Universities Wales response to the National Assembly for Wales' Economy, Infrastructure and Skills Committee inquiry into Research and Innovation

1. About Universities Wales

1.1. Universities Wales represents the interests of universities in Wales and is a National Council of Universities UK (UUK). Universities Wales' Governing Council consists of the Vice-Chancellors of all the universities in Wales and the Director of the Open University in Wales.

2. Executive Summary

2.1. Key to solving the challenges facing Wales, growing our productivity and increasing prosperity for all, is to support a healthy research and innovation ecosystem that provides the right conditions for universities, businesses and others to be able to deliver. Quality-related research funding (QR) underpins this whole ecosystem.

2.2. Within the research and innovation ecosystem there are many pathways between research - at all stages - and the economy, and multiple interdisciplinary inputs and benefits. It is a complex ecosystem that cannot be separated simply into 'pure' and 'applied' research and will flourish for the benefit of Wales if universities and businesses are empowered to deliver.

2.3. The research and innovation funding landscape is rapidly changing. In particular, the UK Government is investing an extra £2 billion a year for R&D until 2020-21, the vast majority of which is awarded competitively. However, Wales' comparatively low levels of research and innovation funding compared to the other UK nations puts us in a difficult position to compete for and win these opportunities to bring this investment into Wales.

2.4. Universities Wales strongly recommends that overall investment in research and innovation in Wales is increased – both for universities and for businesses. We fully support the recommendations in the Diamond Review and Reid Review on research and innovation funding. Their implementation – in full and without delay – is crucial to growing Wales' productivity.

3. Q1: Welsh Government says that there needs to be a "major increase" in research intended to help solve specific challenges facing Wales (challenge-led research). It also says this type of research needs to be balanced with the more traditional type of long-term research undertaken by universities which pushes the boundaries of knowledge. **To what extent do you agree with this view and how can Welsh Government ensure that an increase in one type of research activity doesn't mean the other type loses out?**

3.1. We strongly agree that there needs to be a "major increase" in research in Wales as this is crucial to raising productivity and increasing prosperity in Wales. Research is

not only key to creating the knowledge needed to solve the grand challenges we face such as the growth of artificial intelligence, an aging population and decarbonisation of energy sources, but it also plays a key role in regional economic growth by drawing in business investment, and creating and growing businesses in Wales. There are some major investment opportunities available in Wales – not least the multi-million-pound investment projects from UK Research and Innovation (UKRI) – and now is the time to capitalise on these opportunities for the benefit of Wales.

3.2. Research and innovation is a complex ecosystem and cannot be simply separated into two 'types' of research as described in this question. This is expanded upon by Prof Graeme Reid in his 2014 report "why should the taxpayer fund science and research":

> *"If there are two complementary rationales for government funding of research, then there is an inevitable temptation to look for an optimal balance between them. This often takes the shape of a debate over funding for pure vs applied research. Such a model of resource allocation may be underpinned by the notion of a pipeline in which pure research brings intellectual advances, which are then turned into economic benefit through an adjacent process of applied research. There are examples of the model working well, often in medical research. Yet it misses many of the pathways between research and the economy and is more likely to mislead than inform a sophisticated understanding of the relationships between science, research and the economy."*

3.3. Equally, this complex landscape is also interdisciplinary, meaning solving a specific challenge will not be achieved by supporting one specific discipline or project. A recent report found considerable interdisciplinarity between research disciplines and corresponding impact topics in Welsh research e.g. Business and Industry impact originated from research disciplines in life sciences, engineering and physical sciences, social sciences and arts and humanities.[1]

3.4. The key to solving the challenges facing Wales is to support a healthy research and innovation ecosystem that provides the right conditions so that universities, businesses and others are able to flourish and deliver. The following are the core characteristics of a healthy and progressive R&I system:

- 3.4.1. Stable
- 3.4.2. Sustainable
- 3.4.3. Competitive
- 3.4.4. Flexible and adaptable
- 3.4.5. Transforms society and the economy
- 3.4.6. Ambitious in growth and impact

3.5. A high level of government control will not achieve this type of system. Whilst Welsh Government can, and should, award competitive research funding to solve the challenges facing Wales, the Reid Review rightly identified that *"this initiative can only succeed if the research and innovation ecosystem is fort for competition. To that*

[1] King's College London 'Impacts of academic research from Welsh universities' (2017)

end, it is essential that Wales has at least parity in the levels of un-hypothecated research and innovation funding compared to the rest of the UK."

