



Llywodraeth Cymru
Welsh Government

Wales: Protecting research and innovation **after** EU exit

Securing **Wales'** Future

Contents

Foreword	1
<hr/>	
Executive Summary	2
<hr/>	
Research and Innovation: Drivers of economic and social prosperity	4
Investing in R&D to grow productivity	
Wales: Growing a strong research base in support of economic development	
<hr/>	
The Impact of Brexit for Wales' Research and Innovation base	8
UK R&D Funding	
EU Funding	
European Research Funding (2000-2018)	
Wales' Universities	
<hr/>	
International engagement: Growing Research beyond borders	22
Research Publications	
European Collaborations: Horizon 2020 Funding	
<hr/>	
Conclusion	29
<hr/>	
Annex 1: Wales' Research and Innovation Performance	30
<hr/>	
Annex 2: Translating research and innovation into business	46
<hr/>	
Annex 3: Growing Wales' research capacity pipeline	58
<hr/>	

Foreword



Mark Drakeford AM
First Minister of Wales



Kirsty Williams AM
Minister for Education

Over the past 20 years, Wales has grown consistently the volume, quality, impact and international reach of its research base. We are now among the most efficient research performers converting relatively small levels of funding into highly regarded research.

This impressive performance stems from a long standing collaboration between Welsh Government, universities and business using a mix of HEFCW, Research Council, and targeted EU Structural Investment Funds.

This has allowed our research base to grow to a point where the impact of Wales' published research outperforms other parts of the UK and similar sized countries internationally. In 2014, Wales obtained the highest share of international collaboration of UK nations, with nearly 70 per cent of publications involving co-authors outside of Wales.

Brexit poses a substantial threat. Nearly 80 per cent of our total EU funding for research and innovation come from Structural funds and we can have no confidence that the UK Government will make up this deficit.

The UK Government has plans to introduce a Shared Prosperity Fund but has not yet set out details about the value of the fund and how it will operate for the devolved nations.

Money is not the only issue. Research and innovation depend on researchers and innovators passing freely across borders. Welsh Universities have established a reputation for working internationally and it is vital that the UK's post-Brexit migration regime does not damage Welsh Universities or businesses.

In this document, we explain why research and innovation are so important to Wales and how it has contributed to our economy. The Welsh Government is committed to working with others and doing all it can to secure outcomes which protect Wales and our prosperity now and in the future.

Executive Summary

There is compelling evidence that research and innovation generate large and lasting returns for the economy¹. Economic growth generates the taxes that enable the delivery of high quality public services that helps countries prosper.

Wales has a proud history of leading and supporting cutting-edge research and innovation. Wales is a globally engaged nation for research that has managed, over the past 20 years to grow the volume, quality, and international reach of its research base.

The Welsh research and innovation base is a national asset, delivering economic, social, cultural and health benefits for Wales, and collaborators around the world.

Wales' small but effective research base, however, is vulnerable to competitive global pressures and competing priorities. As we leave the European Union (EU), the need to build on our strengths to maximise the return on high impact research and innovation that supports the Welsh economy has never been more important.

Wales' research and innovation performance has resulted from a mix of funding from UK Research Councils, the Higher Education Funding Council for Wales (HEFCW), charities, EU research funding and Welsh Government support.

*The Reid Review*² (2018) highlighted, that while **...‘the research and innovation ecosystem in Wales is strong and includes strikingly successful examples of university-business collaboration and research impact’...‘the research base does not have the scale needed to deliver its full potential to the people of Wales’.**

Unlike most of the UK, which secures EU funding for research and innovation through competitive Horizon 2020 programmes, the review noted that Wales secures most of its EU research and innovation funding from the EU Structural Funds.

During the current Programme funding period (2014-2020), the Welsh Government has invested £340m in Research and Innovation priorities. This represents 20 per cent of all EU structural funds allocated to Wales and continues to play a vital role in growing Wales' research capacity and infrastructure³.

Given that Wales receives only 2 per cent of overall UK R&D funding⁴, the loss of EU structural funds will have a significant and disproportionate impact on future research and innovation investment for Wales.

The loss of EU structural funds poses a significant threat to the research base that Wales has been growing successfully over the past decade. *The Reid Review* argued for additional funding from both Welsh and UK Governments for universities and businesses to ensure that Wales continues to have the ability to adapt to the post-Brexit funding environment.

The Welsh Government has a clear record of investing in Wales' research base as demonstrated by the internationally recognised *Sêr Cymru* programme. But Welsh Government funding alone, even with increasing success in the nationally competitive UKRI funding system cannot compensate for the loss of EU structural funding.

¹ *Our Plan For Growth*, HM Government, 2014

² <https://gov.wales/docs/det/publications/reid-review-en.pdf>

³ Data includes commitment and spend at ERDF and ESF level

⁴ <https://gov.wales/statistics-and-research/research-development-expenditure/?lang=en>

The UK economy cannot be rebalanced from London. If the UK government is serious about accelerating growth and productivity, this will require the replacement of EU Structural Funds to help counter the historical higher level funding in research and innovation towards London and the south-east. The Welsh Government in *Securing Wales' Future*⁵ (2017) calls for the replacement of EU funding with UK funding. We are committed to investing at least the current levels of funding to research and innovation from the replacement arrangement to EU funding.

In keeping with the UK Industrial Strategy's commitment to rebalance the UK economy while not compromising on research excellence, we call upon the UK Government:

To make good, promises made in the EU referendum campaign to ensure Wales is not a penny worse off as we leave the EU. This will require a permanent upward adjustment to the Welsh Government baseline of at least the levels received historically via the EU Structural and Investment funds with no spending constraints.

To negotiate full and continued access and participation to the range of post-2020 EU Research and Innovation (FP9) Horizon Europe and Erasmus+ programmes.

To secure ongoing access to the European Investment Bank Loan finance.

Ensure a research-friendly migration system that facilitates a free flow of researchers across borders, with guarantees for the EU nationals working in our universities, and continued student mobility.

To bring together Ministers and their officials from the Welsh Government, Scottish Government, the Northern Ireland Executive and the UK Government for economic policy matters on an ongoing basis designed to enhance cross-UK coordination and cooperation in the areas of research and innovation.

⁵ <https://beta.gov.wales/sites/default/files/publications/2018-10/white-paper-securing-wales-future.pdf>

Research and innovation are recognised twin drivers for competitive economic advantage and driving productivity. The importance of developing an innovative and knowledge based society, built upon research and innovation, is regarded as an integral factor of driving global competitiveness and an indispensable element of national government policies intent on sustainable economic and social improvement⁶.

Welsh and UK excellence in research and innovation brings major economic, social and health benefits by underpinning industries, creating jobs and applications that improve the quality of lives and enrich cultural wellbeing⁷. Businesses that invest in research and other forms of innovation tend to have higher productivity, create high quality jobs and are more likely to export⁸.

In the USA, over the past 50 years, scientific and technological advances produced roughly half of all economic growth and currently 75 per cent of the fastest growing occupations require STEM skills and knowledge⁹.

Evidence from the National Academies show that research and innovation have a global reach that underpins and sustains successful science diplomacy, where the quality of a nation's science base is an attractor for multinational R&D businesses.

The UK Government has shown that 50 per cent of productivity growth between 2000 and 2008 was largely due to innovation: firms that consistently invested in R&D were 13 per cent more productive than those that did not.¹⁰ Publicly funded R&D

creates a strong 'multiplier effect' that produces 'crowding-in' from the private sector, charitable and inward investment, stimulating around 30 per cent more self-investment from industry¹¹. There is evidence that every £1 spent by government on R&D, resulted in private sector R&D output rises of 20p per year in perpetuity¹².

There is also a strong association between public sector funding and private involvement in research. Over the past decade, many countries, such as China, Canada, France, Germany, Israel and South Korea, have strategically invested in their research base with the objective of accelerating the research and innovation cycle considered critical for economic growth and global competitiveness.

The contributions of research and innovation to economic productivity, population health and social well-being are well documented¹³. In adopting the 3 per cent target spending of gross domestic product (GDP) for public and private sector R&D in 2002, the European Council expected that the policy would 'have a significant impact on long-term economic growth and employment in Europe, to the order of 0.5 per cent of supplementary output and 400,000 jobs per year after 2010'¹⁴. The proposed new EU research and innovation programme, Horizon Europe, with a budget comprising some €100billion is similarly designed to build on the achievements and success of Horizon 2020 and keep the EU at the forefront of global research and innovation.

⁶ Investing in World Class Science and Research, BIS, May 2014

⁷ Investing in UK R&D, Royal Society

⁸ Our Plan For Growth 2014

⁹ STEM: Australia's Future, 2014. In the UK, STEM is estimated to underpin at least a quarter of the UK's gross domestic product (CASE, 2011)

¹⁰ <https://publications.parliament.uk/pa/cm201516/cmselect/cmsctech/340/34006.htm#footnote-071>

¹¹ <https://publications.parliament.uk/pa/cm201516/cmselect/cmsctech/340/34006.htm#footnote-071>

¹² Haskel, Hughes and Bascavusoglu-Moreau, 2014

¹³ Haskel, Hughes et al. 2014, Reid 2014, 2018

¹⁴ <https://publications.parliament.uk/pa/cm201516/cmselect/cmsctech/340/34006.htm#footnote-071>

Since the 1980s, there has been an increase in total gross expenditure on research and development (GERD) as a proportion of GDP across OECD countries, reflecting the growing importance placed on R&D expenditure and innovation as key drivers of productivity and economic growth¹⁵.

In addition to knowledge production, one of the pervasive positive aspects of growing a country's academic research base is the production of highly skilled people, trained in a knowledge-rich environment, with relevant competencies and abilities covering a diverse range of careers across the economy¹⁶.

Investing in R&D to grow productivity

In preparing to leave the European Union, the UK Government's Industrial Strategy placed research and innovation firmly at the heart of growing the UK economy, recognising the integral role that research and innovation plays for many of the UK's competitors¹⁷. Consequently, despite tight control over public spending, the UK Government in 2017 committed significant investment in research and innovation, boosting public spending on research and development (R&D) to £12.5 billion in 2021-2022, an increase of £500 million on the year before¹⁸. This funding is explicitly linked to the need to increase the productivity of the UK economy and comprises part of a wider plan to grow total UK investment in research from 1.68 per cent in 2015 to 2.4 per cent of GDP in 2027 and then to 3 per cent over the longer term.

The UK however will leave the EU as the most regionally unbalanced economy in Europe. The UK has areas that have never fully recovered from deindustrialisation, remaining trapped, with poor infrastructure and low investment and skills¹⁹.

The UK has the largest regional economic disparity in GDP per person of any of the 28 EU Member States. In 2016, Inner London West had a GDP per head of 611 per cent of the EU average, while West Wales and the Valleys' GDP per head was 68 per cent of the EU average, the lowest of all of the UK NUTS2 regions²⁰. The productivity of most of these areas has lagged behind that of London and the South East for a long time, creating an imbalance that is increasingly seen as unsustainable²¹.

According to the Industrial Strategy Commission (2017) the future performance of the UK economy will be held back by this high degree of regional imbalance. The UK Government's own Industrial Strategy emphasises 'place' as one of its five foundations of productivity improvement. A new UK-wide 'Shared Prosperity Fund' is currently being developed, as a direct successor to Structural Funds but the scale and allocation remain currently unknown²².

¹⁵ Halligan and Bright, 2015, <https://www.lfhe.ac.uk/en/research-resources/research-hub/2015-research/the-case-for-growing-stemm-research-capacity-in-wales.cfm>

¹⁶ The Future of research, 2010 <https://www.universitiesuk.ac.uk/policy-and-analysis/reports/Pages/the-future-of-research.aspx>

¹⁷ <https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future>

¹⁸ <https://www.nature.com/news/uk-government-announces-research-spending-hike-ahead-of-budget-1.23028>

¹⁹ <https://www.theguardian.com/science/political-science/2017/nov/01/the-uk-has-the-most-regionally-unbalanced-economy-in-europe-time-for-change>

²⁰ National Assembly for Wales, 2018, Enterprise, Infrastructure & Skills Committee

²¹ <https://www.theguardian.com/science/political-science/2017/nov/01/the-uk-has-the-most-regionally-unbalanced-economy-in-europe-time-for-change>

²² Bachtler, 2017, <https://onlinelibrary.wiley.com/doi/full/10.1111/pirs.12351>

Wales: Growing a strong research base in support of economic development

In 2012, the Welsh Government announced an ambitious new science strategy. *Science for Wales*, was designed to accelerate efforts to create a globally competitive science and technology base intended to create jobs, spark new businesses and draw more interest from industry to stimulate the economy. The Welsh Government's five-year vision planned to invigorate Wales' economy by building upon strengths in life sciences and health; low carbon, energy and environment; and advanced engineering and materials, and launched the internationally recognised **Sêr Cymru** capacity-growing research programmes.

In 2017, the Welsh Government published its economic strategy, *Prosperity for All: Economic Action Plan (EAP)*²³. This amplification of the *Programme for Government* was designed to secure a more competitive, prosperous and fair economy, by driving sustainable growth that generates the resources to secure a prosperous future for Wales.

The EAP is clear that '*The engine of this economic growth and social progress is research, innovation and the development of the right skills for a changing world*'²³.

Mindful of Brexit, in 2017 the Welsh Government commissioned Professor Graeme Reid, of University College, London, to review the strengths, gaps and future potential for Wales to sustain and grow its strong research and innovation activity. Professor Reid's *Review of Government Funded Research and Innovation in Wales (2018)* (*Reid Review*) highlighted that, while the research and innovation ecosystem in Wales was strong and included strikingly successful examples of university-business collaboration and research impact, it lacked the scale needed to deliver Wales' full potential.

Moreover and unlike most of the UK, which secures EU funding for research and innovation through competitive Horizon 2020 programmes, Reid noted Wales' historic reliance on EU Structural Funds for research and innovation.

The *Reid Review* set out the case for an incentive and reward system that involved additional funding from the Welsh and UK Governments, for universities and businesses to ensure that they had the ability to adapt to the new UKRI highly competitive funding environment and significant post-Brexit loss of EU Structural Funds. The key messages that the Welsh Government took from the *Reid Review* include the need to:

- Increase the visibility and influence of Welsh research and in particular press forward with 'a dedicated London presence to promote Welsh Research and Innovation'²⁴.
- Ensure that Wales had parity in the levels of un-hypothecated research and innovation funding, compared to the rest of the UK. This was designed to strengthen the current Welsh research base, to enable Welsh researchers to compete for a greater share of new UKRI-wide funding by implementing the 2017 recommendations by Sir Ian Diamond, for QR funding and knowledge exchange funding and, in addition, creating a fund specifically that could incentivise Welsh researchers to win greater funding from outside Wales.
- Increase the coherence and impact of research and innovation support for **business support**. This involved creating a new fund under a single new overarching brand designed to grow the scale of activity and achieve more effective engagement with investors, outside the Welsh Government, post-Brexit.

²³ <https://gov.wales/topics/businessandconomy/economic-action-plan/?lang=en>

²⁴ <https://gov.wales/about/cabinet/cabinetstatements/2018/ReidReview/?lang=en>

Given the small scale of the Welsh research base, it is not realistic that increased success in the nationally competitive UKRI funding environment alone, would be sufficient to grow or even maintain Wales R&D, at the levels of previous EU structural funding. Consequently, the Welsh Government confirmed its commitment in June 2018 to implement Reid's three proposals but only using funds ***secured alongside the UK Government*** as part of a post-Brexit settlement for the nations and regions of the UK, in keeping with the UK Government's plans to rebalance research spending across the country, in pursuit of accelerating regional growth and productivity.

The Welsh Government's position, outlined in *Securing Wales' Future* (2017), states how important it is that EU funding is replaced by an upward revision to the Block Grant, managed by the Welsh Government.

UK R&D funding

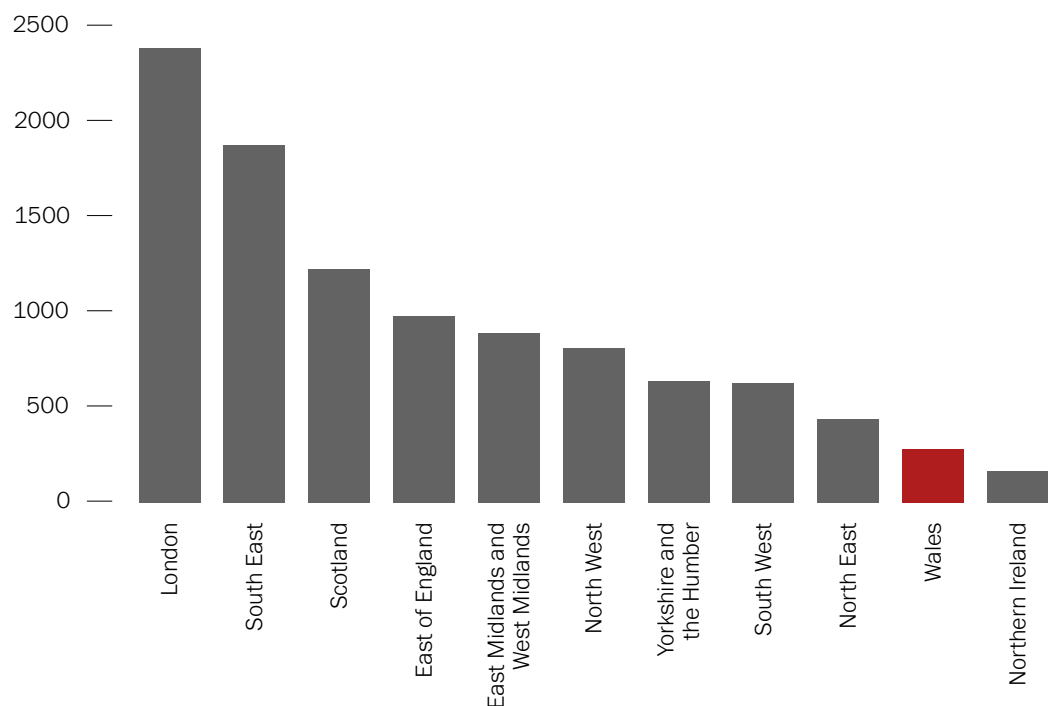
In 2016, most of the UK's Gross Domestic Expenditure on Research and Development (GERD) was carried out in England (89 per cent) with the South East and East of England accounting for some 37 per cent of expenditure (£12.3 billion). In the same year, Scotland accounted for £2.3 billion (7 per cent), with Wales securing £0.7 billion (2 per cent) and Northern Ireland £0.6 billion (2 per cent)²⁵.

Despite the impressive research and innovation performance outlined in Annex 1, Wales' level of R&D investment is, significantly below that of the UK and

EU averages. Gross Expenditure on Research and Development (GERD) in Wales is one of the lowest of the 12 UK regions, both for GERD as a per cent of GDP (Research intensity) and GERD per head of population.

Over the past 18 years, structural funds allocated by the Welsh Government to R&I have contributed to growing Wales international research base and wider international collaboration. Brexit will bring an end to the significant EU Structural funds and in particular funding directed at research and innovation activities distributed across several interlinked EU programmes across Wales.

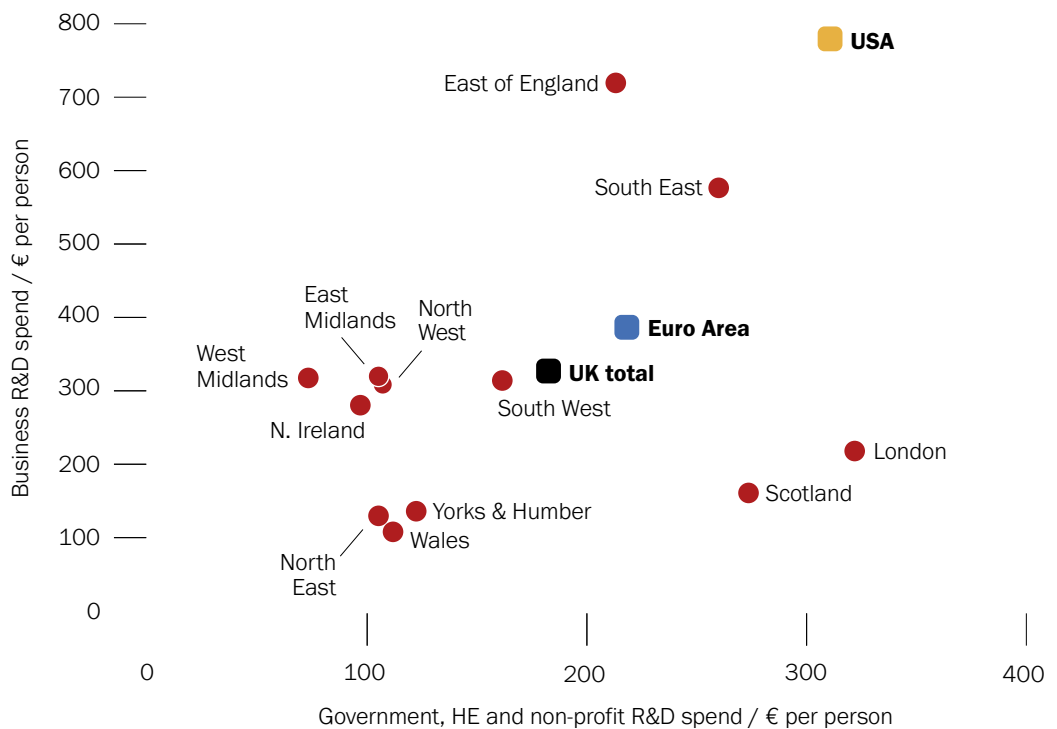
Figure 1:
Gross Expenditure on R&D by UK region, 2016, £m



Source: ONS

²⁵ <https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2016>

**Figure 2:
Business and
Government/
Higher Education
R&D in the UK by
NUTS 2 Regions**



Source: Eurostat, Updated March 2016

EU Funding

In budgetary terms, Wales is a net beneficiary of EU membership, currently receiving about £680 million in EU funding each year²⁶. Not only is this funding hugely important for driving the Welsh Government's economic action plans, but it also provides a platform to leverage additional resources from both public and private sources when perusing a coherent regional approach for economic development.

During the period 2014–2020, Wales will benefit from over £2 billion of Structural Funds. Over the most recent framework period (2014-2018), 20 per cent of the ERDF and ESF proportion has been allocated to research and innovation²⁷. This equates on average to approximately £60 million per annum.

