'While we score well on measures of research and innovation, we need to do more to ensure this translates in to improvements in earning power' and that 'within R&D the 'D' for development needs a particular boost'.

By bridging across disciplines and sectors, and from discovery to implementation, the enabling capability relates to one element of 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'.

The strength in depth across the four capabilities, developed in more detail in subsequent chapters, has cemented our ambition to work together and to define ways ahead to establish the region as a global leader in innovation for Clean and Sustainable Growth (Chapter 7).

Capability 1

Environmental Industries, Technologies & Services – Chapter 3

Capability 2

Future Energy Systems – Chapter 4

Capability 3

Advanced Manufacturing, Chemistry and Materials – Chapter 5

Capability 4

Cross-cutting research and innovation for Clean and Sustainable Growth – Chapter 6

Figure 1.2

The relationships between the three prime 'Science and Technology' capabilities of this audit and elements

The relationships between the three prime 'science and technology' capabilities of this audit and elements of the three recent UK strategy documents, UK Industrial Strategy White paper, the Clean Growth Strategy and the 25 Year Environment Plan. Our enabling capability in research and innovation for Clean and Sustainable Growth naturally crosses both other capabilities and the different policy documents.

		IDEAS	PEOPLE	UK INDUSTRIAL STRATEGY					25 YEAR ENVIRONMENT PLAN			
				CLEAN GROWTH GRAND CHALLENGE					CHAPTERS			
				SECTORS								
				Improving Business & Industry Efficiency and supporting Clean Growth	Improving our Homes	Accelerating the shift to Low Carbon Transport	Delivering, Clean Smart Flexible Power	Enhancing the Benefits and Value of our Natural Resources	Recovering Nature and Enhancing the Beauty of Landscapes	Using and Managing land Sustainably	Increase resource efficiency and reducing pollution and waste	Protecting and Improving our global Environment
NWCA Clean and Sustainable growth SIA	**Chapter 3** Environmental Industries, Technologies & Services	■	■	■		■	■	■	■	■	■	■
	Chapter 4 Future Energy Systems	■	■	■	■	■	■					■
	Chapter 5 Advanced Manufacturing, Chemicals and Materials	■	■	■		■	■			■	■	■

The Centre for Global Eco-Innovation

The Centre for Global Eco-Innovation (CGE) is a long-standing collaboration between the region's higher education institutions and SMEs to drive Clean and Sustainable Growth through the joint development of new products, technologies and services for global markets.

CGE has grown from two periods of support from the European Regional Development Fund. The first phase (2012-2016) led by Lancaster University in collaboration with University of Liverpool supported SMEs from across the region then covered by a single European Structural and Investment Funds (ESIF) programme. From the start CGE has been 'challenge-led and solution focused', rather than driven by any particular technology, and has drawn on expertise and disciplines from across its partners to find multidisciplinary solutions to complex problems. The first phase of CGE drew on research from thirteen different academic departments across the two universities. It supported approximately 300 regional SMEs, including fifty business-led post-graduate research projects (all the researchers were registered for PhDs), fifty internships and fifty undergraduate research projects. The headline conclusions from an independent audit of CGE Phase 1 are summarised below.

In 2015, the success of CGE was recognised by it winning the "Outstanding Knowledge Exchange and Commercialisation Initiative" category in the Impact Awards, which are backed by all seven UK research councils, and the "Research and Development" category in the Green Gown awards.

The second phase of CGE (2016-2020) builds on these successes, supported by funding managed by the Cumbria, Cheshire, Lancashire and Liverpool City LEPs. Collaboration between higher education partners has broadened to include the Universities of Cumbria, Chester, Central Lancashire (UCLan) and Liverpool John Moores, together with the national research institute, the Centre for Ecology & Hydrology. This second phase of CGE is supporting 80+ business-led post-graduate research projects. By 2020 it will have supported a total of 660 businesses, across all partners.

In addition, CGE has begun to develop a genuine international dimension. In 2017 the University of Benin, in close collaboration with Lancaster, established CGE (Nigeria) to translate CGE's experience in the UK into West Africa. Lancaster also leads "RECIRCULATE", a £7M project funded by the Global Challenges Research Fund, with the University of Benin, the Council for Scientific and Industrial Research (Ghana) and Lancaster University Ghana, plus four more partners in Botswana, Kenya, Malawi and Zambia. Again, the aim of this project is to build the capacity of project partners to drive Clean and Sustainable Growth in their countries through eco-innovation collaborations with the research user communities, based on our experience in the UK.

Headline conclusions of independent audit of CGE carried out by Amnion, in 2014

Benefits to companies and graduate researchers

+ Over 80% of beneficiaries stated that the project had helped overcome the lack of qualified staff, the most commonly cited barrier to innovation.
+ Over 80% of respondents felt that the project had met the objective of developing new products and services, and to better understand the market. 75% of beneficiaries expected the support received to have either a significant or a very significant impact on the business.
+ 37% of the businesses surveyed forecast an increase in exports resulting from the support provided.
+ Those benefitting from the project have also benefitted from an increasing willingness to undertake further R&D and to collaborate with other businesses and the knowledge base.
+ The project has also had a positive impact on Graduate Researchers in relation to academic progress, employment prospects and developing employment related skills.

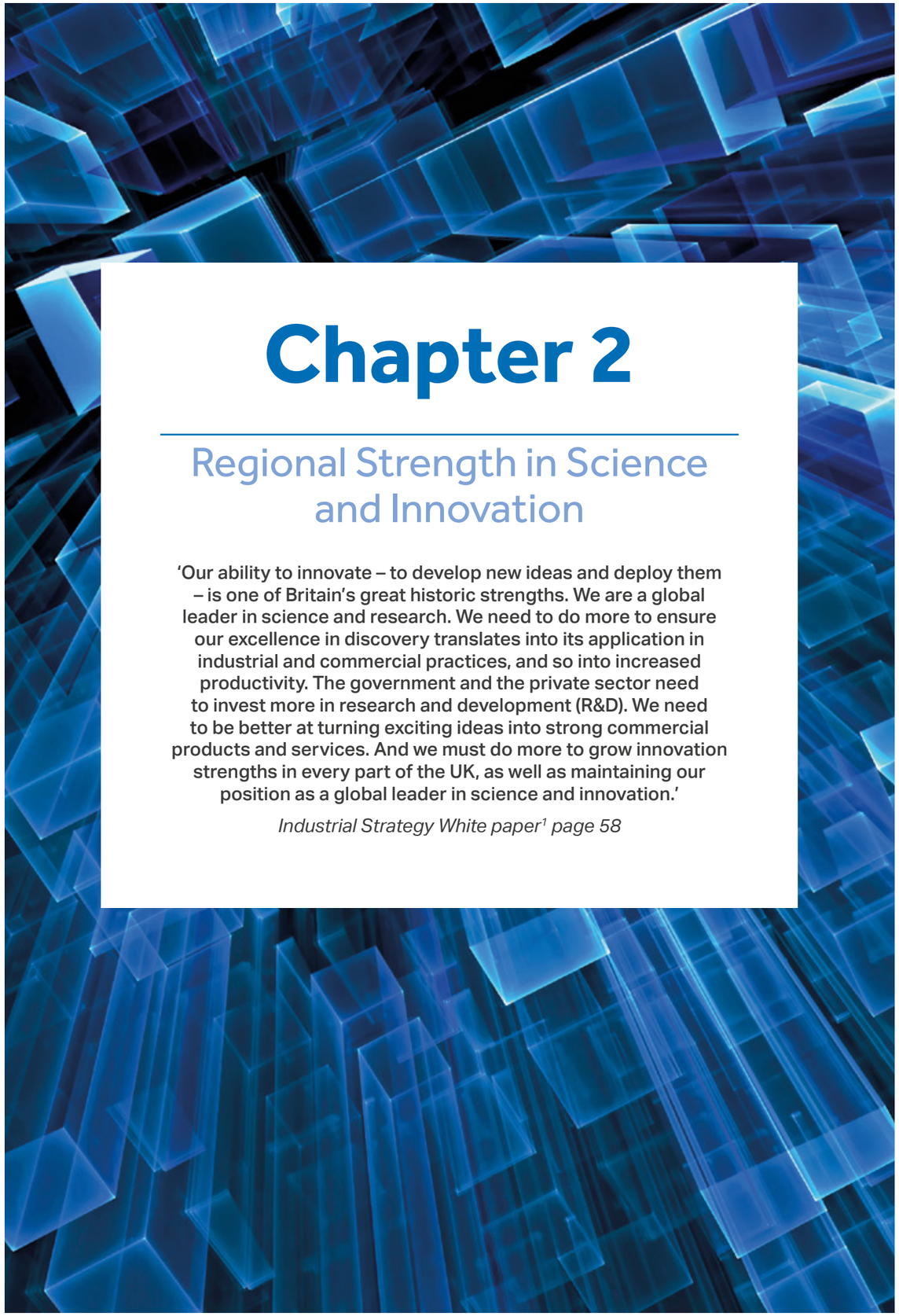
Benefits to the economy

+ It is forecast that by 2018 the first phase of CGE will have created 314 gross jobs and some £45 million of gross GVA, and £35 million in net additional GVA. By 2026 the forecast is for £65 million of gross GVA and £50 million in net additional GVA.
+ In terms of efficiency, CGE out-performed the regional benchmark for net additional jobs identified in the review of RDA spending: £20,922 per new job compared with the benchmark of £37,600.
+ In terms of return on investment for enterprise support projects, the forecasted ratio for CGE is 5.5:1 by the end of 2017 (10.2:1 by 2026), well above North West regional benchmark (1.8:1) and the national average (2.8:1).

Benefits to the environment

+ In early 2014 the environmental benefits of CGE were assessed both within the life of the project and out to 2027, with predictions based on project outcomes that are already being achieved, or where there was a very high confidence that they will be achieved.
+ The target for reductions in greenhouse gas emissions (27,000 tonnes CO_2 equivalent) was met well ahead of schedule.
+ Targets for reductions in water and material use are expected to be met by 2022 according to the evaluation, but were met and exceeded by 2016, with reductions of 78,000 tonnes and 60,000 tonnes respectively.

Lancaster University | Centre for Global Eco-Innovation



Chapter 2

Regional Strength in Science and Innovation

'Our ability to innovate – to develop new ideas and deploy them – is one of Britain's great historic strengths. We are a global leader in science and research. We need to do more to ensure our excellence in discovery translates into its application in industrial and commercial practices, and so into increased productivity. The government and the private sector need to invest more in research and development (R&D). We need to be better at turning exciting ideas into strong commercial products and services. And we must do more to grow innovation strengths in every part of the UK, as well as maintaining our position as a global leader in science and innovation.'

Industrial Strategy White paper[1] page 58

2.1 Innovation drivers

As highlighted in Chapter 1, it is clear that Clean and Sustainable Growth encompasses several of the 'mega trends' that will drive change in future global trade and so support significant commercial opportunities. 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 urbanisation, upgrading poor drinking water and waste water infrastructure, and feeding the world's growing population.

Our experience echoes the conclusions of the Energy Technologies Institute Report[7] that these opportunities demand more than just a change in how we generate energy. The report concluded that meeting these challenges will require significant innovation across all sectors, including the way energy is generated and delivered, plus the way in which it is used in homes, transport systems, industries and the public sector. Resource scarcity and the depletion of non-renewable resources demands alternative solutions across all sectors and maps on to not only the UK's Clean Growth Strategy[2] but also the UK Industrial Strategy[1] and 25 Year Environment Plan[6]. These solutions touch on every commercial sector and the whole range of research disciplines.

Global corporates are also driving Clean and Sustainable Growth across their global supply chains and there are clear leaders in this field in our NWCA geography. As a result, our SIA is founded on the hypothesis that the NWCA is well-placed to develop the products, technologies and services that are urgently needed to meet the pressing market need and opportunity for Clean and Sustainable Growth and to establish our region as the global leader in this regard.

2.2 Excellence in science and research

In terms of the volume of research outputs, the NWCA published 5.2% of all UK research outputs between 2010 and 2015 (See Annex 5 for Methodology). Against that all subject average, the location quotient (LQ) for the volume of research outputs in eleven broad disciplinary areas pertinent to Clean and Sustainable Growth averages 1.18, with LQs for Earth & Planetary Science (1.92), Environmental Science (1.81) and Agricultural & Biological Sciences (1.51) especially notable. LQs for the volume of publications for the other eight cognate disciplines vary between 0.8 and 1.24.

Analysis of research quality, measured as the percentage of publications in the top 5% of cited publications (Annex 5) for the same basket of eleven cognate subjects, demonstrates that the NWCA outperforms the UK as a whole in seven of the eleven subject areas (Figure 2.1). The NWCA also outperforms the USA & Canada in seven of the eleven disciplines, the EU28 in ten of eleven and in all disciplines when compared with the G20 or China (Figure 2.1).

While this overall audit of research performance confirms the excellence of NWCA's research in these broad disciplines, it also highlights that these disciplines do not coincide well with the inter-disciplinary and challenge-led nature of research for Clean and Sustainable Growth. 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 boundaries. As described in Chapter 1, this 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, the Enabling Capability - Cross-cutting Research and Innovation for Clean and Sustainable Growth - by drawing on strengths across disciplines and enhancing collaboration with industry, supports the translation of research excellence across the 3 prime capabilities into new products, processes and services for Clean and Sustainable Growth. All four capabilities cut across traditional disciplinary and sectoral boundaries but EITS, FES and AMCM represent our core strengths in science and technology, facilitated and supported by our excellence in innovation.

We focus here on auditing the NWCA's research performance for EITS, FES and AMCM. Analysis of research volume using the SCIVAL database (Annex 5) gave location quotients (LQ) of 1.29 for EITS, 1.11 for FES and 0.96 for AMCM. Research income was also analysed for these capabilities for the period 2007-2017. Across all topics NWCA partners were involved in 7.5% of all UK projects, with location quotients of 1.30, 1.42 and 1.20 for EITS, FES and AMCM respectively. By value, NWCA partners were involved in 9.3% of all UK projects, with location quotients of 1.58, 1.68 and 1.39 for EITS, FES and AMCM respectively.

Corporate leadership in strategies for Clean and Sustainable Growth in the North West Coastal Arc

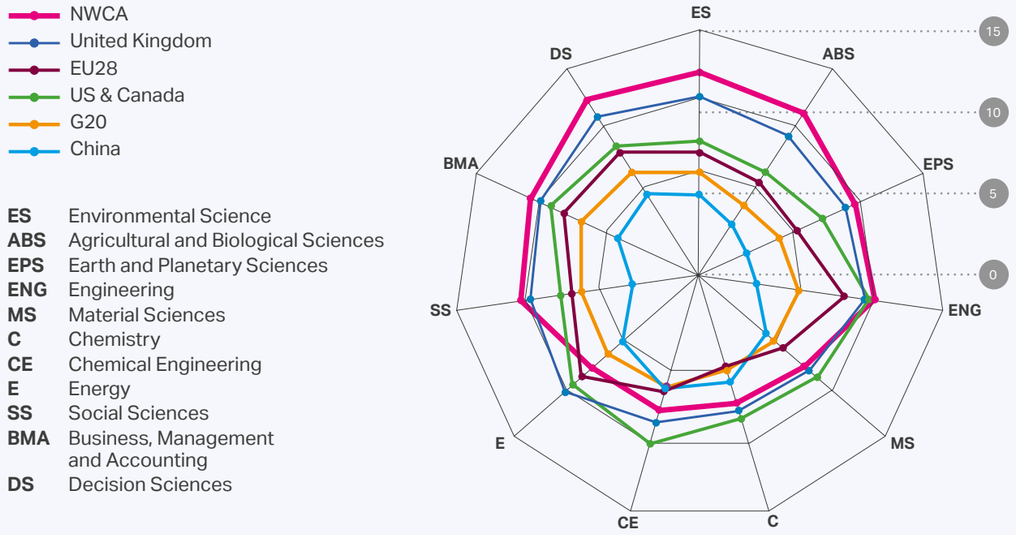
Unilever, based at Port Sunlight in Merseyside, is a world leader in the sustainable business and circular economy movement. Their Sustainable Living Plan aims to double profits and halve environmental impacts through improved efficiencies in waste, packaging and supply chain engagement. Unilever is also leading the move towards solution-driven Open Innovation encouraging ideas from a global community of innovators.

The research base in the NWCA has shown international leadership in building productive collaborations with eco-innovative businesses, especially SMEs.

Walney Wind Farm, Cumbria

Figure 2.1

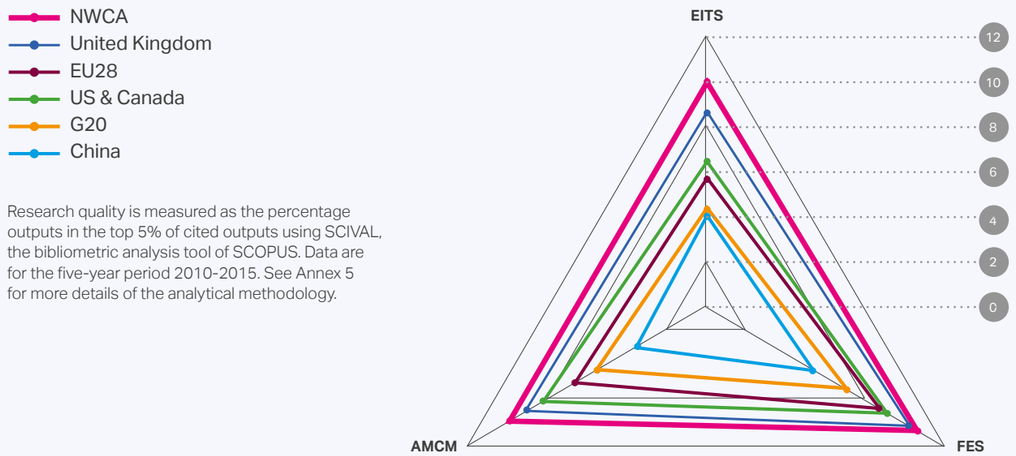
Research quality of the NWCA in eleven broad disciplinary headings compared with the UK, and other nations or nation groups.



Research quality is measured as the percentage of outputs in the top 5% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. This analysis, effectively a broad-based audit of all 'high-level' disciplinary groupings pertinent to eco-innovation, formed the first step of our audit of research quality. See Annex 5 for more detail of the analytical methodology.

Figure 2.2

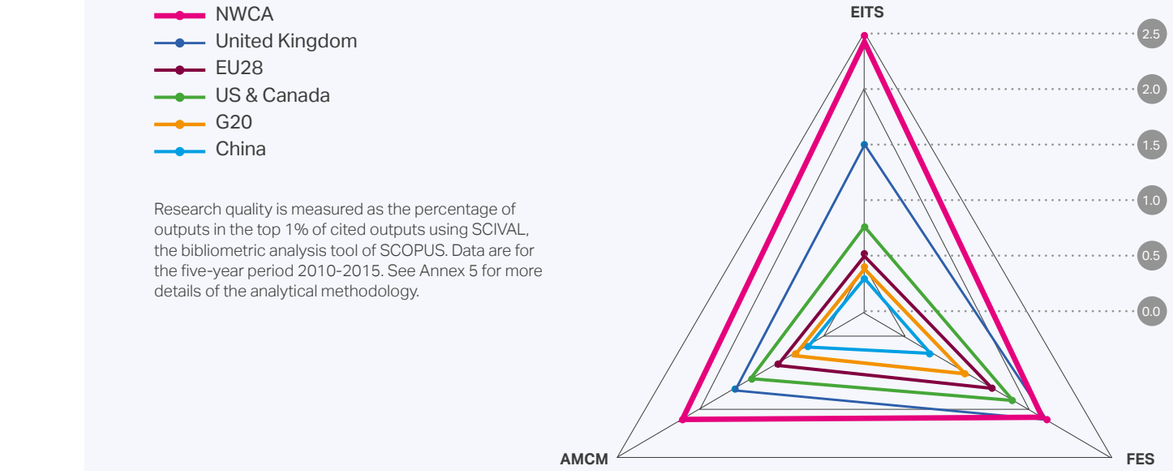
Research quality of the NWCA in the three prime capabilities of this SIA compared with the UK and other nations or nation groups. The three capabilities are Environmental Industries, Technologies and Services (EITS), Advanced Manufacturing, Chemicals and Materials (AMCM) and Future Energy Systems (FES).



Research quality is measured as the percentage outputs in the top 5% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 2.3

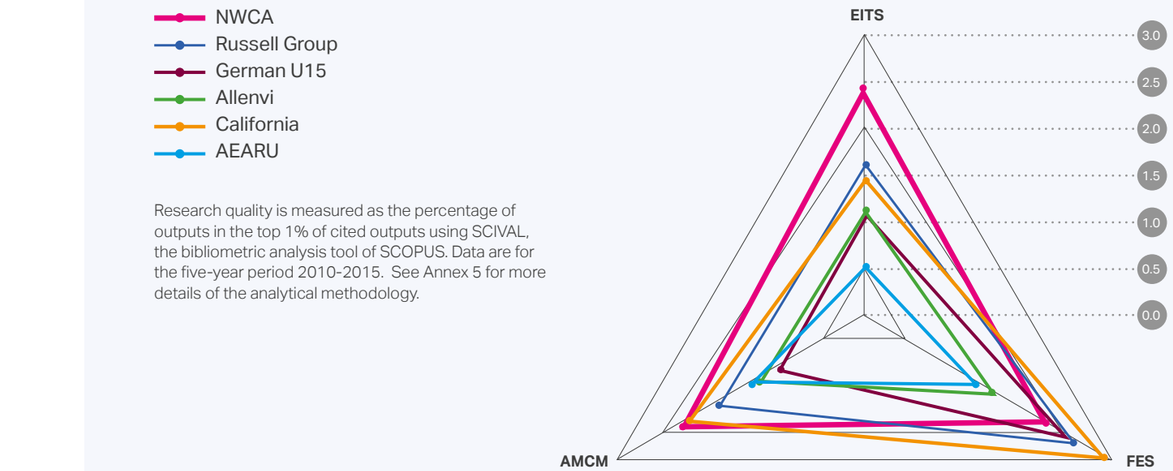
Research quality for the NWCA across our three core capabilities compared with the UK and other nations or nation groups. The three capabilities are Environmental Industries, Technologies and Services (EITS), Future Energy Systems (FES) and Advanced Manufacturing, Chemicals and Materials (AMCM).



Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 2.4

Research quality for the NWCA across our three core capabilities compared with other major university groups or regions. The three capabilities are Environmental Industries, Technologies and Services (EITS), Future Energy Systems (FES) and Advanced Manufacturing, Chemicals and Materials (AMCM).



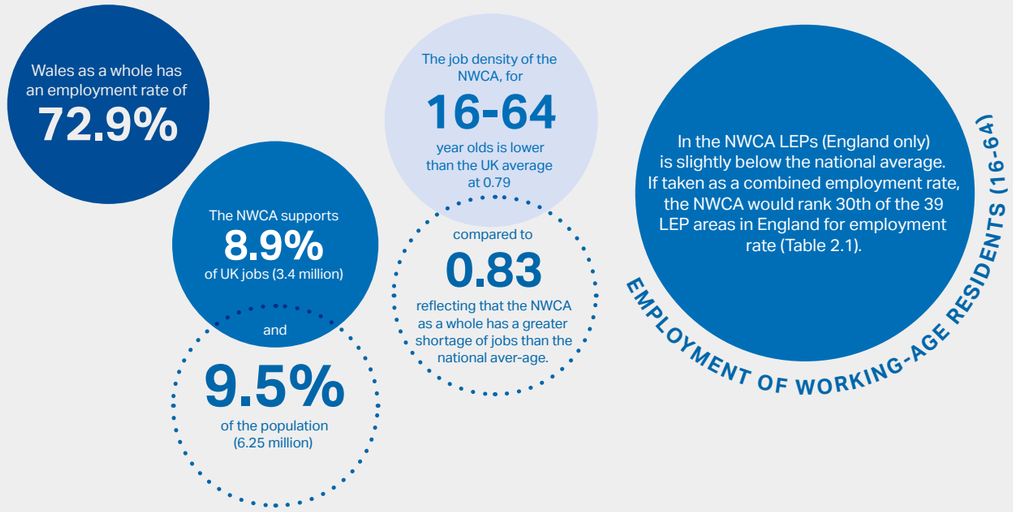
Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Materials Innovation Factory, Liverpool

Using the percentage of publications in the top 5% of cited publications as a measure of research quality in these three capabilities places the NWCA ahead of all our comparator nations and nation groups (Figure 2.2). In analysing research quality in the three prime capabilities, we then applied a highly rigorous approach to identify areas of exceptional strength. First, rather than using the percentage of papers in the top 5% of cited publications, the metric used in the initial broad-brush audit, we used the percentage of papers in the top 1% of cited publications. Applying this measure of quality to compare the NWCA with nations or groups of nations (as in Figure 2.1) demonstrates that the region substantially outperforms all comparators in EITS and AMCM (Figure 2.3). For the Future Energy Systems capability the NWCA is similar to the UK overall, but well ahead of all other comparators (Figure 2.3).

Our second element of additional rigour was to compare the NWCA against other major university groups, plus California included as a region recognised for its global leadership in innovation (Figure 2.4 and see Annex 5). In this more rigorous analysis the NWCA substantially outperforms all comparators in research in the EITS capability (Figure 2.4). For AMCM only California has as high a percentage of papers in the top 1% as the NWCA, which is well ahead of all other comparators. The region's performance in FES, although still well above the global average, is less strong relative to these very powerful comparators (Figure 2.4). Nonetheless, based on this overall audit our assessment is that this most rigorous analysis of research strength is the most appropriate for the SIA. This approach has been used in the detailed analysis of the specialised strengths in each prime capability (Chapters 3, 4 and 5).

Innovation strengths and growth points



LEP/Area	Employed	16-64 Population	Percent %
Cheshire and Warrington	421,800	558,700	75.5
Cumbria	224,700	294,100	76.4
Lancashire	665,300	901,000	73.8
Liverpool City Region	656,200	960,000	68.4
Stoke-on-Trent and Staffordshire	522,400	686,000	76.1
NWCA	2,490,400	3,399,800	73.3
England	27,568,200	36,959,200	74.6

The NWCA area generated GVA of £130 billion in 2015, (8.6% of the UK total). The Compound Annual Growth Rate (CAGR) for the region was 3.3% 2002-2015, slightly below the UK rate of 3.6%. Overall productivity in the five LEPs in the NWCA, at £45,100 per job worked, is below the UK average of £50,830 and the rate of productivity growth between 2002 and 2015 was 2.5% per annum, slightly below the UK average of 2.8%. When looking at the whole NWCA region, including the Welsh Local Authorities, GVA per head is £20,891, which is significantly below the UK average of £25,351, with average earnings also ranking below the national average, at £24,231 compared to £28,213.

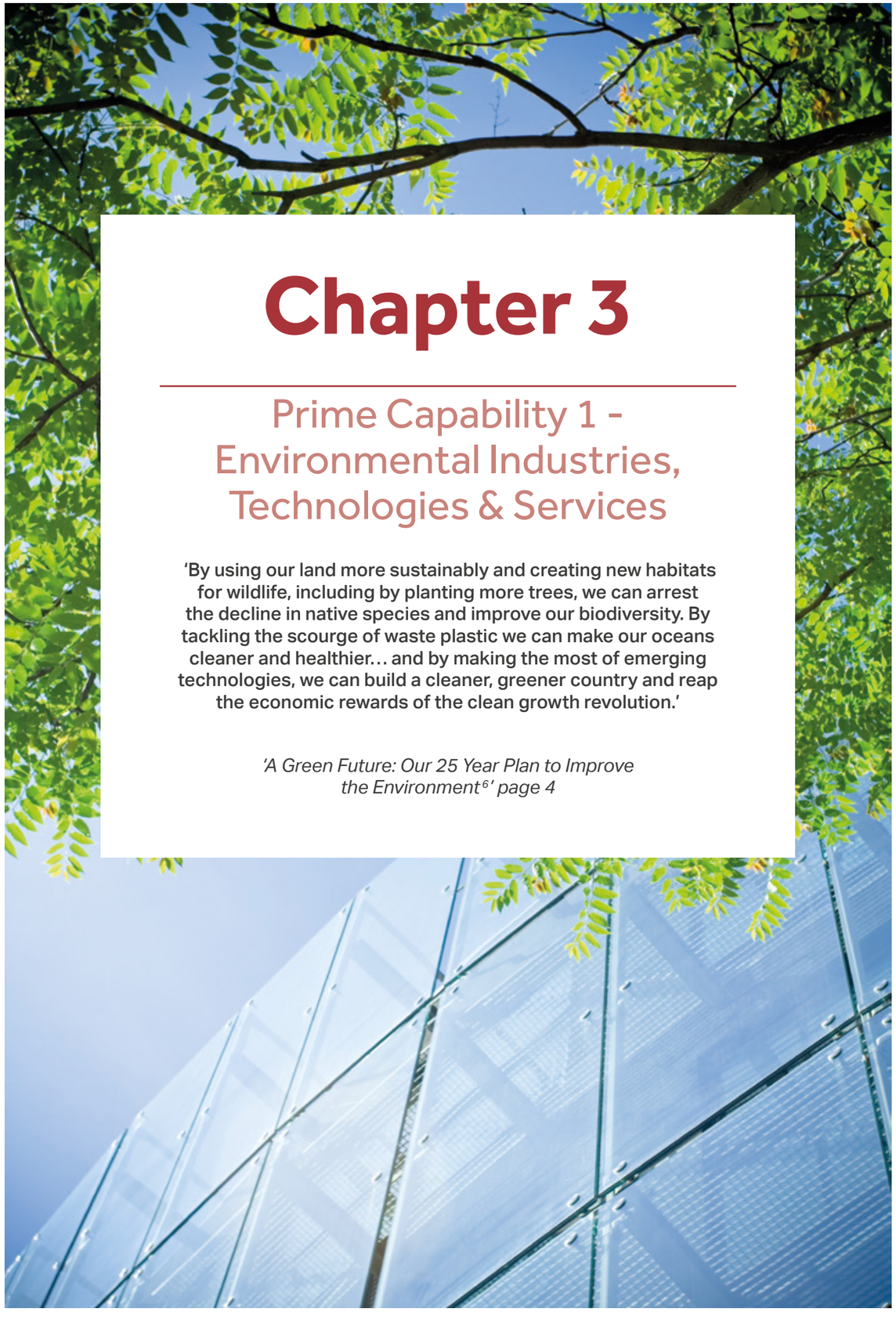
The region's strength in depth in the research base supporting EITS, FES and AMCM (Chapter 3-5) is enhanced by both underpinning research in our cross-cutting research areas and significant cross-cutting knowledge exchange and business collaboration assets, both described in detail in Chapter 6. In summary, 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, such as the Centre for Global Eco-Innovation (see page 20).

(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 and innovation units across the whole NWCA, many developed jointly between academia and industry (see Chapters 3-5, and Annex 3 for full details). It is notable that more than half of these units described themselves as undertaking research that cut across the three capabilities identified in this SIA, one line of evidence for the inherent connectedness across research and innovation for Clean and Sustainable Growth (Chapter 6). However, at present, this infrastructure has been predominantly developed by individual higher education institutions and their key local research users, with only a few exceptions where facilities and activities are joined-up across the region. The lack of connectivity identified in our hypothesis is very clear from the data.

(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 (page 20). Since 2012 CGE has been established and grown supported by ERDF funding and industrial contributions (£30M across all components). 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 the development of 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. CGE was initially a partnership between the Universities of Lancaster and Liverpool, but since 2016 has expanded to include Cumbria, Chester, Liverpool John Moores University and University of Central Lancashire. 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.



Chapter 3

Prime Capability 1 - Environmental Industries, Technologies & Services

'By using our land more sustainably and creating new habitats for wildlife, including by planting more trees, we can arrest the decline in native species and improve our biodiversity. By tackling the scourge of waste plastic we can make our oceans cleaner and healthier… and by making the most of emerging technologies, we can build a cleaner, greener country and reap the economic rewards of the clean growth revolution.'

'A Green Future: Our 25 Year Plan to Improve the Environment[6]' page 4

3.1 National and international trends and size of global markets

The 25 Year Environment Plan and the North West Coastal Arc Partnership for Clean and Sustainable Growth both recognize that improving the environment also brings the potential for significant economic benefit. That applies not just to 'low carbon' energy systems (see Chapter 4) but to multiple elements of the 25 Year Environment Plan that map closely on to sectors and disciplines that we include here under Environmental Industries, Technologies and Services (EITS). These include Agronomy, Crop and Food Sciences (3.1.1 below and Chapter 2 of the 25 year plan), Water Science & Technology (3.1.2 below, and covered in elements of Chapters 2 and 4 of the 25 year plan) and Waste Management & Disposal (3.1.3 below, and Chapter 4 of the 25 year plan).

