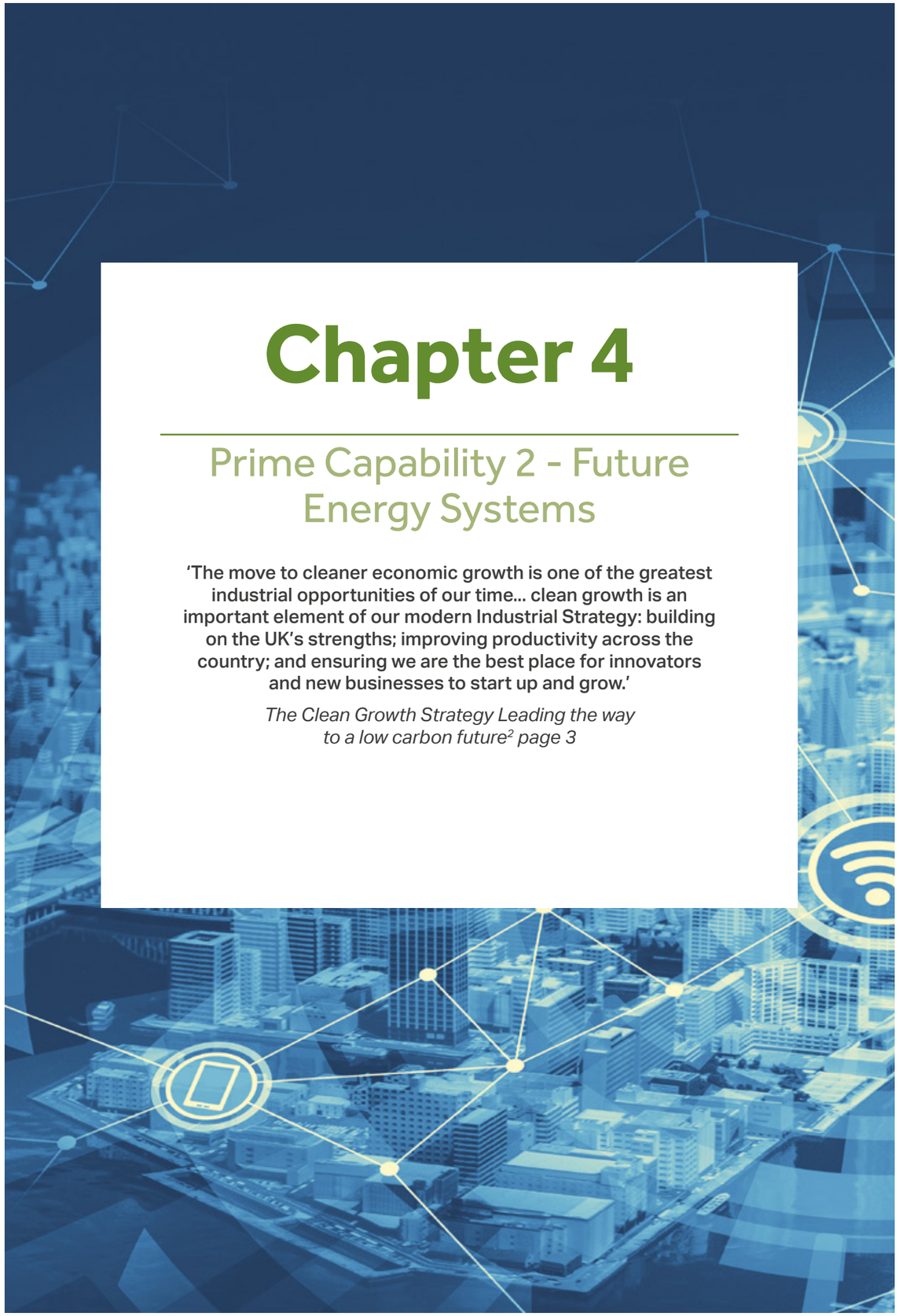


Chapter 4

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

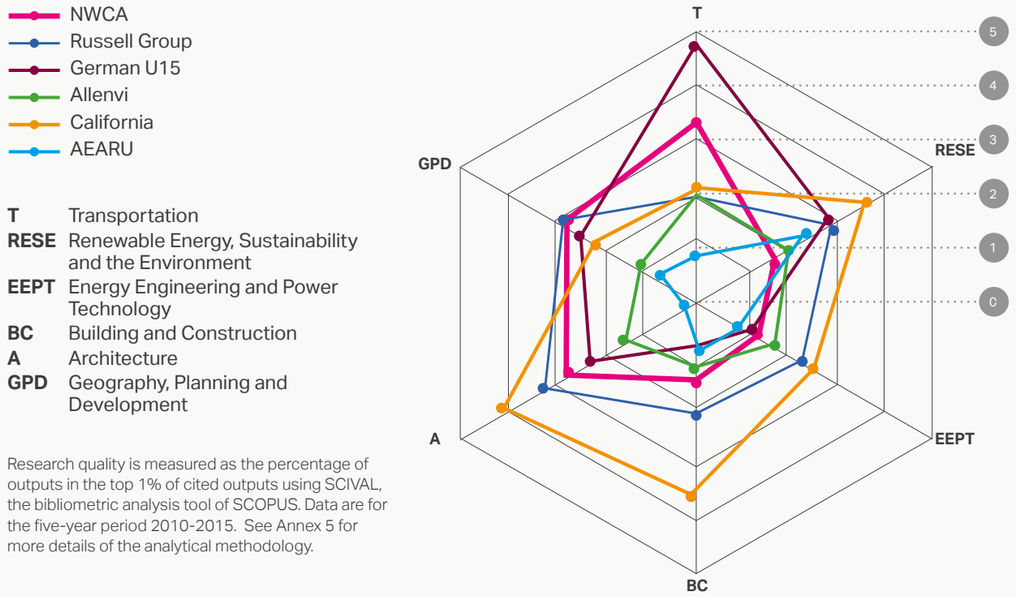
4.3.1 The current workforce and the likely future skills needs and sources