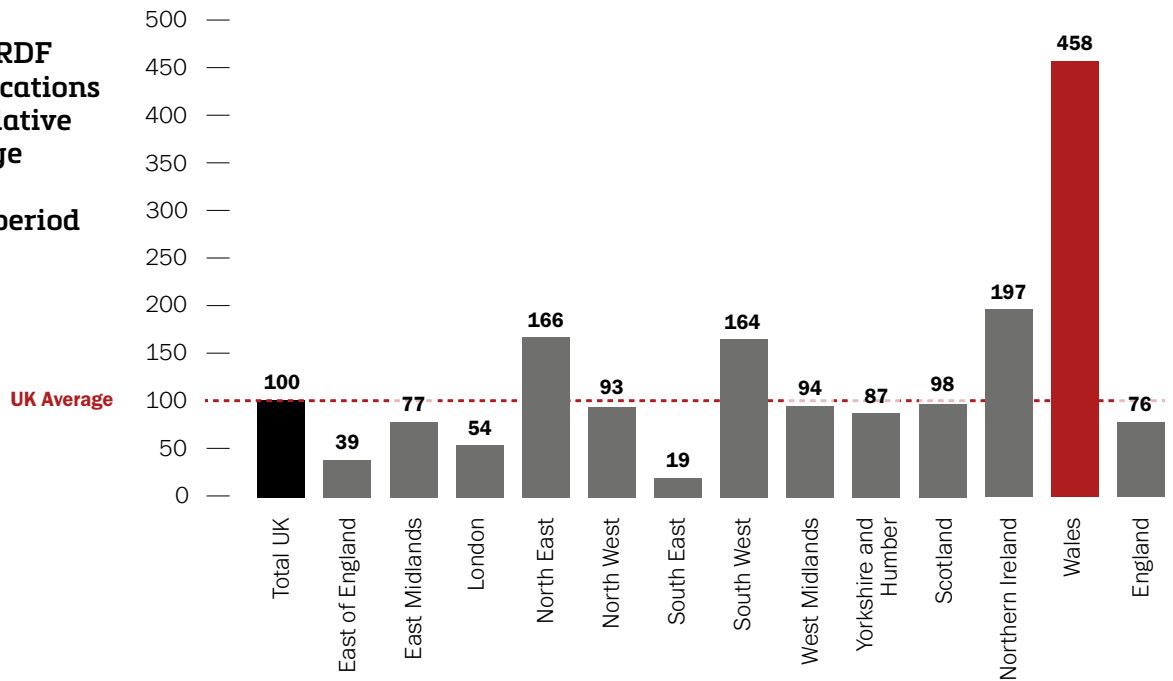
As can be seen from Figure 3, Wales will receive the highest allocations in absolute and per capita terms from ESF and EDRF funding in the UK between 2014-2020.

Unlike the rest of the UK which secures most of its EU funding for research and innovation from the competitive Horizon 2020 programme, Wales secures 79 per cent of its total EU funding for research and innovation from structural funds.

²⁶ Securing Wales' Future, 2017. <https://beta.gov.wales/sites/default/files/publications/2018-10/white-paper-securing-wales-future.pdf>

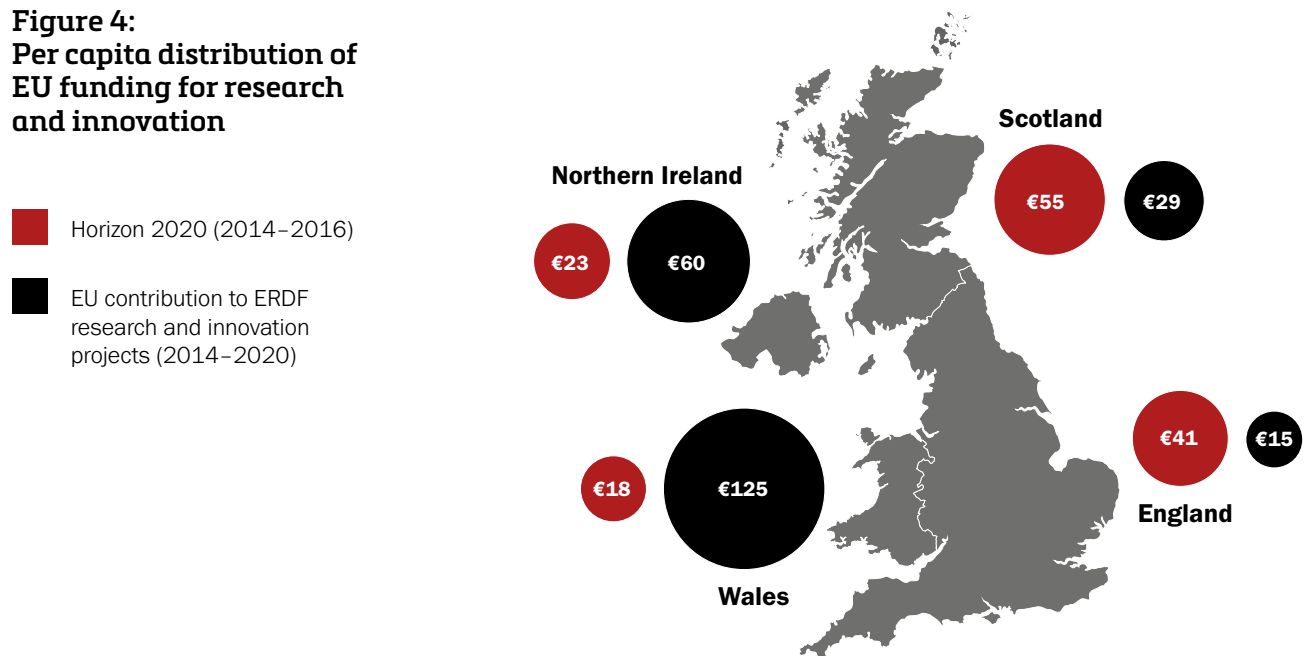
²⁷ Data includes current commitment figures up to 31 October 2018

Figure 3:
Per capita ERDF
and ESF allocations
by region relative
to UK average
(UK=100),
2014–2020 period



Source: ONS - <http://speri.dept.shef.ac.uk/wp-content/uploads/2016/05/Brief24-UK-regions-and-European-structural-and-investment-funds.pdf>

Figure 4:
Per capita distribution of
EU funding for research
and innovation



Source: ONS - <https://royalsociety.org/~media/policy/Publications/2017/2017-05-technopolis-role-of-EU-funding-report.PDF>

Although England secures the largest overall share of EU funding for research and innovation, after adjusting for different country populations, Wales is expected to achieve €125 per capita, (see Figure 4 more than five times the UK average (€23 per capita) and almost 10 times the figure for England (€15 per capita) underlining the importance of European Structural Funds for Wales (Technopolis 2017)).

Brexit will bring a significant reduction in overall UK R&I investment. Any loss of structural funding on this scale, unless addressed, will disproportionately threaten Wales' productive research and innovation ecosystem, having managed over the past two decades to catch up and outperform other UK countries and many similar sized countries and regions in Europe and internationally in terms of research publication impact.

The implications of a UK withdrawal from the EU therefore are likely to impact upon all aspects of Wales' research and innovation activity. Key concerns include:

- Loss of structural funds and potentially competitive EU funding for research and innovation.
- Increased barriers to recruiting talented European staff.
- Damage to international research collaboration.
- Increased barriers to recruiting European research students.
- Reduced outward mobility opportunities for staff and students.

Whilst many of these are shared challenges for other UK regions, Welsh universities will be disproportionately disadvantaged by projected losses of Structural Funding given the high level of historical dependency. Universities in Wales receive a significant amount of funding from EU Structural Funds and this has provided vital investment and

funding for projects and infrastructure that contribute towards economic and social growth in Wales.

EU Structural Funds have also played an important role in addressing the shortfall in UK research and innovation funding in Wales, by comparison with other regions of the UK.

European research funding (2000-2018)

EU funding currently provides support for research and innovation from three main sources:

- i. competitive **EU Framework Programmes** (e.g. Horizon 2020/Framework Programme 8) – programmes created by the European Union/European Commission to support and foster research in the European Research Area (ERA);
- ii. the **European Structural and Investment Funds** (ERDF & ESF) – designed to support building capacity in the least economically developed regions of the EU; and
- iii. loans from the **European Investment Bank** (EIB) – the only bank owned by and representing the interests of the European Union Member States.

The EU Framework Programmes were designed to support research and innovation on a competitive basis. For the period 2007-2013 (FP 7), the UK was the second largest recipient after Germany, securing €6.9 billion out of a total of €55.4 billion²⁸.

A similar situation is developing in the case of FP8 (Horizon 2020, 2014-2020), with the UK being second to Germany, the most successful of all EU Member States, securing 14.3 per cent of funding (€5.1billion) with 11.7 per cent of participations²⁹. Since 2014, Wales has secured just over €100 million from the current Horizon 2020 Framework Programme.

²⁸ <https://royalsociety.org/~media/policy/projects/eu-uk-funding/uk-membership-of-eu.pdf>

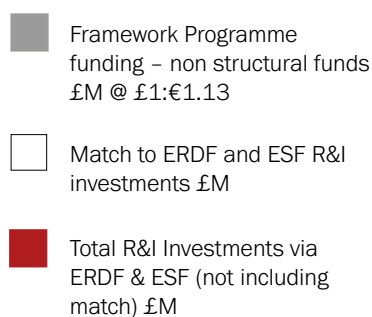
²⁹ [https://webgate.ec.europa.eu/dashboard/sense/app/93297a69-09fd-4ef5-889f-b83c4e21d33e/sheet/PbZJnb/state/analysis down loaded 21 November 2018](https://webgate.ec.europa.eu/dashboard/sense/app/93297a69-09fd-4ef5-889f-b83c4e21d33e/sheet/PbZJnb/state/analysis%20downloaded%2021%20November%202018)

Structural Funds in Wales for Research and Innovation

Under the 2014-2020 programming period, Wales allocated some €388 million of the UK's total €1.5 billion European Regional Development Fund (ERDF) for Research and Innovation, the highest of any of the UK Devolved Administrations³⁰.

Figure 5 provides a summary of the total investment in R&I in Wales from 2000 to 2018 (FP6-FP8) with European funding divided into contributions from structural funds (ERDF and ESF funds), match funding (from the recipients of the awards) and EU Research framework programmes covering the three framework periods. The match funding identified in the figure has been provided by Welsh Government, Higher Education Institutions, Private sector, the third sector and/or local government.

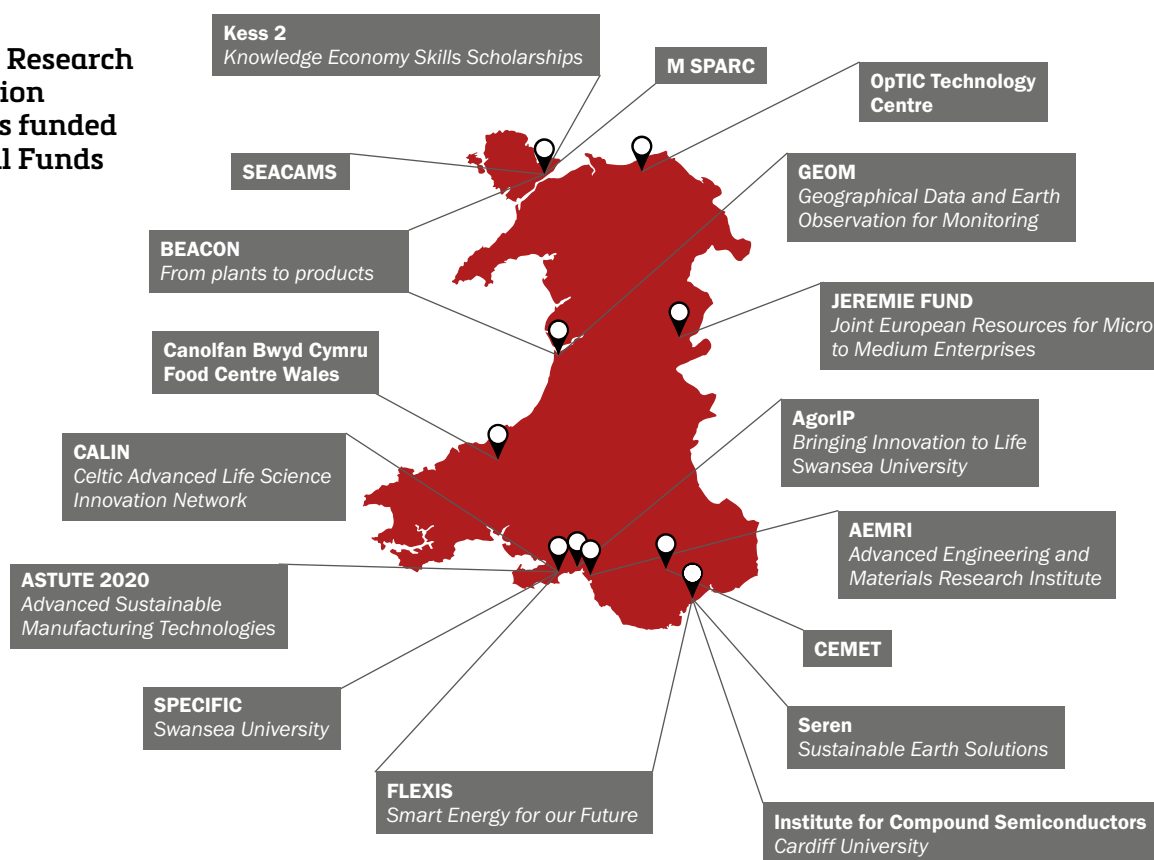
**Figure 5:
ERDF/ESF R&I
Investments
2000-2018
(FP6-FP8), £m**



Source: created from data sourced from WEFO³⁰. An FP is a Framework Programme for Research and Technological Development. Framework Programme 6 was 2002-2006, FP7 was 2007-2013 and Horizon 2020 is the eighth framework programme running from 2014-20.

³⁰ <https://royalsociety.org/~media/policy/Publications/2017/2017-05-technopolis-role-of-EU-funding-report.PDF>

Figure 6:
Examples of Research and Innovation Programmes funded by Structural Funds in Wales



Some examples of where European funding has been awarded are highlighted in Figure 6.

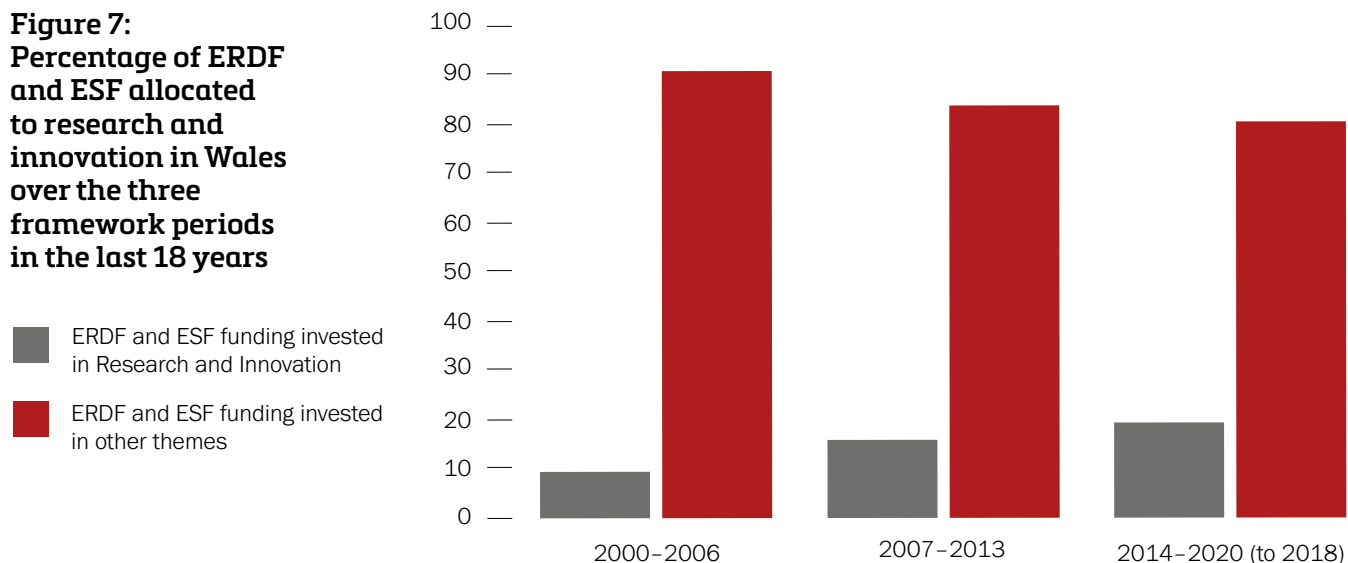
Over the past 18 years³¹, structural funds allocated to research and innovation in Wales have made a significant contribution to growing Wales' international research standing and wider international engagement. The level of structural funds allocated to research and innovation is decided by Welsh Government policy. Figures are agreed by the Welsh Government Cabinet as the basis for negotiation with the European Commission and, as can be seen in Figure 7, the Welsh Government has increased

its commitment to research and innovation via structural funds for each of the 3 framework periods covering the last 18 years.

From a UK-wide level, most EU funding for research and innovation is secured from competitive Horizon 2020 programmes. In Wales, however, over the past 18 years, some 74 per cent of EU funding for research and innovation has come from structural funds.

³¹ To September 2018

Figure 7:
Percentage of ERDF and ESF allocated to research and innovation in Wales over the three framework periods in the last 18 years



Source: Created from data sourced from WEFO.

EU Structural Funds consequently, plays a critical role in growing Wales’ research capacity and facilitating its international research, with Wales expected to be secure around some 26 per cent of the total UK allocation for the 2014-2020 period, more than five times the UK average underlining the importance of European Structural Funds for Wales.

Welsh Government Strategic approach

Wales has taken a strategic approach of using research and innovation regional investment to maximise the value to develop not only the research and innovation landscape but also to achieve greater sustainability for future generations.

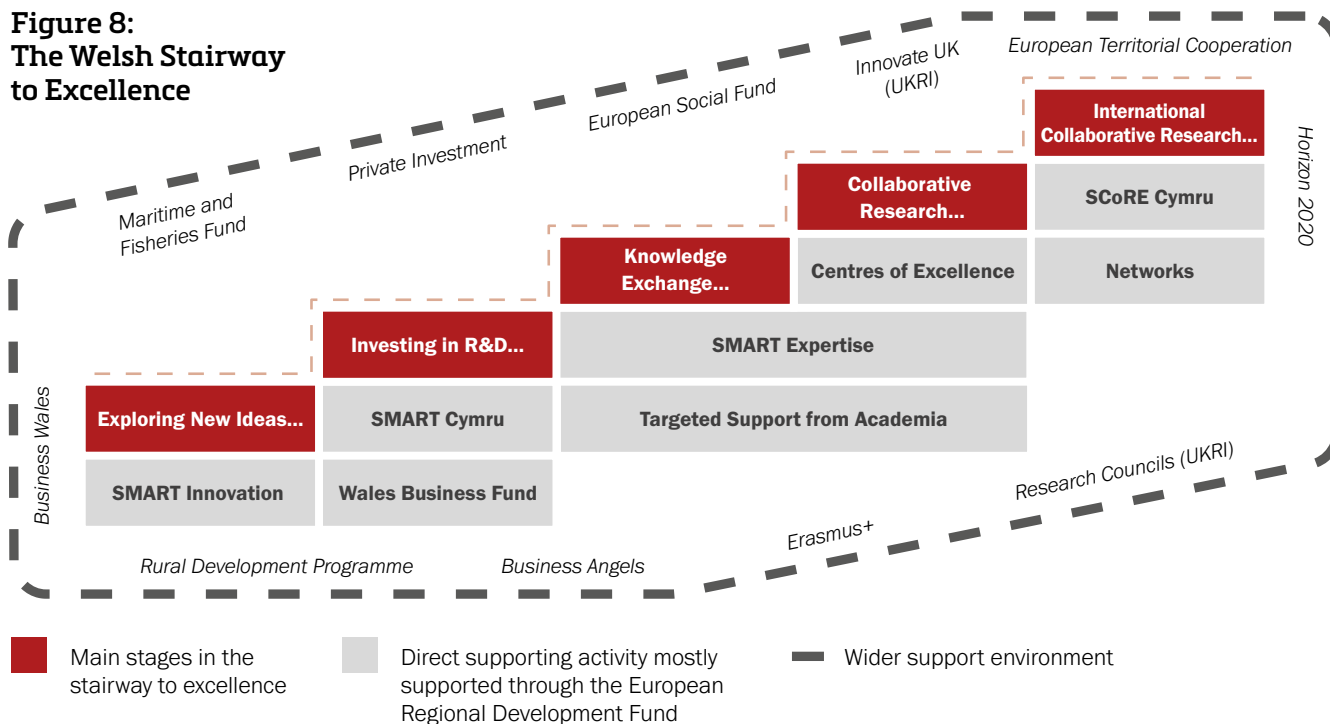
Examples include:

- i. **Stairway to Excellence:** The Welsh Government has adopted a version of the EU’s strategic ‘Stairway to Excellence’ concept, designed to assist the R&I community to address its innovation gaps and facilitate the effective implementation of regional **Smart Specialisation Strategies**³². This enabled the exploitation of the synergies between European Structural and Investment Funds (ESIF) and Horizon 2020 (H2020), as in the Sêr Cymru II programme.

Figure 8 shows how key investments and support are strategically aligned along the ‘Stairway to Excellence’ and where support is made available for Welsh business exploring potential innovation or an excellent research group looking to build an international collaboration.

³² <https://gov.wales/docs/wefo/publications/horizon/180307-horizon-annual-report-2017-en.pdf>

**Figure 8:
The Welsh Stairway
to Excellence**

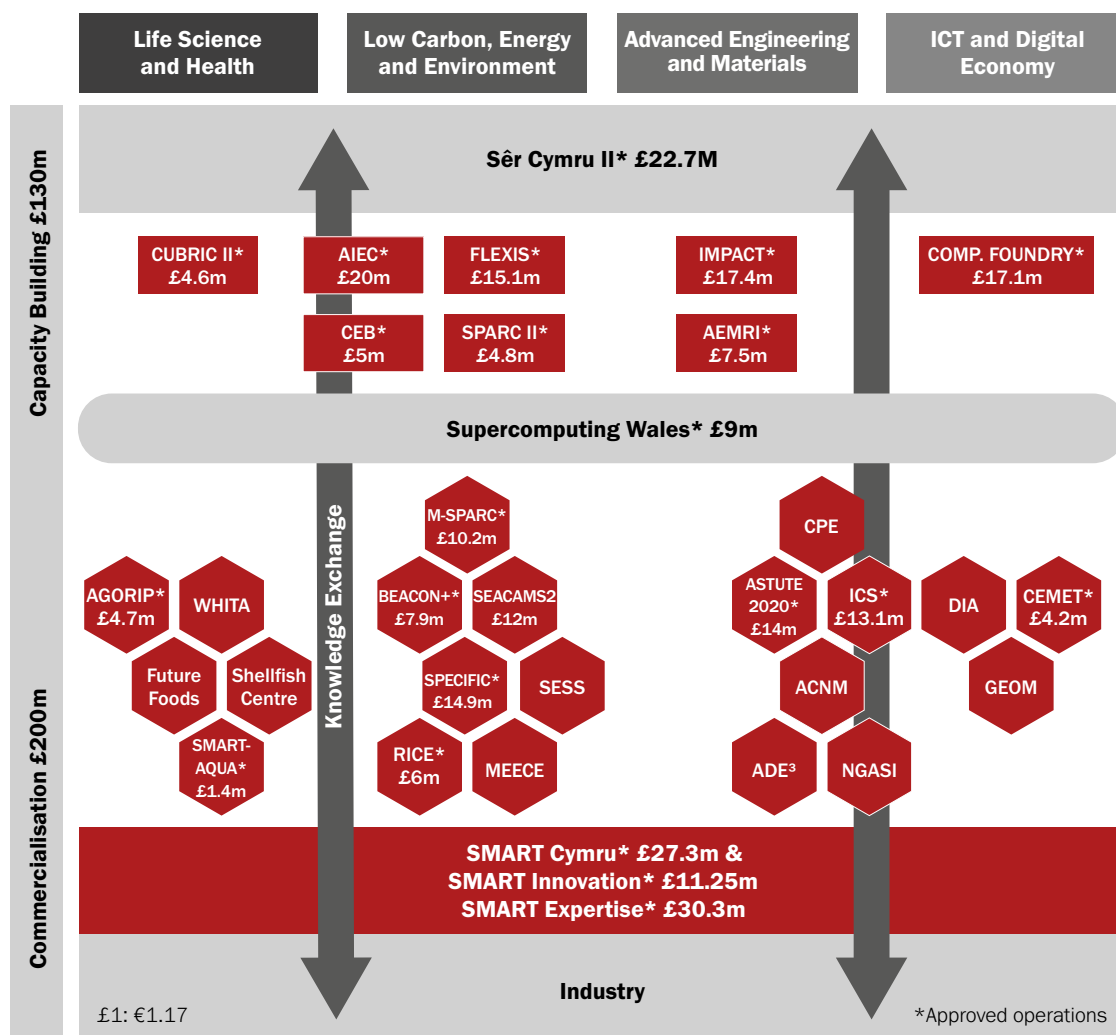


Source: Horizon 2020 in Wales Annual Report 2017 – <https://gov.wales/docs/wefo/publications/horizon/180307-horizon-annual-report-2017-en.pdf> WEF0

ii. **Investment for research and innovation from the EU Structural funds will reach £334 million for Wales between 2014 and 2020.** Some of this investment is shown in Figure 9 below. This includes a significant portfolio of strategic, complementary and specialists investments, covering **Life Sciences, Energy, Advanced Engineering and ICT**. Each investment adds value, helping to target Wales’ Smart specialization programme opportunities while also building on previous capacity investments made during FP7 (2007-2013).