3.6. Quality-related (QR) research funding, which is 'core' funding from Welsh Government and distributed by HEFCW, is un-hypothecated research funding, and is fundamental to achieving a healthy and progressive R&I system. Contrary to the frequently-mentioned reference that QR funds 'blue skies research', QR underpins a system with all of the characteristics mentioned above in the following ways:

3.6.1. QR funding is unhypothecated funding that is granted on the basis of research excellence, rather than to fund a particular named research project. It funds basic research infrastructure and investment, including the salary costs of permanent high-quality academic researchers, support staff, equipment, facilities and libraries. QR-funding then enables the creation and support of major collaborations with business and public sector by providing the stable foundations on which the competitive, project-based funding streams from other sources can be leveraged e.g. Research Councils, charities or (at present) European Union funding. HEFCW estimate that QR investment facilitates the capture of more than 60% more funding from the UK Research Councils and around 180% more funding from other sources including UK industry, UK central government and the EU.[2] These two streams of funding form the dual-support system, which is used in all nations of the UK and so highly valued as fundamental to a stable and sustainable R&I ecosystem that it was enshrined in law in the Higher Education and Research Act (2017).

3.6.2. QR bridges the gap between project income and Full Economic Costs (FEC) on competitive funding streams and enables universities in Wales to compete on more equal terms with other universities in the UK and overseas. Grants provided by the Research Councils, for instance, are expected to meet 80% of the FEC of the research undertaken. The QR funding provided by the HE Funding Bodies helps institutions meet the remaining 20% of the costs of research funded by the Research Councils.[3]

3.6.3. The stability and resilience of QR funding that cannot be provided by unpredictable and time-limited funding competitions allows universities to retain academic and other support staff.

3.6.4. QR is un-hypothecated, which means it's flexibility plays a critical role in supporting the kind of long-term, speculative inquiry that leads to the significant breakthroughs fundamental to economic growth; discoveries such as fibre optics, stem cells and graphene, the development of technologies like computers and the internet, and life-changing medical breakthroughs. This academic freedom is also key to attracting and retaining the best researchers from around the world – the ones likely to win funding competitions at UK and international levels.

3.7. The implications of a reduction – and even just maintenance - of QR funding in

[2] HEFCW Response to the consultation on the Welsh Government Budget 2016/17

[3] See HEFCW Circular W16/42HE here.

Wales were summed up in the Reid Review:

> *"Stagnation or reduction of core QR funding in Wales unavoidably undermines research competitiveness and brings consequent reductions in funding leveraged from UK-wide and international sources. In turn that dilutes the attractiveness of Wales to the most talented researchers, risking a spiral of decline. Only Welsh Government can provide this underpinning resource: no alternative source of core funding for university research is available".*

3.8. QR funding in Wales was effectively £71m (after taking into account HEFCW's funding adjustment) for 2018/19. The pro-rata equivalent allocations for research and innovation funding, scaled by population size (as used in the Barnett formula) are £117m in England and £164m in Scotland i.e. For a university in Scotland, their funding council is allocating more than twice as much funding for R&I than HEFCW will be pro-rata in Wales. Scotland and England also continued to have higher pro-rata levels of capital funding.

4. **Q2:** Welsh Government has said it wants to bring all research funding together and that this funding should then be available to small and medium-sized enterprises (SMEs), large private businesses, and other organisations as well as universities and colleges. **To what extent should businesses and other organisations be able to receive Government research funding that might have otherwise gone to universities and colleges? How could this be done without under-funding some organisations – might there be unintended consequences?**

4.1. Expenditure on research and development (R&D) is a key indicator of countries' innovative efforts. The ongoing process of innovation improves and increases the rate of technical progress in the economy and is widely recognised as an important source of productivity growth, which is ultimately a key determinant of regional economic growth.

4.2. The overall level of investment in R&D in Wales is low and has been for some time, as recognised by Welsh Government.[4] The most recent figures for R&D expenditure show that Welsh Government's net expenditure on R&D, not including the R&D funding to universities via HEFCW, was £12m in 2016. Scotland's equivalent net expenditure on R&D, based on the relative size of its population, was £95m.[5] Para 3.6 above shows the underfunding of research funding to universities via HEFCW is also putting Wales at a comparative disadvantage to other UK nations.

4.3. The Reid Review states that "this shortage of research capacity along with other factors, contributes to low levels of productivity in Wales compared to the UK and many other OECD countries". [6]

4.4. Universities Wales strongly recommends that overall investment in R&I Wales is increased – both for universities and for businesses. We fully support the Welsh

[4] Welsh Gov publication 'Innovation Wales' 2014
[5] Analysis of UK Government net expenditure on R&D by flow of funds and department 2016 from ONS
[6] Reid Review p.12

Government's commitment to the recommendations given in the Diamond Review to maintain QR funding at 2016 levels in real terms and re-introduce innovation funding in Wales,[7] and their 'in principle' commitment to the Reid Review's recommendations that further funds should be made available for both universities and businesses for additional R&I activities.

