Department for
Business, Energy
& Industrial Strategy

South West England and South East Wales Science and Innovation Audit

Annex H: New Energy Systems Theme Report

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Annex H New Energy Systems Theme Report

1. Introduction

In relation to the New Energy theme, there are a number of clusters of industrial and R&D activity which have specific geographical nuances, and in some cases important synergies with neighbouring regions. In summary these are:

Marine renewables – the South West is the only region with all renewables resources accessible from ports and infrastructure, and with clusters of specialist industrial and academic activity spread across the region, but with significant infrastructure in the far South West (Wave Hub, Fab Test, COASTLab etc). There is an important wider geographical linkage with Southampton (NoC,) which is reflected in the development of the South Coast Marine Cluster. As recognition of the unique set of geographical and industrial assets, the South West was designated as the first Marine Energy Park in 2012, while the Offshore Renewable Energy Catapult also has a dedicated presence in the area.

Hydrogen / fuel cells – a corridor of technical expertise, specialism and capacity along the M4, from the Hydrogen hub at Swindon through to Cardiff, including the research centres at Baglan (University of South Wales) and Bath. This 'corridor' needs to be better co-ordinated and networked to increase its potential for growth.

Nuclear – activity centred on the M5 corridor running from Gloucestershire (EDF Energy Generation at Barnwood, Magnox at Berkeley, and Horizon Nuclear in Gloucester), Bristol and Somerset, with the nuclear skills centre at Bridgwater, EDF's national learning and development centre, not to mention the presence of both Hinkley C and the proposed site at Oldbury.

In addition the audit has revealed an emerging cluster of excellence and good practice in underpinning technologies relating to **distributed energy systems and smart grids**, including the Smart Islands project on the Isles of Scilly, which will have relevance across many new energy technologies.

While this summary paper provides an overview of the strength and depth of this expertise and capacity, it also reveals where the region is ideally placed to develop its science and innovation capacity further, and by so doing drive the development of new technologies where the UK has the potential to achieve competitive advantage.

2. Regional science and innovation assets

The audit area has a wealth of research and innovation assets related to the New Energy theme, with academic research centres, major industrial R&D capacity and focused innovation support and skills infrastructure.

Details of this, specific to each energy technology, can be found in the tables at Appendix NES1. Of particular note are:

- Major research centres and testing facilities relating to marine renewables, with significant synergies across institutions, but particularly Plymouth (the largest marine institute in Europe at Plymouth University, and the home of Plymouth Marine Laboratories - PML), Exeter's Marine Energy Group, and major collaborative projects such as PRIMARE and MARINET. The presence of the unique WaveHub facility off the

Cornish coast has been the catalyst for much of this collaborative effort, while the creation of the Enterprise Zone at South Yard, Plymouth (Now Oceansgate) will be a key driver of innovation led business growth in the future.

- Academic and industrial capabilities in nuclear operation, new build and decommissioning particularly centred on the Bristol-Oxford Nuclear Research Centre, with a strong and complementary industrial R&D capability, as well as significant innovation and skills infrastructure (Somerset Energy Innovation Centre, the approved Enterprise Zone at Huntspill, National College for nuclear at Bridgwater college and the Gloucestershire Science and Technology Park at the old Berkeley nuclear laboratories)
- Significant hydrogen production, storage and fuel cell research with its academic focus at the Sustainable Environment Research Centre (University of South Wales), the Cardiff Catalysis Institute and at Bath, as well as world leading industrial R&D and collaboration including Johnson Matthey Fuel Cells in Swindon
- A number of leading research centres focused on underpinning technologies and energy systems including the Energy Systems Research Institute (Cardiff), the Centre for Integrated Renewable Energy Generation and Supply (National Grid centre) and the Institute for Sustainable Energy and Environment at the University of Bath.

This rich R&D environment, in both research institutions and industry, provides a sound bedrock for further development that will add real value to the UK's innovation capacity.

3. Excellence in science and research

The audit area has an extensive world class research community related to New Energy across a range of academic disciplines, with a track record of attracting research income worth nearly £150m in the past seven years.

Our analysis has shown that **there are 232 academic staff undertaking research related to the New Energy theme, with 164 submitted to the REF**. The New Energy theme covers a broad range of academic disciplines, across 17 REF units of Assessment (UoAs), as outlined in full in the table in Appendix NES2. This table, and an analysis of UoA environment statements and impact case studies, from which a thematic mapping was produced (see Appendix NES3) reveals that the main clusters of academic excellence within the New Energy theme are in the fields of:

UoA		Submitted staff associated with theme	No of Institutions	Doctoral awards 2008-16*	UoA overall profile (% 3 or 4*)
7	Earth Systems and Environmental Sciences	22.75	3	36	91%
Key research themes • Marine renewable energy • Environmental impact • Resource modelling and simulation					
UoA		Submitted staff associated with	No of Institutions	Doctoral awards	UoA overall profile (% 3

		theme		2008-16*	or 4*)
8	Chemistry	23	3	80	97%

Key research themes

- design and synthesis of materials for hydrogen storage, fuel cells and catalysts for the enhanced production of biofuels
- developing a quantitative understanding of structures, mechanisms and interactions in organic chemistry, with applications in energy
- Energy storage

UoA		Submitted staff associated with theme	No of Institutions	Doctoral awards 2008-16*	UoA overall profile (% 3 or 4*)
15	General Engineering	79.8	5	156	81%

Key research themes

- Coastal processes
- Hydrodynamics of marine renewable energy
- Physical and numerical modelling of marine renewable energy
- Autonomous marine vehicles
- Marine composite structures
- Marine systems and interactions on energy generation
- Performance and reliability of advanced structural materials in marine structures, offshore energy devices, and thermal power plant, including nuclear pressure vessels and steam turbine components
- Combined network analysis and smart grids; grid infrastructure; hazard analysis; unconventional fuels; combustion diagnostics and control; emission characterisation; tidal energy
- Integration of renewables, energy networks and infrastructure

Much of this research excellence cuts across a number of New Energy technologies, and indeed is relevant more broadly across the audit themes. These synergies are important as much of the world class R&D being undertaken in the region can be applied across a range of energy (and indeed other technologies). Modelling and simulation is a good example of this, with relevance to a range of engineering and manufacturing sectors.

Research Income

An analysis of research income associated with New Energy shows that in the years 2008-2015 the total research income across the consortium was £149m, with an upward trend over the period. This upward trend has been confirmed in more recent years with major awards totalling £56m in 2014-16.

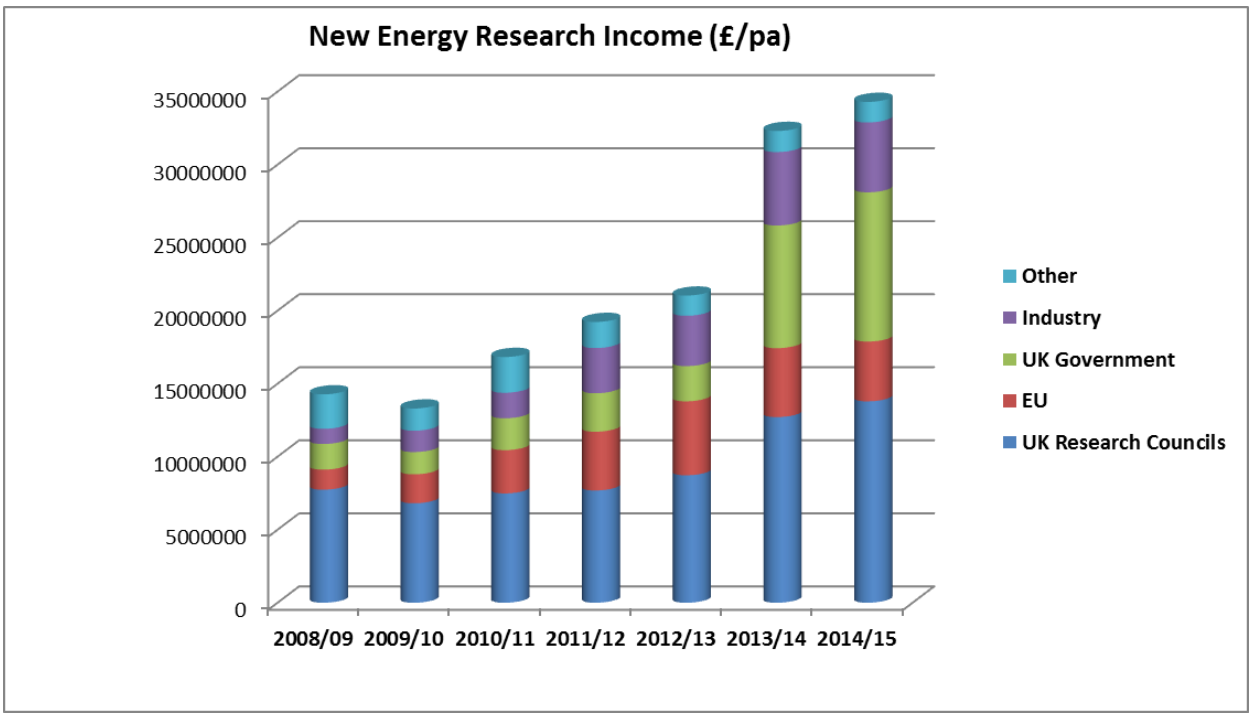


Figure NES1 New Energy Research Income

An analysis of data relating to academic publications related to the New Energy theme has also been undertaken, based on the 230 academic staff identified by consortium institutions that are active in the field, and searching by a comprehensive list of keywords / phrases to focus the search on areas of particular relevance. As the table below shows, there were over 1,400 relevant published articles between 2011 and 2016, and a high level of citation impact. A third of all publications were in publications in the top 10% most cited globally, and over 40% of papers involved international collaboration.