These investments are also delivering significant impact, for example, the current ERDF portfolio has already won over £68 million in competitive research and innovation funding (as of September 2018) with the expectation that this will raise to £230 million by the end of the Operational Programme.

**Figure 9:
Welsh ERDF
research and
innovation
portfolio**



Source: Created from data sourced from WEFO.

iii. Investment across Technology Readiness

Levels (TRLs): Conventional analysis of R&D activity tends to differentiate between pure and applied research often in a university laboratory intent on company-based innovation and downstream commercialisation. One way of further differentiating between these activities is to consider developments in terms of levels or stages of research/innovation development. In engineering, software development, medical research and the commercialisation of new products and services this approach is often used to review progress and consider funding decisions.

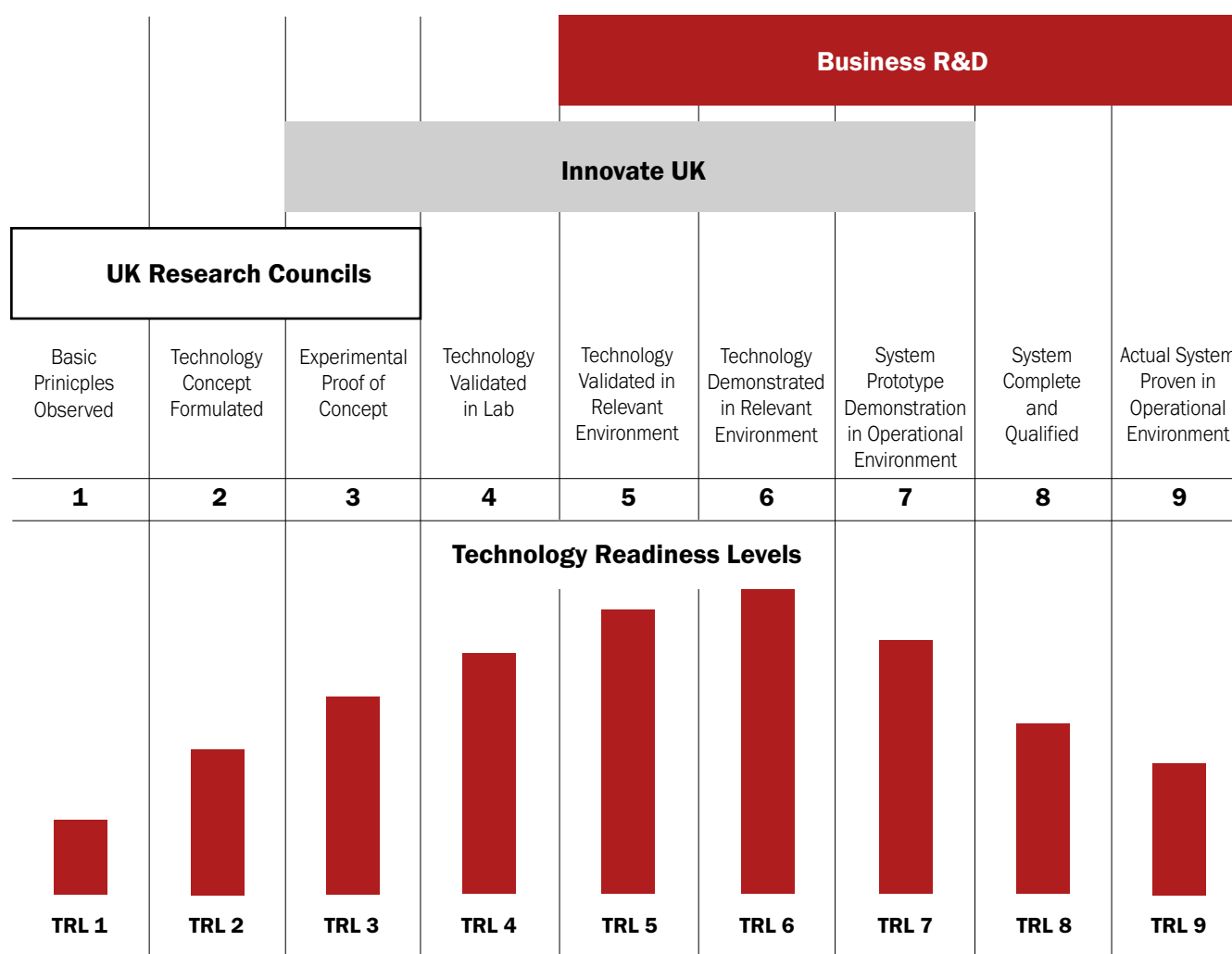
In 2010, the European Commission adopted Technology Readiness Levels (TRLs)³³ following recommendations from the High Level Expert Group on Key Enabling Technologies (HLG-KET), to be used as a policy tool in assessing the development and manufacturing of Key Enabling technologies (KETs) and their potential impact in strengthening Europe's industrial and innovation capacity. Horizon 2020 use the TRL scale as one indicator to better position requested projects across the entire innovation chain.

³³ Communication No. 614 on Advanced Manufacturing, European Commission, 2010

Over the past 18 years in Wales (and covering the 3 Framework programmes 6-7-8) the Welsh Government has employed its EU structural funding to support research and innovation that has coverage across the full TRL spectrum (see Figure 10), but in particular TRL4-7 the stages after basic research and between initial development and early stage commercialisation.

Figure 10 provides a summary of the 134 research and innovation investments supported since 2000 under the ERDF and ESF programmes. Each award was classified according to the main activities supported and then assigned to a range across the overall TRL scale. Figure 10 plots the level of activity under each point of the TRL pipeline, demonstrating the broad range of support covering the full range of the TRL.

Figure 10:
Range of European Regional Development Fund (ERDF) and European Social Fund (ESF) investments in Research and Innovation mapped across the Technology Readiness Levels (TRL) for Wales



Source: Created from data sourced from WEFO.

Project	Description
CUBRIC II – Cardiff University Brain Research Imaging Centre II	CUBRIC II is the expanded Cardiff University Brain Research Imaging Centre employing multi modality state of the art functional and structural imaging.
AGORIP	Brings together academics, clinicians and businesses to pioneer research into cutting-edge technologies, new products, processes and services.
Future Foods	Increasing growth competitiveness and innovation in the Welsh food industry. Promoting consumer well-being through development of healthier products, diets and nutritional services. Assures product quality and safety and protection from food fraud. Encouraging environmentally sustainable practices.
Shellfish Centre	A high profile, internationally-recognised and internationally-connected centre for shellfish-related science and innovation that will develop economic opportunities to drive growth in the shellfish sector in Wales.
SMARTAQUA	Given the scarcity of mainstream sites and the saturated food market, this centre targets non-food aquaculture, including cleaner fish production, fish for medical research and algal-based aquafeeds and nutraceuticals.
AIEC – Aberystwyth Innovation and Enterprise Campus	Construction of a new state-of-the-art, internationally recognised facility to attract further research funding so that companies and researchers can undertake collaborative research projects to boost the bio-economy, with a focus on sustainable food, health, biotechnology and renewable energy.
FLEXIS	World-leading energy research scheme, involving collaborations with industry and research organisations in Wales, Europe and worldwide. The scheme investigates how multiple energy sources can be supplied to consumers through more flexible and efficient systems that integrate traditional and renewable energy sources
SPARC II – Solar Photovoltaic Academic Research Consortium	A five-year research programme at Welsh universities designed to address the key challenges of developing next generation solar photovoltaic technology
CEB – Centre for Environmental Biology	A world-leading facility, developing new biotechnologies for the chemical and advanced materials industries by exploiting biomolecules from extreme environments.
M-SPARC – Menai Science Park	The Menai Science Park (MSparc) was designed to create highly skilled long-term employment opportunities for local people, developing a knowledge-sharing environment and creating an economic hub in sectors such as low carbon, energy and environment and ICT.
BEACON plus	Designed to help Welsh businesses develop new ways of converting feedstocks, such as rye grass, oats and miscanthus (Asian elephant grass) amongst others and waste streams into products which have applications in the pharmaceutical, chemicals, fuel and cosmetic industries.
SEACAMS 2	Collaborative research and development organisation between universities and industry intended to grow Wales' marine science sector and supporting the low carbon economy.
SPECIFIC	Developing and delivering the first examples of buildings as power stations which are able to generate, store and release their own energy both thermal and electrical.
SESS – Smart Energy Storage Solutions	A low carbon energy storage initiative, working alongside businesses to help drive innovation and develop new products, technologies and processes for the commercial market

Project	Description
RICE – Reduced Industrial Carbon Emissions	RICE combines established expertise, in algae conversion and hydrogen generation, with emerging expertise in heat-to-electricity, CO2 capture and chemical waste and their conversion to high value added products, in order to create new enterprises that can be integrated into present energy intensive industries to reduce CO2 emissions
MEECE – Marine Energy Engineering Centre of Excellence	Based in Pembroke Dock, MEECE will enhance an existing Marine Engineering cluster and complement the Marine Energy Test Area (META)
IMPACT	A new building on the Swansea Bay Campus providing an innovative materials, processing and numerical technologies research base
AEMRI – Advanced Engineering and Materials Research Institute	New specialised structural integrity centre to develop and validate advanced engineering materials and low carbon energy innovations using full scale test structures currently unavailable in the UK.
CPE – Centre for Photonics Expertise	CPE aims to unify the Wales Photonics research capability to deliver cross sector, industry driven photonics solutions and strengthen the Photonics market in Wales. Leading to effective improvement in new product and process development for Welsh industry
ASTUTE 2020	Bringing together expertise from across Welsh universities in collaboration with manufacturing companies to support the development and adoption of advanced technologies, increasing growth in the Welsh manufacturing sector.
ICS – Institute for Compound Semi Conductors	This involved building, equipping and running a state-of-the-art cleanroom at the new Institute for Compound Semiconductors (ICS) along with skilled personnel to deliver the research support for the development of new products, processes and services.
ACNM – Avenues of Commercialisation for Nano and Micro-technologies	ACNM is an application from the Centre for Nano Health and the Welsh Centre for Printing and Coating and Cardiff University on the semiconductor side. The centres will deliver a highly skilled service to companies, where they do not have facilities or expertise. Focused on facilitating innovation to make new products, improvement to existing products or processes.
ADE – Advanced Design Engineering	This will be working with Welsh businesses in the manufacturing sector to adopt advanced technology in their process and production
COMP FOUNDRY – Computational Foundry	Construction of a world class centre for computer science research, establishing Wales as a global destination for computer scientists and industrial partners.
DIA – Data Innovation Accelerator	Data science and analytics collaboration between SMEs and Cardiff University to develop and grow business. Companies specialising in ICT and cyber security, advanced materials, energy and eco-innovation.
CEMET – Centre of Excellence in Mobile and Emerging Technology	Helping small and medium sized enterprises (SMEs) to design and test new mobile and emerging technologies to create products and services for commercial success.
GEOM – Geographical Data & Earth Observation for Monitoring	GEOM will help grow the space technology sector through earth observation and navigation. Aiming to increase the number of university / industry collaborations associated with spatial data science and/or downstream space technologies.

Although the UK and all devolved Governments have indicated the strong desire to explore association with the future competitive research and innovation programmes, Horizon Europe (dependent upon an agreed UK financial contribution), Brexit will bring to an end to the EU structural funds to the UK and Wales, unless addressed by replacement funds from the UK Government.

Wales' Universities

A well-educated and skilled population is essential for the efficient creation, acquisition and exploitation of knowledge and an indispensable resource for competitiveness in a country³⁴. Universities play a crucial role in the Welsh economy by conducting world-class research and innovation and developing graduate skills that support local and national economic growth.

Wales' has eight universities, which together with the Open University educate more than 140,000 students every year, ranging from undergraduate and postgraduate degrees to lifelong or work-based learning modules. With academic provision spanning all major areas including Arts and Humanities, Creative Industries, Science and Technology, Business, Education, Social Sciences, Medicine and Healthcare, around half of the university courses are vocational or professional, providing training for teachers, lawyers, doctors, nurses and social workers, as well as the public servants of the future.

Of the more than 26,000 universities worldwide, Wales has 4 universities ranked in the top 500 of the QS World University, one of the highest concentrations of top-ranked universities, in terms of population and GDP per capita³⁵. When compared to other countries of similar population size, Wales ranks third for the number of universities ranked in the top 500 globally, per million population (see Figure 11).

A significant number of Welsh university staff are from the EU. In 2015–2016 1,355 EU staff³⁶ were working at Welsh Universities – more than 10 per cent of the workforce.

³⁴ 'The Relationship between the Knowledge Economy and Global Competitiveness in the European Union' Sustainability 2018,10(6), 1706; doi:10.3390/su10061706

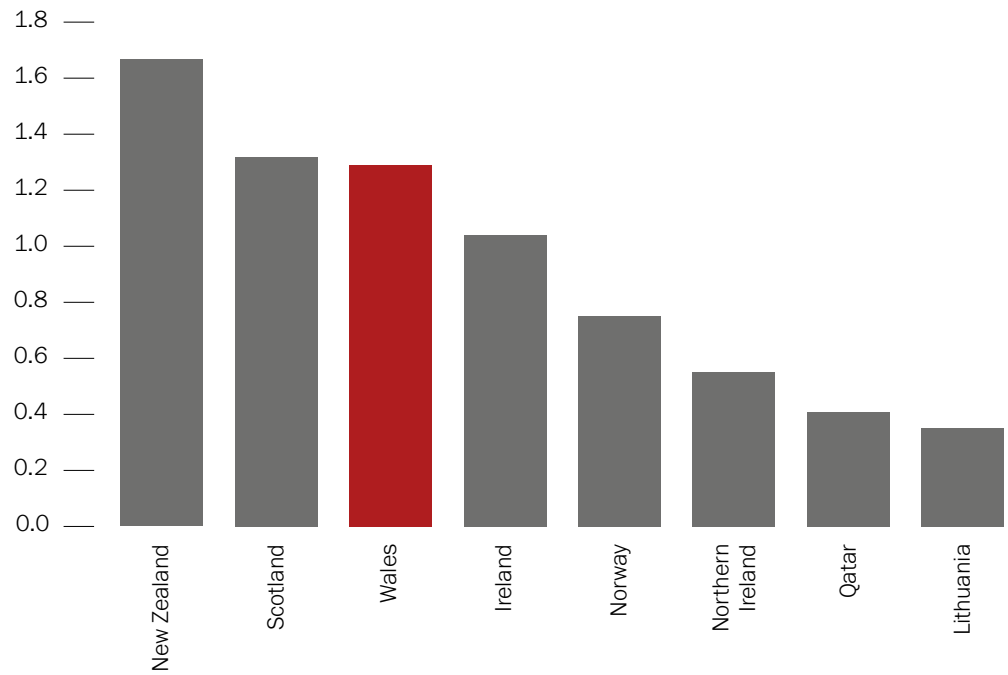
³⁵ *Wales and the World*, Learned Society of Wales, 2017

³⁶ <http://uniswales.ac.uk/wp/media/Unis-Wales-Welsh-Higher-Education-Brussels-response-to-External-Affairs-and-Additional-Legislation-Committee-inquiry-on-Wales.pdf>

In the academic year 2016–2017 there were 6,235 EU students³⁷ enrolled on a higher education qualification in Wales.

Brexit is likely to result in a fall in EU students. Consequently, any decline in EU and international student numbers is likely to impact significantly on Welsh Universities.

Figure 11:
Number of
universities ranked
in the top 500,
per million
population



Source: Welsh Government analysis from QS University rankings and latest country-level population (including 2018 ONS projected population statistics for UK nations taken from 2018 based projections published in Oct 2017).

³⁷ <https://hesa.ac.uk/data-and-analysis/students/where-from#detailed>

As an outward facing, globally engaged nation, Wales recognises the importance of growing international relationships for future prosperity. Wales has a strong and productive history of collaborating with European partners on research, through EU and pan-European initiatives.

The standing of Wales, published research, described in more detail in **Annex 1**, is underpinned by extensive collaborations worldwide, demonstrating the productive outcome of years of international networking. This positive 'nation brand' provides a catalyst for securing future competitive engagement, increasing international influence ('soft power') and stimulating strong international partnerships.

Science and research, are now regarded as important tools for science diplomacy all of which helps generate trust and confidence between nations and regions, and facilitate strategic opportunities for building international relationships including trade. By linking the research community and policy makers around the world, 'science diplomacy' helps translate scientific outcomes for impact and support international relations³⁸.

Continuing to cultivate research partnerships post Brexit will be critical for the general prosperity of Wales and the UK. Faced with global grand challenges such as climate change, ageing populations and infectious diseases, continuing strategic international engagement on research is essential.

Research publications

International collaboration supports cutting-edge research & development in fields, from space exploration to clean energy and medical research, by providing access to infrastructure, expertise, data and population aggregation, on a scale beyond the reach of any one nation³⁹. The principles of excellence and competitiveness, that underpin European collaboration, has helped drive up the quality of research outputs and also contribute to higher skills levels. Partnerships between the UK and other EU Member States have significantly increased the impact and influence of EU science and research activity worldwide.

Researchers have greater impact when they collaborate internationally. EU programmes have helped foster and strengthen scientific cooperation and Wales has been a major contributor. While the UK's decision to leave the EU does not preclude future collaboration, it has the potential to significantly restrict the ability of researchers and institutions to secure funds to work together collaboratively.

A key contributor to Wales' impressive research performance, over the past decade, has been growing its level of international collaborative networking. International collaboration not only accounts for a growing number of the Welsh articles, but also results in high field-weighted citation impact.

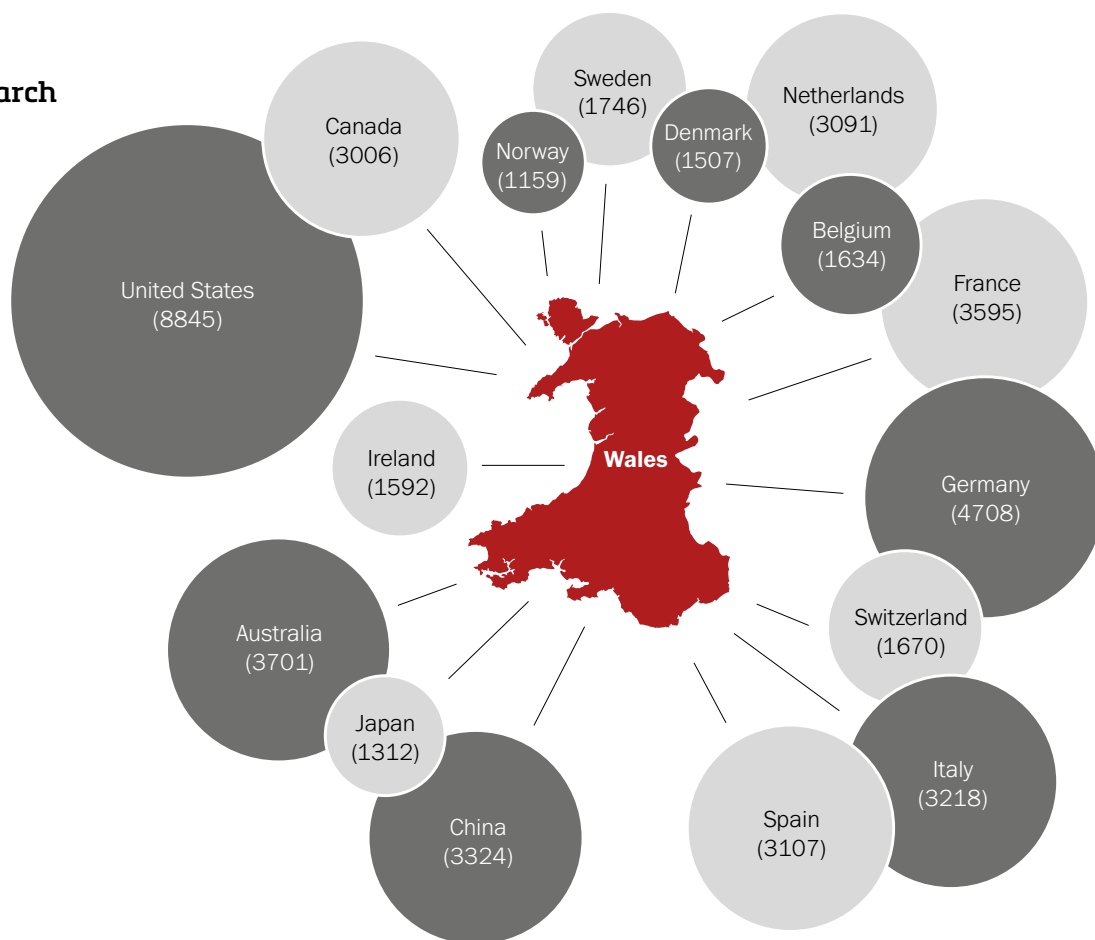
Between 1997 and 2001, about 25 per cent of Wales' research outputs were conducted internationally. By 2016, Wales secured the highest international collaboration share across all UK constituent countries with nearly 70 per cent of its publications involving co-authors outside Wales⁴⁰ (see Figure 12).

³⁸ <https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0568>

³⁹ *Collaboration on Science and Innovation*, HM Government, 2018

⁴⁰ *International Comparative Performance of the Welsh Research Base*, Elsevier, 2014–2016

Figure 12:
Wales' 10 year
world-wide research
publication
collaborations,
2008–2017



Source: Elsevier data base

Research collaboration like this, has mutual benefits for research impact in the countries involved. Welsh leadership in the compound semiconductor (CS) market is well recognised and it was announced last year that a new Compound Semiconductor Applications Catapult will be based in Wales. Two years ago, Cardiff University, IQE, the Welsh Government and the UK Government aligned their visions for CS innovation by committing over £80 million in collective investments, aimed at creating the world's first CS technology cluster in South Wales⁴¹.

According to Elsevier, collaboration with Wales produces above average citation impact for all of Wales' top 25 most prolific international collaboration countries, making Wales an attractive research base to collaborate with⁴².