4.5. As outlined above, R&I is an ecosystem and therefore taking already comparatively low levels of funding from one part to give to another will not create any net benefit and will result in damage. Universities Wales recommends that funding is not redistributed by allowing businesses and other organisations to receive Government research funding that might have otherwise gone to universities and colleges, but to increase overall investment in R&I, as recommended by the Reid Review.

4.6. The underfunding of research and innovation for higher education in Wales has been compounded by the fact that funding for research and innovation in England has increased:

- QR funding in England increased by £26 million in 2018/19
- The Higher Education Innovation Fund (HEIF) was increased by £40 million in 2017/18 (of which £15 million was non-recurrent) and by a further £25 million in 2018/19, taking the total for HEIF in England to £210 million per annum. Research England intends to further increase HEIF to £250 million by 2020/21 in order to support the ambitions of the Industrial Strategy. In Wales, the equivalent of HEIF – HEFCW's Innovation and Engagement Funding - had to be phased out entirely in 2013/14 because of funding constraints.

Whilst Wales has high levels of productivity from its science and research base, the relatively low level of funding when competing for UK funds matters e.g. when trying to find match to cover the full economic cost of research bids (usually around 20%).

5. **Q3:** In a recent review into research funding, it was argued that there was a strong risk of university research and innovation interests overshadowing the research and innovation interests of private businesses. But it didn't then go on to suggest a way of stopping this happening. **What needs to be done to ensure businesses and their interests are not over-shadowed by universities when it comes to research and innovation funding and activity?**

5.1. We assume this is a reference is to a point of the Reid report on the implications of including responsibility for funding business innovation within the Research and Innovation Wales (RIW) Committee of the new Commission. This is a specific observation and we would be concerned if this were to be taken out of context.

5.2. Welsh Government's technical consultation on the Commission was not clear, and were in fact contradictory, in defining the scope of Research and Innovation Wales.

[7] 2016 levels: QR £71.1 million; PGR £5.2 million. Reductions to HEFCW budgets means that that a continuation in real terms was not achieved in either 2016/17 or 2017/18 (a pro rata reduction of £15.4 million to QR/PGR in 2016/17; and a reduction £8.6 million to QR/PGR in 2017/18).

For example, the consultation states *"RIW should be able to pursue and fund any eventuality across all activities listed in both groups below and not on an exclusive basis. It is intended to allow either the Welsh Government to fund all R&I activities (as listed in both the groups below) and to allow RIW to do the same, or any combination of both, without prejudice to either."* This is one of a number of concerns that will need to be addressed before a Bill is laid and we strongly recommend that the Welsh Government further involves stakeholders in the development of the proposals and on the official groups that will look at and develop draft legislation.

5.3. Aside from the formation of the Commission, in examining both business and university R&I interests it is crucial for the Committee to understand that the research and innovation funding landscape is rapidly changing following the publication of the Welsh Government's Prosperity for All Economic Action Plan and the UK Government's Industrial Strategy. In particular, the UK Government has committed to raise total UK-wide R&D investment to 2.4% of GDP by 2027 and as such has invested an extra £2 billion a year for R&D by 2020-21, the vast majority of which will be awarded competitively. The Reid Review proposed action to deal with the shortfall in our research capacity, so that Wales can compete on an equal footing with the rest of the UK and compete for these new opportunities for funding. Reid was clear on the need to prioritise early investment in our research and innovation base. Otherwise, he argued, we will miss the opportunity to make our universities competitive, and therefore sustainable, in a post-Brexit landscape. We strongly recommend that Welsh Government implements the Review's recommendations urgently and does not wait for the formation of the new Commission before acting.

5.4. Business research and innovation activity is arguably at a low level (as covered in Q2) but needs appropriate support from Welsh Government programmes. The Reid Review recommended the establishment of a St David's Investment Fund that would incentivise collaboration between HE, FE and business, though the provision of core infrastructure funding and three industry-led "innovation hubs".

5.5. We would also highlight to the Committee that charities and the public sector are also an integral part of the R&I ecosystem and crucial to delivering benefit to Wales. Universities work closely with Public Health Wales, Natural Resources Wales and others to create social and economic benefit through innovation.