The 25 year plan is part of the UK's wider environmental commitments to a legally binding target of reducing carbon and other greenhouse gas (GHG) emissions by at least 80% by 2050. This means the national market for low carbon goods and services will grow significantly over this period. While many elements of this are covered in Chapters 4 and 5, agriculture and the water and waste industries are significant sources of greenhouse gas emissions. More sustainable approaches in these sectors must recognise wider demographic and socioeconomic changes. Over the next 30 years, the world population will exceed 9 billion and the global economy will quadruple.

Almost 70 per cent of the population will live in urban areas. Food and energy demand will double, with renewable sources including biofuels and bioenergy accounting for 10 per cent of commercial supplies.

The North West Coastal Arc Clean Partnership for Growth & Sustainable and 'A Green Future: Our 25 Year Plan to Improve the Environment'

Agronomy, Crop Science and Food Sciences

The 25 Year Environment Plan[6] sets out a series of measures to improve how we manage and incentivise land management including a new environmental land management system beyond the Common Agricultural Policy, using fertilizers more efficiently, promoting Integrated Pest Management and reducing the impact of chemical pesticides. It places more emphasis on soil, water and environmental management both to protect the environment and resources, but also to ensure efficient crop performance. It recognizes that growing crops will become more complex and akin to manufacturing in the sense that measurements, data, and control are critically important to manage costs, maximize yields, and boost profits.

Water Science & Technology

The 25 Year Environment Plan sets out a key target around clean and plentiful water, reducing damaging abstraction from rivers and groundwater, improving river basin water quality and biodiversity indicators and improving bathing water quality. Protecting water assets in turn improves biodiversity, securing the value of wildlife, woodland and coasts and making sure decision-making on land use supports multiple benefits to society and ultimately boosts the long-term resilience of homes, businesses and infrastructure.

Waste Management & Disposal

The 25 Year Environment Plan sets out a number of ambitious UK policy targets for waste minimisation working towards the stated ambitions of eliminating avoidable plastic waste by end of 2042 and zero avoidable waste by 2050.

Climate change mitigation will require the cultivation of crops for energy and the production of bio-based ingredients to displace petrochemicals. The need for innovation to deliver Clean and Sustainable Growth globally has never been more urgent, nor a greater opportunity for UK research and businesses.

3.1.1 Agronomy, Crop Science and Food Sciences

In 2015, agriculture, together with food preparation, was the biggest single productive sector in the UK. The UK's agri-food supply chain accounts for an annual turnover of £96 billion with revenues of £14.3 billion. It accounts for 7% of the UK's GDP, and employs around 4 million people. Agronomy is a large and key part of agricultural science that focusses on the technical study of crops and the soils in which they grow. Future challenges focus on raising productivity while minimising energy and resource use. The agri-tech industry, supporting farmers and growers with all kinds of technology, is also a multi-billion pound sector; the UK has a 4–5% share of the world market. The Bioeconomy of the North of England SIA[8] (2017) highlighted the role of agri-tech and biotechnology to improve agricultural resilience, resource use efficiency and productivity.

The global food and beverages market was estimated to be over $5,65 billion in 2017. Asia Pacific and Latin America are expected to see fastest growth and change in food markets due to a large potential consumer base and a changing lifestyle of the middle class population in China, India and Brazil.

The NWCA's vision for 'Clean and Sustainable Growth' focusses on developing the tools - the eco-innovations - needed to deliver the aims and aspirations of the 25 Year Environment Plan as well as The Clean Growth and Industrial Strategies.

The Clean and Sustainable economy in the UK

As well as the three specific sectors discussed below, Environmental Industries, Technologies and Services forms one element in the multi-sectoral Clean and Sustainable Growth economy. In 2015 BIS published a review[5] of that economy across the UK, focussing on low-carbon. In summary:

Of the 9 regions in England, the Northwest has the greatest employment in the low carbon economy.

80,500 from a total of 391,700

THE DIRECT LOW CARBON ECONOMY GENERATED

£26.2bn

in GVA13 in 2013

Which suggests it is about five times larger than Aerospace, two and a half times the size of Pharmaceuticals, almost twice as big as Chemicals and approximately equivalent to Food and Drink in GVA terms.

Between

2010 & 2013

the direct low carbon economy grew by **12%** in terms of employment and **25%** in terms of turnover.

A total of

11,550

businesses were directly engaged in the low carbon economy across the UK in 2013.

Gross Value Added (GVA) increased by **29%,** with a compound annual growth rate of **8.7 percent** and [in 2015 stood] at **£44.9 billion**. This is almost nine times larger than aerospace, and four times larger than the chemicals sector.

M-SParc Science Park, Anglesey

The science underpinning crop production clearly relates closely to food science, which the Institute of Food Technologists defines as, 'the discipline in which the engineering, biological, and physical sciences are used to study the nature of foods, the causes of deterioration, the principles underlying food processing, and the improvement of foods for the consuming public'. One key point of intersection between crop production and food science is the global growth in demand for 'healthy food', whether so-called 'functional food and drink products' or products that meet individual dietary requirements (in 2017 the 'free-from' market was valued at $25billion and growing). Another intersection is the drive to reduce food waste, almost 15m tonnes per year in the UK with 6m tonnes of food ending-up in landfill (linked also to Waste Management & Disposal below).

Environmental Plant Phenotyping Innovation Centre (EPPIC) to support global agri-food productivity

Lancaster University is scoping a state-of-the-art multi-environment phenotyping facility to support a step-change in global agri-food yields. As a national interdisciplinary 'beacon' research facility it would allow the development of next generation crops and a range of bio-product developments including pharmaceuticals, flavour and functional foods for enhanced nutrition. Focused on global climate change impacts and adaptation, it will provide multiple climates, soil, plant and atmospheric conditions.

3.1.2 Water Science & Technology

Water, sanitation and drainage services are provided by 32 privately-owned companies in England and Wales.

Ensuring resilient, reliable and sustainable supply and waste water services are essential for individuals, for the economy and for the environment. Future threats to the sector are likely to increase, including the frequency and unpredictably of extreme weather events (floods and droughts) due to climate change, cyber security threats and a rapidly changing labour market.

The global world market is estimated by Goldman Sachs (2008) to be worth around $425 billion, with a long-term growth of 4%-6% per annum[9]. In industrial markets an average annual growth of 3%-5% (USA and Western Europe) is expected through an improvement in existing water and waste water infrastructure within 5 to10 years, compared with 10% or more in developing markets (China and India) through the creation of a new water and waste water infrastructure.

Owing to the substantial imbalance between supply and demand, the strongest growth areas in the global water market will come from high-end water treatment technologies such as ultrafiltration, reverse osmosis, desalination, disinfection systems and water testing.

Projections about environmental and socio-economic changes are not precise, therefore long-term planning for Clean and Sustainable Growth and resilience depends heavily on data analysis and modelling multiple 'what if' scenarios. In the water sector, in particular, there are many significant near-term capital investment decisions that have very long-term consequences, and so decision sciences and environmental computing are crucial for those systems (Chapter 6). For example, in one sector alone, flood risk management, in England the Environment Agency invested approximately £17m per year on modelling and mapping studies[10], which influence annual capital spend currently running at approximately £700m[11].

The importance of analytics products and services, a part of the digital economy, is set to grow in line with trends in smart infrastructure and data science.

Turning Coffee Cups into Beautiful Papers

Due to their mixed-material composition – paper with a plastic lining – disposable drinks cups require a more specialized recycling technique than many paper re-processors can offer. Cumbria-based paper manufacturer James Cropper has developed a new process to recycle some of the 2.5 billion takeaway coffee cups thrown away every year in the UK. It's trademarked CupCycling™ process allows the company to separate the plastic and paper and use the fibre to make bespoke papers and packaging, while the plastic lining is processed at a separate facility. Their innovation represents the world's first recycling process dedicated to upcycling take-away cups.
James Cropper, Cumbria.
https://www.cupcycling.co.uk

3.1.3 Waste Management & Disposal

The Global Solid Waste Management Market is set to be in excess of $US 350 billion by 2024 as waste generation rates double over the next 20 years. The waste sector in the UK has undergone a technical transformation as resource efficiency targets and Landfill Tax diversion have driven higher rates of recycling, diversion of waste form landfill and innovative ways of upcycling a wide range of resources. The circular economy is changing the way resources are valued and the focus across all sectors is sustainable resource management. Whether in research or skills, these trends again emphasise the connections between capabilities within the wider Clean and Sustainable Growth agenda.

The UK's waste management industry has a total annual turnover of £9 billion. There are 70,000 people employed in the sector across 3,000 companies.

Table 3.1

Environmental Industries Technologies and Services Research and Innovation Assets

Asset	Location	Agronomy, Crop & Food Science	Waste Manage-ment & Disposal	Water Science & Technology
BEACON Biorefining Centre of Excellence	N Wales	×	×	
Biocomposites Centre	N Wales		×	×
British Oceanographic Data Centre	M'side			×
Built Environment & Sustainable Technologies Institute at LJMU	M'side	×	×	×
Centre for Ecology & Hydrology	Lancs & N Wales	×		×
Centre for Environmental Biotechnology at Bangor	N Wales		×	
Centre for Global Eco-Innovation (CGE)	Lancs	×	×	×
Centre for National Parks and Protected Areas (CNPPA)	Cumbria	×		×
Centre for Offshore Renewable Engineering	M'side			
Centre for Waste Management at UCLAN	Lancs		×	
Centre for Water Soluble Polymers	N Wales			×
Centre of Excellence in Sustainable Food Systems	M'side	×		
Combined Food and Power Centre of Excellence	N Wales		×	
Edge Hill University	Lancs	×		
Environment Centre Wales at Bangor University	N Wales			×
Hartree Centre	M'side	×	×	×
Institute for Risk & Uncertainty	M'side			×
Lancaster Environment Centre	Lancs	×		×
Lancaster Leadership Centre	Lancs	×	×	×
Low Carbon Eco-Innovatory	M'side		×	×
Lloyd's Register Foundation	M'side			×
Marine Centre Wales	N Wales			×
M-SParc (the Menai Science Park)	N Wales		×	
National Oceanography Centre	M'side			×
Research Vessel Prince Madog	N Wales			×
River Eden Demonstration Test Catchment	Cumbria	×		×
School of Environment, Natural Resources and Geography, Bangor University	N Wales	×	×	×
School of Environmental Sciences, University of Liverpool	M'side	×		×
School of Ocean Sciences, Bangor	N Wales			×
Sensor City, Liverpool	M'side	×	×	×
SEACAMS 2	N Wales			×
Sêr Cymru National Research Network for Low Carbon, Energy and Environment	N Wales		×	

For example, there is significant growth in energy from waste markets nationally and globally and new waste treatment technologies, a clear link between waste management and our Future Energy Systems capability (Chapter 4). Similarly, there are linkages between EITS and Advanced Manufacturing, Chemicals and Materials through the need for further innovation to stimulate plastic recycling processes and for new bio-plastics to replace oil-based polymers.

3.2 Local science, innovation and industrial assets

Of the sixty internationally significant NWCA research and innovation assets identified by this audit, thirty-two have activities related to one on more aspects of the Environmental Industries, Technologies and Science Prime Capability (Table 3.1 and see Annex 3 for full details). Of these, eighteen undertake research that encompasses the Future Energy systems capability as well as EITS, and ten in which research links EITS with Advanced Manufacturing, Chemicals and Materials.

Notable businesses include United Utilities, Welsh Water, Nestle, AMEC, ACM Environmental, Sita, numerous Global Environmental consultancies and testing services in addition to a growing number of high growth SMEs e.g. Yordas Group.

As is evident throughout, this audit encompasses multiple aspects of Clean and Sustainable Growth, some across all three capabilities of this SIA, described in Chapter 6. Notable examples with a primary focus on Environmental Industries, Technologies and Services include (i) the Lancaster Environment Centre, (ii) the Sêr Cymru National Research Network for Low Carbon, Energy and Environment and (iii) two elements of the research capability of the Natural Environment Research Council (the Centre for Ecology & Hydrology and the National Oceanography Centre).

The **Lancaster Environment Centre (LEC)** represents one of the world's largest centres for environmental research, with academic expertise spanning the natural and social sciences, offering balanced perspectives on what are complex societal challenges. The Plant and Crop Science Group represent world-leading capability. They work from the molecular to the crop scale with researchers and end-users of research, with a particular strength in applying research to provide solutions to real-world problems, particularly in relation to agri-food challenges.

Bangor University is home to the Sêr Cymru **National Research Network for Low Carbon, Energy and Environment (NRN-LCEE)** a pan-Wales initiative funded by the Welsh Government and the Higher Education Funding Council for Wales. The network supports collaborative and interdisciplinary research in Wales into the interactions between land, water, the provision of food and energy production.

The Centre for Ecology & Hydrology (CEH) is a UK Government research facility co-located with the Lancaster Environment Centre on the Lancaster University campus and Bangor University's Environment Centre Wales in Bangor. CEH has national capability (recognised as internationally leading) in earth observation, natural hazard management, sustainable energy potential and impacts, informatics and water management that generates knowledge to populate toolkits for optimising decision making at a range of scales.

The National Oceanography Centre (NOC) is the United Kingdom's centre of excellence for oceanographic sciences and is one of the world's top oceanographic institutions.

The NOC undertakes world leading research in large scale oceanography and ocean measurement technology innovation. Liverpool University and NOC host the British Oceanographic Data Centre (BODC) - a national facility for looking after and distributing data concerning the marine environment. It is internationally recognised for work on tides, sea level and shelf sea physics, along with the development of new instruments and techniques for observing the oceans.

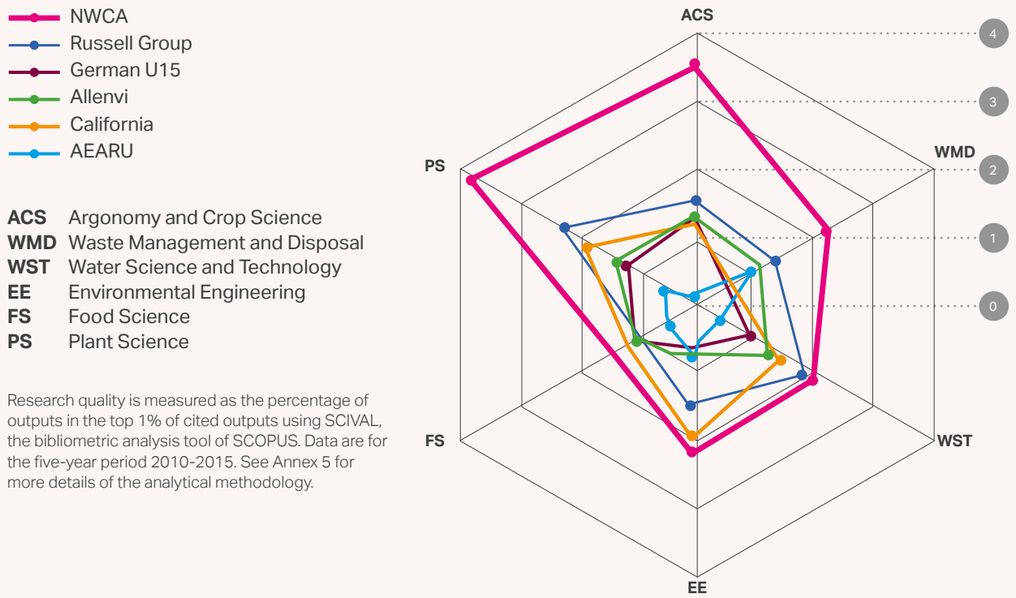
In addition to our local research and innovation assets the region has good links to other Clean and Sustainable Growth assets on the periphery of the NWCA. A notable example is the Tyndall Centre for Climate Change in Manchester. Established in 2000 with funding from the UK Research Councils, The Tyndall Centre for Climate Change's work covers the whole spectrum of geographical, time and human scales, linking research efforts across disciplines through an integrated approach.

"The Yordas Group, based in LEC, provides chemicals based regulatory advice and services to both industry and government bodies across the globe. In the initial conceptual stages, and before the incorporation of Yordas in 2007, the university provided pivotal strategic advice and access to scientific research and resource based in LEC. Ten years on, and we now employ over 50 staff from various disciplines including chemistry, human toxicology, ecotoxicology, software engineering and marketing.
We enjoy the benefits of a very multi-national workforce and now serve companies from over 30 countries. Our growth has been fundamentally underpinned by utilisation of the university's various student engagement opportunities, collaborative R&D programmes and international reach, underpinned by expertise across the institution. Around 70% of our employees to date originated from the university."
Chief Executive,
The Yordas Group

The industry focus is on innovation, research and development in priority fields such as Energy and Waste Management, Water Treatment, Environmental Monitoring and the Built Environment.

Figure 3.1

Research quality for the NWCA in the six sub-disciplines included under our Environmental Industries, Technologies and Services (EITS) capability, compared with other major university groups or regions.

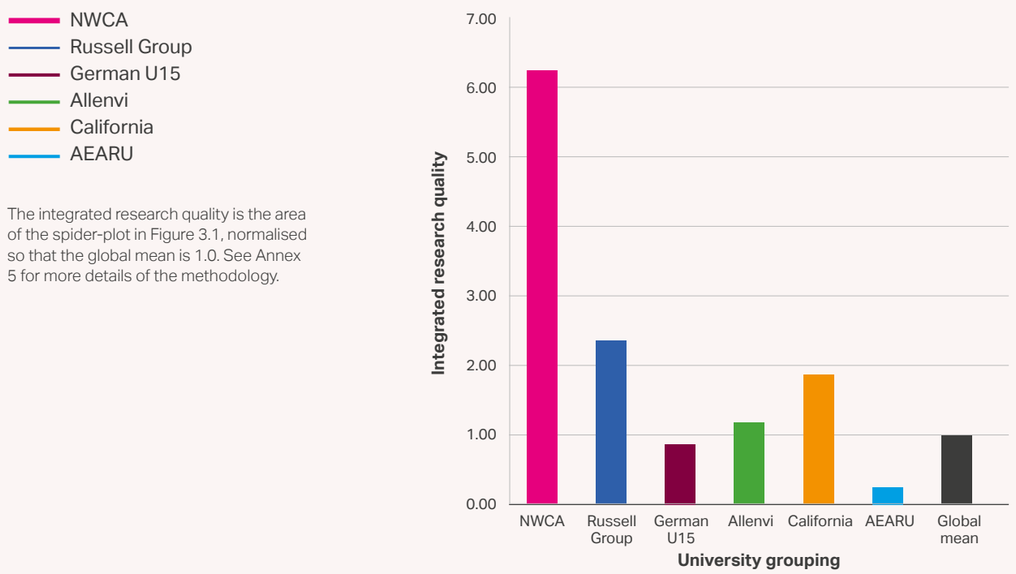


ACS Argonomy and Crop Science
WMD Waste Management and Disposal
WST Water Science and Technology
EE Environmental Engineering
FS Food Science
PS Plant Science

Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 3.2

Integrated research quality across Environmental Industries, Technologies and Services for the NWCA compared with other major university groups or regions.



The integrated research quality is the area of the spider-plot in Figure 3.1, normalised so that the global mean is 1.0. See Annex 5 for more details of the methodology.

3.3 Local science and innovation talent

3.3.1 The current workforce and the likely future skills needs and sources

Our audit of the current NWCA workforce relevant to Clean and Sustainable Growth showed the challenge of separating sectors that are strongly inter-linked. For that reason, we cover this across all capabilities in Annex 6. There are also substantial cross-capability overlaps in training provision and need at all levels, so these common elements are also covered in Annex 6, while we focus here on specific skills need and provision for EITS.

One common theme across the EITS sub-capabilities is the need for training that keeps pace with the rapid evolution of the skills needed across these sectors. In Agronomy, Crop Science and Food Sciences training at all levels needs to recognise that the growing emphasis on 'smart production' systems noted in the 25-year plan[6], demands skills very different from the 'traditional' skills of our land-based industries. Within the region, this is exemplified by the £3 million Food and Farming Innovation Technology Centre at Myerscough College (Lancashire), the £8 million National Centre for Horticulture, Environment and Sustainable Technology at Reaseheath College (Cheshire), the Agri-Food Training Partnership (AFTP) a collaboration focused on agri-food training including Bangor University and the 'Food Challenges for the 21st Century' postgraduate training at Lancaster University developed in partnership with Waitrose.

This audit has highlighted the lack of focused training to meet the needs of the Water Science & Technology sector, a notable gap given its economic value and wider significance.

Within the NWCA this need has been recognised, for example, by the PG Cert/Dip/Masters in Water, Energy & the Environment at Liverpool John Moores University, the PG Cert/Dip/Masters in Flood and Coastal Risk Management at Lancaster University, and the Flood Risk, Assessment, Modelling and Engineering (FRAME) Degree in development at the University of Chester.

The new resource-oriented direction of the Waste Management & Disposal sector calls for a transformation in its skill requirements and demand for operational staff with a technical, process-related background[12]. Within the NWCA this need is being met by the Centre for Waste Management at the University of Central Lancashire where a range of postgraduate CPD courses accredited by the Chartered Institute of Waste Management (CIWM) are delivered on a full or part-time basis. Courses focus on Waste Awareness, Resource Solutions and Resource Optimisation for the Low Carbon Economy.

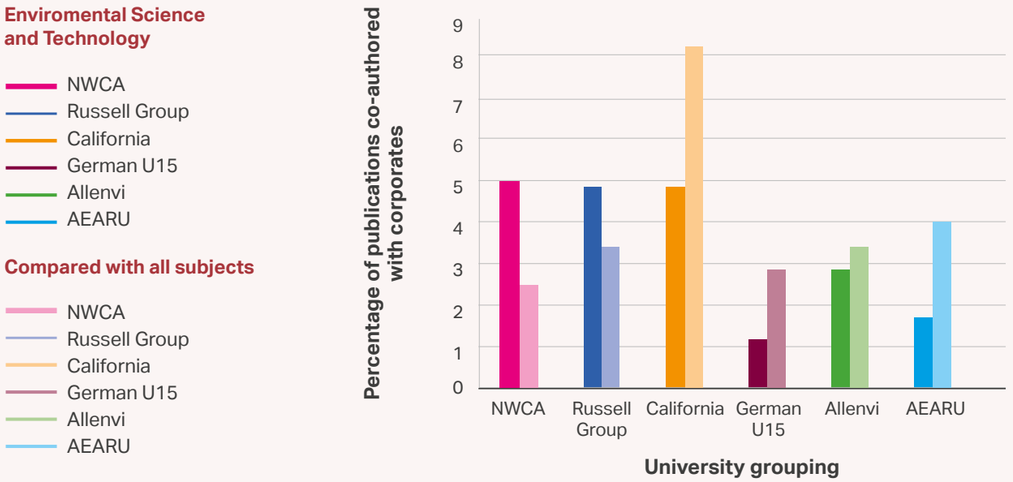
The award-winning Centre for Global Eco-innovation (see p20) has supported over 100 SME led postgraduate level research projects with businesses across Lancashire, Cumbria, Cheshire and Merseyside in the last 5 years. The Centre's pioneering post-graduate programme is designed to give ambitious graduates opportunities to kick-start a well-paid career in the UK and overseas, by linking doctoral-level research with ambitious and growing enterprises. The programme recognises the need for multi-disciplinary skills that go beyond a narrow technology domain and demand a mix of science, management and entrepreneurial thinking as key skill sets.

3.3.2 Evidence-based assessment of the region's existing science and innovation talent

We use here the approach to comparing research quality described in Chapter 2, i.e. defining quality as the percentage of outputs in the top 1% of citations in the field, and comparing the NWCA with leading national and international university groupings, plus California, included here as a region recognised for its leadership in innovation. Even with this very rigorous comparison the quality of the NWCA's research outputs in the EITS subjects is consistently above that of the national and international university groupings chosen as comparators (Figure 3.1). Measured in this way research in the Agronomy and Crop Science, Plant Science and Waste Management sub-disciplines is exceptionally strong, and the three remaining sub-disciplines are also all above all comparators. As a result of this consistent strength across all EITS sub-disciplines the NWCA's integrated research quality in EITS scores 6.2 against a global mean of 1.0, and substantially exceeds that of all the comparators (Figure 3.2). In summary, the NWCA has exceptional strength in depth across EITS and this supports our other eco-innovation capabilities. For example, Waste Management and Disposal is also relevant to Advanced Manufacturing, Chemicals and Materials, while Water Science and Technology relates closely to some elements of Future Energy Systems.

Figure 3.3

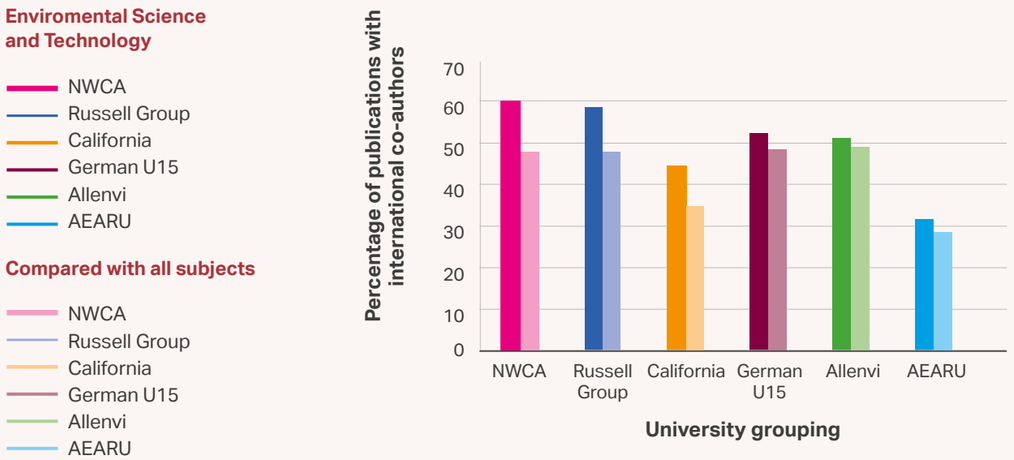
Percentage of Environmental Industries, Technologies and Services (EITS) research outputs co-authored with colleagues from a non-academic (corporate) organisation. Data for the NWCA are compared with other major university groups or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

Figure 3.4

Percentage of Environmental Industries, Technologies and Services (EITS) research outputs co-authored with colleagues from outside the UK. Data for the NWCA are compared with other major university groups or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

Environmental Plant Phenotyping Innovation Centre (EPPIC) to support global agri-food productivity

Axion Recycling has grown a business around innovation in polymer recycling. Established in 2002, with two staff, the business is now an SME of c. 100 employees which focuses on using innovative technology and chemical and engineering expertise to produce technology, products and services to increase the amount of recycling product from mainly Automotive Shredder Residue (ASR). The company's technology can separate complex plastic materials from other ASR and produce high quality recycled polymers and products, largely for the construction, drainage, household and storage industry. With the emergence of the circular economy, businesses such as this provide local sustainability development. Due to the majority of the markets served being local, this business adds the key element of traceability to the circular economy.

The success of this business has been aided by a sister consultancy department, which offers expert advice to the sector and enabled the business to build its reputation. Axion's collaboration with Northwest regional universities and Innovate UK/Horizon2020 funding have also been significant, as has the ability to attract graduates in the environmental/sustainability industry. Having technology at the leading edge of the sorting and recycling sector and offering the added value of consultancy services have been identified as key drivers of success.

3.4 National and international engagement

Engagement between the NWCA's research based and national and international research users in EITS is evident from the many assets listed in Section 3.2. Other measures of engagement emerge from the SCIVAL analysis of research metrics for publications with corporate co-authors and publications with international co-authors.

Across all the non-UK university groups audited, a smaller percentage of research outputs are jointly published with corporate co-authors in EITS than expected from the mean across all subjects (Figure 3.3). By contrast, the Russell group and especially the NWCA published more papers with corporate co-authors in EITS research areas than the mean of all subjects (Figure 3.3). In EITS the NWCA publishes more research outputs with corporate co-authors (5.1%) than any of the university groups or regions chosen as comparators, including the Russell group and California (4.9%).

EITS publishes a greater percentage of research outputs jointly with international co-authors than expected from the mean across all subjects (Figure 3.4). This is the case for NWCA and all the groups audited. The NWCA publishes a higher percentage of its EITS research outputs with international partners (61%) than all our chosen comparators. As with the other Prime Capabilities, the NWCA stands up well in terms of publications with international partners, even against these strong comparators.

"I was particularly interested in an industry focused PhD because it would allow me to contribute to fundamental science research alongside creating an opportunity to see a direct real-world impact of my work. There is a global drive for greater partnerships between academic and industry and it was exciting to be able to be a part of a unique scheme."
Stephanie Bryan, CGE graduate researcher with Arcis Biotechnology Limited.

3.5 Developments in the wider funding landscape

3.5.1 The wider landscape

In common with all three Prime Capabilities of this SIA, EITS is closely related to the needs of the Clean Growth Strategy and Industrial Strategy Challenge Fund, and we further see a clear potential fit with the recently announced UKRI Strength in Places programme. The Government's Industrial Strategy identifies Clean Growth as one of the Grand Challenges to put the UK at the forefront of industries of the future. The strategy sets out a comprehensive set of policies and proposals that aim to accelerate the pace of 'clean growth', i.e. deliver increased economic growth and decreased emissions and will be a key driver for investment in innovation via The Industrial Strategy Challenge Fund. This will provide funding and support to UK businesses and researchers and is part of the government's £4.7 billion increase in research and development over the next 4 years. The Smart Cities' Agenda, especially in relation to new housing needs, will lead to increased demand for water and water treatment solutions, in addition to waste processing innovation. Housing growth offers opportunities to design and develop innovative solutions for delivering low carbon homes effectively, alongside retrofitting existing buildings in the public, commercial and domestic sectors.

The National Infrastructure Assessment, published in 2018, is also pertinent as a current focus is overcoming threats to UK prosperity and quality of life by congestion and lack of capacity. Environmental science and technology research is at the heart of understanding these issues, particularly in terms of the priority areas associated with transport, air quality and reducing the risks of extreme weather including drought and flooding.

Transforming Food Production represents £90 million of Industrial Strategy Challenge funding to help business and research to work together to transform food production systems to create a more resilient food supply better able to manage climate change impacts. Funding will be directed towards translation hubs, innovation accelerator funds, demonstrator projects and international research.

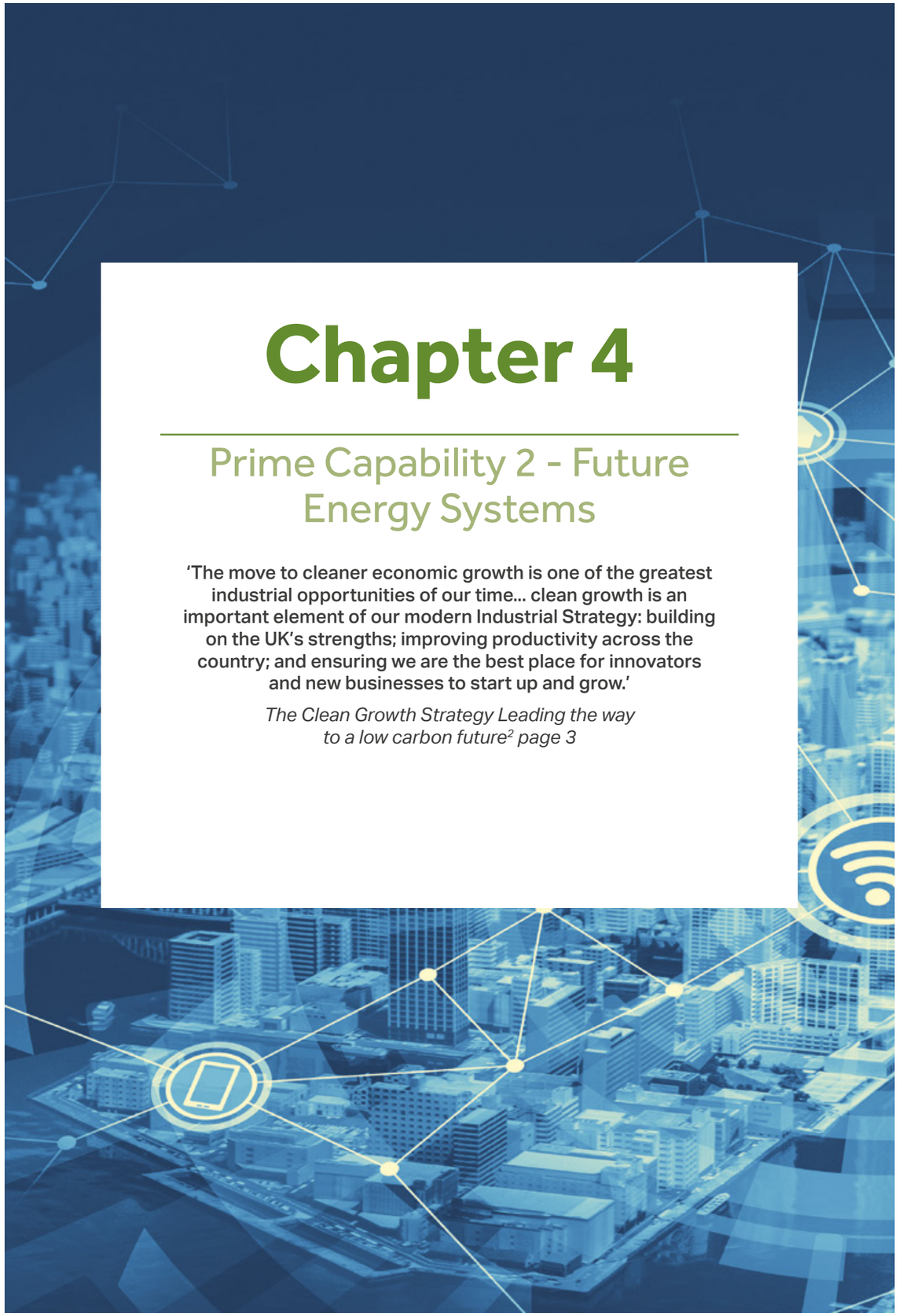
This challenge will help find new ways to maintain food supply in a way that cuts pollution, safeguards soils, minimises waste, and protects air quality and water supplies.

