

Institution: University of Bath
Unit of Assessment: B12

1 Unit context and structure, research and impact strategy

1.1 Unit context and structure

As climate change and digitalisation are affecting every aspect of life and society, our *vision* is to conduct fundamental and applied engineering research to drive social, economic and technological advancements coupled with stewardship of the environment. Our *ambition* is to deliver research capable of positively addressing the challenges created by climate change, maximising the benefits of digitalisation and developing healthcare technology to improve wellbeing. Our *approach* is informed by the UN Sustainable Development Goals, UK's Research and Development Roadmap, UKRI delivery plans and the UK's Industrial Strategy.

This vision is supported by a transformation of our research base from being discipline oriented to a multidisciplinary ethos to tackle major national and global challenges, the first phase of which has coincided with the current REF period. This vision is further supported by ongoing efforts to create a more diverse research base, from PhD students to leadership teams. The Unit of Assessment covers the entire Faculty of Engineering & Design comprising four Departments (Fig.1), which were submitted separately in REF2014. During the current REF period, we have started a process of re-orienting our research around three core themes, *Resilient Environment*, *Sustainable Materials & Processes* and *Energy & Systems* (Fig.1). This has resulted in a more integrated, multidisciplinary research approach, with the creation of new and refocused research groupings spanning the entire Faculty, while at the same time disbanding other grouping where research has decelerated. To achieve this, strategic investments have been made in new academic positions, career development of researchers and development of new partnerships with industry, as well as in response to Government initiatives (ISCF and GCRF). As a result of this strategy, this combined UoA is returning a qualifying FTE of 157, a 45% increase over the REF2014 submission.

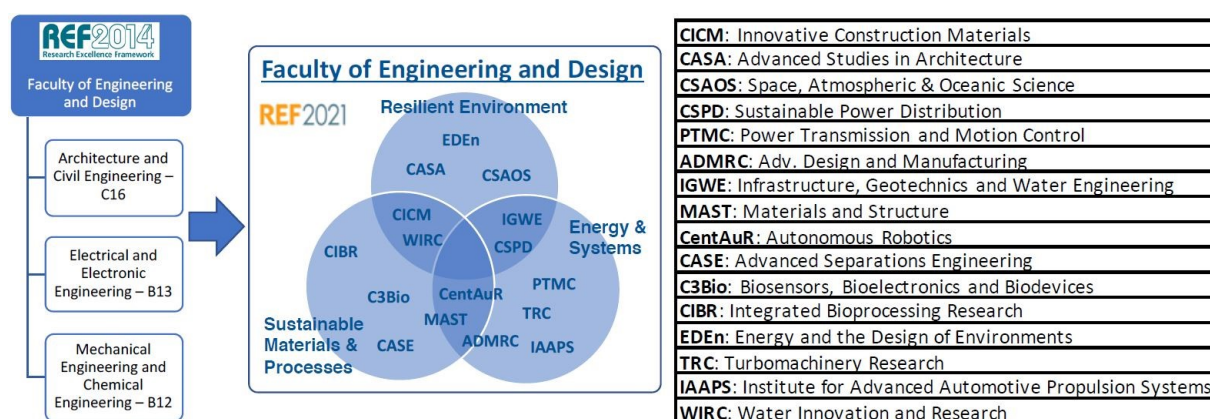


Figure 1. Unit of Assessment Structure from REF2014 to REF2021

Major achievements during the REF period include:

- Over £95m in new research grants awarded, a 9-point increase in the number of highly cited papers to 72% (top 10% field weighted average) and a tripling of citations to 27,000;
- 18% increase in academic staff, doubling of female staff to 24%, tripling of colleagues from BAME backgrounds to 26%, and staff now coming from 38 different countries (Section 2);
- Over £109m of new investment in infrastructure and equipment (Section 3);
- A major expansion of our engagement with local, national and international academic, industrial and institutional partners (Section 4).

Our research objectives over this REF period have been underpinned by a proactive approach to Equality, Diversity & Inclusion. This is evidenced by the four Departments having secured a total of six Athena Swan awards during the REF period: Architecture and Civil Engineering Bronze 2014, Silver 2019; Mechanical Engineering Bronze 2014, Silver 2018; Chemical Engineering Bronze 2018; Electronic and Electrical Engineering Bronze 2019.

Delivery on the plans set forth for the current REF period is discussed in Section 1.2, with a particular focus on our approach on impact in Section 1.3. Plans for the next phase of our transformation are discussed in Section 1.4.

1.1.1 Research centre structure

The **vitality** of our research environment is demonstrated by the dynamic approach to our research centres shown in Fig.1, each focusing on activities in one or more of three core themes. We assign research centres ambitious objectives, with tailored targets, including research income, outputs, scholarship, internationalisation and development of early career researchers (ECRs), thereby ensuring the long-term **sustainability** of our approach. Centre Directors are allocated time in their workload to deliver on targets, with membership of multiple Centres encouraged to foster a multidisciplinary research culture. Details on all the Centres are here: <https://www.bath.ac.uk/corporate-information/research-centres-institutes-and-groups/>.

1.2 Achievement of strategic aims during the REF period

As we transform our research base around our three core themes, our focus during the REF period is to consolidate our reputation as an international centre of research excellence, knowledge exchange and research-informed teaching excellence, achieving national and global impact through our research, industry connectivity, strategic partnerships and alumni relations. Through our strategy, we have realised the research objectives submitted by the 3 UoAs to REF2014 (now the 'Faculty'), which can be summarised as follows:

- Investment in new build, research infrastructure and equipment. This included a visionary intention to secure capital to develop a new Research & Innovation facility supporting our future research priorities;
- Development of new research initiatives;
- Investment in new academic positions;
- Funding for doctoral students.

1.2.1 Investment in research new build, research infrastructure and equipment

The increase in the size of our research base has led to over £74m investment in new infrastructure and equipment. **On campus**, this has included a new £22m building for Architecture and Civil Engineering providing 300 m² of new research and PhD space; and over 1,000 m² of research space, out of a total of 6,000 m², has been redeveloped, improved and upgraded by investment of over £7m since the REF2014. The Faculty has also significantly increased its footprint **off-campus**, with the centrepiece of this expansion being a combined £69m investment (£45m infrastructure, £24m equipment) to build a new Research & Innovation facility at the Bristol and Bath Science Park (BBSP) for research into future automotive propulsion systems. This investment is part of the creation of the Institute of Advanced Automotive Propulsion Systems (IAAPS) which will assist the UK to compete in the global race to realise the ultra-low and zero carbon passenger cars of the future, as evidenced by the South West England and South East Wales Science and Innovation Audit. The sum includes £29m awarded through a competitive UK Research Partnership Investment Funds bid, £10m from the Local Enterprise Partnership and £30m direct investment from the University. The new facility has 10,000 m² of research space that is being populated with £24m of state-of-the-art equipment. To accommodate the new facility, the University of Bath purchased the BBSP from the Department for Business, Energy & Industrial Strategy (BEIS) for £18m in 2018 in a joint venture with South Gloucestershire County Council. Additional space includes the HIVE (a 250 m² purpose-built facility to do *research in the wild* at the Science Museum, Wroughton, Wiltshire).

Equipment: The Faculty has secured a total of £35m to acquire, refresh and deploy state-of-the-art equipment in our priority research areas, including £24m in new equipment for IAAPS, £4.1m from the award of four EPSRC strategic equipment grants; £2.2m from the University's central Capital Refresh Budget – matched by £600k from the Faculty; and £1m from EPSRC for equipment for ECRs. Notable examples include investments in new equipment specifically to support ECRs, including a new materials characterisation facility, an advanced composite machining facility and a comprehensive chemical analytical suite developed in 2020 with a total of £1.2m of new equipment.

Highlight: Over £109m has been invested in research infrastructure and equipment.

1.2.2 New research initiatives and investment in new academic positions

Over this REF period the Faculty has invested strategically in specific new research initiatives around our three core themes. These are delivering impact and high-quality research by nurturing and sustaining multidisciplinary working while addressing national and international challenges. These investments have been matched by an expansion of the academic base, with a focus on increasing diversity and enhancing multidisciplinary research. A detailed analysis of the pattern of recruitment and the fit with our strategy is provided in Section 2.2. Exemplars of strategic investment include:

In the Resilient Environment theme, we launched the Water Innovation Research Centre (WIRC) in 2014 with initial funding of £4.1m from Wessex Water and the University to undertake leading edge multidisciplinary research on the whole water ecosystem, to support the water industry's challenge to reduce its carbon emissions while improving water quality. This innovative approach has led to five new academic staff in our UoA and catalysed focused recruitment in other UoAs in the University, notably in Chemistry and Biology. Led by **Hofman**, WIRC is co-leading the NERC CDT on Freshwater Biosciences (FRESH), and the EPSRC CDT on Water Informatics, Science and Engineering (WISE) and is a core member of the GW4 Water Security Alliance (Universities of Bath, Bristol, Cardiff and Exeter).

In the Energy & Systems theme, we created the new Centre in Autonomous Robotics (CentAuR), in support of the UK Government's industry strategy, focusing on AI, robotics and autonomous systems. The Faculty has invested in new laboratory facilities and 5 new and reprioritised academic posts in human-machine interface, power electronics and battery systems. The strategic vision is to integrate traditional aspects of robotics research, hardware, software, power and control with AI and autonomous operations. Led by **Wilson**, CentAuR now comprises members from Mechanical and Electrical Engineering, to Psychology and Computer Science and is co-leading the new UKRI CDT in Accountable, Responsible and Transparent AI (ART-AI).

In the Sustainable Materials & Processes theme, we created the Centre for Sustainable Chemical Technologies (CSCT) with the Faculty of Science (leads **Mays** and Davidson) in 2008. During the current REF period, this has evolved in the Centre for Sustainable and Circular Technologies, co-directed by **McManus** and Davidson. CSCT is the top research centre in the University and the linchpin of Bath's initiatives to address climate change. We have invested in eight new academic positions across the Faculty, covering research in life cycle assessment, sustainable manufacturing, biofuels and systems modelling. CSCT comprises 60 core academics, 26 from our Faculty, and leads the EPSRC CDT in Sustainable Chemical Technologies.

1.2.3 Funding for doctoral students

Our Faculty has delivered a doubling in PhD students during the REF period from 237 to 471, following a three-pronged approach to increase doctoral numbers: First, internal funding, via the University Research Studentship Allocation (URSA) has been prioritised for allocation to ECRs to support their applications for the EPSRC New Investigator Award, leading to a total of 90 studentships. Second, we have been successful in leading or participating in a number of CDTs, including the newly awarded CDTs in Advanced Automotive Propulsion Systems (APPS) and in ART-AI, and the existing CSCT, FRESH, and dCarb (see Section 2.3 for further details). Finally, we have placed significant effort to increase external funding for PhD students, including philanthropic and alumni donations of over £1m, iCASE awards from industry and directly funded studentships from industry, e.g. from GKN, Jaguar Land Rover and AVL. To strategically support the latter, we have used the EPSRC DTP allocation to our Faculty for match-funding with industry, to support the development of industrial relationship and, ultimately, impact. For details see Section 2.3.

Highlight: Our doctoral student population has doubled from 237 to 471 since 2014.

