Institution: University of Strathclyde
Unit of Assessment: 12
1. Unit context and structure, research and impact strategy

1.1 Context

Engineering at Strathclyde addresses the global challenges facing society by undertaking multidisciplinary and collaborative research for the generation of new knowledge and understanding. It also strives to deliver impact at scale and at pace, in keeping with the University's founding ethos as a "place of useful learning". This is achieved through Strathclyde's distinctive model of partnership working to deliver impact for business, industry, society and government (see Institutional Statement).

The strategic research plan articulated in REF2014 was to grow research excellence, capability and infrastructure whilst promoting high standards of research governance and practice. Accordingly, the key elements of the Engineering research strategy are to:

(a) expand and strengthen our talented and highly-qualified research community;
(b) strengthen multidisciplinary research by supporting strategic cross-disciplinary research themes;
(c) collaborate with UK and internationally leading research institutes;
(d) create the environment and mechanisms that lead to effective translation;
(e) increase research income; and,
(f) communicate our research findings in high quality and appropriate journals.

The approach taken has been successful with an 80% increase in research income (Table 1a) over this REF cycle. This has enabled year-on-year strengthening of our existing capabilities and brought new investment to areas of strategic importance (e.g. decarbonisation, manufacturing, informatics, digitalisation, automation). Strategically, we have invested in cross-Department, multidisciplinary facilities based on the Strategic Themes and Research Clusters, (see section 1.3) and supported cohort-based PGR training through expanding Centres of Doctoral Training (CDTs). Research communication from the UOA is strong, with the number of peer-reviewed journal articles and datasets published (2013 to 2020) exceeding 6100 and 346 items respectively. We have provided training and support for our researchers to ensure adherence to Open Research principles and host more than 10,000 curated items on our open access repository (https://strathprints.strath.ac.uk/). This portfolio of work represents 39% of content on Strathprints and helped place the University 4th in the 2020 Leiden Global Ranking on Open Access.

Table 1a: Staff, PGR, income and research output comparisons over REF audit cycle.

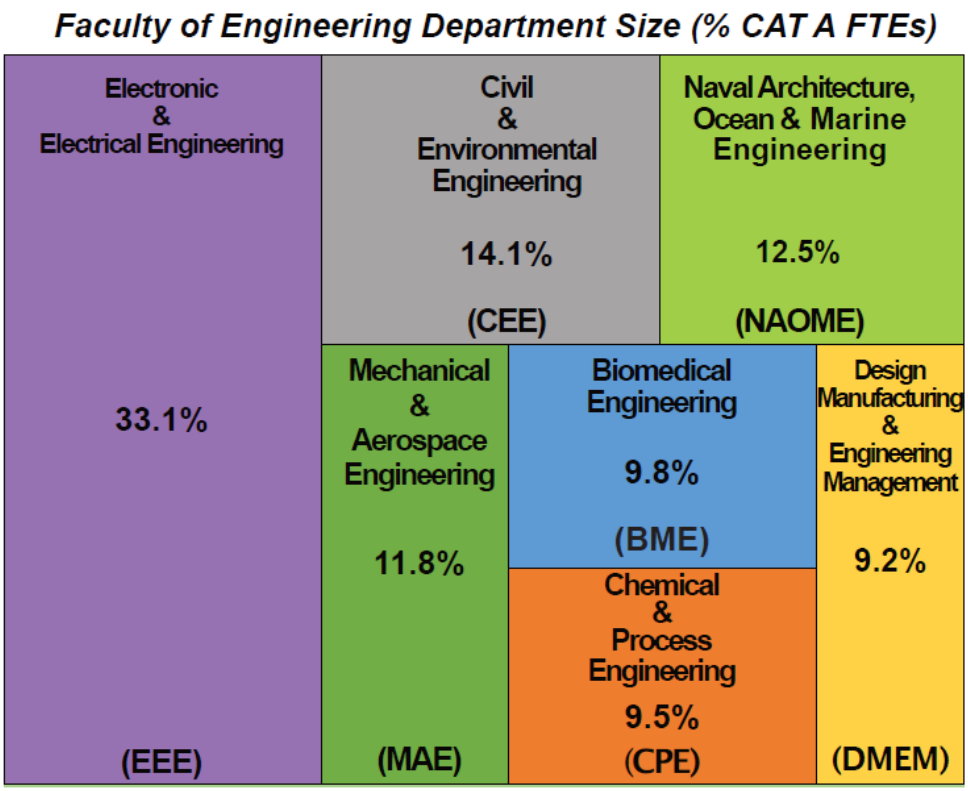
	REF2014	**REF2021**	**% change**
CAT A FTEs	158	220	+ 39%
Researchers	215	235	+9%
Knowledge Exchange	10	174	+1640%
PGR population	530	610	+15%
Research income	£28.7m	£51.6m	+80%
Research outputs in peer-reviewed journals	593 (2013)	950 (2020)	+60%

Our research is conducted in groups distributed across seven Departments of the Faculty (Table 1b and Figure 1). It also includes three large-scale Industry–University collaboration centres established

to accelerate translational activities and impact: the **Advanced Forming Research Centre** (AFRC); the **Power Networks Demonstration Centre** (PNDC); and, the **Advanced Nuclear Research Centre** (ANRC). These centres operate semi-autonomously with Departmental oversight to ensure effective academic/translational collaboration.

Table 1b: Departments and number of CAT A FTEs submitting to UOA12	
Academic Departments (*affiliated Industry-University Research Centres*)	**REF2021 Cat A FTE**
Biomedical Engineering (BME)	21.6
Chemical & Process Engineering (CPE)	21
Civil & Environmental Engineering (CEE)	31
Design, Manufacturing & Engineering Management (DMEM) *(Advanced Forming Research Centre, AFRC)*	20.3
Electronic & Electrical Engineering (EEE) *(Power Networks Demonstration Centre, PNDC)* *(Advanced Nuclear Research Centre, ANRC)*	72.9
Mechanical and Aerospace Engineering (MAE)	26
Naval Architecture, Ocean & Marine Engineering (NAOME)	27.6
Total	**220.4**

Figure 1: Departmental distribution of Cat A staff FTE as % of total UOA submission.



Further support for industrial engagement and impact generation is provided through a number of well-funded industry strategic programmes and partnerships. Lessons learned through our longest established partnerships such as the Rolls-Royce University Technology Centre in Electrical Power Systems (since 1997) and the Weir Advanced Research Centre (since 2012) have driven models

and experience of high impact engagement. This has inspired new strategic partnerships during REF2021, including: BAE System's Strategic University Partnership Programme; the Low Carbon Power and Energy Programme with ScottishPower, SSE and the Wood Group; and, hosting MarRi-UK at Strathclyde, a tier-level membership organisation for UK companies and researchers in Maritime Technologies and Systems. This approach is augmented through industrially funded academic posts, with examples including: Xilinx Inc Industry Professor of Signal Processing; ScottishPower Chair in Smart Grids; Texas Instruments Chair in Digital Signal Processing; RAEng/BAM Nuttall Chair; RAEng/Spirit Aerosystems Chair; Nokia Lectureship; and, the Leonardo Lectureship.

We are at the forefront of UK engineering initiatives, including the Innovation Districts (http://investglasgow.com/innovating-the-future/) and "place" agenda (see Institutional Statement). Within the Scottish Research Pools, we chair the Scottish Research Partnership in Engineering (https://www.srpe.ac.uk/about-srpe) and the Energy Technology Partnership (https://www.etp-scotland.ac.uk). We host the Centre for Sensor and Imaging Systems (CENSIS) and the Industrial Biotechnology Innovation Centre (IBiolC) and serve on the boards of the Glasgow City Innovation District (GCID), the Advanced Manufacturing Innovation District Scotland (AMIDS), (see Figure 2b, c and Section 1.3 for further details) and two UK-wide Innovation Catapults (Offshore Renewal Energy and High Value Manufacturing). We lead a number of significant UK wide research programmes including a £7M Industrialisation Centre as part of the UK Government's Driving the Electric Revolution (DER) challenge, and the £10M Energy Revolution Research Consortium within the 'ISCF Prospering from the Energy Revolution programme'.

The updating and refinement of the University's Research and Impact strategies, the selection of its Strategic Research Themes and the formation of the Research Clusters to support Innovation Districts have been undertaken at Institutional level. The strategies have then been further refined and fine-tuned by the Engineering Faculty, informed by the policies and delivery plans of the UK and Scottish Governments, the Scottish Funding Council (SFC), UKRI, engineering academies and the needs of industry and society.

Looking forward, the University's 5-year strategic plan, **Vision2025**, is focused on excellence and translation and sets our research on a pathway to support economic growth and wellbeing. Guided by Vision2025, we aim to ensure that engineering at Strathclyde is an internationally leading engineering and technology innovator and recognised as one of the best staffed, supported, and equipped units. Our research performance indicators for the next 5 years are summarised in Table 2.

Table 2: Vision2025: Engineering Key Performance Indicators (KPIs)

Targets and KPIs		2019/2020	2025/2026
Staff	Academic Staff (FTE)	220	340
	Contract Research Staff	260	350
	Knowledge Exchange Staff	174	210
	Administrative Staff	211	260
	Technical Staff	100	132
Research Income		£51M	£80M
PGR Headcount		660	900+

By 2025 we will grow to 340 engineering academic staff to provide the critical mass in support of research delivery, an enlarged modern estate with world-class facilities and a doctoral training programme exceeding 900 PGR students. Growth in research and KE staff will be instrumental in

delivering research that has lasting academic impact that translates to industry and society. With strong research interests in energy, environment, decarbonisation, health and sustainable development we also expect our research within this UOA to contribute to Net-Zero campaigns and actions in support of the UN's Sustainable Development Goals. We recognise the value of public engagement and in making research accessible. Accordingly, we will grow our outreach activities and we will continue to commit to principles of Open Research.

