Institution: University of Bath

Unit of Assessment: UoA8 Chemistry

1. Unit context and structure, research and impact strategy

The Department of Chemistry at the University of Bath, which forms the UoA8 submission, has grown during the REF period, building on its previous strengths through significant investment, reflected in increases in staff numbers and research outputs. Bath Chemistry research ranges from fundamental studies to highly cross-disciplinary initiatives targeted at solving global grand challenges. The latter is a strength of the Unit and reinforces both the quality and relevance of our research. This cross-disciplinary approach forms the keystone of our achievements in the REF period and is integral to our ongoing strategy.

Bath Chemistry research is supported by excellent infrastructure, sustainable and strategic staff growth, a substantial PhD student cohort, a strong funding portfolio and a wide range of national and international collaborations. Research outputs (SciVal) have grown by 23% since REF2014 from an average of 183 outputs/year (2008-2013) increasing to 249 outputs/year (2014-2020). Research income since 2014 is in excess of £33M, with staff in the Unit leading and partnering in large, interdisciplinary projects of value close to £100M and placing the UoA at the centre of a number of £10M+ high-profile research programmes, as well as holding a diverse range of individual research grants and fellowships. Infrastructure has benefitted from substantially increased new laboratory space and investment in both core and strategic equipment. The vibrant PhD cohort based in the UoA has consistently been >130 including jointly supervised and visiting students, boosted by our involvement in several Centres for Doctoral Training, particularly that in Sustainable Chemical Technologies led from Bath Chemistry, but also in nine further CDTs or equivalent doctoral training entities. Our academic staff numbers have grown strategically with excellent retention rates combined with strong recruitment of early career researchers (ECRs). Excellence has been recognised by a number of Fellowships and Prizes won by Bath Chemistry academic staff, while the Unit's standing has been acknowledged through excellent performance in a range of national rankings based on publication metrics including joint 8th in UK in the Academic Ranking of World Universities (ARWU) in Chemistry (ranked by publications) and a particularly noteworthy 2nd in the UK for the QS World University Rankings by Subject 2020 (ranked by citations per paper) with consistent strong performance and continuous improvement within the available QS rankings: 4th 2019; 4th 2018, 5th 2017, 7th 2016. Analysis of our publications 2014-2020 using SciVal indicates that over that period Bath Chemistry ranks 8th in the UK for total citations (over 47,000) at a rate of 23 citations per publication.

Bath Chemistry research is organised into five overlapping and interdisciplinary themes, with flexible and often cross-theme membership by academics in the Unit. These themes, which cut across the traditional chemistry sub-disciplines, are **Materials**, **Interfaces**, **Transformations**, **Healthcare** and **Analytical**, within which both excellence and applicability thrive. The five themes are underpinned by the unifying concept of **Sustainability**, a particular strength in terms of both excellence and critical mass, which pervades much of the chemistry research at Bath. The cross-disciplinary Centre for Sustainable and Circular Technologies (CSCT), established in 2008, is led from and physically based in the Department of Chemistry (Director *Davidson*). CSCT has a long track record of success (see below) and provides direct and beneficial links to other Departments in the University (and more widely), facilitating collaborative research.

The research themes reflect both our current research excellence and future strategic direction. All Themes reflect in their research substantial contributions to the over-arching Sustainability

focus within the Unit. Theme leads are key members of the Research Committee and feed into the evolution of our research strategy.

Materials *(lead Islam)*: Design and production of novel materials and the understanding of their properties through experimental and computational methods; materials for applications including energy production and storage, gas/molecule capture and degradable plastics. Current strengths include battery materials [*Islam*, *JACS* 2014 (285 citations; WoK, 2021-01), *Morgan*, *Nature Mater.* 2017 (153 citations)] and solar cells [*Cameron*, *J. Phys. Chem. C* 2015 (254 citations), *Islam*, *Nature Comm.* 2015 (1176 citations)]. Substantial funding and partnerships in this area include leadership of the Faraday Institution grant on *Next Generation Li-ion Cathode Materials (CATMAT)* (£2.35M within an overall £11M programme).

Interfaces *(lead Edler)*: Exploring the boundaries between the different states of matter, investigating how materials and molecules interact with each other to create new solvents, nanomaterials (nanoparticles, emulsions, micelles), and ionic liquids. Current strengths include deep eutectic solvents [*Edler*, *Angew. Chem.* 2017 (172 citations), *Green Chem.* 2016 (172 citations)] and cellulose microbeads [*Scott*, Naturbeads spin out company]. Current funding in this area includes awards from EPSRC (EP/N033310/1, £949k & EP/P027490/1, £1.07M) and extensive use of Central Facilities (e.g. *Edler*, £2.7M value of Facilities use).

Transformations *(lead Jones)*: All aspects of chemical reactions, including the development of new reactions and the creation of new catalysts to access novel molecules or enhance existing processes. Catalysis is a particular strength of Bath Chemistry, both in terms of established staff and ECRs [*Hintermair*, *Nature Comm.* 2015 (184 citations), *Hill*, *Chem. Sci.* 2016 (96 citations)]. A node lead for the UK Catalysis Hub since its establishment, in this REF period Bath Chemistry leads one of the three science project nodes (£3.94M) within the £14M renewal of the Catalysis Hub in 2018 and is part of the leadership Co-I team on the core £2.2M award, EP/R026939/1. Current funding includes awards from EPSRC (EP/R027129/1 £3.94M, EP/P024254/1 £1.06M, EP/R020752/1 £1.28M).

Healthcare *(lead Pascu)*: Development of new drug molecules and formulations, materials for tissue engineering, vaccine conservation, implants and infection detection as well as new methods of diagnosis and treatment. Current strengths include sensors and theranostics [*James*, *JACS* 2014 (348 citations), *JACS* 2016 (237 citations), *Angew. Chem.* 2015 (252 citations)], imaging approaches [*Bull*, *Chem. Sci.* 2014 (161 citations)] and wound infection detection [*Jenkins*, Smartwound spin out company]. Major funding in this area has come from the EU (ERC £1.9 M), MRC (£910k) and EPSRC (EP/V00462X/1; £1.2M award with Lancaster, Glasgow).

Analytical *(lead Kasprzyk-Hordern)*: Development of tools and methods to characterise complex chemical mixtures and detect molecules selectively. These methods can be used for monitoring the progress of chemical reactions, testing water quality and in exposure studies [*Kasprzyk-Hordern*, *Addiction*, 2014 (219 citations), *Chemosphere*, 2017 (204 citations)] and the determination of enantiomeric excesses [*James*, *Angew. Chem*. 2015 (61 citations)]. Current highlights include the NMR facilities for *in operando* analysis of reaction mixtures [EPSRC Strategic Equipment Award DReaM Facility (Dynamic Reaction Monitoring), £1.29M], which supports aspects of catalysis research, and the detection of drug metabolites in wastewater which has high impact applications including for urban population profiling [EP/P028403/1, £1.12M; SEWPROF, MSCA ITN €4.2M].

The unifying concept of **sustainable chemical technologies** underpins a high proportion of the Unit's research activities with 30 members of Bath Chemistry staff among the 60+ academics associated with the **Centre for Sustainable and Circular Technologies** (CSCT;

www.csct.ac.uk). Themes within CSCT (Clean energy, Bio-based resources and production, Sustainable materials, Chemical and bio-chemical processes, Waste valorisation and recycling) mirror and reinforce its underpinning role within Bath Chemistry research, but also emphasise the influence of CSCT in interdisciplinary research across the University. The Centre has a grant portfolio of >£25M, a large ongoing PhD student cohort of around 75 (across multiple University Departments) funded from a range of increasingly diverse sources, and a wide range of international and industrial partnerships.

During the REF period, we have enhanced the quality, volume and impact of our research by following a research strategy based on three key elements:

- **Interdisciplinary approaches** to current scientific challenges, ensuring close alignment with key strategic themes at the regional, national and international levels;
- Developing and supporting **critical mass** research efforts within the Department, while simultaneously encouraging and nurturing individual excellence-led approaches to fundamental and applied research;
- Leadership and participation in **major research consortia**, while providing a nurturing environment for early career researchers in order to maximise their potential and develop them into future leaders.