6. **Q4 & Q5:** In the academic year 2016/17 there were 241 graduate start-ups reported by Welsh universities with an estimated turnover of £56 million, this was almost double the turnover of university staff start-ups in the same year. **What is currently in place from universities and Welsh Government to help and support student and graduate entrepreneurs turn their ideas into successful ventures? Is this support systematic and consistent across Wales and is there more Welsh Government and others could do?**

6.1. Wales has a successful track record in encouraging graduate start-ups. Despite having 5% of the UK higher education sector, Wales has 12.4% of graduate start-ups and, as of 2016-17, there are 1,543 active graduate start-ups in Wales. Note: the

figure quoted in the consultation (241) relates to only *new* graduate start-ups[8]. Furthermore, 10.6% of all active staff start-ups are in Wales with an estimated 14.2% of the employment in staff start-ups across the UK.

6.2. Universities across Wales have various support structures in place to support student and graduate entrepreneurs. Many courses will include modules around industry or collaborative modules with other subject areas. Part-time and flexible learning courses also allows individuals to learn alongside pursuing their own entrepreneurial ideas. Universities will also have enterprise teams or departments that support students and graduates in their aspirations including through funding, business planning, working space or ad hoc advice and support.

6.3. At a recent roundtable for Welsh Government to meet a number of graduate start-ups in Wales, the graduate start-ups specifically referenced the following as valuable support from a university:

- Being offered office space at their university during their initial time as a start-up
- Being offered financial support by their university to grow their business
- Being given opportunities to work in a collaborative space and meet people with different/complimentary skillsets
- Being supported by a course coordinator or member of an enterprise team through the process of starting a business.
- The multi-disciplinary approach within universities that gives opportunities to work with people from other subject areas at university or after leaving university.

6.4. At this same roundtable, the graduate start-ups referenced the following as areas for improvement or further consideration by Welsh Government:

- The work space opportunities that were on offer via Welsh Government funded support were restricted by location but more suitable work spaces (outside Cardiff) were provided by universities.
- Additional seed funding would have enabled the start-ups to grow more quickly but some of the requirements to accessing funding from Welsh Government sources were based around age, which had prohibited some of those attending from accessing funding.
- Those attending the roundtable noted that some of the support they had received from non-university organisations had been generalist support and that they would have benefitted from more industry specific advice.
- All those attending noted said they would welcome greater peer-to-peer learning opportunities with other start-ups.

6.5. It is important to note how important the creative industries are for graduate start-ups in Wales and that businesses have reported that they need a wide skillset from their employees, not solely STEM.

6.6. HEFCW previously supported provided underpinning support for entrepreneurship

[8] Higher Education – Business and Community Interaction Survey (HE-BCI) 2015-16

activity (including student and graduate entrepreneurship) via its Innovation and Engagement Fund but this fund was withdrawn in 2013/14 (further information in our response to Q7).

7. **Q6:** The recent review of research made recommendations to help incentivise businesses and universities to work closely together on research and innovation to take their collaborations to "greater heights". **What are businesses and universities able to offer each other when they work in collaboration on research and innovation projects?**

7.1. Both the types of university and business collaboration, and the benefits resulting from them, are wide ranging. The CBI guide to business-university collaboration[9] outlines the benefits for business, which can be summarised as:

- Reduced cost and risk
- Access to new ideas and horizon scanning
- Support in developing research skills, capability and profile

Universities also benefit in many ways, for example:

- Enhanced impact of research
- Enhanced education opportunities for students
- Access to specialist or industrial scale facilities and equipment

7.2. Practically, the types of collaboration can range from the simple sharing of resources to the creation of complex multi-partner programmes. At its simplest, collaboration can encompass the provision or sharing of equipment, knowledge or other resources. It also includes Knowledge Transfer Partnerships, contract research (where a business commissions research from a university) and collaborative research projects that involves an element of funding from a Research Council, Innovate UK, the EU or other public sector source. Our universities also make a vital contribution to ensuring that Welsh businesses and public sector organisations are staffed and supported by highly skilled individuals, and collaboration on skills can include working directly with students, offering placements and sponsored doctorates, sponsoring degree courses and developing workforce skills through bespoke programmes and professional development.

7.3. Our universities play a central role in the City and Growth Deals and regional partnerships in Wales, committing to boost the impact of their research activity through these highly valuable collaborations. (Further information in Annex 1).

7.4. Of course the benefits of university-business collaboration go beyond their own interests, with significant benefits for Wales, including:

- Attracting foreign investment
- Job creation – both directly and indirectly through their supply chains
- Developing new products and services that change people's lives, benefitting communities e.g. making more efficient use of public resources, and growing

[9] Best of both worlds: Guide to business-university collaboration. CBI 2015

regional economies.

There are case studies of different types and benefits of university-business collaboration in Wales included in Annex 2.