1.2 Research Support Structures

Faculty and Academic Departments

The Faculty of Engineering is responsible for the overall strategic planning and management of the combined Departments and centres forming this Unit. Departments have responsibility to determine their research structure and organisation and are required to provide annual plans specifying strategic research and knowledge exchange goals and delivery plans together with outline business cases for strategic investment. Full details of the Departments' and research centres' organisation, staff and groups are given in Section 3.

The Faculty is led by the Executive Dean, who is supported by a Faculty Management Team (FMT) whose membership includes Vice Deans (Research, KE) and Associate Deans (Research) with particular responsibility and accountability for our research environment. The Dean, Faculty leadership and Heads of Department come together at the regular Faculty Planning and Resources Committee (FPRC). At this, the overall research and wider Faculty strategy and plans are agreed, and investments approved against our plans and emergent opportunities to advance our mission.

The Vice Dean Research chairs the Faculty Research Committee (FRC) whose membership includes Departmental Research Directors, Research Development Managers, postdoctoral and PGR representatives. This committee is responsible for directing the delivery of Faculty research strategy, monitoring research performance, collaboration and integration across Departments and Centres and working alongside our professional services to shape the support and development opportunities provided to our research community. A Faculty KE Committee is chaired by the Vice Dean Knowledge Exchange with appropriate inclusive Departmental representation.

Institutional Research Support

All UOA12 staff linked to research and KE receive intelligence, advice and guidance on funding, and commercialisation through the University's Research and Knowledge Exchange Services (RKES) and the Innovation & Industry Engagement Directorate (IIED). Key information resources are provided through direct interaction with RKES and IIED personnel but also through a comprehensive knowledge management web portal. Within Engineering, RKES research development managers provide researchers with pre-grant submission guidance, intelligence, support for strategic bid development and post-award contract management. As examples, through the support provided by the International Team, Engineering has grown its H2020 portfolio to 87 awards (total value of £36M+) rising from seven awards in 2014/15 to 20 in 2019/20. Similarly, through support provided in EPSRC bid management this Unit concluded the REF period with an EPSRC success rate >25%. The consequence of this success has been increased access for our engineering community to funds allocated through our EPSRC Impact Acceleration Account, the Doctoral Training Partnership fund (£4.8M 2018/19), the EPSRC Industrial Case Account (£5.1M since 2015) and an annual SFC Global Challenges Research Fund (GCRF) allocation (£1M in 2020). In addition, joint planning between RKES portfolio managers and our FRC underpin specific workshops on early career fellowships and strategic grant calls. Follow on support to those developing bids is provided.

The IIED supports our research community, students and alumni in Industry Engagement, Intellectual Property (IP) and Commercialisation. Over the course of REF2021 there were 6 high growth potential spin-outs formed and 126 disclosures from engineering staff resulting in 41 patents. 29 new licence agreements were established. The impact of an IIED stage gated system saw 11 licence agreements enacted within the final 2 years of the REF cycle, and a healthy pipeline of spin-outs are progressing to start-up with at least 2 spin outs expected to be completed early in 2021.

Royalty income is growing through successes in licencing (exceeding £1M since 2015). Strathclyde's policy is to share royalties with the inventor(s), their Departments and the University via a scheme that significantly increases the return to those named in the license once initial university investment costs have been recovered. This allows the inventors and Departments to reinvest in their research. Notable recent agreements have been reached with Hubbell (USA) and Linea (Europe) for marketing of devices for microbiological decontamination (EEE) and with Talarmade for a novel wrist orthotic (BME).

We have also developed our estate through continuous on-campus improvements and investments totalling £168M over the audit period. Major projects include the opening of the Technology and Innovation Centre (TIC) (£89M/2015), a £44M redevelopment of the James Weir Building (MAE, CEE, DMEM, CPE) and a £16M redesign of the Wolfson Centre (BME). Through these investments 51% (21,100m^2) of our total footprint is now dedicated to research. Further strategic research and innovation investment centred on Innovation Districts linked to Strathclyde's multidisciplinary research themes and clusters is described below.

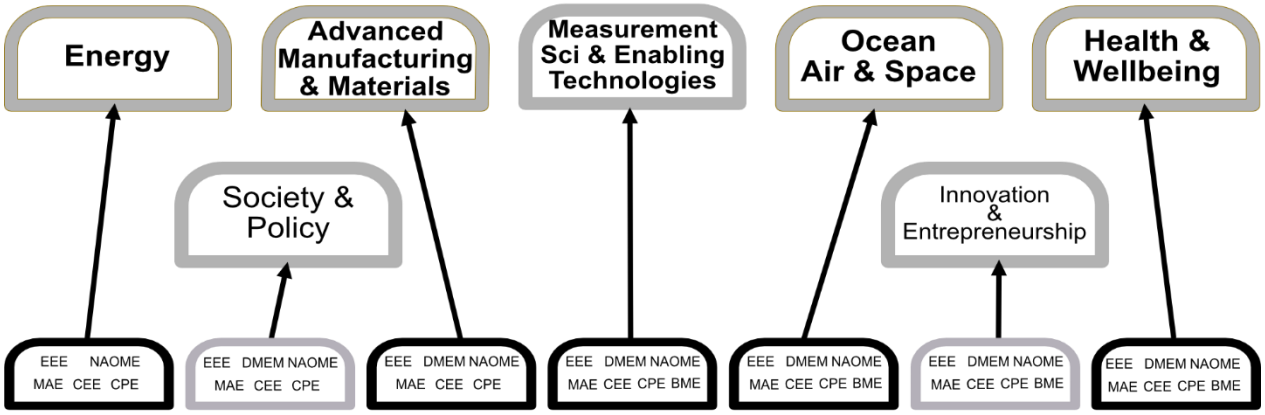
1.3 Research and Impact Strategy

Strategic Research Themes*, *Innovation Districts and Estate

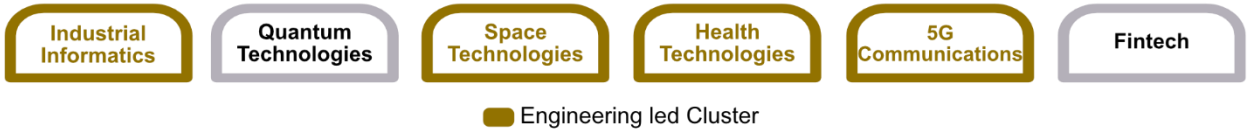
The University has established seven Strategic Research Themes providing a focus for multidisciplinary research and investment. Engineering contributes to all but is most active in five (shown in bold in Figure 2a: Advanced Manufacturing & Materials, Energy, Ocean Air & Space, Health & Wellbeing and Measurement Science & Enabling Technologies). These have driven growth in opportunities for collaborative impact. Highlights include £19M of collaborative grant awards to Engineering PIs working in the Ocean, Air and Space theme, our hosting of the 2019 Low Carbon Energy for Development Network conference (Energy theme) and the resultant Foreign, Commonwealth and Development Office Faraday Project with StorTera bringing clean cooking technologies to Sub-Saharan Africa.

As outlined in the Institutional Statement, Strathclyde has built Research Clusters, four being led by Engineering (Figure 2b) and embedded within two Innovation Districts. These are the Glasgow City Innovation District (GCID), a regional development plan for innovation and research collaboration encircling our campus, and the Advanced Manufacturing Innovation District Scotland (AMIDS, Figure 2c) which is an off-campus development incorporating the AFRC. By 2025, the total invested will be £1Bn with Strathclyde's Engineering led clusters the focal point for further significant research and impact growth.

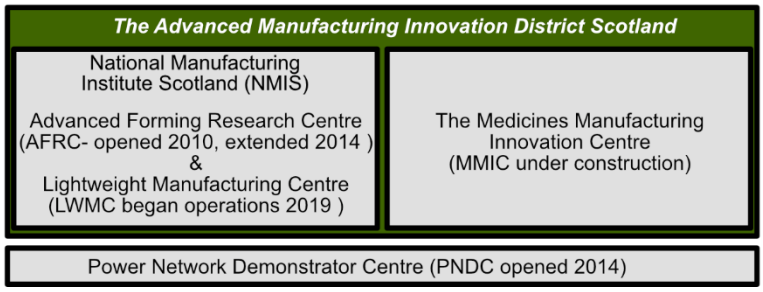
Figure 2: (a) University Strategic Research Themes and contributing departments.
(b) The Glasgow City Innovation District Research Clusters.
(c) Off-campus Innovation and research centres.



(b) Glasgow City Innovation District- University of Strathclyde Research Clusters.



(c) OFF- Campus Innovation Districts & Research Centres



Separate off-campus developments have included the opening of the PNDC and investments centred on future manufacturing through our partnering and management of the National Manufacturing Institute Scotland (NMIS, https://www.nmis.scot/). NMIS comprises the AFRC and the recent £7.25M Lightweight Manufacturing Centre (LWMC) and is a key component together with the Medicines Manufacturing Innovation Centre (MMIC, https://www.uk-cpi.com/about/national-centres/medicines-manufacturing-innovation-centre) in the AMIDS (https://www.gov.scot/policies/manufacturing/national-manufacturing-institute-for-scotland/).