In terms of **EU collaboration** in 2000, around 12 per cent of Wales' publications had an EU

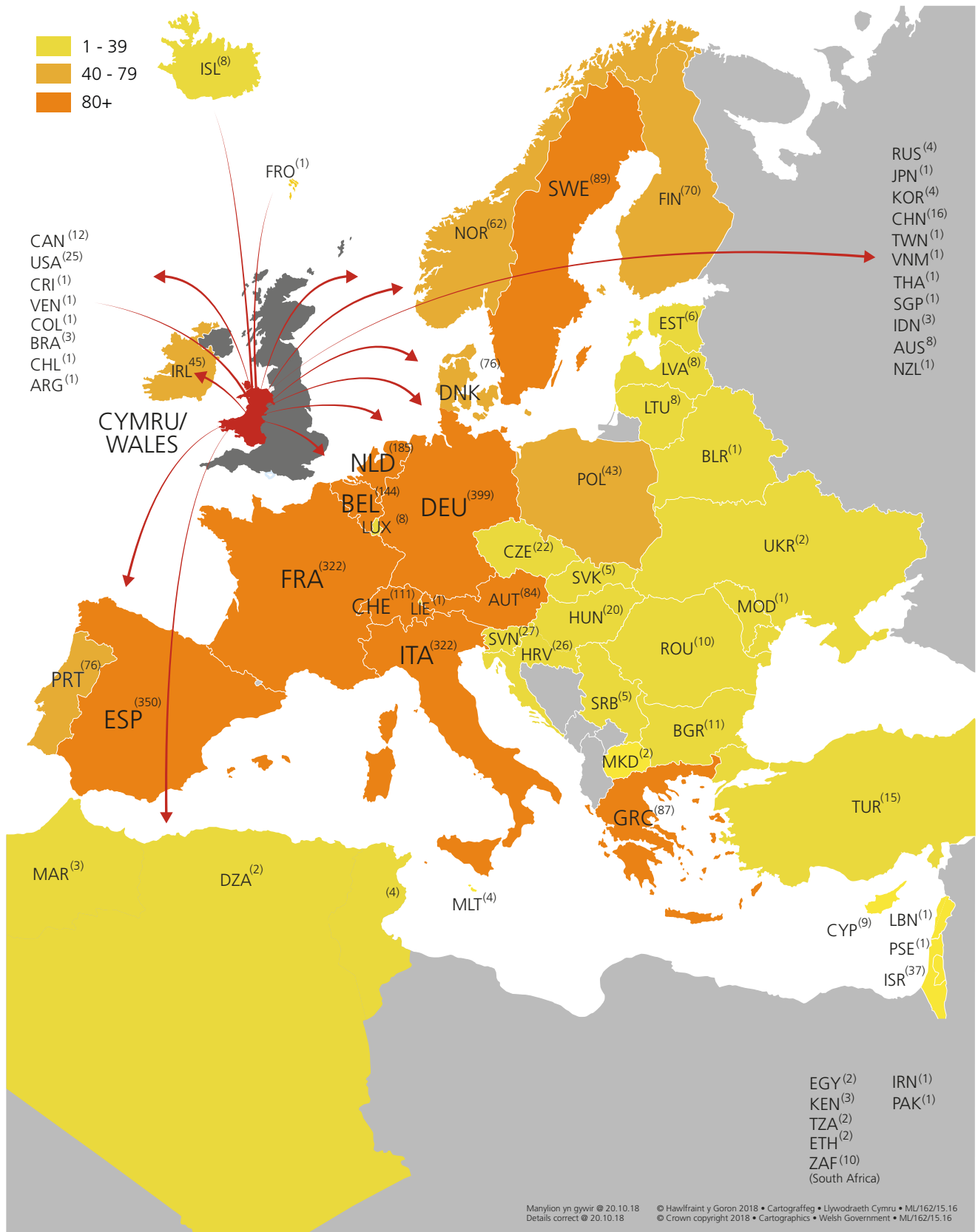
co-author. This increased to around 29 per cent by 2016 indicating the growing importance of the EU collaboration.

Research is a global exercise, which often requires an interdisciplinary approach and typically involves researchers from different countries. Given the UK's proximity, historical links and relative strength of the research base with many EU countries, UK research (which draws extensively on collaboration with colleagues in other EU Member States) could be seriously compromised following Brexit but more so in Wales, which has been successful in growing a significant level of engagement with other EU researchers over the past decade (see Figures 13 and 14a). Wales has also extensive collaborative research links across the whole of the UK. Figure 14b shows the wide range of EU funded collaborations involving other UK partners.

⁴¹ *Collaboration on Science and Innovation*, HM Government, 2018

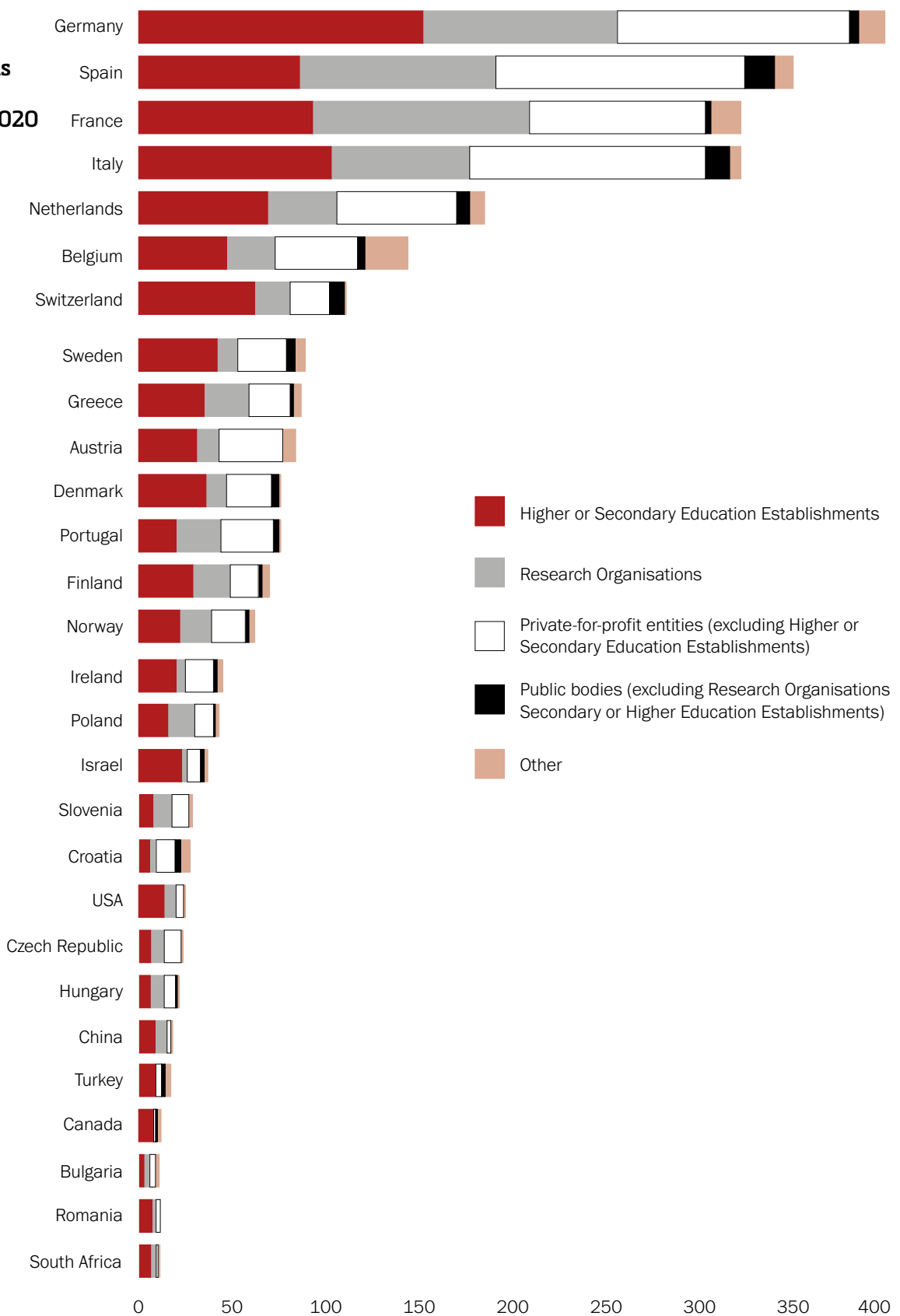
⁴² *International Comparative Performance of the Welsh Research Base*, Elsevier, 2013

Figure 13:
International Collaborations via Horizon 2014–2020



This figure is drawn from administrative data held by the European Commission's database on Horizon 2020. The figure is based on signed grant agreements or closed funding calls as at 29 September 2018. Figures are cumulative from the beginning of the programme unless otherwise stated. Statistics derived from this data have been validated and checked for their accuracy as far as is possible. However, it should be noted that some minor inaccuracies can inevitably occur during the production of these statistics as a result of missing data, human error or other similar information problems commonly associated with the production and analysis of large administrative datasets.

**Figure 14a:
International
Collaborations
with Wales,
via Horizon 2020**



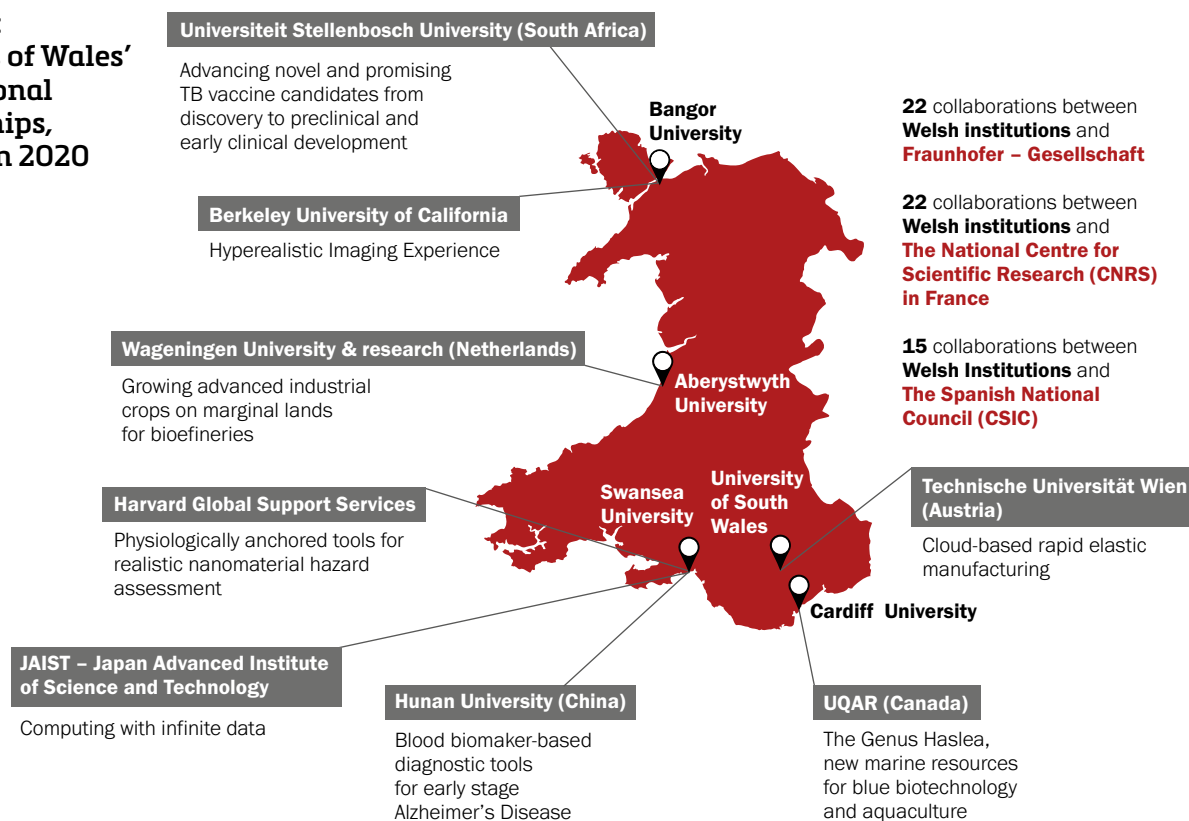
This figure is drawn from administrative data held by the European Commission's database on Horizon 2020. The data is based on signed grant agreements or closed funding calls as at 29 September 2018. Figures are cumulative from the beginning of the programme unless otherwise stated. Statistics derived from this data have been validated and checked for their accuracy as far as is possible. However, it should be noted that some minor inaccuracies can inevitably occur during the production of these statistics as a result of missing data, human error or other similar information problems commonly associated with the production and analysis of large administrative datasets.

Figure 14b:
UK collaborations
with Wales, via
Horizon 2020



Data for this figure has been drawn from the EC's eCORDA (External COmmon Research DAwarehouse) which provides access to the Horizon 2020 Microsoft access databases for downloads of raw data. This map has been created from an extracted list of UK organisations participating in Horizon 2020 27th September 2018. Points are plotted by the post codes of the UK organisations as confirmed in the EC database.

**Figure 15:
Examples of Wales' International Partnerships, in Horizon 2020**



In 2014, Wales had the highest international collaboration share of the UK, with nearly 70 per cent of its publications involving co-authors outside Wales. This highlighted the fact that unnecessary barriers to collaboration, generated before, during or after the Brexit negotiations, are likely to have a negative effect on Wales, and the UK's position as a world leader in research unless addressed.

European collaborations: Horizon 2020 funding

Wales has a strong and long history of collaborating with European partners. Wales is currently an active and valued partner for a large number of EU research collaborations and actively contributes to and has benefited significantly from, successful engagement in a number of centrally-managed EU programmes, opening itself up to new ideas and ways of working, as well as sharing experiences internationally.

The Horizon 2020 programme (2014–2020) facilitated researcher collaboration, with its emphasis on excellent science, industrial leadership and tackling societal challenges. Horizon 2020 funding also provided grant support across the full spectrum of research and development chain, from ground breaking research to close-to-market activity. By September 2018⁴³, Welsh organisations had secured some €102 million of Horizon 2020 funding since the beginning of the programme, based on competitive excellence. This involved over 255 participations (awards) and 2820 international collaborations (see Figure 13) representing a total investment of some €1 billion in projects involving collaboration from Welsh participants.

Breaking down the **2820** collaborations from Horizon 2020 (figure 14a), it can be seen that Welsh research participation covers many EU countries but with the main collaborating countries (over 100 collaborations, in addition to other parts of the UK) are **Germany; Spain; France; Italy; the Netherlands and Belgium** (see Figure 14). As can be seen from Figure 14a, these collaborations involved not just academic institutions but also research organisations, public and private bodies. Some examples of Wales' international partnerships in Horizon 2020 are summarised in Figure 15.

⁴³ Latest performance was recorded as per aggregated signed grant agreements or closed funding calls as at 29 September 2018

Conclusion

Over the past 18 years EU structural funds allocated by the Welsh Government to R&I have contributed to growing Wales international research standing and wider international collaboration. Brexit brings an end to the EU Structural funds and in particular funding directed at research and innovation activities distributed across a wide range of interlinked EU programmes.

Unlike the rest of the UK which secures most of its EU funding for research and innovation from the competitive Horizon 2020 programme, Wales will secure 79 per cent of its total EU funding for

research and innovation from structural funds during the current framework programme period, which is not yet complete.

Although the UK and all devolved Governments have indicated their desire to explore association with future EU competitive research and innovation programmes, Brexit will bring to an end to benefits of EU structural funds to Wales, unless addressed by replacement funds from the UK Government. A recent analysis (Jan 2019) by the Conference of Peripheral Maritime Regions (CPMR) estimated that had the UK remained in the European Union, the UK stood to secure a 22% increase in funding between 2021-2027 compared to the current period. The UK Government is currently preparing a consultation for how regional policy in the UK will be addressed when EU policy no longer applies.

The Welsh Government calls on the UK Government to:

- 1** Make good promises made in the EU referendum campaign to ensure that Wales is not a penny worse off as we leave the EU. This needs a permanent upward adjustment to the Welsh Government baseline of at least the levels received historically via the EU Structural and Investment funds.
- 2** Negotiate full and continued access and participation to the range of post-2020 EU Research and Innovation (FP9) Horizon Europe and Erasmus+ programmes.
- 3** Secure ongoing access to the European Investment Bank Loan finance.
- 4** Ensure a research-friendly migration system that facilitates a free flow of researchers across borders, guarantees for the visa and citizenship status of EU nationals working in UK universities and actively promote greater outward mobility by students and staff studying and working in universities.
- 5** Bring together Ministers from the Welsh Government, Scottish Government, the Northern Ireland Executive and the UK Government on an ongoing basis to enhance cross-UK coordination and co-operation for research and innovation and other economic policy matters.

Annex 1: Wales' research and innovation performance

Wales is home to a number of innovative and dynamic research activities, several of which are world class. Aerospace engineering; energy technologies, including nuclear and tidal; cutting edge metals innovation, such as in steels; marine technology; leading dementia research; automotive production; compound semi-conductors; food production; advanced manufacturing and materials;; bio-sciences; data science and financial and professional services.

Wales has a tradition of achievement and influence in science and technology. It played an important part in the early lives of both innovators of the theory of natural selection. It pioneered early developments in crystallography. It produced the seminal ideas of Richard Price, the Renaissance philosopher and mathematician, who, in turn, influenced the United States' founding fathers and Aneurin Bevan, architect of the world's first National Health Service.

Wales was involved with the discovery of free radicals and meson decay; the invention of the fuel cell, the microphone, radar, the teleprinter and packet-switching, which drives all modern communications technologies worldwide; groundbreaking research into embryonic stem cells and, more recently, establishing unique legislation requiring all public bodies to consider the impact on future generations of their policies and actions⁴⁴.

Moving from an industrial economy, based on natural resources to a knowledge based manufacturing and services economy, Wales has, over the past two decades, developed into a technologically advanced, open economy, with a research profile that by international benchmark standards, punches above its research income – in terms of research outputs, efficiency and impact⁴⁵.

There is, growing evidence that, when compared against countries and regions that spend greater R&D resources, Wales performs better than many with greater R&D funding⁴⁶.

With less than 0.04 per cent of the global population and 0.08 per cent of the research funds, Wales' small research base out performs its small research income producing 0.3 per cent of research articles and 0.8 per cent of world's most highly cited articles despite having the lowest R&D investment as a proportion of GDP in the UK.

Several of Wales' universities boast examples of outstanding research – cutting edge brain-imaging, genetics and neurodegenerative disease research at Cardiff University; the award-winning Institute of Biological, Environmental and Rural Sciences (IBERS) in Aberystwyth; Bangor's impressive work in the fields of environmental protection; Opto-electronics at Wrexham Glyndŵr and Swansea's innovative advances in materials research and testing.

In 2007, the Nobel Prize in Medicine was jointly awarded to Professor Sir Martin Evans of Cardiff University. The building of the Large Hadron Collider – the most powerful particle accelerator ever built and based at the European particle physics laboratory CERN, near Geneva, was overseen by Dr Lyn Evans, a Welsh physicist, who received his research training at Swansea University⁴⁷ – and he is overseeing the design of the next Collider.

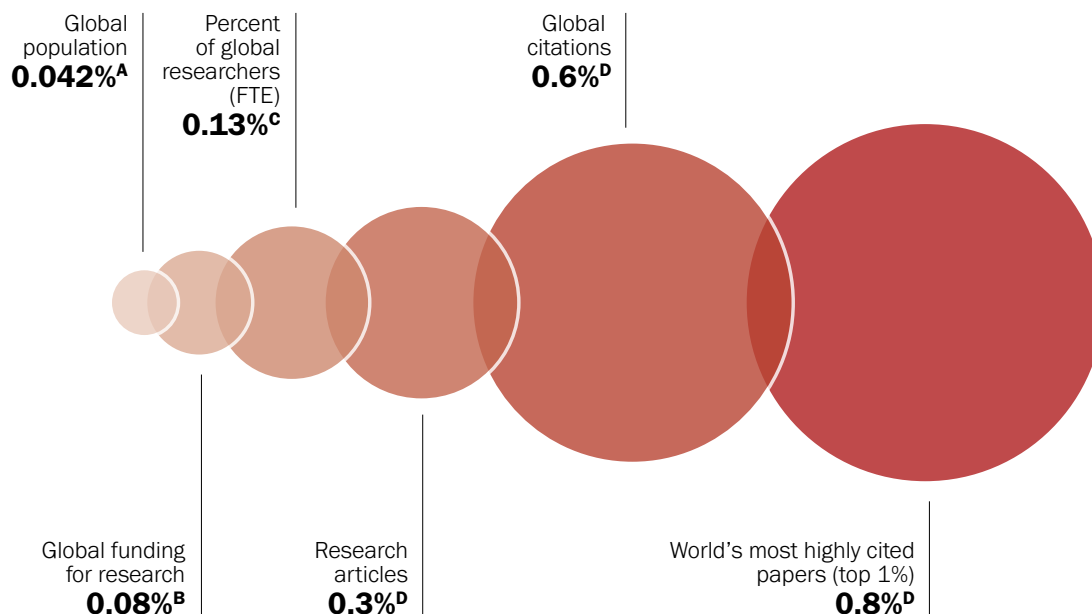
⁴⁴ New Frontiers: Cutting Edge Science in Wales, 2012

⁴⁵ Learned Society of Wales (LSW) Report, 2017

⁴⁶ Halligan and Bright, 2015

⁴⁷ *Recognising the Quality of Research at Universities in Wales*, Learned Society of Wales (LSW), 2013, Wales in the World, 2017

**Figure 16:
Wales' Global
Research
Performance
Data (%)**



A World Bank <https://data.worldbank.org/indicator/SP.POP.TOTL> (for global figure) and ONS

B Multiple sources:

- for Wales GERD as per cent of UK GERD is ONS, published in GBP

- for UK GERD as per cent of global GERD is OECD [here global GERD is assumed to be the same as the OECD total GERD] published in GBP& USD, and USD respectively <https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm#indicator>

C Eurostat for global researchers (calculated as total headcount of FTEs) <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do> and for the NUTS2 regional breakdown: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_persreg&lang=en

(The 2015 dataset has been used as this is the most complete but this comes with the caveat that it is not a complete global dataset).