	All Authors (no keywords)	Keyword dataset
Scholarly Output (publications)	7422	1412
Field-Weighted Citation Impact	1.82	2.11
Citations	66,615	11,921
Citations per publication	8.2	8.4
Outputs in Top Percentiles (Publications in top 10% most cited worldwide) %	28.8	33.3
International Collaboration % (Publications co-authored with researchers in other countries)	46.6	43.1
Publications in Top Journal Percentiles (Publications in top 10% journals by SNIP)	37.6	51
Academic-Corporate Collaboration % (Publications with both academic and corporate affiliations)	4.3	3.8

Further analysis can be found in Appendix NES4, including benchmarking comparison of publications by journal filter. This shows particularly high levels of field weighted citation impact for “materials science” (3.26) and “physics” (3.37) publications – both significantly higher than the Russell Group average.

4. Innovation strengths and growth points

Across all New Energy themes the audit area has potential to deliver significant growth and high value jobs, driven by innovative businesses and collaborative R&D, with positive impact across the whole geography

Using standard measures of economic activity related to sector employment and counts of active enterprises is challenging in the energy field, as many enterprises that supply or are connected with energy generation will identify themselves across a range of engineering and service sector industrial classifications. For instance, the marine renewables “sector” includes businesses involved in a range of activities from technical and engineering consultants to specialist engineers. However, through using a suite of proxy SIC codes (see Annex M), we can broadly estimate the scale of the industrial capacity that could support the development and deployment of New Energy technologies.

This analysis[1] reveals that there are 184,100 employees across the consortium area in sectors with a connection to the New Energy theme. The largest sectors are: other engineering activities (24,600), electrical installation (23,200) and other telecommunications activities (15,000).

Taken as whole, this accounts for the same share of employee jobs (7%) as the Great Britain average. More qualitative analysis has been undertaken that has more specificity to the theme – with the work or Regen SW and Nuclear SW particularly useful in understanding these industries. These are summarised below:

Marine renewables

The number of people directly employed in the south west renewables industry overall has grown to 12,800 people, including 4,800 in renewable heat and 7,700 in renewable electricity. Based on current growth rates, it is predicted there will be 16,000 people working in the south west renewable energy sector in 2020[2]. The South West Renewable Energy Manifesto sets out how meeting the 15 percent target in the south west could deliver £10bn of investment and up to 34,000 jobs.

The majority of the employment above, however, is related to onshore wind, PV, and renewable heat. The marine renewables sector currently makes up only a small part of the total. However, in the past seven years the South West has invested over £100m to provide world leading research and demonstration marine renewables facilities including:

- Wave Hub, the largest consented demonstration area for marine energy in the world;

[1] Undertaken by Marchmont Observatory at University of Exeter – report in full is in Annex M to the main audit report

[2] South West Renewable Energy Progress Report, 2015, Regen SW

- the FaB Test nursery site in Falmouth Bay; and
- Plymouth University's COAST laboratory, which includes a deep water wave tank capable of creating complex, scaled current and wave environments.

The new Demonstration Zones off the north coast of Devon and Cornwall (managed by Wave Hub) provide the next development step to these facilities. The PRIMaRE programme has also funded specialist research facilities such as the South West Mooring Test Facility (SWMTF) and Dynamic Marine Component Test facility (DMAC) at the University of Exeter. These facilities complement existing centres for research such as the National Composites Centre. Reflecting these assets and investment, the South West was designated as the first Marine Energy Park in 2012. This latter is particularly important as it reflects the regional perspective of sector development, bringing together research and assets from the Isles of Scilly to the Severn.

Bristol has become a centre for tidal technology development with both technology specialists and consultancy firms based in the city region. Further down the peninsula in Plymouth and Cornwall the research and demonstration facilities have attracted UK and international wave and tidal developers such as Wello, Carnegie, Seabased, Simply Blue, Seatricity, Searaser, OWEL and Tocardo.

It is estimated that the marine energy sector in the South West currently employs over 450 people in high skilled jobs ranging from research and technology development, design engineering, consultancy, offshore operations, component supply and fabrication to training and business support[3].

The region also has an important underpinning and enabling capability in manufacturing for the marine environment including large scale fabrication in steel and concrete as well as manufacturing services in plastics and composites. Born out of the aerospace and yacht building industry, the region has developed significant expertise and capability in the design and manufacture of complex composite structures. The high strength to weight ratio, corrosion resistance and ability to manufacture complex shapes means composite materials are highly suitable for wind and tidal turbine blades in addition to numerous other components subjected to the highly dynamic offshore environment. This wider marine tech capability in both academia and industry is reflected in the establishment of the South Coast Marine Cluster as the UK's leading marine and maritime hub, an initiative that will be central to driving inward investment across the South coast.

The Supply Chain Directory compiled by Regen SW provides a comprehensive insight to the number and breadth of companies associated with the development, deployment and operation of marine renewable technologies, from device developers to consultancy companies. A summary of this can be found at Appendix NES5.

As the marine renewables sector expands it is expected that the number of long term jobs directly associated with the industry in the region will increase, with an ambition to reach over 3000 permanent and long term jobs in the sector by 2030, plus a potential average of 1900 jobs (2018-2030) involved in the construction of major tidal lagoons and offshore

[3] SW Marine Energy Park - Outlook and statement of ambition to 2030, Regen SW, 2015

wind projects. With regard to tidal lagoons, the current Independent Review, led by industry expert Charles Hendry, will be influential and may provide fresh impetus following previous reviews of the Cardiff Western barrage, to capitalise on the tidal range expertise (both academic, developer (Tidal Lagoon Power) and supply chain) that exists in the audit area.

Recent years have seen significant turbulence in the sector (typical of an industry at early stage), with the loss of long term players Pelamis and Aquamarine Power in wave energy, and in tidal energy, the exit of Voith Tidal and Siemens' decision to divest from Marine Current Turbines (MCT).

With the marine renewables sector at a pivotal point in terms of commercialisation, the extent of investment to date in the region, and its growing cluster of dynamic businesses could be among the key drivers of future growth, but continued development and investment is needed to maintain this position.

Hydrogen Storage / Fuel Cells

According to the UK hydrogen and fuel cell association (UKHFCA) there are currently over 100 UK companies, as well as over 35 academic and contract research groups highly active in fuel cells and hydrogen. Within the audit area, and stretching along the M4 corridor is a cluster of businesses with significant R&D activity in the field including Johnson Matthey, Fuel Cell Systems, Cella and Auriga Energy as well as large global players such as Air Products, MMI and BOC / Linde.

The UK fuel cell industry is characterised by a number of world class system developers, active across a range of application areas. Companies such as Ceres Power, Intelligent Energy, Honda and Rolls-Royce Fuel Cell Systems are designing products which will revolutionise transport and stationary power markets. Others are developing and supplying innovative materials and components; these range from established global players such as Johnson Matthey and UCM Advanced Ceramics through to innovative start-ups, such as BAC2 and Acal Energy.

The UK is also internationally recognised for its research and consultancy services, active across many parts of the supply chain and addressing common issues, such as socio-economic aspects, policy and market development etc.

Nuclear new build, operation and decommissioning

While considerable focus has been given to the development of Hinkley Point C as a driver of supply chain development and investment given its potential to create up to 25,000 jobs during its construction phase, there is an existing cluster of R&D activity (particularly around Bristol). For instance cluster maps for existing nuclear-related entities[4] show that the Region has:

- A very strong professional services, engineering and consultancy capability and reputation with structural and civil engineering a particular strength; and

[4] South West Nuclear Cluster Inward Investment Opportunities Evaluation and Initial Engagement Report, DNA Ltd, June 2015

- A large number of high precision manufacturing companies, and some specialist contract service providers (e.g. inspection services).

Consultancy (and University) capabilities cover a range of nuclear activities beyond new build – including life extension of existing reactors, decommissioning of retired Magnox and early research reactors, and effective solutions for management of radioactive waste.

The Berkeley site in South Gloucestershire is a potentially significant asset for the SIA region. Home of the decommissioned nuclear power station, most of the site has been taken over by South Gloucestershire and Stroud College, and is being developed in partnership with the University of Gloucestershire and Gfirst LEP as the Gloucestershire Science and Technology Park. Magnox and Cavendish Nuclear have a presence there, and Growth Deal funding is supporting the development of skills training, business support, and computing/cyber capacity. If Oldbury is confirmed as the site of a new nuclear power station, the Berkeley site will take on additional significance as a centre for training, innovation and support. Further South, around Bridgwater, there is a complementary set of assets including the approved Enterprise Zone at Huntspill, with a specific focus on nuclear, as well as the recently opened Energy Innovation Centre, which will be the centre of a growing cluster of nuclear and other energy related enterprises.

The region also hosts the two key nuclear regulators: the Office for Nuclear Regulation (ONR, Cheltenham) and the Environment Agency (Bristol) and with the headquarters of EDF Energy Existing Generation and NNB Genco, Magnox Ltd, Horizon Nuclear Power there is an emerging centre of excellence for nuclear power station development, licensing, operation and decommissioning in the Region. A map which very clearly demonstrates the cluster of licensed nuclear sites in the consortium area can be found at Appendix NES6.

This mix creates a fertile environment for innovation in the nuclear sector, by bringing together the experience of companies used to working within the sector, the new science and technologies based on cutting edge science at Universities, and the innovation of SMEs and other companies new to the nuclear sector. Crucially, engagement with the regulatory community enables these new ideas to be developed with their deploy-ability at nuclear licensed sites in mind from the outset. The outcomes are improvements to current nuclear technologies, such as safety and affordability, and the application to new technologies such as Small Modular Reactors (SMRs) and Fusion.

Most companies that are established within or associated with the nuclear industry are members of the Nuclear Industry Association. The NIA publish a list of its members by Parliamentary constituency (summarised in Appendix NES7). This shows 103 individual business units within the consortium area, employing 6,600 people. The vast majority of companies are located in close proximity to the major road networks – M4, M5 and A30. Bristol is home to the largest number of companies (34% of all entities), though in many of the categories there is also notable clustering around Bridgwater/Taunton and Gloucester / Cheltenham.