Chapter 4

Prime Capability 2 - Future Energy Systems

'The move to cleaner economic growth is one of the greatest industrial opportunities of our time... clean growth is an important element of our modern Industrial Strategy: building on the UK's strengths; improving productivity across the country; and ensuring we are the best place for innovators and new businesses to start up and grow.'

The Clean Growth Strategy Leading the way to a low carbon future[2] page 3



4.1 National and international trends and size of global markets

The UK Clean Growth Strategy[2] defines the UK's approach to delivering a prosperous 'low carbon' future. The 2008 Climate Change Act committed the UK to reducing greenhouse gas emissions by 80% of 1990 levels by 2050 and in 2015 the UK played a key role in the Paris Climate Agreement to keep the global temperature rise below 2°C. Commitments made under this agreement will require approx. $13.5 trillion of public and private investment in the energy sector alone. Success in achieving these targets will not only improve quality of life but also increase productivity and economic growth.

We recognise that 'low carbon' is an important element in many Science and Innovation Audits (see Annex 4). In this SIA, as in the Clean Growth Strategy. This will require making systems smarter, more flexible and taking advantage of rapidly developing energy storage technologies.

The NWCA has internationally significant assets for low-carbon generation, strongly linked to the region's varied natural and industrial assets. The North already generates large amounts of renewable energy (48% of the renewable power generated in England) and has seen a faster uptake of renewables compared to the UK average, increasing by 93% from 2003 - 2015[13].

However, the region also has strength in depth across new energy technologies and digital enablers that mean consumer needs for warmth, cooling, light and mobility will be met cleanly and more efficiently. The NWCA already brings together research expertise across the multiple disciplines that need to coalesce and collaborate with industry and the public sector to address and formulate innovative solutions to current and future energy related challenges and opportunities.

We hypothesise that further gains will come from greater connectivity. In addition, sustainable energy systems of the future will demand multidisciplinary and novel approaches to skills training at all levels, delivering people with the competencies and agility to address a fast-changing energy landscape.

Pioneering UK Gas Project aims to reduce domestic CO_2 emissions

A pioneering green energy trial at Keele University could help cut carbon dioxide (CO_2) emissions caused by heating homes. Led by gas network Cadent, and in partnership with Northern Gas Networks and a consortium of technical experts, the HyDeploy project is exploring the potential of injecting zero-carbon hydrogen into the natural gas network. HyDeploy aims to establish the potential for blending hydrogen, up to 20%, into the normal gas supply to reduce carbon dioxide (CO_2) emissions. The trial - which is the first of its kind in the UK - is part of Keele's overarching commitment to environmental sustainability.

4.1.1 Delivering Clean, Smart, Flexible Power

Globally, clean energy technologies are estimated to account for almost all of the $10.2 trillion investment in power generation projected until 2040. Progress is already being enabled by the falling costs of many low carbon technologies and now renewable power sources like solar and wind are comparable in cost to coal and gas in many countries[2]. Both China and India plan to seize the economic opportunity of transitioning to a low carbon economy. For example, India plans to increase its renewable power fivefold to 175 gigawatts by 2022 and China has committed to invest $360 billion in low carbon power by 2020[2].

Annual new global investment in renewable electricity grew more than threefold since 2005, reaching over $240 billion in 2016. In the UK progress is being made and 47% of electricity came from low carbon sources in 2016, which was double the level in 2010. On 21st April 2017, no coal was used within a 24-hour period for the first time since 1882. By 2050, it is estimated that emissions from the power generation sector could be close to zero, but this will only be possible by growing low carbon energy sources to over 80% of electricity generation (and phasing out coal) and enabling a smarter system, enabling flexible interconnection of storage and response. Examples of NWCA regional leadership in this area include the £900 million Liverpool-Manchester hydrogen plan led by Cadent completely transforming the gas grid in the North West by the mid-2020s and the hydrogen demonstration pilot project at Keele University (see case study Box).

4.1.2 Improving Our Homes

To meet climate change targets, there will be a need to fully decarbonise how homes are heated and cooled. Low carbon heating technologies including heat pumps, district heat networks and using hydrogen in existing gas grids, have the potential to support the magnitude of change required. The UK has 27 million domestic homes and can therefore be a leader in the development, manufacture, installation and servicing of low carbon and energy efficiency products and control systems and an exporter of knowledge, skills and products to other countries. The Government's Budget 2017 announcement of the commitment to support 300,000 new house builds a year provides a further market stimulus and 'test-bed' opportunity.

We recognise that innovation for Clean and Sustainable Growth must be about more than simply renewable power generation. The ambition is for a diverse generation system that supplies homes and businesses with power that is affordable, clean and resilient, taking into account wider system and environmental impacts.

Table 4.1

Future Energy Systems Research and Innovation Assets

Asset	Location	Improving our homes	Clean, Smart, Flexible Power	Low Carbon transport
Advanced Manufacturing and Research Institute	N Wales			×
British Oceanographic Data Centre	M'side		×	
Built Environment & Sustainable Technologies Institute (LJMU)	M'side	×	×	×
Centre for Ecology & Hydrology	Lancs		×	
Centre for Global Eco-Innovation	Lancs	×	×	×
Centre for Offshore Renewable Engineering	M'side		×	
Centre in Advanced Energy Systems	Ches	×	×	
Centre of Excellence in Sustainable Energy	M'side		×	
Combined Food and Power Centre of Excellence	N Wales		×	×
DEMAND (Dynamics of Energy, Mobility and Demand) Centre	Lancs	×	×	×
Energy Centre at Thornton Science Park	Ches		×	×
Energy Innovation District	Ches	×	×	
Energy Lancaster at Lancaster University	Lancs	×	×	
UK Geoenergy Observatory	Ches		×	
Environment Centre for Wales at Bangor University	N Wales	×	×	×
Hartree Centre	M'side	×	×	×
HyDeploy project	Staffs	×	×	
Institute for Risk & Uncertainty at Liverpool University	M'side	×	×	×
Lancashire Energy HQ	Lancs		×	
Lancaster Environment Centre at Lancaster University	Lancs	×	×	
Lancaster Leadership Centre	Lancs	×	×	×
Lloyd's Register Foundation	M'side		×	
Low Carbon Eco-Innovatory	M'side	×	×	×
Menai Science Park Ltd	N Wales		×	
National Oceanography Centre	M'side		×	
National Research Network for Low Carbon, Energy and Environment	N Wales		×	
North West Advanced Manufacturing Research Centre	Lancs			×
North West Hydrogen Cluster	M'side		×	×
OpTIC – the Optoelectronic Technology Incubation Centre	N Wales	×	×	
Quantum Technology Centre	Lancs	×	×	×
School of Environment, Natural Resources and Geography, Bangor	N Wales		×	
School of Ocean Sciences, Bangor	N Wales		×	
Sci-Tech Daresbury	M'side	×	×	×
SEACAMS 2	N Wales		×	
Sensor City, Liverpool	M'side	×	×	×
Smart Energy Network Demonstrator	Staffs	×	×	
Stephenson Institute for Renewable Energy at Liverpool University	M'side	×	×	×
West Anglesey Demonstration Zone	N Wales		×	×

The North West Coastal Arc Clean Growth & Sustainable Partnership and 'The Clean Growth Strategy: leading the way to a low carbon future'

Delivering Clean, Smart, Flexible Power

In 2015, 47% of electricity came from low carbon sources. However, there remains a need to grow low carbon sources to in excess of 80% of electricity generation, and to phase out coal power. The low carbon electricity sector generated over £12 billion in turnover and directly supported 47,000 jobs. The Government expects to invest £900 million in research and innovation in the power sector between 2015 and 2021.

Improving Our Homes

There are now approximately 25% more homes than in 1990, but the overall total of emissions from the sector has reduced by 20% over the same period. Support is needed for innovation to test and bring down the cost of low carbon heating technologies, many of which are currently too expensive. Through the Renewable Heat Incentive (RHI), the Government is spending £4.5 billion between 2016 and 2021 to support innovative low carbon heat technologies in homes and businesses, such as heat pumps, biomass boilers and solar water heaters.

Accelerating the Shift to Low Carbon Transport

30% to 70% of new car sales are expected to be ULEVs by 2030. Modernisation of aerospace and shipping sectors, will be enabled through support for sustainable alternative fuels, improved efficiency and new technologies. The Automotive Council is developing a Sector Deal, building on the £1 billion Advanced Propulsion Centre, which is seeking to establish the UK as a world leader in zero emission vehicle technologies. Industry and Government have made a joint £3.9 billion commitment between 2013 and 2026 to the development of new aircraft technology with the Aerospace Technology Institute.

4.1.3 Accelerating the Shift to Low Carbon Transport

There are now 115,000 Ultra Low Emission Vehicles (ULEVs) on the road in the UK. This has been driven through a combination of grants and improved charging infrastructure. To achieve 2050 targets, almost every car and van will need to be zero emission by that year. There is also a desire to double the use of sustainable bioenergy in the transport sector and a need to develop and deploy advanced low carbon fuels derived from wastes or industrial and agricultural by-products in the aerospace sector. Future of Mobility is one of the Grand Challenges within the Government's Industrial Strategy with the electrification and automation of road vehicles and the modernisation of rail services recognised as ways to dramatically reduce carbon emissions and other pollutants.

4.2 Local science, innovation and industrial assets

4.2.1 Science and Innovation assets

Of the sixty internationally significant NWCA research and innovation assets identified by this audit, thirty-nine have activities related to one or more aspects of the Future Energy systems capability (Table 4.1 and see Annex 3 for full details). Of these, eighteen undertake research that encompasses the Environmental Industries, Technologies and Science theme as well as FES, and another ten have research that links FES with Advanced Manufacturing, Chemicals and Materials. The audit further highlights that many of the NWCA's research and innovation assets take a holistic perspective on low carbon energy that encompasses multiple aspects of the Clean Growth strategy.

Notable examples with a primary focus on Future Energy Systems include (i) the **Smart Energy Network Demonstrator (SEND)** at Keele University, (ii) the Stephenson Institute for Renewable Energy (SIRE) at Liverpool University and (iii) The Energy Centre at Thornton Science Park.

The region's industrial legacy contributes a potential renewable energy source by exploiting water in flooded mines that is heated naturally by warm rocks at depth below the surface. This potential for geothermal heat generating capacity has led to the development of a first at-scale smart energy network demonstrator at Keele University and a new district heating network for Stoke on Trent. The Stoke-on-Trent District Heat Network alone will deliver up to 45GWh per annum; lowering heat energy costs by up to 10%; saving approximately 10,000 tonnes of CO_2 per annum and supporting 180 construction jobs, 30 permanent jobs, and 1,350 indirect jobs. This Smart Energy Network Demonstrator (SEND) will allow Keele University campus to become the largest single, demonstrator in Europe that integrates electricity, gas and heat in to a smart energy network, acting as an at-scale living laboratory research, development and demonstration of new smart energy technologies and services in partnership with business.

There may be synergies, currently unexploited, between SEND and the **Energy Security and Innovation Observing System for the Subsurface (ESIOS)** at Thornton Science Park in Chester, which is also focused on the huge potential of Britain's underground energy resources. The recently completed 'Intelligent Energy System Demonstrator (IESD)' facility at Thornton Science Park will focus on storage solutions and advanced software control systems and provides a flexible space where industry and researchers are able to work together to develop and demonstrate new intelligent energy technologies.

The Stephenson Institute for Renewable Energy (SIRE) at Liverpool University is a specialist energy materials research institute, focusing on the physics and chemistry for future energy generation, storage, transmission and energy efficiency with c £18m of active research funding. Partner companies include AMEC, AREVA, AWE, EDF, the Nuclear Decommissioning Authority, the NNL, Rolls-Royce and Sellafield Ltd.

4.2.2 Industrial assets

4.2.2.1 Delivering Clean, Smart, Flexible Power

The region's geography is a significant asset that adds considerably to our comparative FES strengths. Liverpool Bay has the second highest concentration of offshore wind turbines in the world. The City Region was recently designated as a Centre for Offshore Renewable Engineering (CORE Status). Growth is being stimulated through £3.5bn invested in Liverpool Bay and the exploitation of commercial opportunities in Low Carbon environmental goods and services, energy and heat networks. Dong Energy, Scottish and Southern Energy operate one of the world's largest offshore wind farms at Walney (Cumbria), with additional investment at the Walney Extension site and at Heysham (Lancashire), a key location to bring this offshore electricity onshore to connect with the National Grid, providing the opportunity to create a focal point for nationally significant infrastructure investment.

As well as wind power the NWCA's marine energy assets include very large potential for tidal energy generation. The Minesto Deep Green project includes a 10MW tidal array (Annex 3), and the proposed Northern Tidal Power Gateway across Morecambe Bay and the Duddon Estuary in NW England could produce more than 6,500GWh of electricity per annum, enough to power approx. 1.5 million homes. In addition to the power generated, the proposal would vastly improve transport infrastructure and boost economic growth.

Both projects offer the opportunity to secure and enhance the UK's global leadership in tidal energy generation.

The NWCA's uplands in Cumbria, Lancashire and North Wales may be a resource for large-scale forest-based biomass production. The region is also well-placed to exploit and demonstrate systems to meet the growing global demand for distributed small-scale renewable energy generation, whether solar, water or wind power. Of the total potential hydropower generation capacity for England and Wales (approx. 150-250 MW) about 25% is in North West England and 30% in Wales. Gilkes Energy Ltd (Cumbria) specialises in the development of hydro power projects in the UK and is one of the most respected designers and developers of turbine systems for hydro power with installations across the globe.

Work recently started on the construction of one of the world's largest battery storage facilities at the site of the former Roosecote power station in Barrow (Cumbria). Once complete, the facility will be capable of responding to fluctuations in demand in under a second, holding enough power to meet the needs of around 50,000 homes.

4.2.2.2. Improving Our Homes

The Clean Growth Strategy suggests a pathway where hydrogen could provide up to 60% of domestic heat demand by 2050[2] and this audit identifies that the NWCA is leading the way in exploring hydrogen as a low carbon fuel for homes and transport. In addition, Cadent, the gas network operator in the north west, is engaging in other long-term projects to decarbonise the gas network under the Ofgem-run RIIO system. Projects include connecting bio-methane to the gas network, currently a 2% blend but with the potential for 10%, including bio-methane produced from 'black bag' waste, which has the potential to supply 30% of network demand.

4.2.2.3 Accelerating the Shift to Low Carbon Transport

This audit has also highlighted that there is a very substantial overlap between this Future Energy Systems theme and our Advanced Manufacturing, Chemicals and Materials theme, particularly around the aerospace and automotive sectors. Although those are dealt with in detail in Chapter 5, their direct relevance to the Clean Growth Strategy is clear. The audit has also revealed the scope for the region's research base to act as conduits for understanding between these sectors, for example around 'light-weighting', to be made known and used in other ways.

4.3 Local science and innovation talent

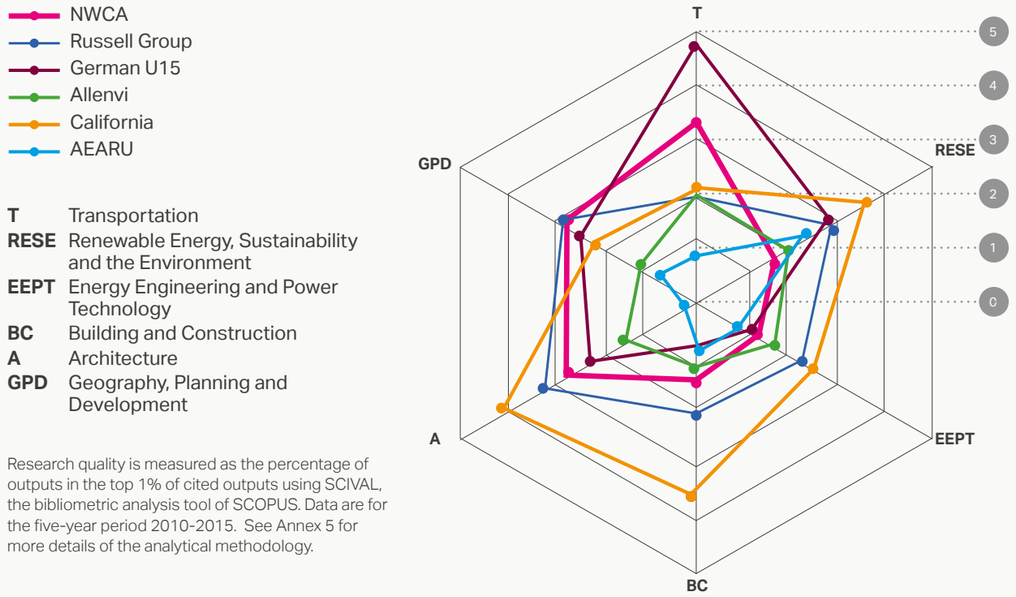
4.3.1 The current workforce and the likely future skills needs and sources

Our audit of the current NWCA workforce relevant to Clean and Sustainable Growth showed the challenge of separating sectors that are strongly inter-linked. For that reason, we cover this across capabilities in Annex 6. There are also substantial overlaps between capabilities in training provision and need at all levels, so these common elements are also covered in Annex 6. We focus here on specific skills need and provision for FES. One example is Lancashire Energy HQ, a £10.7m dedicated education and training facility developed by Blackpool and Fylde College in collaboration with industry partners and opened in March 2018.

Hydrogen may be a significant fuel for low carbon transport systems, as well as homes, and the NWCA is taking a leading role in research and innovation in hydrogen powered public transport systems.

Figure 4.1

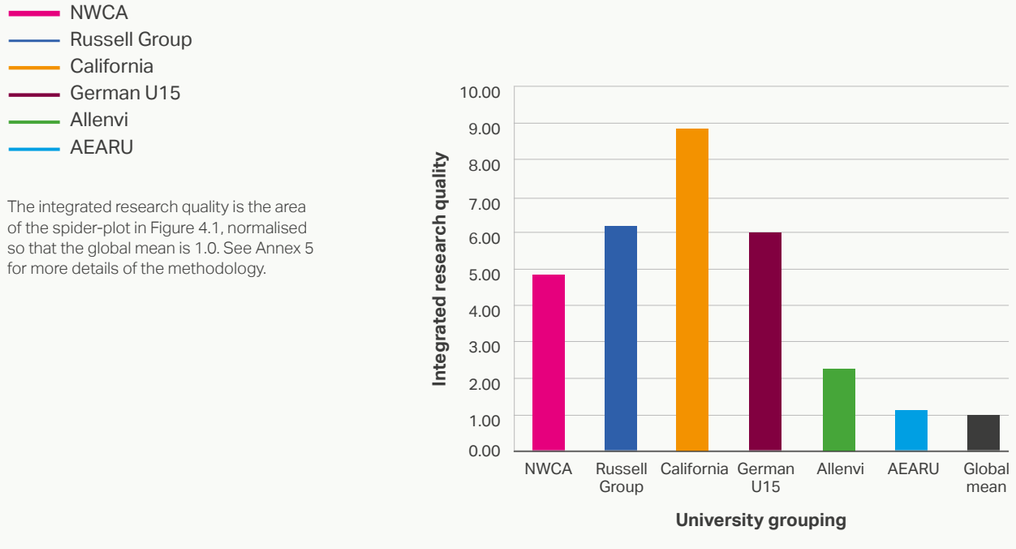
Research quality for the NWCA in the six sub-disciplines included under our Future Energy Systems capability (FES), compared with other major university groups or regions.



Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 4.2

Integrated research quality across Future Energy Systems for the NWCA compared with other major university groups or regions.



The integrated research quality is the area of the spider-plot in Figure 4.1, normalised so that the global mean is 1.0. See Annex 5 for more details of the methodology.

Clean but controversial? The role of energy from tidal lagoons, nuclear and shale gas

The Clean Growth Strategy refers to the diversity of generation options needed for low-carbon growth. Even some 'Clean' energy options remain controversial, for example the recent rejection of the Swansea Bay Tidal Lagoon may well influence future planning for Northern Tidal Power Gateway across Morecambe Bay and the Duddon Estuary. Nuclear power is included in the Clean Growth Strategy, and the NWCA has great strength in nuclear power and associated research and innovation. This is largely the domain of the North West Coastal Arc Nuclear SIA, and we have worked closely with that SIA to review interfaces and synergies, for example with respect to sustainability in decommissioning. Another example of synergy is Bangor University's planned Centre of Excellence in Sustainable Energy which seeks to capitalise on the major investment in nuclear power planned for Anglesey, broadening its remit to other technologies and industries.

Perhaps most controversial of all in the context of 'Clean and Sustainable Growth' is how to make best use of the Lancashire's Bowland Shale gas reserves, which are one of the largest in Europe. Shale gas is clearly not 'low carbon', it is a fossil fuel. However, while not 'zero carbon' shale gas may be a lower carbon than alternatives such as coal as the UK faces loss of generation capacity (by the end of 2030, over 30 GW generation capacity will close down) concurrent with rising demand as electricity is increasingly used to power transport and heating. There are also strong socioeconomic drivers to develop the resource, recognised in the UK Industrial strategy, as well as strongly held local concerns. The NWCA's position is that if UK energy policy supports the use of shale gas then its use should be supported by an evidence base to drive best practice.

The imperative for any growth of hydraulic fracturing operations both in the UK and around the globe is to ensure minimal risks for water quality, natural capital and climate change. The impacts on the environment are potentially significant without scientifically-informed best-practice and regulation. There is an urgent need to gather the evidence base to ensure best practice and operational excellence. This maps extremely well on to the research strengths of our higher education institutions and new assets such as the NERC/BGS ESIOS facility at the Thornton Science Park. Understanding the controversy around shale and other elements of future energy systems also draws on the region's strength in environmental aspects of the social sciences.

In Cheshire, the Cheshire Energy Hub was founded in 2014 as a multi-employer partnership between a number of leading international Cheshire-based organisations, including C-Tech, Capenhurst Nuclear Services, EA Technology, Encirc, ESSAR Oil, NNL, STORENGY, Scottish Power, URENCO, and was awarded the Innovative Collaboration Initiative of the Year award for its graduate development programme. Other examples include the Energy & Power Systems MSc at Liverpool University, the Marine Renewable Energy MSc at the University of Bangor and ESPRC Centre for Doctoral Training in New and Sustainable Photovoltaics at Liverpool University.

4.3.2 Evidence-based assessment of the region's existing science and innovation talent

Using our very rigorous approach to comparing research quality (i.e. defining quality as the percentage of outputs in the top 1% of citations in the field, and comparing the NWCA with leading national and international university groupings plus California), the region is consistently well above the global average but not quite as outstanding as in our other two prime capabilities (Figure 4.1). This is most evident in the Engineering-based aspects of FES (the SCOPUS sub-disciplines of Renewable Energy, Sustainability and Environment, Energy Engineering & Power Technology and Building and Construction), where the region's rapid recent development of research infrastructure (see 4.2) is not yet reflected in research outputs. Conversely, the region is strong against these international comparators in the wider social aspects of Energy Systems (Transportation and Geography, Planning and Development), which we see as essential for the effective deployment of innovations in the energy sector. Taking this holistic view, and including our strength in cross-cutting supporting disciplines, not least synergies with the other themes of this SIA (see Conclusions), gives the NWCA a distinctive niche in FES research. Overall the region's integrated research quality, the area of the research space defined by the subjects, currently lags behind other major research groupings, but it remains well ahead of the global average (Figure 4.2).

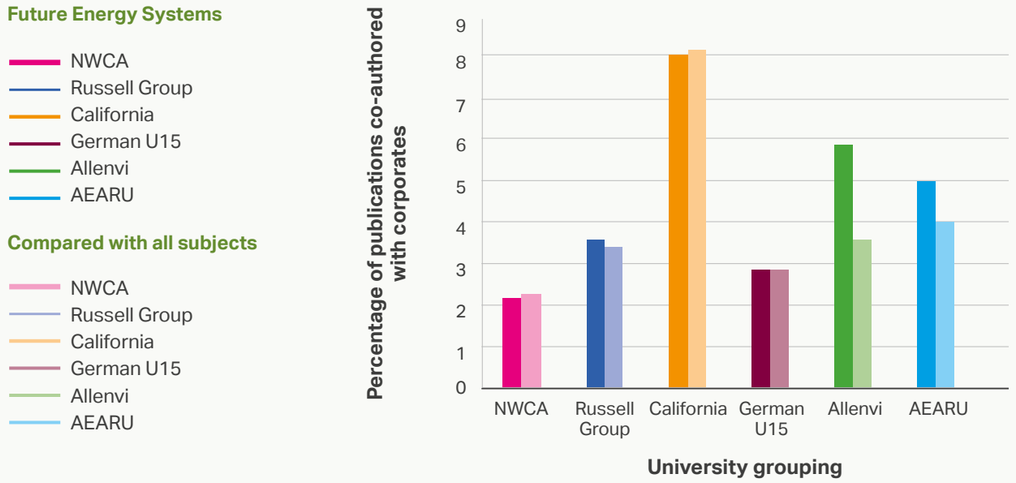
Lancashire Energy HQ- delivering the next generation of energy engineers and technicians

A £10.7m dedicated education and training facility developed by Blackpool and Fylde College in collaboration with industry partners opened in March 2018. It offers a wide range of energy-related training for future employment across all aspects of the energy industry, including renewables as well as nuclear, and oil and gas. The Energy HQ also provides opportunities for those already working in the sector to renew their industry accreditation and licences, with industry partners using the facility to further develop their workforce.

One common theme across FES is the need for training that keeps pace with the rapid evolution of the skills needed across its sectors. The region has been pro-active in addressing that demand.

Figure 4.3

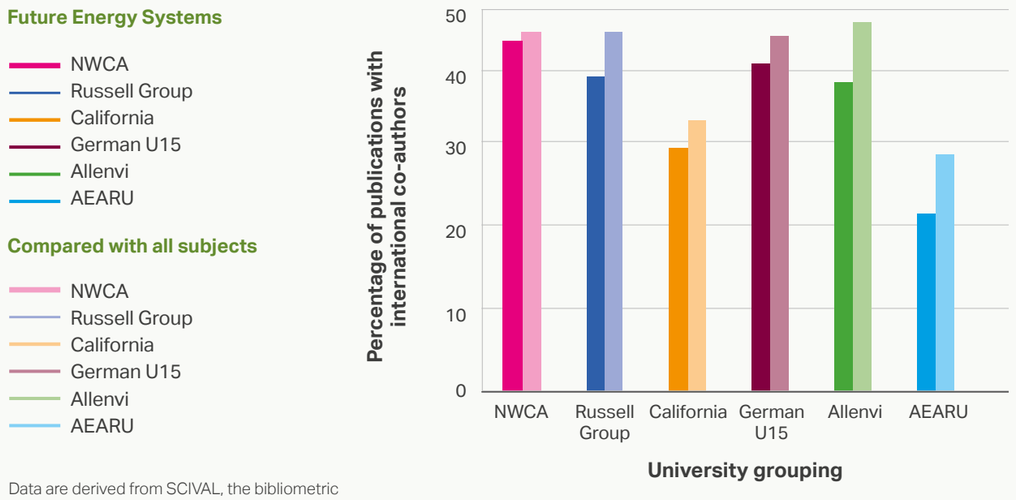
Percentage of Future Energy Systems (FES) research outputs co-authored with colleagues from a non-academic (corporate) organisation. Data for the NWCA are compared with other major university groups or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

Figure 4.4

Percentage of Future Energy Systems (FES) research outputs co-authored with colleagues from outside the UK. Data for the NWCA are compared with other major university groups or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

Hydrogen power for homes and transport

Hydrogen is an increasingly viable option for many energy uses as it is cheaper than electrification due to being more compatible with existing infrastructure. For larger scale transportation, where the charging time for electric powered vehicles is too long to be viable, the use of hydrogen in fuel cell driven vehicles is an emerging opportunity.

In 2017 a feasibility report by Cadent and industrial partners identified the region as the most suitable and cost-effective location for a hydrogen conversion project and proposed Liverpool-Manchester Hydrogen Cluster (in development). Hydrogen would be supplied to a core set of major industrial gas users (up to 100%), with a blend being fed into the local gas distribution network (up to 20%). Liverpool City Region is the home to industries which produce hydrogen as a by-product. For example, Inovyn incurs substantial carbon taxes due to CO_2 emissions associated with the hydrogen produced as a by-product from its processes. The company is working with local authorities in the Liverpool City Region to assess the potential for using hydrogen for public transport, reducing its costs and facilitating the region's shift to low-carbon transport.

Alstom, a global company manufacturing trains in Europe, has a new technology centre in Widnes (Cheshire) and is investing heavily in electric and hydrogen powered transportation. Alstom is the first company to get a hydrogen powered train to market, and hydrogen trains are a USP for the company, which is currently pushing investment in the technology to replace diesel trains. The Liverpool City Region is a key target area for Alstom due to the nearby stakeholders in the Merseyside area that are already creating this energy. This technology is a priority in the rail sector, with the UK aiming to trial this by 2020.

In parallel to these activities in Merseyside and Cheshire, Keele University is collaborating with National Grid plc and Northern Gas Network on HyDeploy, a project to blend up to 20% hydrogen into the existing natural gas grid, the first UK practical deployment of hydrogen onto a live gas network.

These closely related but currently isolated activities show both NWCA's strengths and the unexploited scope for bringing activities together to create 'critical mass' in a key low-carbon fuel-hydrogen.

4.4 National and international engagement

Engagement between the NWCA's research base and national and international research users is evident from the many assets listed in Section 4.2. Other measures of engagement emerge from the SCIVAL analysis of research metrics for publications with corporate co-authors and publications with international co-authors.

In most of the university groups audited, including the NWCA, the percentage of research outputs that are jointly published with corporate co-authors in FES subjects is broadly comparable to the mean across all subjects (Figure 4.3). Across the whole FES theme, the NWCA is publishing a lower percentage of its research outputs with corporate partners than is the case for our comparators (Figure 4.3). This comparison between the NWCA and world-leading university groups or geographies may reflect the relatively new development of some areas of energy research in the region. That is very evident in the many, substantial, recent investments in research and innovation assets in the last five years.

Across the NWCA and comparators groups FES subjects publish a slightly lower percentage of research outputs jointly with international co-authors than expected from the mean across all subjects (Figure 4.4). The NWCA publishes a higher percentage of its FES research outputs with international partners (46%) than all our chosen comparators (Figure 4.4).