D Elsevier (2018)

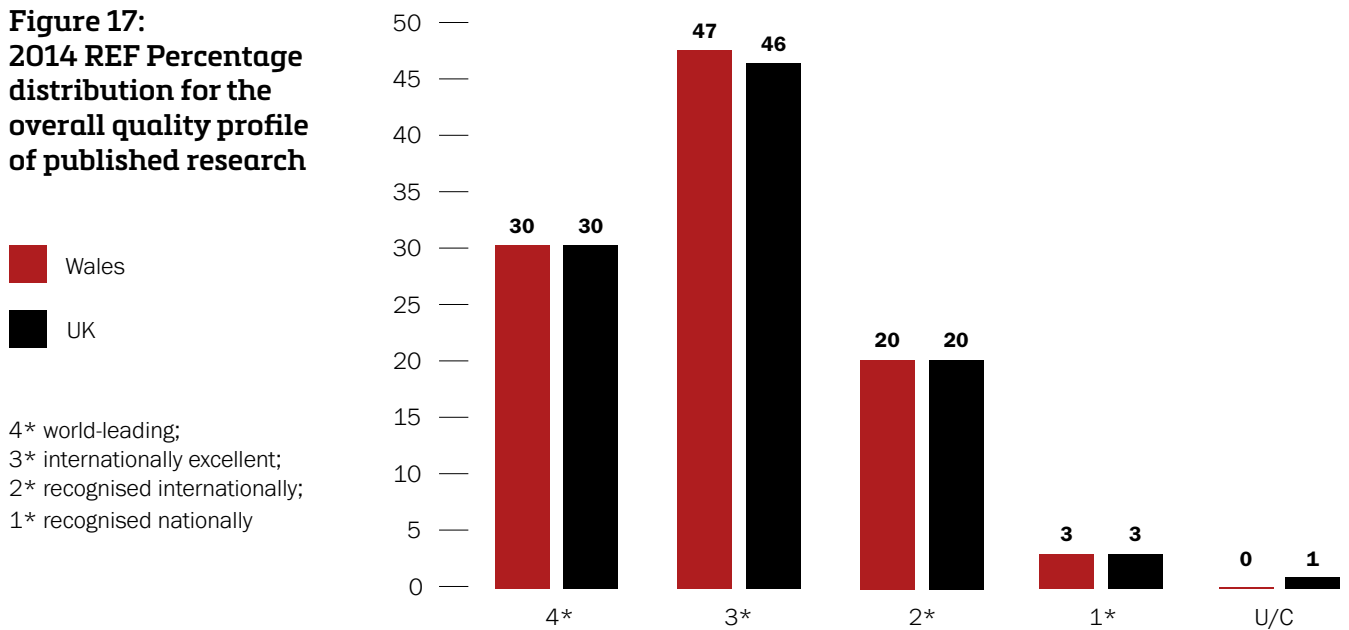
Recent developments in Wales span diverse fields including: biotechnology, such as the identification of diagnostic biomarkers for detecting early-stage lung cancer; advanced manufacturing; cyber security; energy, such as patenting of microbial fuel cell technology; medicine, such as treatments for neurodegenerative diseases; opto-electronics, such as next generation computer graphics based on ray tracing and photon mapping and agriculture, such as methods for containment of fallen stock⁴⁸.

The fact that Wales secures only 2 per cent of the total UK spend on research and development (R&D) has sometimes contributed to a misleading perception regarding Wales' overall research performance.

To obtain a better appreciation of a country's research performance, over and above its total research income, it is important to consider how effective that funding has been in producing impactful research outputs. When one employs established bibliometric output measures of research productivity and citation and research impact, it is clear that the quality of Wales' research performance has grown significantly over the past decade, when compared to similar-sized countries.

⁴⁸ Welsh Government, *Advances*, Issue 69, Summer 2013

Figure 17:
2014 REF Percentage
distribution for the
overall quality profile
of published research



Source: 2014

Research Excellence Framework (REF) 2014

The 2014 Research Excellence Framework (REF)⁴⁹, the UK Government’s formal assessment of published research quality from UK universities, showed that Welsh research is on a par with the UK higher education (HE) sector. The results in Figure 17 show that more than three-quarters (77 per cent) of all Welsh research submitted was assessed as being world-leading or internationally excellent, with almost a third rated as world-leading.

When compared to the 2008 **Research Assessment Exercise (RAE)**⁵⁰ it can be seen that Wales shows a significant improvement with 4* research outputs presenting an impressive increase from 14 per cent in RAE to 30 per cent in REF and with 3* outputs increasing from 35 per cent in RAE to 47 per cent in REF 2014.

Research citation

The UK’s published research base is rightly regarded as an international leader and one of the most productive countries for research in the G8 in terms of citations and publications per £1 pound spent. Publications provide one established, quantifiable deliverable output of research. By tracking these and their influence in the global academic community, it is possible to get a picture of the quality and efficiency of a country’s overall research system.

Citations are used by researchers as an indicator of research interest in a published work, with the number of citations received by a research article from subsequent-published articles commonly taken as an indicator of the quality, relevance or importance of the cited research⁵¹. **Field-weighted citation impact (FWCI)** is a recognised established measure of publication citation impact that accounts

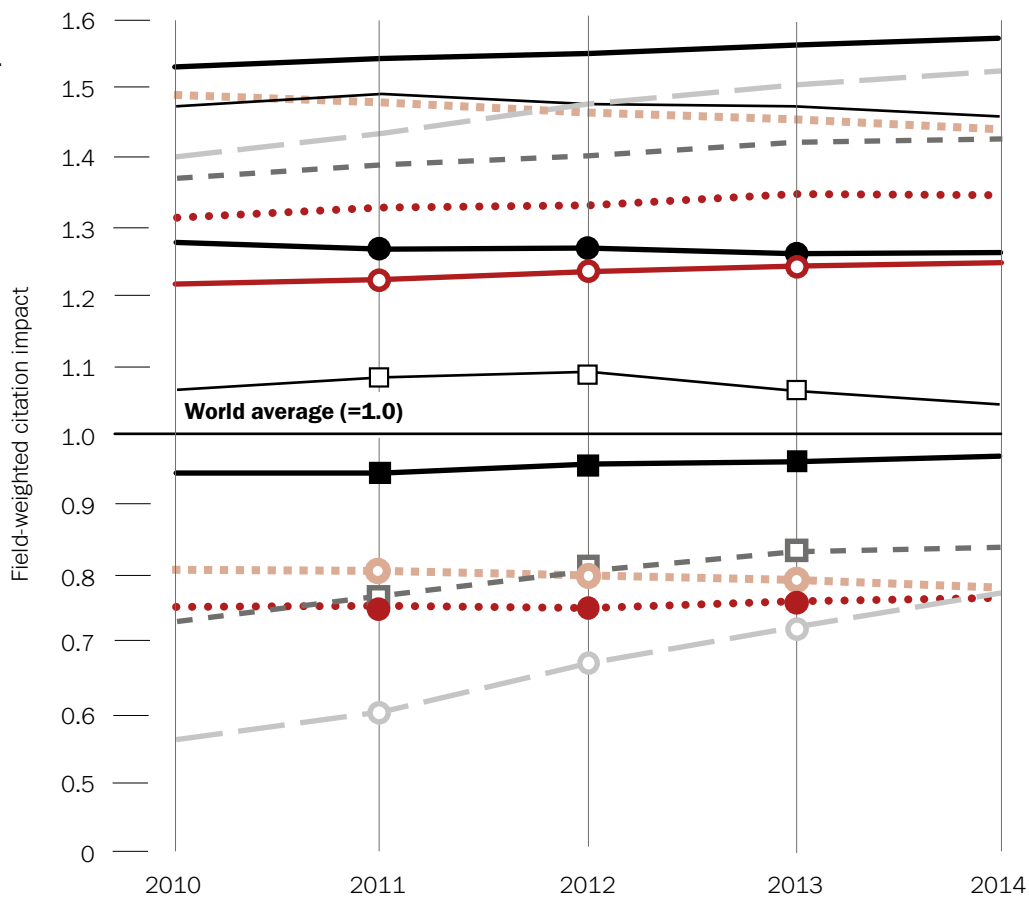
⁴⁹ <http://www.ref.ac.uk/2014/>

⁵⁰ <http://www.rae.ac.uk/>

⁵¹ Davis, P.M. (2009) ‘Reward or Persuasion? The Battle to Define the Meaning of a Citation’ *Learned Publishing* 22 (1) pp. 5-11

Figure 18:
Field weighted citation impact for the UK and G8 comparators, 2010-2014

- UK
- - - Italy
- Canada
- - - US
- - - Germany
- France
- G8
- EU28
- South Korea
- Japan
- China
- Russia
- Brazil
- India



Source: Elsevier 2017

for differences in citation behaviour between different subject fields, publication types and publication years, normalized to a world level of 1.0.

In 2014, the UK had a field-weighted citation impact of 1.57 well above the world average of 1.0 and ahead of the comparator countries in the G8. (See Figure 18).

However, by calculating the UK's FWCI where articles are counted for each of the constituent countries that contribute, allows for a more direct comparison for how the different UK constituent countries perform⁵². A breakdown of the field-weighted citation impacts for the four UK constituent countries in 2016, shows that Scotland, Wales and Northern Ireland all out perform the UK average (see Figure 19).

⁵² Elsevier Report, 2017

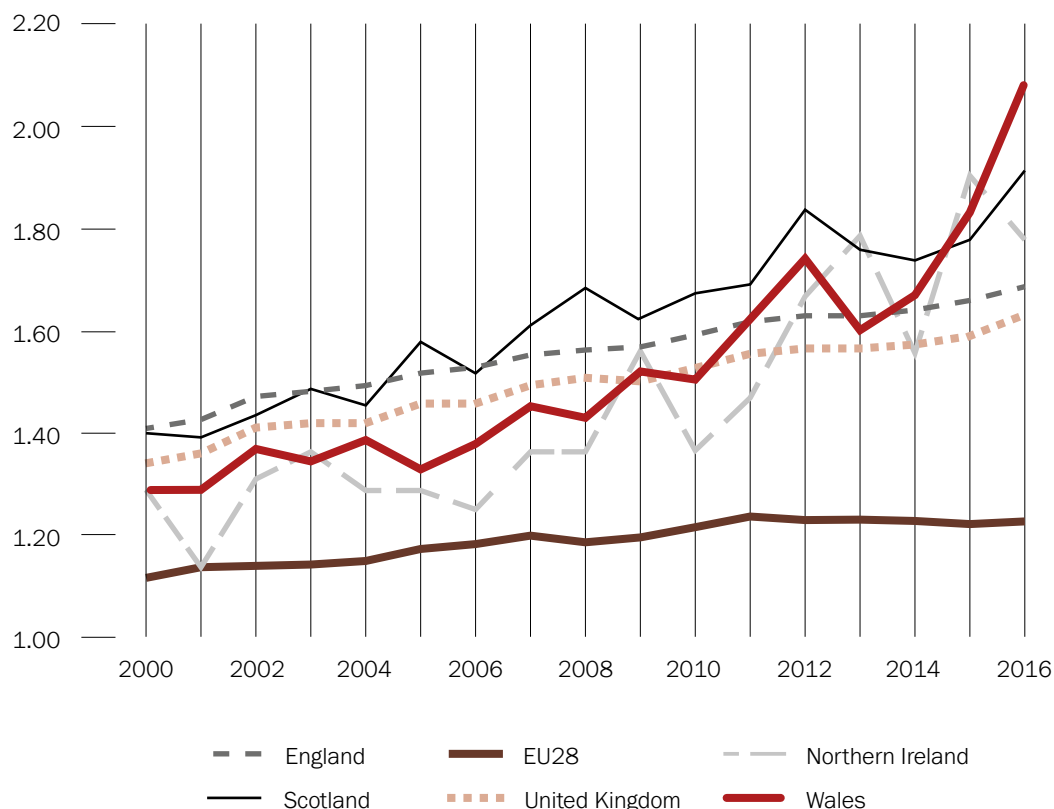
This has not always been the case for Wales. For much of the early 1990s, Wales' research performance was below the world average but by the mid-1990s Wales' citation impact began to equal and exceed the world average. From 2000 onwards, Wales' research impact grew steadily, exceeding the EU average and in the process overtaking several well-performing but similar-sized countries such as Finland; Norway; New Zealand and Hungary, despite these countries investing a greater percentage of their GDP on R&D and having a large researcher base.

In 2016, Elsevier produced an independent report (commissioned by HEFCW) on the Welsh research base, that showed how academic researchers from Wales compared internationally and to other parts of the UK across a range of established bibliometric measures⁵³.

Highlights of this 2016 Elsevier report (which covers citation data up to 2014) showed that:

- Welsh Universities produced the largest proportion of research publications from Wales (88 per cent).
- Wales accounted for 0.47 per cent of global citations despite having only 0.24 per cent of the world's published articles.

Figure 19:
Wales' growing FWCI performance (for all subjects) compared to the other UK constituent countries and EU 28 average over the past 16 years



Source: Elsevier database 2018

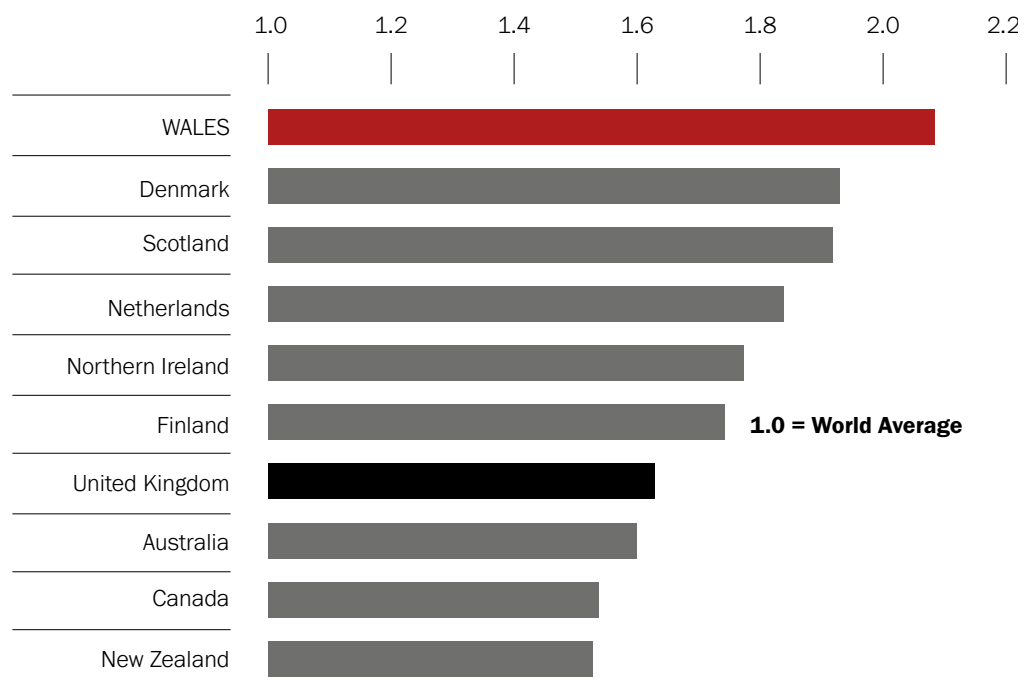
⁵³ International Comparative Performance of the Welsh Research Base, Elsevier 2014-2016

- Despite having 0.14 per cent of the world’s researchers, Wales secured 0.59 per cent of the world’s top 1 per cent most cited articles and 0.49 per cent of the world’s top 5 per cent most cited articles.
- Wales was more productive than the UK average in terms of publications per researcher.
- The average number of citations per researcher for Wales increased from 7.6 in 2007-2011 to 9.6 in 2010-2014.
- Welsh research resulted in high field-weighted citation impact, with Welsh publications being cited 68 per cent more often than the world average, (compared to 59 per cent above the world average in 2011).

Recent (unpublished) analysis from Elsevier (2018) show that for the period (2000-2016), Wales gradually grew its citation impact by 1 per cent, from 0.4 per cent in 2000 to 0.5 per cent in 2016 – the highest growth rate among the UK nations. In terms of UK citation share, Wales also had the fastest growth with 3.5 per cent, ahead of all other UK constituents again demonstrating that Wales produces reputable research greater than its spend might suggest.

Wales’s performance remains particularly impressive when one considers that, from 2003 onwards and with productivity and citation impact growing rapidly, the size of the Welsh academic research base remained relatively unchanged.

Figure 20:
Field-weighted
citation index
2016–some
comparable nations



Source: Elsevier database 2018

The recent Elsevier data (2018), covering the period up to 2016 shows that Wales' FWCI grew from 1.29 in 2000 – one of the lowest in the UK – to 2.09 in 2016, ahead of other UK nations and overtaking Scotland for the first time (see Figure 19). This performance is not only well above the world average but it is also above the UK and EU28 averages.

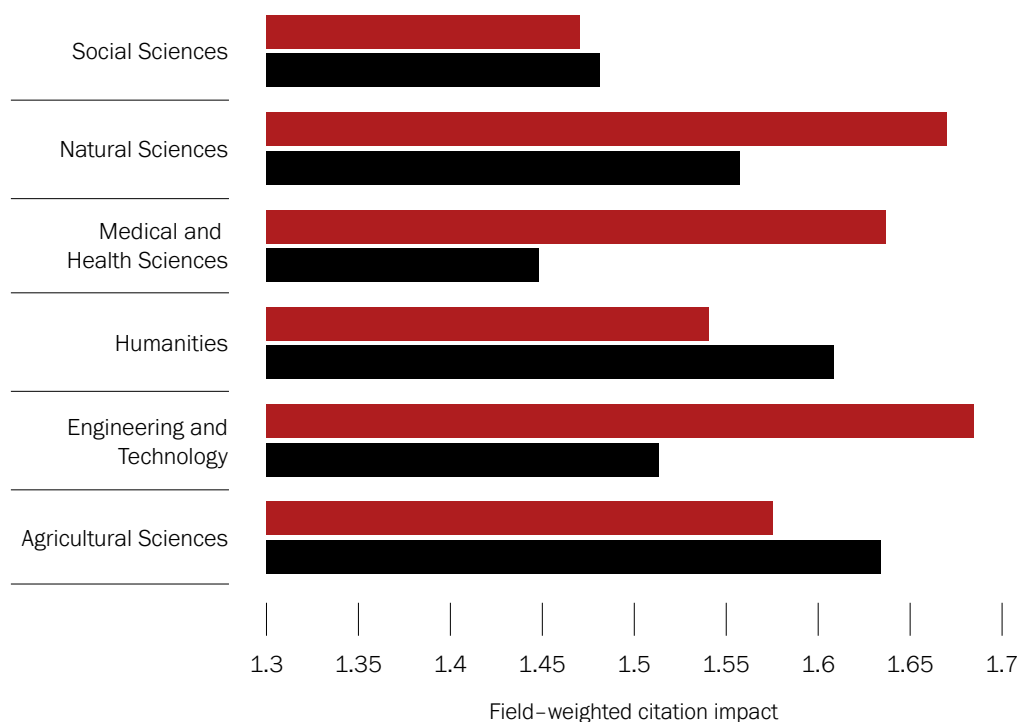
Field-weighted citation impact (FWCI) is an established measure of publication citation impact that accounts for differences in citation behavior between different subject fields, publication types and publication years, normalized to a world level of 1.0.

Figure 20 provides a snap-shot of how Wales compares against other countries on FWCI in 2016.

A breakdown by main subject areas shows the performance over a 5 year period for Welsh research categorised into the six main OECD subject groupings, comparing the five year period 2007–2011 with 2010–2014. In the period 2010–2014, the 6 main subject areas scored well above the world average (1.0) with Natural Sciences, Medical and Health Sciences and Engineering securing the largest increases over the previous period from 2007–2011 (see Figure 21).

Figure 21:
Field-weighted citation impact for Wales per OECD subject; 2007–2011 and 2010–2014

■ 2010–2014
■ 2007–2011



Source: (HEFCW/Elsevier database 2016) – International Comparative Performance of the Welsh Research Base, Elsevier 2014/2016

In summary, over the past 18 years the Welsh Research base has produced publications that have performed collectively above the World, UK and EU average.

Research impact

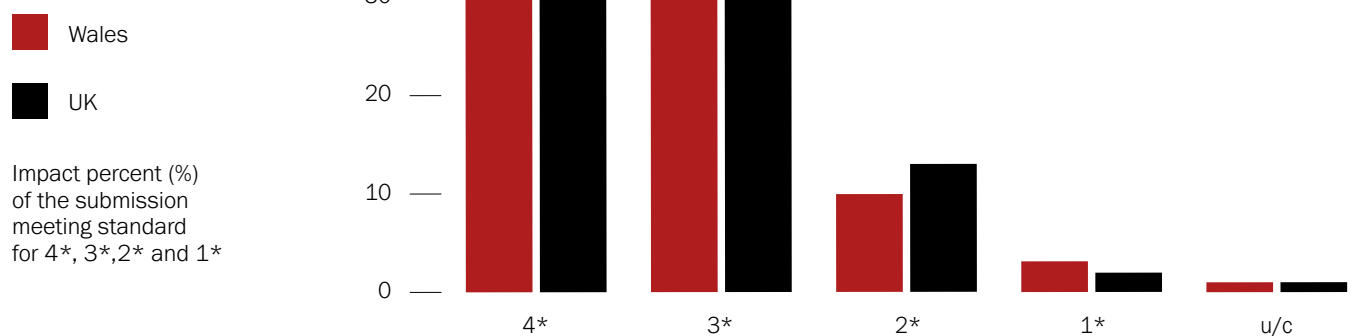
The 2014 Research Excellence Framework (REF) was the first time the UK Government formally assessed the ‘impact’ of research beyond assessing the academic publications and involved the largest such impact evaluation carried out in any country.

In addition to contributing to the subsequent allocation of research funding, the prioritising of impact in the REF assessment offered an unprecedented opportunity for researchers to demonstrate, to government and tax payers, how research had delivered significant beneficial difference for the economy, culture, government and society at large, both locally and internationally.

REF Impact was defined ‘as an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia’.

In REF (2014), 154 higher education institutions (HEIs) submitted a total 6,975 impact case studies. While amounting to 4 per cent of the UK’s total submissions, 86 per cent of Welsh research was judged to have an ‘outstanding’ or ‘very considerable’ impact on the economy, society and culture beyond academia, compared with 83.9 per cent for the UK overall.

Figure 22:
2014 Research Excellence Framework, Impact measure Sub-Profiles for UK and Wales



Source: REF 2014

Figure 22 summarises Wales' performance on REF impact and shows how research from a small country, with a small number of HEIs, produced well recognised changes and benefits, both regionally and internationally. Impressively, Wales outperformed all other UK countries on the highest impact judgment category with 49 per cent of its impacts case studies considered to be outstanding⁵⁴ (4*), compared to the overall UK average of 44 per cent; and with a further 37 per cent of impacts from Wales judged as having very considerable impact (3*).

In 2017, a formal report commissioned by the Learned Society of Wales and carried out by Kings College London⁵⁵, provided a comprehensive analysis of all these Welsh impacts. Combining a comparative analysis of Wales' submissions with the rest of the UK, the report found that areas of research that led to impact for Welsh HEIs were comparable to those within the rest of the UK, with the same proportion of case studies originating from research in the Life Sciences, Engineering and Physical Sciences, Social Sciences and the Arts and Humanities.

The King's College report found that Wales' research had considerable international reach, with Wales' impact submissions covering **102 countries** across six continents. Research in the Life Sciences and in Advanced Materials and Manufacturing and Energy and the Environment within Engineering and Physical Sciences, showed the greatest impacts **abroad**.

The three disciplinary areas that saw most submissions from Wales also showed comparatively higher levels of impact internationally. These included: Allied Health Professions; Dentistry; Nursing and Pharmacy; Business and Management; and Psychology, Psychiatry and Neuroscience.

Across all of the 273 Welsh submissions, research from Wales impacted on a variety of sectors, and ranged from developing or reforming government policy to informing clinical practice in health and social care settings.

The King's report showed a relatively even distribution of case studies from universities in Wales submitted across the four main REF disciplinary panels (Life Sciences; Engineering and Physical Sciences; Social Sciences and Arts and Humanities).

A selected number of these case studies are summarised in the following table all of which highlights the breadth, depth and reach of Welsh research achieving impact in a measurable way in STEM-related areas (Science, technology, Engineering, Maths & Medicine.)