This strategy has been underpinned by the Unit's approach to increasing diversity and supporting staff development and wellbeing. Our research excellence has benefited from these approaches, which have led to three of our five themes being led by female colleagues underpinned by their high achievement in publications and research, the presence of two of our BAME colleagues amongst the RSC's 175 Faces of Chemistry, the advancement of four of our female colleagues (plus one further appointment) to Professorships in the REF period and the development of a vibrant group of ECRs whose excellent research has led to their securing fellowships and grant funding.

In addition to the three elements noted above, our future strategy involves continued support for our cross-disciplinary research themes which have been honed over the REF period to better reflect the UoA's research strengths and align them with future societal needs.

- We expect the underpinning concept of sustainability to increase in importance over the next decade. The Unit's focus on this is underpinned by the substantial grant holding in this area, including recent high critical mass awards in catalysis and battery materials; awards such as these form the cornerstone for continued growth of our research.
- We will increasingly emphasise the development and growth of international links and further develop collaborations with colleagues in other disciplines both in Bath and elsewhere. We have steadily grown both international links and collaborations over the REF period, and our strategy seeks to encourage and strengthen this direction of travel.
- We will continue to identify and acquire key equipment, largely through the University's Materials and Chemical Characterisation (MC^2) facility, both to increase the impact of current research programmes and underpin future projects. This is bolstered by access to the University's major equipment fund, a £1M annual allocation from which MC^2 facilities will continue to benefit to ensure a vibrant equipment portfolio, and we will also build on our successes in securing strategic equipment funding externally.
- We aim to diversify funding streams, both for research projects and support of PhD students, notably by expanding our international and industrial PhD partnerships.
- We will intensify efforts to maximise research impact through engagement with potential end users.

Our Research Committee (Chair *James*) will play an important role in the identification of opportunities and the organisation of events (physical and virtual) to bring people together to

develop cross-disciplinary projects. We will build upon our proven success in delivering excellent research and impact, and securing funding in the theme areas, which represent significant future opportunities that the Unit is well positioned to exploit.

Collaboration and interdisciplinarity remain at the core of Bath Chemistry research, with strong and substantive links both within and outside the University and will continue to do so going forward. The Unit has research links within Bath through relevant University Research Centres, including CSCT, C3Bio (Centre for Biosensors, Bioelectronics and Biodevices), WIRC (Water Innovation and Research Centre), CNAN (Centre for Nanoscience and Nanotechnology) and CTI (Centre for Therapeutic Innovation). Inter-departmental links are particularly strong with Chemical Engineering (£6.65M joint funding; major links through CSCT), Biology & Biochemistry (£1.46M), Computer Science (£1.60M; notably through the Fellow for Industrial Research Enhancement (FIRE) doctoral training programme) and Electronic & Electrical Engineering (£1.03M; strong links through C3Bio). Funded collaborations are also significant with other areas in Science and Engineering (£2.3M awards across five Departments) and reach into Humanities and Management (five Departments, £899k). Our successful approach to external collaboration through leading or participating in major strategic funded programmes involves >30 UK institutions, across a range of disciplines, along with more than 200 industrial and other project partners.

International links are strong, building on both the international profile of staff and University efforts in this area. The Unit has established collaborative research with the University's strategic international partners Monash University (Australia), Universidade de São Paulo (USP, Brazil), Zhejiang University (ZJU, China), Stellenbosch University (South Africa), Yonsei University (Korea) and Nanyang Technological University (Singapore), benefitting from funding for exchange visits and growing research collaborations that have led to multiple publications with all six institutions. Major project-led international links specific to the Chemistry UoA include those associated with the CSCT (RWTH Aachen (Germany), Università Ca' Foscari (Italy), Sydney, Monash (both Australia), Warner-Babcock Institute and Ohio State (both USA)) and with the *Catalysis for Sensing and the Environment* initiative (ECUST, China). Memoranda of Understanding are in place with numerous other overseas institutions, further expanding and broadening the diversity of our international partners. Such links provide many benefits including recruitment of overseas PhD students bringing a range of scholarships. The most recent development has been establishment of the Bath-Monash joint PhD programme, which was initiated and developed by staff from the UoA; this was the first joint international PhD programme established at the University of Bath. The first four PhD students started on this programme in 2019-20, with a second group recruited in 2020-21 and further cohorts planned for future years.

Industrial links and innovation with more than 200 companies, including both multi-nationals and SMEs, and in the innovation and translation space (including Catapults, particularly in High Value Manufacturing), as detailed in Section 4 "Collaborations". Interactions with these companies within our impact strategy includes direct funding, project partnership, membership of industry advisory groups for larger projects and programmes, studentship support, consultancy, production partnerships, pre-clinical testing and direct commercialisation. Health-related research also benefits from direct clinical collaborations in the UK and internationally. These collaborations and partnerships exploit the relevance of our research themes to potential clinical applications, including developing and designing new therapeutic materials, sensors, healthcare technologies and delivery systems. These collaborations are harnessed extensively to identify research targets and funding opportunities whilst advising our research strategy.

During the REF period £804k has been allocated to the Unit from the University's EPSRC Impact Acceleration Account (IAA), with an additional £5.1M being contributed by external

partners. Notable projects include those from *Kasprzyk-Hordern* on wastewater fingerprinting for public health assessment in partnership with Wessex Water, B&NES, Bathscape, Avon Wildlife Trust, Bath City Farm/Time Bank Plus, Environment Agency and Defra (Impact Case Study); *Scott* on biobeads in partnership with Chanel and Croda; *James* on analysis of protein glycation in sera from diabetes patients with Glysure Ltd; *Frost* on sustainable selective catalytic C-H activation in partnership with GSK; *Johnson* on semiconductor thin-films with PragmatIC Printing Ltd; *Webster* on iron catalysis for the synthesis of ligands with CatSci Ltd.; *Jenkins* on Smartwound development with Bristol Royal Hospital for Children and Paul Hartmann AG and a flexible commissioned fund allocated to Sustainable Chemical Technologies (*Wilson, Davidson*).

Bath Chemistry has a strong tradition of joint-funded industry-matched PhD studentships and in securing, for example, iCASE and other direct industry-funded awards. During the REF period, around 30% of all new PhD starts were partly or fully funded through these routes. Building upon this outward-facing approach to ensure vibrancy in our PhD programme, and leveraging existing industrial links, an industrial PhD programme has been established with Evotec Ltd (*Bull*), leading to six Evotec employees undertaking PhD degrees within the Department as part of high level CPD funded by the company and delivered by Bath Chemistry. We are currently in the process of renewing this venture and have recently extended it to AstraZeneca.

Impact strategy and approach. Chemistry research at Bath delivers impact in a number of ways: industrial applications, including the adoption of more sustainable chemical processes; sensor development for diagnostic, clinical and environmental applications; wealth creation including commercialisation of intellectual property (IP) and capitalisation of companies; provision of enhanced postgraduate training and industrial placements / internships; outreach and engagement outside academia and influencing policy at senior levels. Indeed, our research themes were established to have the potential to build large consortia, including those involving major industrial or clinical partners. Activities to deliver the potential for impact include:

- Protection and commercialisation of Bath-generated IP, including the establishment of spin-out companies (e.g. Smartwound (*Jenkins*) and Naturbeads (*Scott*), both in this REF period);
- Primary publication of excellent research with application potential, leading to take-up of Bath-generated chemistry in industry including generation of joint IP/patents (e.g. *Jones* – Synthos & *Davidson* – Total Corbion PLA Impact Case Studies);
- Industrial collaboration (joint funded and iCASE studentships) including strategic partnerships (e.g. with Wessex Water; *Kasprzyk-Hordern* Impact Case Study), direct academic-clinical collaboration for clinical applications and Innovate UK funding partnerships;
- Direct translation of research into therapies and diagnostics, including translation of boron sensor chemistry into diabetic and intensive care monitoring (*James*; Eversense, Glysure Ltd), DNA sensor technology for rapid sensing for detection of sexually transmitted infections (*Frost* – Binx Impact Case Study), and Smartwound wound dressings (see above);
- Converting research to impact *via* internal pump-priming funding routes (GCRF, IAA, etc). Examples include IAA funding to support the major engagement with Wessex Water, the Naturbeads activity, and GCRF funding for wound dressing applications in the developing world;
- Wider engagement activities for societal benefit: Extensive activities in public and wider engagement are supported by Bath's Public Engagement Unit. These include dissemination beyond normal disciplinary environments (e.g. to clinicians), funding and awards for outreach activities and involvement in major events; these activities are described in more detail in Section 4;

- Influencing policy; Bath chemists are involved at high levels advising UK funding policy directions, in UKRI, Government and industry-facing bodies. During the REF period *Wilson* was part-seconded as STEM lead in the University's Institute for Policy Research;
- Impact in the talent pipeline is delivered through our provision of highly trained researchers for the workforce, notably in technical industrial roles and other high value areas.