4.5 Developments in the wider funding landscape

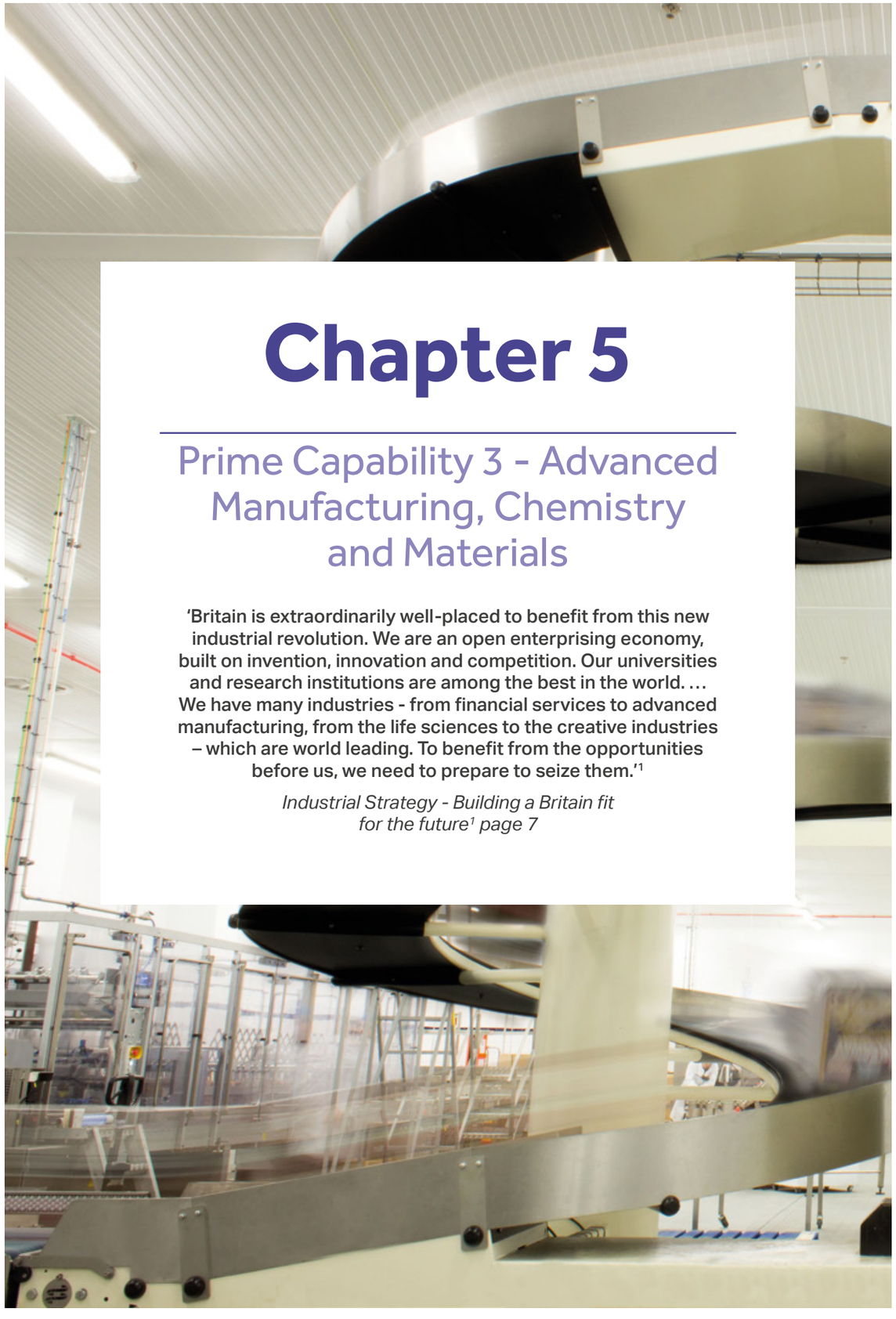
Within this, the government will launch a new Industrial Strategy 'Prospering from the energy revolution' programme to develop world-leading local smart energy systems. Expressions of Interest are being sought for Industrial Challenge Strategy Fund (ISCF) Wave 3 topics including Clean Growth and UKRI has announced a new £41.5 million fund for research and industry to develop future smart energy systems and prove their use at scale (as part of ISCF Wave 2).

More generally, the Government has significantly increased its investment in low carbon innovation. Between 2015 and 2021 it is expected that more than £2.5 billion will be invested in research, development and demonstration of low carbon energy, transport, agriculture and waste. Specific examples include BEIS's Energy Innovation Programme (up to £505 million, aiming to accelerate the commercialisation of innovative clean energy technologies and processes); the Faraday Challenge (up to £246 million to build on strengths in the design, development and manufacture of electric batteries), and UKRI's Energy Programme (more than £625 million in research and skills to pioneer a low carbon future).

The Government's Industrial Strategy identifies Clean Growth as one of the Grand Challenges to put the UK at the forefront of industries of the future.

Keele University campus

In addition to these national initiatives, the Northern Energy Strategy, produced by the Northern Energy Taskforce in 2017[13], defines a vision of the North of England as the leading low carbon energy region of the UK by 2050. Northern leaders are working with central government, Ofgem and the Committee on Climate Change to negotiate a long-term Northern Energy Compact to provide the transparency and continuity necessary to facilitate public and private investment in Northern energy assets and opportunities. The Northern Energy Strategy[13] proposes the formation of a new Northern Energy Accelerator to work alongside northern universities, Local Enterprise Partnerships, Innovate UK and national catapult centres, in order to identify, coordinate and drive energy sector opportunities from early-stage innovation to commercial and social success.



Chapter 5

Prime Capability 3 - Advanced Manufacturing, Chemistry and Materials

'Britain is extraordinarily well-placed to benefit from this new industrial revolution. We are an open enterprising economy, built on invention, innovation and competition. Our universities and research institutions are among the best in the world. … We have many industries - from financial services to advanced manufacturing, from the life sciences to the creative industries – which are world leading. To benefit from the opportunities before us, we need to prepare to seize them.'[1]

Industrial Strategy - Building a Britain fit for the future[1] page 7

The North West Coastal Arc Clean Growth & Sustainable Partnership and UK strategy documents

Advanced materials are a key tool for advanced manufacturing and are named as one of the UK's Eight Great Technologies. UK businesses that produce and process materials have a turnover of around £170 billion per annum, represent 15 per cent of the country's GDP and have exports valued at £50 billion. There is particular interest around additive layer manufacturing also known as '3D printing'. This new technology is possible not just because of advances in IT but also because of advances in the materials that go into the process.

The UK Chemistry Growth Strategy Group (CGSG) has committed to the following vision 'By 2030, the UK chemical industry will have further reinforced its position as the country's leading manufacturing exporter and enabled the chemistry-using industries to increase their Gross Value Added contribution to the UK economy by 50%, from £195 billion to £300 billion.' Analysis completed by Chemistry Innovation highlight three areas as priorities: raw materials for the 21st century; smart manufacturing processes; and design for functionality. The scale of each area's contribution was assessed within the 2013 Chemistry Innovation Strategy[18].

Moving towards a regenerative circular economy. Raw materials: The potential longer term benefits of using biomass or waste as raw materials reach £8 billion. There is also potential for using new technologies to replace scarce metals, as defined in the Industrial Biotechnology Innovation and Growth Team Report.

Design for functionality: A further £10 billion opportunity is identified for formulated products with designed-in functionality. Currently, the formulated products market in the UK is worth about £180 billion a year, and the UK is recognised as a strong player globally.

That advantage needs to be better coordinated and developed, to enable growth in both domestic and global markets. A conservative estimate of the potential benefit of intervention on materials chemistry (to create substitutes for materials currently imported) stands at £5 billion. Chemical products designed for a 'circular economy' offer additional potential: about £1 billion is currently achievable through design for waste management and recycling, and this figure could grow up to tenfold by 2020. The Industrial Strategy highlights the importance of raising the resource productivity of businesses, including through the promotion of recycling and strong secondary materials markets where products are designed with recyclability in mind.

5.1 National and international trends and size of global markets

As well as the national perspective of the Industrial Strategy, the Northern Powerhouse Independent Economic Review[3] (June 2016) identified Advanced Manufacturing as one of four 'prime capabilities' of the North as a whole, which are 'differentiated and distinctive at a pan-Northern level, highly productive, and able to compete at national and international levels'. This is echoed across the NWCA in the economic strategies of our LEPs (Annex 1). This strategic focus on manufacturing is driven by its significance to the global economy, to which it currently contributes £6.7 trillion, and by the UK's significant current rank as the eighth largest industrial nation. Manufacturing in the UK employs 2.6 million people, creates 11% of total GVA, 44% of total UK exports and drives 70% of business R&D. Sectors of particular importance for the UK include Aerospace, Automotive, Chemicals (and Pharmaceuticals), Plastics, Electronics, Steel, Energy (including Nuclear) and Textiles[14].

This is also a time of rapid change in manufacturing. The full integration of digital capabilities in manufacturing - referred to as 'Industry 4.0' - and adoption of new materials and manufacturing processes, will drive high productivity growth in businesses able to adopt them. The 'Made Smarter Review 2017'[15] was built around this concept and focuses upon a need to equip the UK with the means to fully embrace the next industrial revolution through a series of recommendations around Adoption, Innovation and Leadership activities designed to make the UK a leader in industrial digitalisation technologies and skills.

The 2013 report Emerging Trends in Global Manufacturing Industries (United Nations Industrial[16] Development Organisation) identified 'sustainability' as one of eight megatrends influencing the future of Advanced Manufacturing. Innovation around advanced manufacturing, chemistry and materials, by extending the life of materials and products, lowering carbon intensity and increasing the recovery and reuse of high value elements, will improve the resource use efficiency of manufacturing, whether energy, water or other natural resources. As such, this capability has natural and fundamental linkages to Environmental Industries, Technologies and Services (especially resource use efficiency, recycling and waste management: Chapter 3), and Future Energy Systems (reduced greenhouse gases emissions and energy use: Chapter 4).

The Government's Industrial Strategy identifies Clean Growth as one of the Grand Challenges to put the UK at the forefront of industries of the future.

The NWCA boasts a rich industrial heritage and is often quoted as 'the birthplace of the industrial revolution'. The manufacturing assets, skills base and research excellence that have evolved here over generations, today provide the innovation capacity needed to develop the new tools to deliver key elements of the 'Industrial Strategy' in the context not only of the 'The Clean Growth Strategy[2]' and the 25 Year Environment plan[6] but also the Future of Mobility Grand Challenge in the Industrial Strategy. As already highlighted in the Wave 1 Sheffield City Region and Lancashire SIA[17], our region has particular strengths in aerospace and automotive manufacturing (5.1.1 and 5.1.2 respectively), and so is intimately linked to the drive towards low carbon transport highlighted in the Clean Growth Strategy. Beyond that, these major sectors have been the stimulus for a diverse and innovative supply chain, often of SMEs, across many types of advanced chemicals and materials (5.1.3). This audit has further clarified the potential of that supply chain to deliver materials and know-how that could contribute to the productivity, efficiency and sustainability in sectors beyond aerospace and automotive.

5.1.1 Aerospace

The UK Aerospace industry has an annual turnover of £31 billion and its productivity has grown by 30% in the last five years. With an 18% global market share (largest in Europe and second only globally to the US) the sector employs at least 128,000 directly and 140,000 indirectly. Almost a decade's worth of work is in hand with an order book of more than 13,000 aircraft worth up to £195 billion to the UK. (Information courtesy of ADS group)[19]. In aerospace, the fundamental drivers remain the rapid international growth of markets, fuelled by increasing demand for air travel and the need for modern aircraft in both civilian and defence sub-sectors. As a result, opportunities lie in the processing of advanced lightweight materials, and expertise in how best to exploit these.

Global Centre of Excellence in Glass for R&D, Innovation and Training (Glass Futures Ltd)

Glass Futures Ltd is a new collective comprising a number of the world's largest glass industry companies in partnership with leading glass research universities including Liverpool, Nottingham, Swansea and Cambridge and Liverpool City Region's Metro Mayor, and St Helens Council. With a primary hub based at Pilkington's St Helen's site, the group's vision is to revitalise the domestic glass industry and diversify its application across other sectors to drive national economic and productivity growth.

5.1.2 Automotive

The Automotive sector is equally important to UK PLC employing at least 169,000 people directly and a further 78,000 across the supply chain. Manufacturers claim that 80% of a vehicle can be made on UK soil with more than 2,000 automotive suppliers (including 18 of the world's top 20) situated here. The sector has an annual turnover of £71.6bn and annually adds approximately £12.4 billion to the UK economy. The Made Smarter Review 2017 identified Automotive as a key sector for growth with clear opportunities presented through the adoption of innovation and digitalisation within manufacture. The production of connected and autonomous vehicles is also predicted to grow with an estimated 25,000 new jobs forecast to be created[20].

In parallel to the Clean Growth agenda, the automotive sector clearly has a significant role to play in the UK Industrial Strategy's[1] Grand Challenge around the Future of Mobility, which aims to put the UK at the forefront of the design and manufacturing of zero emission vehicles, with all new cars and vans effectively zero emission by 2040.

Aligned to this ambition will be £1bn support over 10 years for the development of low carbon power trains, grants for the purchase of low emission vehicles, investments in electric vehicle charging infrastructure and an Automotive Sector Deal setting out how government and industry will work together to achieve this strategic mission.

5.1.3 Cross-cutting advanced chemicals and materials

This is part of a UK manufacturing sector that relies on chemistry to generate £600 billion of annual aggregate sales[23]. With an annual turnover of £60 billion the sector is consistently the UK's biggest manufacturing contributor to the national balance of payments, posting an annual £5 billion trade surplus. It supports 500,000 jobs and contributes 6.8% of UK manufacturing GVA. From a global perspective, world chemicals turnover was valued at €3,4 trillion in 2016, of which the UK contributed 7% of total sales. However, since 2012 the UK's chemicals imports have risen faster than exports, reducing the traditional surplus in chemical and pharmaceuticals from around £0.5 billion per month to around £0.3 billion per month[18].

The Northern Powerhouse Chemicals and Process SIA[21] has identified the Circular Economy and Resource Efficiency as strong enablers that cut across the key subsectors as a means of restoring activity and driving growth. This assertion echoes messages on the importance of eco-innovation and Clean and Sustainable Growth with this SIA. Both groups have been in preliminary discussions and will seek to continue dialogue on coordinated and collaborative interventions after completion of the audit phase.

The NWCA's strength in aerospace and automotive has acted as a stimulus for a strong and innovative community of businesses, often SMEs, across the range of advanced chemicals and materials.

Table 5.1

Advanced Manufacturing, Chemicals and Materials Research and Innovation Assets

Asset	Location	Aerospace	Automotive	Advanced Chemicals & Materials
Advanced Manufacturing and Research Institute	N Wales	X	X	X
Advanced Manufacturing Centre for Skills Development and Employer Engagement	Lancs	X	X	X
BEACON Biorefining Centre of Excellence	N Wales			X
The BioComposites Centre	N Wales			X
Built Environment & Sustainable Technologies Institute at Liverpool John Moores University (LJMU)	M'side			X
Centre for Global Eco-Innovation	Lancs	X	X	X
cTAP (Collaborative Technology Access Programme)	Lancs			X
Engineering Innovation Centre	Lancs	X		X
Environment Centre for Wales at Bangor University	N Wales			X
Glass Futures	M'side			X
Hartree Centre	Ches	X	X	X
Institute for Risk & Uncertainty at Liverpool University	M'side	X	X	X
Lancaster Leadership Centre	Lancs	X	X	X
Lancaster Product Development Unit	Lancs			X
LCR4.0	M'side	X	X	X
Lloyd's Register Foundation	M'side	X	X	X
Low Carbon Eco-Innovatory	M'side	X	X	X
Manufacturing Technology Centre (MTC@LJMU)	M'side			X
Materials Innovation Factory	M'side			X
Northwest Advanced Manufacturing Research Centre	Lancs	X		X
Optoelectronic Technology Incubation Centre	N Wales		X	X
Quantum Technology Centre	Lancs		X	X
Sci-Tech Daresbury	M'side	X	X	X
Sensor City, Liverpool	M'side	X	X	X
Unilever R&D	M'side			X
The Virtual Engineering Centre	M'side	X	X	X

Sub-sectors of advanced manufacturing and chemicals

The UK plastics industry consists of approx. 6,200 firms with an annual turnover of over £23.5 billion and employing approx. 170,000 people. In 2015 the UK exported £7.5bn of plastic and plastic products making it one of the UK's top ten exports. The use of plastics globally has increased 20-fold in the last 50 years and is expected to double again in the next 20 years (The New Plastics Economy, Ellen Macarthur Foundation (2016). By 2020 it is expected that the global plastics industry will be worth in excess of £500 billion. The UK Plastic Industry's 'Strategic Vision for Growth' identified key objectives for future growth including, 'improving the Industry's skills base and educational support' and 'accelerating the sustainability of the plastics industry and its alignment to the circular economy', both closely aligned with the objectives of this Science and Innovation Audit. The growing concern over plastic pollution provides a very strong link to Environmental Industries, Technologies and Services (Chapter 3).

The global ceramic composites market was valued at £1.7 billion in 2016 and is projected to reach £5.6 billion by 2026. The market is expected to expand at an estimated compound annual growth rate (CAGR) of 9.65% from 2016 to 2026 due to increasing demand for lightweight and high-performance ceramics that substitute metals and other conventional materials. Technological adaptiveness and R&D are critical factors for companies in this market because of intense competition, rapid change in technology, and customers with evolving demands. A significant amount of energy is consumed during ceramic composite production and technology providers are making efforts to develop energy-efficient production processes to reduce both greenhouse gas emissions (Chapter 3) and overall cost.

The global market for high performance metals alloys was estimated at £5.9 billion in 2016, growing at a CAGR of 4.7% over the forecast period (2016-26). The industry is likely to grow due to increasing demand for the high-performance alloys in critical applications across multiple sectors. One example is the growing demand for light materials in the aerospace industry which is expected to drive rapid market growth over the next decade.

The current market value of nanomaterials is around £17 billion (EC, 2014a) and the spectrum of commercially viable applications is increasing rapidly (e.g. medicine, imaging, energy and hydrogen storage, catalysis, lightweight construction, and UV protection). Applications such as carbon black and amorphous silica have already reached high volumes. Other nanomaterials target low-volume but very high value markets such as medicine, which currently accounts for the highest share of applied Nano products (Vance et al., 2015).

5.2 Local science, innovation and industrial assets

5.2.1 Science and Innovation assets

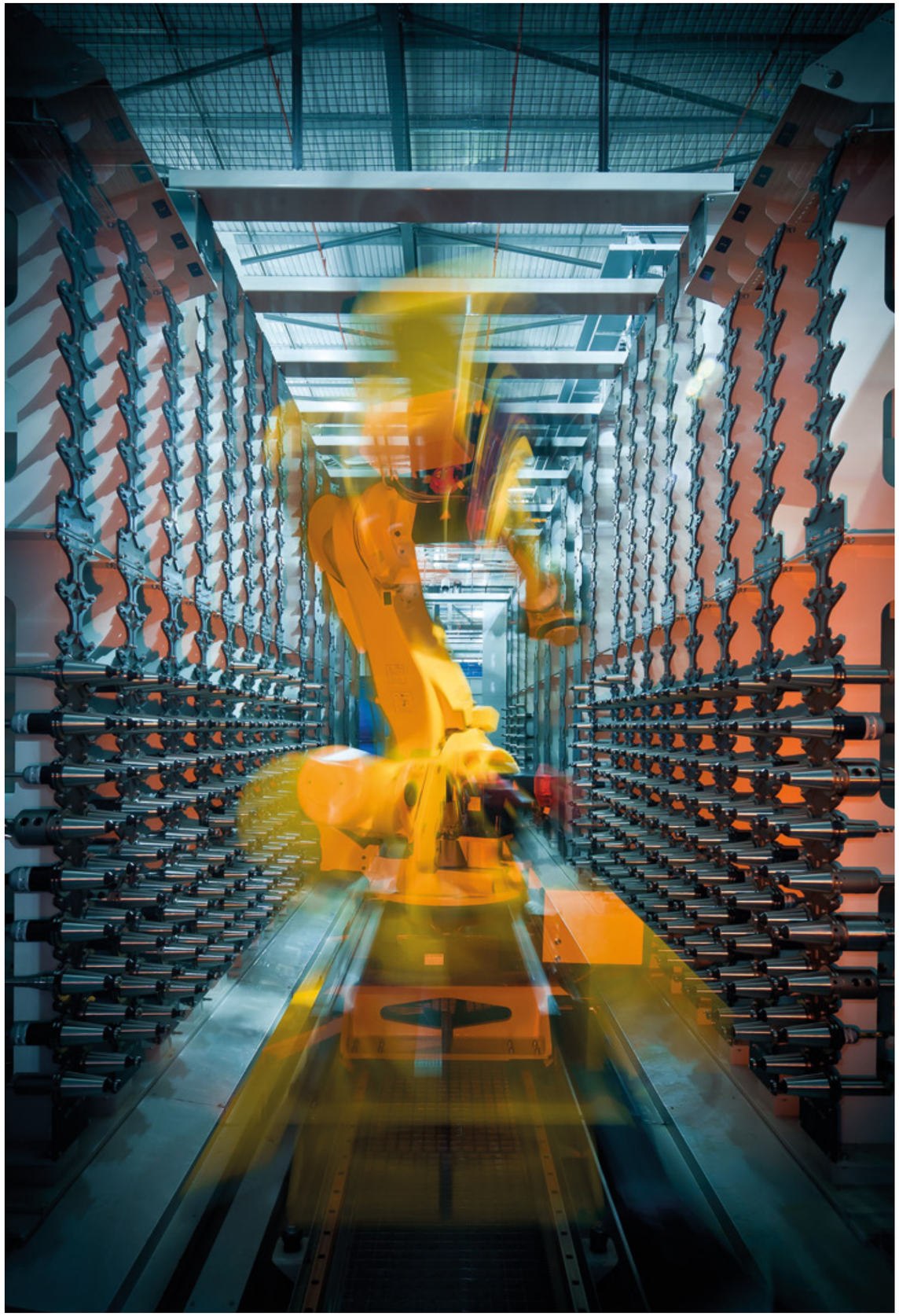
Of the sixty internationally significant NWCA research and innovation assets identified by this audit, twenty-six have activities related to one or more aspects of the Advanced Manufacturing, Chemicals and Materials theme (Table 5.1 and see Annex 3 for full details). Of these, ten have research and innovation that integrates AMCM with the Future Energy Systems and ten with Environmental Industries Technologies and Services. This again illustrates the key role of the aerospace and automotive sectors for low carbon growth and the wider significance of advanced materials and chemicals, for example in resource efficiency and improved recycling and waste management.

Notable examples with a primary focus on Advanced Manufacturing, Chemicals and Materials include (i), Materials Innovation Factory (MIF) (ii) Virtual Engineering Centre and LC4.0 and (iii) the North West Advanced Manufacturing Research Centre.

In Merseyside, the **Materials Innovation Factory (MIF)** is a £65 million partnership between the University of Liverpool, Unilever and HEFCE to develop a unique materials chemistry research hub. Officially opening in late 2018, it will provide an unparalleled suite of open access, state-of-the-art equipment and internationally-leading academic expertise to develop fundamental innovations in manufacturing at the molecular level and create new materials with step-change functional enhancement in a range of important applications. Liverpool John Moores University provides complementary support in specific areas, for example in materials technology design and performance.

The **Virtual Engineering Centre (VEC)** is a UK centre leading in the integration and exploitation of Virtual Engineering technologies such as advanced modelling and simulation and immersive visualisation for industrial and commercial applications. VEC comprises a multi-disciplinary team including specialists in engineering, computer science, visualisation and manufacturing technology, and is underpinned by the University of Liverpool and specialist Centres of Excellence. Located at both Sci-Tech Daresbury and The University of Liverpool. It acts as a hub in communicating research back to potential end users, while providing competitive advantage to industry. VEC is part of **LCR 4.0**, a collaborative community that connects SMEs to expertise and support from key knowledge assets in the region.

Many of our research and innovation assets are active across multiple aspects of Clean and Sustainable Growth, some across all three themes of this SIA.



SMEs are able to explore the potential of Industry 4.0 technologies by accessing support ranging from research and development, knowledge transfer and the acceleration of ideas from concept through to commercialisation. Other partners include Liverpool John Moores University, the University of Liverpool, Sensor City, Liverpool City region LEP and the Hartree Centre.

The audit has also highlighted that two major new research and innovation assets focused on advanced manufacturing are being developed in different parts of the NWCA and are led by the Advanced Manufacturing Research Centre (AMRC) part of the High Value Manufacturing Catapult Network. These are the **North West AMRC** based on the Samlesbury Enterprise Zone (EZ) in Lancashire, focused on supporting advanced manufacturing supply chains and driving productivity improvements in regional SMEs and the **Advanced Manufacturing and Research Institute** in Brought on North Wales focusing on aerospace, automotive, nuclear and food. Both integrate across multiple sectors and all three capabilities of this Science and Innovation Audit and so are described in detail in Chapter 6.

5.2.2 Industrial assets

5.2.2.1 Aerospace Sector

As highlighted by the Wave 1 audit (high value manufacturing) led by the Lancashire and Sheffield City Regions[17], Lancashire holds the greatest concentration of aerospace production in the UK and 4th largest globally. Lancashire's key capabilities include the design, testing, manufacture and assembly of aerospace components and a tightly integrated supply chain feeding into those larger companies. Around 20,000 people in the county are employed in 120 companies, including major players such as BAE Systems, Rolls-Royce and Safran-Aircelle, and supply chain companies such as Kaman, Assytem and Spirit Aero Systems.

Lancashire sites are contributing roughly £6 billion of output to the F35 fighter jet programme, which is the UK's single largest trade contract.

The North West Aerospace Alliance (NWAA) is a key industry organisation in the region, representing and uniting companies and organisations involved in the aerospace supply chain. Formed in 1994 NWAA represents approximately 25% of the UK aerospace industry with over 220 member companies and a combined turnover in excess of £7 billion.

North Wales also has particular strengths in this area, playing host to companies including Airbus Broughton (which manufactures wings for all Airbus commercial aircraft), BAE Systems, Gardner Aerospace and CAV Aerospace which develops new 'green' technologies for aeronautical applications.

5.2.2.2 Automotive Sector

The strength of the automotive sector in the NWCA region lies in its diversity, ranging from volume car manufacturers and prestige brands to niche vehicles and truck manufacturers. Companies include: PACCAR (Leyland Trucks), Sanko-Gosei, and Erlson in Lancashire; Bentley Motors in Staffordshire; Vauxhall in Cheshire; Toyota's engine plant in Deeside, North Wales and Jaguar Land Rover and Getrag Ford in Merseyside. These key employers are supported by an extensive supply chain operating across the design and manufacture of vehicles and components, including high value parts for Aston Martin and Bentley. A recent addition to the automotive supply chain in the area is Plastic Omnium which has opened a 240,000 sq ft state-of-the-art manufacturing facility in Warrington. The company provides bumpers and plastic body parts for Jaguar Land Rover's Halewood plant.

The North West automotive cluster generates some £9 billion of the total UK automotive manufacturing economy which equates to approximately 12% of the UK total, placing it as the second most significant region for automotive manufacture in the UK. It employs an estimated 16,200 people. The Northern Automotive Alliance is an independent, not for profit, company which provides membership service combined with a project management delivery function to the automotive community.

5.2.2.3 Multi-sector Assets related to Advanced Manufacturing, Chemistry and Materials

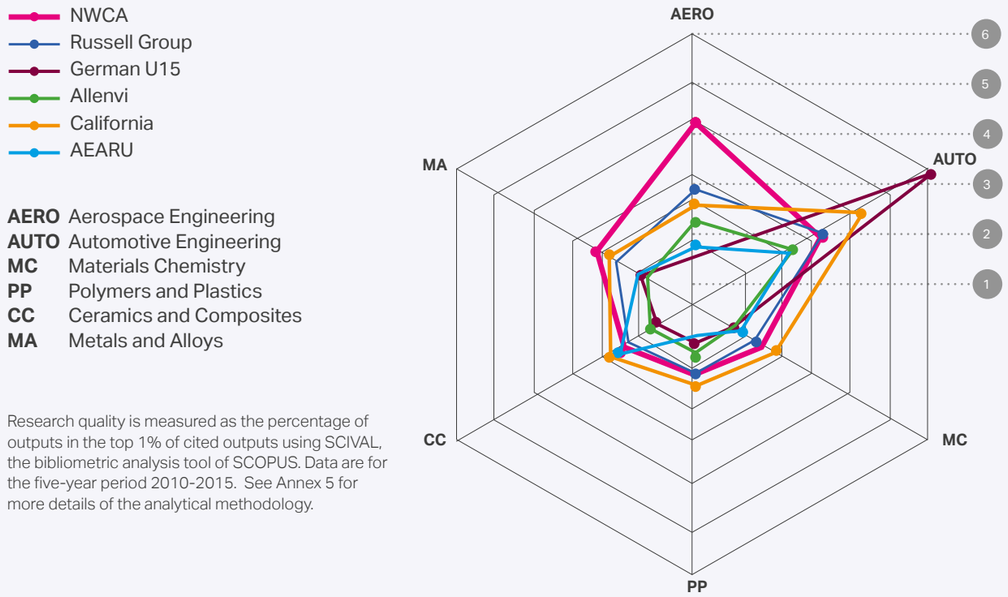
Stoke-on-Trent and Staffordshire host Alstom, Coors, JCB, Moog, and Zytek alongside Bostik, Fuchs (polymers), Michelin (lubricants), Perkins, MG Sanders, Goodwin (engineering), Steelite International, Wedgwood Waterford and Royal Doulton (ceramics). All use novel and new applied materials (metallic and non-metallic) in their products and demand low carbon innovation to remain globally competitive.

The Cheshire and Warrington economy was founded upon chemicals, petrochemicals and minerals with much of the sector remaining an important employer today (over 5,000 people work in the chemicals industry in Cheshire and Warrington which represents almost 1.2% of total employment in the region)[22]. Companies include Astra Zeneca (chemicals/pharmaceuticals), Bodycote PLC (surface engineering technologies), Siemens (variable speed drive manufacture) and Tata Chemicals (producing feedstock materials for the glass industry).

As well as these focused strengths in aerospace and automotive, the region is home to numerous international businesses across advanced manufacturing, chemicals and materials.

Figure 5.1

Research quality for the NWCA in the six sub-disciplines included under our Advanced Manufacturing, Chemicals and Materials capability (AMCM), compared with other major university groups or regions.

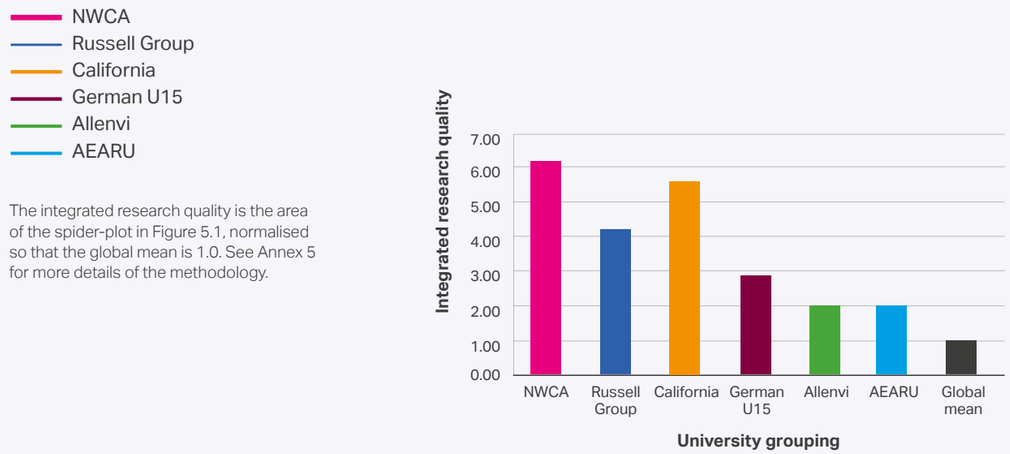


AERO Aerospace Engineering
AUTO Automotive Engineering
MC Materials Chemistry
PP Polymers and Plastics
CC Ceramics and Composites
MA Metals and Alloys

Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 5.2

Integrated research quality across Advanced Manufacturing, Chemicals and Materials for the NWCA compared with other major university groups or regions.



The integrated research quality is the area of the spider-plot in Figure 5.1, normalised so that the global mean is 1.0. See Annex 5 for more details of the methodology.

Other niche and specialist companies include Surface Transforms, who design and make high-performance brakes from carbon fibre reinforced ceramic composite materials, and Waters Corporation's 'International Centre of Excellence' for Mass Spectrometry. The 37-acre site employs some 500 staff and in addition to its expanded manufacturing capacity the facility contains enhanced research and development capabilities. Other global companies include Henkel Consumer Adhesives, Britton Taco (polyethylene production) and Flexfilm (UK prime specialist polyethylene extruder), Thor Specialities and Harman Technology (specialist products for the professional imaging industry).