Distributed / smart systems

The UK is uniquely placed to be a market leader in smart systems and energy storage, creating a major new supply chain with opportunities to develop high value jobs, innovation and inward investment. As highlighted in the recent National Infrastructure Commission report on Smart Power, the UK already has an established position as a world leader in data analytics and software development. These capabilities are essential for the active management of the emerging flexible energy system. The sector can be broken down into key categories:

- smart grid infrastructure
- advance meter infrastructure
- smart distributed generation integration
- energy storage
- demand side response
- consultancy services

There are clear linkages with these capabilities and other themes within this audit, particularly around digital living. These categories cover a range of technologies and services that create a more flexible and responsive grid, improving energy efficiency across the network from producer to end-user. Regen SW have produced a national directory for the Smart energy and storage supply chain. This reveals particular clusters of activity in the region around battery and inverter manufacturing, and electric vehicles.

Smart grid and storage technologies have begun to move from R&D to deployment. A key driver for this is the limited capacity on the distribution grid network, illustrated by Western Power Distribution's announcement that there will be many years of delay for any new connection, other than those to the low voltage network. The government has recognised the challenges that grid constraints pose to the growth of the renewables industry and Ofgem published a consultation on how distribution connections could be made quicker and more efficient.

In 2014, Western Power Distribution started to roll out technology to manage the grid network in real time, based on actual energy flows and constraints, rather than modelled figures. This will potentially enable the grid to take much more generation. The first area where Active Network Management connections will be available is within the audit area in Bridgwater, submitted under Regen SW's Renewable Energy Grid Collaboration Service.

Also within the consortium area, the Smart Cornwall programme aims to develop the UK's first fully integrated smart energy network, providing new high value jobs and supporting local businesses to grow into this new market; and providing a test-bed and launch-pad into the European market for multinational companies. Analysis of this opportunity concludes it could deliver over 2,000 jobs and £110m GVA in 2020 and just under 7,000 jobs and £370m in 2030. These jobs would be weighted toward knowledge-based industries with an estimated 59% of businesses working in smart energy in knowledge-based sectors compared to a current average figure of 11 per cent for Cornwall and the Isles of Scilly[5].

The Smart Cornwall ambition is now being realised through the Smart Islands programme which will be a first of its kind project to demonstrate a replicable, scalable model of how

[5] Smart Cornwall Evidence base report, Regen SW 2013

an individual community can both rapidly transition from a carbon intensive to a low carbon community, as well as localise much of the value of energy generated in the locality. Underpinning this will be a smart energy platform utilising the latest Internet of Things (IoT) advances to balance energy supply (through a range of new low carbon sources) and demand (from buildings, water, waste and electric vehicles).

The region also has considerable experience at delivering on shore PV and wind RE in both green space and on buildings. This gives the region a good base load of infrastructure with which to develop the supporting infrastructure in terms of load balancing, storage, alternative business models etc. Research on driving distributed / localised / decentralised energy systems in communities such as Wadebrdge (WREN) and Exeter (Cranbrook and Science Park as well as city wide ongoing developments) has been highly influential on local development policy.

The Energy Systems Catapult runs the Smart Systems and Heat demonstrator programme which has a multitude of projects including three large scale demonstrators, one of which is just outside the audit area in Bridgend, South Wales, using the expertise from South Wales Universities.

5. National and international engagement

Consortium partners have been involved in a number of large-scale national and international research consortia, in particular various SUPERGEN projects, as outlined in the table in Appendix NES1.

Currently there are 7 SUPERGEN consortia (Bioenergy, Energy Storage, HubNet, Hydrogen and Storage, Marine, Solar and Wind. Only one (Wind) does not have a SW partner. These consortia provide expertise, knowledge exchange and facilities which attract business locally and internationally to work with them. Leading and fostering such collaboration is particularly important in some of the more nascent renewables technologies.

A particularly relevant example of world leading collaboration within the region is PRIMARE – the Partnership for Research In Marine Renewable Energy - a consortium of marine renewable energy experts across higher education, research and industry which have joined together to establish a ‘network of excellence’ centred in the south of the UK. The Universities of Plymouth, Exeter, Southampton, Bristol and Bath, along with the Marine Biological Association of the UK and Plymouth Marine Laboratory, work together on research projects across the spectrum of marine renewables. The South West Marine Energy Park (SW MEP) and the Wave Hub facility act as conduits between the research community and industry. It currently focuses on the following research areas:

- Materials
- Fluid Dynamics/ Hydrodynamics
- Survivability and Reliability
- Environmental Resources
- Power Conversion and Control
- Infrastructure and Grid Connection
- Impacts on Environment & Ecosystems
- Marine Operations & Maritime Safety
- Marine Planning and Governance

In recognition of the academic skills, test capability, enabling technology supply chain, and the opportunity for commercial arrays using the demonstration zones, the Offshore Renewable Energy Catapult has invested in having a dedicated and supportive presence in both the South West and in Wales, an important factor in forging collaborations with other parts of the UK, particularly Scotland.

The South Coast Marine Cluster is a key academic/industrial collaboration across the wider marine tech sector, involving four Universities as well as other research organisations such as the National Oceanography Centre and Lloyd's Register's Global Technology Centre.

Nuclear energy offers a further example of how the region is either leading, or well connected to, strategic developments at the national and international level. The South West is home to a number of national-level collaborative initiatives aimed at meeting strategic challenges by bringing together academia, government and industry, such as:

- Nuclear South West
- South West Nuclear Hub (Bristol)
- Bristol-Oxford Nuclear Research Centre
- National College for Nuclear (Bridgwater)
- Somerset Energy and Innovation Centre (Bridgwater).

The majority of these have an international scope of interests and links to companies, government agencies and institutions overseas. This is enabling both the export of nuclear expertise developed in the UK as well as the inward attraction of international experts from around the world.

Wales has an extensive research and development base in renewable energy and smart energy solutions. For instance, SPECIFIC (Wales' national Innovation and Knowledge Centre) and the Low Carbon Research Institute are carrying out world-leading research and can play a central role in informing energy policy development in Wales and the UK. They are both working with industry to develop innovative products that will reduce dependence on carbon rich fuels and increase long-term economic growth and the creation of employment opportunities for Wales such as the SOLCER house.

A further example of significant national and international engagement in smart energy systems is Cardiff University's FLEXIS project. This £24m, five year research programme will be supported by £15m of EU funds and will investigate how flexible energy systems can meet modern-day energy challenges. The programme involves collaborations with industry and research organisations in Wales, Europe and worldwide. As part of the scheme, demonstration sites will be established to act as a test bed for new ideas and to show how new and cost-effective technology and energy solutions are being developed – including a project promoting the use of ground energy from mine water.

With a track record of international, national and regional collaboration, the SIA area is ideally placed to lead further R&D and innovation activity in the New Energy field, ensuring activities complement and enhance efforts elsewhere to maximise return on investment.

6. Developments in science and technology – international markets and opportunities

Analysis shows that the region is ideally placed to both benefit from, and drive, new and rapid developments in marine renewables, nuclear and hydrogen technologies, where the opportunity exists to create global leadership in the UK

The Paris Climate Change Summit in November 2015 has given new impetus to the move towards a lower-carbon and more efficient energy system, but does not alter the picture of rising global needs for energy. Energy use worldwide is set to grow by one-third to 2040[6], driven primarily by India, China, Africa, the Middle East and Southeast Asia. Policy preferences for lower carbon energy options are reinforced by trends in costs, as oil and gas gradually become more expensive to extract while the costs of renewables and of more efficient end-use technologies continue to fall, where technology gains are proceeding apace and there are plentiful suitable sites for deployment.

More specifically, recent and projected developments related to R&D and innovation specific to the thematic focus of this audit are outlined below

Marine renewables

Europe is currently at the forefront of the exploitation and development of Marine Renewable Energy, hosting more than 50% of tidal energy and about 45% of wave energy developers[7]. At present, many of the infrastructures required for the development of MRE are located in Europe, including MRE test centres; demonstration and pilot zones; research laboratories; developers etc. At a European level the UK is the leader in both wave energy (with 29 developers) and tidal energy (with 32% of the global technology developers). Across both wave and tidal energy eleven UK developers have reached an advanced technology readiness level. These technologies are therefore at a crucial stage as the technologies at the forefront are going through the critical “valley of death”, where support is critical to reach full commercialisation.

Wave and tidal are still early stage technologies with tidal slightly ahead (with the first array build commencing in the Pentland Firth). It will be critical for the sector (particularly in the UK) to demonstrate how it can drive down costs to be competitive with other energy types. Key to this is technology innovation and particularly technology transfer from other sectors. Increasing competition is being seen from emerging markets – France and Canada for Tidal, and the US and Australia for Wave. Across both, China is engaged in heavily funded catch up research and development.

Public support is crucial for the growth and development of the MRE sector, and in European countries research and development activities have been mainly funded with governmental support. At national level, there are a wide range of initiatives that different European governments have adopted to support the development of MRE technologies, from subsidies such as feed-in-tariffs and quota systems to investment programs or setting

[6] World Energy Outlook, 2015, International Energy Agency / OECD, 2015

[7] Magagna, D., and Uihlein, A.: ‘Ocean energy development in Europe: Current status and future perspectives’, International Journal of Marine Energy, 2015, 11, pp. 84-104

deployment targets. The main financial support mechanism at European level is the 'NER 300 programme'; a joint initiative of the European Commission, the European Investment Bank and Member States. The programme aims to support demonstration projects within emerging carbon capture and storage (CCS) and innovative renewable energy (RES) technologies. Between its two calls for proposals (December 2012 and July 2014) two wave and another two tidal energy projects have been selected for NER300 funding, three of which were located in the UK and Ireland. The implications of Brexit on future support for UK based device developers are uncertain, but uncertainty is in itself one of the primary barriers to future development.

With its wealth of assets to support marine renewables device development, the region is ideally placed to play a key role in enabling the sector to bridge the "valley of death". The commitment of regional economic stakeholders to this is demonstrated by large scale investments in infrastructure, and creation of marine technology and renewables focused Enterprise Zones (for instance South Yard in Plymouth). It will be important to maximise the value of these new assets enabling them to complete the R&D and innovation jigsaw in the region, and attract inward investment.