Furthermore, the UoA contributes toward the civic and regional agenda, through these engagement activities and our interactions with Local Enterprise Partnerships (LEPs), for example in our SME-supporting Sustainable Technologies Business Acceleration Hub (STBAH; Section 4).

Supporting impact. The Unit and the University provide a supportive and engaged environment for encouraging impact-generating activities. Senior academics in Bath Chemistry with significant experience in impact play an active mentoring and delivery role for impact within the Unit. The impact and commercialisation teams in Research and Innovation Services (RIS) provide outstanding, focused professional services support in this area, particularly evident in empowering the spinouts Naturbeads and Smartwound and in enabling the STBAH and related ERDF programmes. The latter in particular, and Bath Chemistry impact-generating activities in general, also benefit from the world-leading SETsquared business incubator unit. Substantive support of our environment for impact has also been provided by the EPSRC IAA funding noted above, gained by nine academics in the Unit.

Examples of Impact generation. In addition to the Impact Case Studies presented as part of the Unit's submission to REF2021, the impact activity of the Unit can be illustrated by further examples, which highlight the approaches adopted in the Unit to generating impact and also point towards potential Impact Case Studies in future REF assessments. These include:

- Creation of spin-out companies to deliver directly on Bath Chemistry developments (*Scott*, Naturbeads (investment from Sky Ocean Ventures); *Jenkins,* Smartwound);
- Direct deployment of Bath-generated IP in boron chemistry in a range of sensing applications (*James* with Eversense, Glysure Ltd);
- Development of wound dressings in a long-standing academic-clinical partnership (*Jenkins*, with senior clinician Dr AE Young, Bristol Children's Hospital and commercial partner Hartmann AG). These have been tested successfully in initial clinical trials in the UK and the low-cost SPaCE Swab point-of-care sensor is approved for clinical testing in Myanmar;
- Development of advanced crystallisation protocols and platforms for pharmaceutical continuous manufacturing through participation in major academic-industry collaboration (*Wilson*, part of CMAC Manufacturing Hub; Bath research deployed directly with AstraZeneca, Pfizer, Roche);
- Chemistry for the detection of fluoride in drinking water (*Lewis*, GCRF-funded project with applications in preventing skeletal fluorosis in India and Tanzania);
- Development of inorganic matrices for the encapsulation of vaccine biomolecules (*Sartbaeva*, with developing countries including Indonesia);
- IAA-funded direct interventions with industry problems in Sustainable and Circular Technologies including Veolia (testing of microbeads for waste treatment), envoPAP (understanding barrier properties to develop tree-free packaging for food and personal care products), Cell Ag Ltd (advancing technology to produce large volumes of cells for cellular agriculture) and National Composites Centre (developing fibre-reinforced polymer composite materials).

Research openness and integrity are important to the Unit; we embrace the University's robust and transparent policies on data storage and management, and on ethical conduct of research. The Director of Research, with the Library, monitors Open Access compliance for publications

while an ethical assessment is carried out for all research projects, monitored by a Departmental Research Ethics Officer.

2. People

The Bath Chemistry staffing strategy is based around a balanced approach to growing our staff profile by recruiting, developing, rewarding and retaining. Our recruitment policy has always been to attract the best talent we can while emphasising key strategic research areas and being fully consistent with our Equality, Diversity and Inclusion (EDI) strategy. This underpins our research strategy of gaining critical mass and maximising opportunities for collaboration while ensuring staff research interests retain breadth and complementarity. We have recently used this approach to increase our expertise in soft matter and catalysis; in both cases we specifically targeted these research areas to best fit with development of the research themes and we will take a similar approach with future appointments.

Recruitment to full academic positions in the Unit over the REF period (with an F/M gender balance of 4/6) has been largely at early career level, augmented by one replacement at professorial level (*Domene; F*) and another at Senior Lecturer (*Squires*). ECRs have been appointed directly as Lecturers (*Kopec, Taylor, Grayson*) or as Bath Prize Fellows (*Webster (F), Liptrot, Freakley, Suturina (F)* and *Krewald (F; now academic in Germany)*) in the key strategic areas of catalysis and sustainable technologies. The Bath Prize Fellow scheme was initiated in 2012; these Fellows are appointed for a two-year period focussing on research, with the expectation that they transfer onto permanent Lectureship positions at the end of their Fellowships. This model has been successful in attracting outstanding appointments; both *Webster* (EPSRC Early Career Fellowship) and *Liptrot* (Royal Society URF) have used a Bath Prize Fellowship as a springboard to securing a longer, externally funded fellowship. The Department has been very successful in attracting Royal Society URFs, and in addition to *Liptrot*, it is currently hosting *Buchard, Cresswell, Morgan* and *Hintermair* (*Buchard* and *Hintermair* secured URFs having been appointed originally as Whorrod Fellows within the CSCT). All current URFs are anticipated to transfer to permanent academic positions at the end of their fellowships. Furthermore, *Sartbaeva* recently completed her URF and transferred to a Lectureship at its conclusion. Other fellowship holders within the Department include *Pascu* (ERC Consolidator, 2013-20), *Taylor* (Leverhulme Early Career Fellow, 2015-18), *O'Malley* (Whorrod Fellow, 2018-23) and *Schwamm* (International 1851 Fellow, 2018-21).

We have an outstandingly successful track record in developing ECRs, who benefit from our interdisciplinary approach to research and whose success (evidenced by securing external funding, producing high quality publications, winning external Fellowships and recognition) reflects well upon the nurturing environment Bath offers for mentoring and development. All ECRs are appointed a formal mentor, though the collegiate nature of the Department ensures other colleagues also act as informal mentors. All Royal Society URFs, Prize Fellows and Whorrod Fellows completing their fellowships during the REF period attained permanent positions in the Department. This progression, and our high level of retention of ECRs reflects our strong and proactive approach to scientific and professional mentoring. In addition to the allocation of reduced teaching and administrative workloads, early career appointees are supported by generous start-up funding, priority allocation of PhD students, provision of appropriate laboratory space and ready access to analysis facilities. ECRs are supported in developing their independent research but are also encouraged as key partners in larger projects in which Bath Chemistry is involved, with four ECRs currently Co-Is on externally funded projects. The Unit's very strong record in retention of talented researchers throughout the REF period is also reflected in the fact that we have lost only one academic to a UK institution (*Walsh;* Chair, Imperial).

The retention, development and success of our ECRs, and our actions in supporting this, reflects our implementation of the *Concordat to Support the Career Development of Researchers*, to which we are fully committed. This aims to provide a productive and supportive working environment for researchers. In recognition of this, the University of Bath was awarded the *HR Excellence in Research* badge from the European Commission and has undertaken steps to ensure that its principles are embedded across the University.