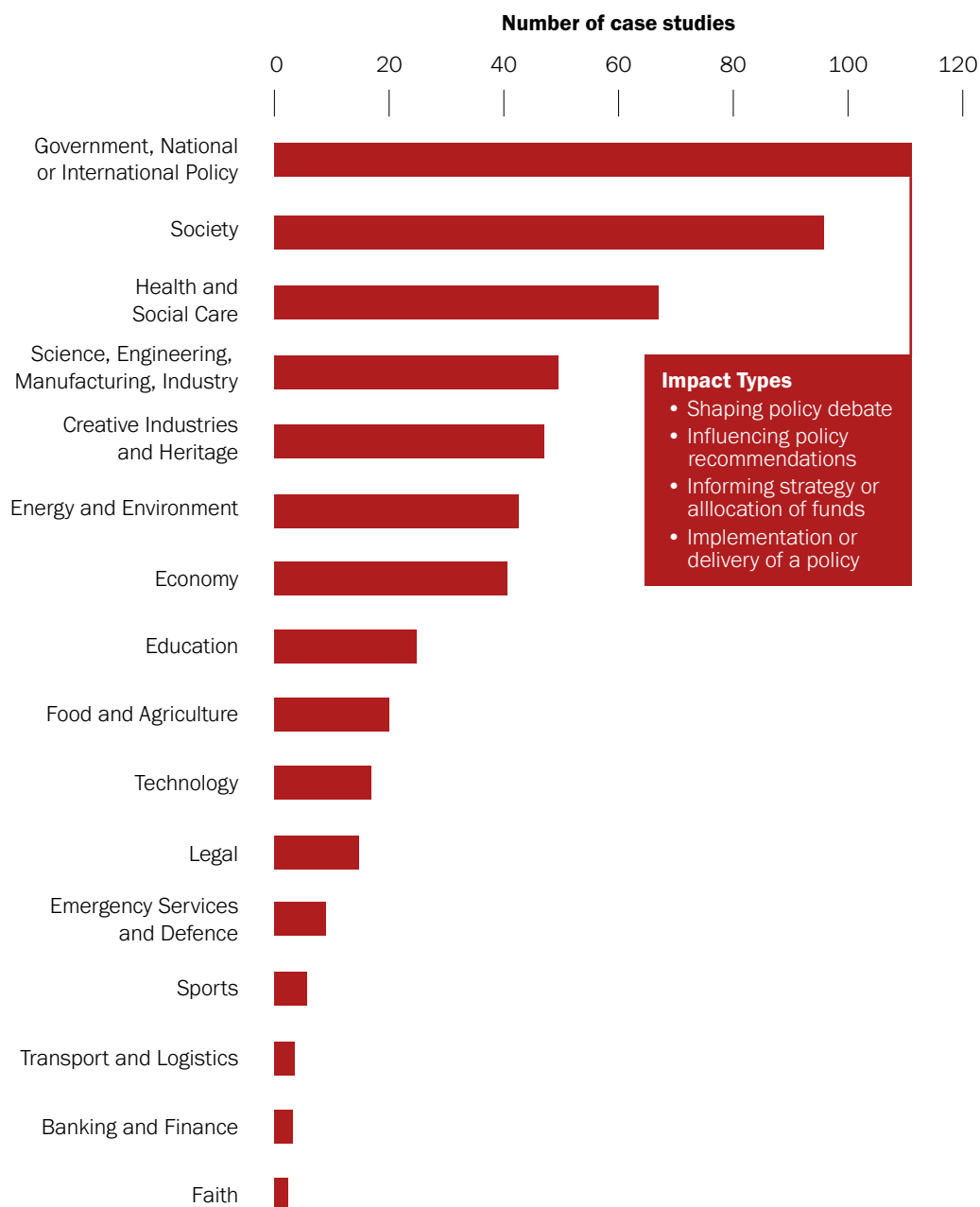
Over one-third of the case studies specifically related to research impacts within Wales, many of which complemented activities within the UK and abroad.

Science, engineering, manufacturing and industry saw the highest concentration of activity outside of Wales, with 42 per cent of all references to impacts situated in the UK and 45 per cent internationally. Similarly, over half of all activities reported within 'health and social care' referred to the UK. Impacts on 'energy and environment' had the highest proportion of inter-national reach, with over two-thirds of references to impacts occurring overseas. See Figure 23 for the number of impact case studies submitted per sector.

⁵⁴ [https://results.ref.ac.uk/\(S\(xzo4e5gsy1bcw5pwgeeyodcx\)\)/](https://results.ref.ac.uk/(S(xzo4e5gsy1bcw5pwgeeyodcx))/)

⁵⁵ <https://www.learnedsociety.wales/societal-economic-impact-welsh-universities/>

Figure 23:
Case studies
submitted for
REF2014 by sector



Source: King's College London commissioned by the Learned Society for Wales – <https://www.learnedsociety.wales/societal-economic-impact-welsh-universities/>

A selection of Research Impacts for Wales from REF 2014

Introduction of national and international policies to support victims of sexual or domestic abuse

Collaboration with policymakers that led directly to legislation in England and Wales and later in Scotland and Northern Ireland, permitting underage test purchasing of alcohol under official supervision and resulting in sales of alcohol to minors falling by over 60 per cent

Development of a Knowledge, Innovation and Technology Exchange programme, with food manufacturing businesses in Wales to improve food production and food safety management systems

New evidence-based treatment guidelines for the diagnosis and treatment of acquired haemophilia A or AHA

Identification of the first recessive gene – MUTYH – to improve the management of familial colorectal cancer.

Development of a new drug clinical trial and a new standard of care for Prostate Cancer

Improved biopsy training and improved standard of care in Breast Cancer Surgery

Breast feeding rates improved by evidence based guidelines

Reduced antibiotic prescriptions to help contain increase in antimicrobial resistance

Development of a powerful, new antiviral agent against shingles.

Better dialysis outcomes for patients undergoing peritoneal dialysis

Improving life care in Down's syndrome through bettering eye care and improved learning potential

Development of new varieties of rice for 5 million households improving livelihoods of millions of people in India and Nepal

Development of novel types of Oat – improved grain composition and changed retail and consumers habit for the benefit of human and animal health

Development of space age camera technology – used for precision agriculture

Improving lives and reducing cost to the NHS and tax payers using 3D printing reconstructive surgery.

Improving fisheries management and reducing wildlife crime by developing new DNA forensic tools.

Reforming school food – influencing international food policies

Improving data security – working with Hewlett Packard to mitigate data security risks

Modelling flooding hazards and water quality to provide for better flood hydrodynamics predictions

Engineering solutions for high level nuclear waste disposal

Practical wave form engineering – reshaping current communications

More effective school based smoking prevention programme – introduced in national strategy documents and recommended by NICE

Ultra precision computer controlled polishing and metrology – contributed to the ESO European Extremely Large Telescope project

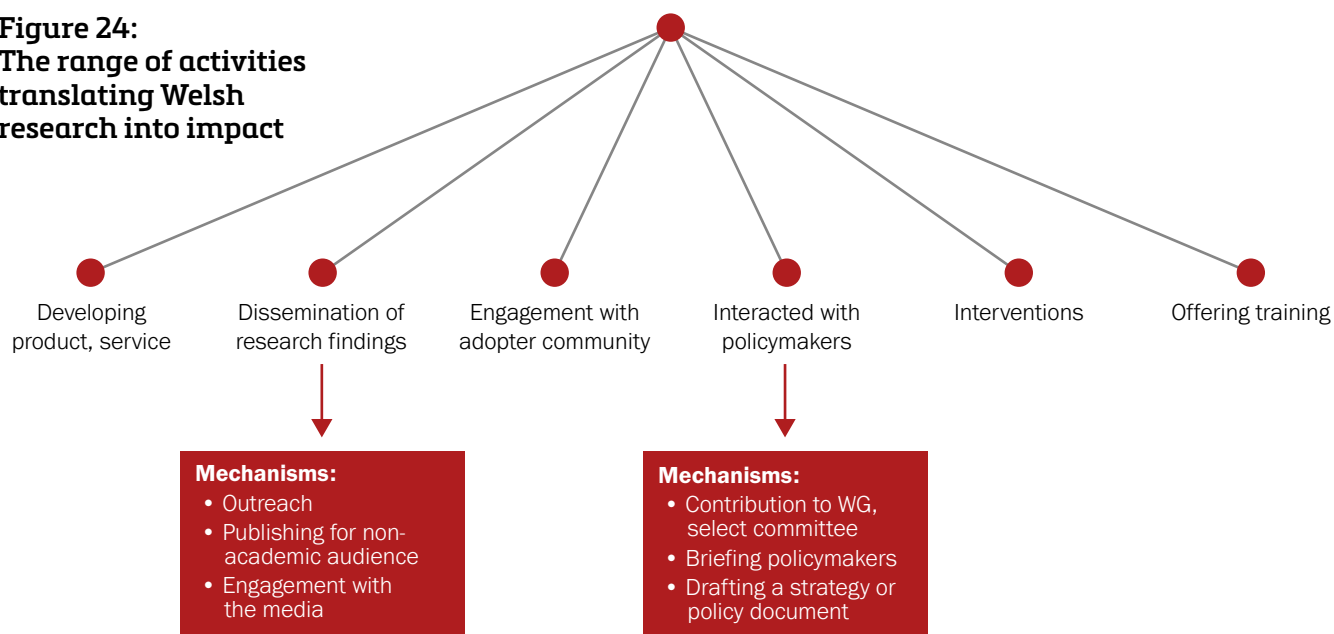
The Kings College report found that small and medium-sized enterprises (SMEs) were key beneficiaries of the research impact with many of the impacts relating to economic growth in Wales foregrounding complementary research and policy initiatives to support the growth of start-ups and small businesses and encourage industry within Wales. The public was also a notable beneficiary locally, reflecting initiatives from researchers in Wales to empower, connect and make provisions for local and especially rural, communities.

Impacts were often the result of multiple activities that translated the original research into a medium that enabled the impact to take place. These ranged from the dissemination of research findings to collaborations with direct adopters of the research, such as engaging with policymakers, via participation in working groups, select committees or in private briefings.

While impacts on policy and society were prominent, reflecting trends in Wales' submission as a whole, the geographic distribution of impact, relative to the size of the sector, showed that culture, heritage and the economy were important areas for research impact within Wales. This took the form of contributing to the reform of Welsh Government policy, transforming public awareness on topics, ranging from equality to national identity, increasing participation in the arts or supporting national economic growth.

Over two-thirds of case studies produced examples where such beneficiaries directly adopted their research in practice. This was especially so with policymakers and local governments, as well as professionals from health and social care and science, engineering, manufacturing and industry.

Figure 24:
The range of activities translating Welsh research into impact



Source: <https://www.learnedsociety.wales/societal-economic-impact-welsh-universities/>

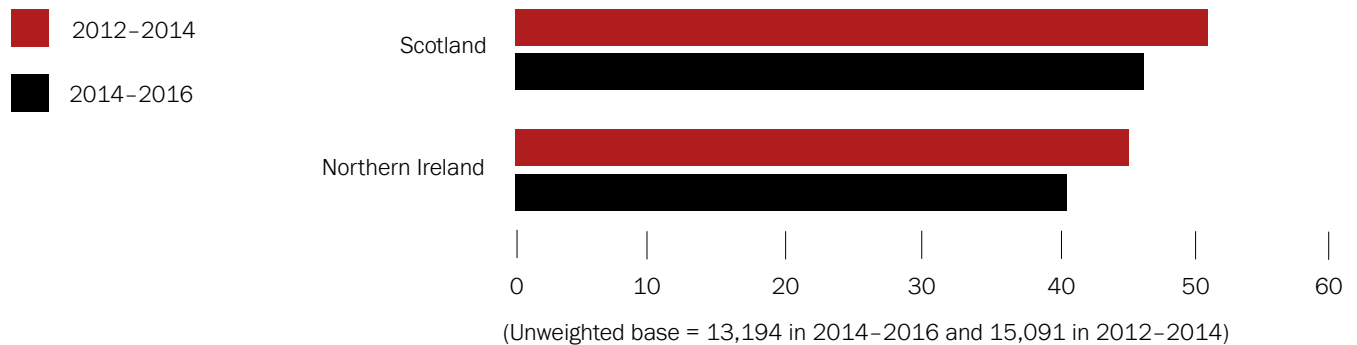
Innovation

Over the past 20 years, Wales has developed a rich landscape of innovation activities, programmes and supporting organisations including universities, anchor companies and SMEs⁵⁶.

In 2017 the **UK Innovation Survey** ranked Wales second only to England (see Figure 25).

The 2018, UK Tech Innovation Index showed that the clusters in Wales, together with the South West of England, has significant strengths across a range of sectors, including Artificial Intelligence and Data; Clean Growth; Advanced Manufacturing and the Ageing Society⁵⁷. Moreover, as can be seen in Figure 26, the 2017 Innovation Survey⁵⁸ showed that many levels of innovation by Welsh firms were on a par with UK averages as a whole.

Figure 25:
Proportion of innovation activity by country, 2012–2014 and 2014–2016, %



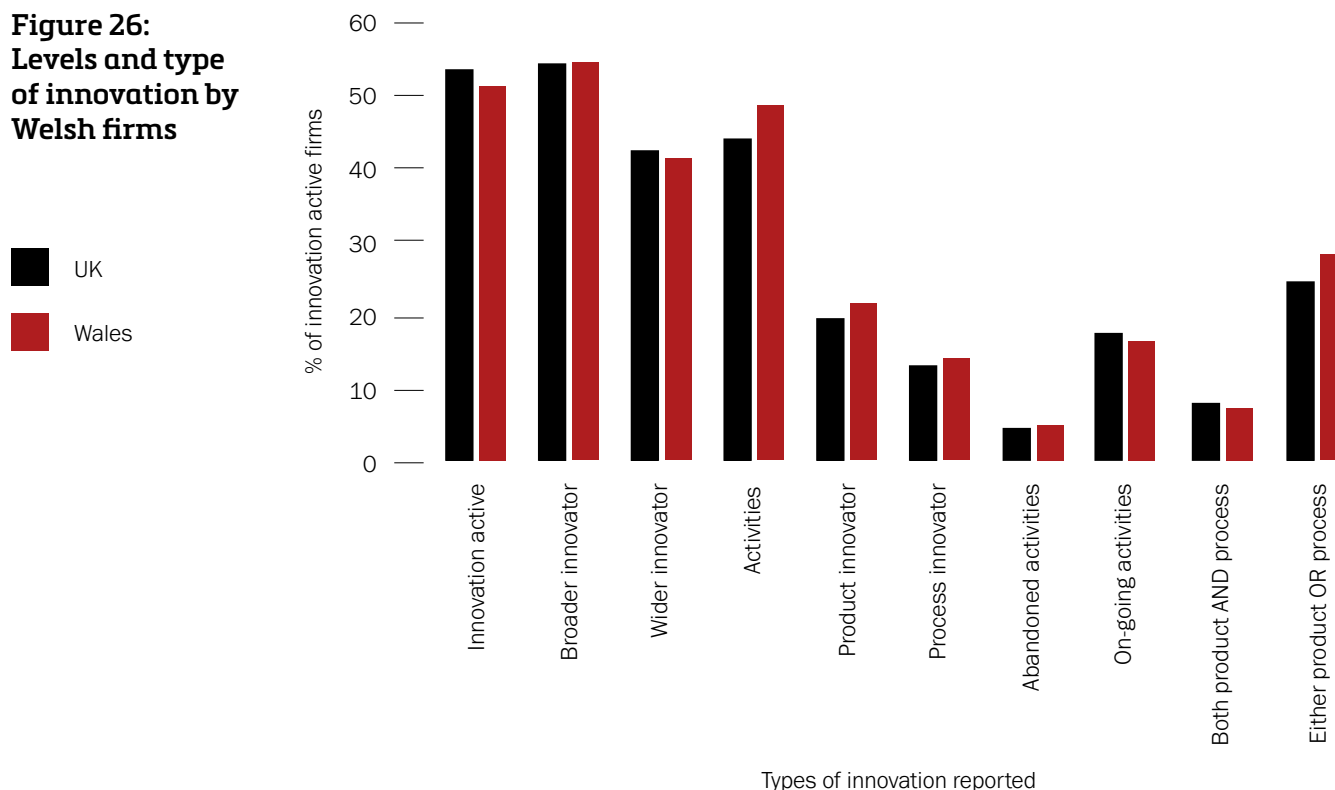
Source: <https://www.gov.uk/government/statistics/uk-innovation-survey-2017-headline-findings>

⁵⁶ https://www.cardiff.ac.uk/__data/assets/pdf_file/0005/794030/Growing-the-Value-of-University-Business-Interactions-in-Wales-Summary-Report.pdf

⁵⁷ <https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/wales>

⁵⁸ <https://www.ons.gov.uk/surveys/informationforbusinesses/businesssurveys/ukinnovationsurvey>

Figure 26:
Levels and type
of innovation by
Welsh firms



Source: UK Innovation survey 2017

The level of Innovate UK funding secured for Wales has also risen significantly, from £3.8 million (€4.45 million) in 2011 to £18.4 million (€21.5 million) in 2016, following strategic engagement from the Welsh Government⁵⁹.

The **European Innovation Scoreboard (EIS)** provides a comparative analysis of strengths and weaknesses of national innovation systems across EU countries. The *Regional Innovation Scoreboard*⁶⁰ (RIS), a regional extension of the European Innovation Scoreboard⁶¹, assesses the innovation performance of some 220 regions, across 22 EU countries, employing 17 indicators, including R&D expenditure, patent applications, employment, lifelong learning, international scientific co-publications, most-cited publications, public-private co-publications

According to the Regional Innovation Scoreboard for 2017, Wales ranks top in Strong Innovator Group (see Figure 28).

Wales' performance on the RIS has seen a significant improvement since 2011 showing a 10.2 per cent increase with only 14 per cent of the other 216 regions across Europe showing a similar improvement by more than 10 per cent and contributing towards the UK being ranked second, behind the Netherlands, in terms of EU countries with the most regions to have improved by more than 10 per cent.

⁵⁹ <https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/wales>

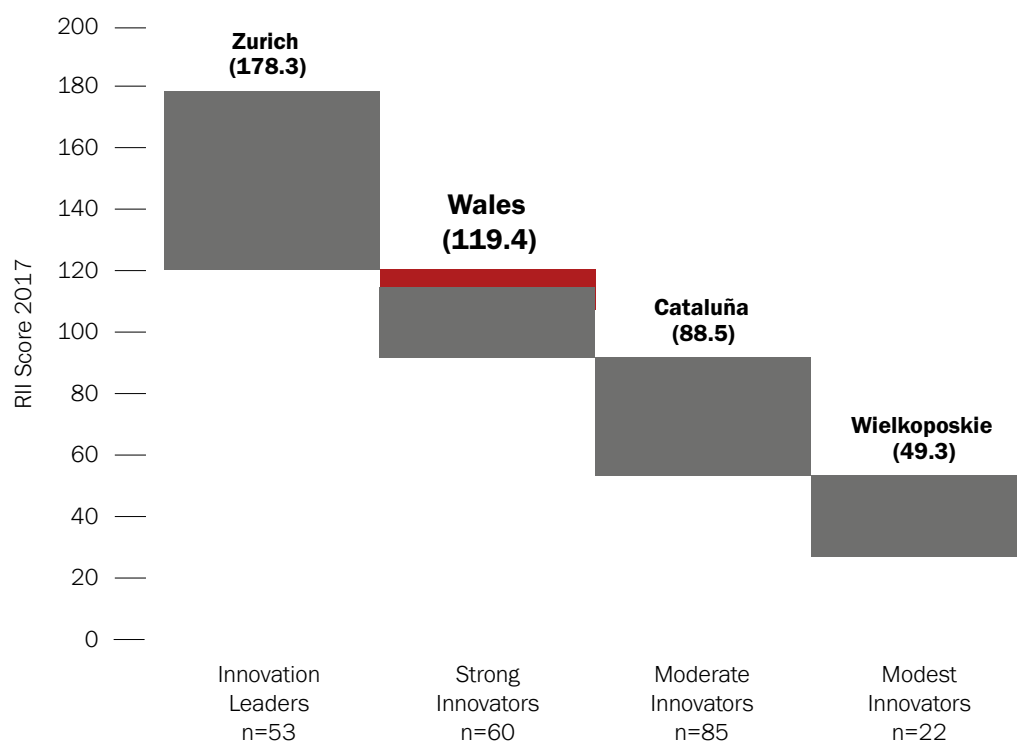
⁶⁰ http://ec.europa.eu/growth/industry/innovation/facts-figures/regional_en

⁶¹ https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

Wales' 2017 Regional Innovation Index is slightly below UK average (by 2.8 per cent) but well above the EU average (by 19.4 per cent). Wales was ranked as the top region of Strong Innovator grouping in the Regional Innovation Scoreboard ranked 54th out of the total 220 regions with Wales on average performing more than 19 per cent above the EU average.

Wales outperforms the European average in the areas of collaborating with SMEs, lifelong learning, scientific publications and sales of new-to-market/firm innovations.

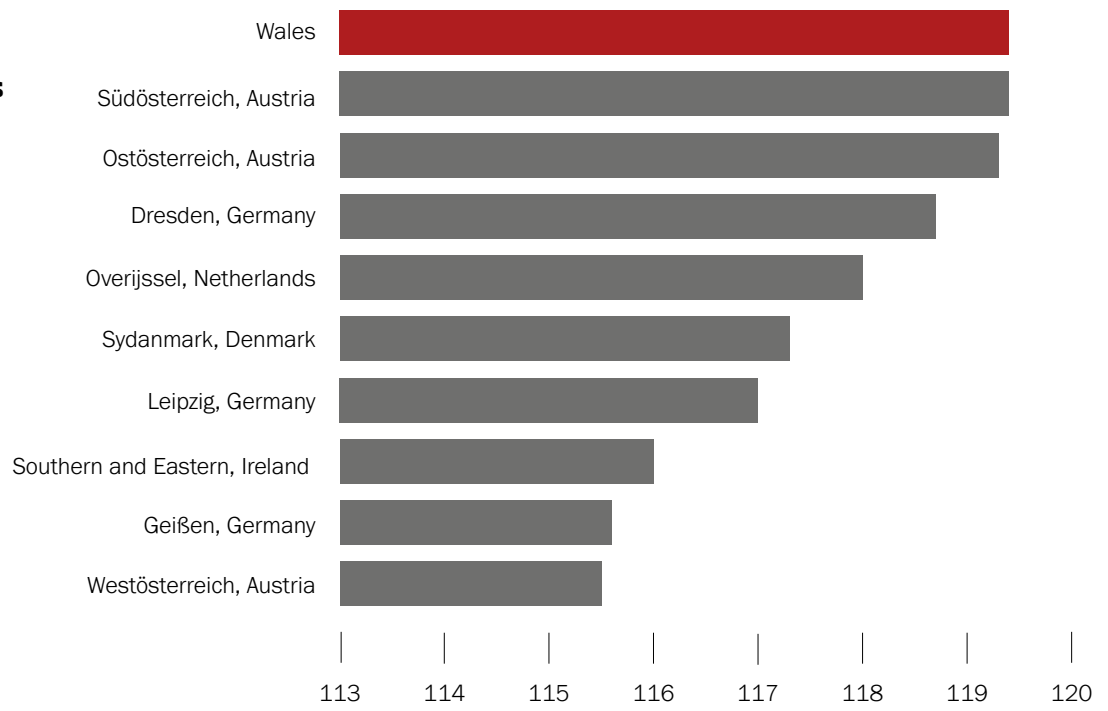
Figure 27:
Regional Innovation Scoreboard performance: showing the top performing region for each group



Source: Created with data from Regional Innovation Scoreboard - http://ec.europa.eu/growth/industry/innovation/facts-figures/regional_es

⁶² http://ec.europa.eu/growth/industry/innovation/facts-figures/regional_es

**Figure 28:
Top 10-ranked
European regions
in the Strong
Innovators group**



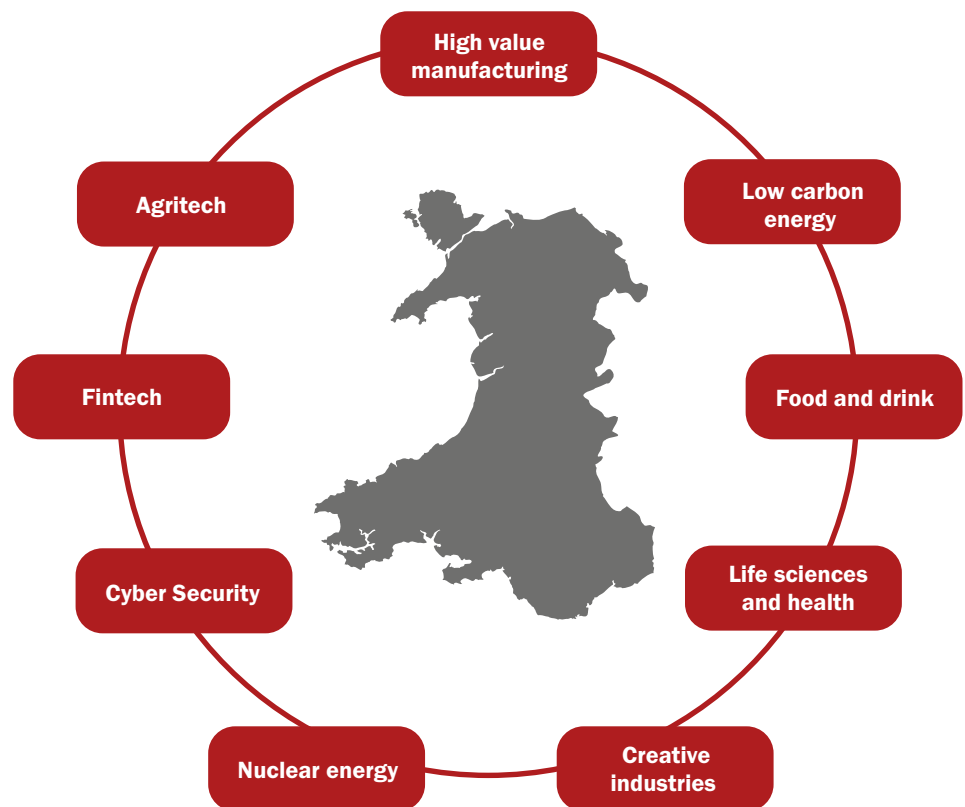
Source: Regional Innovation Scoreboard 2017

Annex 2: Translating research and innovation into business

Wales has a range of established and emerging businesses that contribute to Wales' industrial base. These are located across several key industries (see figure 29 and [REF <https://tradeandinvest.wales/key-industries>]) and collectively contribute to Wales' national research, innovation and industrial ecosystem. Several of these are considered in more detail below.