Global Reach

Our global outreach has matured through international funding, links to global industry, and the introduction of the University's International Strategic Partnership (ISP) programme.

In 2013/14 our international footprint was focused mainly on Europe, but through the ISP initiative we have expanded our collaboration with leading European institutions and established new collaborative research programmes in North America and Asia (see Table 3). Stimulated by investment through the University and the Engineering Faculty, we are collaborating with 20 ISPs and have supported research workshops, reciprocal early career exchanges and 11 doctoral pairing partnerships. The doctoral pairing agreements support matched numbers of doctoral studentships with congruent ISPs. This £1.7m investment from the Faculty serves as a model for facilitating new international collaborations for our researchers, and will continue to expand through additional investment.

Internationalisation has also escalated through funded programmes (119 individual external awards since 2014) and our work with overseas partners has contributed to regional benefits including resilience in local energy provision (Gambia), improved sanitation and clean water resource (Malawi), EU compliant health and safety standards within ship dismantling yards (Turkey and Bangladesh) and support for improved health outcomes for people with disabilities through new low cost technologies (India and Columbia). Further testament to our increasing international reach is an increase from 42% (2014) to 63% (2020) in the number of journal outputs with international co-authors (source Scopus).

Table 3: List of ISP institutions with joint research programmes with this UOA

Asia	**Europe**	**North America**
• Hong Kong University of Science and Technology • Nanyang Technological University • Tsinghua University	• Aalto University • Chalmers University of Technology • Danish Technological University • Delft University of Technology • ETH Zurich • Katholieke Universiteit Leuven • Politecnico di Milano • RWTH Aachen • University College Dublin • Graz University of Technology • Comillas Pontifical University	• City University of New York • California Institute of Technology • Massachusetts Institute of Technology • New York University • Stanford University • Waterloo University • University of Southern California

2. People

Our values are to be: People-Oriented; Collaborative; Innovative; Ambitious; and, Bold. These establish our responsibilities in supporting staff, their career development, their aspirations, and their wellbeing and how we engage with stakeholders for the betterment of society. They promote an environment where researchers are able to develop, exercise leadership, receive recognition and gain reward. Our commitment to support and invest in our staff links to our strategy to translate our research and we appraise research, KE performance and potential in promotion and recruitment.

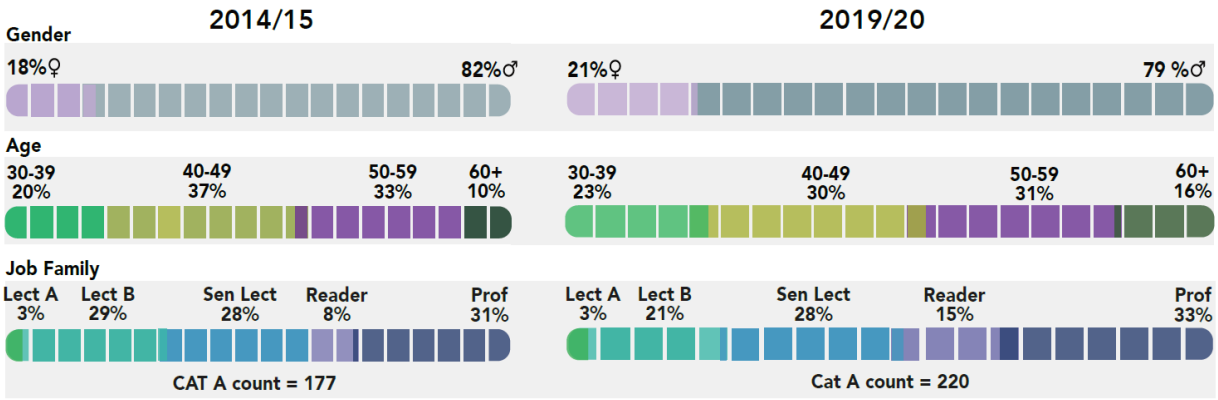
Our latest values survey reported that 90% of our colleagues consider our values reflect positively on their workplace experience.

2.1 Staff Demographics

Our staff growth since REF 2014 has been accompanied by change toward a more equitable and inclusive community and six Departments have achieved Bronze Athena Swan Awards with CEE gaining Silver in 2016. Through our staffing policy, we aim to achieve a balance between experience and skill whilst mitigating against risks from demographic shift, retirals and resignations.

Fifty-three percent of our academic workforce are below 50 and whilst our 60+ demographic has risen (10% to 16%) the net increase in staff below 40 (see middle row Figure 3) together with the observation that 58% of professors are aged under 60 (16% younger than 50) protects against future retiral choices.

Figure 3. Comparative demographic data for 2014/15 and 2019/2020 showing overall headcount, gender, grade and age of staff holding academic contracts within engineering.



On gender, the number and percentage of females in academic positions has risen from 32 (18% in 2014) to 45 (21% in 2020) (Figure 3) of which 15 (33%) hold Reader or Professorial appointments compared with six (3%) in 2014. On ethnicity, our BAME workforce rose from 32 (19% in 2014) to 46 (22% in 2020) with non-EU-BAME nationals making up half of this population.

Whilst our people strategy is centred on the creation of an inclusive and diverse community, we recognise our demographics reveal continuing equality gaps in gender, ethnicity and protected characteristics. Through merit and equal opportunity practices four female staff completed periods as Heads of Department during this REF period compared to one during REF2014. Similarly, the position of Vice Dean Research was held by Prof Shipton (2013-2016) before she succeeded as the second consecutive female Head of Department for CEE (2016-2020), both periods of significant research leadership and growth for the Faculty and Department. The increased influence and impact of our leading female staff is also reflected by the increase in the number of females holding senior appointments. We have implemented and strengthened policies to help minimise bias in short-listing, interviews and promotion processes. This includes unconscious bias training for staff engaged in recruitment and promotion and we practise inclusivity when constituting recruitment and promotion panels.

Recognition and promotion of achievement are important aspects of our environment and we conduct two promotion rounds annually. For academic promotions, performance in research, KE, teaching and citizenship are assessed against job descriptors, benchmarks and annual review.

During REF2021 we promoted 71 academic staff to Senior Lecturer, 25 to Reader and 14 to Chairs. In 2019, we introduced to our KE job-family the post of Professor of Practice to recognise staff who excel in delivering knowledge transfer, innovation and impact.

Over the REF period we employed 500 contract researchers with 254 currently employed (20% on open-contracts). In 2019/2020 our annual research staff turnover was 27% reflecting a trend for increasing employment security. For those whose contracts ended over the audit period 38 gained academic positions with us, 41 moved to open-ended KE posts and 9 transferred to open-ended teaching contracts. For those who did not secure extensions or new positions we provide a redeployment service. All research staff are reviewed annually, offered mentorship, considered for promotion and can access skills and career development through the Strathclyde Programme in Research and Leadership described in more detail in section 2.3. Contract researchers can also apply for pilot project funding provided by the Faculty but administered independently through the Researchers Group, the community's representative body to which all researchers are members.

In support of independent research careers, we hosted 31 post-doctoral researchers through Marie Skłodowska-Curie schemes and 28 Research Fellows via varied funders including UKRI, Leverhulme and Royal Academy of Engineering. Importantly, we honoured all cases where a lectureship was a condition of award.

The use of our innovative KE job family (as detailed in the Institutional Statement) has powered growth in our strategic engagements and collaboration centres. Over the REF period we have expanded our KE staff from 10 to 174 demonstrating the success, value and importance this community now contributes to the Unit's environment.

2.2 Recruitment

At the core of our staffing policy is a commitment to meet our long-term strategic objectives and ambitions for quality enhancement. Responsive recruitment is our standard recruitment tool and new academic posts are co-funded from Faculty for 3 years as a means to facilitate growth in keeping with Departmental needs and demographics. The number of positions filled through responsive recruitment varies yearly but the approval process is swift giving departments the ability to fine tune the skill set of its workforce in order to realise ambitions for excellence.

As described in the Institutional Statement, the Faculty also participates in the Chancellor's Fellowship Scheme (CFS) and the Global Talent Programme (GTP) to drive forward our research and innovation agenda.

The CFS calls are international searches in areas selected following consultation between Faculty, Departments, Research Cluster and Strategic Research Theme leads. The scheme provides a 5-year academic fellowship with protected time for research after which the Chancellor's Fellows (CFs) transfer to open-contracts. Through this scheme we have recruited 45 CFs who on appointment enter our Academic Career Development Framework which sets out to assist career progression and leadership. CFs gain access to targeted internal funding calls for PGR studentships, equipment support and impact acceleration funding.

Through the GTP, Departments are encouraged to scout for leading researchers who see benefit in relocating to Strathclyde. Across Engineering, fourteen notable leaders have been recruited through GTP posts since 2016 such as Prof Haas in the field of Li-Fi communications (EEE), Prof Wynne in manufacturing and materials (MAE) and Prof Reid in bioengineering and optoelectronic devices (BME) as examples.

In all cases new staff are supported through competitive remuneration and start-up packages commensurate with grade. New starts are allocated protected time for research and given priority in all internal funding calls including studentships, equipment and ISP exchange programmes. For professorial appointments start-up packages are negotiated at the outset and can include significant capital and/or staff investment.