1.3 Enabling impact

The management of our approach to impact has a defined structure. Following REF2014 we created a Faculty-wide Impact Delivery Group (IDG) which consists of a pool of Impact Mentors, drawn from existing Knowledge Exchange Champions and academics who have demonstrated impact through their submitted case studies. The IDG is led by the Associate Dean for Research (**Mattia**) to ensure that 'impact' and 'research' are viewed as integrated activities with support from the Faculty Impact Champion (Ibell) as well as representation from the University's Central Impact Team. The IDG undertakes activities to promote, identify, capture, disseminate and demonstrate impact, which has resulted in 9 impact case studies (**ICS**) submitted for REF2021:

Identifying impact: Regular meetings with Research Centre Directors to document impact within their research areas identifies the maturity and extent of impact, allowing resource planning to take place and to encourage further development. Such resources include support for onsite visits to assess the extent of impact with end users, independent evaluation of impact claims and sabbaticals to undertake impact activities. For example, the Faculty supported site visits to Siemens, which contributed to the **ICS Improving Design and Efficiency at Siemens**, where novel seal designs have been incorporated into the new Siemens 9000HL gas turbines, four of which have been sold for £100m each and resulting in 3,000 tonnes/annum CO₂ emission reduction per machine.

The IDG ensures that previous successful REF2014 impact case stories are being tracked and enhanced for REF2021. An example is the **ICS Improving Quality in Manufacture of High Value Aerospace Parts**, where novel modelling and testing methodologies for aircraft wing spars, have resulted in direct savings of £11m/year and over 1,200 tonne/year in CO₂ emissions for GKN.

Developing impact: Numerous mechanisms exist to assist staff to develop impact. The Faculty provides dedicated training to ECRs to nurture, identify and develop impact and to establish industrial partnerships. The Faculty has focused on supporting applications to the EPSRC Impact Acceleration Account (IAA) and Knowledge Transfer Partnerships (KTPs) to develop impact with end users, with 21 IAA projects and 20 KTPs awarded during the REF period (see Section 3.1.4). An example of impact arising from IAA funding is the **ICS Creating next generation actuation components via additive manufacturing (AM)**, where research into the optimisation of AM has created new business for Moog, Renishaw and Blatchford, with combined new investments of £45m and 68 new jobs. An example resulting from KTPs is the **ICS Industrial tomography for the energy sector**, where two new businesses, iPhase and LeEngSTAR Technology Ltd, have been created to exploit our novel tomographic imaging methodologies, resulting in 46 new jobs and over £6.75m in capital raised.

Our impact spans the economy, society and the environment, and engagement with local, national and international partners, with examples detailed throughout this document. Examples include the **ICS Improving the efficiency of electricity distribution networks**, where novel methodologies for real-time monitoring and control of the network voltage have resulted in £116m/year savings to customers and a reduction of CO₂ emissions of 575k tonne/year, with Western Power Distribution; the **ICS Delivering reductions in CO₂ and pollutants from Ford vehicles**, where faster and better product development procedures, resulting in a 9% reduction in CO₂ emissions from 1.4m new cars, which equates to removing 109,000 vehicles off the road every year;

Our research has also had a direct impact on policy, for example via the **ICS Protecting critical infrastructure reliant on satellite navigation signals**, where our research on satellite navigation systems has directly influenced UK Government's policy on critical infrastructure and led to new commercial products by UK Chronos, sold to police and military clients around the world. Further policy impact is highlighted in Section 4.1.

Demonstrating impact: Our three-year Research Centre review process includes an explicit requirement for reporting on impact activities and how each centre encourages and nurtures impact. Good practice is disseminated across the Faculty. An example of this is senior members of a research centre including junior colleagues in industrial (impact related) meetings. This approach ensures that our impact strategy, plans and goals have prominence throughout our

academic management structure. It also ensures two-way communication exchanges and dissemination of ideas, developments and successful good practice, which benefits all our researchers. Examples of the success arising from centre-based research includes the **ICS** *Increasing efficiency and reliability in transportation systems using adsorption media tubes*, where a start-up company setup to commercialise our novel sorbent technology has been sold for £6.1m to IMI plc with over 700 new units sold per annum, equivalent to £2.5m/annum; and the **ICS** *Extending the life of our aging concrete infrastructure*, where our research has allowed the life of concrete structures to be prolonged, preventing building and bridges owned by Highways England and Network Rails from premature disposal, with savings into many millions of pounds each year.

Our systematic approach to identifying, developing and demonstrating impact has produced significant additional impact. Exemplars of the effectiveness of our strategy and its implementation are reported throughout this document, including the following:

Housing for the Displaced: Building on prior EPSRC funding, the research was further supported via internal IAA and GCRF funding to investigate the temperatures within shelters in refugee camps in Jordan, led by **Coley**. This was followed by a £1.6m EPSRC interdisciplinary GCRF grant (EP/P029175/1), which discovered air temperatures in excess of 40 °C and below freezing and internal surface temperatures high enough to burn children, pointing to a design and engineering process failure in refugee camps around the world. This led to the development of a low-cost solution, which has now been adopted by UNHCR, with, to date, 12,000 spacers fitted, and a 5 °C reduction of peak temperature.

1.3.1 Approach to supporting multidisciplinary research

The Faculty recognises that multidisciplinary research is essential to tackle the most important challenges our society faces, from mitigating the effects of climate change, to providing clean water to making transportation sustainable. This understanding is a key underpinning of our strategy, with a transition from discipline-based research to Faculty-wide research centres, clustered around three core themes: Resilient Environment, Sustainable Materials & Processes and Energy & Systems (Figure 1). We used investments in new academic staff to support this approach, with recruitment focused on creating critical mass in our three core themes, with the creation of the new research centres, C3Bio, WIRC and CentAuR, with membership from across the whole University. Our strategy is also reflected in PGR education, e.g. with the new CDT in Advanced Automotive Propulsion Systems (AAPS) involving researchers from Mechanical Engineering to Psychology to Chemistry, and participation in the new CDT in Accountable, Responsible and Transparent AI (ART-AI), with researchers from Electrical Engineering, Psychology, and Computer Science. As a result, 8% of our output submission is classed as multidisciplinary, i.e. with co-authors from disciplines outside our UoA and 6% of our outputs include co-authors from more than two Departments inside our UoA. Furthermore, this approach is also reflected in our impact, with two exemplars being:

Cellulose beads to replace microplastics: Since 2013, **Mattia** has worked with colleagues in the Department of Chemistry to explore the fabrication of cellulose microbeads as a replacement for plastic microbeads used in cosmetics and personal care products. Subsequent IAA funding was awarded to explore the commercialisation of this technology, leading to the founding in 2018 of a spin-off company, Naturbeads, which has received over £1m in funding and grants from private investors and Innovate UK. The company is being further supported by the Faculty with the use of laboratory space and facilities to deliver on a newly secured Innovate UK award.

Self-healing concrete: Since 2013, **Paine** has worked with microbiologists in the Department of Biology and Biochemistry through three EPSRC funded research projects to develop bacteria-based self-healing concrete. The microbiologists have worked on strain collection, spore production, growth kinetics and precipitation mechanisms that have enabled us to encapsulate spores in concrete and demonstrate that after cracking of concrete, metabolic actions from the reactivated bacteria seal the crack providing a recovery of durability. The work has led to the only full-scale site trials of bacteria-based self-healing concrete in the UK.

1.3.2 Progress towards an open research environment

The Faculty actively promotes the University's Open Access Publications Deposit Mandate to academic and research staff, ensuring that a full text version is always available via the University's online repository (Pure), which fully complies with REF Open Access Policy requirements. The Library data management service supports researchers in the planning, curation, preservation, and publication of research data and software. In addition, the Faculty mandates that researchers align with the Concordat on Open Research Data and the FAIR (Findable, Accessible, Interoperable and Reusable) data principles as set out in the internationally recognised Research Data Policy, with a particular focus on reproducibility.

1.3.3 Supporting a culture of research integrity and reproducibility of research.

As a research-led Faculty, we consider it critical that research is conducted in a way which allows others to have trust and confidence in it, the methods used and the findings that result from this. Using as a starting point the definition of research integrity provided by the Concordat to Support Research Integrity, we operate a Code of Good Practice in Research Integrity, setting out the principles and standards that are expected of all research conducted in the Faculty. To support this Code, the Faculty has developed systems and practices that embed these principles into all our research. These include the completion of an Ethical Review before undertaking any research, alongside dedicated training; University procedures to investigate potential cases of misconduct; and the requirement to declare any conflicts of interest to the Head of Department and in publications.

1.4 Future strategic aims and goals for research and impact

The transformation of our research base from discipline-focused to tackling grand challenges is a multi-year process, started during this REF period, to ensure the long-term sustainability of our research. We intend to further progress in this journey over the next 5-10 years, by consolidating all our research in eight multidisciplinary areas focusing on addressing the challenges created by climate change, maximising the benefits of digitalisation and developing healthcare technology to improve wellbeing. These multidisciplinary areas will span the Faculty with close collaboration with researchers across the University, stakeholders, industry and policymakers (Fig. 2). We see this as the next phase in the transformation started within the current REF period, where we have delivered on the equally ambitious plans as discussed in Section 1.2.

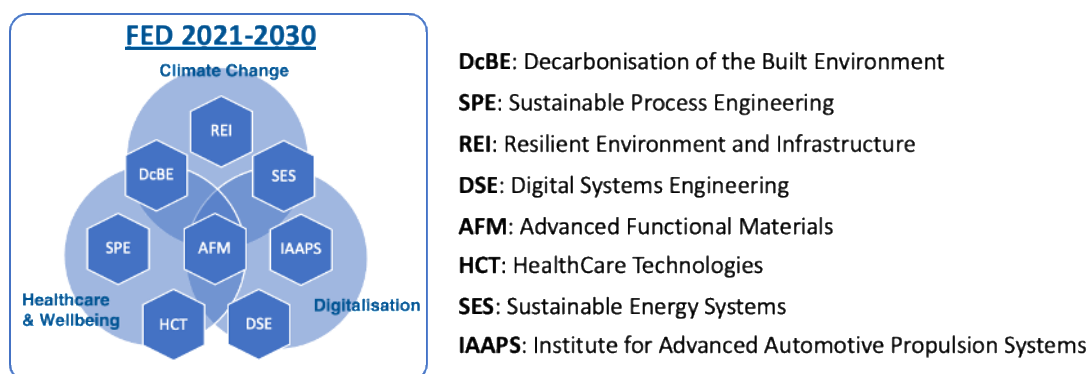


Figure 2. Unit of Assessment future structure for research.

We will invest in these areas, providing substantial support for leadership teams to deliver on clearly identified key performance indicators (KPIs) over a five-year period, subject to careful review. These KPIs will focus on achieving the objectives detailed earlier. Dedicated support will include targeted mentoring of researchers, tailored professional development, allocated time in their workload, dedicated administrative support (e.g. secretarial, communications, grant development) and seed funding to support emerging ideas and consortia development. A key deliverable for these areas will be developing the large cohort of ECRs we have hired in the current REF period, with the leadership and critical mass to sustain a major growth in funding and to lead engineering research and impact at the national and international levels. We have

developed a successful 'Bath model' to develop ECRs, discussed in Section 2, particularly in terms of building relationships with industry, as discussed in Section 1.3.