Hydrogen / fuel cell

Contrary to common perception, the often-quoted technical obstacles to a hydrogen economy, namely, the storage, safety, cost and distribution of hydrogen have already been sufficiently resolved to support its rapid deployment. The sector is already generating billions of dollars in revenues every year, with annual growth (from a low base) of over 50%[8]. This trend is expected to continue for some time. In Asia, car manufacturers will produce around 3,000 fuel cell cars in 2016 and around 50,000 fuel cell combined heat and power devices. Detailed projections by all OEMs for the Californian Air Resources Board suggest that more than 30,000 cars will be on the roads in California by 2021. Fuel cell technologies are performing reliably to deliver many energy services: some hydrogen buses in London's fleet have operated for nearly 20,000 hours since 2011, while individual stationary fuel cells have generated power for over 80,000 operating hours.

However, most hydrogen and fuel cell technologies are still in the early stages of commercialisation within the UK and currently struggle to compete with alternative technologies, including other low-carbon options, due to high costs and a lack of confidence in the technology. Additional attention will be required before their potential can be fully realised. Government support can help accelerate the development and deployment of hydrogen and fuel cell technologies by ensuring continued research, education, development and demonstration funding for hydrogen generation and conversion technologies, such as electrolysers and fuel cells. This will facilitate early commercialisation of fuel cell electric vehicles and support demonstration projects for integration using hydrogen-based energy storage applications.[9]

The UK has a long and impressive track record in fuel cell research and development. The UK has developed a number of leading, and highly innovative, industry programmes,

[8] E4tech "The Fuel Cell Industry Review 2015" http://www.fuelcellindustryreview.com/

[9] Technology Roadmap - Hydrogen and Fuel Cells, International Energy Agency / OECD, 2015

supported by a strong academic base in both science and engineering[10]. The Research Atlases for both Hydrogen and Fuel cells summarise the UK's capability in particular areas and can be found at Appendix NES8. The UK hydrogen research community has relatively few gaps and an appropriate range of knowledge/skills and activities to address future challenges. However, hydrogen and fuel cells are not currently considered either a short or medium term development priority for the UK government (see, for example, the lack of substantial mention in Planning our electric future: a White Paper for secure, affordable and low carbon electricity, July 2011) and the UK lags badly behind Germany, the United States and Japan with regard to the kind of large scale demonstration projects required to capitalise on the UK knowledge base and develop native commercial expertise. The UK has played a part in HFC support to date, and has developed pockets of excellence, but has had no overarching strategy for the sector. In comparison with countries such as Japan and Germany, support has been less consistent and coordinated, and thus far the benefit to the UK has been more limited. But with an increasing number of hydrogen and fuel cell technologies now close to commercial application, small but coherent and coordinated actions could open pathways to large benefits. The production of the UK's Hydrogen and Fuel cell road map (August 2016) is therefore timely in identifying the UK's role and opportunity, as other countries start to commercialise and adopt this technology.

The value of such support is clear. With 20 public hydrogen refuelling stations, Germany is clearly the trailblazer in Europe in terms of hydrogen infrastructure. The further development of the infrastructure in Germany has now taken shape with the establishment of H2 MOBILITY, a company which will establish and operate the first 100 hydrogen refuelling stations by 2018/2019 unconditionally and irrespective of vehicle numbers Hydrogen could cover up to 40% of the demand for energy in Germany's transport sector by 2050.[11]

Nuclear Energy

The production of nuclear energy around the world is growing as countries look for secure, reliable and affordable energy sources that do not contribute to climate change. In the UK, the nuclear energy sector is undertaking a huge science and engineering effort to extend the lives of its unique fleet of Advanced Gas-Cooled Reactors (AGRs), planning and building a new generation of light-water reactors, decommissioning the legacy of the world's earliest nuclear power programme, while facing a workforce of highly experienced experts rapidly approaching retirement. The scale of the effort to train the scientists and engineers and then to deliver this programme is unprecedented.

The UK government has recognised the opportunity of renewing and growing its nuclear energy capability and skills base, both in terms of energy production domestically and opportunities for UK people and companies to contribute to large science and engineering projects around the world. Nuclear new build in the UK is forecast to generate up to 40,000 jobs in the sector at its peak, but employers are currently reporting skills shortages – particularly in engineering. Tackling the skills gaps will be one of the actions to be taken forward through a focussed Skills Delivery Plan led by the Nuclear Energy Skills Alliance.

[10] UKERC Research Atlas,

[11] H2 MOBILITY Deutschland GmbH & Co.KG marks the first time that a private company has coordinated, planned, built and operated hydrogen stations for an entire country - http://h2-mobility.de/en/h2-stations/

The South West region is recognised as a cluster for nuclear expertise, similar to the cluster around Sellafield in the North West, and is thus well positioned to play a significant role in this renewal.

New technologies such as Small Modular Reactors, which the UK has relevant experience in the design and construction of for naval applications, potentially offer solutions to challenges such as construction costs and adaptability to the unknown future energy landscape. The UK is unique in the world in having operated a fleet of high temperature, gas-cooled nuclear reactors, a design which is highly relevant to next-generation (Gen-IV) reactors, offering leaps forward in areas such as fuel utilisation and waste management. However a strategic intervention may be needed to ensure this knowledge is not lost, as the AGR fleet steadily retires over the coming decades, before such new reactors can be designed and constructed.

Both current and future nuclear energy technologies also have the significant potential to deliver a step change in value by being applied in new ways, such as exploiting the radiation environment for the production of high-value materials, production of hydrogen for the hydrogen economy and the large-scale desalination of sea-water to provide freshwater for human populations around the world.

Importantly, this regional excellence is of truly global relevance. It is not predicated on the construction of any one nuclear power station in the UK, and as such the potential developments at Hinkley and Oldbury are further elements of this expertise, not the central components. However the strategic importance of these major new nuclear developments to the SIA area should not be understated, in terms of their potential to drive high value jobs and supply chain innovation, and to deliver a legacy of economic transformation.

7. Conclusions

The analysis provided in this report shows that in new energy technologies there is both significant opportunity to develop competitive advantage and an existing research base of global quality. However, further investment and development is required to ensure that these opportunities are seized and this research exploited for commercial benefit.

This section summarises projects and initiatives that will further deepen capacity and capability to support new energy science, innovation and commercialisation. These are at various stages of development, with a full “Project Portfolio” table in Appendix NES9.

While such investments in particular technology development and commercialisation are important, consultation with industry representatives in the development of this audit confirmed that **the main barrier to the development and commercialisation of new energy technologies was lack of certainty regarding government energy policy, and therefore market certainty and future support for marine renewables, nuclear and hydrogen fuel cell technologies**. Without clear policy drivers in place the opportunity to maintain momentum and global leadership in some technologies may be lost.

Marine renewables

Marine renewables are at a pivotal point in terms of their development. It will be important for the growth of this industry across the UK that opportunities and capabilities in Scotland (Wave Energy Scotland and opportunities in the Pentland Firth, EMEC) are effectively

linked up with those in the South West. The ORE catapult regional representatives will be key to this. The following developments will complement and add value to the significant investment in research and commercialisation capabilities to date in the audit area, and across the UK.

Offshore renewables – modelling, simulation and testing

As described in this audit, the South West has seen significant investment in testing facilities for marine renewables, particularly wave and tidal energy. However there is an increasing focus on offshore floating wind energy, able to exploit deeper water conditions. The Ocean Wave Basin within the COAST Laboratory at Plymouth University currently allows waves and currents to be generated at any relative orientation and can be run at different water depths. It is accessible and utilised by a range of regional, national and international companies. However adding integrated **wind simulation capability** to the offer would expand its applicability and would be a significant in responding to an anticipated offshore floating wind market in providing test, design and specialist supply chain support. This would also complement other regional activity such as the strategic alliance between the Offshore Renewable Energy Catapult and University of Exeter to support capability expansion of FaBTest which would include testing floating wind at scale

Oceansgate – the marine innovation and production campus

The audit has highlighted the rich network of R&D support across the area, with a complementary and unique set of assets that can support marine renewables device developers to commercialisation. The creation of the Enterprise Zone at South Yard in Plymouth (Oceansgate) is intended to provide development opportunities for the manufacture of marine renewables devices, as well as deep water access for testing, particularly for autonomous vessels. An important strand of Oceansgate is to develop a Marine Technology Centre to enable marine businesses to launch and test prototype devices in waters in and around Plymouth Sound. This represents a significant opportunity to complete the TRL ladder within the South West, and has already led to multi-national interest in investment. However, there is a need for significant enabling works on the waterfront that will provide the catalyst for this investment. A dock in Oceansgate has been earmarked for boats and devices to be moored and launched or for devices to be tested within the confines of the dock. However, a programme of works needs to be undertaken before the dock can become operational again.

The marine autonomy test range

As this audit has highlighted a number of underpinning technologies are crucial to this and other themes. Autonomy is one of these, and an area where there is significant expertise and capacity (both academic and industrial) in the SIA area. The concept of an at sea test range for marine autonomy is one that has the support of key industry players (MSubs and Qinetiq) as well as stakeholders across the breadth of the South Coast marine cluster, complementing existing facilities in Southampton. Accessible from Oceansgate, Plymouth Sound is the ideal location for this, as it is a relatively quiet stretch of water, and has support infrastructure planned on the waterfront (see above). The establishment of the test range would make the region the centre for standards around autonomous vessels, and provide a key enabling facility identified in the UK marine technology roadmap.

North Devon demonstrator

This audit has highlighted the importance of the North Devon / West Somerset demonstration zone as the next development step to R&D facilities in the South West peninsula. In order to exploit this fully, the partners in this project; Wavehub, North Devon Council, Devon County Council, and Exmoor National Park have each contributed a small amount in start-up costs for the project. RegenSW are offering expert advice on the sector and the current commercial opportunities.