Our supportive culture extends throughout our research community. Support and development opportunities offered to our growing cohort of post-doctoral research associates (RAs; cohort growth by around 20% (~45 to ~55) since 2013) mirror this environment with all RAs offered annual one-to-one *Career Conversation* sessions with an experienced academic who is not involved in their research project. A number of our RAs have benefited from Faculty-organised development opportunities including the Bath Science Academy and the Bath Science Leadership and Fellowship Academy; RAs can also be appointed formal members of supervisory teams for PhD students. Many RAs take the opportunity to gain experience in teaching, typically through taking a tutorial group. Our RAs run a successful PDRA Network which organises seminars, career events and social activities. In addition, RAs have the opportunity to hone their presentation skills by giving short presentations before the external speaker in our departmental seminars. We believe that preparing our researchers for future careers is a key element of our supportive approach to staff development. Reflecting this, RAs leaving Bath after completing their research projects have an outstanding record of securing excellent positions elsewhere, with a large number (16) winning Fellowships or moving directly to permanent academic roles within the REF period, while >50 RAs and PhD students have obtained positions in industry (e.g. Astra Zeneca, GSK, BASF, JM, Oxford Instruments), including senior positions.

Although generally line-managed at Faculty level, our research technical professional (RTP) staff are fully integrated into our community and activities and in many cases are strongly integrated into research teams within the Unit. The University is a signatory to the Technician Commitment and our RTPs benefit from focussed networking events, supporting their professional development. For much of the REF period, line management of instrument specialists in MC^2 and its predecessor CCAF was held within the UoA. This arrangement was instrumental in ensuring the development of the facility in a way that ensured the expertise, talent and contribution of these RTP colleagues is fully harnessed for the benefit of our research and for the development of the individuals involved. These instrument specialists are frequently formal members of doctoral supervision teams and investigators on research grants led from the Unit, while two hold advisory roles with the EPSRC.

Recognising and Rewarding Excellence at all levels: Our strategy emphasises the retention of established researchers and this is reflected in rewarding excellence by internal promotions to all levels including Chair. This approach is underpinned by a positive and supportive Staff Development and Performance Review scheme, based on ambitious objective setting, identification of challenging but realistic targets, and achievement of full potential. Our workload model and strategic appointment of talented teaching-focussed lecturers enables the workload of our talented researchers to be managed to best effect. During the REF period, there has been a healthy throughput of internal promotions with *Edler* (2014), *Burrows* (2016), *Bull* (2016), *Jenkins* (2016), *Pascu* (2016), *Kasprzyk-Hordern* (2017), *Scott* (2018) and *Jones* (2019) promoted from Reader to Professor, *Morgan* (2018), *Buchard* (2019), *Hintermair* (2019) and *Webster* (2019) promoted from Lecturer to Reader and four UoA staff promoted to Senior Lecturer. The University runs a Research Sabbatical scheme which allows experienced academics the time to (re-)focus their research and build new collaborations. During the REF period, five UoA members were awarded sabbaticals.

Departmental culture, equality, diversity and inclusion. As part of the strong University-wide commitment to staff development, the Department of Chemistry embraces the central Bath approaches to EDI issues, rooted in a high degree of institutional emphasis on the importance of these issues and reflected in continued good practice and the provision of compulsory diversity training. All of our staff are made aware of unconscious bias, and must undertake online training, while completion of a number of online EDI training courses is required before taking part in recruitment, promotion and other internal roles.

A supportive and inclusive culture within the Unit is important for its ongoing health and vitality, and this is overseen within Bath Chemistry by the Positive Involvement Committee (PIC) which includes members from academic, technical, administrative and research staff alongside both postgraduate and undergraduate students. The HoD is a member of this committee, and its Chair sits on the Department Executive Committee. The committee helps ensure that a positive environment is maintained for all staff and students and acts as a point of contact for staff and students wishing to raise issues relating to EDI and bullying or harassment, and to encourage proactive suggestions and initiatives to improve the culture within the Unit. Our approach to EDI was recognised by the Athena SWAN Silver Award in 2019. Significant progress in this area includes improvements in the gender balance within the Department, including in more senior roles; during the REF period we have been delighted to progress from having no female professors to having five (four internal promotions, one appointment) and have significantly improved the gender ratio in early career recruitment. Our RA and PhD cohorts each approach 50:50 gender balance, reflecting the ongoing translation of this balance towards a more equable situation with the same gender balance achieved with Prize Fellow appointments. In addition, one female colleague (*Shrinifar*) has recently restarted her research career as a Daphne Jackson Fellow (2020-22). Beyond gender, we embrace a highly multi-national and diverse community across all levels of the Unit, with increasing representation of BAME colleagues evident; again, this balance is being developed from the bottom up, with particularly healthy diversity at PhD and RA level. The Unit ensures that all of our policies, approaches and activities are compatible with encouraging this diversity; the PIC group plays a major role in developing and monitoring this. PIC also guarantees that EDI pervades all aspects of the Unit, from ensuring meetings take place within core hours on varying days to allow participation of part-time staff and those with caring responsibilities, to improving recruitment and induction processes. A proactive approach to Health and Safety also forms a key aspect of departmental culture, in terms of both encouraging embedded awareness and ongoing positive actions. The HoD chairs the Health and Safety Committee, with academics, RTPs, RAs and PhD students represented on the committee.

Response to Covid. The Unit responded to Covid by embracing flexible and remote working and supported colleagues through regular virtual gatherings. Supported by the University, the Unit was able to deliver rapid, phased, reopening of research labs in a safe, Covid-secure environment, offering as much research continuity as possible.

Postgraduate Research (PGR) Students. After a significant rise from 2009 to 2013, PGR student numbers have been steady over the current REF period, recruitment averages around 30 PhD students per annum. Our PhD student cohort is fully integrated within the life and culture of Bath Chemistry, both with representation on relevant Department Committees and substantial involvement in important aspects of the academic life of the Unit, including leading on our seminar programmes, through the Postgraduate Executive (PGExec) group. Support for our PGR students is comprehensive, in line with our departmental culture; we provide an outstanding research and training experience for all our PhD students. Those both within and external to CDT structures are provided with comprehensive opportunities for training and

personal development as well as the facilities and academic support to undertake excellent research.

Centres for Doctoral Training (CDTs). Many of our PGR students over the REF period have been associated with a CDT. Bath Chemistry hosts the EPSRC CDT in Sustainable Chemical Technologies, which was inaugurated in 2009 and has ongoing EPSRC funding until 2023 (*Davidson*, *Scott*, EP/L016354/1, 2014-23, £4.58M)**.** The inaugural and long-standing themes within the CSCT CDT have been key in harnessing core excellence in Bath Chemistry research over the REF period; these have now evolved still further in a cross-disciplinary direction as research in this area has developed towards Sustainable & Circular Technologies, as noted above. As the CDT moves beyond its EPSRC-funded intakes, it is demonstrating long-term sustainability. The last cohort funded by the EPSRC CDT was recruited in 2018, and in the succeeding two recruitment cycles (2019 & 2020), 31 new students have been recruited into the CSCT, supported by a combination of Industry, International (notably from Monash), DTP and strategic University matched funding; the established principle of CSCT building its cohort through externally matched PhD funding has played a key role in ensuring this ongoing successful recruitment. The CSCT CDT provides a comprehensive training and development programme, the success of which is reflected in outstanding research outcomes for its PhD student cohort, a high proportion of placements secured in industry and a number of awards for CSCT PhD students. In particular, the cohort have been proactive in undertaking independent initiatives such as establishing the cross-University Bath Science in Policy group.

In addition to leading this major PhD centre, Bath Chemistry is a partner in the EPSRC CDTs in New and Sustainable Photovoltaics (now led from Bath Physics), Water Informatics Science and Engineering (WISE, led by Exeter), CMAC (Future Manufacturing, led by Strathclyde), Catalysis (led by Cardiff) and Aerosol Science (led by Bristol), the last of which started in 2019. Bath Chemistry also contributes projects to the Bath-led CDT in Advanced Automotive Power Systems. Furthermore, the Fellow for Industrial Research Enhancement (FIRE) programme is a Doctoral Training programme bringing together the Bath-based CDTs in Sustainable Chemical Technologies and Digital Entertainment and seeking to increase the international aspects of these inter-disciplinary programmes and to develop their elements of transnational mobility and career development. This is supported by the EU through Horizon 2020 (*Scott*, £800k). The Unit is also engaged in the 'CDT-like' doctoral training programme run by the Faraday Institution, including PGR supervision. GW4, the consortium of Universities of Bath, Bristol, Cardiff and Exeter, hosts a NERC-supported Doctoral Training Programme (FRESH) studying aspects of freshwater including analytical chemistry, again including Bath Chemistry PGR students.