Lancashire boasts one of the largest economies in the Northern Powerhouse with 52,350 businesses generating over £29bn per year[23]. Around 85,000 workers are employed in the manufacturing and engineering sectors with major employers (outside of aerospace and automotive) including Alstom Transport, Victrex, Eka Chemicals, Ashi Glass Fluoropolymers, Hanson Heildelberg Cement Group, Crown Paints and Promethean.

In Merseyside, Unilever R&D at Port Sunlight employs c.1,000 scientists and a further 1.500 senior staff in their manufacturing hub, in addition to the powders manufacturing site at Warrington Bank Quay. Unilever has recently announced the closure of 4 major European sites (including the Rotterdam R&D hub) with the associated 2,000 jobs potentially destined for relocation to the UK subject to planned infrastructure investment in the North. Liverpool John Moores University has partnered with the Manufacturing Technology Centre (MTC), part of the High Value Catapult Network, to create MTC@LJMU. The Centre encourages collaborative partnerships between the University and businesses to develop products for the maritime industry, as well as highlighting the potential of emerging technologies and access to new funding streams. MTC@LJMU contributes to delivering world class services to industry through LCR4.0.

Insumate Ltd. Innovative Insulation Fixing and Hanging Devices

Insumate Ltd is a Cumbrian based SME specialising in the development, manufacture and sale of insulation products for the construction industry. They are working with the Lancaster Product Development Unit at Lancaster University to develop an innovative method of positioning and installing cavity wall insulation systems for installation during the construction process. Lancaster has provided Computer Aided Design (CAD) models and used them in Selective Laser Sintering (SLS) to allow the company to produce accurate prototypes, mitigating the need for costly tooling or time-consuming subtractive manufacturing methods. As a result, Insumate moved quickly to produce a final mould tool for use in the first production run.

Cambridge BioPolymers Ltd. Commercial applications for vegetable oil derived thermosetting 'bioresins'

Cambridge Biopolymers Ltd are working with the BioComposites Centre at Bangor University to commercialise novel proprietary patented technology around the manufacture of thermosetting 'bioresins' from vegetable oils. These products will find use in applications currently dominated by formaldehyde-based resins, such as wood-based panels and fibre reinforced composite applications.

North Wales is also home to a number of globally significant manufacturers and engineers including Warwick Chemicals, Headland Agrochemicals, BASF Coatings, Kingspan, Tata Steel Europe, Sharp Manufacturing and Honeywell[24].

Cumbria has a long industrial heritage and manufacturing companies continue to be significant employers. Two of the UK's largest industrial sites are located in the county, Sellafield (treated in detail in the NW Nuclear Arc SIA) and the submarine shipyard operated by BAE Systems at Barrow-in-Furness. Other multinational companies manufacturing in the county include Pirelli Tyres, Nestlé, United Biscuits, Iggesund Paperboard, Kimberley-Clark, Heinz, Sealy Beds, GSK bio-pharmaceuticals, Innovia Films and Siemens sub-sea technologies.

5.3 Local science and innovation talent

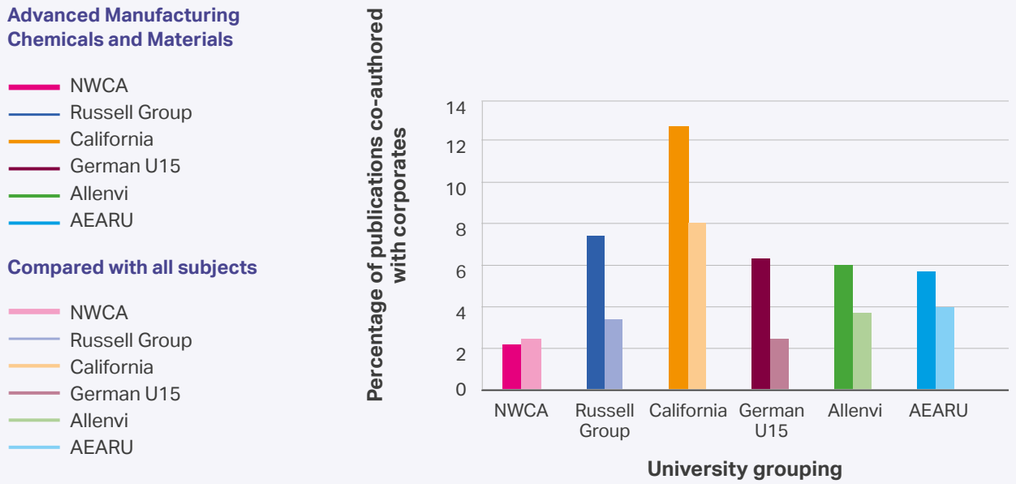
5.3.1 The current workforce and the likely future skills needs and sources

Our audit of the current NWCA workforce relevant to Clean and Sustainable Growth showed the challenge of separating sectors that are strongly inter-linked. For that reason, we cover this across capabilities in Annex 6. There are also substantial overlaps between capabilities in training provision and need at all levels, so these common elements are also covered in Annex 6. We focus here on specific skills need and provision for Advanced Manufacturing, Chemicals and Materials.

Whilst the output of the region's higher education institutions includes substantial numbers of STEM and management graduates and some can demonstrate good 6-month retention rates, the loss of highly trained graduates to the south of England remains a consideration. To combat this in part, university and private sector partners have responded by developing award winning or best practice schemes working with the SME community to unlock barriers to graduate employment and to break down graduate perceptions of SME careers.

Figure 5.3

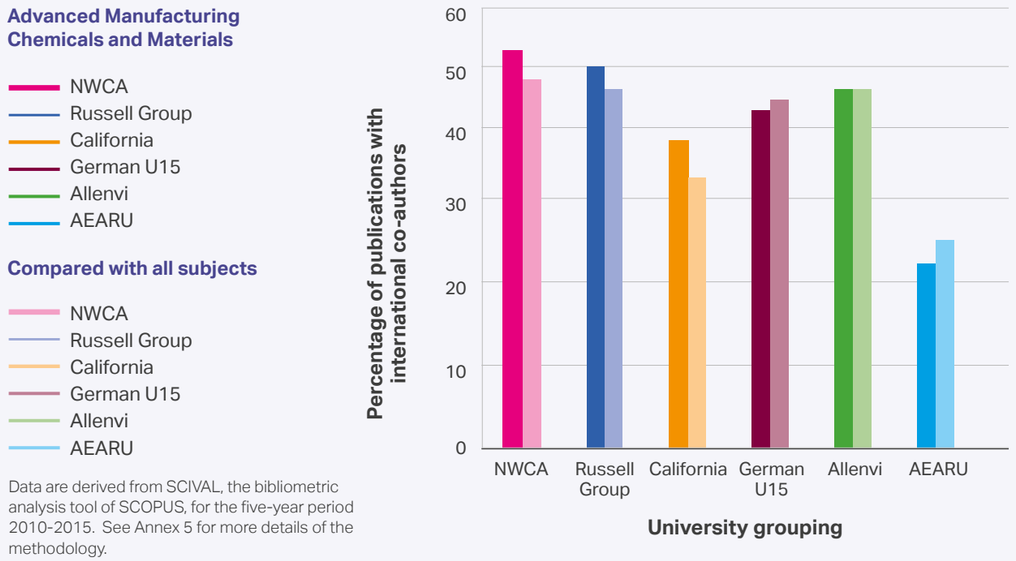
Percentage of Advanced Manufacturing, Chemicals and Materials (AMCM) research outputs co-authored with colleagues from a non-academic (corporate) organisation. Data for the NWCA are compared with other major university groups or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

Figure 5.4

Percentage of Advanced Manufacturing, Chemicals and Materials (AMCM) research outputs co-authored with colleagues from outside the UK. Data for the NWCA are compared with other major university group or regions.



Data are derived from SCIVAL, the bibliometric analysis tool of SCOPUS, for the five-year period 2010-2015. See Annex 5 for more details of the methodology.

The University of Central Lancashire's **Engineering Innovation Centre (EIC**) is a £40m project developing the University's research, knowledge transfer and training capabilities in Engineering. The EIC is a signature knowledge transfer project within the Lancashire Strategic Economic Plan, working with local SMEs to prime the advanced engineering and manufacturing sector.

The Knowledge Economy Skills Scholarships (KESS 2) scheme is a major pan-Wales operation led by Bangor University supported by European Social Funds (ESF) through the Welsh Government. KESS 2 links companies and organisations with academic expertise in the Higher Education sector in Wales to undertake collaborative research projects, working towards a PhD or Research Masters qualification. Research elements are integrated with a higher-level skills training programme, leading to a Postgraduate Skills Development Award. Lancaster University is a partner in the Institute of Coding, a national consortium of more than 60 universities, businesses and industry experts that will tackle the UK's digital skills gap. The government's £20m investment will be matched by a further £20m from industry, including in-kind contributions such as training and equipment. A pipeline of world class digital skills is essential to exploit the productivity improvements enabled through increased industrial digitisation as outlined in the Made Smarter Review[15] and the collaboration of universities, employers and industry leaders can help graduates build the right skills, in fields ranging from cybersecurity, artificial intelligence through to industrial design.

Lancaster is leading the **Employer Engagement for Skills in Manufacturing and Engineering (EnginE)** project. This £2.3m project will build capacity within Advanced Engineering and Manufacturing SMEs for higher level skills provision and degree apprenticeships. EnginE has been co-designed by Higher Education (Lancaster), Further Education (Blackpool and the Fylde College, Blackburn College) and industry partners (North West Aerospace Alliance, Northern Automotive Alliance and BAE Systems) and will engage with 200 SMEs within the project lifetime.

Blackpool and The Fylde College Degree Apprenticeship Provision

In providing the requisite skills for Clean and Sustainable Growth, Blackpool and the Fylde College are acutely aware of the importance of developing a multi-disciplinary portfolio of core knowledge competencies in line with requirements of the relevant sectors. The approach adopted is one of co-creation where the graduating skill sets required by specific technicians and entry level staff are identified in close collaboration with employers. The aim is to effectively fulfil forward demand for apprenticeships at all levels by bringing together experiential learning and an enquiry–led approach where theory can be contextualised into practice. The Apprenticeship in Civil and Defence settings is now in its third year, with a Materials Science Degree Apprenticeship (spanning the physics and chemistry of matter, engineering applications and industrial manufacturing processes) in the early stages of development.

5.3.2 Evidence-based assessment of the region's existing science and innovation talent

As with other capabilities our very rigorous approach to comparing research quality (i.e. defining quality as the percentage of outputs in the top 1% of citations in the field, and comparing the NWCA with leading national and international university groupings plus California: Figure 5.1a) highlights not just research excellence but also clear specialisations in some groups. The NWCA's outstanding research excellence in Aerospace Engineering is clear against all comparators, as is the specialisation of the German U15 in Automotive Engineering (Figure 5.1.). However, unlike the U15, the NWCA's excellence in Aerospace Engineering is supported by real strength in depth across Materials and Chemistry disciplines. The percentage the NWCA's outputs in the top 1% of cited outputs is equal to or greater than that of the Russell group across all six AMCM disciplines, substantially so for Metals & Alloys and Polymers & Plastics (Figure 5.1). The region outperforms these comparators, including the Russell group and other international comparators, only California shows similar breadth in research excellence (Figure 5.1). The NWCA's integrated research quality in AMCM, the area of the research space, slightly exceeds that of California, and is well ahead of all other comparators (Figure 5.2). Looking ahead, this SIA and other activities are beginning to highlight how excellence in AMCM can cross-fertilise our other capabilities, notably Future Energy Systems (Chapter 4). Equally, the region's excellence in Waste Technology and Management (included under Environmental Industries, Technology & Services, Chapter 3) offers synergies with AMCM in relation to an integrated perspective on the circular economy of a wide range of materials.

As well as these focused strengths in aerospace and automotive, the region is home to numerous international businesses across advanced manufacturing, chemicals and materials.

This further illustrates the power of the NWCA's holistic vision of eco-innovation, based on current experience and as developed further in Chapters 6 and 7.

5.4 National and international engagement

Engagement between the NWCAs research based and national and international research users in AMCM is evident from the many assets listed in Section 5.2. Other measures of engagement emerge from the SCIVAL analysis of research metrics for publications with corporate co-authors and publications with international co-authors.

Across all the comparator groups audited, a much greater percentage of research outputs are jointly published with corporate co-authors in AMCM than expected from the mean across all subjects (Figure 5.3). Surprisingly, despite the region's many research and innovation assets and high-quality research across the AMCM subject area, this difference is less evident in the NWCA than in our comparators (Figure 5.3). We are publishing fewer AMCM research outputs with corporate co-authors (2.3%) than all our chosen comparators.

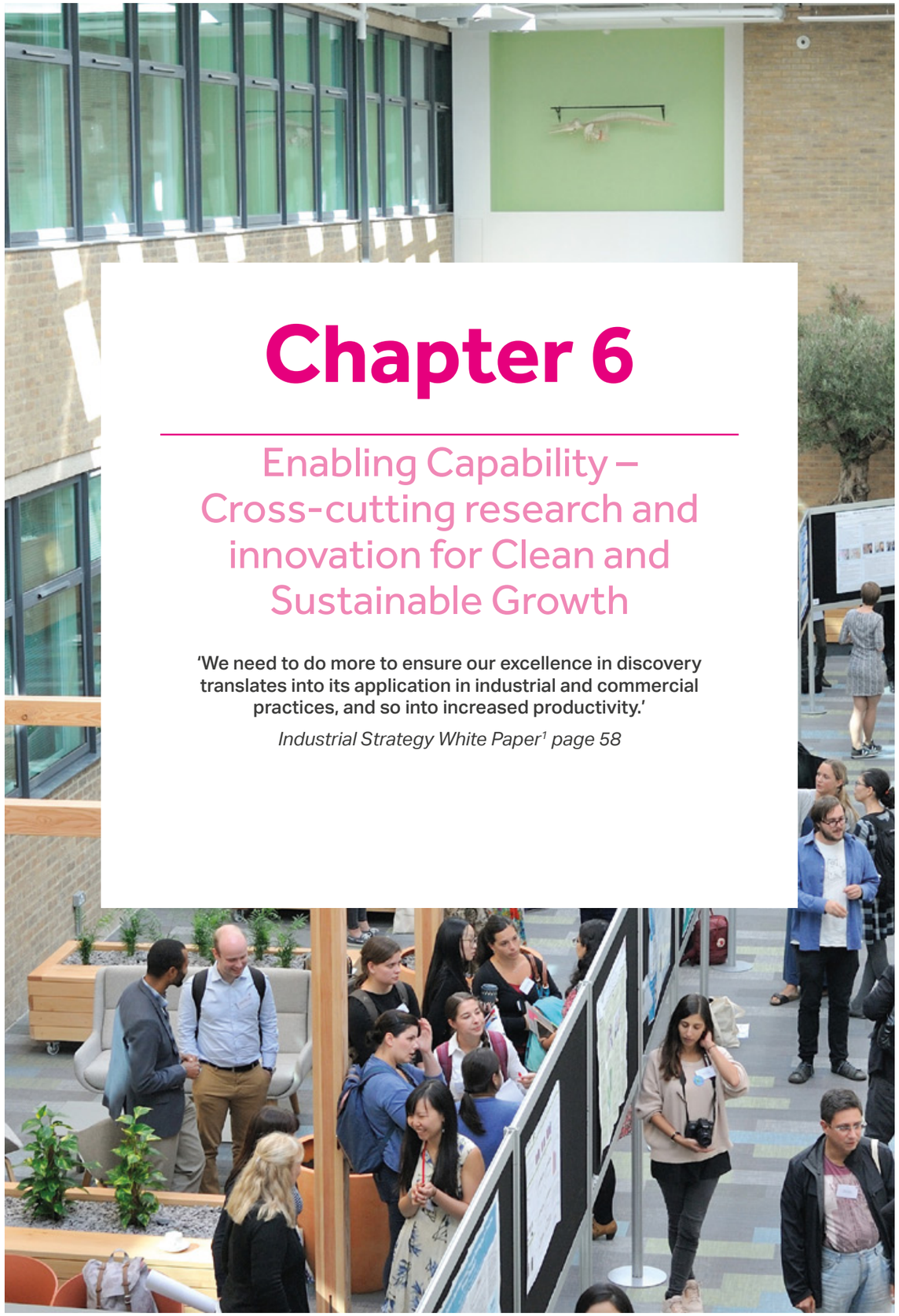
The other two comparators are much lower (38% in California and 23% in the East Asia AEARU group). With the exception of AEARU, the percentage of research outputs published jointly with international co-authors in AMCM subjects is similar to or slightly higher than expected from the mean across all subjects (Figure 5.4), with the NWCA having the largest difference (55% in AMCM compared with a mean of 48% across all subjects). As with the other themes, the NWCA stand up well in terms of publications with international partners, even against these strong comparators.

5.5 Developments in the wider funding landscape

The UK Government Industrial Strategy aims to make the UK the world's most innovative nation by 2030. To support this aspiration government has committed to investing a further £725 million over the next three years into the Industrial Strategy Challenge Fund. Of the four Grand Challenges (Artificial Intelligence, Clean Growth, Ageing Society, Future of Mobility) identified in the industrial strategy, Advanced Manufacturing, Chemistry and Materials is likely to play an especially significant role in improving productivity and sustainability under the Clean Growth and Future of Mobility Grand Challenges. In particular, Innovate UK has recently announced opportunities for up to £30 million of collaborative match funding for UK-developed late stage R&D to support advanced low carbon propulsion technologies in automotive. Through the scheme UK based R&D projects are sought that will significantly reduce carbon dioxide emissions and improve air quality. A further £20 million is also available to support the commercialisation of prototype quantum devices.

The Research councils also have a role to play in supporting the acceleration of innovation through designated funding calls. Of particular relevance to the Advanced Manufacturing, Chemistry and Materials theme are the EPSRC funding streams which will make almost £800 million available from EPSRC resource funding and the £15 million Global Challenges Research Fund, plus a further £54 million of capital funds designed to pump prime the development of EPSRC World Class Labs.

The NWCA publishes a higher percentage of its AMCM research outputs with international partners (55%) than all our university group comparators.



Chapter 6

Enabling Capability – Cross-cutting research and innovation for Clean and Sustainable Growth

'We need to do more to ensure our excellence in discovery translates into its application in industrial and commercial practices, and so into increased productivity.'

Industrial Strategy White Paper[1] page 58

The North West Coastal Arc Clean Growth & Sustainable Partnership and UK strategy documents

Industrial Strategy White Paper[1]
The third chapter- 'ideas'- emphasises the UK's great strength in research and innovation, but also (page 61) highlights as a challenge '…improving our ability to turn exciting ideas into commercial products and services and capture their maximum value' and 'Our world-class science and research does not always feed through to world-leading home-grown businesses.' It goes on to state that 'Within R&D, the 'D' for development needs a particular boost' (page 61) and 'There is no single path to innovation. Successful products and services come from a range of sources – from businesses developing new products and universities creating businesses to the lone inventor commercialising an idea.' (page 72). The fourth chapter of the Industrial Strategy White paper- 'People'- highlights the skills and training agenda, for example on page 97 '…. we need to tackle particular shortages of STEM skills. These skills are important for a range of industries from manufacturing to the arts.' We agree, but also assert that the STEM graduates benefit from a wider skill set to grow innovation leadership (6.3 below).

The Clean Growth Strategy[2]
These statements are echoed in the Clean Growth Strategy, for example on p11 'We are clear about the need to …support entrepreneurs and investors who will develop the new technologies at the scale we need. …It is only through innovation – nurturing better products, processes and systems - that we will see the cost of clean technologies come down.' These statements are very close to our experience of the multi-layered nature of innovation, and are especially relevant to this cross-cutting element that we see as fundamental to the skills needed in both our research organisations and our businesses to translate 'invention' in to 'innovation'.

6.1 National and international trends

As the Industrial Strategy White Paper highlights, all innovation takes place within an interlinked system that starts with research and then progresses through development, demonstration, and adoption. Both the Dowling[25] and Witty[26] reviews noted the difficulties for industry, particularly SMEs, finding appropriate expertise, facilities and equipment for all these stages of innovation. Both reports highlighted this as a significant inhibitor of business innovation and scale-up.

In this SIA, we have asserted that Clean and Sustainable Growth, which cuts across business sectors, research disciplines and multiple aspects of government policy, has a particular need for a 'joined-up' approach that (i) provides an 'escalator' that effectively links research, development, demonstration and adoption and (ii) escapes the conventional business, academic and policy 'silos'. Our consultation with business and other stakeholders supports the fact that this escalator is a critical and underfunded element in the innovation system. However, the audit also shows that the NWCA has significant cross-cutting innovation accelerator capabilities with a proven track-record of success that give us a significant foundation on which to build.

The NWCA's distinctive regional strengths and assets driving innovation in our core prime capabilities of Environmental Industries, Technologies and Services, Future Energy Systems, and Advanced Manufacturing, Chemicals and Materials, are described in previous chapters. However, as discussed in Chapter 1, we treat our prime capabilities as parts of a wider, integrated approach to Clean and Sustainable Growth.

This distinctive approach emerges from the region's successful cross-cutting innovation and productivity accelerators, which are a key element in the region's ability to develop the tools needed to deliver both the Clean Growth Strategy and 25 Year Environment Plan[6]. For this reason, we have treated our 'cross-cutting assets' as a separate capability here.

The combined ability of our higher education institutions to work effectively at the business interface and demonstrate national leadership in knowledge exchange is well-documented and accelerates impact through translation. The region's higher education institutions have distinct and complementary strengths across our knowledge exchange and innovation assets and programmes. As stated in our hypothesis, there is a clear opportunity to optimise the innovation system for Clean and Sustainable Growth through better connectivity across the NWCA, building upon existing and strong collaboration and extending these across our entire regional geography, to drive productivity and growth.

Our Innovation and Productivity Accelerator assets include sector-leading co-location, research support and demonstrator facilities (6.2), innovation and skills/talent development programmes (6.3.1), a world-class research base in disciplines that support and enhance innovation for Clean and Sustainable Growth (6.3.2), and our network of international partnerships that can be leveraged to drive international trade opportunities (6.4). These combine with our unique geographical assets that provide a test-bed for the development of eco-innovative products, processes and services.

'Being based on the campus is of immeasurable value to my business. We have frequent contact with academics from many different departments. We draw upon the academics' expertise, and they often draw upon ours. At any one time there are usually several collaborations going on, some commercial and others research based. Above all we value the continuous exchange of ideas.'

Mike Berners-Lee, Director, Small World Consulting Limited

Table 6.1

Cross-cutting science and innovation accelerator assets in the North West Coastal Arc and their relationships across the three prime capabilities of this SIA

Asset	Location	EITS	FES	AMCM
Advanced Manufacturing and Research Institute	N Wales		×	×
BEACON Biorefining Centre of Excellence	N Wales	×		×
Biocomposites Centre	N Wales	×		×
British Oceanographic Data Centre	M'side	×	×	
Built Environment & Sustainable Technologies Institute at Liverpool John Moores University	M'side	×	×	×
Centre for Ecology & Hydrology	Lancs/ N Wales	×	×	
Centre for Global Eco-Innovation– see page 4	Lancs	×	×	×
Centre for Offshore Renewable Engineering	M'side	×	×	
Combined Food and Power Centre of Excellence	N Wales	×	×	
Environment Centre for Wales at Bangor University	N Wales	×	×	×
Hartree Centre	M'side	×	×	×
Institute for Risk & Uncertainty at Liverpool University	M'side	×	×	×
Lancaster Environment Centre at Lancaster University	Lancs	×	×	
Lancaster Leadership Centre	Lancs	×	×	×
Lloyd's Register Foundation	M'side	×	×	×
Menai Science Park Ltd	N Wales	×	×	
National Oceanography Centre	M'side	×	×	
National Research Network for Low Carbon, Energy and Environment	N Wales	×	×	
Northwest Advanced Manufacturing Research Centre	Lancs		×	×
Optoelectronic Technology Incubation Centre	N Wales		×	×
Quantum Technology Centre	Lancs	×	×	×
School of Environment, Natural Resources and Geography, Bangor University	N Wales	×	×	
School of Ocean Sciences, Bangor	N Wales	×	×	
Sensor City, Liverpool	M'side	×	×	×
Sci-Tech Daresbury	M'side	×	×	×
Unilever R&D	M'side	×		×

6.2 Local science, innovation and industrial assets

6.2.1 Cross-cutting science and Innovation assets: co-location, research-support and demonstrator facilities

As described in Chapters 3-5 many of our research and innovation assets are active across multiple aspects of Clean and Sustainable Growth. Of the sixty internationally significant NWCA research and innovation assets identified by this audit, twenty-seven have activities that extend beyond any single prime capability and eight cross all three capabilities (Table 6.1). These cross-cutting assets provide co-location facilities (6.2.1.1), support for collaborative research and development (6.2.1.2) and demonstration capabilities (6.2.1.3).

The diversity of these cross-cutting science and innovation assets is a further indication of the range of disciplines and sectors required to drive Clean and Sustainable Growth. For example, Sensor City in Merseyside is a collaboration between the University of Liverpool and Liverpool John Moores University and is a flagship University Enterprise Zone. As a technical innovation centre it focusses on the creation, development, production and promotion of cutting edge sensor technologies for use in a wide range of sectors. Positioned at the intersection of industry and academia, Sensor City facilitates connectivity and fosters progress, helping partners to capitalise on the growing sensor revolution. LJMU has been working with United Utilities for over 25 years on innovations in the water and wastewater sector, including the use of novel sensors for water quality monitoring.

6.2.1.1 Co-location facilities

The NWCA's co-location facilities provide the region's innovative, knowledge-based businesses, especially SMEs, with access to the high-quality office and laboratory space, state-of-the-art equipment and infrastructure and research expertise provided by our research base. They include Liverpool Science Park (base for over 60 companies), Sci-Tech Daresbury (c.100 companies), the STFC CERN Business Incubation Centre, the Menai Science Park (M-Spark-just opened and currently 13 companies), The OpTIC Centre (21 companies and organisations), and Lancaster University (60 companies across the Lancaster Environment Centre, InfoLab 21 and cTAP).

6.2.1.2 Innovation support

Across the North West Coastal Arc there are a number of existing, nationally award-winning innovation and R&D support programmes that complement our co-location facilities and provide support for businesses, particularly SMEs, to develop new products, processes and services for Clean and Sustainable Growth. The programmes are designed to meet the barriers to R&D and are aligned to enhance SME leadership and absorptive capacity as critical to driving innovation, productivity and scale-up.

Key exemplars within the NWCA include the Hartree Centre and the Centre for Global Eco-Innovation (CGE), as described on page 20. CGE has grown from a partnership between the universities of Lancaster and Liverpool to now also include University of Cumbria, Liverpool John Moores University and University of Chester.

The Hartree Centre

Located at Daresbury, Cheshire, the Hartree Centre was founded by the UK government in collaboration with IBM in 2012. The centre provides industry and academia with access to advanced high-performance computing technologies, expertise and training to encourage innovation in emerging sectors. The centre encourages interaction between start-ups, large business (e.g. Unilever), and universities. Its success is demonstrated by the demand for business space at the Daresbury site, with demand higher than supply.

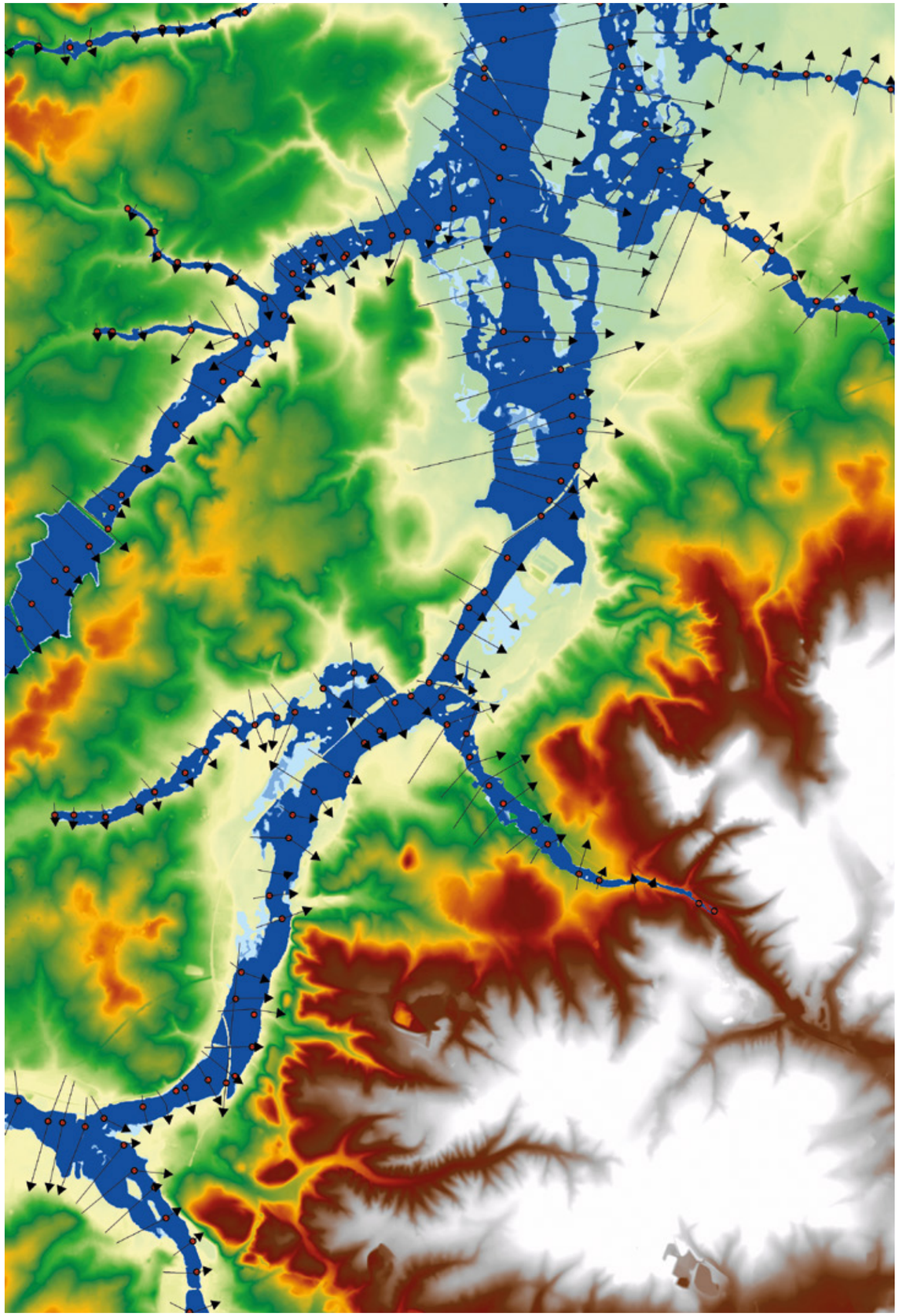
A major feature of Eco-Innovation at Hartree is the ability to take away the requirement for physical testing in many developments, reducing the environmental impact. Further to this, it is involved in Eco-Innovation projects including collaborating with Rolls Royce to make data-based engine energy efficiency improvements, improving factory productivity through layout redesign, and developing future energy systems. The centre also works closely with Unilever to reduce and improve packaging and formulation of products such as shower gels, using digital formulation methods, which also reduces development time.

6.2.1.3 Demonstration

Our audit has highlighted that demonstration is vital to strengthen Clean and Sustainable Growth Innovation across the NWCA. Demonstration enables technology developers, investors, and users to obtain credible information about cost, reliability, safety, and other dimensions of performance under conditions that approximate actual conditions of use. Many of our demonstration facilities exploit the region's geography, including not just our natural and industrial resources but also the power of university campuses as test-beds.

'Key to our success is our alignment with leading academic institutions around the world. We are an Associate Company of the Lancaster Environment Centre, at Lancaster University, providing our staff access to the world class research and development facilities, academic and students on campus.'

Dr Ben Herbert, Director of Research & Environment, Stopford Energy & Environment Ltd



Perhaps inevitably, the region's demonstration facilities are quite focused on specific themes, including the **Minesto Deep project** (N Wales) and **Smart Energy Network Demonstrator** (Staffs page 49) for Future Energy Systems. A notable example for Environmental Industries, Technologies and Services, and strongly linked to elements of the 25 Year Environment Plan, is the **River Eden Demonstration Test Catchment** (Cumbria) which assesses how farming practices can be used to mitigate diffuse pollution from agriculture whilst maintaining food productivity.