To take the project to the next level and make the offer more attractive to the commercial operators interested it will be necessary to invest in the consenting process as the first phase of developing and enabling actions. This work will include:

- Technical Feasibility Study – further consultation with developers, initial design and technical specification, site location and impact assessment
- Legal Study - consenting and permitting considerations scoping
- Business Case – market, case for the project, project delivery vehicle, services, finance
- Economic impact study
- Grid studies – solutions to any capacity constraints (energy storage, smart grid, innovative approaches)
- Environmental Scoping Assessment (not full EIA at this stage)
- Baseline surveys
- Delivery vehicle business plan
- Geophysical surveys (side scan/sonar)
- Developer selection
- Economic Impact Assessment (local, including supply chain)

Industrial Doctoral Centre

EPSRC funding for PhD studentships are targeted through Centres for Doctoral Training (CDTs) and Industrial Doctorate centres (IDCs). The Engineering Doctorate (EngD) is an alternative to the traditional PhD for students who want a career in industry. A four-year programme combines PhD-level research projects with taught courses, and students spend about 75 percent of their time working directly with a company. IDCORE is the Industrial Doctorate Centre for Offshore Renewable Energy and funds EngDs based in Edinburgh University. It trains world-class industrially focussed research engineers who will, with the help of sponsoring companies, accelerate the deployment of offshore wind, wave and tidal-current technologies. Given the intensity of MRE research and development activity utilising the assets outlined in this audit, being able to offer EngDs to industry partners and device developers as a method of interaction with the research expertise and facilities available in the SIA area would be a really positive development.

Advanced manufacturing design, build and test facility to support marine renewables

The co-location of key elements of the engineering design, build, test review journey for marine renewables and marine tech developments would complement activities at South Yard, and elsewhere but would also apply to electronic, robotics and autonomous vehicles / vessels so has application across the audit themes. Such a facility, easily accessible to SMEs and larger companies would incorporate (all underpinned by skilled staff allocated to manage and support businesses)

- Composites construction, computer aided design and build maker suite; dry test rig for 6DOF dynamics and control and hardware-in-the-loop testing
- Prototyping through the use of professional rapid prototyping equipment, light manufacturing CNC equipment and studio space for assembly. Access, through an internal bureau type service, to a toolmaking workshop
- Other specialist laboratories and areas such as composites, heavy structures, thermos-dynamics etc.
- Co-location and augmentation of specialist materials characterisation and testing facilities, including the Electron Microscopy Centre.

Nuclear

The nuclear sector, while building on well-established technology, is similarly at an important moment for renewal and innovation-driven growth.

A proposal for **NUCLEATE – Nuclear Futures Open Innovation and Technology Centre** has been submitted to the West of England LEP for Growth Deal round 3 funding. Located on the Bristol-Bath Science park. The 3500m2 facility will house state-of-the-art nuclear technology laboratories and equipment; an early stage incubator for start-up businesses and open innovation environments for co-location of nuclear primes, SMEs, other nuclear businesses and nuclear regulators. Nucleate will attract new business to emerge that will provide methodologies, software, hardware and services for the development of new affordable and safe and secure nuclear power generation. These businesses would not be able to afford the equipment and facilities by themselves to prove safety and reliability of their new products so will benefit from this investment.

Hydrogen / distributed energy systems

The recently published Hydrogen and fuel cells Roadmap[12] sets out a number of priorities for action in the period to 2025, which will help achieve the greatest benefits from hydrogen and fuel cells to the UK. These are summarised as:

[12] Hydrogen and Fuel Cells: Opportunities for Growth, E4Tech and Element Energy, August 2016

Actor	Priorities
Policymakers	• Strategic decisions around future energy systems options are needed before 2020 • Policies and market frameworks should allow the benefits of HFC technologies to be valued • Commercialisation support is needed in transport and fuel cell CHP • Support for research, feasibility, demonstrations and systems analysis
Industry associations	• Providing reliable and timely information to government to support policymaking • Making links between the HFC sector and end use sectors • Supporting HFC industry cooperation
Hydrogen and FC product developers	• further work is needed to hit technical and commercial targets • articulate and demonstrate the benefits of HFCs and their timescale for commercialisation to consumers and policymakers
Research funders and academics	• academic work should focus on technologies that go over and above the current expectations (lower cost, scaling up etc)
Regional organisations	• Driving HFC activity through policy to meet local objectives • Supporting demonstrations and early deployment

As this shows, early support through demonstration and, at a later date, suitable designed incentives are necessary to move towards a diverse energy system involving hydrogen. A key research challenge where the capacity and expertise within the audit area can contribute is to assess the “whole system” viability of such low carbon energy economies and their socio-economic and environmental costs and benefits.

Building on the capabilities and industrial expertise, as well as the public sector support for such a distributed energy system in the region, the creation of a large scale **New Energy Systems Distributed Demonstrator** would provide a national test bed for technologies, and business models (such as impact accelerators) across diverse geographies from core cities to peripheral rural areas, integrating existing initiatives such as Smart Cornwall and the Growth Deal investment in renewable energies at the Berkeley site to create a distributed project that investigates allowing towns/cities to share renewable energy generation and storage (for instance with high energy use public buildings such as hospitals) to create a network of resources that can work together to be more than the sum of the parts. For example, the energy systems demonstrator would able to model how intermittent sources like renewables (marine, wind, PV) could work alongside low-C base-load sources (i.e. nuclear), including modelling the role of disruptive new storage/transmission technologies like Hydrogen and its production using high-temperature nuclear reactors.

This concept would be developed with the recently established Energy Systems Catapult, complementing other systems demonstrators, and taking a whole systems approach incorporating the three core components:

- Supply and demand;
- Technical enablers
- Market enablers

The expertise and geography of the audit area provides a unique opportunity to test this whole system approach, bringing knowledge, energy sources and end-user products together.

Underpinning technologies

Simulation, modelling and visualisation

Our analysis of the academic and industrial strengths across the sub themes have highlighted a number of underpinning technologies and capabilities where the opportunity to create synergies and research partnerships will have real value. Across all of the sub themes, simulation, modelling and visualisation have been flagged as particular strengths with wide application. To foster collaborative and multi-disciplinary R&D with academic and industrial partners, the development of new energy technologies would be stimulated through the establishment of a network of **simulation and visualisation facilities** with multiple applications, and accessible to industry and academic researchers.

Appendices

Appendix NES1 List of Assets

The following tables summarise the main assets for each sub theme:

Marine			
Asset / initiative	**Location**	**Host / Lead**	**Descriptor**
Marine Institute	Plymouth	University of Plymouth	The first and largest such institute in the UK. Provides the external portal to an extensive pool of world-leading experts and state-of-the-art facilities.
COASTLab	Plymouth	University of Plymouth	Housed in the new Marine Building at Plymouth University, the Coastal, Ocean And Sediment Transport (COAST) laboratory provides physical model testing with combined waves, currents and wind, offered at scales appropriate for device testing, array testing, environmental modelling and coastal engineering.
FaB Test	Falmouth Bay	University of Exeter	Pre-consented, 2.8km2 test area, for up to three devices to be deployed concurrently, for the testing of marine energy technologies, components, moorings and deployment procedures
Wave Hub	Hayle	Wave Hub Ltd	the world's largest and most technologically advanced grid connected site for the testing and development of offshore renewable energy technology
North Devon Demonstration Zones	North Devon coast	Wave Hub Ltd	A new tidal energy site with the potential to support the demonstration of tidal stream arrays with a generating capacity of up to 30MW for each project
Plymouth Marine Laboratory	Plymouth		Development and application of world-leading, integrated marine science
Marine Innovation Centre (MARIC)	Plymouth	University of Plymouth	Aims to make the South West's marine and maritime businesses globally competitive; accelerating growth by creating intelligent connections between organisations, world-class knowledge, technologies, people

			and infrastructure.
Exeter Marine Energy Group	Penryn	University of Exeter	Resource Assessment, Marine Operation and Hydrodynamics, and Offshore Reliability. Actively engaged with wave energy developers and has a number of ongoing collaborative research projects
PRIMARE (Partnership for Research In Marine Renewable Energy)			A network of world-class research institutions based in the west, south, and south west of England who undertake research and development to address challenges facing the marine renewable energy industry at the regional, national and international level.
€17M H2020 CEFOW (Clean Energy from Ocean Waves) project,		Partners include Wave Hub, Mojo Maritime, Plymouth & Exeter Universities	Aims to deploy advanced multiple wave energy converters (WECs) with improved power generation capability and demonstrate that they are able to survive challenging sea conditions
Hydro-environmental Research Centre	Cardiff	Cardiff University	Pursues research into the development, refinement and application of hydro-environmental computational models for predicting flow, water quality, sediment and contaminant transport processes in coastal waters, estuaries and river basins
MARINET - Marine Renewables Infrastructure Network for Emerging Energy Technologies (FP7)			Co-financed by the European Commission specifically to enhance integration and utilisation of European marine renewable energy research infrastructures and expertise. MARINET offers periods of free-of-charge access to world-class R&D facilities & expertise and conducts joint activities in parallel to standardise testing, improve testing capabilities and enhance training & networking.
€1.9M **SOWFIA** (Ocean Wind Farms Impact Assessment) project		University of Plymouth	Sharing and consolidation of pan-European experience of consenting processes and environmental and socio-economic impact assessment (IA) best practices for offshore wave energy conversion developments

EPSRC SUPERGEN Marine 3 UKCMER (2011 – 2019)		Exeter and Plymouth Universities are consortium partners	Conducts world-class fundamental and applied research that assists the marine energy sector in the UK to reliably and dependably accelerate deployment rates and ensure sustained growth in generating capacity to meet the 2020 targets.
EPSRC/ETI £6.5M Industrial Doctoral Centre for Offshore Renewable Energy		Universities of Exeter, Strathclyde & Edinburgh	The IDCORE programme will train world-class industrially focussed research engineers who will, with the help of sponsoring companies, accelerate the deployment of offshore wind, wave and tidal-current technologies in order to meet the UK's ambitious offshore renewable energy targets.
Oceansgate (Enterprise Zone)	Plymouth	Plymouth City Council	Bringing together marine-based businesses to create a world-class hub for marine industries, with opportunities for research, innovation and production in a collaborative environment.
Cornwall Marine Hub	Hayle	Cornwall Council	Marine focused Enterprise Zone
Bolt 2 WaveHub		Fred Olsen	Innovate UK funded wave energy demonstrator project ‘Lifesaver’, in collaboration with University of Exeter
Cornwall Marine Hub	Hayle	Cornwall Council	Marine focused Enterprise Zone
Cornwall Marine Network	Cornwall		An organisation dedicated to supporting the Marine sector in Cornwall via initiatives that improve profitability and encourage growth through quality and innovation
Falmouth Marine School		Cornwall College Group	Specialise in Boatbuilding, Leisure & Watersports, Marine Engineering and Marine Science.
DNV GL	Bristol		through their design verification activities are creating specific standards for wave and tidal
Waveport		OPT, Exeter University	€9M FP7 marine energy demonstration project,
£1.1m Dynamic Loadings on Turbines in a Tidal Array (DyLoTTA)			including Airborne, Ansys UK Limited, Arup Group Ltd, Bosch Rexroth Ltd, EPSRC, LLoyd's Register Energy, National Instruments Corporation UK Ltd,