7.5. It is very important for the Committee to understand that the context in which the report was talking about taking collaboration to “greater heights” was under the assumption that HEFCW’s Innovation and Engagement Fund should be re-introduced in order to enable such collaboration.

7.6. In terms of reaching “greater heights” it should be noted that the Reid Review recommendations were designed to ensure that our ambitions should not be limited to playing catch up with the competition in the rest of the UK but to also enable Wales to “leap-frog” levels of investment in research and innovation elsewhere, and reap corresponding levels of economic and societal impact as a result.

8. Q7: Should Welsh Government and others be doing anything differently to bring smaller businesses together with universities to collaborate on research and innovation projects? What is working well and what isn’t?

8.1. Universities play an important role in collaborating with and supporting SMEs, both in R&D and skills. However, it is especially resource intensive as it greatly depends on quality relationships and people. The greatest tool Welsh Government has in bringing SMEs and universities together is HEFCW’s Innovation and Engagement Funding (IEF). As covered in para 4.6, Research England intends to further increase HEIF to £250 million by 2020/21 whereas HEFCW’s Innovation and Engagement Funding - had to be phased out entirely in 2013/14 because of funding constraints from Welsh Government.

8.2. We would encourage Welsh Government to recognise the role of universities in the Welsh economy and to maximise their potential as national assets. Universities are keen to work more closely with government and business – a successful tripartite relationship has the potential to transform the Welsh economy. An example of this is the role of universities in building regional clusters (see Annex 3 for an example of this in the development of a Compound Semiconductor Cluster).

8.3. It is very important for the Committee to note the role of European Structural and Investment Funds (ESIF) in supporting innovation in universities and business in Wales. Most of Wales’ ESIF funding (over £1.1 billion) will come via the European Regional Development Fund, which includes a budget of £310 million to support research and innovation. It is crucial for Wales’ future prosperity that replacement funding has a high proportion of R&I funding.

9. Q8: What should Welsh Government and others be doing to help businesses use the knowledge gained from research activity and turn it into marketable products or improved services?

9.1. Universities already help businesses use the knowledge gained from research activity and turn it into marketable products or improved services, but could do much more with the reintroduction of HEFCW's Innovation and Engagement fund, as recommended by the Diamond and Reid Reviews and covered above.

9.2. One key way to ensure research and innovation activity is turned into marketable products that have a transformational impact to Welsh society and contribute to the Welsh economy, is focussing on supply chains, with business and universities working together to effectively market and distribute innovative inventions. For example, the partnership between Cardiff University and Panalpina World Transport Ltd was established to develop a demand-driven inventory forecasting model to facilitate inventory reductions. Together they developed a tool to analyse Panalpina's customer supply chain and identified opportunities to reduce inventory, free up cash and improve service levels. The project was graded outstanding by Innovate UK and clearly demonstrates the gains to be made from innovative university-business collaboration.

9.3. Welsh Government should have a role at a strategic level to create the right conditions for success with regard to connecting universities and businesses. For example, we support the Committee's own report 'Industry 4.0 – The future of Wales' that recommended that work is done to identify the expertise and commercial strengths that exists in Wales (e.g. in compound semi-conductors, insurance and healthcare) and that a review is needed of Welsh Government support to companies in Wales who are seeking support from the UK funds for R&D. However, there will be a limit to the practical support that Welsh Government can give, and we recommend that through setting strategic policy, accompanied by appropriate funding that they empower, not control, universities and businesses to deliver results.

ANNEX 1 - City and Growth Deals

1. Cardiff Capital Region and Swansea Bay City Deals

1.1. Cardiff City Deal (£1.2bn) - The UK Government announced that it will provide £50m to help develop the compound semiconductor technology of the future as part of the UK Government's City Deal investment. Cardiff university and Cardiff-based compound semiconductor specialist IQE will spearhead the UK national 'catapult'. However, the university's involvement is expected to go much further. The City Deal foresees the potential for investment in other areas in which the university is able to offer expertise, such as software development and cyber security, energy and resources and health and wellbeing. The deal also includes support for the region's infrastructure including the delivery of the South-East Wales Metro and the Valley Lines Electrification programme.

1.2. The Swansea Bay City Deal (£1.3bn) - The Internet Coast, the Swansea Bay City Deal, aims to turn the whole of the region into a digital super hub to transform the regional economy, the future of energy and transform the way health and social care will be delivered in future. It aims to create 10,000 new jobs and increase the value of goods and services produced in the region by £1.8bn. There is potential available for the area, and wider Wales, to be lead in new technologies such as wireless 5G connectivity.