While CDT-supported PGR students receive training through their CDT, a comprehensive range of training opportunities is available through the Unit and the University-wide Doctoral College in which Chemistry students form the largest cohort. Training includes accredited courses on demonstrating and teaching; PGR students involved with teaching are eligible to apply for Associate Fellowship of the Higher Education Academy (AFHEA). A significant number of our PGR students are given the opportunity to secure placements in industry or at a University overseas through either a CDT or direct links with partners. As noted above, our PGR students organise departmental seminars through the PGExec and also run an annual showcase event (Bolland Symposium) where final year students present their research work orally whilst first year students present posters. PGR students within the CSCT CDT organise events as part of an annual three-day Showcase, which are open to all of our PGR students. Our PGR students are also involved in a wide range of outreach and public engagement activities (see also Section 4) and have gained high profile recognition at national and international level in competitions such as the Reaxys PhD Prize and the 3-Minute Thesis (3MT) competition. Our PhD students have also received >50 conference poster/presentation prizes and awards for outstanding contributions at research meetings in the UK and internationally.

3. Income, infrastructure and facilities

Income. UKRI income has been strong throughout the REF period (£30.2M awards), underpinning our longstanding strategy to embrace leadership and participation in large scale and interdisciplinary collaborations. Senior PIs provide leadership of major grants or consortia involvement as part of substantial teams within the Unit, which often involve ECRs; we ensure that contributions of "co-investigators" at all career levels are fully recognised within the Unit and the University, as well as contributing towards career development. Extensive support is provided for staff applying for funding. Within the UoA, research funding opportunities are disseminated and discussed at Research Committee and staff meetings, while a combination of formal and informal mentoring and internal peer review from fellow academics is provided to take research ideas from early stages to developed proposals. Specialist support is provided for the delivery of research funding applications by Research & Innovation Services (RIS), who also provide extensive support and infrastructure targeted at specific funding calls and opportunities such as larger scale grants and fellowship applications.

Examples of major funding partnerships led by Bath Chemistry include Lithium ion cathode materials (CATMAT; *Islam*, Faraday Institution, £11.2M), UK Catalysis Hub (*Davidson*, EP/K014668/1, 2013-18, £2.98M & EP/R027129/1, 2018-23, £3.94M; the latter part of the £15M CatHub renewal), Dynamic structural science at the RC@H (*Raithby*, EP/I01974X/1, 2011-16, £1.49M) and Terpene-based manufacturing for sustainable chemical feedstocks (*Davidson*, EP/K014668/1, 2013-18, £2.98M). Bath Chemistry academics have also been involved in three EPSRC programme grants, with two led from the Department: Applying long-lived metastable states with switchable functionality via kinetic control of molecular assembly (*Raithby* (PI), *Burrows, Carbery, Marken, Parker, Walsh, Wilson*, 2012-18, £3.24M); Energy materials: computational solutions (*Islam* (PI), *Walsh, Parker*, EP/K016288/1, 2013-19, £3.27M); Enabling next generation lithium batteries (Bruce (Oxford, PI), *Islam*, EP/M009521/1, 2015-20, £6.80M).

Other major grants have emphasised the expertise of Bath Chemistry across our Theme areas (and our overarching **Sustainability** effort, marked †). **Transformations**: Catalysis Hub 'Science' 3† as above (*Davidson* (PI), *Hintermair, Buchard, Webster*, EP/R027129/1, 2018-23, £3.94M); Nucleophilic alkaline earth boryls (*Hill* (PI), *Cresswell*, EP/R020752/1, 2018-21, £1.28M); Augmentation of alkaline earth reactivity (*Hill*, EP/N014456/1, 2016-20, £739k); New catalytic protocols for carbon-phosphorus bond synthesis† (*Webster*, EP/P024254/1, 2017-22, £1.06M). **Interfaces**: Advanced manufacturing for sustainable biodegradable microbeads - BIOBEADS† (*Scott* (PI), *Edler*, EP/P027490/1, 2017-21, £1.07M); New enzymatically produced interpenetrating starch-cellulose gels† (*Edler* (PI), *Scott*, EP/N033310/1, 2016-20, £950k). **Materials**: CATMAT† as above (*Islam*); three EPSRC Programme Grants as above (*Raithby*, *Islam*, Bruce/*Islam*); CLEVER - Closed loop emotionally valuable e-waste recovery† (*Scott*, EP/K026380/1, 2013-16, £1.26M)**; Healthcare**: Developing resilient nations - Towards a public heath early warning system via urban water profiling (ReNEW)† (*Kasprzyk-Hordern* (PI), *Frost*, EP/P028403/1, 2017-20, £1.12M); GREENER - Integrated systems for effective environmental remediation† (*Scott*, *Kasprzyk-Hordern*, EU Horizon 2020, 2019-22, €506k); and **Analytical**: DReaM Facility† (see below; EPSRC Strategic Equipment Fund; *Davidson* (PI), *Hintermair*, EP/P001475/1, 2016-18, £1.29M incl. £503k University contribution).

Bath Chemistry involvement as a partner in large projects includes: New manufacturable approaches to the deposition and patterning of graphene materials (Wright (Exeter, PI), *Raithby*, *Pantos, Johnson, Hill, Pascu*, EP/K017160/1, 2013-16, £1.13M); SUPERSOLAR solar energy hub† (Walls (Loughborough, PI), *Hill*, EP/J017361/1, 2012-17, £4.09M); Future continuous manufacturing and advanced crystallisation research hub† (Florence (Strathclyde, PI), *Wilson*, EP/P006965/1, 2017-23, £10.3M; EP/I033459/1, 2011-16, £6.06M); Flow-XI: A new UK facility for analysis of crystallisation in flow systems (Meldrum (Leeds, PI), *Wilson*, EP/T006331/1,

2020-22, £1.13M); SUPERGEN storage network plus† (Ding (Birmingham, PI), *Islam*, EP/S032622/1, 2019-23, £1.01M); SUPERGEN energy storage hub† (Bruce (Oxford, PI), *Islam*, EP/L019469/1, 2014-19, £3.91M).

Physical Environment. The Unit has primarily been located in a bespoke Chemistry Research building (1S) since 2001. Enhancements to this building have been extensive since it was first occupied; ongoing upgrades in the REF period ensure it continues to offer state-of-the-art laboratories fit for purpose as the core base for the Unit's research. However, since this building was constructed and particularly over recent years, the number of staff, RAs and PGR students has increased substantially, underpinned by funding successes and University investment in Chemistry expansion. This ongoing success has meant that the 1S building has been increasingly unable to host the full research capacity of the department.

Extensive additional laboratory space for Bath Chemistry researchers has subsequently been established across other buildings on the campus close to the 1S base. Initially this additional capacity was in building 5W; this capacity has been substantially increased and upgraded in the current REF period, with a further *ca*. 300 m^2 fully equipped space including refurbished laboratories with fume hoods and enhanced analytical equipment hosting seven key critical mass research groups in Sustainable Chemical Technologies, Transformations and Healthcare. The 5W laboratory suite also hosts one of the key equipment nodes of the MC^2 Materials and Chemical Characterisation facility; the EPSRC-funded Chemistry DReaM reaction monitoring facility (see below) is hosted in further expansion laboratory space, in a neighbouring bespoke 100 m^2 laboratory. In parallel, additional space has been made available for the Unit in two other buildings close to the 1S base. In addition to providing additional research space, this expansion has increased physical proximity to key collaborating departments and helped facilitate interdisciplinarity.