For Advanced Manufacturing, Chemicals and Materials, the **Materials Innovation Factor**y (Merseyside page 63) is a £65 million partnership between the University of Liverpool, Unilever and HEFCE (now Research England) to develop a unique materials chemistry research hub. Officially opening in late 2018, it will provide an unparalleled suite of open access, state-of-the-art equipment and internationally-leading academic expertise to develop fundamental innovations in manufacturing at the molecular level and create new materials with step-change functional enhancement in a range of important applications.

6.2.2 Industrial assets

Many of the region's industrial assets relevant to Clean and Sustainable Growth focus largely within one of the three prime capabilities identified in this SIA, described in detail in Chapters 3-5. However, there is also growing recognition across the spectrum from major multi-nationals to SMEs that their activities cut across themes and sectors. This recognition has contributed to the focus of this SIA on improved connectivity across all the region's research, innovation and industrial assets relevant to Clean and Sustainable Growth.

River Eden DTC- a national demonstration test catchment

Climate change and the intensification of agricultural food production pose threats to water quality and aquatic ecosystem functions and services. The Eden DTC in Cumbria was set up as a long-term Defra funded research platform to evaluate mitigating diffuse pollution from agriculture whilst maintaining agricultural productivity.

The DTCs are representative of 80% of UK soil/rainfall combinations and were chosen to build on existing infrastructure, datasets and knowledge. Eden DTC represents a collaborative project led by Lancaster University with CEH Lancaster working closely with local stakeholder practitioners and policy-makers. The project supports the need for landscape-scale demonstration facilities being important to develop the joined-up approach required for EITS to deliver Clean and Sustainable Growth and the wider aims of the 25 Year Environment Plan.

6.3 Local research and innovation talent

6.3.1 Skills - Innovation Leadership and Talent

Leadership and absorptive capacity are well-established skills and talent attributes critical to driving innovation, productivity and scale-up. Unless these needs are addressed then the capacity for technological innovation to drive business growth and productivity is significantly constrained. To address that need, our collaborative activities under the Centre for Global Eco-Innovation (see page 20) and related projects have drawn on the long and successful history of the Lancaster Management School (LUMS) in engaging with SMEs to improve productivity through enhanced leadership.

In particular we have benefitted from LEAD®, a ten-month intensive leadership development programme created by LUMS for owner-managers, MDs, and senior managers of SMEs. The programme is based on high-quality research in the management sciences (see 6.3.2), including research into entrepreneurial learning. To date, LEAD® has supported 1,700 businesses that collectively employ approx. 30,000 people and have a combined turnover of approx. £1 billion. In an independent evaluation[27], 70% of participants reported increased profit and 65% increased productivity. LEAD® has informed policy initiatives[28] and was identified in a House of Lords Report as exemplary in supporting small businesses. The LEAD® programme has also led to the Productivity through People (PtP) programme. The demonstrable synergies between LEAD® and the science and technology elements of the Centre for Global Eco-Innovation are a further demonstration of the capacity of the NWCA partners to develop absorptive capacity and the future talent necessary for establishing the region as an international exemplar for Clean and Sustainable Growth.

6.3.2 Evidence-based assessment of the region's existing cross-cutting research and innovation talent

As with other capabilities, we have compared research quality in this cross-cutting theme as the percentage of outputs in the top 1% of citations in the field, and comparing the NWCA with leading groupings, plus California as a region recognised for its global leadership in innovation (Figure 6.1). The disciplines here are diverse, but united in their contribution to underpinning and enhancing the region's strengths in the science and technology of Clean and Sustainable Growth. For example, the region has outstanding research excellence in Statistics, Probability and Uncertainty, well ahead of all our comparators.

Productivity through People Programme

The LEAD® programme has created a culture of increasingly strong engagement with corporate anchor organisations and their supply chains, for example, BAE Systems and Siemens, where LUMS has facilitated the development of enhanced absorptive capacity at the interface between large and small businesses.

BAE Systems' experience of the benefits of LEAD® led to the development of the Productivity through People (PtP), a nationally unique programme focused on behavioural change within advanced manufacturing owner/managers to empower positive employee engagement to boost productivity. Supported by BAE Systems, Rolls Royce and Siemens, a pilot programme is being delivered within the Northwest. While focused on Advanced manufacturing (Chapter 5) the approaches that PtP is developing can be applied across all aspects of Clean and Sustainable Growth.

Lancaster is emerging as the leading university in the National Programme Network tasked with scaling the programme nationally in support of the newly formed Be the Business (formerly the Productivity Leadership Council). The national rollout will enable the university to support universities in the NWCA and across the UK to develop appropriately 'localised' versions of the PtP programme, resulting in significant productivity improvements within participating SMEs at a national scale and more broadly, help inform future Government industrial policy.

This is a key 'Decision Science' that, for example, underpins both prediction of extreme events such as flooding and understanding the interface of highly variable energy generation from renewables with varying demand. This strength also interfaces with digital and sensor technologies (e.g. Sensor City in Merseyside) and Data Science relevant to the sectors and disciplines covered by this audit, including Computers in Earth Science (where the NWCA is ahead of all our comparators except California). Management Science and Operations Research is similarly outstanding, and in combination with strengths in 'Strategy and Management' and 'Management of Technology and Innovation' frames our technical innovation strengths with world-class management science research.

The final element included under this cross-cutting theme is SCIVAL's 'multidisciplinary' category (Figure 6.1). This category includes journals, such as Nature and Science, generally recognised as the natural outlet for the very highest quality research across all scientific disciplines. The NWCA's performance under this heading, comparable to California and ahead of all our other competitors, reinforces our assertion that our success with delivering 'impactful' research with SMEs does not prevent the region from producing publications at the very top of global research outputs.

The NWCA's integrated research quality in these cross-cutting disciplines (Figure 6.2) is higher than that of all our comparators. This highlights the NWCA's strength in this broad basket of disciplines that support the more focused 'science and technology' of our other themes.

We assert that this has been part of the region's current success in leveraging our world-leading research in EITS, FES and AMCM to support our region's businesses, especially SMEs. It has allowed us to move beyond 'invention' to deliver real innovation, for example through our shared activities around the Centre for Global Eco-innovation (see page 20). It is at the heart of the NWCA's holistic vision of Clean and Sustainable Growth.

6.4 National and international engagement: HEIs as drivers of internationalisation

UK manufacturing recently posted its biggest fall in production in over five years. It has been proposed that one of the reasons for this is manufacturing companies not taking the opportunity to export more using the benefit of a more competitive exchange rate. This is turn has constrained improvements in UK trade figures.

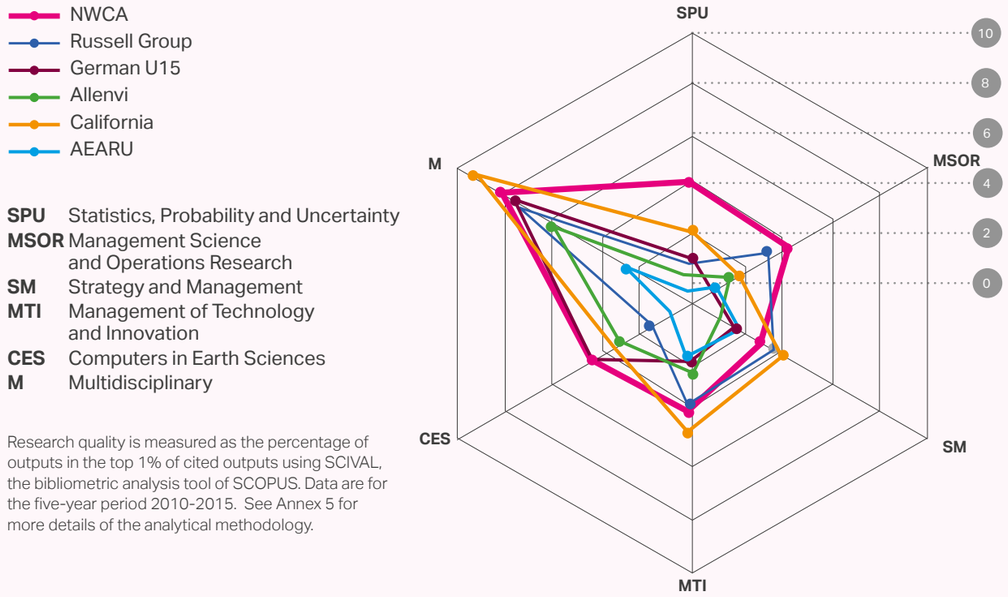
Products, processes and services for Clean and Sustainable Growth offer significant opportunities to scale-up export trade with the growing economies of China, India, the Middle East and Africa. The 2015 Goldman Sachs report 'Unlocking UK Productivity: Internationalisation and Innovation in SMEs'[29] 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 approx. 20% of SMEs are exporters, with only 5% classified as 'persistent exporters'.

'Our business chose to locate in the region due to Keele University – They showed the most interest in our technology, offered a position at the Energy Hub and provided an independent academic assessment of noise and vibration.'

Philip Mayer, Chairman, McCamley UK

Figure 6.1

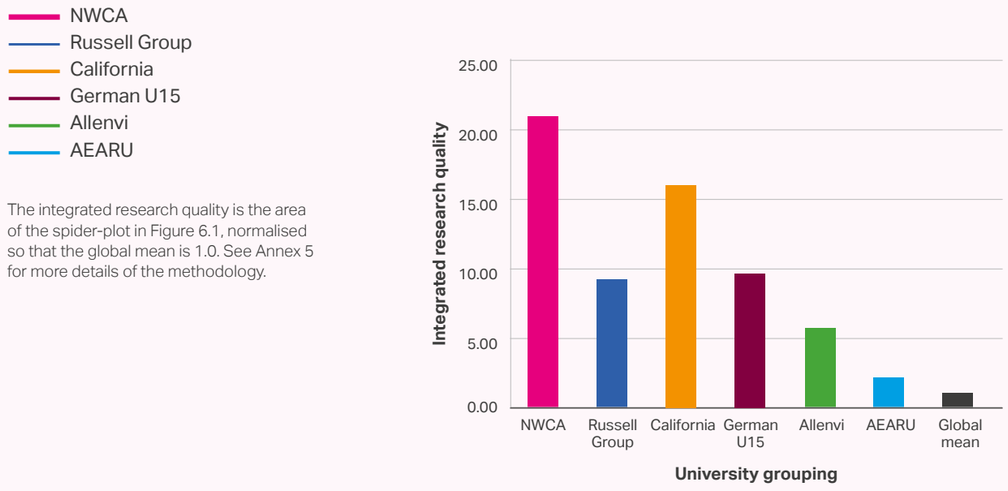
Research quality for the NWCA in the six sub-disciplines included under our cross-cutting research capability, compared with other major university groups or regions.



Research quality is measured as the percentage of outputs in the top 1% of cited outputs using SCIVAL, the bibliometric analysis tool of SCOPUS. Data are for the five-year period 2010-2015. See Annex 5 for more details of the analytical methodology.

Figure 6.2

Integrated research quality across our cross-cutting research capability for the NWCA compared with other major university groups or regions.



The integrated research quality is the area of the spider-plot in Figure 6.1, normalised so that the global mean is 1.0. See Annex 5 for more details of the methodology.

One key barrier identified by that report was gaining access to networks, and the 2016 Universities UK 'International Innovation by UK Universities' report[30], highlights the potential of universities to deliver a wide range of beneficial outcomes including 'building new global partnerships', especially for SMEs. The report also highlights that HE can provide a robust stabilising framework for international collaboration that enables universities and businesses to access different or larger markets and resources.

The NWCA universities have significant 'on-the-ground' presence in key export markets (Table 6.2). These already provide opportunities to show-case 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.

The role of 'Decision Science' in supporting Clean and Sustainable Growth: JBA Consulting

Risk-based analysis of extreme weather events using computer models has numerous applications cutting across infrastructure, land management, community resilience and other economically and socially beneficial applications. One such application is in managing the risk of flooding. Improved flood risk modelling based on the application of research* led by Lancaster University has had global impacts in improved flood defence policies and planning by governments, and in assisting insurers with their underwriting**, for example in pricing and policy decisions. Technological advances in data science, have allowed JBA Consulting to develop the world's first commercially successful GPU-based flood model, and Lancaster to produce the first probabilistic flood risk maps. Data generated by JBA's software system has since been used by government and insurers in the UK (including the top five UK insurers by market share) and world-wide.

In the marine environment, collaboration with Lancaster University and others has helped JBA to support growth in offshore renewables with commercial products and services that enable resilient operations planning, combining analysis of offshore weather extremes, risk profiling and optimisation technology. These innovations in EITS highlight the value and opportunity created by inter-disciplinary and multi-sectoral collaborations (in this case, drawing on research across both physical and mathematical sciences, and finding routes to market within the public sector, and private financial services, energy and infrastructure sectors).

*REF2014 Impact Case Study: Societal and economic benefits from improved flood modelling based on pioneering Lancaster research in to risk and uncertainty in environmental modelling. Lancaster University.

** REF2014 Impact Case Study: Optimisation of the UK's flood defence infrastructure through the use of innovative statistical research on extreme values Lancaster University.

'If we want to achieve clean growth and resilience with innovative ways of enhancing natural capital, then we need to test new approaches to our use of land, air and water at large scales.

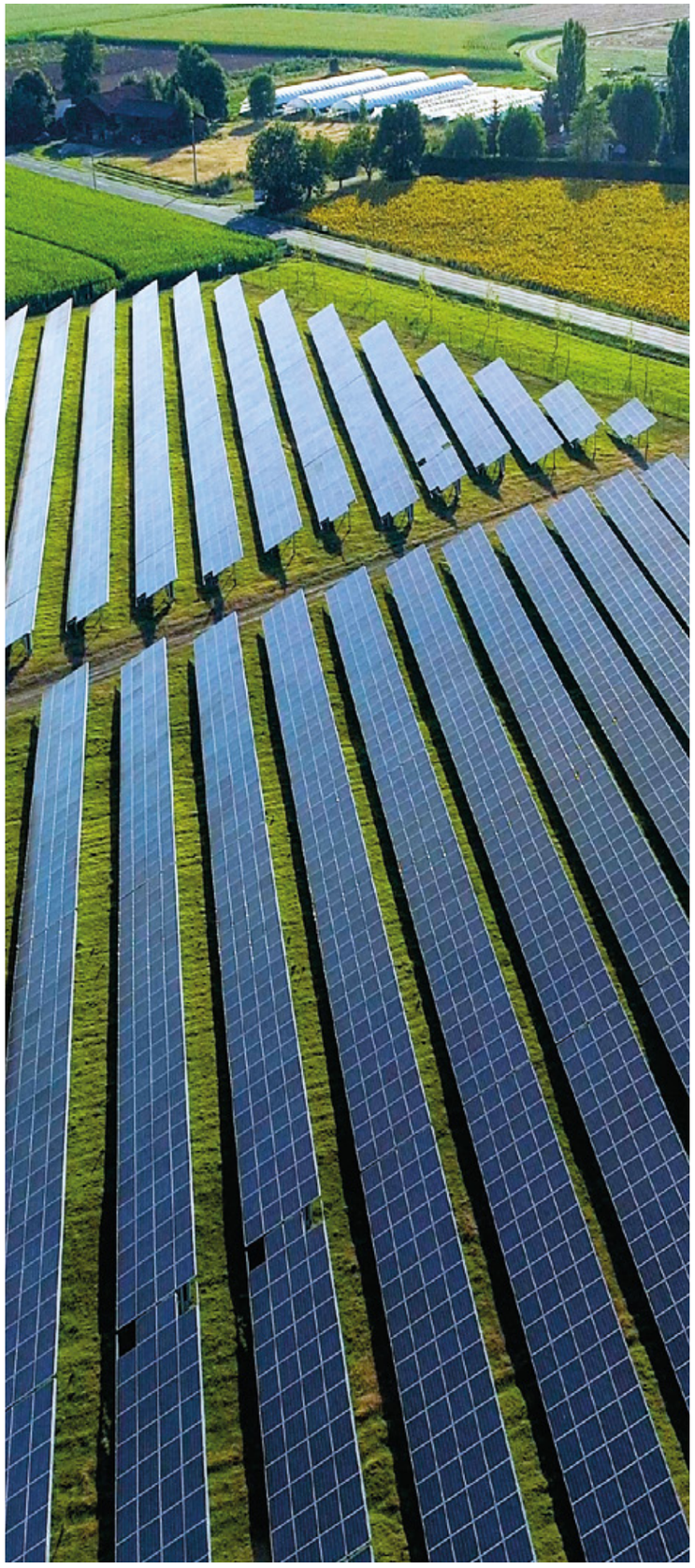
The step up from small pilots to full scale implementation can be supported by models, but landscape scale demonstrators are vital to confirm those models and provide evidence for investment planning.'

Professor Rob Lamb, Managing Director, JBA Trust

Table 6.2

International research innovation and engagement assets of HEIs in the North West Coastal Arc™

China	UCLAN	Shenzen Office for Research & Innovation undertakes partnership development work, research development and support to UK and Chinese entrepreneurs.
	Lancaster	New Lancaster University College-Beijing Jiaotong University and the HEFCE-supported Lancaster China Catalyst Programme (Annex 7) all support the creation of partnerships between UK SMEs and Chinese partners to develop new eco-innovative products, processes and services for the Chinese marketplace.
	Lancaster	International Research & Innovation Centre for the Environment (I-RICE) based in Guangzhou, is a joint venture between Lancaster University and The Chinese Academy of Sciences.
	Liverpool	Xi'an Jiotong-Liverpool University (XJTLU) and its recently established International Technology Transfer Office.
	Bangor	Bangor College China (BCC) is a collaboration founded in 2013 between Bangor and the Central South University of Forestry and Technology (CSUFT) in Hunan Province.
	Bangor	The UK-China Centre for Improved Nitrogen Agronomy (CINAg), is led by Rothamsted Research and include Bangor as one of the collaboration partners.
SE Asia	Lancaster	Sunway University, Malaysia and Lancaster University established a partnership in 2006 which is developing beyond teaching towards research and innovation.
	Lancaster	LU Ghana represents the first British branch campus in Ghana with development of a new 'Centre for West African Studies' underway focused on research and business innovation across science and management.
Sub-Saharan Africa	Lancaster	CGE Nigeria was launched in 2016 as the first international satellite for the Centre for Global Eco-Innovation.
	Lancaster	GCRF-funded RECIRCULATE is a 4 year, £7M programme with partners in sub-Saharan African to develop 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.

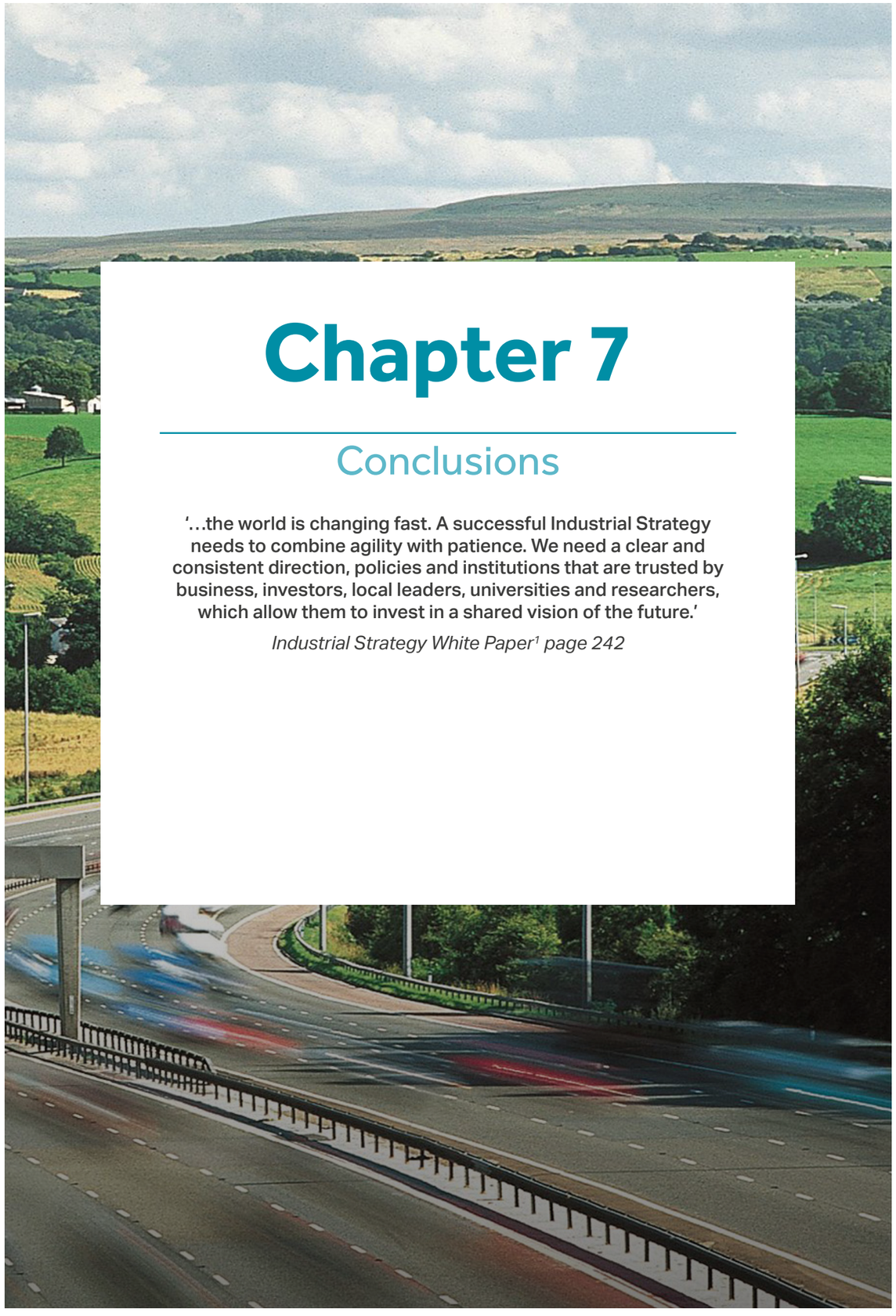


6.5 Developments in the wider funding landscape

The **Global Challenge Research Fund** represents 0.7% of UK GDP that is focused on research and innovation to support sustainable development. It presents an opportunity for the region's excellent research base to support access to secure and resilient food systems, sustainable health and wellbeing, clean air, water and sanitation and affordable and sustainable energy in developing countries across the globe. In doing so, there may be opportunities to involve our SMEs and other partners as researchers to develop strong and durable international networks.

The **UKRI Strength in Places Fund (SIPF)** led by UK Research and Innovation, represents a new competitive funding scheme that takes a place-based approach to research and innovation funding, to support significant relative regional growth. It will be driven by business need that can be met by existing research strengths. Funding will be competitively awarded to consortia representing 'economic geographies' across the UK that (a) have existing research excellence and high-quality innovation capability that are focused on wealth creating opportunities and aligned to the needs of their local industry and business supply chains; and (b) where activities are likely to bring significant, relative economic impact and regional growth. Activities that will be funded will need to show a significant positive impact in rate of growth, relative to the baseline for the chosen delivery geography.

Both of these schemes present significant regional through to international opportunities for increased collaboration between our region's science and innovation base to drive further growth across the NWCA's Clean and Sustainable Growth industries.



Chapter 7

Conclusions

'…the world is changing fast. A successful Industrial Strategy needs to combine agility with patience. We need a clear and consistent direction, policies and institutions that are trusted by business, investors, local leaders, universities and researchers, which allow them to invest in a shared vision of the future.'

Industrial Strategy White Paper[1] page 242

7.1 Gap analysis: connecting current capabilities with future opportunities

The overarching hypothesis for this SIA was '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'.

Those assets include not just research and innovation 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. As detailed in chapters 1-6 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 (see Table 1.2 for example). 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.

However, the audit has also further clarified the challenge of 'networking, integration and connectivity'. That challenge remains substantial despite a strong existing culture of collaboration, but this is also an opportunity to build on what we have now to work together to address this issue. 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 in Clean and Sustainable Growth (see Section 7.2).

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

In the expression of interest, we hypothesised 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. Many of those who were interviewed were unclear how 'Clean and Sustainable Growth' was relevant to their own planning, both in business and local/regional policy (Annex 8). 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, HEIs 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 in the expression of interest 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.'

Again, this audit has confirmed that synergies could be optimized, and began to identify specific examples. Inputs from businesses and stakeholders recognised lack of connectivity between sectors, and the audit also 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 and opportunities, for example by supporting 'open innovation' through CGE and other cross-cutting activities (Chapter 6). Yet the audit made clear that we have only just started this journey. The audit has drawn out our distinct 'capabilities', but also the inherent integration required at the heart of Clean and Sustainable Growth. The many points of contact between capabilities were clear, and re-emphasised the need to find new ways of working that are truly 'post-disciplinary' to meet the challenges and opportunities of Clean and Sustainable Growth.

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.

A specific 'valuable, additional mechanism …. to optimize synergies across the NWCA' identified through the audit was a 'joined up' approach to demonstration facilities: the 'test-bed' opportunity, a need clearly identified by businesses and stakeholders (Annex 8). The region is growing a range of demonstration facilities that looks to be unparalleled globally. 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. The model is currently based on 'home turf' but the audit identifies real potential for a more collaborative vision.

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

In the expression of interest, we hypothesised that '… the region's HEIs have a 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 (Annex 8) 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 maximise shared benefits

The audit identified the scale and diversity of international research and innovation connections of NWCA university partners (Table 6.2). These international campuses, partnerships and 'commercialisation' offices represent an important bridge for two-way business innovation supporting Clean and Sustainable Growth.

Examples of skills and training needs

There is a need for much better provision of apprenticeships at all levels and relevant to businesses across the whole spectrum relevant to Clean and Sustainable Growth. This need was identified by our numerical analysis (Annex 6) but also, critically, by our stakeholder consultation (Annex 8), and despite notable achievements such as Lancashire Energy HQ at Blackpool and Fylde College. There is a particular gap in high-level apprenticeships. It seems likely that a collaborative approach across NWCA partners might allow the development of a unique training 'offer' in the region to address this need.

Within this audit the businesses highlighted 'difficulties accessing skilled workers with STEM skills ..', echoing the 'People' chapter of the Industrial Strategy White paper- for example on p97 '…. we need to tackle particular shortages of STEM skills'. The LEPs expanded on this and noted '…eco-innovation is a sphere of multiple careers in a lifetime - opportunities need to be created to transition between these easily'. This relates to the other graduate skills gap that was identified in this audit, STEM graduates lacking the broader skill-set needed by business. That need coincides with what is described in the 2017 NESTA 'The Future of Skills' report as '….higher-order cognitive skills such as originality, fluency of ideas and active learning. Skills related to system thinking — the ability to recognise, understand and act on interconnections and feedback loops in sociotechnical systems — such as judgement and decision making, systems analysis and systems evaluation…'. For us, that relates closely to the need highlighted in the Industrial Strategy 'Within R&D, the 'D' for development needs a particular boost.'

However, as with UK-based facilities each institution's connections remain 'siloed'. 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 to support industrial trade 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 (page 20). 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 European Structural and Investment Fund (ESIF) programme. The current ESIF programme, as with further recent related regional funding such as Local Growth Deal, is effectively 'devolved' to single LEP areas. This has meant that as the network of CGE partners expanded in phase 2, each of the four new projects were evaluated and effectively funded separately by Cheshire, Cumbria, Lancashire, and Liverpool City Region LEPs. This has resulted in operational inefficiencies to programme development and delivery, and unnecessary multiplication of administrative effort. There was a very clear view from all stakeholders, businesses and LEPs, as well as from HEIs, that this detracted from the ability of the project to support business and deliver its economic and environmental targets at scale. We welcome the freedoms and flexibilities introduced in new funding streams such as the recently announced Strength in Places call under UKRI, and would urge Government to consider this issue under emergent programmes such as the proposed Shared Prosperity fund.

7.2 Target opportunities for Clean and Sustainable Growth

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

Opportunity 1 Communicating the economic importance of Clean and Sustainable Growth

This audit itself is providing a detailed and publicly-available evidence base of research/ innovation assets and networks in Clean and Sustainable Growth across the NWCA. It also provides regionally-specific information about scale, location and eco-innovation needs of the many industrial sectors and markets that contribute to, and benefit from, the drive for Clean and Sustainable Growth. Communication will need to consider multiple audiences, business sectors, national, regional and local government and LEPs, and, underpinning those, the wider public.

There are immediate opportunities in both 'Green Great Britain Week' outlined in the Clean Growth Strategy[1] and the proposal in the 25 Year Environment Plan[6] to make 2019 a 'year of action for the environment'. Both are excellent opportunities 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

This audit provides policy makers, innovation funders and industry with the necessary evidence base to facilitate strategic decisions both locally and nationally on large–scale investments that will ultimately deliver the ambition of a globally-leading Clean and Sustainable Growth capability in the NWCA. This will be able to contribute significantly to UK productivity, prosperity and sustainability.

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[1] and 25 Year Environment Plan[6]. 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).

A new Eden Project for the North in Morecambe Bay

The Lancashire Enterprise Partnership, Lancashire County Council, Lancaster City Council and Lancaster University are currently working with the Eden Project to develop the Eden Project North in Morecambe Bay, a transformational project to develop an internationally significant visitor attraction, a unique centre for environmental and related research and for public engagement with science.

Morecambe Bay forms an integral part of a network of natural assets across Cumbria, Yorkshire and Lancashire that attracts millions of visitors from across the globe each year. The Eden North project will provide a year-round destination for the region. 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 project is currently undergoing a series of detailed feasibility studies.

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. There are also opportunities for facilities at different locations focused on particular research disciplines or business sectors. For example, there may be specific opportunities to address the current lack of a world-leading facility for collaborative R&D in water management, to deliver new products and services encompassing drinking water supply, waste water management (treatment systems, drainage) and irrigation, as well as those related to enhancing resilience (including flood risk management). This would clearly map effectively on to both the Clean Growth Strategy[1] and the 25 Year Environment Plan.

Finally, returning to the need for 'greater networking, integration and connectivity', highlighted in our expression of interest, the audit has identified specific opportunities for a more 'joined-up' approach to the region's existing research, development, demonstration and co-location facilities. Several specific possibilities have emerged from the audit and we will advance these in focused discussions between relevant partners, typically two or three organisations.

Examples of cognate but currently isolated activities

Hydrogen-based energy systems at Keele and Liverpool/LJMU. Below-ground energy resources at Keele, Chester and, given Lancashire's shale gas resources, potentially also UCLan.

'Place-based synergies' between North Wales, Lancashire and Cumbria: in essence their shared geographies with extensive uplands and coasts supporting the region's urban areas, for example as both a source of water, food and recreation but also a key resource for reducing 'down-stream' flood risk.

In-depth SME R&D post-graduate student supported projects to support product, process and service development, including the Centre for Global Eco-Innovation that currently only involves Lancaster, Liverpool, Liverpool John Moores, Cumbria and Chester, together with the University of Wales' Knowledge Economy Skills Scholarships programmes, led by Bangor University.

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 HEIs in order to develop SME internationalisation support programmes across the HE partners. This ambition will need to start with discussions between our HEIs, 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. Firstly, to help identify UK companies that could export goods and services into growth markets. Secondly, 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 and retaining regional talent to support and lead Clean and Sustainable Growth

The wider concerns around the 'skills gap' led to the identification of two issues, apprenticeships and widening the skill sets of STEM graduates. Again, the complementary resources of partner organisations, building on current provision might allow a step-change in how both pre-degree, undergraduate and postgraduate training is seen and delivered. 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 might start with a 'phase 2', in-depth audit of the region's training offers relevant to Clean & Sustainable Growth across FE and HE providers, how these relate to each other and how they could be connected to provide a 'skills escalator', perhaps 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. This might include increased engagement with Degree Apprenticeships. The vision is to complement technical training with leadership and management elements, building on existing activities (Chapter 6) such as those developed across several NWCA partners through the various elements of the Centre for Global Eco-Innovation (see page 20). 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[2]) that operate at an appropriate and transformational regional scale across individual LEP boundaries.

Eden North concept

7.3 Next steps

The preceding sections have outlined specific opportunities identified through this audit. Together they define a set of actions needed to deliver the greater networking, integration and connectivity that the audit confirms are essential for the NWCA to fully exploit its capabilities and become a global leader in developing both the solutions (products, services and technologies) and the skilled people needed for Clean and Sustainable Growth.