1.3. Swansea University has been heavily involved in all 11 Internet Coast projects, with particular leadership in the projects focused on:

- The Life Science and Well-being Campuses, and Life Science and Well-being Village projects, to support innovative growth of the life science sector
- The unique ARCH (A Regional Collaboration for Health) project - already established to develop the region into a globally relevant ecosystem for integrated Open Innovation in Life Science and Well-Being
- The Factory of the Future Initiative Growing Smart Manufacturing practice
- The Steel Science Centre at Tata's Port Talbot Steel Works
- Swansea University's SPECIFIC Innovation & Knowledge Centre

2. Growth Deal for North Wales

2.1. Bangor University is heavily involved in the development of a North Wales Growth Deal, working with the North Wales Economic Ambition Board, its members and partners across the region, including the North Wales Business Council, Mersey Dee Alliance and other Universities and Colleges, to put together a strong proposal which will drive growth across the region.

2.2. Given its considerable strengths in teaching, its research expertise in sectors such as Science, Engineering and Sustainable Energy, and its strong

collaborative network, Bangor University is a catalyst to ensure that investment under the Growth Deal delivers real growth in GVA not just in the north west but along the entire north Wales region.

2.3. The north Wales economy is closely connected to the major developments planned in the Northern Powerhouse, and Bangor University's involvement will assist the region in leveraging the benefits of that investment. Post Brexit, the opportunities to capitalise on the region's connectivity with Ireland will also be key, and the university also has a substantial amount of expertise which will assist the region in that respect.

2.4. Bangor University's expertise in developing high-level skills, R&D, Knowledge Transfer, Innovation and Commercialisation will be central to the success of the Growth Deal in North Wales. Bangor University is also ensuring that valuable research and knowledge assets created by HEIs are translated into real economic gains: high value jobs, increased exports and successful growth patterns by North Wales firms in priority sectors such as Energy, Environment and Advanced Manufacturing.

2.5. The effect of the North Wales Growth Deal could be to create real growth and momentum in high value business sectors. The University's expertise and involvement in the energy sector is a good example of how Bangor University will be a focus for innovation and development in this area. It is heavily engaged in a number of low carbon energy projects in the region, including the estimated £12bn investment in the new BWR nuclear reactor at nearby Wylfa, as well as a new biomass power station, a number projects involving marine renewable energy and a number of other projects.

ANNEX 2 - University – business collaboration case studies

BioComposites Centre: Innovation in biomaterials for industry

BioComposites Centre combines the technical and academic resources of Bangor University with a practical and commercial outlook to offer a fully rounded package of research, innovation and application for biomaterials technology. The Centre has unique facilities that enable them to take an idea from bench to pilot scale.

BioComposites Centre undertakes collaborative research projects to develop sustainable biobased technologies that will minimise the impact of materials on the environment. Working with large multinationals, SMEs, micro companies and research institutes interested in lowering their global warming potential.

BioComposites Centre is a self-financing concern with real knowledge of the demands of industry and the need to be pro-active, flexible and competitive. Established in 1989, the Centre has a track record in delivering projects successfully. This is backed by experience and expertise from dedicated professional scientists, technologists and managers that are client focused. With such a long history there are numerous cases studies of successful industrial partnerships.

The biggest success came from the work to develop new anti-corrosive coatings with Liverpool based paint company, Beckers – taking an idea from lab to pilot scale. The Beckers Group is a global industrial coatings company that employs almost 1,800 people over 24 manufacturing sites and makes specialist coatings to protect surfaces. A key drive for change in this industry is the reduction in chromate additives that stop metal rusting. Working together new compounds were developed that could replace these chromate additives. Using accelerated weathering tests the best compounds were selected for trials on Beckers' pilot-scale coating line. Steel was coated using the primers and will now be tested outdoors to see if the coating can outperform the older chromate paints.

Senova Ltd and the Institute of Biological, Environmental and Rural Sciences

Research carried out at the Institute for Biological Environmental and Rural Sciences (IBERS) at Aberystwyth University has led to the development of new and improved varieties of oats which can reduce heart disease and have produced benefits for the UK economy. These oat varieties contain high levels of beta-glucan, offering enhanced health benefits. IBERS' strategic alliance with Senova Ltd, a dominant player in cereals, oilseeds and pulses, seeks radical changes to existing oat varieties through breeding and research aimed at novel valuable genetic recombinants.

Varieties developed by the IBERS oat breeding programme seek to contain higher levels of beta glucan than other oat varieties and therefore offer enhanced health benefits to society as 65% of all oats used in the UK have been developed at IBERS. The research has also led to the development of more nutritious animal feed, leading to better productivity for farmers.