			Nautricity Ltd, Offshore Renewable Energy Catapult, SKF (UK) Ltd, Tidal Energy Ltd, Universities of Cardiff and Strathclyde

Nuclear			
Asset / initiative	**Location**	**Host / Lead**	**Descriptor**
Bristol-Oxford Nuclear Research Centre	Bristol	University of Bristol / University of Oxford	Providing leading edge and innovative research to support the safe operation of current and future generation nuclear systems.
South West Nuclear Hub	Bristol	University of Bristol	Provides a link between the Higher Education, Nuclear Industry and Government sectors, and creates a single door for the nuclear industry to access and form partnerships in academic research and teaching
Geo-environmental Research Centre	Cardiff	University of Cardiff	Tackling the problems caused by the environmental effects of waste, including high level nuclear waste
Advanced Centre for Composites in Innovation and Science (ACCIS)	Bristol	University of Bristol	World leading centre for composites research and education, combining cutting edge fundamental science with strong industrial links for exploitation and technology transfer.
EDF Generation	Barnwood	EDF GenCo	
EDF New Build	Hinkley Point C	EDF	Potentially the first new nuclear power station in the UK for a generation
EDF NNB Command Development Centre	Bristol	EDF	Will be home to 750 staff, the centre of excellence for nuclear new build in the UK
Magnox nuclear labs	Berkeley	Magnox	
Horizon Nuclear Power	Tewkesbury		UK energy company (wholly owned subsidiary of Hitachi,Ltd) developing a new generation of nuclear power stations at Oldbury and Anglesea
National College for Nuclear	Bridgwater	Bridgwater College	Development of programmes and curricula to target a

			strategic skills gap at the advanced technician level, below traditional degree programmes
EDF national Learning and Development Centre	Cannington	EDF Energy	Forms part of EDF Energy's "Campus" programme for all staff which includes an online hub and courses run across the UK. Develops skills to work on smart metering, customer service, existing power stations, nuclear new build, human resources, finance, digital projects and other aspects of EDF Energy's business.
Somerset Energy Innovation Centre	Bridgwater	Somerset County Council (operated by SWMAS Ltd / Business West / Somerset Chamber)	A hub for ambitious businesses seeking to collaborate and exploit opportunities in the low carbon and nuclear energy sectors.
Nuclear South West		Business West / Davies Nuclear	Not-for-profit business platform focussing on supply chain development, networking and sharing of knowledge.
Gloucestershire Science and Technology Park	Berkeley	South Gloucestershire and Stroud College with University of Gloucestershire	Site of the former Berkeley Nuclear Laboratories; with a continuing presence of Magnox and Cavendish Nuclear; now being comprehensively redeveloped to provide facilities for engineering and construction skills training; business support; advanced computing and cyber facilities; and a University Technical College

Hydrogen / Fuel Cells			
Asset / Initiative	**Location**	**Host / Lead**	**Descriptor**
Sustainable Environment Research Centre	South Wales	University of South Wales	Groundbreaking research centre bringing together leaders from biology, engineering, chemistry, and physics, including a focus on hydrogen energy and vehicles
Cardiff Catalysis Institute (CCI)	Cardiff	Cardiff University	Established to • improve the understanding of catalysis • work with industry to develop new catalytic processes

			• promote the use of catalysis as a sustainable 21st century technology
SUPERGEN • Energy Storage Hub (2014-19) • Sustainable Hydrogen Energy Consortium, (2007-12) • Hydrogen and Fuel Cells Hub • Biological Fuel Cells			Various EPSRC funded consortia - part of the wider SUPERGEN initiative from the Research Council's Energy Programme. The programme is led by EPSRC in partnership with BBSRC, ESRC and NERC. It aims to contribute to the UK's environmental emissions targets through a radical improvement in the sustainability of the UK's power generation and supply.
CymruH2Wales (£6.3m)		University of South Wales	Aims to ensure that Wales can play an active role in establishing new hydrogen technology products, processes and services
£1.24m Royal Society/DFID Consortium on "New materials for a sustainable energy future:		Cardiff University	Consortium with Addis Ababa University, University of Botswana and Kwame Nkrumah University of Science & Technology
£1.7M IUK funded project with ITM Power and Cardiff City Council	Cardiff	Cardiff University	Development of a hydrolysis plant in Cardiff to generate hydrogen for injection to grid with landfill gas, to store for use in vehicles or for putting back through a generator to produce electricity
Swindon Hydrogen Hub	Swindon	Johnson Matthey	LEP supported initiative including Honda, Hyundai, Doosan, Johnson Matthey
Johnson Matthey Fuel Cells	Swindon		R&D activity dating back to 1990s and purpose built state of the art facility for flexible manufacturing methods to produce large volumes of fuel cell components for hydrogen and methanol fuelled systems
Auriga Energy	Bristol		Developed and continues the development of high efficiency fuel cell systems, for the marine, stationary power (including UPS/backup and standalone generators) and materials handling applications.

Other (integration of renewables, energy networks and infrastructure)			
Asset / Initiative	**Location**	**Host / Lead**	**Descriptor**
Energy Systems Research Institute	Cardiff	Cardiff University	Undertakes internationally leading research into the development of sustainable, affordable, socially acceptable and secure energy systems through a multi-disciplinary approach that supports collaboration and innovation
Low Carbon Research Institute	South Wales	Cardiff University	Unites the diverse range of low carbon energy research across Welsh universities at Cardiff, Glyndwr, Bangor, South Wales and Swansea, covering research topics relating to the built environment, solar PV, hydrogen, large scale power generation and marine.
Centre for Integrated Renewable Energy Generation and Supply	Cardiff	Cardiff University	A multidisciplinary engineering group with international expertise in both generation and supply of renewable energy
Advanced High Voltage Engineering Research (National Grid Centre)	Cardiff	Cardiff University	Focuses on systems and phenomena related to very high voltage electricity. establishing collaborative partnerships between university researchers and National Grid engineers
Cabot Institute	Bristol	University of Bristol	Cross-disciplinary research institute, conducting world-leading research with main themes including energy security.
Electrical Energy management Research Group	Bristol	University of Bristol	Undertakes research into low carbon electrical systems that are enabled by advanced, compact and highly efficient electrical machines and power electronic conversion.
FLEXIS	South Wales	Cardiff University	£24m European Structural funds project which sets out to meet the diverse, complex and inter-dependent challenges that arise when new sources of energy are integrated into the grid by suppliers, including establishment of a demonstration test bed.
SPECIFIC	South Wales	Swansea University	£3m European Structural funds project which aims to address the

			challenge of low carbon electricity and heat by enabling buildings to generate, store and release their own energy, in one system, using only the energy from the sun
Advanced Renewable Energy Research Centre	Berkeley	University of Gloucestershire	£4m Growth Deal capital investment in renewable energy capacity as part of the wider development of the Gloucestershire Science and Technology Park. The Centre will deliver STEM skills development, business incubation, strategic and applied research and specialist business and consumer support in relation to secure renewable energy generation, storage and management. The aim of the Centre is to build, develop, test and evaluate sustainable energy technologies in a setting where the skills and research can be shared and then demonstrated to industry, existing and future customers, and schools.
Smart Cornwall Programme	Cornwall		UK's first fully integrated smart energy network
Smart Islands	Isles of Scilly	Council for the Isles of Scilly / Islands Partnership / Duchy of Cornwall & Tresco Estates / Hitachi Europe	Proposed smart grid/smart energy programme to support the Islands objectives: - • 20% reduction in electricity bills by 2020 (40% by 2025) • 40% of the Isles' energy demand met through renewable generation by 2025 • 40% of vehicles being low carbon or electric by 2025 • Internships, cultural exchange and STEM skill delivery for young people • 5. Full programme of energy efficiency measures delivered by 2020
Building Research Establishment Trust Centre for Sustainable Engineering	Cardiff	Cardiff University	Research themes include management of energy in buildings with a view of delivering lifelong sustainable facilities

Appendix NES2 REF 2014 Units of Assessment with staff associated with New Energy

UoA		Submitted staff associated with theme	No of Institutions	Doctoral awards 2008-16*	UoA overall profile (% 3 or 4*)
3.	Allied Health Professions	1	1	1	63%
4.	Psychology, Psychiatry and Neuroscience	3	1	-	92%
5	Biological Sciences	1	1	7	88%
7	Earth Systems and Environmental Sciences	22.75	3	36	91%
8	Chemistry	23	3	80	97%
9	Physics	9	3	34.5	89%
10	Mathematical Sciences	14	2	40	70%
11	Computer Science and Informatics	2	2	18	82%
12	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	15	1	43	89%
13	Electrical and Electronic Engineering, Metallurgy and Materials	5	2	30	78%
14	Civil and Construction Engineering	11	1		76%
15	General Engineering	79.8	5	156	81%
16	Architecture, Built Environment and Planning	5	2	15	83%
17	Geography, Environmental Studies and Archaeology	8.4	3	24	75%
19	Business and Management Studies	3	2	3	68%
21	Politics and International Studies	1	1	.5	84%
23	Sociology	1	1		86%
				500	

*Awarded to students supervised by staff associated with the theme

Appendix NES3 Mapping of academic themes from analysis of UoA environment statement extracts and impact case studies