In the current REF period, the Faculty has seen about half its academic staff change, mainly due to retirements with senior retirees being replaced by ECRs and expansion of overall staff numbers due to success in both teaching and research. This has allowed us to re-orient significant parts of our research, developing new multidisciplinary areas. Our focus for the next five years will be to continue to develop home-grown leadership with targeted mentoring guided by the principles of *fit* with our eight multidisciplinary areas, *focus* on targeted areas with significant growth potential and *capacity* of leadership teams to adequately support and develop new appointees to succeed. All these activities will continue to be underpinned by our commitments to equality, diversity and inclusion (ED&I), discussed in Section 2.

2 People

2.1 Staff development strategy

During the REF period the Faculty has seen a major renewal of academic staff, with targeted investment in our three core themes (Fig. 1) and significant expansion, with a focus on creating a more diverse research base from PhD students to leadership teams. In this context, research and impact play a central role, with the Faculty supporting research staff to develop research skills including complex project management, translational skills, strategic landscape positioning, entrepreneurship, financial management, conflict resolution and multidisciplinary approaches to research. Exemplars of Faculty initiatives to support this strategy include:

Emerging Strategic Leaders: We have developed a programme of dedicated training for emerging leaders in the Faculty (e.g. Heads of Department, Associate Deans), via participation in the annual Academic Leaders Programme. The Aurora leadership programme is also available for women in academia; since 2014, seven staff members have participated in the Aurora programme, with **McManus** having been promoted to a personal chair and **Ellis** promoted to Head of Department (Chemical Engineering).

Faculty Fellowship Academy: The creation of a Faculty Fellowship academy, a year-long programme to support PDRAs to develop their research ideas into a Fellowship application. The programme has been so successful that it has been transformed in the University-wide Academic Career Academy programme. A successful example of this approach is provided in Section 2.2.3.

2.1.1 Mentoring, probation and appraisal and training

All academic staff are actively supported throughout their career via formal processes, including probation, annual development and performance review, dedicated training and mentoring. Research and impact are central to all of these processes. As part of their annual appraisal, academic and research staff discuss their training needs with their line manager. Examples of training for researchers include courses on managing research projects, IP protection and promotion of entrepreneurship. CPD is actively encouraged with dedicated provision for scholarship in each academic's workload allocation. Additionally, the Faculty has developed dedicated courses on impact, discussed in Section 1.3.

All academic staff are allocated a mentor as part of their probation support in a developmental scheme unconnected to career progression or line management. Heads of Department consider any protected characteristics of a staff member during the mentor assignment, to enable the mentees access to more bespoke support for their needs. Mentors support their mentees on all academic aspects, with focus on career progression and research, e.g. reviewing grant proposal drafts, development of academic and industrial networks across disciplines and institutions.

2.1.2 Policy for research, impact leave/sabbatical leave

The Faculty uses sabbatical leave strategically to support emerging and established research leaders to develop international links; to develop major grant applications; or to translate fundamental research into societal impact. During this REF period, 12 academics have benefitted from sabbatical leave, and we have plans to further support uptake of the scheme in the future. An exemplar is:

McManus: Undertook a sabbatical in 2017 at the University of Toronto and the Athena Sustainable Materials Institute (Ottawa), Canada, working on research underpinning the assessment of impact of emerging technologies on the local and global environment. This allowed her to include temporal and spatial modelling into life cycle system assessments, enabling more appropriate decision making on issues such as greenhouse gas emissions. This resulted in McManus advising DEFRA and BEIS on policy on the use and production of green gas and advising the DfT on sustainable fuels, transport and the impact of increased penetration of electric vehicles with the National Grid. The additional publications, workshop and conference session organisation, method development, international profile and government advice supported her successful promotion to a personal chair.

2.1.3 Exchanges between academia and business, industry or public or third sector bodies

Close connection with industry is a characteristic feature of our Faculty's research since the University's foundation. Examples of these two-way exchanges during the current REF period include the recruitment of several academics directly from industry (Hill, Hunter, Zeng, Vagg, D Zhang, Lanham, Hofman, Allen, Lunt); a RAEng Industrial Fellowship in Railway Infrastructure Resilience, with Network Rail (**Briggs**); a Royal Society Fellowship with Wallingford Hydro Solutions (**Kjeldsen**); and 2-year industry secondment for a PDRA, funded by Ford.

2.1.4 Recognising and rewarding staff for research and impact

The Faculty and University value the commitment, achievements and talents of our workforce and recognise these contributions through a range of initiatives and benefits, including the Contribution Pay scheme and academic promotion. The Faculty has been pro-active in supporting diverse voices by advertising leadership roles, targeted mentoring and staff development. An example of how research and impact has been recognised via promotion:

Perera: Professor Perera was promoted to a personal chair in 2015 following a Royal Society Brian Mercer Award (<https://royalsociety.org/topics-policy/industry-innovation/case-studies/perera/>) and the creation of her successful spin-off company, n-psl solutions, from her EPSRC and industry-funded research on porous sorbents. The company was subsequently sold for £6.1m to a major multinational company within the current REF period. In 2017 Professor Perera was also awarded the FDM Everywoman in Technology Award and is a mentor and the leader of the Bath chapter of the Women in Engineering Society.

2.2 UoA's Staffing and recruitment policy and evidence of its effectiveness

Our principal ambitions are to undertake world-class research and to produce graduates of the highest quality. We require the full diversity of talent to achieve and sustain these ambitions and this continues to drive our staff recruitment and promotion initiatives. Research is a central expectation for academic staff in the teaching and research job family within the Faculty. Thus, the Faculty ensures that all staff have a supportive, inclusive and developmental environment in which to pursue their research and to progress their careers. Our staffing strategy is to recruit at the highest quality, to provide focus, fit and capacity building across our strategic research activities and to actively develop, support and monitor the careers of all staff. Our academic staff succession plans are central. For instance, appointments following retirements are now used strategically to enhance research capability, encourage multidisciplinary, and promote inclusive working and diversity. The Faculty has fully embraced the principles of the Athena SWAN Charter with a commitment to gender equality and inclusivity with all departments in the Faculty having achieved Athena SWAN recognition over the census period of the REF2021.

2.2.1 The pattern of staff recruitment over the assessment period

Since the REF2014, the Faculty has expanded its academic base by 39 (an increase of 18%). This is due to investment in University-funded Prize Fellows (15 in total, 7 male and 8 female) and support for new and increased research capacity in our core themes, especially in the areas of Water Science and Engineering, Automotive Propulsion, Biosensors and Bioelectronics, Bioprocesses, Robotics, Geotechnical Engineering, Gas Turbines and Functional Materials. Also, 40 externally funded Fellowships were awarded to researchers during this REF period (see Section 3.1.1) and where these exceeded a three-year timescale the University has backfilled with new and permanent positions to further strengthen and expand critical and important areas of research. The Prize Fellow scheme provides two years of research in a managed and supportive environment to pursue top-level research before an expected transfer to a permanent academic position.

Our underpinning progress on ED&I over this REF period is evidenced by our recruitment of new academics, primarily at Lecturer or Prize Fellow (L/PF) level (Fig.3). This includes 18 male and 22 female academics. The changes in our academic recruitment process have had a positive impact, doubling the proportion of female L/PFs from 15% to 30% since the previous REF

period. The number of female Professors has tripled to 6, with 3 out of the 4 women promoted to Personal Chairs having been recruited initially as Lecturers. This is a direct result of our recruitment strategy to provide a sustainable talent pipeline for our future research activities, by investing in ECRs. The overall percentage of female colleagues has increased from 15% to 24% during the REF period, considering academic and research staff. The percentage of BAME academic and research staff has increased by 8% to 26% of all staff (Fig. 3). The number of staff with a declared disability has remained stable, while the number of part-time staff has decreased slightly, and the number of fixed term contracts has decreased by 5%. The Faculty has also significantly increased diversity in terms of national origin of staff, with 49% of staff being of non-British origin, up from 34% in 2014 from a total of 38 different national origins across the world.

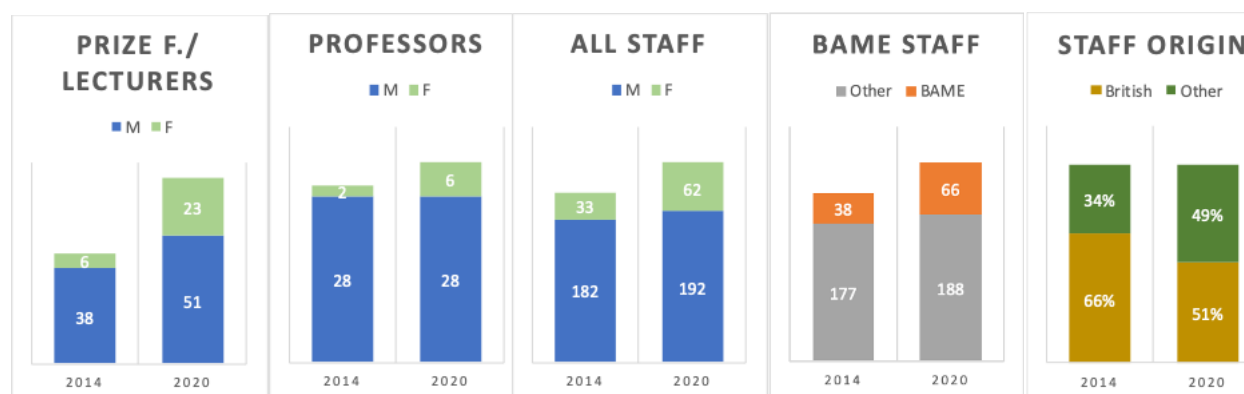


Figure 3. Change in staff profile during REF period

While encouraging, we see these results as an intermediate step in terms of our ambitions for ED&I and we will maintain a focus on this in the future (see Section 1.4).

As a result of the significant increase and renewal of staff, the demographic profile of the Faculty is tilted towards ECRs, with key hiring of senior staff to provide leadership and experience (e.g. Düren, Wilson, Butler). This expansion of the Faculty over the REF period has been matched with a strategic approach to promotion and succession planning for key roles.

Promotions: During this REF period, there have been over 50 promotions at all levels, demonstrating the successful ethos of the Faculty in mentoring, developing and promoting our staff, from Prize Fellows and lectureship positions through to personal chairs. This provides a sustainable way of underpinning our future research activities and our succession planning rather than engaging in recruiting 'developed' talent.

Highlight: Female staff increased from 15% to 24%, BAME staff increased from 8% to 26%.

2.2.2 Support for early career researchers

The Faculty has pursued a clear strategy to support ECRs in their development, using the internal workload model to ensure a balance across research, teaching and management. This is reviewed annually as part of the annual development and performance review, to set and monitor targets for research proposals, publications, and other longer-term goals, in line with our ED&I action plan. This integrated approach has been highly successful in terms of both career progression and grant capture including 14 EPSRC First grants/New Investigator Awards (Sangan, Courtney, Rhead, M Zhang, Ciampa, du Bois, Pan, Eslava, Scobie, Pountney, Pei, Mohammadi, Pinto, Roscow) and 10 early career fellowships from EPSRC, RAEng and RS (see Section 3.1.1).

We have developed a comprehensive support package for ECRs, which starts with each new appointee being assigned an experienced mentor and the allocation of a fully funded doctoral research studentship from the Faculty allowance with start-up funds of up to £20k and funding for travel, conferences and industry engagement. Teaching and administrative loads of ECRs are introduced gradually, also allowing ECRs to participate in career development activities.