This audit has also proved the strength of the NWCA partnership and 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. The conclusion of the audit is the starting point for the plan of co-ordinated action on Clean and Sustainable Growth described in Table 7.1.

Throughout the audit we have linked the NWCA's capabilities to current UK strategy, in particular the UK Industrial Strategy White paper, the Clean Growth Strategy and the 25 Year Environment Plan. Our action plan is equally focused on those strategy documents.

The first chapter of this audit begins with the following quote from Industrial Strategy White paper 'The move to cleaner economic growth – through low carbon technologies and the efficient use of resources – is one of the greatest industrial opportunities of our time. By one estimate, the UK's clean economy could grow at four times the rate of GDP. Whole new industries will be created, and existing industries transformed as we move towards a low carbon, more resource-efficient economy'.

These opportunities are very large, but also time constrained and the subject of intense research and innovation by all industrialised nations. Taking full benefit from these opportunities to grow UK competitiveness in global markets, and to develop the tools to deliver the wider aims of these strategy documents, requires action now. This includes meeting our national commitment to limit greenhouse gas emissions, which as described on page 242 of the Industrial Strategy '…is not just an economic opportunity; it is also a moral duty', a responsibility also highlighted in the report of the Committee on Climate Change report published in June 2018[31].

This implementation plan defines the mechanisms by which the outcome of this audit will be put into practice to empower the region to work collectively to drive forward the economic, social and environmental benefits provided by Clean and Sustainable Growth. The learning, innovation assets and benefits developed as a result of the audit can then be applied across the UK to increase productivity, create good jobs and scale-up earning power right across the country and so maximise the nation's competitiveness in this fast-growing global market.

Since the formal submission of this SIA in July 2018, the Intergovernmental Panel on Climate Change (IPCC) published a special report[32] on the impacts of global warming of 1.5°C above pre-industrial levels. The report makes clear that limiting warming to 1.5°C would prevent many of the risks associated with a 2°C rise.

The IPCC report states that to limit global warming to1.5°C *"…would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems. These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options."*

This conclusion of the IPCC report further reinforces a major outcome of this audit in highlighting the urgent need for Clean and Sustainable Growth that addresses the needs of all sectors and industrial systems.

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.
	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.
Autumn 2018	"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.
	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.
Winter 2018-2019	Initial alliance communications and engagement activities under '2019 Year of Action for the Environment' (continues through the year).
Early 2019	Final work streams agreed, including decisions on which partner leads which work-stream.
Spring 2019	Work streams carry out their activities.
Early summer 2019	Work-stream assessments and recommendations submitted to alliance steering group.
Late summer 2019	Steering group agrees priority actions.

References

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[2] HM Government Clean Growth Strategy

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[32] 2018 Intergovernmental Panel on Climate *Change. Global Warming of 1.5°C - An IPCC Special Report*

Annexes

Annex 1: LEP and North Wales Growth Priorities

Cheshire & Warrington

The low carbon goods sector in Cheshire and Warrington is well established, with over 800 companies, producing an estimated £1,888 million in sales and supporting 18,000 employees. The sector has performed strongly in Cheshire and Warrington even during the recession, maintaining growth rates of 4.6%. Cheshire and Warrington have comparative strengths in energy efficiency: building technologies and energy management; renewable energy: geothermal, photovoltaic and biomass; waste and recycling: recycling and recovery and waste management sub-sectors. Cheshire and Warrington also benefits from the innovation provided by higher education which work on a number of low carbon issues, including sustainability, community carbon reduction and community energy schemes.

The Cheshire and Warrington sub-region has made progress towards emission reduction over the last five years. In terms of emissions, per capita local CO_2 emissions in Cheshire (Cheshire East and Cheshire West and Chester) fell from 13.8 tons in 2005 to 11.9 tons in 2011. In Warrington, emissions fell from 9.8 tons to 7.7 over the same period. Nationally, however, emissions per capita were 6.7 tons per person in 2011, indicating that there is still further progress to be made.

Future priorities include measures to support increased production of renewable fuels and energy, in particular wind energy, solar and biomass that could include demonstration and deployment of renewable energy technologies.

Support for the wider deployment of renewable heat, including micro-generation, geothermal, renewable heat networks or district heating, ground source and air source heat pumps, and biomass systems with recycling processing, reprocessing and remanufacturing facilities also represent priorities.

Other priorities include anaerobic digestion plants and other biomass or landfill gas schemes as well as support to build capability and capacity for supply chains in renewable energy. Supporting SMEs to improve their energy efficiency and increase their renewable energy by the implementation of low carbon technologies, products, processes and approaches and best practice in energy efficiency management. This will be done in all areas of the business process in order to reduce energy consumption, make financial savings, increase SME productivity and mitigate the impacts of CO_2 emissions.

Cumbria

With energy as one of the key sectors for the Cumbrian economy, supporting growth within the low carbon sector has the potential to make a significant contribution to both the nation's energy security as well as meeting carbon reduction commitments.

The 2013 report, *The economic potential of low carbon and environmental goods and services (LCEGS) sector in Cumbria*, undertaken by the ERDF-funded ESTA project, shows that Cumbria has around 400 LCEGS companies that employ around 8,100 people and command sales worth around £1 billion per year. Within this, the Low Carbon sector, which includes building technologies, carbon capture & storage, carbon finance, and energy management, accounts for 26% of sales and employment. It is recognised that small companies in Cumbria, developing diverse technologies which encompass new forms of insulation materials, the deployment of microgeneration renewables products, new building materials, low-impact solvents and household products, and energy advice services, can offer significant levels of growth to the Cumbrian economy. In addition, many companies in other sectors have the potential to supply into the growing LCEGS markets; for example, manufacturing companies or those with expertise in sub-sea technologies can supply into the burgeoning offshore renewables industry.

The total onshore potential renewable energy resource in Cumbria identified in the SQW report *The Cumbria Renewable Energy Study 2011*, is assessed to be 4,542MW or 4.5GW.

This includes on and offshore wind, wave, geothermal, biomass, hydropower, micro-generation, large scale solar and combined heat and power. The same study particularly highlights micro-generation as 'providing an exciting opportunity in terms of economic benefits and job creation'.

Lancashire

Lancashire is one of the largest economies in the north of England, generating £29 billion of GVA and supporting over 623,000 jobs. It has a large and diverse economic base with over 51,000 enterprises, a growing number of world class companies and key strengths in aerospace and advanced engineering and manufacturing.

Although Lancashire has experienced sustained economic growth the area's economic performance consistently lags behind UK with Lancashire's GVA per head only 77% of the UK's average. To significantly raise productivity Lancashire's economy needs to generate more high value economic growth by promoting the growth of SMEs, supporting innovation, including the dissemination and adoption of new technologies, and capitalising on the high value growth sectors where Lancashire has real competitive strengths or potential.

The challenge for Lancashire is to promote high value economic growth, develop low carbon technologies and improve the competitiveness of the local business base, whilst at the same time reducing the levels of Green House Gas (GHG) emissions, increasing the share of renewable energy and enhancing the energy efficiency of businesses.

Lancashire has a number of key strengths in low carbon, with energy generation, renewables and low carbon industries representing a key growth sector for both the UK and Lancashire. The sector, valued at over £100 billion for the UK, is highly diverse, encompassing sub-sectors such as nuclear and renewables, environmental services and emerging low carbon activities. The opportunity for Lancashire is to ensure that the right interventions are in place to support the expansion of the low carbon sector and exploit the associated supply chain opportunities and technological developments.

Low Carbon Goods and Services is a key growth market for Lancashire with opportunities in carbon capture and storage market and natural economy activities. It comprises approximately 650 businesses, nearly all SMEs, and employs 8,000 people. Lancashire has growing strengths across these sub-sectors with a strong, predominantly SME, business base and supply chain.

Liverpool City Region

Liverpool City Region covers the Local Authority Districts of Liverpool, Halton, Knowsley, Sefton, St. Helens and Wirral, with a population of 1.5 million people. It is home to over 48,000 Small and Medium Enterprises (SMEs), with an economy worth £28 billion annually.

Liverpool City Region's unique Atlantic coastal city location, including the River Mersey, iconic waterfront and the Port of Liverpool, presents significant opportunities for future energy generation, low carbon sector development and strengthening the City Region's position as a low carbon logistics hub and an attractive and resilient place for future investment. In particular, the Mersey estuary and tidal waters of Liverpool Bay offer a unique resource with the potential to generate a significant proportion of the region's future energy needs.

The low carbon environmental goods and services sector in Liverpool City Region is made up of some 1,200+ companies that employ around 22,000 people and command sales worth more than £2.7 billion per year. Demand for low carbon environmental goods and services is growing. In 2012/13 the sector grew at 4.9%.

A key sector strength is offshore wind. Environmental conditions mean that the areas off the coast of the City Region offer some of the best wind resources in Europe. The scale and size of the UK offshore wind market offers a range of supply chain opportunities in design, build, maintenance and operation. More supply chain capacity is needed to meet future demand from this sector. Other strongly performing industries include installers of micro-generation technologies, businesses which retrofit energy efficiency measures and the biomass sector.

The low carbon economy also links strongly to Liverpool City Region's Innovation Plan with overlap in areas of smart specialisation, offshore and marine technologies and sensors. The Innovation Plan has within it an innovation ecosystem, which will support the growth in four priority areas, including 'Solutions for Sustainable Growth'.

Liverpool City Region has an aspiration to be energy self-sufficient within 20 years. It is an aspiration which the City Region has many of the natural, built and business assets to achieve, whether it is through the ways that energy is generated, the way it is distributed through smart grids, heat and energy networks, or the way it is consumed and preserved through energy efficiency actions and building retrofitting schemes. Activities to deliver this aspiration are the cornerstone of the investment priorities for Liverpool City Region under Priority Axis 4 (PA4).

ERDF Low carbon priorities for Liverpool City Region sit within the blue green economy portfolio of the Liverpool City Region European Structural Investment Funds Strategy. Whilst this portfolio covers investment priority axis PA4 and PA6 of the ERDF Operational Programme, the scope of this call is solely for PA4 (supporting the shift to a low carbon economy).

Stoke-on-Trent & Staffordshire

The Stoke on Trent and Staffordshire area has a strong set of businesses with growth potential in key sectors which sit centre-stage in plans for the future. The business growth agenda is based on recognised strengths in five key aspects of advanced manufacturing:

+ Energy Generation: building on the long-standing presence of Alstom in Stafford, ABB, Siemens Wind Power, GE Power Conversion and the sustainable energy programme centred around Stoke-on-Trent and beyond, to meet growing local and international demand by diversifying into geothermal, anaerobic digestion, biomass and energy-from-waste.
+ Auto-Aero: capitalising on the supply-chain opportunities emerging from global businesses such as JCB, Michelin, Jaguar Land Rover, Moog, and Zytek in our area.
+ Medical Technologies: in which Keele University and its Science Park are internationally recognised leaders.
+ Agri-Tech: drawing on our agricultural back-drop and Harper Adams University on our border to capitalise on an increased global focus on food security and the agri-plant capacity of JCB, Muller and Adams Foods.
+ Applied Materials: building upon our recognised heritage in metals and ceramics in both Stoke-on-Trent and Staffordshire to exploit opportunities in applied uses for polymers, ceramics, glasses and composites. The area is home to leading companies in this sector (e.g. polymers – Bostik, Fuchs Lubricants, Michelin; engineering companies such as JCB, Perkins, MG Sanders, and Goodwin use novel and new applied materials (metallic and non-metallic) in their products and to remain globally competitive need to invest heavily in the development of new materials; and ceramics – Steelite International, Wedgwood Waterford, Royal Doulton).

Stoke-on Trent and Staffordshire Strategic Economic Plan builds on a detailed understanding of the socio-economic context and characteristics of the LEP area, and the implications of this for economic growth.

Strengths and opportunities include the fact that Stoke-on-Trent and Staffordshire is home to numerous international businesses including Alstom, Coors, JCB, Jaguar Land Rover, Michelin, Moog, Steelite, and Zytek. Similarly, the area is home to a buoyant SME sector making a significant contribution to economic growth. The area benefits from location at the heart of the UK, with strong connectivity via road (including the M6, A50, A500, A38, A5) and rail (including the West Coast Mainline). Inward investment performance has been strong in recent years, with notable recent projects including Jaguar Land Rover and Amazon. There is a genuine opportunity to develop strengths in sectors such as Advanced Materials, Advanced Manufacturing and Energy, driving higher levels of gross value added and productivity. There is also an opportunity in the region to create a unique local energy offer based upon existing and new assets and investment in emerging technologies and energy supply chain development.

North Wales

The Welsh Government Report, *"Prosperity for All: the national strategy"*[1] maps a focused ambition to build a Wales that is prosperous and secure, healthy and active, ambitious and learning, and united and connected.

The strategy recognises the need to build prosperity in a way that supports and sustains Wales' stunning natural environment, ensuring that current and future generations will continue to benefit, and make a tangible contribution to the fight against climate change. Economic resilience underpins the ambitions for Wales. The strategy has a strong focus on Low Carbon Growth including:

+ Setting out a low carbon pathway providing clarity and certainty for action and investment around the low carbon economy through setting targets for 2020, 2030 and 2040.
+ Accelerating the decarbonisation of our public services, creating new opportunities for businesses in Wales in the transition to a low carbon economy.
+ Setting out a route map for a more resource efficient economy, building on our success in recycling and reducing the environmental impacts of production and consumption.
+ Delivering a post-EU agricultural and fisheries policy for Wales, designed with stakeholders to reflect the needs of the modern Welsh agricultural and fisheries sectors and to manage the impact on the environment.

The Economic Action Plan[2] aligned to the strategy sets out how the resources, expertise and knowledge in Wales can be pooled to strengthen economic foundations and future-proof the Welsh economy. The Action Plan recognises the core need to improve competitiveness, the productivity gap, economic inactivity and unsustainable spatial variations. As carbon intensive products see their market shares significantly decline, it recognises that the shift towards a low-carbon future offers huge opportunities for the economy to new models and methods to decarbonise the traditional models of business, public services and infrastructure. Growth needs to be sustainable and inclusive.

The North Wales Economic Ambition Board (NWEAB) Growth Deal bid is committed to lead innovation in low carbon and nuclear energy, advanced 'smart' manufacturing and the digital and creative sectors. The bid for £383m could generate investment of £1.3bn into the economy of North Wales.

Annex 2 The North West Coastal Arc geography and partners

We bring 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 (LMJU), Glyndwr and University of Central Lancashire (UCLAN) and other national research assets, together with Further Education (e.g. Lancashire's Energy HQ at Blackpool & The Fylde College, Myerscough College). Additional research capacity is delivered from the Centre for Ecology and Hydrology (at Lancaster and Bangor) and the National Oceanographic Centre at Liverpool. The consortium also includes all regional LEPs, the North Wales Economic Ambition Board, our strong regional communities of eco-innovative SMEs and large industry players with international reach, including Unilever and the Aerospace Alliance.

Annex 3:
Overview of the NWCA's research and innovation assets for Clean and Sustainable Growth

Asset	Description	Location	Type	EITS	FES	AMCM
Advanced Manufacturing and Research Institute (in planning)	Airbus confirmed it will be the first anchor tenant for the new centre at Airbus Broughton ensuring maximum benefits for the supply chain and wider economic advantages. The Welsh Government is providing £20m pump-priming funding and a further £10m from project partners.	N Wales	R&D/ Skills		×	×
Advanced Manufacturing Centre for Skills Development and Employer Engagement	A Lancaster University and BAe Systems partnership to facilitate skills development through cadet, apprenticeship, undergraduate and postgraduate schemes with significant employer engagement at all stages.	Lancs	Skills/ Tech Access			×
BEACON Biorefining Centre of Excellence	A partnership between Bangor, Aberystwyth, and Swansea Universities, BEACON helps Welsh businesses develop new ways of converting plant-based feedstocks and waste streams into products which have applications in the pharmaceutical, chemicals, fuel and cosmetic industries.	N Wales	R&D	×		×
Biocomposites Centre	The Biocomposites Centre undertakes collaborative research projects to develop sustainable biobased technologies that will minimise the impact of materials on the environment.	N Wales	R&D	×		×
British Oceanographic Data Centre (BODC)	Hosted by Liverpool University and the National Oceanographic Centre (q.v.), the BODC is a national facility for looking after and distributing data concerning the marine environment.	M'side	R&D	×	×	
Built Environment & Sustainable Technologies Institute at Liverpool John Moores University (LJMU)	LJMU has specific strengths in civil engineering (materials technology design and performance, sensor technology for the built environment and life cycle analysis of materials) and water research (waste water treatment, water resource management).	M'side	R&D/ Skills		×	×
Centre for Ecology & Hydrology (CEH)	A Government research organization with two centres co-located with NWCA universities (Bangor and Lancaster). CEH is recognized as internationally leading in earth observation, natural hazard management, sustainable energy potential and impacts, informatics and water management.	Lancs N Wales	R&D	×	×	
Centre for Environmental Biotechnology at Bangor	This facility currently under development will provide state-of-the-art equipment and world-leading expertise for identifying and isolating enzymes in extremophiles (microorganisms that thrive in extreme conditions such as high temperature, salinity, or acidity). The enzymes can be used to transform industrial processes in key sectors of the economy.	N Wales	R&D/ Skills	×		

Asset	Description	Location	Type	EITS	FES	AMCM
Centre for Global Eco-Innovation (CGE) – see page 20	The Centre for Global Eco-Innovation supports the development of new products and services with environmental benefits. The centre delivers high quality business led research, through enabling enterprises to access the expertise resources and global contacts of Lancaster University and its national and international partners.	Lancs Cumbria M'side Ches	R&D/ Skills	×	×	×
Centre for National Parks and Protected Areas (CNPPA) Cumbria University	An international and national centre of excellence for the transdisciplinary study of national park and protected area management – developing sustainable solutions to global challenges.	Cumbria	R&D/ Skills	×		
Centre for Offshore Renewable Engineering	The City Region was recently designated with CORE status in recognition of continued potential in the low carbon and renewable sector. Growth is being stimulated through £3.5bn invested in Liverpool Bay.	M'side	Infrastructure Skills Supply Chain	×	×	
Centre for Waste Management (CWM) at UCLAN	The Centre for Waste Management (CWM) was established in 2002 to provide a focus for existing waste/environmental research, consultancy and course provision at the University of Central Lancashire. The Centre provides a range of business services designed to increase business efficiency, productivity and improve environmental performance.	Lancs	R&D/ Skills	×		
Centre for Water Soluble Polymers	This centre at Glyndwr University focusses on the characterisation, properties & application of polysaccharides and proteins (hydro-colloids) in a broad range of industrial formulations including food.	N Wales	R&D/ Skills	×		
Centre of Excellence in Sustainable Energy	Funding in excess of £50m is being sought to deliver this Centre at Bangor University's Science Park on Anglesey, capitalising on the major investment in nuclear power and, broadening its remit to other technologies and industries.	N Wales	R&D		×	
Centre of Excellence in Sustainable Food Systems (CESFS)	The Centre focusses on the genetic improvement of crops to address the needs of sustainable intensification, whilst informing conservation efforts within native communities.	M'side	R&D/ Skills	×		
Centre in Advanced Energy Systems	University of Chester, public and private partners are now jointly investing £17m to develop an internationally recognised Centre in Advanced Energy Systems, including an Intelligent Energy Systems Demonstrator to test new power saving and distribution technologies.	Ches	R&D/ Skills		×	
cTAP (Collaborative Technology Access Programme)	This £11.4m ERDF funded facility is dedicated to industry collaboration around chemical analysis, characterisation and synthesis; a Quantum Technology Centre leading innovation of semiconductor science and a new Engineering facility with specialist additive manufacturing and design capabilities.	Lancs	R&D / Tech Access			×

Asset	Description	Location	Type	EITS	FES	AMCM
Combined Food and Power (CFP) Centre of Excellence	A joint development by Bangor University and the Energy Centre and Eco Park created at Holyhead by the Orthios Group (which will include a 299 MWe biomass power station, the world's largest on-land aquaculture facility and a large indoor vegetable growing hydroponics facility).	N Wales	R&D/ Skills	×	×	
DEMAND (Dynamics of Energy, Mobility and Demand) Centre	The centre's research focusses on the social science of future energy systems at home, at work and in moving around. Partners include: DECC, Ofgem, Energy Technologies Institute (ETI), Energy Systems Catapult, EDF and the International Energy Agency.	Lancs	R&D/ Skills		×	
Edge Hill University	EHU has particular strengths in computer and data science, environmental modelling, forest and coastal management and molecular biology as enablers of eco-innovation.	Lancs	R&D/ Skills	×		
Energy Centre at Thornton Science Park	The Centre promotes the development and exploitation of new energy technologies including new types of photovoltaic solar cells, innovative electrical energy storage solutions, low power motor drives, new algorithms for load balancing on micro-grids and non-electrical energy systems.	Ches	R&D/ Tech Access		×	
Energy Innovation District	This is the first of its kind in the UK, bringing together generators, energy-intensive manufacturers, innovators and academics to combine forces to create a joined-up solution to the UK's energy challenge.	Ches	Collaboration Hub		×	
Energy Lancaster at Lancaster University	Energy Lancaster brings together Lancaster University's world leading expertise in a wide range of energy related areas covering the demand and supply of energy. Energy Lancaster is working in partnership with global organisations in the development and management of secure and sustainable energy supplies.	Lancs	R&D/ Collaboration		×	
Engineering Innovation Centre (EIC) at UCLAN	Within the Lancashire Strategic Economic Plan this £40M+ project develops UCLAN's research, knowledge transfer and training capabilities in Engineering to work with local SMEs and prime the advanced engineering and manufacturing sectors.	Lancs	R&D/ Skills			×

Asset	Description	Location	Type	EITS	FES	AMCM
Environment Centre for Wales at Bangor University	Environment Centre for Wales is a new partnership between the Centre for Ecology and Hydrology and Bangor University. The innovative centre brings together 60 environmental scientists whose combined scientific knowledge and experience cuts across traditional academic boundaries. This new way of working makes significant contributions to solutions for environmental problems.	N Wales	R&D/ Skills	×	×	×
Glass Futures	Glass Futures connects the glass industry and academia to create an industry cluster to ensure increased productivity and sustainability in the sector.	M'side	R&D/ Skills/ Collaboration			×
Hartree Centre	Focused on high performance computing, big data analytics and cognitive computing (including IBM's latest data-centric and cognitive computing technologies), two of Hartree's four key sectors, advanced engineering & materials and clean technologies, coincide directly with themes in this SIA.	M'side	R&D/ Collaboration	×	×	×
HyDeploy project	This collaboration between Keele University, National Grid plc and Northern Gas Networks aims to deliver blended hydrogen into the existing natural gas grid – the first UK practical deployment of hydrogen onto a live gas network.	Staffs	R&D		×	
Institute for Risk & Uncertainty at Liverpool University	The University's Institute for Risk and Uncertainty is dedicated to helping people and organisations create a safer world. Our multidisciplinary research team includes experts from architecture, engineering, environmental sciences, financial and actuarial mathematics, computer science, electrical engineering & electronics, economics and finance, social sciences and psychology.	M'side	R&I/ Skills	×	×	×
Lancashire Energy HQ	A £10.7m dedicated education and training facility developed by Blackpool and Fylde College in collaboration with industry partners. The facility offers energy related training for future employment across all aspects of the energy industry including renewables, nuclear, oil and gas.	Lancs	Skills		×	
Lancaster Environment Centre (LEC) at Lancaster University	A partnership between Lancaster University, the Centre for Ecology & Hydrology and 25 environmentally focused businesses, is one of the world's largest centres for environmental research and development, with expertise spanning the natural and social sciences, offering balanced perspectives on what are complex societal challenges.	Lancs	R&I/ Skills	×	×	
Lancaster Leadership Centre	Based at Lancaster University Management School, the Leadership Centre draws upon the work of many members of the Management faculty in several departments, centres and institutes. More than 80 staff work in the LLC. Their work is pioneering new ways of building leadership capability in organisations across the world.	Lancs	R&D	×	×	×

Asset	Description	Location	Type	EITS	FES	AMCM
Lancaster Product Development Unit	Bespoke design and additive manufacturing technology expertise.	Lancs	Collaboration / Tech Access			×
LCR4.0	LCR 4.0 aims to put the Liverpool City Region at the heart of an evolution which is set to transform production in the modern world economy. The initiative helps SMEs explore the potential of Industry 4.0 technologies by providing support ranging from research and development, knowledge transfer and the acceleration of ideas from concept through to commercialisation.	M'side	Collaboration / Tech Access			×
Lloyd's Register Foundation	Including a base in Liverpool, the Foundation has significant programmes concerned with critical infrastructure resilience. It supports eco-innovation on the coast by combining the positive benefits of offshore energy generation with seaweed production for food, biochemicals and energy.	M'side	Grants for R&D/ Skills	×	×	×
Marine Centre Wales (MCW)	Marine Centre Wales (MCW) is a new national resource designed to meet the need for integration of research, innovation, commerce and policy in the marine sector. MCW provides access to specialist facilities including conference and meeting rooms, offices, laboratories, aquaria and research vessels including the RV Prince Madog.	N Wales	R&D	×		
Materials Innovation Factory (MIF)	This £65 million partnership between the University of Liverpool, Unilever and HEFCE provides open access to state-of-the-art equipment and world-leading academic expertise to create new materials with step-change functional enhancement in a range of important applications.	M'side	R&I/ Skills			×
Menai Science Park Ltd (M-SParc)	Bangor University is developing a Science Park on Anglesey to drive growth in knowledge-based science, with an early focus on low carbon energy, the environment and ICT sectors. It includes the installation of a 10MW tidal array (the Minesto Deep Green project).	N Wales	R&I	×	×	
National Oceanography Centre (NOC)	NOC is the United Kingdom's centre of excellence for oceanographic sciences and is one of the world's top oceanographic institutions. The NOC undertakes world leading research in large scale oceanography and ocean measurement technology innovation.	M'side	R&D/ Skills/ Collaboration	×	×	
National Research Network for Low Carbon, Energy and Environment	Bangor University is home to this pan-Wales initiative funded by the Welsh Government and the Higher Education Funding Council for Wales. The network supports collaborative and interdisciplinary research into the interactions between land, water, the provision of food and energy production.	N Wales	R&D/ Skills	×	×	

Asset	Description	Location	Type	EITS	FES	AMCM
Northwest Advanced Manufacturing Research Centre	NWAMRC has emerged from a Wave 1 SIA as an industry focused centre of excellence for innovation, product development and manufacturing skills for aerospace, automotive and energy supply chain. Founding industrial partners include BAE Systems, Siemens, and Cammell Laird.	Lancs	R&I/ Skills		×	×
North West Hydrogen Cluster	This brings together Cadent, one the largest chlor-alkali hydrogen producers in the UK, Alstom (who are developing hydrogen powered trains) and the Cheshire & Warrington salt caverns, which have the capacity to store 160 million cubic metres of gas.	M'side	Industry led R&I		×	
OpTIC – the Optoelectronic Technology Incubation Centre	The Centre, based in St Asaph and owned by Glyndwr University, has become a business focus for a thriving industry focused on photonics and optoelectronic technology, that has emerged from the area's heritage in manufacturing specialist glass.	N Wales	Industry led R&I Cluster		×	×
Quantum Technology Centre	The Quantum Technology Centre contains state-of-the-art nanofabrication facilities, supported by molecular beam epitaxy reactors for atomic layer-by-layer growth of semiconductor nanostructures and devices. Fabrication techniques available include electron-beam lithography using a dedicated electron-beam writer, plasma processing and thin-film deposition.	Lancs	R&I	×	×	×
Research Vessel Prince Madog	State-of-the-art, purpose-built research vessel commissioned by Bangor University using a £2.8 million Joint Infrastructure Fund grant. Managed and operated by P&O Maritime Services, delivered and in service July 2001.	N Wales	R&D	×		
River Eden Demonstration Test Catchment (Eden DTC)	This Defra funded project assesses cost effective mitigation of diffuse pollution from agriculture whilst maintaining agricultural productivity.	Cumbria	R&D	×		
School of Environment, Natural Resources and Geography (SENRGy), Bangor University	The School has a world-class reputation in research, with particular expertise in forest ecology and management; environmental studies and soil science; agricultural systems; agroforestry; biodiversity conservation; and tropical ecosystems.	N Wales	R&D/ Skills		×	
School of Environmental Sciences, University of Liverpool	The School of Environmental Sciences studies Planet Earth. Research investigates its core and mantle, through to the dynamic lithosphere and crust and the tectonic processes that are expressed at the Earth's surface in the form of volcanoes and earthquakes.	M'side	R&I/ Skills	×		
School of Ocean Sciences, Bangor	One of the largest university Marine Science departments in Europe, including purpose-built research vessel Prince Madog.	N Wales	R&D/ Skills	×	×	

Asset	Description	Location	Type	EITS	FES	AMCM
Sci-Tech Daresbury	One of two national science and innovation campuses which support scientists, researchers and industry by providing a collaborative environment for cutting edge research, including the Innovation Centre, Vanguard House and the Cockcroft Institute, and two grow-on facilities, Techspace One and Two.	M'side	R&I/ Collaboration	×	×	×
SEACAMS 2	SEACAMs 2 is a £17 M three-year project partnership between Bangor and Swansea universities, part funded by the European Regional Development Fund. The main objective of SEACAMS2 is to assist the development of opportunities in Low carbon, Energy and Environment in the convergence regions of Wales, especially the potential in the marine economy and marine renewable energy.	Wales	R&D		×	
Smart Energy Network Demonstrator (SEND)	Funded by Keele University, the BEIS, and the European Regional Development Fund (ERDF), SEND will allow Keele University campus to become the largest single, integrated electricity, gas and heat smart energy network demonstrator in Europe.	Staffs	R&D/ Skills		×	
Stephenson Institute for Renewable Energy (SIRE) at Liverpool University	This specialist energy materials research institute focuses on the physics and chemistry for future energy generation, storage, transmission and energy efficiency. Partner companies include AMEC, AREVA, AWE, EDF, the Nuclear Decommissioning Authority, Rolls-Royce and Sellafield Ltd.	M'side	R&I/ Skills		×	
Unilever R&D	Currently employing ~1000 scientists at Port Sunlight, Unilever has recently announced the closure of 4 major European sites (including the Rotterdam R&D hub) with the associated 2000 jobs potentially destined for relocation to the UK subject to planned infrastructure investment in the North.	M'side	R&I	×		×
UK Geoenergy Observatory	£31M has been allocated to the British Geological Survey to establish this pioneering system to realise the huge potential of Britain's underground energy resources including carbon capture and storage, geothermal energy, underground coal gasification and underground gas storage.	Ches	R&D		×	
The Virtual Engineering Centre (VEC)	The VEC is a partnership between, the School of Engineering at the University of Liverpool, the Science and Technology Facilities Council (STFC), BAE Systems, North West Aerospace Alliance (NWAA) and Morson Projects. The centre offers technology development, research, training and knowledge transfer in support of product design and manufacturing innovation to drive global competitiveness.	M'side	R&I			×
West Anglesey Demonstration Zone	This demonstration zone is being developed by Crown Estates to encourage and accelerate marine energy technology development.	N Wales	R&I Demonstration		×	

Internationally Significant Environmental Industries Technologies & Services Assets

Asset	
1.	British Oceanographic Data Centre
2.	Built Environment & Sustainable Technologies Institute at LJMU
3.	Centre for Environmental Biotechnology at Bangor
4.	Centre for Excellence in Sustainable Crop Systems
5.	Centre for National Parks and Protected Areas (CNPPA)
6.	Centre of Excellence in Sustainable Food Systems
7.	Edge Hill University
8.	Institute for Risk & Uncertainty
9.	Lancaster Environment Centre
10.	Lloyd's Register Foundation
11.	Menai Science Park
12.	National Oceanography Centre
13.	National Research Network for Low Carbon, Energy and Environment
14.	SEACAMS 2
15.	The Biocomposites Centre
16.	The Centre for Ecology & Hydrology
17.	The Centre for Waste Management
18.	The Centre for Water Soluble Polymers
19.	The River Eden Demonstration Test Catchment
20.	The School of Environment, Natural Resources and Geography
21.	The School of Ocean Sciences, Liverpool University

Internationally significant assets related to Future Energy System

Asset	
1.	Built Environment & Sustainable Technologies Institute at Liverpool John Moores University (LJMU)
2.	Centre for Ecology & Hydrology (CEH)
4.	DEMAND (Dynamics of Energy, Mobility and Demand) Centre
5.	Energy Centre at Thornton Science Park
6.	Energy Lancaster at Lancaster University
7.	Hartree Centre
8.	HyDeploy project
9.	Lancaster Environment Centre (LEC) at Lancaster University
10.	Lloyd's Register Foundation
11.	Menai Science Park Ltd (M-SParc)
12.	National Oceanography Centre (NOC)
13.	National Research Network for Low Carbon, Energy and Environment (NRN-LCEE)
14.	Optoelectronic Technology Incubation Centre
15.	School of Environment, Natural Resources and Geography (SENRGy), Bangor
16.	School of Ocean Sciences, Bangor
17.	Sci-Tech Daresbury
18.	Smart Energy Network Demonstrator (SEND)
19.	Stephenson Institute for Renewable Energy (SIRE) at Liverpool University
20.	The Energy Centre at Thornton Science Park
21.	West Anglesey Demonstration Zone

Internationally significant assets for Advanced Manufacturing, Chemicals and Materials

Asset	
1.	Collaborative Technology Access Programme
2.	Engineering Innovation Centre
3.	Glass Futures
4.	Hartree Centre
5.	Lancaster Product Development Unit (LPDU)
6.	Liverpool John Moores University (LJMU)
7.	Lloyd's Register Foundation
8.	Materials Innovation Factory
9.	Optoelectronic Technology Incubation Centre
10.	Quantum Technology Centre
11.	Sci-Tech Daresbury
12.	The BioComposites Centre

Annex 4:
Matrix of other Science and Innovation Audits with overlaps with The North West Coastal Arc™ Clean and Sustainable Growth SIA

We are aware of a number of existing audits that cover some elements of Clean and Sustainable Growth, especially energy generation, but without the integration that is at the heart of the NWCA's vision of innovation to meet the challenges and opportunities identified by the Industrial Strategy White paper, The Clean growth Strategy and the 25-year Environment Plan.