Across the different buildings, this extensive new space for the Unit amounts to a University investment of more than £3M (plus extensive additional equipment funding, captured below). Within the next five years, the University is planning new developments on campus which will involve the refurbishment of the 5W laboratories, along with expansion of laboratory facilities elsewhere, which will further improve our infrastructure.

The provision of high-quality physical environment also covers non-laboratory facilities within the Unit. All RAs and PGR students are provided with office space separate from, but in proximity to, their laboratories. A large open plan interaction area in building 1S provides a well-frequented, lively, dynamic environment for discussion, interaction and relaxation, while our PhD students also benefit from the recent establishment of a Doctoral Commons area within the Doctoral College, providing a new, additional environment for study and interaction.

In addition to the space available at Bath, many of the Bath Chemistry research groups make use of laboratory space and equipment at the Research Complex at Harwell (RCaH). As part of the UK Catalysis Hub (*Davidson*), Dynamical Structural Science (*Raithby*; to 2017) and CMAC Future Manufacturing Hub (*Wilson*) consortia, Bath Chemistry researchers have access to fully equipped laboratory space and a comprehensive suite of analytical equipment at RCaH. A number of Bath Chemistry researchers (academics, PDRAs, PhD students) have been partly based at RCaH during the REF period. The Chemistry-led Sustainable Technologies Business Acceleration Hub (STBAH; Section 4) is hosted in the University of Bath Innovation Centre in Bath city centre, co-located with the SETsquared Business Incubation Centre to offer direct and convenient access for businesses benefiting from its expertise.

Facilities. Bath Chemistry has excellent equipment to support its research, with key facilities available through the University's integrated Materials and Chemical Characterisation suite

(MC^2). These include NMR spectroscopy (five instruments: 300 MHz, 400 MHz ×2, 500 MHz ×2), mass spectrometry (seven instruments, many coupled to HPLC or UPLC: ESI-TOF, ESI-Q-TOF ×4, MALDI, GS-MSD), X-Ray diffraction (single crystal – RIGAKU SuperNova Dual (Mo and Cu radiation) and RIGAKU Xcalibur (Mo radiation), powder – STADI P (Cu radiation) double setup in transmission and reflection mode), microscopy (five instruments, SEM, FESEM, TEM, AFM, Confocal Microscope; two of the EM instruments are capable of EDX analysis), FTIR and Raman spectroscopies, gas sorption, TGA, DSC, microcalorimetry and size exclusion chromatography. Much of the equipment is available for hands-on use by RAs and PGR students following appropriate training, through high level dedicated scientific support is provided by experts in mass spectrometry, NMR spectroscopy and X-ray diffraction. All of these facilities are heavily used by Chemistry, whose researchers make up a high proportion of the userbase.

Substantial investment of more than £4M has been obtained from the University to ensure that MC^2 continues to provide enhanced leading-edge analytical capabilities to support research in the Unit. In the REF period this investment has included: Transmission Electron Microscope (£580k); Laser Scanning Confocal Microscope (£520k); Scanning Electron Microscope (FESEM; £750k); Powder X-Ray Diffractometer (£450k); 400 MHz NMR (£400k); Small Angle X-ray Scattering (SAXS; £380k); LC electrospray Q-TOF MS (£400k). In addition, the University provided a £350k contribution to augment EPSRC funding secured for core chemistry equipment provision (EP/L027267/1, £1.08M), and a contribution of ca. £500k towards the £1.29M DReaM Reaction Monitoring Facility (EPSRC Strategic Equipment; EP/P001475/1, 2016). This Facility, developed with partners Bruker and AstraZeneca, represents a highly significant and innovative addition to our analytical capacity in the REF period. DReaM provides integrated NMR spectroscopy (500 MHz), mass spectrometry (micrOTOF-Q and gas phase), UV-visible spectroscopy and polarimetry coupled with in-line reactors to allow dynamic monitoring of chemical changes in homogeneous reactions as they are taking place. It has attracted collaborators and users from academia and industry, and two international showcases have been hosted during its establishment phase. The University has an award-winning scientific glassblower based in the core chemistry building and primarily associated with the UoA.

The University's high performance computing facility, Balena, has provided an integrated HPC environment throughout the REF period. It has 3136 cores and is used extensively by computational chemists in the Materials, Transformations and Healthcare themes. Balena operates with a dual access model: larger jobs require funding but capacity for smaller runs is freely available to all researchers, supporting code development, pilot projects and occasional users. Research Software Engineers support projects and offer training in modern software development. Through the GW4 regional collaboration, Bath Chemists also have access to the Tier-2 regional HPC ISAMBARD, the world's first ARM-based supercomputer.

Use of National and International Facilities. Bath Chemistry academics and their research groups are extensive users of Facilities such as Synchrotron X-ray Sources, Neutron and Muon Sources and Central Laser facilities. Thirteen groups have benefited from such access, provided by STFC in the UK or by direct application to overseas facilities (in some of which the UK is a partner); beamtime is awarded through competitive peer review. This usage is costed in-kind and amounts to around £7.3M over the REF period; *Edler* has been among the biggest overall users of the ISIS Neutron and Muon Facility (£1.2M, from her total facilities portfolio of £2.7M).

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

Bath Chemistry is involved in a wide range of research consortia (Sections 1 and 3), and has substantial national and international community links; we contribute to the health and sustainability of the discipline through these activities, including substantial contributions to peer review and in a large number of advisory roles, detailed below. As noted in Section 3, we are heavy users of national and international central facilities (e.g. synchrotron, neutron and laser), also contributing to those in peer review and senior advisory roles.

Major consortia over the REF period include those led from Bath Chemistry, including the UK Catalysis Hub (Bath, Bristol, Cardiff, UCL, with 27 project partners), for which Bath leads one of the three nodes (*Davidson*, with Bristol, Imperial, Leeds, Manchester, Oxford, QUB, York), the Faraday Institution-supported consortium on lithium ion cathode materials (*Islam*, with Birmingham, Cambridge, Diamond Light Source, Liverpool, Oxford, UCL and 12 industrial collaborators) and the Dynamic Structural Science consortium at RCaH (*Raithby*, with Durham, Leeds, Manchester, Nottingham, STFC). Bath Chemists (*Raithby*, *Wilson*) also led the EPSRC Directed Assembly Grand Challenge Network until 2018, with a network of 50+ institutions and industry partners involved. The CSCT has provided a focus for collaborative work and major research awards in the UoA, both through the core CDT at Bath (with 24 project partners), its broader collaborative network of 25 institutions in the UK and overseas and 31 industry partners, and its Business Acceleration programme with more than 100 SME partners.

Bath's partnerships as a collaborator in major research consortia include the SUPERSOLAR solar energy hub (led by Loughborough; 6 institutions, 9 project partners), CMAC Future Manufacturing Hub (led by Strathclyde; 7 institutions, 8 Tier-1 pharma partners), Flow-XI Facility (led by Leeds; 4 institutions), SUPERGEN storage network (led by Birmingham, 11 institutions, 32 project partners). Further details of these and other consortia either led by Bath or with strong Bath involvement are provided in Section 3. Our collaborative networks also benefit from involvement in a range of consortia-based CDTs (Section 2); these involve ten CDTs and CDT-like doctoral training entities.

Bath Chemistry is involved in numerous consortia relating to water research, led at Bath by *Kasprzyk-Hordern*, who sits on the Management Boards of the University's cross-faculty Water Innovation and Research Centre (WIRC) and the GW4 Water Security Alliance. These include the EU Networks GREENER (2019-22), which aims to develop integrated systems for environmental remediation, INTERWASTE (2017-20) which seeks to develop scientific understanding of issues related to environmental contamination with toxic organic chemicals and SEWPROF (2012-16) which provided information on drug use and health through sewage profiling as well as the SCORE Network.

Kasprzyk-Hordern has also played a prominent role in the response to Covid-19, as part of a UK-wide team developing a standardised system for detecting coronavirus in wastewater, to provide an early warning of future outbreaks and reduce reliance on costly testing of large populations. Our researchers also developed Covid (and anti-malarial) testing with London School of Tropical Medicine (*Bull*) and the CSCT led a Bath Virtual Sandpit on interdisciplinary research challenges for emergence from the pandemic.