These are tailored for each ECR and include centrally organised courses as well as a suite specifically designed by the Faculty, including dedicated REF and impact training. ECRs on probation have a mentor assigned and are enrolled on the accredited Bath Course, leading to FHEA status on completion. All ECR lecturers are required to complete the Bath Course in Enhancing Academic Practice, as part of their probation. The Faculty provides additional dedicated training on:

- Building industrial relations and impact (see Section 1.3);
- Innovation and commercialisation, providing insights on identifying opportunities for commercialising outcomes from research and guidance on how to make this a reality;
- Writing retreats, monthly sessions organised with the Research and Innovation Services, providing support for grant bid writing or engaging with industry to support funding applications.
- Internal peer review and mock panels to strengthen funding applications.

Highlight: Support for ECRs has led to 15 EPSRC NIAs and 10 early career Fellowships.

2.2.3 Specific support for postdoctoral researchers:

The Faculty actively supports the University's commitment to implementing the Concordat to Support the Career Development of Researchers at Bath and has a regularly updated action plan. The University holds the HR Excellence in Research Award since 2011 and has implemented a Vision for Research Staff and Code of Practice for the Employment of Research Staff to create a supportive and active research culture that fosters high achievement. Implementation of this vision is managed by the Research Staff Working Group which includes representatives from our Faculty. Key achievements include the implementation of a promotion process from Research Associate to Research Fellow and the introduction of the annual Outstanding Postdoctoral Member of Research Staff Prize to recognise outstanding performance by research staff.

In addition to these activities, the Faculty has placed a particular effort in supporting the development of postdoctoral researchers. This includes the appointment of 17 postdoctoral researchers from the Faculty (10 male and 7 female) to ECR positions, including Prize Fellowships. All these appointments were won in open competition, demonstrating the high-quality mentoring, leadership and inclusiveness that we afford to all our postdoctoral researchers. An exemplar of our approach in supporting postdoctoral researchers to succeed in competitive funding applications is:

Engineering for Development Research Fellowship: **Shen** participated in the Faculty Fellowship Academy while a PDRA in 2017 and the next year was awarded a 5-year Fellowship from the RAEng to tackle excessive fluoride in drinking water causing large-scale health problems in East Africa. Partnering with academic institutions and water treatment research stations in Tanzania, he aims to provide fluoride-free water to poor and vulnerable communities in East Africa by developing an energy-efficient, environmentally benign, and cost-effective desalination technology. This project has the potential to directly benefit large populations living in rural and remote areas in East Africa.

2.3 Research students: Training, supervision and integration in research culture

In 2017, the University created the Doctoral College (DC) to provide institution-wide and dedicated support, training, development and administration for our diverse doctoral population. Recognising that PhD students are on a 'journey' and as such their requirements will change over time, the DC offers pre-arrival support with student mentoring pre- and post-arrival, a comprehensive array of tailored induction activities (offered throughout the year, including integration into professional doctorate residential), and milestones to support web pages. The Faculty, working with the DC through the Associate Dean for Research, the Faculty Director of Doctoral Studies and the Departmental PGR Director of Studies, conducted an in-depth analysis of PhD recruitment, progression and completion from 2010 to 2017. From this analysis, the Faculty has identified three priorities, in line with our ED&I commitments, and has implemented action plans for each:

Recruitment of doctoral students: The Faculty enacted a policy that all candidates must be interviewed, and all staff involved in the recruitment of doctoral students must complete online Unconscious Bias, Diversity in the Workplace and interview training modules. The Faculty also raised entry requirements for both degree award and English proficiency. This has resulted in a significantly higher quality of PhD students and a more diverse student intake. The Faculty has a yearly allocation of studentships, from both University internal funding and the EPSRC DTP. This allocation has been used strategically to support ECRs (Section 2.2.2) and strategic growth areas (Section 1.2.3).

Monitoring and support mechanisms for PhD progress and completion: The Faculty Doctoral Studies Committee regularly reviews progress via 6-months reports with input from both students and supervisors. Departmental PGR Director of Studies intervene early on to address any emerging issues. The Faculty also decided to increase the duration of Faculty studentships from 3 to 3.5 years, with preliminary data showing a 43% decrease in the number of students leaving without an award during the REF period (the data is incomplete due to many PhDs having started during the current REF period but lasting beyond it). PhD students also have access to a team of independent Advisors for Research Students, who actively support students to address challenges throughout their degree.

PGR skills and career development: The Faculty also provides tailored activities for our students, including dedicated workshops on writing papers and on REF; career development seminars and career panel events with doctoral alumni. Access to professional networks in and out of research are promoted and facilitated. A measure of our success is that 11 of our own PhD students have graduated and been awarded Lectureships in the Faculty on a competitive basis within the current REF period. An exemplar of our success in developing our research students is:

Metcalfe: After graduating with a PhD in 2016, Metcalfe took up two posts simultaneously as both as a Research Fellow and a Teaching Fellow at the University, followed by the award of a Lectureship in bioelectronics in 2018, arising from an open selection process. Metcalfe's focus is on the interface between electronic engineering and biology to treat a wide range of diseases and disorders by modulating the nervous system, using implantable and wearable neuromodulation devices. One project, involving the development of an ECG specifically designed for horses, was presented to HM The Queen, generating significant publicity surrounding the issue of equine welfare. This has led directly to a new collaboration with Hartpury College and the University of Aberystwyth, along with a funded project with EquiNTy Ltd, which is a current manufacturer of equine ECG devices.

Studentships from major funding bodies: In a challenging funding environment, the Faculty has been successful in securing studentships from the UKRI, the China Scholarship Council, Industry and philanthropic donations. Examples include:

Centre for Doctoral Training: Faculty academics supervising nearly 50 PhD students from a range of CDTs we are leading or participating in: EPSRC CDT in Advanced Automotive Propulsion Systems (AAPS); UKRI CDT in Accountable, Responsible and Transparent AI (ART-AI); NERC CDT in Freshwater Bioscience and Sustainability; EPSRC CDT in Sustainable Chemical Technologies; NERC CDT in Water Informatics, Science and Engineering; EPSRC Centre for Decarbonisation of the Built Environment (dCarb) CDT.

iCase Studentships: Abbott Diabetes Care, Erba Molecular, Biobean, UK Atomic Energy Authority, Malaysian Rubber Board and Unilever, TetraPak, Renishaw, GKN, McLaren and Materion, BRE, Silent Sensors, DST Innovations.

Philanthropic and Alumni: Roger and Sue Whorrod, Dino Fuschillo, Find a Better Way, Dr Brian Nicholson, Hughes family, Enid Linder Foundation, James Dyson Foundation, Rosetrees Trust,

Anthony Best, Esther Parkin Trust, Leverhulme Trust, Mickey Ko, Andrew McIntyre and Hamilton-Fletcher.

International Funders: CONACyT Mexico; Malaysia Petroleum technology development fund; The Republic of Turkey, Ministry of National Education; Al-Ahliyya Amman University, Jordan; Qatar University, Qatar; Embassy of the state of Kuwait; Egyptian Ministry of Defence; Hashemite University, Jordan; Government of Iraq.

Highlight: Our doctoral population has doubled from 237 to 471 PhD students.

2.4 Equality and Diversity

The Faculty is committed to providing an environment that is supportive and enabling for all. The major changes in staffing in the Faculty during the REF period have been enabled and supported by the principles of the Athena SWAN Charter with a commitment to equality, diversity and inclusivity. All departments in the Faculty have successfully achieved Athena SWAN recognition over the census period of REF2021. As evidence of our progress and commitment, the Faculty's Athena SWAN champion (**Harney**) has now taken on the role of Athena SWAN Leader for the whole University.

We have further broadened the Faculty's approach looking beyond Athena Swan, to consider all protected characteristics. This involves the continuous collection of information that will help us to embed best practices and promote equality. Each Department in the Faculty has Departmental ED&I teams and champions who drive change locally, with regular meetings to share best practices across the Faculty. Equality of opportunity is a core value of the Faculty and recruitment and selection procedures have been designed to provide ways to assess and appoint the most capable and effective employees while ensuring that all individuals are treated with fairness and sensitivity. All academic staff on recruitment panels are now required to have passed a mandatory course on recruitment, with a specific component on ED&I. Additional training includes a 'Diversity in the Workplace' eLearning course launched to enhance and promote inclusive practices and diversity and training workshops for Departments (e.g. on unconscious bias). Staff can request an unpaid extended period away from employment to meet their personal needs e.g. taking care of dependants, undertaking long term full-time study of relevance to their job, to travel. The University also recognises the need to provide flexible employment options to give staff choice over their working hours subject to the overriding operational needs of the University to deliver services effectively.

2.4.1 Support for staff and research students with caring responsibilities, ill health etc

As a Faculty we strive to remove barriers for all staff and researchers to enable them to achieve their research goals, e.g. while away for conference attendance and research travel. The University has an on-site nursery assessed as OFSTED Outstanding and provides NurseryPlus, a salary sacrifice scheme to support parents with these costs. Through the University's flexible working policy, support is provided including, but not limited to, temporary transfer of duties, reduced workload, altered working patterns, with 12 members of staff having requested and agreed to flexible working arrangements over the REF period. Since 2014, 21 members of staff have taken parental leave, and there was a noticeable increase after the introduction of the University's new Parental-Leave Policy in 2016 which allows for shared parental leave and more flexibility.

2.4.2 Support for staff returning from periods of leave

Return to work meetings provide opportunities to discuss how the University can support the individual's successful transition back to work. Staff returning from parental leave are entitled to paid KIT (Keeping in Touch) days and may submit flexible working requests. Specific to the Faculty, academic staff returning from leave are included in the priority list for the award of Faculty PhD studentships, provided candidates who meet our requirements are put forward. Similar support is provided to PhD students who may suspend their studies for a range of reasons, which include a serious injury, illness or medical condition, a sudden deterioration of

ongoing physical or mental health condition suddenly getting worse or unforeseen disruption of personal life.

2.4.3 Supporting the wellbeing of staff and research students

During the current REF period, our approach to wellbeing has significantly evolved, with particular emphasis on mental wellbeing and an aspiration to create a learning environment and organisational culture that enhances health and wellbeing across our community. Each Department has a Wellbeing Champion, supported by training and resources to help improve mental and physical wellbeing at work and in life, including the Mental Health and Wellbeing workshops. Anonymous counselling for staff is available through the Employee Assistance Programme, and via Student Services for PhD students. At a Faculty level, unconscious bias training and recruitment training is compulsory for all line-managers and encouraged for all staff. Furthermore, staff training in line with the “NeverOK” anti-bullying/anti-harassment campaign and the Mental Health campaign have been rolled-out through the Faculty. Staff and students are encouraged to discuss concerns with their mentor(s) and share them with their peers during the numerous social activities across the Faculty. Through these initiatives we are fostering a culture of inclusion and belonging.

Pandemic response: With the emergence of Covid-19, the Faculty, in line with University policies, has significantly increased its focus on staff and research students’ wellbeing. Targeted actions include dedicated webpages and apps, training for line managers to support the wellbeing of academic and research staff whilst remote working, ergonomic assessment and the provision of IT equipment and office supplies for remote working, and the opening of a dedicated Covid-19 test centre for staff and students. The Faculty also undertook a full health and safety review before re-opening research laboratories in summer 2020, including the provision of specialised PPE equipment to operate safely (see Section 4.1.1).