2.3 Support for Career Development

It is our experience that inclusive and career long support through provision of resource and awareness of development opportunities accelerates productivity, collaboration and long-term performance.

The Faculty works closely with the University's Organisational and Staff Development Unit (OSDU) to shape the research development opportunities provided to new and established staff through the Strathclyde Programme in Research and Leadership (SPIRAL, see https://www.strath.ac.uk/hr/spiral/) and via mentoring. Importantly, the SPIRAL programme serves as an integral part of our commitment to the Concordat to Support the Career Development of Researchers as it integrates with our annual appraisal processes (Accountability and Development Review (ADR)) which places strong emphasis on research enhancement, KE, esteem and citizenship.

Induction of new staff is a dual process involving generic knowledge on the University workplace provided through Human Resources and comprehensive departmental induction designed to help staff integrate into our communities and systems of work. For established staff we offer access to Research Leadership training and external coaching if requested.

Linked to SPIRAL is our Academic Career Development Framework which supports early career academic staff set out a development plan and complete probation. For early career academics early engagement in our Supervisor Development Programme is necessary before approval to operate as a PGR first supervisor. This programme ensures staff are familiar with our Policy and Code of Practice for Postgraduate Research Study, and introduces them to tools and methods to support students through their research, thesis writing and examination. In 2020, engineering staff accounted for 500 event attendances with the greatest percentage increase in engagement occurring in early career academics (62%, +5%) and researchers (65%, +13%).

Furthermore, the Faculty in collaboration with RKES and OSDU run workshops on Fellowship and Research Funding, managing research projects and teams all tailored to Engineering to improve and facilitate staff progress as independent researchers. These workshops supplement specialist department and centre delivered development. In tandem with the University's ISP initiative the Faculty also support research networking opportunities for staff to participate in international research missions and will co-fund research exchanges that enhance research skills and international collaboration.

2.4 Research Students

All PGR students enrol in the Strathclyde Doctoral School (see Institutional Statement), and gain membership of the Doctoral Researchers Group (DRG). The DRG is a PGR association that promotes cross-Faculty events, peer-to-peer support frameworks and lobbies for the PGR community. It is also the representative body for the PGR community with membership to all governance and research committees. By listening to the student voice, we have improved Codes of Practice and PGR regulations, enhanced support and policies on funded leave entitlement, flexible working and paid-graduate teaching and training opportunities.

The Engineering PGR Cohort

The current pool of 635 PGR students (118 EngD and 517 PhD students) compares with 480 during 2014. PGR admission is devolved to Departments and follows competitive selection, and interview. Our PGR staff student ratio was 2.9 at the audit census date. 36% of our PGR students hold tier 4 visas and all PGR students must engage in annual PGR review and monitoring (detailed below).

Centres for Doctoral Training

Over the REF2021 assessment we have supported 370 full-time doctoral students through 12 UKRI engineering CDTs associated with this UOA (see Table 4). All CDTs have extensive connectivity with industrial partners, many co-funding studentships in-line with EPSRC's expectation for 20-40% of studentship costs to be from non-UKRI funding sources.

Table 4. UKRI Centres for Doctoral Training hosted in Engineering.

Centre name (end date)	**Department**	**Academic Partners**
Future Innovation in Non-Destructive Evaluation (end 2027)	EEE	Universities of Bristol (lead), Nottingham & Warwick
Wind and Marine Energy Systems and Structures (end 2027)	EEE (lead)	Universities of Edinburgh & Oxford
Industrial Doctoral Centre in Offshore Renewable Energy (end 2027)	NAOME	Universities of Edinburgh (lead) & Exeter
Future Ultrasonic Engineering (end 2027)	EEE	University of Glasgow (lead)
Medical Devices and Health Technologies (end 2022)	BME (lead)	None
Prosthetics & Orthotics (end 2027)	BME	Universities of Salford (lead), Imperial College, Southampton.
Advanced Manufacturing Industrial Doctorate Centre (end 2018)	DMEM (lead)	None
Industry Inspired Photonic Imagine, Sensing and Analysis (end 2027)	EEE	Universities of Heriot-Watt (lead), Glasgow, St Andrew's, Dundee
Optical Medical Imaging (end 2022)	EEE	University of Edinburgh (lead)
Future Power Networks and Smart Grids (end 2022)	EEE (lead)	Imperial College
NERC CDT in Oil & Gas (end 2021)	CEE	Herriot Watt University, plus 17 partners
Centre for Doctoral Training in Renewable Energy Marine Structures (end 2022)	NAOME	Cranfield (lead), Oxford

As detailed in the Institutional Statement, we introduced Strathclyde CDTs (SCDT) to seed fund our own cohort-based PhD training. The University has funded 32 SCDTs, and engineering is a partner in 24.

PGR Programmes in Engineering

University PGR studentships are managed through the Strathclyde Research Studentship Scheme (SRSS). This scheme pools Engineering's EPSRC DTP allocation with additional funding from the University, Faculty, Departments and external partners to fund upwards of 32 new PGRs per annum. Through co-funding this UOA has invested £24.3M in support of 125 SRSS studentships since 2014.

In addition to UKRI and University supported schemes (SCDTs and SRSS) the Faculty holds EPSRC iCASE awards with a host of industrial partners and an increasing number with the National Physical Laboratory. Internal funding schemes with industrial or international partners are also supported through our 'Engineering the Futures' studentship scheme and our ISP scheme mentioned in Section 1. Over the REF period the Faculty invested £7.1M in support of these schemes bringing our total internal financing of studentship support to £31M.

PGR Training and Skills Provision, Support and Monitoring

The PGR experience begins with an induction event hosted by the Strathclyde Doctoral School with Faculty support. Here we welcome students, provide details on development programmes and provide information on key infrastructure and service provision. In-depth induction is thereafter provided within host Departments and CDTs where PGR handbooks and Codes of Practice are introduced and detail the responsibilities associated with PGR study. Here we also set out health and safety training requirements, our dignity and respect expectations and the respective roles and responsibilities of supervisors.

Engineering accounts for 45% of the University's PGR population and as the largest provider of PGR training in the University we have been central in the development of both specialised and generic training based on Vitae domains (https://www.vitae.ac.uk/). Our success in CDTs has been instrumental in widening and enhancing PhD and EngD training and ensuring we have a vibrant and supportive environment that encourages original thinking, ambition and ethical enquiry. Through our CDT successes we have learned how to migrate the benefits that cohort training brings to PGR communities and we aim for all our PGRs to benefit from access to peer interactions and networking to build confidence in communications (academic, industry, public) and in seeking multidisciplinary collaboration, advice or specialist knowledge.

Investments arising from our CDTs has empowered successive cohorts to drive their own extended training activities towards Chartered Engineer status and because many CDTs and PhD programmes enjoy engagement with external academic and industry partners we can provide enhanced access to specialist summer school events and research placements within our researcher development pathway.

Student-driven and managed Professional Engineering Development or Training Societies are a key part of our environment and integrate communities of interest beyond supervisory groups. Through simple governance structures that support succession planning across study years we build sustainable cohorts who can request budgets for events and experiential visits that broaden training beyond core and elective provision. For example, several cohorts have self-organised external course provision on "Project Management in the Real World", enabling progression toward a Certified Associate in Project Management (CAPM). CDT and PhD cohorts also arrange regular research seminars where they can present advances or current projects to each other or invite external speakers supplementing our annual Faculty and Departmental seminar series.

Throughout the REF period, PGR students are encouraged to gain experience of running their own conference events supported by funding and mentoring from within Engineering. An example, is "futureWind&Marine" (https://www.futurewindandmarine.com/), a collaboration between students from Strathclyde, Oxford and Edinburgh that began in 2015 and annually attracts over 100 attendees. The students invite speakers, plan the conference to showcase their best work, secure industry sponsorship and set out the final programme in-keeping with EDI principles.

Our Professional Engineering Development and Training Societies also participate in outreach events and we encourage members to train as STEM Ambassadors. International secondment opportunities have grown over the REF period enabled by our ISP initiatives, increased success in EU networks and an expanded programme of research focused on the delivery of UN Sustainable Development Goals in low-income countries.

Doctoral Progress, Review and Assessment

All PGR students are allocated 2 supervisors and as a minimum all PGRs are required to complete a 60 credit Postgraduate Certificate in Researcher Professional Development (PGCert RPD, see Institutional Statement).

Supervisory teams and independent Departmental councillors/advisers serve as points of contact for students experiencing academic problems or requiring support via welfare, hardship or health services. This ensures that issues that cannot be resolved between the supervisor and student can be confidentially treated and action taken.