Industrial and clinical links: As part of its approach that embraces applied research and impact delivery, Bath Chemistry has substantial collaborative links outside academia. These include more than 200 companies, including multi-nationals (e.g. major pharma including AstraZeneca, GSK, Bayer, Novartis, Pfizer, Roche, Lilly and Evotec; and catalysis, healthcare, materials and processes including Johnson Matthey, Infineum, Unilever, Reckitt Benckiser, Airbus, Wessex Water and Hartmann AG), SMEs (e.g. Artis, Binx, CatSci, Digital Diagnostics AG, Lambda

Energy, PragmatIC Printing, Integrated Graphene, Lifecare, Glysure Ltd and GlucoSet) and the 100+ companies engaged through the STBAH business engagement programme (see below). Links in the innovation and translation space include those with the High Value Manufacturing Catapult (specifically the Centre for Process Innovation (CPI) and the National Composites Centre (NCC)), together with international collaborators including the Warner-Babcock Institute, Los Alamos National Laboratory and the Department of Energy in the US. Bath Chemists also have a number of direct clinical collaborations including Royal Hospital for Children, Queen Victoria Hospital (East Grinstead), Royal United Hospital (Bath), Southmead Hospital (Bristol), Hammersmith Hospital (London), Addenbrooke's Hospital (Cambridge), Guy's and St Thomas' Hospital (London) and Yankin Children's Hospital (Yangon, Myanmar).

Contributions to the economy. As exemplified in the UoA Impact Case Studies and other examples of impact (Section 1), research in the Unit has led to significant direct economic benefits from our strong record of knowledge exchange with industry through collaborative research work, technology transfer and provision of highly skilled employees into industrial positions.

There has also been an increasing emphasis on contributions to the regional economy, with researchers in the Unit engaged with Local Enterprise Partnerships (LEPs) in the region, often in collaboration with the SETsquared business incubator partnership. As an example, the links of our research with SMEs has been boosted over the REF period by the award and implementation of the Sustainable Technologies Business Acceleration Hub (STBAH; 2017-2021) and its successor the Sustainable Technologies Scale-Up Programme (2020-2024), both supported through the European Regional Development Fund (ERDF, total funding £2.7M, in partnership with the West of England LEP; *Davidson, Wilson*). These programmes support businesses interested in developing low carbon or sustainable technologies; 108 companies are in the programme, which delivered £4.1M direct grant income and £6.3M further investment in its first 24 months. A Digital Business Acceleration Hub has also recently been funded (ERDF, with Swindon and Wiltshire (SW) LEP; £700k, *Davidson*), and in 2020 sustainable chemical technologies was included in the SWLEP Local Industrial Strategy, with CSCT as a key partner.

Public Engagement. Many Bath chemists undertake extensive public engagement activities. In the most significant of these, *Islam* presented the Royal Institution (RI) Christmas Lectures in 2016. The three televised lectures in the UK's flagship science series, on energy, were titled *'Supercharged: fuelling the future'*. *Islam* was also featured on 'The Life Scientific' (BBC Radio 4) in 2019. A number of Chemistry academics and research students regularly deliver Science Cafes, talks at Pint of Science and at the Bath Royal Literary and Scientific Institution, Science Soapbox, 3MT, and there is Unit-wide involvement in the Salters Festival and Bath Taps into Science. Bath Chemistry staff and PhD students take part in Spectroscopy in a Suitcase (RSC), taking a portable spectrometer around to local schools. CSCT members regularly present at events like STEM4Britain. Royal Society Summer Science Exhibition, Festival of Nature (Bristol), Cheltenham Science Festival, *I'm a Scientist, Get me out of here!*, Glastonbury Festival, Green Man Festival (Einstein's Garden), FameLab, TEDx Open Mic night, Meet the Engineer, Science Showoff and the IET's Present Around the World (PATW). Many of these events allow us to engage with individuals from non-traditional backgrounds.

News Stories. Bath Chemistry research has been widely reported in the media. *Sartbaeva*'s research on an ensilication method to protect proteins and vaccines and eliminate cold chain has featured in more than 500 outlets reaching a potential audience of more than 1.3 billion worldwide, £11.7M Advertising Value Equivalent Coverage (AVEC); *Scott*'s work on biobeads; gained extensive media publicity estimated at 46 million total news reach world-wide (£2.1M AVEC); *Jenkins*' infection detecting wound dressing featured on the BBC and The Guardian and has been covered in Japan, South Korea and the US; *Jones*' research on plastic from pine

needles and in recycling plant-based plastics resulted in more than 80 articles across online, print and broadcast, including Newsweek and Stern with potential news reach of 78 million worldwide; and *Lewis*' research on synthetic derivatives of naturally occurring molecules and their potential for treatment of pancreatic cancer attracted worldwide coverage in 79 outlets (£743k AVEC).

We have many outgoing and incoming Visiting appointments in the REF period:
Visiting Positions held by Bath Chemistry academics. *James* (France – Bordeaux (AMADEus Invited Chair); China – seven including Zhejiang; Japan – Sophia; South Korea – Ewha), *Bull* (Japan – Osaka), *Edler* (Sweden – Lund), *Davidson* (Australia – Monash); *Buchard* (USA – Minnesota). *Raithby* and *Wilson* hold Visiting Scientist positions at Diamond Light Source, *Pascu* holds Visiting Scientist positions at the University of Oxford and the Research Complex at Harwell and *Freakley* holds a Visiting Research Fellow position at Swansea University.
Visiting Positions held at Bath Chemistry by high profile external colleagues. GM Whitesides (Harvard, Honorary Degree 2015), RH Crabtree FRS (Yale, Honorary Degree 2016), PP Power FRS (UC Davis, Global Chair 2016-19, Honorary Degree 2016), V Moliner (Jaime I, Spain, David Parkin Visiting Professorship, 2016-17), J Warner (Warner Babcock Institute/Zymogen, USA & Monash, Australia, Global Chair, 2020-21), Y Long (Nanjing University, Visiting Professor since 2014), JR Dilworth (Oxford; Honorary Professor since 2013), K Kikuchi (Osaka, Visiting Professor, 2019). An Honorary Degree was also awarded (in 2019) to A Harrison (CEO, Diamond Light Source), reflecting the strong links between Bath Chemistry and the Central Facilities on the Harwell site and other links into the use of advanced radiation sources. R Barden (Wessex Water) is a Visiting Industrial Fellow facilitating collaborations with the Water Innovation and Research Centre, while G Gobius du Sart (Total Corbion PLA) is a Visiting Industrial Fellow in the CSCT.

Peer Review. 26 members of staff are EPSRC College Members; over the REF period 11 members of staff have chaired or been members of EPSRC panels**.** Bath Chemistry staff also have UKRI peer review roles with NERC & STFC and have sat on prioritisation or grant review panels in Germany, Spain, Portugal, Ireland and Sweden.