	Marine renewables	New nuclear	Hydrogen storage / Fuel cells	Other
PLYMOUTH UNIVERSITY	international reputation in research related to marine renewable energy	maximise performance and reliability of advanced structural materials in nuclear pressure vessels and steam turbine components (strong links with the South African Energy Utility, ESKOM)		
	-Wave structure interaction / simulation - **Marine systems** & interactions			
	-Offshore wave farms **impact assessment** **-**Understanding the sediment dynamics and coastal impact of offshore wind farms			
	Advanced research into **materials and structures**			
	the application of Artificial Intelligence (AI) techniques to the navigation, guidance and control of **autonomous marine robotic vehicles**, and has extended this expertise into wave energy devices			
	research on marine **composite structures** for the			

	renewable energy domain			
	optimisation of welding and bonding processes seeks to minimise residual stresses and maximise **performance and reliability of advanced structural materials** in marine structures, offshore energy devices,			
CARDIFF UNIVERSITY	evaluating the environmental and engineering implications of tidal energy recovery schemes	research on the physicochemical behaviour of fine-grained soils and its application to high-level nuclear waste	the design and synthesis of materials for hydrogen storage, fuel cells	developing materials for use in energy applications including membranes for natural gas purification and carbon capture
	-design, testing and **simulation of tidal stream turbine** -simulating marine renewable energy structures (e.g. Severn Barrage) -marine renewable energy and in particular on new numerical strategies for **simulating related hydrodynamic processes**	research on processes of reasoning associated with nuclear fusion as an energy technology	Polymer-based hydrogen storage materials	-catalysts for the enhanced production of biofuels -the Cardiff Catalysis Institute - sustainable fuel-to-energy transformations
	scientific data and modelling predictions		Hydrogen End-use Catalysis of reforming reactions at moderate temperature	research on geo-energy and sustainability, including work on ground source heat, underground coal gasification, carbon sequestration in coal and

				soil, and geoinformatics
				-combined network analysis and smart grids -grid infrastructure and smart-grids -National Grid Centre for research into new materials and systems for power transmission -studies and training on the influence of renewables integration on the electrical grid
				linking the built environment to future energy supply options, combining technologies in energy supply, energy demand reduction and energy storage
UNIVERSITY OF BATH			Hydrogen storage	-New materials -Chemical Analysis & Characterisation
			Hydrogen / fuel cells hub	Solar cells / PV
			development of special carbon structures, porous oxides and structured adsorbents, used for H storage	Gas turbine heat transfer research
			Structural chemistry of hydrogenous materials	Smart grid

UNIVERSITY OF EXETER	the consequences of marine renewable technologies (ecosystems)			synthetic approach to Biofuel generation in bacteria
	mathematical research in the areas of dynamical systems, control theory, computational modelling and statistics (interface with renewable energy)			design and fabrication of novel nanoelectronic and photonic devices
	optimal control techniques for wave energy converters			integrated photovoltaics
	issues of power production in offshore renewable energy devices			
	understanding spatio-temporal variation of waves, coupled dynamic behaviour of ocean energy devices			
UNIVERSITY OF BRISTOL		Structural integrity-Fracture mechanics, residual stress, high temperature materials Measurement and role of residual stresses, role of temperature, irradiation and the environment on material(s) properties		
		Nuclear reactor core materials		
		Thermal modelling		

		Nuclear Materials and modelling - Uranium chemistry, metallurgy, corrosion and surface science		
		Simulation and modelling techniques to understand the properties of solids and surfaces at the atomic level, modelling irradiation effects across length and timescales		
		Nuclear waste and fuel management		
		Software reliability / safety systems modelling		
		Nuclear hazards and risks		
		Monitoring technologies		
		Development of new materials		
UNIVERSITY OF SOUTH WALES			broad portfolio of hydrogen, anaerobic system and fuel cell R&D, spanning fundamental materials research through to industrial research and testing.	
			Advanced Control and Network Technology Research Unit has a focus on fuel cell control and electrical systems	

			development, particularly for automotive applications.	
			Hydrogen Research Centre and Baglan provides a platform for the experimental development of renewable hydrogen production and novel hydrogen energy storage. The centre enables further research and development of hydrogen vehicles, fuel cell applications and overall hydrogen energy systems.	
			CymruH2Wales aims to ensure that Wales can play an active role in establishing new hydrogen technology products, processes and services.	

Appendix NES4 Publication Analysis

Summary of SciVal data from 20/07/16

	All Authors (no keyword)	**With Keywords**	Extended keywords
Scholarly Output (publications)	7422	**1412**	2998
Field-Weighted Citation Impact	1.82	**2.11**	1.9
Citations	66,615	**11,921**	24,318
Citations per publication	8.2	**8.4**	8.1
Outputs in Top Percentiles (Publications in top 10% most cited worldwide) %	28.8	**33.3**	30.8
International Collaboration % (Publications co-authored with researchers in other countries)	46.6	**43.1**	45.6
Publications in Top Journal Percentiles (Publications in top 10% journals by SNIP)	37.6	**51**	43
Academic-Corporate Collaboration % (Publications with both academic and corporate affiliations)	4.3	**3.8**	4.0

Top Academic/industry collaborations (no of publications) based on 'all authors' dataset:

Rolls-Royce United Kingdom	**27**
China Electric Power Research Institute	22
Airbus Group	20
Jaguar Land Rover	19
Johnson Matthey Plc	19
CTTC - Catalan Telecommunications Technology Centre	18
KDDI R&D Laboratories	18
Hydro-Quebec	16
Shell	15
Atomic Weapons Establishment	13
Telefonica	12
ExxonMobil	11
Toshiba	10
Fraunhofer - Heinrich-Hertz-Institut - HHI	8
Thales	8
Alcatel-Lucent	7
Fujitsu	7
Osaka University	7
TriQuint Semiconductor, Inc.	7
QinetiQ	6
Deutsche Telekom	5
ETH Zurich	5
Rutherford Appleton Laboratory	5
Siemens	5
Smith & Nephew	5
BT	4
GlaxoSmithKline	4

Benchmarking: Filtered by 'Energy'

	Keyword Dataset	World	UK	Russell Group
Scholarly Output	**440**	459576	19365	10283
Field-Weighted Citation Impact	**2.1**	1.11	1.57	1.78
Outputs in Top 10% of the World (%)	**48.2**	21.7	27.7	33.3

Benchmarking: Filtered by 'Engineering'

	Key word Dataset	World	UK	Russell Group
Scholarly Output	**685**	2895624	115484	65205
Field-Weighted Citation Impact	**2.04**	0.99	1.54	1.74
Outputs in Top 10% of the World (%)	**23.4**	13.3	18.1	21.2

Benchmarking: Filtered by 'Materials Science'

	Keyword Dataset	World	UK	Russell Group
Scholarly Output	**219**	1396227	56772	37052
Field-Weighted Citation Impact	**3.26**	1.11	1.49	1.65
Outputs in Top 10% of the World (%)	**41.1**	21.8	26.4	30.2

Benchmarking: Filtered by 'Physics'

	Keyword Dataset	World	UK	Russell Group
Scholarly Output	**207**	1635271	97976	68390
Field-Weighted Citation Impact	**3.37**	1.05	1.57	1.71
Outputs in Top 10% of the World (%)	**30.4**	18.8	27.6	30.4

Benchmarking: Filtered by 'Maths'

	Keyword Dataset	World	UK	Russell Group
Scholarly Output	**76**	922410	53606	34030
Field-Weighted Citation Impact	**2.69**	1.02	1.46	1.53
Outputs in Top 10% of the World (%)	**10.5**	11.9	15	15.8

Top 20 academic collaborations (publications):

Institution	**Publications**	**Citations**	**Authors**	**Citations per Publication**	**Field-Weighted Citation Impact**
University of Bristol	305	1598	367	5.2	1.68
University of Bath	249	3693	259	14.8	3.64
Cardiff University	222	1414	248	6.4	1.53
University of Plymouth	182	1353	127	7.4	2.65
University of Exeter	167	998	113	6	1.73
University of Edinburgh	74	241	64	3.3	1.46
University of South Wales	63	625	36	9.9	1.36
Universidad de Santiago de Compostela	54	405	46	7.5	2.86
University of Michigan	44	284	9	6.5	2.7
Heriot-Watt University	34	453	30	13.3	2.58
Virginia Polytechnic Institute and State University	33	278	21	8.4	1.18
Tsinghua University	27	240	39	8.9	1.89
Imperial College London	23	409	68	17.8	7.41
Aristotle University of Thessaloniki	22	43	15	2	0.83
University College London	22	258	25	11.7	2.74
University of Cambridge	22	185	60	8.4	2.53
University of Southampton	22	403	35	18.3	3.13
University of Manchester	21	135	56	6.4	1.34
University of Oxford	20	191	55	9.6	3.28
Loughborough University	18	264	30	14.7	2.3