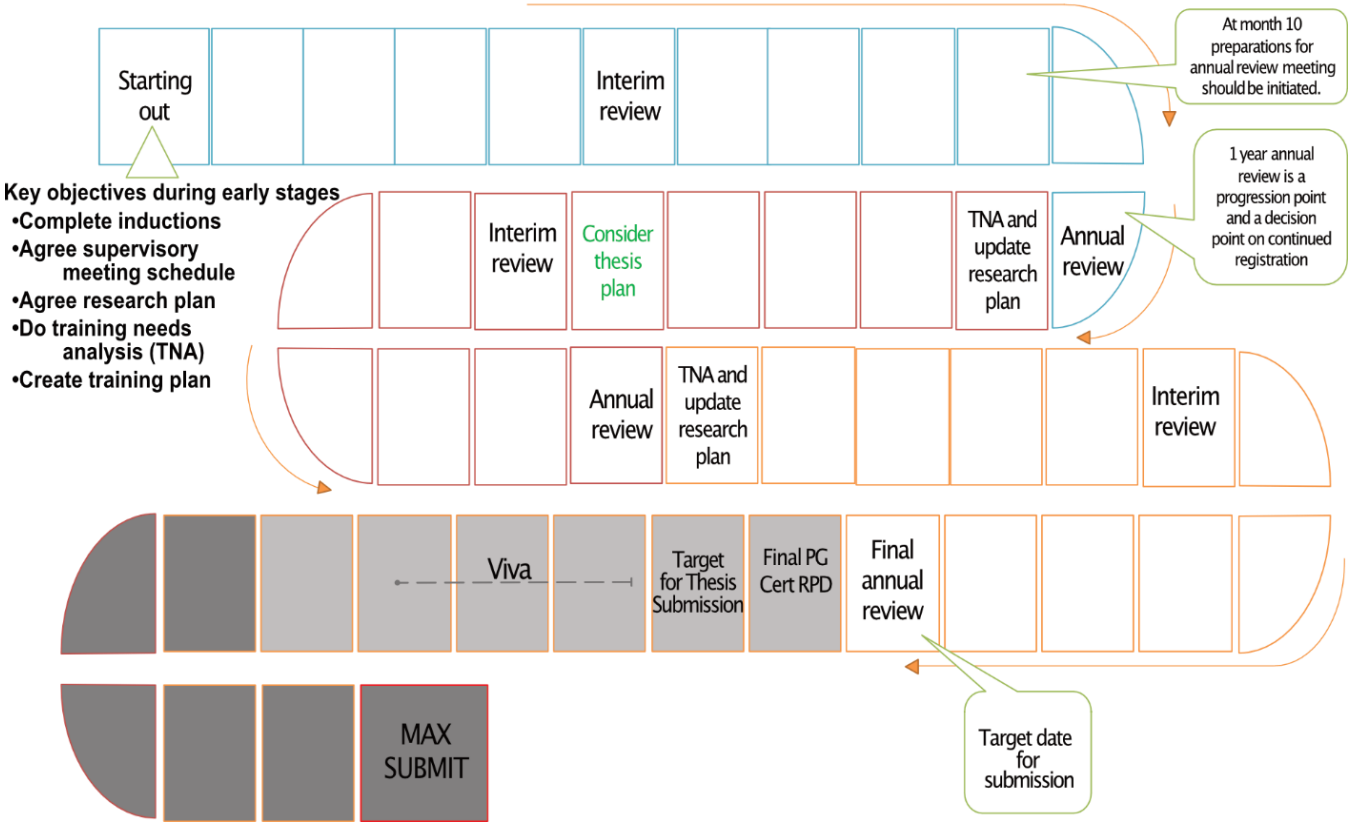
All PGRs participate in interim and formal annual assessments that monitor progress against a project plan and the PGCert RPD. Figure 4 outlines the typical PGR journey highlighting the key review and progress points. Annual reviews are independent of supervisors and a satisfactory first year review is required for progression. PGR students entered on 4-year doctoral programmes that follow a 1+3 year model (e.g. CDTs) have additional progression regulations associated with instructional and project work in year 1.

All PGR students are expected to publish and are supported to present to at least one international conference, participate in public engagement and KE events. Students also are encouraged to contribute to the annual Doctoral School Multidisciplinary Symposium. This symposium, organised by the DRG, is a University wide 3-day event for PGR students. It is a forum where students can present their research to a highly diverse peer group and so widen their local academic network and knowledge.

Quality of Supervision and Progression

The 2020 Postgraduate Research Experience Survey (PRES) reported an overall supervisor satisfaction score of 87% (60% response rate) for engineering. Questions on progression recorded 80% satisfaction and between 85% to 93% satisfaction in respect of supervisor expertise, provision of feedback, working environment and access to facilities and resources. PRES2020 benchmarking places Strathclyde in the top quartile of institutes participating in PRES.

Figure 4. The timeline and review cycle for standard doctoral programmes.



2.5 Equality and Diversity

We expect all our six departments holding Athena Swan Bronze Awards to progress to Silver at the earliest possible dates guided by the lead taken by CEE (Silver Award Holder) and our embedded Equality and Diversity Committees supported by the Faculty's Gender Equality Steering Group.

As a Faculty we are committed to achieving equality but recognise that gaps remain in relation to equality across protected characteristics. Our strategy to close these gaps extends from our obligations under the Equality Act 2010 through annual reporting and publication of monitoring reports to internally generated supplementary analyses that provide longitudinal monitoring that informs on actions to accelerate change. We recognise that training is critical to combat embedded behaviours and we provide introductory and refresher courses on diversity for all and inclusion training is mandatory for all staff engaged in people management, resource allocation, recruitment and assessment.

EDI is incorporated into PGR and ECR induction and our occupational health and wellbeing services are promoted to all. Within Engineering we have striven for inclusivity in membership or secondment to committees and candidature is encouraged from underrepresented groups where representation is considered weak. Strongly influencing our approach and helping to close equality gaps are the findings of two EPSRC Inclusion Matters awards. These are the STEM Equals project (£538K EP/S012133/1) led by Strathclyde (PI MacGregor) and the VisNET project (EP/S012079/1) led by the University of Glasgow with Strathclyde co-investigators (Mulvana, Renshaw). The STEM Equals projects build on initiatives to improve equality and diversity for female and LGBT+ academics across STEM areas and are generating recommendations on equality and diversity and best practice

sharing in STEM academia. (https://www.natureindex.com/news-blog/inclusion-time-covid-pandemic-how-to-seize-the-moment-for-change).

We also recognise the important role our senior staff can play in supporting others reach their potential irrespective of race, gender or disability. The increased influence and impact of our senior female staff is reflected by the increase (from 2013/14) in the number of women holding reader/professorial appointments and the increasing recruitment of female staff to early career academic positions (Section 1). Furthermore, in recognition of how inequalities affect people in the work place we implemented new agile working practises and support flexible working and leave whenever it can enhance work-life balance and wellbeing. We also operate a family friendly leave policy that provides protected time to undertake research for staff returning from parental leave, and Heads of Department have authority to approve sabbatical leave requests.

3. Income, infrastructure and facilities

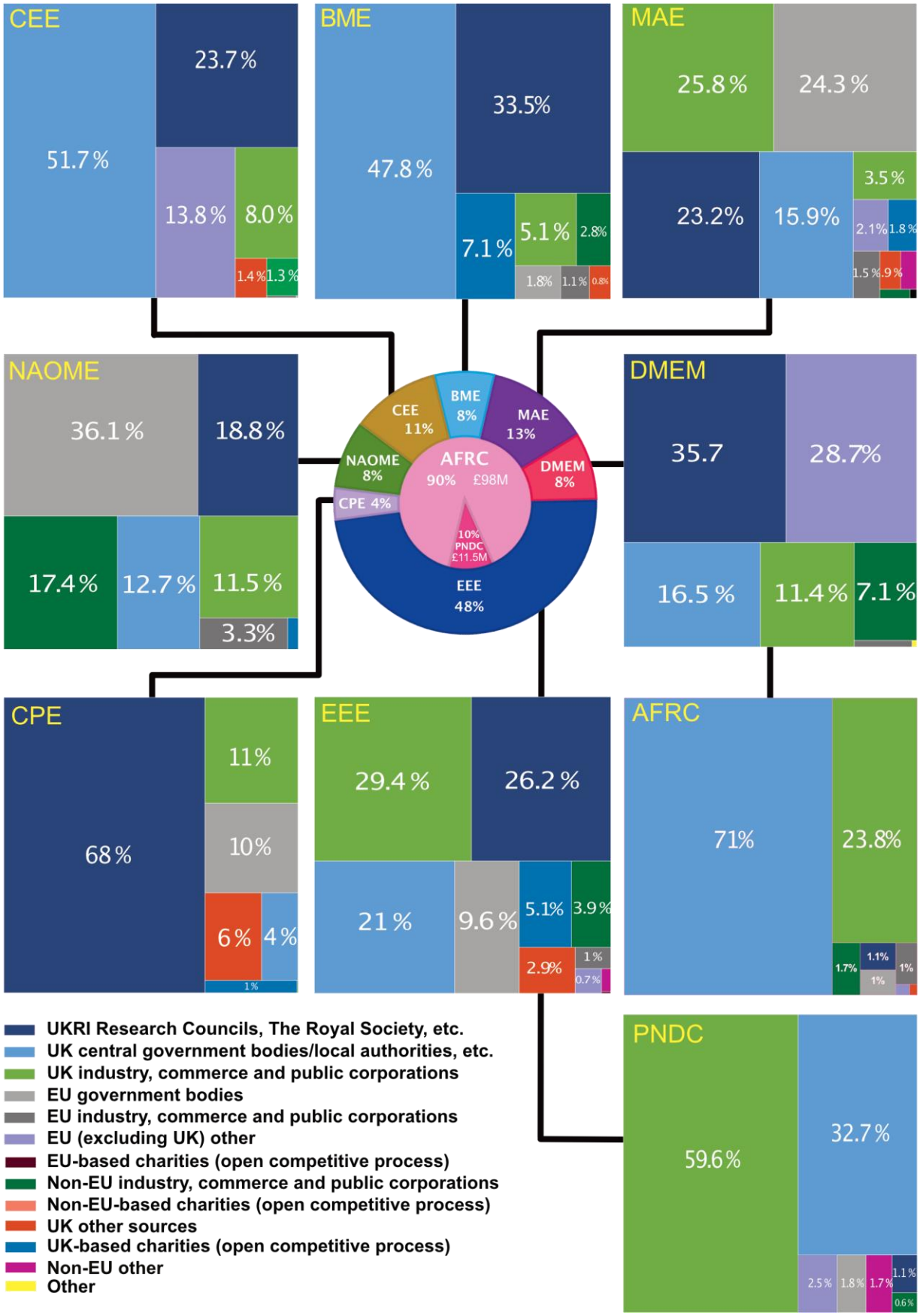
Our strategy has been to deliver research and its translation for economic and societal benefit as detailed in the Institutional Statement. Underpinning this is the ability to attract funding in a competitive landscape. This section details our growth over the REF period, and how our income, infrastructure and facilities have supported us and developed.