2.5 ED&I considerations in the construction of our REF submission

To ensure equality and diversity in the REF process, a Code of Practice has been written which outlines the measures taken (<https://www.bath.ac.uk/publications/research-excellence-framework-ref-2021-code-of-practice/>). The Code has been promoted internally via email as well as using the homepage, digital signage and staff twitter account. Open staff meetings have been held both as part of the consultation exercise on the Code and to discuss the Code once it was finalised. All staff involved in REF decision making processes have been trained in equality and diversity, including the Equality Act 2010 in the context of REF as well as more broadly.

Outputs: The final 393 submitted outputs, selected from a pool of over 3000 reviewed papers, includes 23% assigned to female colleagues, comparable with the percentage of female Category A Staff. The proportion of female authored outputs is slightly below the proportion of female Category A staff reported in Section 2.2.1 due to small differences in staff eligibility. In line with the University Code of Practice, the primary criterion for selecting outputs was quality, as assessed by an internal panel which reflected the diversity of the Faculty’s academic staff in terms of experience as well as protected characteristics. Where there was evidence that authors who shared a protected characteristic were disproportionately under-represented, but whose outputs achieved all the criteria for selection, we took proportionate action with the aim of achieving balance in our submission.

Impact Case Studies: Out of nine impact case studies submitted, three are led by women, reflecting the increase in female senior academic staff. Although all our impact case studies are led by Professors, ECRs and mid-career researchers are contributors in seven out of nine. The final selection of the impact cases is the result of a multi-year process, described in Section 1.3, with substantial efforts to be inclusive and capture and assess all potential impact. As a result of these efforts, significant impact, which could not be included in the submitted impact case studies, has been reported throughout this document, to showcase the relevance and impact of our wider research activities.

Environment Statement: In the preparation of this document, the Faculty conducted a wide consultation with all staff in the Faculty, to ensure that all perspectives could be considered, particularly regarding examples of excellence in the different facets of our activities. The consultation included an online survey and direct discussions with all staff members via each departmental Director of Research (DoR). Staff on maternity or sick leave were consulted upon their return or via their DoRs. The latter consultation, representing the views of their respective Departments, have also directly contributed to the final version of this document. In line with the transformation beyond discipline-based research discussed in Section 1, we see additional value in this document as the first overarching summary of the whole Faculty's activities over the past six years. As such, we plan to share this document with academic and research staff to celebrate success in research and impact, but also to use it as a basis to accelerate the transformation of our research as discussed in Section 1.

3 Income, infrastructure and facilities

3.1 Research funding strategy

To support our research vision, focused around three core research themes (Fig. 1), the Faculty of Engineering and Design has identified three strategic priorities to increase research income, along with a desire to increase the quality of our research outputs and breadth of our impact:

- Support for ECRs in preparing EPSRC NIAs and early career Fellowships
- Support for Fellowship applications for mid-career and established academics
- Support for large grants, particularly as leads

Working together with our Research and Innovation Services and the Research Centres, we have concentrated support on these three funding routes, including internal peer-review, sandpits and consortium building activities, scouting of potential industrial partners and institutional support, in the form of PhD studentships, funding for equipment and for laboratory refurbishment/upgrade. These efforts have been underpinned by our ED&I strategy, with a particular effort to encourage female and BAME staff to apply for funding (see Section 2). As an example of our approach, we have worked hard to ensure a diverse range of co-investigators in institutional equipment applications, internal funding calls, including the annual capital refresh budget call (Section 3.2), IAA and GCRF internal calls.

Our approach has resulted in over £100m in grant awards during the REF period, accompanied by an increase in the number of highly cited papers from 63% to 72% (top 10% field weighted average) and an increase from 9962 to 27579 citations (source SciVal). We see the simultaneous increase in income, highly cited papers and citations as additional indicators of the success of our strategy in support of academic staff. Furthermore, we see this as particularly significant in view of the very large cohort of ECRs hired during the REF period, showcasing the high quality of staff recruited. Exemplars of the success of our approach include:

3.1.1 Fellowships

Over this REF period, 27 externally funded Fellowships and 13 University of Bath Prize Fellowships have been awarded to Bath academics (Fig. 4). The University has enhanced Fellowships won by academics within the Faculty with new and permanent academic appointments to increase research power and to provide strategic investment in areas of strength and growing importance.

Bryant, 2016-18 Ke, 2017-19 Khanbareh, 2016-18 Leese, 2017-19 Maskell, 2016-18 Moschou, 2016-18 Pountney, 2016-18 Roscow, 2017-19 Samsatli, 2016-18 Scobie, 2016-18 Stephenson, 2017-19 Tang, 2017-19 Wu, 2017-19 Prize Fellowships	Gu, 2014-17 Kim, 2014-2020 Orr, 2015-21 Torrente, 2015-2020 Mattia, 2018-23 Eslava, 2019-24 EPSRC	Ellis, 2014-15 De Paola, 2018-19 Pan, 2019-22 Blenkinsopp, 2020-21 RAEng/Leverhulme	Wain, 2018 Nicoll, 2014-19 C. Mitchell, 2016-19 Wright, 2019-22 NERC
	Butler., 2013-23 Briggs, 2017-18. 2020-24 Zhang, 2016-21 Shen, 2018-23 Moschou, 2020-21 RAEng	Bowen, 2014-19 Patterson 2015-20 Düren, 2015-20 ERC	Kjeldsen, 2019 Wright, 2017-22 Royal Society
			Düren, Mercator Wilson-Jones, Augustus Found Other Burstons, 17-22 STFC

Figure 4. Fellowships awarded during the REF period.

3.1.2 Major grants

Programme Grants: **Mattia**, "From Membrane Material Synthesis to Fabrication and Function (SynFabFun)", EP/M01486X/1, £4.5m (£1m to Bath), lead institution University of Newcastle (2014-20); **Paine**, "Resilient Materials for Life (RM4L)", EP/P02081X/1, £4.8m (£1.8m to Bath),

lead institution Cardiff University (2017-22); **Briggs**, “Assessment, Costing and Enhancement of Long Life, Long Linear assEtS (ACHILLES)”, EP/R034575/1, £4.9m (£245k to Bath), lead institution University of Newcastle (2018-22); **Butler**, “Certification for Design – Reshaping the Test Pyramid”, EP/S017038/1, £6.9 (£1m to Bath), lead institution University of Bristol (2019-24); **Ibell**, “UK FIRES: Locating Resource Efficiency at the Heart of Future Industrial Strategy in the UK”, EP/S019111/1, £5.1m (£1m to Bath), lead institution University of Cambridge (2019-24).

Hub Grant: **Keogh**, Future Advanced Metrology Hub, EP/P006930/1, £10.4m (£1.2m to Bath), lead institution University of Huddersfield (2017-24).

Platform Grant: **Newnes**, “Designing the Future: Resilient Trans-Disciplinary Design Engineers”, EP/R013179/1, £1.8m (2017-22).

EPSRC Prosperity Partnership: Road to Zero, £4.8m (**Akehurst** – see Section 4.1.2).

Strategic Equipment Grants: **Hawley**, “Centre for Low Emission Vehicle Research (CLEVeR)”, EP/L011964/1, £1.8m (2014-17); **Shields**, “Manufacturing of Nano-Engineered III-nitride Semiconductors”, EP/M015181/1, £1m, (2015-20); **Cleaver**, “Versatile Fluid Measurement System for Aerospace Research”, EP/M000559/1, £511k, (2015-20); **Darby**, VSimulators: Human Factors Simulation for Motion and Serviceability in the Built Environment, EP/P020704/1, £1.6m (2017-21).

Capital Investment: Institute for Advanced Automotive Propulsion Systems (**Hawley**), £69m combined investment from RPIF, LEP and the University of Bath (see Sections 1.2.1 and 3.2.2).

3.1.3 Engineering for development

The Faculty has invested significantly in supporting GCRF applications focused around our core theme of Resilient Environment. In particular, we have focused on improving building resilience and water quality in a changing climate, with over £4.1m of GCRF (EPSRC, Newton Fund, RAEng, British Academy) awarded to Faculty members, working with partners in Vietnam, Jordan, Turkey, India, Mexico, Sierra Leone, Brazil, Sri Lanka, Colombia, Ghana, Peru, South Africa and Uganda:

Building Resilience: Improving building materials, construction, resilience and liveability of buildings in developing countries is a focus of our research: **Maskell** is working in India to improve wellbeing in earthen residences; **Walker** is working on developing more resilient housing in Sri Lanka; **Coley** is working on housing the marginalised under a changing climate in Peru. **Natarajan** is leading a £1m EPSRC project on addressing peak energy demand reduction in buildings (ZED-I) to increase the resilience of energy distribution systems in India and reduce the high frequency of blackouts, which have major negative effects on the health, productivity and safety of people. The project will deliver a construction method that is compatible not only with the Indian climate but also with its building practices and social customs, thus avoiding the trap of an “imported” standard.

Improving Water Quality: As part of WIRC (Section 1.2.2), our research has focused on improving water quality in the developing world, with projects including working with rural communities in Mexico to map water pollution (**Di Lorenzo**), community-led phytoremediation in Sierra Leone (**Bryant**), mining effluent remediation in Colombia (**Castro Dominguez**), impact of mercury in gold mining in Ghana (**Kjelsden**), low-cost fluorine-free water in Tanzania (**Shen**) and removal of microplastics from drinking water in Thailand (**Expósito**). The £1.1m EPSRC GCRF ReNEW project (**Estrela**) is developing a real-time community-wide public health early warning system (EWS), working with the local University and public health authorities in the city of Stellenbosch in South Africa as a first deployment of the technology.

3.1.4 Impact Acceleration Account and KTPs

Throughout this REF period we have continued with our commitment to success at engagement with industry, particularly SMEs, via the IAA, KTPs, Innovate UK projects, and the Advanced

Engineering Hub (see Section 4.1.1). The Faculty has secured 20 KTPs, which often serve as the first step to build long-lasting relationships with our industrial partners. In addition, the Faculty has been awarded over £1.9m in 21 IAA projects with 3rd party contributions of £2.4m and in-kind contributions of £215k, with a wide range of companies including Wessex Water, Augusta Westland Ltd., MOOG, Ford, Jaguar Land Rover, Thales UK, Cross Manufacturing, ASV Global, Effect Photonics, Metropolitan Police, Airbus UK, Weir Advanced Research Centre, HiETA Technologies, Croda, Alba Ultrasound, Kraken Robotics, Croda, Ashley Cooper Ventures, Veolia, LANL, Adaptavate. Exemplars of our success include:

Navtech Radar: This is the forerunner in the design and manufacture of high resolution, cost-effective security and safety systems, which combine the company's patented radar technology with sophisticated analytical software. Navtech offers an impressive application portfolio which includes wide-area security surveillance, surface movement, traffic management and incident detection as well as industrial automation, branded respectively as AdvanceGuard™, ClearWay™ and SafeGuard™. Three KTPs led by **C Mitchell**, have been secured with the company and the last one (2014-2016) was graded 'Outstanding' by Innovate UK. The impact of the work provided Navtech with a new product, a sensor designed to detect people and vehicles across sites, providing alert and track data of the target to the operator.

Seiche Water Technology Group: Two KTPs were secured (**Hunter**) during this period in addition to other two in the previous REF period. Seiche Group is a global specialist in underwater acoustics and noise measurement. The latest award (2019) operates with two of Seiche Group's flagship technologies: AutoNaut, the wave-propelled unmanned surface vessel powered entirely by renewable energy, and an enhanced version of Seiche's towed Digital Thin Line Array (DTLA), integrating hydrophones to detect and analyse targets underwater or at the surface. These two research strands will merge to offer Seiche Group a powerful new platform for unmanned, remote acoustic surveying, generating little self-noise and enabling long endurance.