The work of IBERS at Aberystwyth University has received royal recognition and was a recipient of The Queen's Anniversary Prize for Higher and Further Education for public good plant breeding in 2009. IBERS now has a substantial number of commercial oat varieties registered under UK Plant Breeders' Rights and Community Plant Variety Rights and available for marketing by Senova. Through Senova's marketing activities, IBERS' contribution to the oat market generates around £123 million each year. Additionally, its oat varieties generate £19 million in gross value added for the UK economy and support around 800 jobs in the UK supply chain (2014 figures).

Airbus Centre of Excellence in Cyber Security Analytics

Cyber security is a priority research area at Cardiff University, supported with strategic investment. Since 2012 Cardiff has established an interdisciplinary research team of technical and social researchers. Collaborative projects have received more than £5 million in funding from UK Research Councils (Engineering and Physical Sciences Research Council and Economic and Social Research Council), Welsh Government (Endeavr Wales) and industry (Airbus).

The collaboration has led to the development of the Airbus Centre of Excellence in Cyber Security Analytics. Cardiff University researchers partner experts from Airbus to carry out world-leading studies into machine learning, data analytics, and artificial intelligence for cyber-attack detection.

The centre works across industry, academia and government to provide a focus for cyber security analytics in the UK. As the first centre of its kind in Europe, the aim is to strategically position the UK as a leader in cyber security analytics.

Collaboration covers areas of mutual interest to the Cyber Operations Team at Airbus and Cardiff University, including data science, big data analytics, machine learning and artificial intelligence. The Centre opened in 2017 and builds on a mutual agreement to develop industry-relevant academic programmes in cybersecurity at the University, to fill the skills gap that currently exists in the field. Knowledge sharing between Airbus and the University is also supported, with opportunities for secondments and industrial placements for researchers and students.

In August 2018 it was named as an Academic Centre of Excellence in Cyber Security Research by the UK's National Cyber Security Centre, becoming the first institution in Wales to be given this status. The award is in recognition of the internationally excellent research developed at the University over a number of years and will allow academics to feed directly into the UK Government's strategy of making the UK more resilient to cyber-attacks.

Creative industries: USW front door always open to industry

The University of South Wales is a powerhouse for the creative economy in Wales. Their Faculty of Creative Industries in the heart of Cardiff is a 'porous' facility, a space where the front door is always open to industry, where professionals feel they can come, use the facilities, share their ideas and show how they work.

The Creative Industries Research Institute delivers excellent research that makes a significant impact on culture, civil society and the industries themselves. In the most recent UK research assessment exercise all of the Institute's research was deemed to have world-leading or internationally excellent impact. The Institute works closely with academic partners from around the world and have long-established ties with partners in the arts, broadcasting, and third-sector organisations. Research spans both traditional academic publications and practice-based outputs including exhibitions, films and performances.

The University is a rich resource for the UK's creative industries, from the major production studios and BBC at Roath Lock, to the abundant ecosphere of smaller specialist creative businesses set up by graduates.

Key elements of each student's education are interaction with industry, and simulation of the professional environment, developing of an individual's personal network and profile through a close link with industry, whether it is through one-to-one teaching by professional performers or work placements, guest lectures, and industry collaboration.

To strengthen industry connections the University of South Wales has three BBC Fellows, drawn from many different areas of specialism, who bring their industry experience to influence teaching and course development.

Advanced Sustainable Manufacturing Technologies: Embedding advanced and sustainable technologies into Welsh manufacturing

Advanced Sustainable Manufacturing Technologies (ASTUTE) supports the stimulation of ideas in the Welsh manufacturing sector through provision of resources, facilities, advice and guidance exploiting the wealth of world-class research in Welsh universities in close research collaborations with industry. It is a collaboration of four Welsh universities; Swansea University, Cardiff University, Aberystwyth University and the University of Wales Trinity Saint David.

In its first round of funding (2010-2015), the project supported more than 250 Welsh enterprises in West Wales and the Valleys, supporting them towards long term sustainability and competitiveness, the most evident improvements experienced by companies were improved processes, accelerated research and development, improved growth prospects and new product developments. The final evaluation of the first phase of ASTUTE concluded that its work created economic impact of well in

excess of £200 million in West Wales and the Valleys showing that for each £1 invested an outstanding return of over £8 of economic impact was achieved.

Phase 2 (2015-2020) has been part-funded by the EU through the Welsh Government. ASTUTE 2020, the five-year operation, will support industrial research, development and innovation through world-class academics and a team of highly qualified technical experts and project managers.