3.1 Externally Generated Research Income & Funding Diversity

The annual research income from the UOA rose from £29M in 2013/14 to £51M in 2019/20.

Evidence on the diversification of our income shows increases across all funding sectors over the REF period with the largest increases arising in UK government funding (up 174%), the industrial sector (up 52%), EU Government (up 22%) and UKRI (up 27%). Our diversified funding position is further evidenced by reference to Figure 5. In Figure 5 the funding landscape is summarised for each Department, the AFRC and PNDC. Funding to ANRC is incorporated into data for EEE due to its operating model. The central pie-chart illustrates income distribution (%) for each Department and centre over the REF2021 period (Figure 5). Linked to the central chart are normalised summaries for each Department's research income by source. The figure serves to illustrate that for each Department the research portfolios are of significant scale and that each portfolio features income from UKRI, public sources, UK and non-UK industry. Research funding for AFRC and PNDC, in keeping with their innovation focus, is attained mainly from industry and government bodies.

Figure 5. Research income summary showing the %income share for each department (central pie chart) and the relative size of funding by source within each department, AFRC and PNDC.



3.2 Strategic Funder Relations, Consortia and Industry Partnering

We are a Tier 1 Strategic Partner (top 20 EPSRC funded institutes) with the EPSRC, our largest UKRI funder, and on the REF2021 census date the EPSRC 'Grants on the Web' site reported there were 31 active Engineering research awards (value = £56M, excluding centrally held institutional awards) under our administration and £13M of collaborative awards as partners to others.

We are key partners in a range of academic and industrial research consortia, an important aspect of our collaborative ethos, including:

- Leadership of the £10M UKRI Energy Revolution Research Consortium (EP/S031863/1, EP/S031901/1, EP/S031898/1, EP3188X/1) within the ISCF *Prospering from the Energy Revolution* programme.
- Our capability to build upon long standing industry partnerships, with two EPSRC Prosperity Partnership awards in collaboration with Babcock International, Bruce Power, Doosan Babcock, EDF, BAM, Kinectrics, Weir, EGS Energy, GEO Dynamics and Silixa Ltd.
- Leadership of the EPSRC Programme Grant "Laser Imaging of Turbine Engine Combustion Species" (LITECS, EP/T012595/1), a £5.8M collaboration with Edinburgh, Loughborough, Manchester, Sheffield and Southampton Universities with industry involvement from M^2 Lasers, Siemens, Rolls Royce, and others.
- Our technical leadership of the £2.1M BEIS Energy Innovation Programme (Automated Welding Equipment System Inspection and Monitoring), a consortium with Peak NDT, Cavendish Nuclear and the Nuclear Advanced Manufacturing Research Centre (University of Sheffield).

Aligning with our industry engagement and industry-centre models, our EPSRC Impact Acceleration Award (IAA) allocation (2012 to 2022) remains an important support for pathways to impact generation. During REF2021, £3.5M of IAA funding has been invested in support of EPSRC project related impact generation within this UOA. Figure 6 illustrates how both EPSRC funding and support for impact generation has flowed through our primary strategic themes.

We have demonstrated success in supporting knowledge transfer for SMEs through the Innovate UK KTP scheme with 52 awards funded over the REF2021 cycle (15 active at the REF census date) contributing income of £6.1M.

We have been lead/partners in multiple FP7 and H2020 awards. At the beginning of REF2021 we were partners in 15 FP7 awards, generating a total income over the REF period of £10M. However, through H2020 with its greater focus on innovation we have seen our total cumulative H2020 income grow to £12.7M with 58 awards still to complete (total award value £36M). Examples of H2020 awards with consortia of different size and sectors are listed in Table 5.

Additionally, we have a large set of long-term and high-value, impactful, industry partnerships which are described throughout Section 3.5.

Figure 6. Alignment of IAA funding in support of EPSRC grant awards aligned to the 5 strategic themes areas attracting the greatest number and value of EPSRC support. The cumulative level of external co-funding is included in this figure.

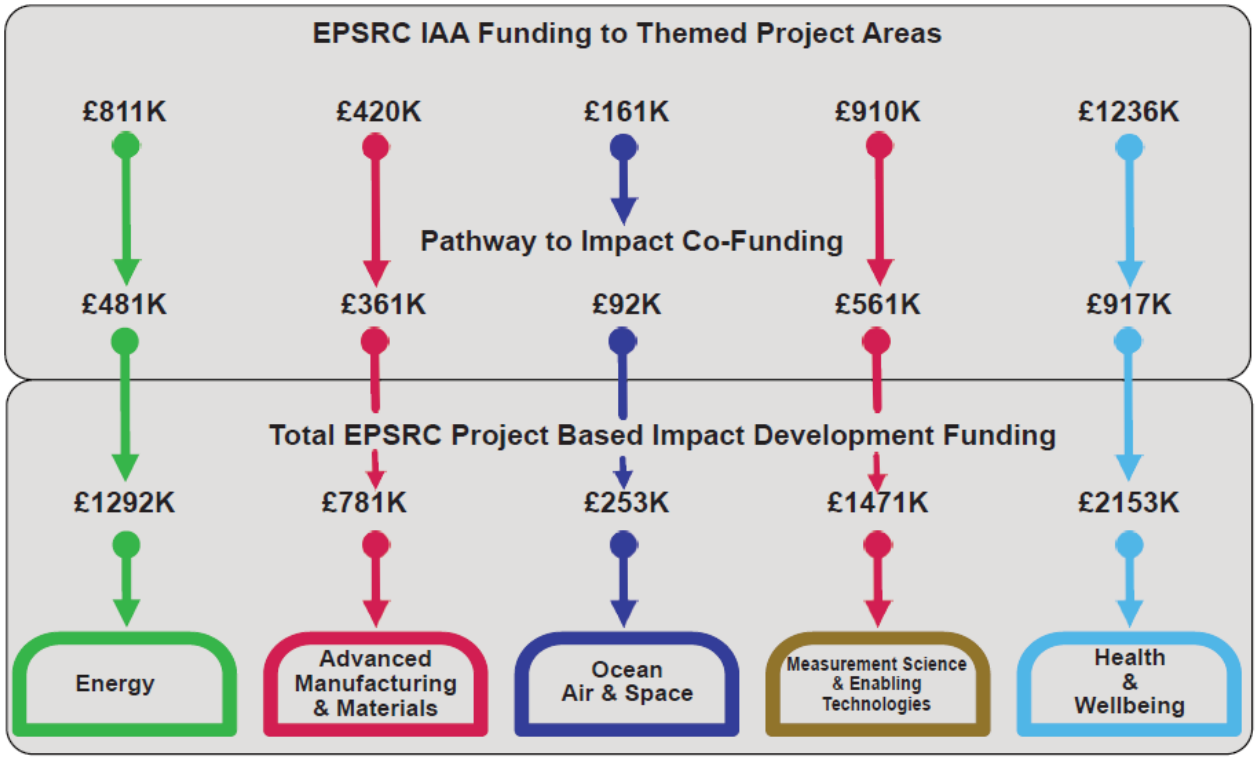


Table 5: Example H2020 consortia projects and award values.

Project Name	Coordinator	Consortia Partners	Overall Budget /**Strathclyde Award** (€)
SENSIBLE	Strathclyde	6	€859,500/**€301,500**
UTOPIAE	Strathclyde	10	€3,876,853/**€546,575**
SHIPLYS	The Welding Institute, UK	11	€6,144,150/**€814, 491**
FAST-SMART	Strathclyde	12	€ 6,945,201/**€1,105,916**
STARDUST-R	Strathclyde	13	€ 3,867,284/**€606,345**
ERIGrid	Austrian Inst. of Technology	19	€9,999,987/**€749,366**
ERIGrid 2.0	Austrian Inst. of Technology	20	€9,999,988/**€601,717**
AUTOSHIP	Ciao Tech, Italy	11	€29,546,161/**€894,093**
IoF2020	Stichting Wageningen (NL)	79	€34,277,154/**€547232**
PROMOTION	DNV-GL, Norway	37	€42,691,662/**(€740,100)**

3.3 Internal Funding Support for Research.

Our goal is to support our research by constantly reinvesting funds for growth and impact. During the REF2021 period we distributed over £10M of overhead income for use in supporting research activity. In the majority of Departments up to 50% of this income is distributed to the centres and research accounts of investigators generating the overhead. This allows for local independent

investment in support of equipment procurement, studentships, contract bridging for key researchers and other scholarly research activities not recoverable from other accounts.