3.2 Organisational and operational infrastructure supporting research and impact

The sustained and significant growth in academic and research staff the Faculty has achieved during the current REF period has been accompanied by major investments in infrastructure, equipment and specialised support for research, a strategic aim for this REF (see Section 1.2). This has occurred using a mix of internal and external funding routes, worth £11m. For the former, we have secured over £2.2m from annual competitive bids to the centralised Capital Refresh Budget (CRB), matched by £600k from the Faculty during the REF period, to purchase and replace existing 'work-horse' research equipment judged not to be suitable for funding via research councils. Externally, we have strategically developed bids for the EPSRC strategic equipment fund (see Section 3.1.2) as well as annual EPSRC core equipment calls to support our targeted areas for growth.

3.2.1 Technical and support staff

Within the Faculty, technical staff has increased to 61 members during the REF period in support of research activities. In 2018, we signed up to the Technician Commitment, a national university and research institution initiative. The Commitment aims to ensure technicians within the organisation are identifiable and their valuable contribution is visible within and beyond the institution. It seeks to help technicians gain recognition through professional registration and external awards schemes. Further, it aims to create clear, documented career progression opportunities, ensuring the future sustainability of technical skills across the organisation and maximising the full potential of that technical expertise. We are now acting on our commitment. A Technicians' Conference ran in June 2019, attended by technical and non-technical staff alike, and a steering group has been formed to drive the Technician Commitment for this valued community. One of our technical managers is leading the implementation of the Commitment across the University and specifically within the Faculty. An example of investment in our technical provision is the provision for dedicated technician development associated with the new Faculty materials characterisation facility (see Section 1.2.1).

3.2.2 Estate, facilities and advanced equipment

The campus footprint of the Faculty has increased with the addition of a new £22m building for Architecture and Civil Engineering, and over 1,000 m² of research space has been redeveloped, improved and upgraded (see Section 1.2.1). At the same time, the Faculty is proceeding with the consolidation of large equipment items in Faculty-wide facilities, with dedicated technical personnel, to ensure the long-term maintenance and financial viability of the equipment through a pay-per-use model. In addition, the Faculty has expanded its research facilities off-campus.

Campus Faculty Upgrades: During the REF period, the Faculty invested £29m in refurbishment and improvements to physical infrastructure on campus, with resources coming from a mix of external, central and Faculty sources. An exemplar of our activities is:

Chemical and Mechanical Characterisation of Materials Facilities: Two new Faculty-wide facilities have been developed, with a total investment of £1.02m to refurbish dedicated laboratory space and purchase new equipment, including a micro/nano intender, an Atomic Force Microscope (AFM), a 3D microscope, a total carbon analyser, a high pressure liquid chromatography and a particle size analyser, as well as ancillary equipment for materials preparation. Part of the new equipment has been acquired via an EPSRC capital award with three of our early career researchers being co-investigators on the award (EP/S017615/1). The two facilities have academic oversight and dedicated technical staff, whose skills have been developed to manage the new equipment.

Off-campus Facilities:

IAAPS: In 2018, the University of Bath and South Gloucestershire Council entered a joint venture and purchased the Bristol & Bath Science Park (BBSP) for £18m. The BBSP hosts the National Composites Centre and the site of the new IAAPS Experimental Facility scheduled for opening in July 2021 (Fig. 5). The Institute for Advanced Automotive Propulsion Systems is a £69m investment from UK Research Partnership Investment Fund, West of England Combined Authority, Local Enterprise Partnership and the University of Bath (see Section 1.2.1 for details on support from industrial partners). IAAPS will enable the UK to compete on a global scale in advanced engineering, especially automotive propulsion, to realise the ultra-low and zero carbon passenger cars of the future. The new research and innovation facility will support the automotive industries as they transition to the delivery of future generations of clean and efficient vehicles. It will host a range of state-of-the-art experimental research platforms to enable precise systems level investigations to be conducted including whole vehicle assessments under real world driving conditions. Designed for the future, the facility will enable deep insights into the complex nature of transitioning to full electrification and include layouts and configurations for use in fully autonomous vehicles.



Figure 5. IAAPS building, opening 2021

HIVE: Located at the Science Museum site in Wroughton, Wiltshire, the HIVE is an experimental full-sized reinforced concrete frame building with 16 individual cells designed to enable real-time research to be undertaken on novel building materials and systems to investigate the environmental impact of the Built Environment. Supported by an EPSRC Strategic Equipment grant, the structure also includes a large-scale environmental test chamber facility for experimental testing under controlled conditions, full-sized wall panels, and a series of individual test platforms for real-time testing under varying environmental conditions.

3.2.3 Impact activities enabled by infrastructure, facilities and expertise

Advanced equipment, specialised technical personnel and dedicated infrastructure have been key to enable our impact activities. Exemplars of this are:

Industrial Bioprocessing Research Scale-up Facility: The Facility is designed to support the development and assessment of novel biotechnology by placing industrial requirements at the heart of the discovery process. To this end, processes at an early stage can be scaled, mimicking an industrial process economically. This demonstrates some of the major barriers that will be faced on scale up, so these challenges can be addressed early in the research programme de-risking future development. The Facility houses multiple large-scale fermenters and bioreactors, as well as pre-treatment and downstream separation equipment. The Facility is run with a blend of direct contract research, contract processing, grant funded research, PhD research and PGT teaching sessions. The Facility, started in early 2020, has been key to the success of a collaboration with AB Vista (see Section 4.1.2).

Reducing Emissions in Water Treatment: Since 2014, **Arnot** has worked with Wessex Water to improve the shut-down/maintenance/start-up cycle for their anaerobic digester (AD) train at Avonmouth Wastewater Treatment Works (WwTW), to integrate with a biogas upgrading plant and allow the injection of biomethane to the gas grid. Supported by an IAA, we developed process modelling techniques for the optimisation of the process and enhancement of biogas production. Implementation of the proposed approach resulted in a reduction of the shut-down/restart cycle from six months to six weeks for the process intervention, in turn leading to cost savings estimated at £0.5m (reduced down time, hence reduced ancillary and sludge disposal costs, and greater biogas production) as well as significant savings in CO₂ emissions. This strategy has now been successfully applied to other water works in Trowbridge and Berry Hill, with further savings of £1m.

3.3 Specialist research infrastructure, facilities and equipment

The Faculty identified at an early stage the need to strengthen the provision of specialised infrastructure and equipment alongside the investment in centralised facilities (see Section 3.3.2). Whereas the latter have been developed primarily using internal funding, the Faculty has focused on using the EPSRC strategic equipment route for the former. Exemplars of the success of this approach include:

CLEVeR: An EPSRC Strategic Equipment award (**Hawley**) led to establishing the Centre for Low Emission Vehicle Research, a state-of-the-art equipment upgrade to an existing vehicle research facility. This built on existing expertise with the ability to accommodate new users. It provided the UK with the only university leading edge vehicle facility capable of supporting multidisciplinary research on future EV/HEV and ultra-low carbon vehicle platforms and their associated systems under real world driving conditions including sub-zero temperature operation.

VFMS: The Versatile Fluid Measurement System for Aerospace Research (**Cleaver**) is a suite of equipment for non-intrusive laser measurements of fluid flows. This system is flexible and can be used across multiple aerodynamic and gas turbine facilities. It has enabled seven further EPSRC and Innovate UK funded research projects which have achieved *several world firsts* including: the application of CO₂-PLIF to study gas turbine flow interactions; the application of volumetric velocimetry to film cooling and to extract the vortical structures inside gas turbine rotor systems; and the first ever full 4D flow fields associated with unsteady swept wings.

VSIMulators: A collaboration between the Universities of Bath (**Darby**) and Exeter, VSIMulators consists of a moving chamber equipped with virtual reality projection to aid the study of human reactions to different buildings, including swaying skyscrapers and bridges. Combined with lighting, sound, temperature and airflow controls, VSIMulators embeds sophisticated projected virtual reality (VR) and movement capabilities, which allows researchers to investigate a range of questions about responses to the built environment. These include how to design buildings to boost the wellbeing of their occupants, how their productivity can be affected by working in tall buildings and what level of movement is acceptable in a footbridge or train carriage.

3.4 Cross-HEI shared or collaborative use of research infrastructure

The Faculty is particularly active in the equipment sharing stream of the GW4 alliance between the Universities of Bath, Bristol, Cardiff and Exeter. An example is given by our collaboration with the MET Office to develop and deploy the Tier-2 Isambard HPC service, following a £3.2m EPSRC award. This is currently the largest ARM-based system in the world outside of the U.S. and one of the first systems of its kind to be used for scientific research as well as to explore future computer architectures in the exascale era.

3.5 Significance of major benefits-in-kind

The Faculty has received industrially funded/sponsored/donated equipment for over £3m, including a metal additive manufacturing printer (AM250) from Renishaw (£400k); a metalorganic vapour phase epitaxy growth reactor from NanoGaN (£1m), and equipment to emulate home energy usage from Western Power Distribution (£1m). An example of how we have leveraged donated equipment is:

Gen3D: Dhokia has worked with Renishaw for over 10 years on several projects focused on advanced manufacturing technologies and processes, including EPSRC iCASE studentships, IAA funding and Innovate UK projects, VITAL and FALCON. As part of this partnership, the Faculty invested to create a new AM laboratory, which led to the donation of the AM250 machine in 2015. This has further strengthened our relationship and research in the field, leading to the award of an EPSRC 'Design the Future' grant (EP/N005910/1) in which Dhokia and Flynn developed novel algorithms to automatically design components for AM processes. Further funding from the ICURE programme led to the spin-out of Gen3D Ltd in 2018. The company now has 3 full-time employees with over 100 clients, and has, so far, received £435k in grants and investment. They have recently launched a new AM design course developed through an Innovate UK COVID-19 grant.

4 Collaboration and contribution to the research base, economy and society

4.1 Academic, industrial and government partnerships enriching the research environment

Our research is conceived, informed and developed through collaborations, networks and partnerships, with public and private organisations, with the general public, and through roles and relationships within the broader academic community. Engagement with the people, groups and organisations that use our research is integral to how our research is designed and implemented. This ethos is underpinned by a support structure, based both in the Faculty of Engineering and Design and in the University's Research and Innovation Services. This facilitates the creation and development over time of links with industry, academia, the public, charities, and government, particularly local government in Bath and North East Somerset and the Southwest of England. The Faculty continues to strongly support industrial collaborations and has strategically invested in key academics to nurture and develop these over many years. Successful exemplars of our approach, in addition to the ICSs discussed in Section 1.3.1, follow:

4.1.1 Engagement with local partners

Advanced Engineering Business Acceleration Hub: The Faculty led a successful application (**Hawley**) to the West of England LEP's European Structural Investment Fund panel in the area of 'Advanced Engineering'. The £730k project (2018-2021) is delivering start-up, scale-up, open innovation and investment support to grow 130 advanced engineering businesses. Support includes grants of up to £10,000, knowledge exchange, mentoring, research and innovation expertise and resource, business-university research partnerships, as well as bringing SMEs together with large corporate businesses. The project involves Bath & North East Somerset Council, Bristol City Council, North Somerset Council and South Gloucestershire Council supporting, primarily, the automotive, maritime, aerospace, energy, defence and space sectors.