SIA	Environmental Industries, Technologies & Services	Future Energy Systems	Advanced Manufacturing Chemicals & Materials	Cross-Cutting
Midlands Engine		×		×
Sheffield City Region & Lancashire		×	×	×
SW England and SE Wales	×	×		×
Scotland's Central Belt		×	×	
Innovation South	×		×	
Offshore Renewable Energy	×	×		×
Liverpool City Region		×	×	
Manchester and Cheshire East		×	×	
Bioeconomy in the North of England	×	×		
Innovation South		×		
North West Nuclear Arc		×		
The Northern Powerhouse Chemicals and Process			×	
The South Wales Crucible	×	×		×

Source: SDG Economic Development.

Annex 5:
Approach and methodology in auditing excellence in science and research

A5.1 Approach

We audited scientific production and scientific quality using SCIVAL, the bibliometric analysis tool of SCOPUS (https://scival.com/home). We adopted a step-by-step approach to the audit of scientific production and scientific quality.

The first step used the "high level" subject areas defined by SCOPUS, selecting a "basket" of eleven subject areas that a "pre-audit" of our activity showed were pertinent to eco-innovation. For example, the first phase of the Centre for Global Eco-Innovation (see page 20) supported collaborative academic-SME research projects at the Departments of: Lancaster Environment Centre, Physics, Engineering, Computing and Communications, Chemistry, Lancaster University Management School and Faculty of Health and Medicine at Lancaster University. At Liverpool projects were in the School of Engineering, School of Electrical Engineering, Electronics and Computer Science, School of Physical Sciences, School of Environmental Sciences, Management School, Chemistry and Architecture.

At this high level we compared the NWCA with the UK as a whole as well as against international comparators which were:

+ EU28 (i.e. all 28 EU member states, including the UK);
+ The USA and Canada;
+ The G20 (including the EU, USA and Canada plus 17 other leading global economies)
+ China

Having confirmed the NWCA's research strength at this low resolution, we then focused on the research base supporting the four capabilities that had emerged in the planning and development of this SIA. This recognised that eco-innovation has a fundamentally trans-disciplinary perspective, so that the four capabilities of this SIA do not map simply on to the high-level subject areas in SCOPUS. Therefore, we explored secondary subject areas that come together to form the research base for the four capabilities.

For example, the Environmental Industries, Technologies and Services capability (EITS) draws on many but not all research areas that come under the SCOPUS "Environmental Science" (Figure A5.1) and not exclusively from this main heading. For example, our research, innovation and development activities under EITS also includes "Agronomy and Crop Science", "Food Science" and "Plant Science", which are sub-disciplines under the Agricultural and Biological Sciences main subject heading of SCOPUS.

Clearly, the NWCA performance would appear much stronger if compared against nations or groups of nations, as the comparators used in our high-resolution analysis are "research intensive" and may be seen as the "gold standard" for comparison. This is a very rigorous comparison for a group like the NWCA, which includes a diverse group of universities and other research partners with complementary balances of specialisation in research, translation and training but, in our view, best illustrates our real strength internationally.

A2.2 Methodology

We audited scientific production and scientific quality using the following SCIVAL metrics.

A2.2.i Research production was measured by the number of publications (outputs) from the NWCA in the SCOPUS database for the period 2010-2015. This metric is clearly extremely scale dependent. For example, over this period, total publications (i.e. all SCOPUS subject areas) totalled 10,423 from the NWCA, 193,662 from the whole UK and 2,146,663 for the G20. For that reason, we present data as (i) NWCA as percentage of all UK publications in a particular research area and (ii) location quotient calculated using the Technopolis method which is:

Location Quotient (LQ) =

Outputs from NWCA in discipline ÷ Outputs from UK in discipline

Outputs from NWCA in all disciplines ÷ Outputs from UK in all disciplines

A2.2.ii Research quality was measured using the "outputs in top citation percentile" metric in SCIVAL. For our initial low-resolution audit (see above) we used the percentage of outputs in the top 5% of citations in a SCOPUS subject heading. For our more detailed analysis of our four capabilities, we used the more rigorous criterion of the percentage of outputs in the top 1% of citation in a SCOPUS subject heading. Since these metrics are percentages of total publications they are independent of scale, removing any need to calculate location quotients. In addition, all our citation data were field weighted, i.e. corrected for between-discipline differences. This normalisation allows direct comparison of citations across disciplines.

We typically present the citation data using spider plots that allow easy comparison between NWCA and comparators across disciplines. In the spider plots the area delimited by the component points visualises the integrated research strength across all the disciplines included in the plot. We have formalised this as a means to compare overall research quality across the disciplines included within a capability by explicitly calculating the area bounded by the citation data for the component disciplines. This was calculated as the sum of the areas of all the component "segments" of a spider plot. Each segment is an irregular triangle, so its area can be calculated by:

Area = ½ sin(360/N) x Citation datum1 x Citation datum2

Where Citation datum1 and Citation datum2 are the two citation data bounding the triangle and N is the number of segments in the spider plot (six in this audit).

In our detail audit of our four capabilities, we also used two additional SCIVAL metrics.

A2.2.iii Percentage of publications co-authored with colleagues from more than one country as a measure of the extent of international collaboration in the NWCA and comparators.

A2.2.iv Number of publications arising co-authored with colleagues from a non-academic (corporate) organisation as a measure of one aspect of academic-corporate collaboration in the NWCA and comparators.

Figure A5.1 SCOPUS Environmental Science main subject area and its component sub-disiplines.

Environmental Science
Ecological Modeling
Ecology
Environmental Chemistry
Environmental Engineering
Environmental Science (miscellaneous)
General Environmental Science
Global and Planetary Change
Health, Toxicology and Mutagenessis
Management, Monitoring, Policy and Law
Nature and Landscape Conversation
Pollution
Waste Management and Disposal
Water Science and Technology

We audited six secondary research areas for each capability, based on our previous experience of eco-innovative collaborations across the NWCA, as follows.

SCOPUS sub-disciplines	CAPABILITY			
	Environmental Industries, Technologies & Services	Future Energy Systems	Advanced Manufacturing, Chemicals and Materials	Cross-cutting Research and Innovation
	Agronomy & Crop Science	Transportation	Aerospace Engineering	Computers in Earth Science
	Food Science	Geography, Planning & Development	Automotive Engineering	Management Science & Operations Research
	Plant Science	Architecture	Materials Chemistry	Management of Technology and Innovation
	Environmental Engineering	Building and Construction	Ceramics and Composites	Multidisciplinary
	Waste Management & Disposal	Energy Engineering & Power Technology	Metals and Alloys	Statistics, Probability and Uncertainty
	Water Science & Technology	Renewable Energy, Sustainability & Environment	Polymers and Plastics	Strategy and Management

For this high-resolution audit of the research specialisations within the four capabilities of this audit, we initially compared NWCA with the UK and other nations or groups of nations, as above. However, we were conscious that analysis of these large or very large geographies might be more prone to exaggerating our relative strength due to the potential "dilution effect" of making comparison with very large number of institutions. For this reason, we adopted a more focused comparison against groups of universities or regions, as follows.

GROUP	Number of members	Description and website
AEARU	17	Leading research-oriented universities in East Asia (http://www.aearu.org/members.html)
California	N/A	Included as a region with a global reputation for innovation and using SCIVAL data for the state as a whole rather than just its universities (as is the case with the NWCA)
German U15	15	Coalition of fifteen major research-intensive and leading medical universities (https://www.german-u15.de/index.html)
Russell Group	24	Member universities are world-class, research-intensive universities. (http://russellgroup.ac.uk/about/our-universities/)
Allenvi	12	France's 'national alliance for environmental research" including agri-food, climate, and water with 12 founding and 16 associate members: (https://www.allenvi.fr/)

Annex 6: Local science and innovation talent: skills provision now and for the future

As noted under research, the inter-disciplinary nature of eco-innovation for Clean and Sustainable growth means that all three of our capabilities transcend traditional boundaries between academic subjects. For example, while businesses under the Environmental Industries Technologies and Services (EITS) capability will draw skilled staff from degrees such as Environmental Sciences, Ecology or Earth Science, they might also draw on Engineering, Chemistry and many biology-based programmes. Future Energy Systems will draw on skills from Engineering, Advanced Manufacturing and the Environmental Sciences. Advanced Manufacturing Chemical and Materials will rely on skills from Advanced Manufacturing, Engineering, Materials Science, Chemistry but also, especially given the growing importance of waste management and a circular economy, multiple aspects of the Environmental Sciences.

That also links to NWCA's recognition, developed over a number of years, (i) that training in science and innovation needs to encompass multiple levels and (ii) that "traditional disciplinary training" within STEM needs to be complemented by training for the wider skill-sets demanded by business. Our position resonates with the NESTA report (2017) which concludes that future trends in key skills for 2030 include strong drivers from environmental sustainability, globalisation, technological change and demographic change as the population grows and ages. Unlike low and middle-level skills there is growing demand for higher level professionals as roles become more cross-cutting and need to think 'outside the box'. Report findings also confirmed the importance of higher-order cognitive skills such as originality, fluency of ideas and active learning. Skills related to system thinking — the ability to recognise, understand and act on interconnections and feedback loops in sociotechnical systems —such as judgement and decision making, systems analysis and systems evaluation feature prominently. Again, this is close to the NWCA's long-standing focus on growing absorptive capacity to drive innovation, leadership/entrepreneurialism and ultimately improve productivity.

On that basis, this chapter takes an integrated perspective on local science and innovation talent across all three capabilities and is structured as follows. After assessing employment in sectors pertinent to our capabilities (A6.1), we first summarise training at pre-degree provided by the NWCA's HEIs and FEIs provision (A6.2.1). We then (A6.2.2) consider provision of undergraduate degrees, and graduate inflow and outflow. Thirdly, we summarise the NWCAs post-graduate training at Masters (A6.2.3) and doctoral level, including doctoral training centres (A6.2.4). We then (A6.3) focus on activities within the NWCA that "cross the great divide" to provide wider skill sets and business awareness for the region's STEM graduates.

6.1 Employment in relevant sectors

Compared with the UK average, the NWCA has a lower percentage of residents qualified to NVQ4 or above (37.6% compared with 43.5%). This statistic varies markedly within the region, from almost 50% in Fylde to 25% or less in Eden, Stoke-on-Trent and Barrow-in-Furness.

The percentage of residents employed in science, research, engineering and technology professionals (SOC21) and science, research, engineering and technology associate professionals (SOC31) are both lower in the NWCA than the UK as a whole (4.08 compared with 5.60 for SOC21, 1.17 and 1.80 for SOC31). These averages disguise very large variation within the region with some areas (e.g. Barrow-in Furness, Copeland and Warrington) being well above the UK average whilst others, notably the more rural areas (e.g. Eden), having extremely low employment in these professions.

A6.2 Training and talent for Clean and Sustainable Growth

A6.2.1 Pre-Degree level training

The region has invested strongly in supporting training pertinent to this SIA. For example, 'Lancashire Energy Skills HQ' owned and operated by Blackpool and The Fylde College is leading an initiative that will support oil and gas in addition to renewable and low-carbon energy generation training and skills. The £9.8m project, which opened in 2017, houses the National College for Onshore Oil & Gas sited in the newly formed Blackpool Enterprise Zone. The project represents significant investment by the College and the Lancashire Enterprise Partnership, who are providing £6.2 million of Growth Deal funding towards the cost.

A6.2.2 Higher level apprenticeships

All higher education institutions within the NWCA are committed to the co-creation of industrially relevant education options, including high quality apprenticeships, to meet the needs of regional and national industry. Degree and Higher Degree apprenticeships remain a recent addition to the training portfolio and few connected to our SIA focus areas are currently available (Table A6.1).

This provision of apprenticeships relevant to Clean Growth is still developing at all levels, within the region and nationally.

A growing number of Apprenticeship standards are being published, particularly in the broad area of Engineering, where there are currently 89 at L3, 25 at L4, 3 at L5, 16 at L6 and 5 at L7. At Masters level a Postgraduate Engineer (L7) Standard is now available with Cranfield, Aston, Warwick and Sheffield the only registered training providers. Apprenticeship standards related to water management are still limited with 10 at L3, 1 at L4, and no Standards at higher levels. Only 10 Standards focus on energy, the majority are at Level 3 (e.g. Junior Energy Manager and Facilities Manager) and the most recently agreed is a Power Manager at Level 7 with currently no training providers in place. Of the 17 Waste management apprenticeships open, only one is above level 5.

Within the NWCA the only apprenticeships at Level 7 are in business, management and leadership but there are a number of developments within the region or just beyond its boundaries that aim to address this issue. The Liverpool City Region (LCR) Apprenticeship Hub is a collaborative group, responsible to the LCR Employment and Skills Board. Funded by the European Social Fund through the Education and Skills Funding Agency, it aims to increase the awareness, number and quality of apprenticeships available to regional residents by supporting and coordinating activities, making apprenticeships work for businesses and individuals.

Just outside the NWCA, Wigan & Leigh College is the largest College provider of apprenticeships in Greater Manchester offering 50 different apprenticeships at Level 2 and 3. A £6 million City Deal programme, supported by the Skills Funding Agency and the Department for Business, Innovation and Skills, is now operational and is designed to 'gap fund' the Apprenticeship Hub to address identified market failures in Greater Manchester around low levels of unemployed young people entering apprenticeships and low volumes of apprenticeships offered at level 3 and above in priority growth sectors. Staffordshire University has secured £8 million funding from the Higher Education Funding Council for England's Catalyst Fund towards the cost of a landmark project, which will see a new state of the art Digital Apprenticeships and Skills Hub built on its Stoke-on-Trent campus.

While these developments will offer many new opportunities, the evidence from this audit suggests there is a real gap in higher level apprenticeship provision across the NWCA region and nationally in energy, water and waste management. Set against a backdrop of the regional need for higher level skills in the workforce, there could be a strong case for aligning new programmes across the NWCA towards these sectors.

Table A6.1
Current degree apprenticeships relevant to our SIA themes (including business management) at NWCA higher education institutions

Liverpool John Moores University	Building Surveying (L6) Construction Management (L6) Business & Management Practice (L6) Civil Engineering (L6) Digital & Technology Solutions (L6) Electrical and Electronic Engineering (L6) Business Scale-ups MBA (L7) Leadership & Management Practice MSc (L7) MBA (L7)
University of Central Lancashire	Chartered Manager (L6) Software Engineering designed with BAE for the aerospace industry (L6) Building Surveying L6 Executive MBA L6
Blackpool & the Fylde College	Business and Management (L 6) Engineering apprenticeships x 10 (L 3 and 4) Sustainable Waste Management (L3)
University of Cumbria	Chartered Manager Degree Apprenticeship (L6) Senior Leaders Masters Degree (L7)
Lancaster University	Management & Leadership (L6)
Keele University	Exploring options
University of Liverpool	Exploring options

Table A6.2
STEM recruitment NWCA institutions

Level of study	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Undergraduate	13,140	11,545	12,440	12,955	13,615	13,725
Postgraduate (taught)	2,470	2,085	2,210	2,225	2,240	2,885
Postgraduate (research)	700	740	790	800	840	905

6.2.2 Degree level training

An analysis of HESA data for the NWCA partner higher education institutions suggests STEM recruitment in Undergraduate and Postgraduate taught programmes has remained relatively static over the six years from 2011/12 to 2016/17 (Table A6.2). Just over 40% of undergraduate students in STEM subjects recruited across the NWCA originate from the North West and this proportion is relatively static over the period, approximately 8% from Wales and the West Midlands, 5% from Yorkshire and 4 % from the South East (Table A6.3). Overseas recruitment has remained relatively constant at approximately 18% over this period (Table A6.3).

Over the five years 2011/12 and 2015/6 an average of 6706 individuals graduated in STEM subjects from the higher education institutions in the NWCA (HEIDI+). Of those graduating in 2015/16 more than two-thirds were employed in regions that include members of the NWCA; 54% in the North West of England, 7.3% in the West Midlands and 6.2% in Wales. Another 6.2% were employed elsewhere in the north of England.

Of those 2015/16 STEM graduates just over 70% found employment in STEM-based sectors, and of those approximately 20% were employed in sectors explicitly linked to Clean and Sustainable Growth as defined in this SIA.

6.2.3 Masters level training

In the six years between 2011/12 and 2016/17 NWCA institutions trained just over 14,000 students on postgraduate taught degrees in STEM subjects. Over this period annual recruitment increased 14% overall from 2470 in 2011/12 to 2885 in 2016/17 (Table A6.4). North West based individuals make up approximately 30% of the intake, and Wales and West Midlands combined add an additional 12% of total PGT recruited (Table A6.4). Overseas recruitment to the region's taught Masters programmes has varied from year-to-year but represented a noticeably lower percentage in 2016/17 (29%) than in previous years (37-40%).

6.2.4 Doctoral level training

In the six years between 2011/12 and 2016/17 NWCA institutions trained just under 5,000 students on postgraduate research degrees in STEM subjects. Over this period postgraduate research degrees recruitment increased 23% from 695 in 2011/12 to 900 in 2016/17 (Table A6.4). North West based individuals make approximately 30% of total PGT recruitment, with 12% coming from Wales and West Midlands combined (Table A6.5). It is notable that the region recruits as many overseas candidates into our post-graduate research degrees as we recruit from within our broad area (averaged over the six years 41% from overseas, 42% from the North West, Wales and the West Midlands).

The region is host to fifteen doctoral training centres (DTCs) pertinent to this SIA (Table A6.6). It is notable, given our underlying hypothesis of the need for greater connectivity across the region and across disciplines, that a high degree of connection is evident in these DTCs. The Centre for Global Eco-Innovation (page 4) plays a key role in this existing network, already bringing together five of the NWCA's universities (Lancaster, Liverpool, LJMU, Chester and Cumbria). In addition, two Lancaster-led NERC funded DTCs (ENVISION and STARS) also include Bangor University. It is equally notable that our DTCs, especially the Centre for Global Eco-Innovation and Waitrose Collaborative Training Partnership, directly link post-graduate research with industry. As noted elsewhere, this existing successful collaboration around DTCs is one powerful foundation for this SIA and one which we are confident can be built on in the future, expanding to embrace all participating higher education institution, regions and sectors.

Table A6.3
STEM recruitment for UG at participating institutions by UK region

Domicile (UK region)	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
North West	5,930	4,830	5,180	5,545	5,610	5,720
Wales	905	1,040	1,070	1,020	1,045	1,115
West Midlands	805	790	845	940	1,180	1,200
Yorkshire and The Humber	645	530	595	675	710	705
South East	490	410	455	465	525	530
East Midlands	395	390	420	445	475	390
East of England	385	315	360	375	425	380
London	300	270	325	385	435	390
South West	320	275	290	295	315	295
Northern Ireland	295	190	240	275	380	390
North East	220	185	185	190	245	180
England region unknown	5	5	5	10	15	15
Scotland	55	45	50	55	65	45
Channel Islands and the IoM	60	45	40	45	45	60
UK region unknown				5	0	0
UK total	10,810	9,320	10,060	10,725	11,470	11,415
Non-UK	2,330	2,225	2,380	2,230	2,145	2,310
Grand total	13,140	11,545	12,440	12,955	13,615	13,725

Table A6.4
STEM recruitment for Postgraduate Taught (PGT) at participating institutions by UK region

Domicile (UK region)	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
North West	705	560	590	625	685	1,050
Wales	165	135	125	120	105	110
West Midlands	160	135	155	145	145	200
Yorkshire and The Humber	75	55	65	75	60	95
South East	75	60	75	90	65	90
East Midlands	55	30	45	60	45	70
East of England	45	40	40	60	45	80
London	50	55	50	70	50	70
South West	45	40	40	40	50	50
Northern Ireland	10	10	15	20	15	15
North East	30	20	10	25	15	30
England region unknown	95	90	85	5	110	170
Scotland	35	40	30	35	25	15
Channel Islands and the IoM	5	10	5	5	5	10
UK region unknown		5				0
UK total	1,550	1,285	1,330	1,375	1,420	2,055
Non-UK	920	800	880	850	820	830
Grand total	2,470	2,085	2,210	2,225	2,240	2,885

Table A6.5
STEM recruitment for Postgraduate Research (PGR) at participating institutions by UK region

Domicile (UK region)	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
North West	220	220	235	255	275	250
Wales	50	50	55	55	45	75
West Midlands	35	35	35	30	35	55
Yorkshire and The Humber	25	25	20	25	20	25
South East	20	20	25	25	20	25
East Midlands	10	10	15	20	15	20
East of England	15	15	10	20	10	10
London	10	10	5	10	15	20
South West	10	10	10	20	15	20
Northern Ireland	5	0	5	5	0	5
North East	5	10	5	10	5	10
England region unknown	5	25	15	0	40	10
Scotland	5	10	10	10	10	10
Channel Islands and the IoM	5	0	0	0	0	5
UK region unknown	0	5				
UK total	420	445	445	485	505	540
Non-UK	280	295	345	315	335	365
Grand total	700	740	790	800	840	905

Table A6.6
Doctoral Training Centres within the NWCA

Lancaster University	Centre for Global Eco-innovation ENVISION Soils Training and Research Studentships (STARS) HiWire Centre for Doctoral Training (CDT) EPSRC STOR-I Centre for Doctoral Training BBSRC Doctoral Training Partnership in Food Security The North West Nanoscience Doctoral Training Centre
University of Liverpool	Centre for Global Eco-innovation Manchester & Liverpool Doctoral Training Programme Fusion DTC EPSRC/ESRC Centre for Doctoral Training in Quantification and Management of Risk & Uncertainty in Complex Systems & Environments EPSRC Centre for Doctoral Training in New and Sustainable Photovoltaics The EPSRC Centre for Innovative Manufacturing in Additive Manufacturing EPSRC Centre for Doctoral Training in the Science & Technology of Fusion Energy NERC Adapting to the Challenges of a Changing Environment (ACCE) NERC Understanding the Earth, Atmosphere and Ocean
Bangor University	ENVISION Soils Training and Research Studentships(STARS)
Keele University	NERC CDT in Oil and Gas
Liverpool John Moores University	Centre for Global Eco-Innovation
University of Chester	Centre for Global Eco-Innovation
University of Cumbria	Centre for Global Eco-Innovation

Annex 7: Overview of the Lancaster China Catalyst Programme

The Lancaster China Catalyst programme exploits the global links of Lancaster University for the benefit of UK companies. Since 2014, with initial investment from the Higher Education Funding Council for England (HEFCE), Lancashire County Council and participating businesses, the programme has provided:

+ A staged programme of support to UK companies to develop partnerships with commercial partners in China.
+ UK company access to collaborative partners within China for new product and service development.
+ A programme of planned visits for UK companies to China and Chinese-partner visits to the UK.
+ Dedicated human resources to companies via an experienced UK and China-based support team.
+ A dedicated team of graduates with technology, management and design expertise.
+ An opportunity for recent graduates to form part of an international team and study for an MSc in International Innovation.
+ Access for UK companies and their Chinese partners, to significant grant investment from Chinese funders.
+ Access to expertise from across Lancaster University and Chinese academic partners to underpin product or service R&D and commercialisation.

Benefits for Business. Recognising both the challenge and the opportunity for UK and Chinese businesses in commercialising products, services and technologies for global markets, the Lancaster China Catalyst Programme provides UK companies with dedicated support worth over £70k to plan and develop an international collaborative R&D and commercialisation project with a Chinese partner.

It aims to enhance international innovation capacity, access a dedicated highly skilled postgraduate team resource, gain support from a programme team in the UK and China and potentially unlock significant amounts of grant funding from the Guangdong Provincial Department of Science and Technology (GDST). The programme takes companies on a competitively focused, phased journey from initially investigating the Chinese market, to accelerating the level of engagement with Chinese partners through to actively collaborating with Chinese business partners on commercialisation projects. Over the course of this journey, UK companies will work on commercialisation plans to both adapt existing and develop new products, processes and services for the Chinese and/or global markets.

Benefits for Students. Through the Masters in International Innovation the LCCP uses the significant graduate talent available to the university from both the UK and China, to develop multi-disciplinary teams to support UK-Chinese company collaborative partnerships. The Masters in International Innovation also provides graduates with taught postgraduate provision and an extensive period of project-based work in both the UK and China, supported via a tax free bursary of £16,000 over the course of their study. The Masters offers six pathways (Engineering, Environmental Sciences, Entrepreneurship, Design, Computing and Telecommunications).

Benefits for the UK. The LCCP has been created by Lancaster University and part-funded by the Higher Education Funding Council for England's Catalyst Fund, the university and Lancashire County Council. It aims to revitalise the UK's position in global export markets, create 240 jobs, help up to 400 UK businesses and boost the economy by £40m. Via significant funding from Lancashire County Council, the programme aims to ensure the economic impact of the programme is significant to Lancashire companies in terms of safeguarding and creating new jobs for people living in Lancashire.

Annex 8. Summary of Stakeholder Consultation

Throughout spring 2018, nearly 40 businesses, stakeholders, aggregator bodies, research centres, councils and Local Enterprise Partnerships were consulted on their views on eco-innovation relating to clean growth.

Organisations consulted included:

+ Alstom
+ BAE Systems
+ Cadent Gas
+ C-Tech Innovation
+ Cheshire & Warrington, Cumbria, Lancashire, Liverpool City Region Local Enterprise Partnerships
+ Electricity North West
+ Innovate UK
+ New Economy Manchester
+ North West Aerospace Alliance
+ Northern Automotive Alliance
+ North Wales Economic Ambition Board
+ Pilkington
+ Siemens
+ STFC Hartree
+ Staffordshire County Council

Large and small businesses and research centres that engage in Clean Growth driven by Eco-Innovation were targeted structured around our four capabilities, i.e. Environmental Industries Technologies & Services (EITS), Future Energy Systems (FES), Advanced Manufacturing, Chemicals and Materials (AMCM) and the Cross-cutting research and innovation for Clean and Sustainable Growth.

During May/June 2018, over 100 SMEs associated with environmental technology, advanced manufacturing and energy systems located across the SIA region were invited to undertake an email and telephone follow-up survey.

The following thematic areas were discussed:

+ Background to the business and how it engages in Eco-Innovation/ Stakeholders' experience of, and views on Eco-Innovation;
+ Specific experiences in Eco-Innovation, including successes and barriers;
+ The strengths and weaknesses of the NWCA partnership offering and support network;
+ International competitors and comparators;
+ Actions to strengthen the NWCA competitiveness in Eco-Innovation;
+ Other comments and observations.

Access to finance/funding was a recurring barrier throughout the consultations, this was highlighted as both an issue at local level for start-ups and innovators and businesses wanting to progress from SME to becoming larger, especially at the manufacture and commercialisation stage. Overseas opportunities are missed due to lack of access to capital for the initial cost of establishing a presence outside of the UK. This is a particular issue in China, where the market exists, but is difficult to tap in to. Overall funding streams we considered too inflexible.

The most significant messages from consultees were around the following areas:

Skills shortages were prevalent ranging from a lack of skilled technicians for installing smart meters to university graduates not having sufficient market knowledge to more generally STEM graduates being difficult to find.

Strong messages were given around **disconnected geographies** where resources and programmes tend to be project based and targeted around geographies and specific areas. This creates a lack of coordination of activities across the NWCA. A 'Clean Growth Clustering Network was considered valuable by several SMEs.

Support for overseas expansion and new markets was seen as not easily visible. Recurring in a number of the consultations was the view that the stakeholder would like to, or had tried to, expand overseas, but that the support had not been present to make this viable. Overseas emerging markets such as China and Southeast Asia could be exploited to build the reputation of the area globally.

Demonstrator facilities – consultees involved with the Keele University SEND found the facility to be of huge benefit in that it provided independent feasibility testing and an ability to showcase the technology. This gives technology exposure in the UK and internationally. The success of this facility means that there is scope to develop more, especially at non-academic institutes, where the technologies can be demonstrated to a larger audience and in an applied space. Several SMEs note the need for investment in infrastructure for demonstration to enable international competitive advantage.

Several **national level political barriers** were identified including a generally unstable political climate, particularly around what direction the government will choose to direct the (Energy) sector towards, means it is difficult to develop long-term Eco-Innovation strategies. This was a recurring theme in the consultations, where a large amount of investment is required to develop R&D projects.

Table A8.1
Summary of the key findings from the wider stakeholder consultation exercise in people's own words

Strengths	Strong history of innovation that complements its industrial heritage. The NWCA has significant technological expertise and infrastructure through engaged and outward facing Colleges, Universities and Research Centres to attract investment: Lancaster SME shared lab space, Hartree Centre, Keele University Demonstrator, the Energy HQ at Blackpool etc. Naturally and industrially resource rich – offshore renewables; marine assets; hydrogen as by-product; storage capability. Globally relevant assets across the NW Coastal Arc that can demonstrate experience and understanding that other parts of the UK cannot. Ability to bring together businesses and researchers from different sectors to test innovation relevance to adjacent sectors with an ideal geography to provide a "sandpit" for experimentation and testing. Cheshire and Warrington alone - over 7,000 companies involved in energy/environment businesses employing over 31,000. Neighbouring Greater Manchester has assets and strengths in Low Carbon Environmental Goods and Services.
Barriers	Access to finance/funding. Skilled workforce with sufficient R&D training. Difficulties accessing skilled workers with STEM skills – not universal (Liverpool-Manchester corridor strong). Disconnected geographies /sectors. Lack of awareness of other sub-sector activity. Lack of stable long-term national strategy. Related lack of independent advice and guidance. SMEs don't see relevance of the market to them – as producers or consumers. Fragmentation of clean growth innovation system – lack of a regional coordinating entity. Eco-innovation is a sphere of multiple careers in a lifetime - opportunities need to be created to transition between these easily. UK responsibilities for Eco-Innovation are highly demarcated. If you're not truly "all green" then are you "worthy" of attention and support? More investment in stimulating public demand is required. Where are issues of transport and mass transit infrastructure and planning? Poor connectivity to supply chains (e,g, solar, wind, power electronics).
Opportunities	Gap in the global market for a test-bed Eco-Innovation region. Greater use of demonstrator facilities. Abundance of natural and industrial assets that can be exploited - low-carbon energy and heat generation. Capitalise on local specialist knowledge by exporting this to emerging markets – SE Asia, China, MENA. Businesses in the NWCA generate Intellectual Property (IP), new materials, techniques, products and processes that can be applicable in other sectors. Best practice in low carbon Innovation not limited to the primary function of the business – how to build on this and share best practice? The Eco-Innovation SIA provides a hub for new levels of dialogue and awareness-raising in relation to productivity and growth. The SIA should stimulate proposals that include all of revenue, capital and training needs to enable comprehensive plans to be developed within and across companies (and thereby avoid multiple applications and risk of ineligibility).

Annex References

[*1] Prosperity for All: the national strategy

[*2] Prosperity for All: economic action plan

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