The Welsh Government's ERDF funded SMART schemes⁶³ (SMART Innovation, SMART Cymru and SMART Expertise) provides an integrated suite of interventions that drive innovative behavior in Welsh businesses. SMART Innovation has already engaged with over 1,800 companies and encouraged 240 of these to seek competitive funding, from Innovate UK and Horizon 2020. SMART Cymru and Expertise and have supported over 340 companies with R&D projects worth over £100 million with match funding.

Figure 29:
Some of Wales' National Research, Innovation and Industrial Sectors



⁶³ <https://businesswales.gov.wales/expertisewales/smartcymru>

High value manufacturing (HVM)

Wales has a skilled workforce with a broad range of manufacturing expertise and a focus on innovation and collaboration between industry, government and academic institutions. In this area, Wales has a 165,000-strong skilled workforce with Welsh universities producing over 2,000 engineering graduates every year and the 160 Aerospace and Defence companies, which employ 20,000 people produces a turnover of more than £5 billion. Wales' productivity in the manufacturing sector is higher than the UK average and accounts for 9.5 per cent of all workforce jobs in Wales, compared to 7.7 per cent across the UK.

Wales has several UK-significant HVM industries: These include: **automotive, opto-electronics, space and aerospace, medical devices, advanced materials and metals** and a growing industry in nuclear. These are backed by recent key investments from Welsh and UK Governments.

Advanced Manufacturing Research Institute (AMRI), Broughton

Funded by £20 million from the Welsh Government, the AMRI when built in 2020 will be a collaboration between the University of Sheffield's Advanced Manufacturing Research Centre (AMRC), Deeside Enterprise Zone Advisory Board, Swansea University and Coleg Cambria. It involves developing a new Institute to support Airbus and other key HVM companies. AMRI will focus on R&D in advanced manufacturing techniques and skills development, for HVM sectors in aerospace, automotive, nuclear and food, including for example, the Airbus 'Wing of Tomorrow'.

UK Leader in Compound Semiconductors (CS)⁶⁴

CS technology lies at the heart of the next industrial revolution, a technology that is growing rapidly in Wales. This technology remains a fundamental underpinning technology for many world-leading products, including smartphones; wifi; satellite communication systems; robotics and efficient LEDs. In Wales, industry, academia and Government are working to develop a world Compound Semiconductor cluster, incorporating IQE, the world's leading manufacturer of advanced semiconductor wafers, working in partnership with Cardiff University. The national importance of this IQE-Cardiff University partnership was recognised in 2018 by the UK Government, with its decision to award the £50 million Compound Semiconductor Applications Catapult.

This new cluster comprises the Compound Semiconductor Centre (CSC), Cardiff University's Institute for Compound Semiconductors (ICS), a Manufacturing Hub and Applications Catapult, working with Microsemi Corporation's advanced packaging, IQE PLC's wafer foundry and SPTS Technologies' specialist wafer processing equipment.

The expertise of the CSC lies in the ability to develop CS material combinations, and create novel integrated functionality for technologies, such as sensing, data processing and optoelectronic communications.

By integrating these world class CS capabilities around Cardiff, Wales has established the building blocks for a compound semiconductor ecosystem that will help bridge early stage research, applied industrial research and innovation through to high volume manufacturing and its supporting supply chain.

⁶⁴ <https://tradeandinvest.wales/tech/compound-semiconductors>

The vision here is to grow a cluster of semiconductor-enabled companies, which will generate up to 5,000 high value jobs, over 10 years.

Automotive⁶⁵

Wales produces about 35 per cent of the 2.5 engines produced in the UK. The automotive industry in Wales engages 150 companies and employs 18,500 people, generating a turnover of £3.2 billion each year. The technology range is comprehensive, from Ford, which has produced over 20 million engines in Wales, to Riversimple producing the first zero-emission car. As the sector moves into an exciting new era, two luxury car makers have also turned to Wales for their latest developments.

Aston Martin will build its new DBX Crossover model at Cardiff Airport and St Athan Enterprise Zone, while TVR have identified Ebbw Vale Enterprise Zone as their preferred location to build the new TVR sports car, to be offered with the innovative iStream carbon system manufacturing process.

Academic Links

Strong links between the industry and universities ensure that there is a strong pillar of research and development, to drive the next generation of automotive innovation. Developments, from vehicle design and materials research to next-generation powertrain and fuel technology, are supported by several Welsh academic centres including:

Automotive design, prototyping and testing:

- University of Wales Trinity St David – Automotive Design Non-Destructive Testing
- Swansea University – Computational Fluid Dynamics
- Cardiff Metropolitan University – Product Design and Development
- Alternative powertrain and materials technology

- University of South Wales – Hybrid and full electric vehicle powertrain, Automotive energy storage
- Cardiff University – Emission reduction Mechanical and structural performance
- Swansea University – Lightweighting Composite technology
- Alternative fuel technology.

Aerospace and defence⁶⁶

The Aerospace and Defence sector in Wales is a successful industry, involving over 160 companies and employing more than 20,000 people.

World class skills, training, research, innovation and expertise, have attracted some of the world's leading companies to Wales. These include Airbus; BAE Systems; British Airways; GE Aviation; General Dynamics; Raytheon; Zodiac Seats and Qioptiq. For example, Airbus Group employs 6,500 people in its civilian aircraft wing plant in North Wales, where they make the XWB A350 composite wing and there are a further 500 in Newport (Airbus Defence & Space).

Academic links supporting High Value Manufacturing (HVM) in Wales

With over 6,000 science and engineering graduates a year, from eight universities, there is a wealth of academic expertise available to the HVM industries.

The new **Swansea University** Bay Campus provides world class R&D, in areas such as Computational Engineering, including aerodynamic design for Airbus Wings and the Bloodhound supersonic car. The Institute of Structural Materials and Centre for Printing & Coating further complement expertise in this area. The Innovation Campus at **Cardiff University** includes aerodynamics research, stress evaluation, lightning protection at the Morgan Botti Research Centre and Propulsion performance research at the Gas Turbine Research

⁶⁵ <https://tradeandinvest.wales/advanced-materials-manufacturing/automotive>

⁶⁶ <https://tradeandinvest.wales/advanced-materials-manufacturing/aerospace>

Centre (GTRC). **Wrexham Glyndŵr University** is leading the way in research into adoption of carbon fibre composites in aircraft manufacture, using microwave technology to bring significant reductions in curing cycle time. This research complements the Advanced Composite Training and Development Centre, in partnership with Airbus, Coleg Cambria and the Welsh Government. Also, Glyndŵr Innovations, based at the OpTIC Centre, is a focus for a cluster of Photonics activity including design and manufacture of large optical telescopes and light-weight optics for satellite and airborne imaging systems.

The Aerospace Centre at **University of South Wales** specialises in Aircraft Maintenance Engineering and has two aircraft hangars housing Jetstream and Provost aircraft and Rolls Royce Spey engines. **University of Wales Trinity Saint David** demonstrates expertise in the area of Non Destructive Testing, working closely with **TWI** (originally The Welding Institute). Active within the Wales Academic Space Partnership, **Aberystwyth University** has supported Beagle 2 through its Intelligent Robotics Group. It also offers an Earth Observation Research Centre, providing expertise in both upstream and downstream Space research. **Bangor University** is home to CLARET, Centre for Lifetime and Reliability Testing, providing support to companies involved in aerospace technologies and Space electronics through design, manufacture or integration of opto-electronic and material technologies, with reliability testing facilities.

The **International Centre for Aerospace Training** located at Cardiff Airport and St Athan Enterprise Zone is delivering training for aircraft maintenance. **Coleg Cymoedd** has aerospace facilities providing apprentice programmes in aeronautical engineering. **Coleg Cambria** is providing apprenticeship

training for Airbus and other aerospace companies in North Wales, for both manufacturing and maintenance.

Low carbon energy⁶⁷

Around 58,000 people work in the energy and environment sectors in Wales, generating over £4.8 billion in revenue. The Welsh Government has pledged to make Wales a low carbon economy, delivering results both economically and socially. That ambition has meant an investment in skills and research, matched with a desire to innovate.

Academic research in support of Low Carbon Energy

Wales has rich resources for industrial and academic collaboration and many companies are involved in research and technology transfer projects with academia including Rolls Royce; Siemens; National Grid and Hitachi.

Driven by its vision for 'Buildings as Power Stations', Swansea University's SPECIFIC is a UK Innovation and Knowledge Centre. SPECIFIC's new 5 year £26 million delivery plan will develop building integrated solutions combining solar, thermal and heat storage in conjunction with Photovoltaics/PV and electrical storage to deliver product solutions to its industrial partners, which include NSG Pilkington Glass, Tata and BASF. This collective expertise and capability has been recognised by the UK Government by their £36 million award in 2018 to create the Active Building Centre, which will be a R&D demonstrator site, to develop domestic and commercial buildings, using the most energy efficient, low carbon technologies.

⁶⁷ <https://tradeandinvest.wales/advanced-materials-manufacturing/low-carbon>

The economic potential of the marine environment and the marine renewable energy opportunities is being investigated by SEACAMS 2, which is a £17 million, three year project led by Bangor and Swansea Universities. Through SEACAMS 2, companies wanting to harness the sea's power and create a sustainable marine energy industry in Wales are able to access the vital research support they need, if they are to progress with their multi-million pound developments.

Cardiff University is leading a £24 million FLEXIS project, aimed at developing more intelligent ways of managing future energy systems, alongside Swansea University and the University of South Wales. FLEXIS aims to meet the diverse, complex and inter-dependent challenges that arise, when new sources of energy are integrated into the grid by suppliers, thus helping to meet the low carbon agenda.

Life sciences and health research⁶⁸

The Life Sciences sector in Wales is internationally recognised for R&D. It is one of Wales' fastest growing and most innovative sectors. Wales' life sciences sector employs nearly 11,000 people in 350 companies, with a £2 billion annual turnover, expected to add £1 billion GVA by 2022.

Academic Research

Wales has a first-class combination of academic institutions, industry and government developing innovative solutions. These technological solutions are needed to meet the significant challenges, which lie ahead within the healthcare markets. To help the commercialisation of research a three-year £3 million Bridging Fund, aimed to accelerate the application of life science research, was established in 2015 by Welsh Government.

Cardiff Partnership Fund and Fusion IP Commercialising biomedical research

The Cardiff Partnership Fund (CPF) has helped turn scientific discoveries into commercially viable projects, improved university business awareness and brought new products to market, primarily through spinout companies. The Fund has made 85 investments, supporting 58 research development projects and 16 spinout companies and raised more than £75 million in co-investment, creating more than 100 high value jobs in the Cardiff City Region.

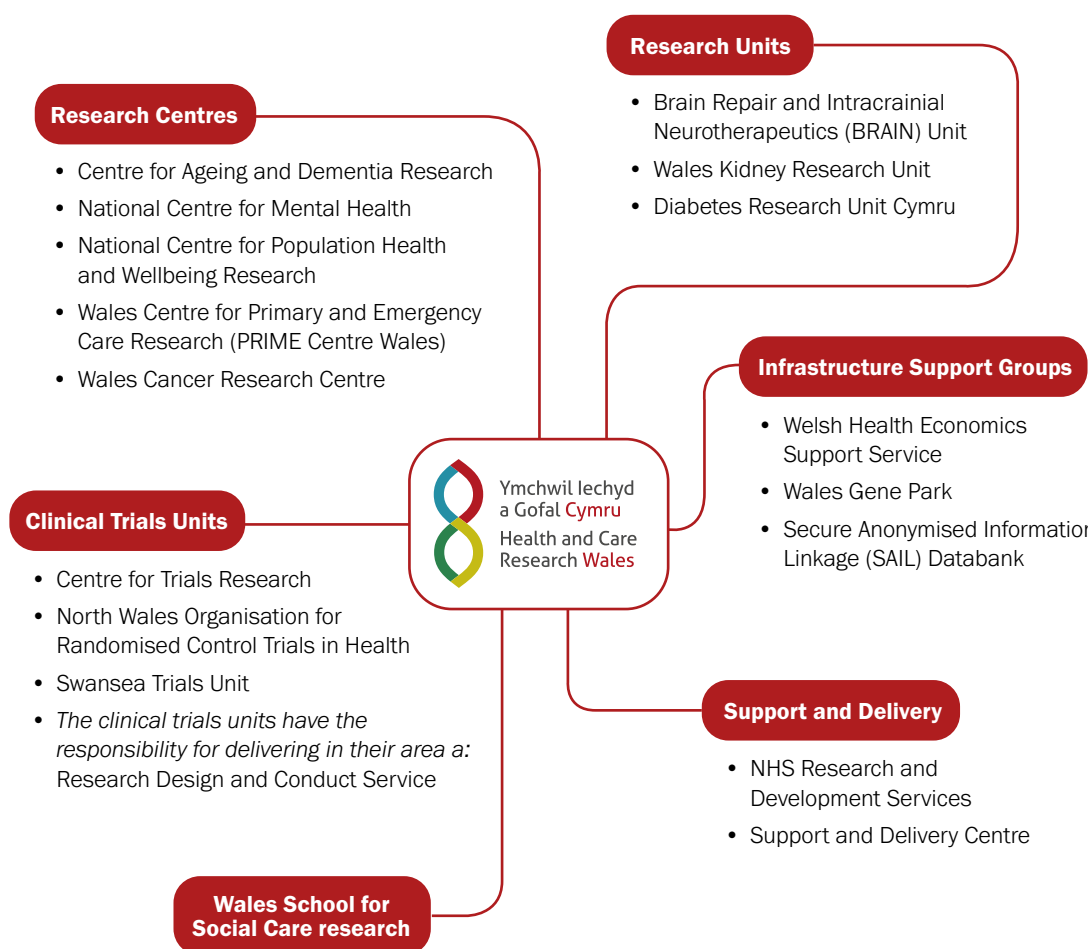
The CPF has underpinned the university's ten-year partnership with Fusion IP Plc, which in turn provided more than £50 million of patient capital investment and experienced management. This enabled four university spinouts to list on the Alternative Investment Market (AIM), with a market capitalisation of more than £230 million.

Health and Care Research Wales (HCRW)

The Welsh Government invests more than £42 million in health and social services research annually. This provides support for an extensive infrastructure of centres, trials units and support groups, which deliver clinical research studies, lead multicentre international research and participate in research that has an impact on the health of Wales, the UK and globally. The Welsh Government has made significant investment in research infrastructure to support and increase capacity in research and development, designed to ensure that Wales builds on research strengths where it excels and includes vital collaborations with the life sciences industry, for the universal benefit of patients.

⁶⁸ <https://tradeandinvest.wales/key-industries/life-sciences>

**Figure 30:
Health and Care
Research
Infrastructure
Map**



HCRW is a national, multi-faceted, virtual organisation funded and overseen by the Welsh Government. It provides an innovative infrastructure to support and increase capacity in research and development. With significant experience of working with industry, HCRW is supported by long standing agreements with commercial partners and is effectively delivering research studies across a wide range of clinical speciality areas. Since it was launched in 2015, HCRW has led on 532 successful grant awards, winning over £139 million research funding and creating more than 580 skilled jobs for

Wales⁶⁹. A figure of the Health research infrastructure is given in Figure 31.

Welsh Wound Innovation Centre⁷⁰

The Welsh Wound Innovation Centre is the first national wound healing centre worldwide and is the flagship facility for clinical innovation in Wales. Established to tackle the challenges associated with acute, traumatic and chronic, non-healing wounds and their treatment and prevention, the Centre has a vital role in Wales' economic development, helping to accelerate growth by stimulating and supporting business-led innovation in wound care.

⁶⁹ https://www.healthandcareresearch.gov.wales/uploads/About/Health_Care_Research_Wales_annual_report_17-18_eng.pdf

⁷⁰ www.wwic.wales

**Figure 31:
Illustration of
North Wales leading
the UK in nuclear
technology and
deployment**



Sail Data Bank⁷¹

Since 2007, the Health Informatics Group at Swansea University has been custodian of the Secure Anonymised Information Linkage (SAIL) Databank, a safe haven for billions of anonymised person-based records about the population of Wales, for use in research. Internationally recognised as world-leading for its innovation in data de-identification, security and linkage technology, SAIL allows researchers to identify influences on health and wellbeing at population scale, helping shape care and policy.

Life Sciences Hub Wales⁷²

The Life Sciences Hub Wales is the ‘nerve centre’ for the life sciences eco-system in Wales, connecting and accelerating businesses. From research and entrepreneurs through to healthcare professionals and multinational corporations, the Hub provides a commercially driven resource for the sector.

Cardiff University Brain Research Imaging Centre⁷³

The £44 million new CUBRIC building, which opened in 2016, brings together world-leading expertise in brain imaging, mapping and stimulation to better understand the causes of neurological and psychiatric conditions using the very latest in brain imaging and brain stimulation. The centre plays a pivotal role in the global endeavour to better understand the causes of neurological and psychiatric conditions such as dementia, schizophrenia and multiple sclerosis, to yield vital clues for the development of better treatments.

⁷¹ <https://saildatabank.com/>

⁷² www.lifescienceshubwales.com

⁷³ <https://www.cardiff.ac.uk/cardiff-university-brain-research-imaging-centre>

The MRC Centre for Neuropsychiatric Genetics and Genomics⁷⁴

This brings together world-leading researchers to investigate the major causes of mental health problems. Established in 2009, it was Wales' first MRC Centre and the largest psychiatric genetics group in the UK. It utilises clinical; genomic; statistical and bioinformatics expertise to tackle the challenges posed by psychiatric, neurodevelopmental and neurodegenerative disorders, with the aim of informing better diagnosis and treatment for the future.

Centre for Ageing & Dementia Research (CADR)⁷⁵

Building on existing internationally recognised and transformative research networks the Centre for Ageing and Dementia Research (CADR) is a world class research centre addressing key internationally important questions in ageing and dementia. The Centre links multi-disciplinary activity and develops areas of expertise from biological, through psycho-social and environmental, to social policy in ageing and dementia and involving staff from Bangor, Swansea and Cardiff universities.

UK Dementia Research Institute (UKDRI)⁷⁶

The £20 million UK Dementia Research Institute (UK DRI) is one of six established across Britain with a total £290 million investment. The UK DRI at Cardiff funded by the Medical Research Council, Alzheimer's Research UK and Alzheimer's Society and Welsh Government is an accolade for Wales and confirms the growing strength of ground-breaking scientific research, aimed at finding effective treatments for dementia. In recent years, more than 40 genes, which contribute to the risk

of Alzheimer's disease have been discovered and the team at Cardiff will use that knowledge to work on new theories and discoveries.

The Midlands & Wales Advanced Therapy Treatment Centre (MW-ATTC)⁷⁷

A recently formed health consortium, jointly led by the Welsh Blood Service (on behalf of NHS Wales) and the National Institute for Health Research Birmingham Biomedical Research Centre was awarded £7.3 million of UK Government funding managed by Innovate UK to ensure more patients benefit from a new generation of breakthrough therapies. £1.5 million will come directly to NHS Wales and £550,000 to Trakcel, a Welsh software company developing scheduling/tracking software for advance therapies; based upon technology developed at Swansea University

The funding will support the Welsh Government's commitment to developing an Advanced Therapies Strategy, which will enable these therapies to be brought to Welsh patients and Advanced Therapy Medicinal Product (ATMP) companies to reach the clinical market, whilst building expertise, capability and capacity across NHS Wales to benefit patient outcomes.

The Midlands & Wales Advanced Therapy Treatment Centre (MW-ATTC) will identify barriers challenges and solutions to facilitate future deployment and adoption of these transformative therapies, within the UK healthcare system.

⁷⁴ <https://www.cardiff.ac.uk/mrc-centre-neuropsychiatric-genetics-genomics>

⁷⁵ <http://www.cadr.cymru/en/>

⁷⁶ <https://ukdri.ac.uk/centres/cardiff>

⁷⁷ <https://www.theattnetwork.co.uk/centres/midlands-wales>

Nuclear energy provides over 20 per cent of the UK's energy in 2015 and the Nuclear Industry Association (NIA) estimates that the civil nuclear sector provides employment to over 65,000 people throughout the UK supply chain. Driven by the need for reliable, cost-effective and low-carbon electricity generation, the planned nuclear growth is anticipated to grow employment by a further 25,000, much of which will be in Wales.

Current and Future Opportunities for Nuclear Research and Innovation in Wales:

- **Deeside Advanced Manufacturing Research Institute** will consider nuclear manufacturing research and innovation as a major component.
- **Bangor University's new £20 million Menai Science Park**, part funded by European Regional Development Funding is designed to drive growth in knowledge based science, with an early focus on low carbon energy, the environment and ICT sectors.
- **Trawsfynydd** near Bangor is a site already licenced for nuclear and has been identified as an ideal site for deploying First of a Kind (FOAK) modular reactors such as Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR).