Supplementary Planning Documents: Bath and North East Somerset (BANES) Council approached the Faculty to provide guidance on overheating in new buildings for their new Supplementary Planning Document (SPD) the "Sustainable Construction Checklist", in 2018. Current building regulations offer a simplistic overheating risk assessment and do not use highly localised weather data. **Natarajan** demonstrated that high-spatial resolution data are needed to obtain a realistic assessment, as local topography can alter microclimates sufficient to cause a 2x error in thermal model predictions. Via the EPSRC-funded COLBE project, the creation of localised current and future weather for the built environment solves this problem through data at a 5 km resolution covering the entire UK land surface for now and the future. More than 100 housing developments in BANES have now used the SPD developed by our team.

Personal Protection Equipment: Academic and technical staff in our Faculty led by **Lunt** have manufactured and donated over 400,000 items of PPE to the Royal United Hospitals Bath NHS Foundation Trust since the outbreak of the Covid-19 pandemic, including face masks, eye protectors and surgical gowns, using designs developed at the University and approved by British Standard for use in medical applications. The face mask design was highlighted at the International Best Practice Advisory Group (IBPAG) and the International Comparators Joint Unit (ICJU), which report directly to the Cabinet and Number 10, respectively. The instructions were shared freely across the UK and internationally by the UN-run Social Development International (SODEIT) organisation to aid PPE production efforts.

Digital Engineering Technology & Innovation: DETi is a £10m strategic programme of the West of England Combined Authority (WECA), delivered by the National Composites Centre (NCC) in partnership with the Universities of the West of England (UWE), Bristol, and Bath (**Butler**), and industry partners including GKN Aerospace, Rolls-Royce, CFMS, and Siemens. DETi will help companies identify and develop tools, technologies and processes to rapidly accelerate digital engineering capabilities, and identify the skills to embed digital innovations. The Faculty's involvement includes highly flexible manufacturing, design automation of next generation automotive systems, rapid design and modelling.

4.1.2 Engagement with national partners

Road to Zero: A 5-year £4.8m Prosperity Partnership has been awarded to Bath led by **Akehurst**, Oxford, Jaguar Land Rover and Siemens Digital Industries, to create the Centre of Excellence for Hybrid Thermal Propulsion Systems, to accelerate the UK's transition to zero CO₂ emission transport in line with the UK government's 'Road to Zero' strategy. The Centre will develop world-leading design capability for hybrid propulsion systems with the aim to provide UK motorists access to highly efficient and more affordable electrified vehicles able to operate at zero emissions within urban environments, significantly enhancing inner city air quality, while delivering lower fuel bills and eliminating CO₂ emissions.

Palm Oil Substitute: The £3.9m Mp² project is developing a new UK biorefinery platform using second-generation biomass source to produce a palm oil substitute. Led by **Chuck**, the project, funded by the EPSRC, BBSRC and Innovate UK, has had great resonance with the public and been featured in multiple news outlets, including the Guardian newspaper and BBC, and was even mentioned in the Netflix comedy show 'Grace and Frankie'. The major impacts, so far, include AB Agri Group developing one of the yeasts used in the project as a food additive; Kerry developing the palm oil substitute and Create Flavours developing a yeast-derived high value fragrance. **Chuck** has received further funding, including from the Bill Gates backed Energy Futures fund, to accelerate the deployment of the palm oil substitute to protect forests in South East Asia.

Developing a Hydrogen Economy: **Mays** is Co-director of the £7.3m EPSRC H2FC Supergen Hydrogen and Fuel Cell Research Hub, comprising 7 UK universities and 18 industry and policy partners. H2FC focuses on low carbon transport (cars, buses, boats/ferries) and low carbon heating/power systems, deploying high efficiency technology capable of using a wide range of low to zero carbon fuel stocks. Beyond a sustained academic impact, the H2FC team in Bath has supported 6 post-doctoral researchers who, over the current REF period, have been appointed as Lecturers in other UK Universities.

4.1.3 Engagement with international partners

The Faculty continues to encourage and support academic staff, particularly ECRs, to develop international collaborations with academia, industry and NGOs. The support includes travel grants and small feasibility awards linked to novel partnerships. During the REF period, the Faculty has focused on three priorities: GCRF funding, links with Brazil and EU funding. The breadth of these relationships is evidenced by Figure 6.



Figure 6. Faculty international collaborations 2015 - 2020 (source Pure).

In parallel with these activities, the Faculty has also pursued strategic partnerships with selected institutions around the globe, providing a framework for academics to develop collaborations and exchanges. An example of this successful strategy is the ongoing partnership with FAPESP and

Universities in Sao Paulo State, Brazil, including USP, UNICAMP and UNESP. This partnership has resulted in over 40 joint journal publications and 15 PhD and PDRA exchanges during the REF period. Further exemplars of our international activities include:

GREENER: Di Lorenzo is the Bath lead for a 2018-2022 H2020 £5m project on Integrated systems for effective environmental remediation. GREENER proposes the development of green, sustainable, efficient, and low-cost solutions for soil/sediment and water bioremediation, by integrating several remediation strategies with innovative bio-electrochemical technologies. Bath leads on soil bioremediation from organic pollutants (including TPHs, pesticides, PAHs, or potentially toxic metals and pharmaceuticals) using low-cost and self-powered sensors.

NeoVAD: Fraser is the Bath lead of a US\$2.5m NIH project to develop the first fully implantable heart pump for infants, in collaboration with the Texas Heart Institute, Griffith University (Australia) and Gunma University (Japan). The device will be designed to stop the progression of advanced heart failure in paediatric patients, enabling young children to live near-normal lives.

CERN: In 2019, the Faculty became an international affiliate member (led by **Lunt**) of the CMS (Compact Muon Solenoid) experiment, which is one of the 4 main experiments on the LHC (Large Hadron Collider) at CERN. Our affiliate status allows engagement with the research activities within CMS, and collaborative PhD projects are currently underway in the mechanical characterisation of thin-walled cooling pipes and two-phase fluid flows.

4.1.4 Engagement with policymakers

Low-Carbon Heating: Demand for space and water heating constitute a significant proportion of the total energy demands in the UK and are predominantly satisfied through natural gas, which makes the heat sector a large emitter of carbon dioxide and therefore an important sector to decarbonise. There are many potential alternative low-carbon heating options for the UK, from improving energy efficiency, to biomass boilers, to district network heating, to injecting hydrogen in the grid. **Samsatli** is working with BEIS to evaluate these strategies using cost-benefit analysis as well as multi-criteria optimisation in order to compare different optimal scenarios, quantify trade-offs between different strategy options and determine a set of value chains for low-carbon heating that have the greatest potential for deployment in the UK.

Power Distribution: Based on research undertaken with Northern Power Distribution (NPD), researchers at Bath, led by **F Li**, modelled different network optimisation strategies, leading to a significant reduction of costs for NPD customers. The experience leveraged in this project was reported in a response to Ofgem's Call for Evidence for "Future supply market arrangements", December 2017. In turn, this led to adoption of this strategy by other network distribution operations in the UK. The team was also commissioned by the Bristol City Council to report on "Mapping Virtual Power Plant and Energy Management System (EMS) Developments across the UK and the Europe", 2018, to support renewable energy deployment in the Bristol area. Li also sat on the BEIS independent panel for Electricity Standards Review, 2019-2020.

4.2 Wider contributions to the economy and society

A key underpinning of our strategy is for our fundamental research to be relevant to the economy and society, with a particular focus on impact in industry to reduce carbon emissions. As discussed in Section 1.3, we have developed a dedicated programme for academic and research staff in the Faculty to support this approach. Exemplars of this work are reported below:

Reducing Emissions in the Automotive Sector: HiETA is a SME located in the Bristol & Bath Science Park developing technologies for CO₂ reduction – heat exchangers, combustion and turbomachinery. During the REF period HiETA has collaborated with **Akehurst** on five Innovate UK projects to develop lighter and more efficient engine components for the automotive sector using additive manufacturing. During this time the company has grown from 4 to 55 employees, transitioning from a grant-based R&D company to a fully-fledged commercial entity, with a doubling of turnover from 2016 to 2019 to £7m.

Bio-Based Building Systems: **Walker** is leading research into low-impact crop-based construction hemp-lime materials. The fundamental scientific innovation has been translated in practice by working with industrial partners to meet UK Government policy to deliver low carbon housing. Greencore has built 44 individual houses during the current REF period, using hemp-lime materials, with an estimated carbon savings of 3,200 tonnes of CO₂ equivalent. This has also resulted in Greencore's turnover increasing 300%, with the houses distributed across the UK.

Landmine Detection: Despite many years of campaigning for their removal, over 100 million mines are estimated to be still active in fields around the world. Unfortunately, detection technology has not progressed in parallel with military technology, with current detectors unable to clearly locate plastic-based mines. **Soleimani**, with support from the Sir Bobby Charlton Foundation charity, Find a Better Way, has developed a camera system integrating electrical capacitance tomography (ECT) with magnetic induction tomography (MIT). This system is capable of detecting and differentiating between traditional conductive metallic, landmines and the modern dielectric plastic variants, which are seeing increased use due to being smaller, cheaper, featuring fewer parts and being harder to detect.

4.3 Engagement with diverse communities and the public through research

The Faculty encourages academic and research staff to engage with the public to showcase our research and to explain the importance of fundamental research in improving society, the economy and the environment. Practical support (e.g. language and imaging, relationships with media) is provided by the Public Engagement Unit. Exemplars of the success of our approach include:

Cultured Meat: **Ellis** is a pioneer in the culture-grown lab meat, introducing the concept to the public and policymakers, and highlighting the environmental benefits of this approach. During the REF period she has been interviewed by the BBC Radio 4 'Farming Today' and The Butchers Kitchen podcast; participated in the Times Cheltenham Science Festival and the British Science Association's British Science Festival; Wellcome Trust Health Exchange dinner and the Food Ethics Council debate. She has also led the submission of a letter to the Chief Executives at the EPSRC and BBSRC to provide an overview of cellular agriculture to outline its potential for the UK; co-wrote a policy paper for Downing Street Scientific Advisor on Protein Alternatives; acted as an expert interview for Food Standards Agency on cellular agriculture; and provided expert advice to the Policy Lead for the National Food Strategy and the Policy Adviser to the Secretary of State at DEFRA.

Citizen Science: Bath is currently the UK lead of the international CoastSnap citizen science project (**Blenkinsopp**). This project collects publicly submitted images of coastlines around the world. The images can be taken by anyone with a smartphone using purpose-built cradles located around the coast and are being used to obtain quantitative data about how the coast is changing with time. The data extracted from the images include shoreline positions, beach profiles, coastal flood areas and cobble coverage on composite beaches. These data are being shared with local government partners responsible for coastal management to supplement their coastal monitoring programmes and are used to communicate coastal issues to members of the public. The CoastSnap project now has over 100 sites and is in every continent. In the UK, the Bath team is overseeing the management of eight CoastSnap sites with more due to be installed in the near future as the project develops.