ASTUTE 2020 is designed to stimulate growth in West Wales and the Valleys by applying advanced engineering technologies to manufacturing challenges, driving cutting-edge research, development and innovation. ASTUTE 2020 will collaborate with the high-value manufacturing industry to stimulate transformational and sustainable growth by facilitating and de-risking the development and adoption of advanced technologies, increasing competitiveness and future proofing.

Demand-led by industry, ASTUTE 2020's focus is on collaborative industrial projects with a research challenge that will bring economic benefit to the area. ASTUTE 2020 will focus only on where it can specifically contribute established world-leading and internationally excellent expertise found across the Welsh universities' partnership to address the industrial research, development and innovation needs:

- Advanced Materials Technology
- Computational Engineering Modelling
- Manufacturing Systems Engineering

ASTUTE 2020 builds on the most successful aspects of the previous ASTUTE project from 2010 to 2015. ASTUTE has successfully demonstrated that it is in an excellent position to support companies via knowledge exchange and intensive collaborative research, development and innovation projects in manufacturing technology. Over 250 Welsh small to medium-sized enterprises (SMEs) benefited from ASTUTE's assistance helping generate more than £9 million in increased manufacturing investment for Wales, stimulated the creation of 174 new jobs and initiated the set-up of ten new enterprises.

Knowledge Economy Skills Scholarships: Developing and retaining research and development skills to strengthen the Welsh knowledge economy

Knowledge Economy Skills Scholarship (KESS) is a major European Convergence programme led by Bangor University on behalf of the higher education sector in Wales. The programme benefits from European Social Funds, KESS supports collaborative research projects (research master's students and PhD) with external partners based in the West Wales and the Valleys. It has an integrated higher-level skills training and development programme, leading to a Postgraduate Skills Development Award. The first phase of KESS provided 453 PhD and master's degree places (230 PhD and 223 research master's degrees) with Welsh organisations, of which 61% were SMEs.

Following the highly successful KESS I programme (2009-2014), KESS II is now running, a major pan-Wales programme developing and retaining the research and development skills needed to strengthen the knowledge economy in Wales, which will provide 645 scholarships over the course of six years. It will enable over 500 businesses to work with academics and postgraduate research students on innovative research projects aimed at driving business growth. The key objectives of KESS II are to:

- Increase the research capacity of small to medium enterprises (SMEs) by linking with a PhD or research master's project;
- Encourage SMEs to undertake research and recruit researchers;
- Prepare and train individuals to contribute to research as professionals;
- Support the development of key technologies in the Convergence Area of Wales; and
- Promote higher-level skills development.

The partners range from SMEs to large companies, social enterprises and public bodies. Examples include Tenovus Cancer Care, Natural Resources Wales, Tata Steel, S4C, National Botanic Garden of Wales, Mencap Cymru, Halen Môn, Qioptiq Ltd., P&S Nano Ltd. and the Tidal Lagoon Swansea Bay. KESS II projects keep the needs of the participating businesses at their heart. The programme offers a low cost means by which a company can engage in a research project, together with the opportunity to develop a long-term relationship with a university. KESS II also provides a platform to access the latest academic developments and a chance to develop in-house research and development activities.

KESS II is part of a transnational network. Students benefit from dynamic interactions with other research students and their industrial partners at some of Europe's leading universities. Collaborations between businesses and universities contribute significantly to the future employability of students, and the students value the experience of the company context. The majority of KESS graduates are now working in industry.

ANNEX 3 - Developing a Compound Semiconductor Cluster

The Institute of Compound Semiconductors at Cardiff University is part of a multi-million-pound development to create Europe's first cluster for compound semiconductors and position Cardiff as the UK and European leader in the field.

The Institute has benefitted from several large-scale investments including £13 million from European Structural Funds, £17.3 million from the UK Research Partnership Investment Fund and £12 million from the Welsh Government. All of which will help fund the University's new Translational Research Facility, due to open in 2021, on its Innovation Campus.

The Institute was formed following the joint venture between Cardiff University and IQE which was established in 2016 to create the Centre for Compound Semiconductors which focusses on materials and commercial development.

The vision is for Cardiff University to be a founding and key partner in the development of the first compound semiconductor cluster in Europe. Providing the small to medium scale fabrication capacity to complement activity at other cluster partners, with the expertise and capability to translate academic excellence through to practical, manufacturable devices and integrated subsystems with the ultimate aim of generating economic impact through commercial and academic exploitation of compound semiconductor technologies.

In August 2018 the UK Government announced funding to expand the catapult centres developing a range of cutting edge new technologies across the UK which included further funding of £51.3 million for the compound semiconductor catapult in Cardiff. The catapult vision is to bridge the gap between ambitious businesses and the academic expertise of the UK's world-class research communities and will support the development of the compound semiconductor cluster.