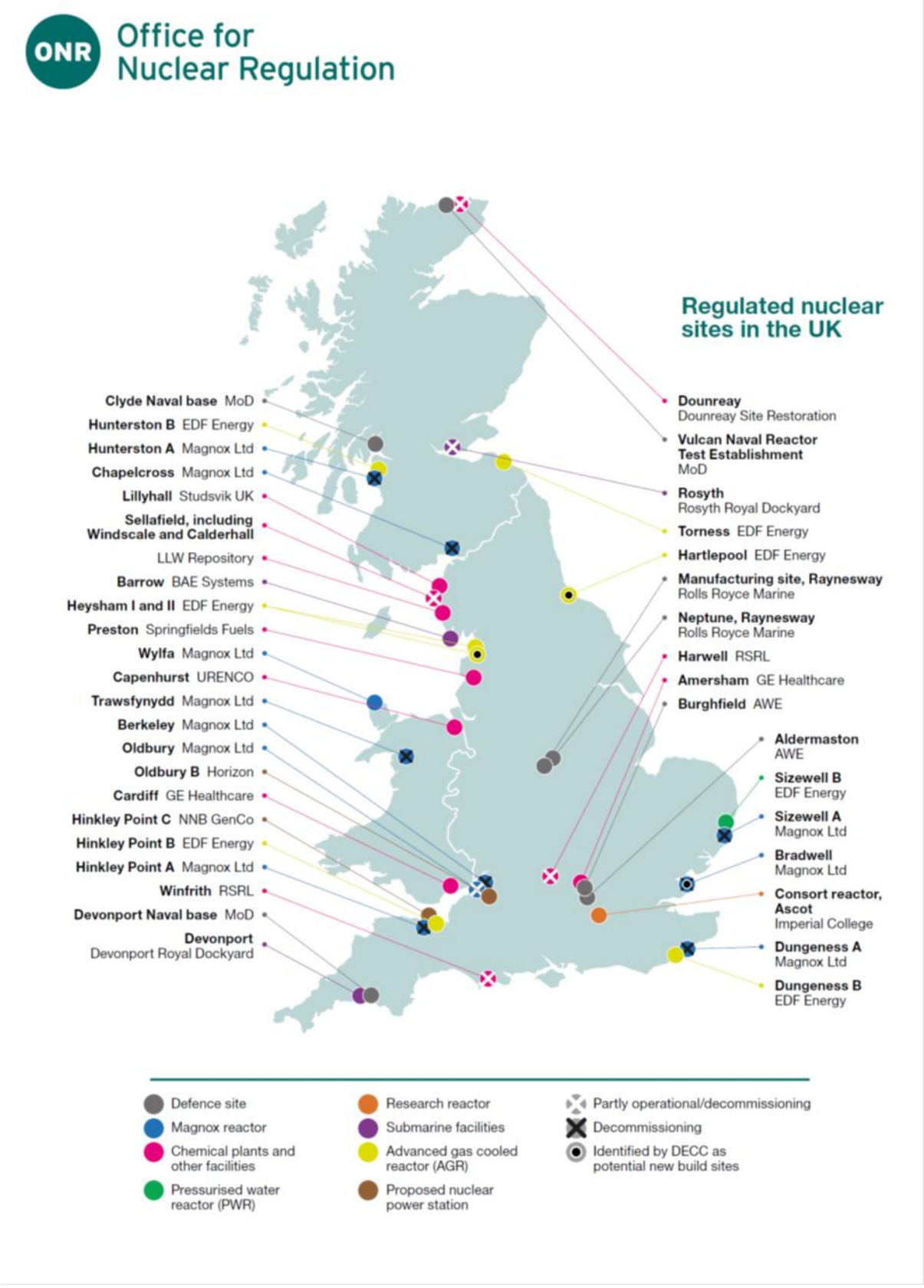
Appendix NES5 marine renewables supply chain

A summary of the marine renewables supply chain, from Regen SW

Tidal Energy Developers	Alstrom	Bristol
	Atlantis Resources Ltd	Bristol
	Longbay Seapower Ltd	Somerset
	Tidal Energy Ltd	Cardiff
	Tidal Lagoon Power Ltd	Cheltenham
	MT Tidal	Exeter
Wave Energy Developers	Carnegie Wave Energy LTd	Cornwall
	Marine Power Systems	Swansea
	Offshore Wave Energy Ltd	Cornwall
	Searaser	Devon
	Seatricity	Cornwall
Renewable Energy Consultants	18 companies	
Technical and engineering consultants	16 companies	
Multi-disciplinary consultants	36 companies	
Environmental consultants and surveyors	21 companies	
Oceanographic consultants and surveyors	9 companies	
Naval architects	9 companies	
Marine engineering	Babcock BMT LICenergy Ocean Fabrication	
Subsea engineering	Sub Marine Services LICEnergy MSubs Viper Subsea	
Specialist engineering	9 companies including Apex Fluid Engineering Thales Underwater Systems Teignbridge propellors	

Appendix NES6 Regulated Nuclear Sites in the UK

Regulated Nuclear Sites in the UK, which shows the cluster within the South West England and South East Wales area.



Appendix NES7 Industrial capacity in the nuclear sector
Nuclear Industry Association members within the audit area.

Constituency	Infrastructure	Business units	Jobs	Significant entities
Bath		2	159	
Bridgwater & West Somerset	Hinkley A (Cavendish Fluor) Hinkley B (EDF) *Hinkley C (EDF NNB)*	23	2,035	BAM – 490 Doosan Babcock – 330 EDF – 718 Magnox - 184
Bristol West		15	301	Frazer-Nash – 144 Small consultancies
Cardiff (x4)		7	55	ARUP - 40
Cheltenham		2	10	
Chippenham		1	110	M&W
East Devon		3	8	
Exeter		2	7	
Filton & Bradley Stoke	Oldbury Power Station (Cavendish Fluor)) *Oldbury Power Station (Horizon)*	9	604	Atkins – 287 Cavendish - 179
Gloucester	Barnwood	6	1471	EDF – 1,332
Newport East				
North Somerset		1	20	
Plymouth (x2)		4	50	
South Swindon		1	33	
Stroud	Berkeley Power Station (Cavendish Fluor)	14	988	Magnox – 494 Fluor - 177
Taunton Deane		2	4	
Tewkesbury		7	325	Horizon Nuclear Power – 233
Thornbury & Yate		4	467	Magnox - 327
		103	**6647**	

Appendix NES8 UK capabilities in Hydrogen and Fuel Cells

UK capabilities in Hydrogen and Fuel Cells from the EPSRC Research Atlases.

UK capability – Fuel Cells	Area	Market Potential
High	FC materials science and engineering	Global market
	Cell and stack engineering	Global market
	Fuel processing	Global market
	System engineering	Global market
	Selected balance of plant components	Global market
	Fuel cell manufacture	Global market
	Techno-economic modelling	Global market
Medium	System demonstration	UK application but a global market
	Control systems	Global market
	Power electronics	UK application but a global market
Low	Product trials	UK application but a global market

UK capability - Hydrogen	Area	Market Potential
High	Hydrogen Production (dark fermentation)	Global (medium/low impact)
	Materials for hydrogen storage	Global (high impact)
	Renewable Energy Systems	Global (high impact)
	Socio-economic analysis	Global (high impact)
Medium	Materials for hydrogen production	Global (high impact)
	Hydrogen production	Global (high impact)
	Hydrogen storage (devices)	Global (medium impact)
	Hydrogen distribution	UK application (low impact)
Low	Hydrogen infrastructure	UK application (high impact)
	Hydrogen systems	Global (high impact)
	Reversible fuel cells	Global (medium impact)

Appendix NES9 Project portfolio

Existing projects/facilities with expansion plans, where local funding is/could be available		
Large scale projects funded already under LEP LGF 1 or 2 (or Catapult, EPSRC etc), full bus case approved but yet to 'open'.		
Advanced Renewable Energy Centre, Berkeley	£4m	Approved under Growth Deal 1, as part of the further development of the Berkeley site, the University of Gloucestershire, in collaboration with South Gloucestershire and Stroud College, is developing the Centre. With a focus on renewable energy, the Centre will work with industry partners to co-deliver skills development, research and development of novel and niche product applications and innovations. It will cover energy management for domestic, community or business use, including retro-fitting of existing plant and purpose-built installations.
Oceansgate (Enterprise Zone) Phase 1 (Growth Deal 1, Heart of the South West)		Plymouth City Council led development to construct new office and industrial space for marine tech industries
Large scale projects put forward by LEPs under LGF3/ Devolution Deals or City Deal or ESIF but not yet funded/approved in full or with full bus cases developed.		
NUCLEATE – Nuclear Futures Innovation Centre (Growth Deal 3, West of England)	£30,000,000	The purpose of NUCLEATE is to provide the Nuclear innovation system access to state of the art facilities, technologies and specialist skills to support the development of a supply chain for an affordable nuclear future.
West of England Centre for Power and Energy	Up to £50,000,000	Discussions are underway with the West of England LEP to secure funding up to £50M
Cornwall Marine RD&I Hub (ERDF Cornwall & Isles of	£8,000,000	Creation of a Marine Technology R&D&I Hub delivering innovation within the marine technology smart

Scilly)		specialisation theme.
Marine Business Technology Centre ERDF Heart of the South West	£4,500,000	Support for marine and supply chain businesses to access and collaborate with all the HotSW knowledge base, (and more widely). It will establish a "Smart Sound" in-sea test facility by co-ordinating and (where market pull exists) filling gaps in the existing marine testing assets around the region
Huntspill Energy Park Enterprise Zone infrastructure Growth Deal 3 – Heart of the South West		A 635 acre brownfield site, to be developed for energy generation and mixed employment uses
Somerset Energy & Innovation Centre Phase 2 Growth Deal 3 – Heart of the South West		Physical space, generic and specialist business support services for high growth businesses wanting to relocate to Somerset in close proximity of Hinkley Point and other regional low carbon initiatives
Oceansgate Phase 2 Growth Deal 3 – Heart of the South West		Unlocking over 800 jobs and continue re-establishing Plymouth as a cutting-edge marine R & D centre
"Shifting Gear" Low Carbon programme (ESIF Bid)		The University of Gloucestershire proposes to build upon ARERC (above) to deliver the project which will: engage businesses in improving energy efficiency through diagnostic audits; deliver a business-to-business mentoring network; provide a development space in which low carbon technology businesses engage with up-to-date research and develop new technologies; and deliver opportunities to test new techniques/technologies.
New Energy Cornwall ESIF – Cornwall & Isles of Scilly stage 2 submitted	£3,000,000	This project aims to combine the best of Cornwall's existing local renewable energy and low carbon environmental good and services (LCEGS) activity and marry it with a more sophisticated 'Big Business' approach to energy supply and the development of local energy markets.

Large scale projects identified through the Audit discussion process		
COASTLab Phase 2		Integration of a unique wind simulation capability integrated with existing wave and current simulation.
Marine advanced manufacturing, testing and innovation Centre		Co-location of key elements of the engineering design, build, test review journey for marine renewables and marine tech developments
Oceansgate Business Technology Centre Dock Enabling		These onshore and offshore facilities will be the first of their kind in the UK and will link to other marine innovation facilities along the south coast. However, a programme of works needs to be undertaken before the dock can become operational again, including new tidal sill and radial gates
New Energy Systems Distributed Demonstrator		A national test bed for technologies, and business models (such as impact accelerators) across diverse geographies from core cities to peripheral rural areas
Simulation and Visualisation Centre		Collaborative and multi-disciplinary R&D facility with academic and industrial partners