4.4 Indicators of wider influence

The Faculty actively promotes and supports academic and research staff contributions to the sustainability of engineering disciplines, e.g. when considering promotion cases, including:

Major Editorial roles: Faculty members currently hold or have held 124 positions on editorial boards as chief, associate, or subject editors, as well as guest editorships for special issues. Examples include **Emmitt** is Editor-in-Chief of *Building Research & Information*, and was Editor-in-Chief of the *International Journal of Architectural Engineering and Design Management* 2014-2019; **Newman** is Editor-in-Chief of the *International Journal of Computer Integrated Manufacturing*; **Codinhoto** is Editor-in-Chief of *Architectural Engineering and Design Management*; **Walker** was Editor-in-Chief, of *Institution of Civil Engineers Journal: Construction Materials*, 2012-2017, and is Editorial Board Member of *Building Research & Information journal*; **Keogh** is a Subject Editor of the *Journal of Sound and Vibration* and an Associate Editor of the *ASME Journal of Tribology*.

Panel Members/Chairs: NERC (Ball, Kjeldsen, N. Mitchell), EPSRC (Bowen, Dhokia, Gill, Ibell, Keogh, Mattia, Newman, Plummer Soleimani, Zang), British Council Newton Fund (Bowen, Burke, Kjeldsen, Natarajan) UKRI GCRF (Di Lorenzo, Walker) BBSRC (McManus, Chuck), Royal Society (Walker), H2020 (Wright, Estrela, Moschou, Düren, Di Lorenzo).

Fellowships, Major Prizes and Awards: **Akehurst** was awarded the 2014 SAE - Arch T. Colwell Merit Award and the 2015 SAE - Harry L. Horning Memorial Award; **Burke** received the 2016 ASME - Internal Combustion Engine Division Award; **Briggs** was awarded the 2018 EPSRC RISE Connector Award; **Chew** was awarded the 2020 Junior Moulton Medal by the IChemE; **Cleaver** Treasurer for the IMechE Western Aerospace Committee, since 2014; **Cole** 2015 Sir McFarlane Medal from the RAEng, 2015 Sir Royce Medal from the IET, the 2015 Silver Medal from the IoM3, the 2016 Roger Taylor Memorial Award from the British Carbon Group and the 2017 Sir Harry Kroto Medal from the NanoSMAT society; **Coley** was awarded the 2017 President's medals for research by the Royal Institute of British Architects; **Ellis** received the 2014 EPSRC - Rising Star Award and was Committee Member of the Biochemical Engineering Special Interest Group, IChemE 2011-2014; **Gill**, Fellow of International Orthopaedic Research (FIOR) at ICORS in Montreal, since 2019; **Harney** won the 2015 John Brinckerhoff Jackson Book Prize; **Ibell** was awarded the 2014 Frederick Palmer Prize by the Institution of Civil Engineers; **Johnston**, **Pan**, and **Plummer** were awarded the 2014 Donald Julius Groen Prize from the IMechE; **F Li** was awarded the 2016 Solar Power Portal Awards for the best "Residential Energy Storage Project" (for SoLa Bristol project); **Lo** Honorary Fellow, Society of Facade Engineering, since 2015; **Maskell** and **Walker** were awarded the 2016 Frederick Palmer Prize by the Institution of Civil Engineers; **McManus** was awarded the 2020 FDM Everywoman in Technology Award and received the 2019 West Woman of the Year Award - Most Inspirational Woman in STEM in the West; **C Mitchell** was awarded the 2019 Edward Appleton Prize and Medal by the Institute of Physics (IOP); **Moschou** was awarded the 2018 EPSRC RISE award; **Newman**, Fellow of CIRP (International Academy of Production Engineers) from 2016; **Newnes** was awarded the 2017 Philip Pugh Award by the Society of Cost Analysis and Forecasting; **Perera** was awarded the 2017 FDM Everywoman in Technology Awards; **Plummer** was awarded the 2016 IMechE - Bramah Medal for outstanding contributions to mechanical engineering science; **Sangan** won the 2016 ASME International Gas Turbine Institute (IGTI) Dilip R. Ballal Early Career Award; **Young** was awarded the 2014 ASME - Gas Turbine Award - the first woman to win this prize since inception; **Shea** was awarded the 2014 Napier Shaw Bronze Medal by the Chartered Institution of Building Services Engineers; **Walker** was awarded the 2019 RIBA Stephen Lawrence Prize; **P Wilson** was awarded the 2020 IEEE Standards Association Medallion "For leadership in standards and technology roadmapping in power electronics".

Best paper awards: **Emmitt** was awarded the 2019 Emerald Literati Awards - Outstanding Award in Engineering Construction and Architectural Management; **Paine**, 2014 Winning Paper Award, Case Studies in Construction Materials; **Dekoninck**, 2015 Distinguished Paper, International Journal of Design Creativity and Innovation Award; **Bonvoisin**, 2018 Design

Science Journal Distinguished Paper Award; **Maskell** and **Walker** were awarded the 2015 Thomas Howard Medal (Prize for Best Paper in Journal) Institution of Civil Engineers (ICS); **Coley** and **Natarajan**, 2017 Best Paper Award, Passive Low Energy Architecture - Design to Thrive (PLEA); **Darby**, 2016 Best Paper Award, 18th International Conference on Civil and Building Engineering; **Georgilas**, Best Medical Robotics Paper, IEEE International Conference on Robotics and Automation 2016; **Herdes-Moreno**, 2016 Champion of the Ninth Industrial Fluid Properties Simulation Challenge, AIChE; **Holley** and **Paine**, 2015 Best Paper Award - UK-India Education and Research Initiative (UKIERI) Concrete Congress; **Lock**, **Sangan** and **Scobie**, 2018 Best Paper Prize ASME Heat Transfer Committee 2018; **Lunt** 2015 Best Paper Award at the World Congress on Engineering; **Soleimani**, 2019 Excellent Paper Award for 9th World Congress in Industrial Process Tomography; **Walker**, 2015 Best Paper Award, Proceedings of Institution of Civil Engineers: Construction Materials; **Wilson**, 2019 IEEE Power Electronics Society Award for the International Technology Roadmap for Wide Bangap Power Semiconductors (ITRW) October 2019; **Wu**, 2018 IEEE Transactions on Energy Conversion Best Paper Award; **Zang**, 2019 5th PRIMaRE Conference and with **Bryant**, 22nd Workshop on Physical Processes in Natural Waters, 2019.

Membership of Research Council: **Mattia**, EPSRC Engineering Strategic Advisory Board (SAT) 2017-2020; **Newnes**, EPSRC Manufacturing SAT 2019-2022; **Allen**, EPSRC Early Career Forum, 2019-2022.

Guest and Special Editorships: **Soleimani** was guest editor: Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2015 and 2016; **Turner** was co-editor of a Special Issue of Institution of Mechanical Engineers Part D on Fuels for Engines; **Mattia** was guest editor Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2016, and guest editor April 2017 issue of the Materials Research Society Bulletin.

Leadership of Learned Societies and/or Committees: **Düren**, Chair of British Zeolite Association, 2018-2021; **Ibell**, President of the Institution of Structural Engineering, 2015; **Brace**, FISITA Chair of Academic Advisory Board, 2019-; **Dekoninck**, Chair of the Special Interest Group in Design Creativity for the Design Society, 2016-20; **Gill**, President of British Orthopaedic Research Society, 2018-2020, and Vice-President of European Orthopaedic Research Society, 2016-2018; **Hofman**, leader of the working groups on 'Urban Water Pollution' and 'Water Security' in Water Europe, the European Water Technology Platform; **Ke**, Chair of Work Group 6, RILEM, 2018-; **Keogh**, Convenor of ISO/TC 108/SC 2/WG 7, 2010-; **Lanham**, IWA Emerging Water Leaders Steering Committee, 2016-2018; **Mays**, Standing Committee of the Heads of Chemical Engineering UK, 2015-2019; **Newnes**, Chair of Consortium of Manufacturing Engineers, 2014-2019; **Plummer**, Chair of IMechE Mechatronics Informatics and Control Committee, 2014, Chair of UK Automatic Control Council, 2014-2015, and Chair of Global Fluid Power Society, 2018-2022; **P Wilson**, Vice President IEEE Power Electronics Society, 2013-2019, and Co-chair International Technology Roadmap for Wide Bandgap Power Semiconductors (ITRW), 2015-.

Membership of Learned Societies Committees: **Astin**, NERC's National Centre for Atmospheric Science (NCAS) Radar Technical Advisory Group (RTAG) in 2016-17; **Bowen**, Smart Materials and Systems Committee of IoM3; **Cleaver**, Treasurer, IMechE Western Aerospace Committee; **Forte**, Radio Occultation Science Advisory Group for the European Space Agency, 2016-; **Harney**, National Trust Council and National Trust Historic Environment Advisory Group; **Hofman**, Management Committee of the Specialist Group on 'Assessment and Control of Hazardous Substances' of the International Water Association (IWA); **Lanham**, IWA Specialist Group on Microbial Ecology and Water Engineering, 2016-; **Mattia**, European Membrane Society Council, 2017-2021; **C Mitchell**, UK GOVT Space Environment Impacts Expert Group, 2017-; **Natarajan**, International Building Performance Simulation Association, England; **Newnes**, Society of Cost Analysis and Forecasting, 2017-; **Nicoll**, Royal Met. Soc. Atmospheric Electricity group, 2014-, and Royal Met. Soc. Meteorological Observing Systems group, 2010-; **Pegg**, Council Member for the UK Society for Biomaterials; **Pe**, UK Magnetics Society

committee, 2019-; **Plummer**, IMechE Mechatronics Informatics and Control Committee member, 2014-; **Shen**, Management Committee, IWA Membrane Technology Specialist Group, 2018-; **Soleimani**, Steering Committee for International Society for Biomedical Electrical Impedance Tomography; **D Zhang**: Board Member of Directors (Steering Committee) of International Functional Electrical Stimulation Society (IFESS), 2016-19.

Conference Organisation: Academics in the Faculty have been chairs/organisers of 234 conferences during the REF period.

Keynotes: Academics in the Faculty have delivered 246 invited keynote presentations during the REF period.

Refereeing Research Proposals: Over 35 Faculty members are part of the EPSRC Peer Review College and regularly review for UKRI, Royal Academy of Engineering, Royal Society, EPSRC, BBSRC, NERC, IUK, STFC and a host of foreign funding bodies, e.g. H2020 (EU), NSF (USA), DFG and DAAD (DE), ISF (IL), NOW (NL), MIUR (IT), FWO (BE), CONICYT (CL), Agence Nationale de la Recherche (France); Research Council of Norway; Science Foundation Ireland; Irish Research Council; National Science Centre (Poland); African Academy of Sciences; National Research Foundation (South Africa); Innovation and Technology Commission (Hong Kong); Research Grants Council of Hong Kong; Mitacs (Canada).

4.5 Conclusion

In conclusion, during the REF period, the Faculty has transformed its approach to research, from discipline-based research to addressing grand challenges, organising its research and impact activities around three core themes: *Resilient Environment*; *Sustainable Materials & Processes*; and *Energy & Systems*. This new approach has been supported by significant investment in new academic staff, with a major effort to improve the diversity of our research base, and in new infrastructure and equipment. These efforts have resulted in a significant increase in new research income, coupled with an increase in the quality of outputs and major advancements in addressing global challenges and delivering impact together with local, national and international partners.

We view these accomplishments as a major intermediate step in our development, with clear plans to further accelerate delivery of our *vision* to conduct fundamental and applied engineering research to drive social, economic and technological advancements coupled with stewardship of the environment.