In addition, this UOA utilised £4.74M of general funds for contract bridging for research staff, activities in support of bid development and in support of start-up funding packages for new staff.

We have also invested £4.4M in support of peer reviewed equipment awards from EPSRC with Faculty and Departments contributing a further £2.5M. The Faculty and Departments also support co-investment in core equipment calls from UKRI and for equipment in support of early career researchers. Via these routes we have been awarded additional sums of £520K over the past 3 years with co-investment equating to a further 30%.

3.4 Research Collaborations

In Section 1, we highlighted our global engagement through our ISPs and in Section 2 we highlighted the success that collaboration in externally funded CDTs (Table 4) has provided. As additional examples of our engagement in collaborative research the following are noteworthy.

Scottish Research Pooling Partnerships and Research Innovation Centres.

We leverage Research Innovation Scotland (https://www.research-innovation-scotland.co.uk/) through partnerships and providing leadership. Within this, the Scottish Research Partnership in Engineering (SRPe, https://www.srpe.ac.uk/about-srpe) and the Energy Technology Partnership (ETP, https://www.etp-scotland.ac.uk) are national initiatives chaired by this Unit. SRPe supports collaborations and networking between Scotland's engineering schools and sustains forums in Advanced Manufacturing, Infrastructure & Environment, Engineering for Healthcare, and Robotics & Autonomous Systems. ETP is focused on delivering research excellence in energy and both support awards for engagement in European research consortia, early career international exchanges (four to this UOA from SRPe since launch) and industrial doctoral studentships (15 to this UOA, total value £1.3M with £530K in-kind industry support).

Through CENSIS our researchers have led projects in cancer diagnostics, agri-tech, rural 5G, water and waste management, high performance component manufacturing and non-destructive testing in challenging environments. Additional SFC Research Innovation Centres where funding has benefited this UOA include the Digital Health & Care Innovation Centre, The DataLab and the IBiolC. This UOA also serves on the board of AMIDS and GCID (see section 1) and the UK-wide Offshore Renewal Energy and High Value Manufacturing Catapults.

3.5 Research infrastructure and facilities.

As stated in Section 1, our research is conducted in groups distributed across seven academic Departments and three large-scale Industry–University Strategic Research Centres. These are now described, and their infrastructure, facilities, operation and achievements summarised.

3.5.1 Strategic Research Centres

As outlined in the Institutional Statement, Strategic Research Centres drive industrial collaboration, research income growth, and place-based, national and international impact. These operate on a tiered membership model and offer the ability for partners to collaborate on joint areas of interest while leveraging their investment. Three of these are led by Engineering.

The **Advanced Forming Research Centre (AFRC)** is one of the seven HVM Catapult Centres with key technical capability in forming and forging, digital manufacturing, machining, additive manufacture, net shape and resource efficient manufacture, and characterisation of materials under manufacturing conditions. As a part of the HVM Catapult, it operates on a semi-autonomous basis from the main university campus. It employs 192 staff. 11 operate as AFRC PIs together with 110 staff on research/KE contracts. The funding to the centre is significant (£98M, see Figure 5) and together with the Lightweight Manufacturing Centre is a key component in NMIS and AMIDS.

AFRC is a state-of-the-art facility with specialist laboratory spaces and industrial scale workshops. At the conclusion of REF2021 the centre had begun an expansion to house the £20m FutureForge facility, a unique physical environment for the development and digitalisation of hot forging. The centre has a broad range of production scale manufacturing equipment including forging presses, superplastic forming presses (understood to be the largest and most capable university setup in the world), and exclusive friction welding equipment. The centre also boasts general purpose manufacturing equipment related to machining and additive manufacture. It houses well equipped laboratories to support materials characterisation during manufacture, metrology, metallurgical investigation, and residual stress measurement. These complement University campus capabilities in material testing and analysis in the Advanced Materials Research Laboratory (AMRL).

Intellectual property is managed by the centre and over the REF period 218 items of foreground IP were registered, of which 173 are owned by the University of Strathclyde. Five licence agreements are progressing and two potential spin out companies are being evaluated.

Key partnerships include all HVM Catapult Centres and founding members Boeing, Rolls-Royce, and Timet along with over 50 other industrial partners. There are additional collaborations on single projects with UK and non-UK SMEs and industrial companies contributing £35M of additional revenue to the University.

The **Power Networks Demonstration Centre (PNDC)** is a research, development and test facility established in collaboration with industry and government to accelerate innovation towards commercialisation and deployment. The centre has unique technical capabilities in electrical power and grid systems from a UK and EU perspective, enabling academia and industry to work collaboratively in innovation projects and demonstrate at scale new products and services.

It employs over 30 full-time staff and has delivered a portfolio of £11.5M over the REF period.

The PNDC is a state-of-the-art facility with a fully operational 11kV and LV electrical network, which provides a flexible arrangement of the equipment required to represent typical rural, urban and suburban networks. The network can be supplied directly from the grid or through a 5 MVA motor-generator set to allow both voltage and frequency disturbances to be applied. It provides a unique physical environment for development, testing and demonstration of innovative products and systems for smart grids. These can be demonstrated and tested in multiple operational scenarios which can include network transients and network faults. The PNDC also houses laboratories to support real-time simulation, which can be coupled with the network for hybrid real and simulation experiments, and with equipment for the testing of power electronics products.

As part of a recent £7M investment from the ISCF Driving the Electric Revolution (DER) Challenge, PNDC is enhancing its capabilities to include MW scale equipment for testing rotating machines and to scale power electronic converters to consolidate and grow propulsion and powertrain manufacturing.

Key partners include Distribution Network Operators (SPEN, SSEN, UKPN) along with Fundamentals, Arqiva, Belcan, Bellrock Technology, Trilliant, Wallet Services, and SSE Enterprise. There are additional collaborations on single projects with UK and non-UK SMEs and other companies.

The **Advanced Nuclear Research Centre (ANRC)** was established in 2015 to direct research that supports infrastructure, management and longevity of nuclear installations. The centre is located on-campus and while led from EEE draws multidisciplinary support from across the University. During the last 5 years ANRC has secured a portfolio of £19.7M and supports work with multiple partners including Bruce Power, Babcock International, Doosan Babcock, EDF and Kinectrics.

3.5.2 Academic Departments

The seven academic departments that contribute to this Unit are now described in greater detail to present the quality of the environment and their delivery against our strategy.

Department of Electronic and Electrical Engineering (EEE)

EEE coordinates its research through two institutes: The Institute for Sensors, Signals and Communications (ISSC) and The Institute for Energy and Environment (InstEE) (see Table 6a). The Institute for Energy and Environment provides leadership for the ANRC and PNDC (section 3.5.1). The research achievements of InstEE, PNDC, ANRC, and their wider collaboration was recognised through a Queen's Anniversary Prize in 2019.

The Department has 9 industry linked chairs and lectureships, and has spun out several successful companies.

Table 6a- EEE Research Institutes, their Research Units, Centres and CAT A FTEs.

Electronic and Electrical Engineering (CAT A FTE = 72.9)		**CAT A (FTEs)**
	Academic Research Unit/Group	
Institute for Sensors, Signals and Communications	Centre for Signals and Image Processing	6.8
	Centre for Ultrasonic Engineering	10
	Centre for Microsystems and Photonics	4.3
	Centre for Intelligent Dynamic Communications	10.8
Institute for Energy and Environment	Advanced Electrical Systems and Power Systems	20
	High Voltage Technologies & Electrical Plant Diagnostics	6.6
	Power Electronics, Drives & Energy Conversion	6.2
	Wind Energy & Control	6.7
Centres	Power Networks Demonstration Centre	
	Advanced Nuclear Research Centre	

Each Institute comprises Academic Research Units (Table 6a) and industry partnership centres (Table 6b). Significant autonomy is delegated to the leadership of both institutes to allow directed and flexible investment toward research priorities, opportunities and targets. An advisory board, chaired by the Head of Department and comprising the leadership of Institutes and Academic

Research Units, define research priorities for the Department which are implemented through an Executive Team and a Research Operations Working Group chaired by the Director of Research.

Table 6b- Listing of EEE Institute hosted Industry Partnership Centres.

Institutes within EEE	**Industry Partnership Centres**
Institute for Sensors, Signals and Communications	DSTL Battlespace Centre
	Hyperspectral Imaging Centre
	FIRST Lab (Structural Test)
	Research Centre for Non-Destructive Evaluation
	Centre for White Space Wireless Comms
	LiFi Research and Development Centre
	Scotland 5G Centre
	Applied Space Technology Laboratory
Institute for Energy and Environment	Rolls-Royce UTC in Electrical Power Systems
	Low Carbon Power and Energy Innovation Programme
	DER (Driving the Electric Revolution) Centre Scotland
	Robertson Trust Laboratory of Electronic Sterilisation
	OREC Electrical Infrastructure Academic Hub
	NPL Partnership in Power Networks Metrology
	Power Networks Demonstration Centre
	Advanced Nuclear Research Centre
	Energy Technology Partnership
	Hydrogen Accelerator (H2A)

The **Centre for Signal and Image Processing** undertakes research focused on fundamental signal and image processing theory, algorithms, systems and techniques. It has 40 researchers and its research is translated to industrial impact with organisations including Clyde Space, Sellafield, Leonardo and Dstl. The application areas include agritech, biomedical, communications, defence, food and drink, nuclear, and space.