The **Welsh Government** has been supporting the following research and innovation activities:

1. **Nuclear Futures Institute at Bangor University:** Through the Sêr Cymru programme, a £5.4million investment has been made by the Welsh Government in two Research Chairs and associated teams that will form the core of the newly-formed Nuclear Futures Institute at Bangor University. These will be well placed to exploit the research and innovation opportunities around the

thermal hydraulics facility, new fuel developments, new applied technologies for nuclear and new nuclear fuels.

2. **North West Nuclear Arc Science & Innovation Audit (SIA):** The emerging North West Nuclear Arc Consortium was initiated by the Welsh Government Office for Science and feeds into the new Industrial Strategy 'Strength in Places Fund'.
3. **BWR Research Hub and Network:** This research and innovation initiative between Bangor University, Imperial College London and Hitachi/Horizon, part-funded by the Welsh Government and Hitachi, is designed to stimulate and lead the UK's research community in Boiling Water Reactor(BWR) research and innovation. BWR technology has not been deployed in the UK previously, so there is a need to develop the research base, to support this reactor type. The Welsh Government funding is managed through the Welsh Government Office for Science.
4. **Proposed UK National Nuclear Thermal Hydraulics Test Facility:** This partnership between the Welsh Government Office for Science and BEIS is to deliver a national research and test facility in north Wales. The project will be at least £40 million part funded, with up to £20 million from the Welsh Government. This will put a major part of the new nuclear R&I infrastructure in North Wales, and the potential 'First of a Kind' reactor deployments at Trawsfynydd (SMR), will put North Wales at the heart of new build within the UK and the world.

Research Links

From north to south Wales, several nuclear research and development programs are underway, addressing a range of industry issues including technology, training, supply chains, production and economics.

⁷⁸ https://tradeandinvest.wales/sites/default/files/nuclear_sub_sector.pdf

With both nuclear decommissioning and new-build projects on its doorstep, Bangor University is building a world-leading capability in nuclear engineering that will be the hub of a global network. With a focus on existing and emerging technologies in the nuclear sector including Pressurised Water Reactor (PWR), Boiling Water Reactor (BWR) and Small Modular Reactor (SMR), Bangor University aims to become a leading centre of expertise. Already, Bangor University and Imperial College London, with Hitachi-GE providing technical expertise and support, have established a joint 'BWR Research Hub and Network'. This BWR brings together the UK research base with Hitachi Nuclear researchers to help develop future generations of Boiling Water Reactor technology.

Aligned with this nuclear activity is Swansea University's 'Atoms to Applications' investment of £9 million by EPSRC and the Welsh Government to establish an Advanced Imaging of Materials facility. AIM is an integrated scientific imaging facility for Wales that can provide imaging and analytical capabilities across several length scales from Angstroms to centimeters.

The Welding Institute (TWI) is working with the nuclear industry to deliver process knowledge and system solutions in specialist joining and welding, non destructive testing and materials testing techniques. Their Advanced Engineering Materials Research Institute (AEMRI) aims to develop a nuclear fabrication Research Centre at TWI Wales in Port Talbot to support the nuclear supply chain in the delivery of skills and knowledge.

Cardiff University runs three nuclear related projects; the Understanding Risk Group at the School of Psychology is researching public attitudes towards nuclear power and radiation; the Geoenvironmental Research Centre at the School of Engineering is researching high-level nuclear waste disposal, nuclear repositories and waste isolation; and the School of Chemistry's Heterogeneous Catalysis and Surface Science Group is using analytical equipment to study the interaction of small molecules with surfaces, part of a collaboration with the National Nuclear Laboratory, studying long term storage of nuclear waste.

Alongside our higher academic programs, Wales is working with Horizon Nuclear Power to provide three year technical apprenticeship opportunities via Coleg Menai in North West Wales. Group Llandrillo Menai is the National Skills Academy for Nuclear's accredited local provider for delivering the Triple Bar qualification, focusing on the basic principles of nuclear generation, health and safety and 'human behaviors'.

Cyber Security⁷⁹

Wales' tech sector is worth and estimated £8.5 billion to the Welsh economy and it continues to grow. Over 40,000 people are actively employed within the Digital Economy in Wales with main hubs focused around Cardiff and Newport in the south, Swansea in the west and Wrexham in the north.

Businesses here have the finest technical backup: Europe's largest Tier 3 Data Centre, run by Next Generation Data, is geared to house hardware, software and fast data connections. Wales is home to over 3,000 homegrown and multinational technology operations, including some of the biggest tech companies, for instance BT, Thales, Qinetiq, Airbus Defence & Space and General Dynamics,

⁷⁹ <https://tradeandinvest.wales/sites/default/files/cyber.pdf>

many of whom are involved in homeland security; policing; counter-terrorism; major event security; and Cyber Security.

The Welsh Government is involved in a series of initiatives to address the issues affecting the further growth of the Cyber Security sector in Wales. Wales Cyber Security Clusters include; the National Cyber Security Academy (NCSA); The EDGE®; Airbus Group Endeavr Wales; CyberLab and Law Enforcement/ Cyber Defence. With over 250 members, the North and South Wales Cyber Security Clusters have been formed, under the umbrella of the UK Government supported UK Cyber Security Forum, by industry with the intention to deliver on Wales' ambition to become the UK hub for cyber security companies.

Academic Links

Talent is a vital ingredient to any country's success. 4000 students each year leave Wales' 8 Universities and 16 Further Education colleges in Wales with qualifications in ICT. With international recognition across numerous fields, Wales has 30 centres of excellence, 91 departments rated 4 star and above for research and 65 departments listed as excellent for teaching quality.

National Cyber Security Academy

The **Information Security Research Group** at the University of South Wales has an international reputation in the areas of network security, computer forensics and threat analysis. The group focuses on the issues associated with the design and development of early warning systems that are capable of detecting and responding to a variety of cyber based attacks and on the issues associated with the field of computer forensics. The University of South Wales is one of only a few in the UK that carries out network forensics for the UK government.

The **National Cyber Security Academy (NCSA)** at the University of South Wales (USW) and the Welsh Government have joined forces to launch an innovative project to help address a shortage of cyber security skills and develop the next generation of cyber security experts.

USW's expertise was recognised in May 2016 when it received formal accreditation from GCHQ for its Masters course in computer forensics. The University collaborates with a wide range of partners such as the MoD, Airbus, BT and Northrop Grumman and has a further range of partners including Wolfberry, Silox Information Security and Westgate Cyber. The NCSA also enables the University to offer high standard bespoke solutions to organisations such as the Police and other public and private bodies.

Airbus Endeavr Centre of Excellence in Cyber Security Analytics

Airbus Group Endeavr Wales is a joint venture company between the Welsh Government, Airbus Defence & Space and Cardiff University that seeks to 100 per cent fund project proposals that generate research and technology in the fields of Secure Mobile and Wireless Communications, Cyber Security, Network and SCADA Security. The Centre of Excellence in Cyber Security Analytics is a new research centre set up to provide world-leading research into the ever-growing problem of cyber security launched by Cardiff University and Airbus in April 2017. In tandem with the launch of the centre, Cardiff University has recently been awarded almost £2 million in external funding from a range of sources, including UK research councils, industry and government, to launch major new programs over the next 3 years, aimed at developing cutting-edge machine learning algorithms to detect cyber threats targeting various internet-enabled environments, including online social media to control systems in critical national infrastructure.

Agri-Food Tech Sector⁸⁰

The agri-food tech sector is underpinned by a production base covering agriculture, fisheries and forestry. UK agriculture is part of a complex global supply chain that represents the largest industry in the world, with an estimated annual GDP contribution of around \$4.8 trillion. The agri-food sector is an important industry both in terms of the proportion of the Welsh workforce employed in it and the 88 per cent of Welsh land committed to agriculture. Wales' leading activity focuses on the academic research strengths of crop improvement, animal health and managing waste streams. This translates into beneficial productivity impacts and support to the clean growth agenda when implemented by industry, ranging from primary producers through to large supermarket chains. The map above shows some of the local authority areas with high levels of employment in agriculture, forestry and fishing relative to total employment, as well as key agri-food tech assets.

Academic Research

Aberystwyth University's **Institute of Biological, Environmental and Rural Sciences** (IBERS) produces internationally recognised research, ranked in the world's top 150 universities and commercial impact, through things such as agricultural productivity improvements and improved crops. Also in Aberystwyth, the BBSRC and EU funded National Plant Phenomics Centre is crucial to crop improvement research, through understanding the impact of genetics and environment on plant phenotype.

The £4.2 million part ERDF funded Vet Hub 1 in Aberystwyth supports animal health research by providing Wales' first biosafety level 3 lab and facilitates collaboration with industry.

The most recent Sêr Cymru II research chair, Professor Glyn Hewinson, will deliver 'A Centre of Excellence for Bovine Tuberculosis (CBTB) for Wales', providing a hub for national and international interdisciplinary research on bovine tuberculosis. In combination with VetHub 1, this will develop capacity and expertise in animal health/bovine tuberculosis, not currently available in Wales.

Swansea University's **Centre of Excellence for Sustainable Aquatic Research** conducts applied research on a diverse range of aquatic organisms. It also advises industry and government. Also in Swansea, the Energy Safety Research Institute (ESRI) is leading two projects using industrial CO₂ plus nitrates and phosphates from wastewater to produce pure protein from Algae as a replacement for animal protein.

Cardiff University **Sustainable Places Research Institute** develops responses to issues such as climate change and resource depletion, linking to the environmental impact aspect of agri-food tech. Zero2Five Food Industry Centre (Cardiff Metropolitan University), The Food Centre Wales (Horeb, Ceredigion) and The Food Technology Centre (Coleg Menai, Grwp Llandrillo Menai) drive continuous improvement and innovation in the food sector and provide technical and operation support to businesses.

Aberystwyth, Bangor and Swansea Universities each have dedicated research capacity in the field of marine science supported by sea-going research vessels providing coverage of the entire Welsh coastline and including substantial programmes on seafood sustainability. All three institutions collaborate on major pan-Wales marine projects such as **SEACAMS**, **ECOSTRUCTURE** and **BLUEFISH**.

⁸⁰ <https://www.southwalescrucible.co.uk/?preview>

Annex 3: Growing Wales' research capacity pipeline

In 2012, the Welsh Government set out the ambitious **Sêr Cymru (Stars Wales)** programme designed to accelerate Wales' efforts to create a globally competitive science and technology base.

The **Sêr Cymru** programme was built on a unique partnership between the Welsh Government, HEFCW, Higher Education Institutions across Wales, the Welsh European Funding Office (WEFO) and the European Commission.

The **Sêr Cymru II** programme was itself innovative: Wales is the only EU country that formally linked the European Union's Horizon 2020 programme funding with that of the EU Structural Funds for the purpose of growing Welsh research capacity.

One of the indicators of the success of **Sêr Cymru** has been the adoption of similar capacity programmes by UK Government including **The Rutherford Fund Strategic Partner Grants** and **the UK Research and Innovation Future Leaders Fellowships (FLF)**.

Building a strong and successful scientific community was one of the Welsh Government's aims when it launched the *Science for Wales* strategy in 2012. A key driver behind this strategy was to grow research capacity in Wales, to support the wider economic and national development of Wales. The Welsh Government provided some £50 million of support which led the establishment of the internationally recognised programme **Sêr Cymru (Stars Wales)**.

The strategy attracted considerable UK and international interest with the prestigious **SCIENCE** journal noting in 2012⁸¹ that *'Wales appears to be headed in the right direction, toward success. If all goes well, Science for Wales will strengthen Wales' ability to achieve a critical mass of resources and researchers to advance in its Grand Challenge areas,*

build a sustainable science-based economy and become a stronger competitor with neighbouring nations.'

SÊR Cymru I (2012-2018)



Launched in 2012, the first phase of **Sêr Cymru** programme involved two complementary 'Strands' designed to: (i) attract new international scientific talent and (ii) support the development and networking of existing research infrastructure. Since 2012, **Sêr Cymru 1** has secured four world class academics as **Sêr Cymru Research Chairs**, (two from the US, one from UK and one from Switzerland) together with additional support for their research teams and other research infrastructure requirements.

It has also supported the development of **three national research networks** in each of the three 'Grand Challenge' areas: *Life Sciences and Health; Low Carbon, Energy and Environment; and Advanced Engineering and Materials*. The 'Grand Challenges' were identified both for their strength in academic departments in Wales and for their potential for commercial exploitation of research outcomes by businesses in and for Wales. All three networks undertook a variety of pan-Wales activities such as providing funding for large scale doctoral training schemes, support for postdoctoral researchers and engagement activities with a broad range of stakeholders, particularly those in industry. To boost capacity even further, the most research active of the Welsh universities in Cardiff, Swansea, Bangor and Aberystwyth have also been investing heavily in infrastructure such as new buildings and equipment.

⁸¹ <http://www.uniswales.ac.uk/wp/media/Science-in-Wales.pdf>

Sêr Cymru I Research Chairs

The 4 research chairs developing key research groups in Wales were:

To date, these four Research Stars have supported over 100 staff including over 30 PhD students and over 70 post-doctoral researchers/research fellows.



Professor Yves Barde (Sêr Cymru Research Chair in Life Sciences and Health). Professor Barde is a world-leading neurobiologist with a long and distinguished academic career in Switzerland before moving to Cardiff University in September 2013 from the University of Basel. He continues to work on the biology of his celebrated discovery, brain-derived neurotrophic factor (BDNF).



Professor James Durrant (Sêr Cymru Research Chair in Advanced Manufacturing and Materials). Professor Durrant, a distinguished photo-chemist, is shared between Imperial College, London and Swansea University and leads on 'Sêr Cymru Solar', a £7 million initiative to establish a research cluster focused on the development of low cost, large area photovoltaic technologies.



Professor Andrew Barron (Sêr Cymru Research Chair in Low Carbon, Energy and Environment). Professor Barron joined Swansea University from Rice University in Texas. His research interests are nanotechnology applied to fundamental problems in energy research with a current focus designed to increase the efficiency and safety of unconventional-gas exploration and extraction, facilitating a large-scale international collaboration on hydrophobic materials.



Professor Diana Huffaker (Ser Cymru Research Chair in Advanced Materials and Devices). Professor Huffaker moved to Cardiff University in 2015 from UCLA, California to take up the role as Director of Cardiff University's Institute for Compound Semiconductors. She has a world class reputation in compound semiconductor research and the development of 'quantum dots' materials used in optoelectronics and laser.

National Research Networks (NRNs):

The three Sêr Cymru National Research networks are: the **Engineering Research Network Wales**, the **National Research Network for Low Carbon Energy and Environment**; and **Life Sciences Research Network Wales**. The aim of these networks was to help Welsh universities to work collaboratively and to strengthen their reputation as centres for scientific enquiry. Each of the NRNs is a significant organisation, with dedicated staff and their own management, governance and advisory boards that help to steer their direction and oversee delivery and different partnership models.

The **Life Sciences Research Network Wales**, most recently led by Professor Andrea Brancale, supports world class science within Wales to develop new therapeutic treatments in areas of unmet medical and veterinary need. By 2018 the Life Sciences and Health NRN has involved 75 Post-doctoral Researchers, 56 PhD Students and secured £34.6 million research income into Wales. Researchers in this network have produced 120 peer reviewed publications and have had 361 national and international conference abstracts accepted.

The **Engineering Research Network Wales** is currently led by Director, Professor Huw Summers and was founded on a strong tradition of engineering ingenuity in Wales. Focused on Advanced Engineering and Materials, the core academic partners across Wales and their industrial collaborator, TWI Ltd. To date the Advanced Engineering and Manufacturing NRN involved 46 Post-doctoral Researchers 40 PhD/ EngD Students and secured £18.2 million research income into Wales. Researchers in this network have produced 204 peer reviewed publications and have had 255 national and international conference abstracts accepted.

By 2018 the Low Carbon Energy and the Environment NRN led by

Professor David Thomas, involved 36 Post-doctoral Researchers, 12 PhD Students and secured £13.1 million research income into Wales. Researchers in this network have produced 94 peer reviewed publications and have had 239 national and international conference abstracts accepted.

Of the almost £66 million competitively-won grant funding for research secured through the NRNs, over £22.5 million was secured from European Research Council and Horizon 2020 funding, £16.5 million from RCUK sources, £14.7 million from industry and Innovate UK and £12.2 million from other sources.

Collectively, the two strands of the **Sêr Cymru I** programme have already secured £131 million of competitively-won research funding into Wales. The impact of the Sêr Cymru I programme is predicted to continue to grow in future years.

This first phase of the Sêr Cymru programme draws to a close in 2018 and, while too early to draw definitive conclusions, as elements are still operating, a commissioned independent report by SQW (2018) found that, overall, the two strands of Sêr Cymru I had performed well – exceeding original output targets.

SQW's evaluation concluded that 'the rationale for Sêr Cymru I was timely and proportional' and that 'the programme was grounded in a solid evidence-base and was located within a well-established policy context that sought to promote the enhancement of the research capacity of Wales, as a key element of wider economic and social development. The need for the programme was consistently identified as sound by stakeholders, with Sêr Cymru 1 recognised as one of the key mechanisms through which the vision established in Science for Wales would be realised practically'.

SÊR Cymru II (2015-2020)

The second phase of the programme, Sêr Cymru II, was launched in December 2015. It involved funding of nearly £60 million, much of which comes from the European Union. Designed to grow Wales' research capacity, this programme differed from the first in that it aimed to attract a wider range of research-excellent stars in the early or middle stages of their career. It also included fellowships to attract those currently on a career break, back into research posts in Wales.

By 2018, Sêr Cymru II has also appointed 8 new research chairs and over 100 fellows (early-mid career researchers). The competitive fellowships were awarded to researchers from 28 countries including: Austria; Australia; Bulgaria; Canada; Chile; China; Denmark; France; Georgia; Germany; Greece; India; Iran; Ireland; Italy; Korea; Mexico; New Zealand; the Netherlands; Pakistan; Poland; Portugal; Romania; Spain; Sweden; the UK; Ukraine and the USA.

The programme has attracted considerable UK and international interest and was highlighted in the UK Industrial Strategy in November 2017⁸². The world's leading science journal SCIENCE, in 2016⁸³ also commented.

Like other countries that see knowledge-growth as a pillar of their economies, Wales has created a science agenda that aims not only to expand academic science but to translate science and technology into applications that lead to economic growth.

As noted above, the Sêr Cymru programme has also influenced recent UK funding calls, designed to attract global talent and strengthening the UK's research base. These include the 'Rutherford Fund Strategic Partner Grants' operated by the Department for Business, Energy & Industrial Strategy (BEIS), and the more recent UKRI funded 'Future Leaders Fellowships'. Given Wales track record and experience seeking new talent internationally, it is encouraging to note that Wales managed to secure 17 (14 per cent) of the 122 Rutherford Fellowships, more than twice the national share predicated by a national population of 4.8 per cent.

⁸² https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

⁸³ http://www.sciencemag.org/sites/default/files/documents/printed-publications/14_per_cent20Oct_per_cent20Wales_per_cent20Feature.pdf

Sêr Cymru II Research Chairs

The 8 research chairs from around the globe developing key research groups in Wales are:



Professor Paul Meredith (Sêr Cymru II Research Chair in Sustainable Advanced Materials). Professor Meredith is based in Swansea University's Physics Department and also holds an Honorary Chair at the University of Queensland in Australia. His current research involves the development of new high-tech materials for applications, such as optoelectronics and bioelectronics and he has particular interests and expertise in next generation semiconductors.



Professor Bill Lee and Professor Dan Cacuci (Sêr Cymru II Research Chairs in Nuclear Engineering) Professor Lee moved to Bangor University to establish a world-leading capability in Nuclear Engineering, arising from the Wylfa Newydd development in Anglesey – Nuclear Futures Institute at Bangor University. Professor Cacuci is from the University of South Carolina, USA and is internationally recognised for researching and developing methods to predict the future behaviour of engineering systems.



Professor Simon Ward and Professor John Atack (Sêr Cymru II Research Chairs in Medical Chemistry). Professor Ward is an acknowledged expert in Medicinal Chemistry who has had extensive experience at with Glaxo SmithKline. Professor Atack has held a number of senior positions whilst at Merck Sharp & Dohme and Janssen in the UK, USA and Europe Discovery Centre. Their aim is to transform Wales' ability to translate fundamental discoveries in disease processes into new drugs.



Professor Peter Ghazal (Sêr Cymru II Research Chair in System Medicine). Professor Ghazal moved to Cardiff University from the University of Edinburgh. He is an internationally respected Systems Immunologist who leads a major research programme in viral infection and neonatal sepsis. He has been at the forefront of multidisciplinary translational research for several years, establishing a vibrant inter- and multi-disciplinary research programme that directly links engineering with genomics.



Professor Richard Lucas (Sêr Cymru II Research Chair in Earth Observation).

Professor Lucas is a globally renowned researcher with expertise in quantifying and understanding the response of terrestrial ecosystems and environments to change, including that associated with climatic variation, through integration of remote sensing data from various sources. He has returned to Wales from the University of New South Wales to take up Aberystwyth University's Chair in Earth Observation.



Professor Glyn Hewinson (Sêr Cymru II Research Chair in Bovine Tuberculosis).

Professor Hewinson joins Aberystwyth University, creating the Centre of Excellence for Bovine Tuberculosis (CBTB) for Wales. He was the Lead Scientist for TB at the Animal and Plant Health Agency (APHA) (responsible for all scientific aspects of bovine TB). He moved to this post from being the Chief Scientist of the Animal Health and Veterinary Laboratories Agency, before it merged into APHA. Here he had led a multidisciplinary team, helping develop tuberculosis vaccines for badgers and cattle.

SÊR Cymru III (2019-2023)

Since the launch of Science for Wales back in 2012, the UK and Wales have undergone significant changes, in the economic, higher education and research policy landscape. To build on the success of the positive brand, the Chief Scientific Advisor for Wales is working on plans to progress a new phase of the programme ... 'Sêr Cymru III' – that builds upon the current programme but also adapts to the new direction of UK future programmes, with a view to securing greater funding for Wales directed at translating research towards innovation and greater commercialisation.

Operating under the principle of 'shared partnership', this new phase of the Sêr Cymru programme is intended to harness better public, academic and private sectors working in partnership – such as WEFO, UKRI, industry and health sectors and employed a level of conditional match-funding that can secure greater collective funding targeted at translating fundamental research towards innovation and greater commercialisation.

KESS: Building research capacity for SMEs (Small to Medium Enterprises)



Ysgoloriaethau Sgiliau Economi Gwybodaeth
Knowledge Economy Skills Scholarships

Separate to the Sêr Cymru programme, EU Structural funding from the Welsh Government have also been used as an important source of innovation support aimed at business and in particular growing the number of individuals with higher level skills in research and innovation working with SMEs.

Following the previous successful **Knowledge Economy Skills Scholarships Programme** (KESS 1) 2009–2014, the KESS 2⁸⁴. The programme offers a low cost means where companies can engage in a research project, together with the opportunity to develop a long term relationship with a University.

Led by Bangor University and involving all Welsh universities, the project will provide 645 scholarships over the course of six years enabling over 500 businesses to work with academics and postgraduate research students on innovative research projects to drive business growth.

Company 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 2 also provides a platform to access the latest academic developments and a chance to develop in-house R&D activities. The majority of KESS graduates are now working in industry.

⁸⁴ <http://kess2.ac.uk/about/>