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

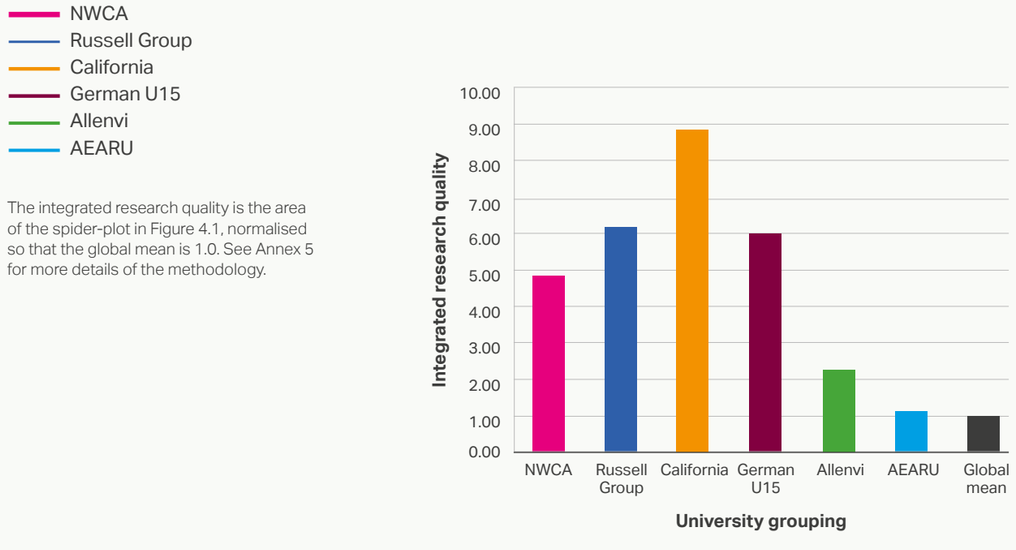
Research quality for the NWCA in the six sub-disciplines included under our Future Energy Systems capability (FES), compared with other major university groups or regions.