Advisory roles. Bath Chemistry staff undertake a large number of advisory roles (more than 50) illustrating the value placed on their expertise and the willingness of colleagues in the Unit to engage extensively in these important roles in the wider community. Amongst the more significant of these are the following: *Davidson*: International Scientific Advisory Board (Fachbeirat) Max Planck Institute for Chemical Energy Conversion (Mülheim/Ruhr) (2019-25), REF 2021 Chemistry Panel member & Interdisciplinary Research Advisor (2018-21), REF 2014 Chemistry Panel member (2011-14); EPSRC UK Carbon Capture & Storage Research Centre Management Board (2014-), external research quality assessor/advisor for three UK, one international chemistry departments, EPSRC International Review of UK Chemical Engineering (2014-15), UK Delegation, 8th Chemical Sciences and Society Summit (CS3; Science to Enable Sustainable Plastics) (2019), Invited to present evidence to Department of Transport Science Advisory Council, London, 2019, US DOE Energy Frontier Research Centre Review Panel; *Domene***:** Resource Allocation Panel, National HPC Service (2013-16), Vice Chair, FET Open Research and Innovation Actions, European Commission Research Executive Agency (2019); *Edler*: Chair, STFC ISIS Triennial International Review panel (2019-20), STFC Science Board (Member 2018-20; appointed Deputy Chair 2020-23), European Spallation Source Scientific Advisory Panel, neutron reflectivity (2011-18), Review panel, Partners in the ILL/ESRF Partnership for Soft Condensed Matter (2019-22); CCP-SAS Executive Committee (2018-present); *Hintermair*: Steering group, UK Catalysis Hub (2016-present); *Kasprzyk-Hordern***:** Global Panel on Chemical Pollution of the Environment (GPCPE); expert advice provider for EMCDDA in Europe and Environment Agency, Defra in the UK, contributed to a White Paper on Initiatives for Addressing Antimicrobial Resistance in the Environment; *Islam***:** Expert Panel of

the Faraday Institution; *Peter*: advisor, Cluster of Excellence Nanosystems Initiative Munich (NIM), Bundesministerium für Bildung und Forschung- Kopernikus Project P2X; *Wilson*: Chair, Scientific Council, Institut Laue-Langevin (2011-16); Science Foundation Ireland National Centre Review (2019); BEIS Review of UK Neutron Provision (2020); STFC Science Board (2013-18); EPSRC Physical Sciences Strategic Advisory Team (SAT; 2017-20) and Manufacturing the Future SAT (2011-17); *Lubben* (Senior Instrument Specialist, Head of MC^2 Facility), EPSRC SAT for Capital Equipment, EPSRC RTP Working Group, Chair of EPSRC Working Group on Sustainability of Research Facilities; *Lowe* (Senior NMR Spectroscopist, MC^2), EPSRC RTP Working Group.

Engagement with learned societies and publications. As part of the collegial, collaborative culture in the Unit, many Bath Chemistry staff act as editorial board and advisory board members, with 20 colleagues engaged in these roles across 42 journals in the UK and internationally. Furthermore, many Bath chemists have acted as Editors for Special Issues of journals, 14 engaged in such roles in the REF period across 23 journals. Bath chemists have also contributed to books as both authors and editors, including: *Bull*, Series Editor, OUP Chemistry Primers (50 books; Commissioned, delayed due to Covid-19); *Burrows*, Author of undergraduate textbook *'Chemistry^3: Introducing Inorganic, Organic and Physical Chemistry'* (3rd edition, 2017); *James*, Editor, *'Boron: Sensing, Synthesis and Supramolecular Self-Assembly'* (RSC, 2015); *Marken*, Editor, *'Electrochemical Reduction of Carbon Dioxide: Overcoming the Limitations of Photosynthesis'* (RSC, 2018) and *'Modern Electrosynthetic Methods in Organic Chemistry'* (CRC, 2018); *Pantos*, Editor, *'Naphthalenediimide and its Congeners: From Molecules to Materials'* (RSC, 2017).

Bath chemists are heavily engaged with the Royal Society, the Royal Society of Chemistry and other learned bodies in both the UK and overseas in a range of roles. Amongst the more senior (of more than 25) are the following: *Davidson*, Chair, Royal Society Meetings: 'Science to Enable the Circular Economy' (2019) & 'Scientific Priorities for Realising a Circular Economy', 2019, Co-authorship of RS Policy Briefing: "The potential & limitations of using carbon dioxide", 2017; *Islam*, Royal Public Engagement Committee (2019-) & Diversity Committee (2015-2017), Chair, Discussion Meeting on Energy Materials for a Low Carbon Future (2018); US National Academy of Sciences Steering Group, Science Forum on Energy Storage; *Domene*, elected member of RSC Council (2015-18 and 2019-22), Council Member of International Society of Quantum Biology and Pharmacology (2016-20); *Islam*, RSC Board of Trustees (2021-); *Hill*, Chair of RSC Main Group Chemistry Interest Group (2013-18); *Edler,* President of International Mesostructured Materials Association (2018-21), *Whittlesey*, UK Representative, EuChemS (Inorganic Chemistry Division), *Cresswell* (SCI Young Chemists Panel).

Conference Organisation & Participation. During the REF period, a range of international and national chemistry conferences have been held in Bath, including those in well-established series and one-off events. These include Molecular Sensors and Molecular Logic Gates (MSMLG; 2016), RSC Joliot-Curie Conference (2017); British Zeolite Association Conference (BZA; 2016); Electrochemistry at Nanointerfaces – Faraday Discussion meeting (2018), Advances in Lithium-Ion Batteries (2016), Meeting for Inorganic Chemistry Recent Appointees (MICRA; 2014), RSC Organic Division South-West Regional meeting (2017). Three annual symposia series hosted by Bath Chemistry were initiated: Bath Organometallic Synthesis Symposium (2018-20); Reaction Monitoring Symposium (2017-20); Energy Materials Symposia (2014-17). Bath academics run regular training / CPD schools including a Catalytic Reaction Monitoring Summer School and the long-established Bath Electrochemistry Winter School (in partnership with Metrohm) and Impedance Summer School (with Ametek Scientific Instruments).

Bath chemists have also organised a number of conferences elsewhere in the UK and overseas; including around 20 in the US, France, Italy, Poland, India, Switzerland, Poland, China, South

Africa, Indonesia and Brazil. In addition, our academics have organised symposia within a number of larger meetings and initiated series of annual meetings, including the UK Catalysis Conference, 2015-20 (*Davidson*) and the RSC Main Group Chemistry Interest Group, Annual Meetings 2014-19 (*Hill*).

Bath Chemists are also widely involved as session organisers and as Advisory/Programme Board members at a range of National and International Conferences – there have been more than 100 in the REF period. In addition, Bath Chemists are regular Invited and Keynote Lecturers at International Conferences, with more than 100 of these in the REF period. These include several named lectures: *Islam* gave the Thomas Graham lecture at UCL (2017) and the Henry H. Storch Award in Energy Chemistry Symposium (2020), *Edler* gave the Inman Lecture in the RSC Molten Salts and Ionic Liquids Discussion Group meeting (2019), *James* gave the MSMLG Czarnik Award Lecture in Dalian (2018) and *Webster* gave the McCamley Lecture at the University of York (2020).

Awards and Recognition. During the REF period, Bath Chemistry academics have received major external awards. These include Royal Society Wolfson Research Merit Awards to *James* (2017-22), *Islam* (2013-18) and *Williams* (2012-17) and many RSC Awards including the Peter Day Award for Materials Chemistry to *Islam* (2017), Geoffrey Barker medal to *Marken* (2018), Main Group Chemistry Award to *Hill* (2016), Inorganic Reaction Mechanisms Young Investigator Award to *Hintermair* (2018), *Webster* (2019) and *McMullin* (2020). In addition, the 1st Prize in the RSC Emerging Technologies Competition has been won by both *Jenkins* (2018) and *Sartbaeva* (2020). *A Wilson* (RA) won the RSC Dalton Emerging Investigator Prize (2020).

Other awards include the Sir John Meurig Thomas Medal of the UK Catalysis Hub (2016), and DECHEMA Willi Keim Prize (2016) to *Hintermair*, Frontiers in Chemistry Diversity Award (2020), Molecular Sensors & Molecular Logic Gates Czarnik Award (2018) and Inaugural CASE Award (2015) to *James*. IChemE awards have been won by *Freakley* in the form of the Andrew Fellowship (2020) and *Sartbaeva* who has won the Biotechnology Award (2017), WISE World Award (2017) and Hanson medal (2019). In addition, *Islam* received the ACS Henry H. Storch Award in Energy Chemistry (2020) and Fellowship of the Institute of Materials, Minerals and Mining (2019). *Hatcher* (RA) won the BCA CCDC Prize (2017).

Other recognition includes the selection of both *Sartbaeva* and *Islam* by the RSC for the 175 Faces of Chemistry, while Forbes Magazine included *Liptrot* in their 30 Top Global Scientists under 30 (2014).