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).

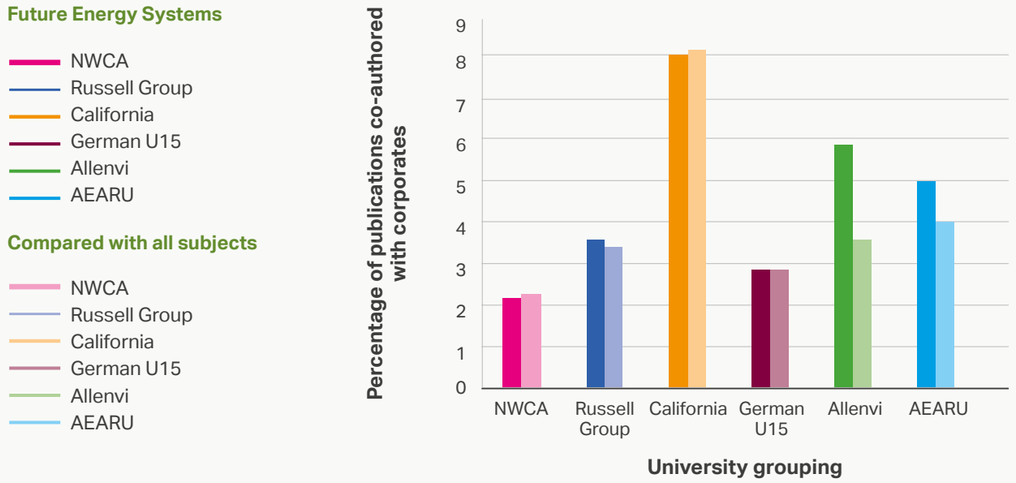
Lancashire Energy HQ- delivering the next generation of energy engineers and technicians

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

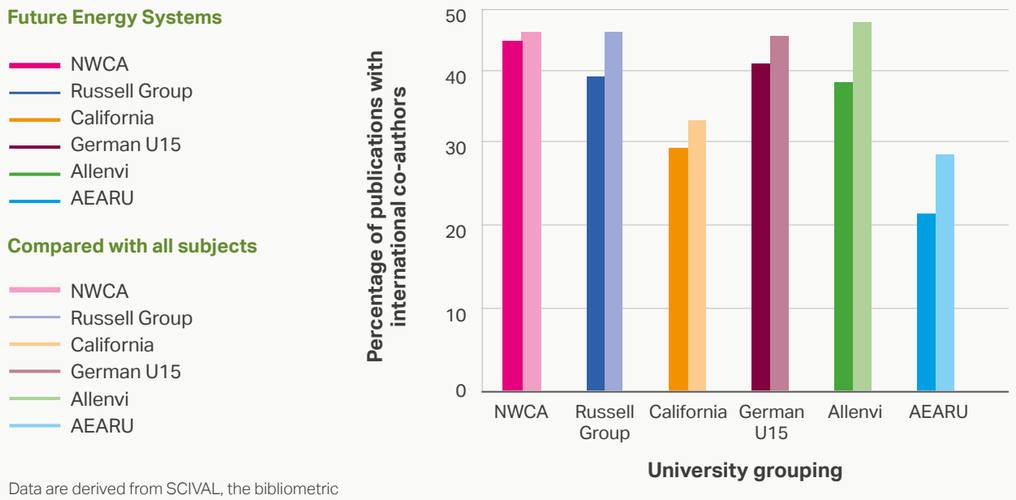
Percentage of Future Energy Systems (FES) research outputs co-authored with colleagues from a non-academic (corporate) organisation. Data for the NWCA are compared with other major university groups or regions.



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.