Major income streams arise from nuclear decommissioning with Sellafield, and the EPSRC/DSTL collaborations in signal processing phases II (EP/K014307/1 and EP/K014307/2, £5.8m) and III (EP/S000631/1, £4.1m). The group are highly collaborative with joint grants with Physics (£719k) and Chemistry (BB/P026494/1, £145k) on electro-optical imaging, and CPE in pharmaceutical manufacturing research (EP/K014250/1, £2.4m). In 2019 Leonardo endowed a lectureship and sponsored a laboratory in Neuromorphic signal processing.

The centre partners in the collaborative EPSRC CDT in industry-inspired photonic imaging, sensing and analysis (EP/S022821/1).

The **Centre of Ultrasonic Engineering** (CUE) undertakes research in Non-Destructive Evaluation (NDE), robotics, automation and autonomous systems, bioacoustics, and sensor technology covering diverse ultrasonic application areas (Energy, Oil & Gas, Nuclear, Aerospace, Health, Consumer Products, Defence, Petrochemical, Pharmaceutical, Remanufacturing).

CUE operates well-funded laboratories and manages a group of 65+ staff and researchers. Both research and technology transfer is supported through The Facility for Innovation and Research in Structural Testing Laboratory which includes 5 industrial 6-axis robotic systems, 2 training robotic

systems, automated welding (MIG & TIG) process capability, large scale optical metrology tracking equipment and multiple advanced phased array controller systems. The Robotically Enabled Sensing Laboratory, having gained investment of £2.6M from the University, will support ongoing projects with Spirit Aerospace, Babcock International and KUKA and be a flagship facility for robotic inspection.

Participating in 3 EPSRC CDTs (EP/S023879/1, £6M; EP/S023275/1, £4.2m; EP/L015587/1, £3M) and large collaborative grants encompassing sensing, automation and NDE (EP/R004889/1, £2.16M; EP/N018427/1, £2M; EP/R027218, £5.9M; EP/L0221125/1, £5.4M; EU ref 730323, €9.8M), CUE has significant reach to industry (>80) and academic (>30) partners. In addition to a RAEng Chair (Pierce, RCSRF1920\10\32, £600k), members of CUE have been awarded an ERC consolidator award (Windmill, EU ref 615030, €2M) and a Leverhulme Fellowship (Reid, ECF-2019-185, £386k) in recent years.

The **Centre for Microsystems and Photonics** (CMP) has 20 PIs and researchers with internationally-recognised expertise in tunable diode laser spectroscopy. This has led to the development of calibration-free gas measurement techniques for use in harsh environments, in turn leading to longstanding collaborative research with companies such as Rolls-Royce, Siemens, Shell, LG and Government research bodies. CMP's research infrastructure includes: an optical gas-sensing laboratory housing unique instrumentation for high temperature spectral analysis of gas species; a microfabrication facility for lab-on-a-chip/microfluidics devices with applications in healthcare and fundamental biology; four class 4 laser laboratories for MEMS based biomedical imaging research, optical MEMS devices for quantum optics applications and general photoacoustic imaging/sensing. CMP operates a cleanroom with equipment for metrology of micro- and nano-systems and state-of-the-art resin-based 3D-printers for prototyping micro-scale components.

Direct industry funding comes from multi-nationals (e.g. Rolls Royce, Shell, Siemens), SMEs (AMS Bio, Orthosensor Inc, Gooch and Housego) and research institutes (Fraunhofer Centre for Applied Photonics). Recent significant awards include an EPSRC Programme Grant for monitoring aero-engine emissions (EP/T012595/1, £5.8M), an award supplemented by a £1m contribution from industry; a 5-year £567k RAEng Engineering for Development Research Fellowship (Bauer, RF1516\15\8) for developing miniaturised biomedical imaging systems; and a £1.17M EPSRC grant (EP/T014288/1) in collaboration with the Institute of Photonics and industry partners to research a manufacturable platform for precision photonics.

The **Centre for Intelligent Dynamic Communications** (CIDCOM) has more than 30 active research staff executing internationally leading innovation and KE in mobile/wireless communications services/applications, design of broadband networks, Software Defined Radio, cyber-security, IoT and optical communications. It includes the LiFi Development and Research Centre (> £1M of equipment investment), which itself has received more than £8.6M in funding since its inception in 2013 (EPSRC Personal Fellowships, (EP/K008757/1 and EP/R007101/1, £3M); EPSRC Programme Grants TOWS (EP/S016570/1, £2.3M) and TOUCAN (EP/L020009/1, £1.4M); Airbus, Germany (£450k); SLD Laser (£200k); H2020, 5G-CLARITY (871428), £450k; H2020, ITN, ENLIGHTEM (814215), £500k).

The SDR team was the principal academic partner on a national 5G test-beds project co-funded by industry and the Department for Digital, Culture, Media and Sport (£25M), co-developing next generation wireless services with 30 partners including SMEs, the BBC, BT and multinationals including Microsoft. With an established record of advancing the evolution of next generation wireless came the hosting of the 'Scotland 5G Centre' (£5.3M, Scottish Government) to deploy a R&D testbeds to stimulate the development of low-cost rural connectivity, broadcasting and remote management for the energy/health/manufacturing sectors.

CIDCOM has expertise in data engineering and analytics. It leads the EPSRC-funded "Future ICT-enabled Manufacturing" project (EP/K014250/1, £2.4M) optimising continuous manufacture of pharmaceuticals and is partner in EU funded projects developing precision agriculture to optimise production efficiency (IoF2020 €30M, CYBELE €14.3M).

The **Power Electronics, Drives and Energy Conversion (**PEDEC) comprises six PIs supported by 9 PDRAs and 25 PGR students. PEDEC focuses on research and development on all aspects of power conversion from individual power modules through to specialised hardware/software control platforms. The group specialises in providing viable solutions to evolving power electronics and drives future applications from research to design, simulation, prototyping, pre-production, and field testing. The research is supported by wide-range environmental testing (77K to 773K) capabilities, extensive and well-resourced power systems and real-time hardware-in-the-loop laboratory facilities. There is active engagement with leading industry-scale R&D facilities such as the UK National HVDC Centre and PNDC. The group enjoy extensive academic and industrial partnerships within the UK and abroad and over the REF period achieved grant income of £4.5M of which 45% was from industry.

The **High Voltage Technologies & Electrical Plant Diagnostics** (HVT) group has 7 academics, 2 PDRAs and 26 researchers contributing fundamental research associated with electrical plant, high voltage materials and components, pulsed power technologies, condition monitoring, discharges in gases and fluids, and non-thermal plasma for environmental and bio-medical applications. Its facilities including the David Tedford High Voltage Laboratory, screened High Voltage/Pulsed Power/Plasma technology laboratories, a High Voltage & Power Modulator Laboratory, and a Plasma Laboratory. Infrastructure includes HV Pulsed Power generators with output voltage up to 0.5 MV, a computerised 300 kV Marx generator, 100 kV HV DC and 100 kV 50Hz HV AC systems, partial discharge testing facilities, specialised insulation diagnostic equipment and a UHF sensor calibration chamber. The Robertson Trust Laboratory for Electronic Sterilisation Technologies (ROLEST) is a unique combined containment level 2 biohazard and high voltage engineering laboratory enabling interdisciplinary research focused on the novel electrical and optical sterilisation and decontamination technologies for clinical and public health applications.

HVT research income over the REF period exceeds £900K, with notable international funding to ROLEST from the Food and Drugs Administration (USA) and industrial support from corporations including Halliburton for Plasma Drilling, Vascutek for work on novel sterilization applications, and PEA in Thailand for condition monitoring. The total KE income from industrial sources exceeds £300K and includes international activities undertaken for CLP (Hong Kong).

Commercialisation activity has led to four successful companies in recent years and licencing agreements enacted over the REF period have generated royalty income >£650K.

The **Wind Energy & Control** group has 8 academics, 7 PDRAs and 52 PGRs. It is the UK's largest group of wind energy researchers. Expertise covers turbine design and concepts, aerodynamics, modelling and control of wind turbines and wind farms, operations and maintenance, condition monitoring, powertrain and grid integration and forecasting. Powertrain research infrastructure includes a 15kW wind turbine and 100kW gearbox test rigs. EPSRC research funding includes EP/L014106/1 (Supergen Wind Hub, £2.9M), EP/R007756/1 (Modelling, Optimisation and Design of Conversion for Offshore Renewable Energy, £809K) and EP/S018034/1 (Future Electrical Machines Manufacturing Hub, led by Sheffield, £10.5M) together with an EPSRC Fellowship to Browell (EP/R023484/1, System-wide Probabilistic Energy Forecasting).

EPSRC funded doctoral training was established in 2009 and the centre's collaborative Wind and Marine Energy Systems and Structures CDT (EP/S023801/1) is funded through to 2027. This CDT enjoys industrial support from 34 industrial partners. In addition, the group engaged in eight H2020/FP7 awards during REF2021.

The **Advanced Electrical Systems** group (AES) has 18 academics, 26 PDRAs and 50 PGRs. The groups research relates to power systems, smart grid technologies, electricity markets and regulation, AI applications, power and propulsion systems, and superconductivity. It also tackles challenge-led research across energy, aerospace, nuclear, marine, oil and gas, and transport sectors.

A number of internationally recognised laboratory infrastructures are operated. The Dynamic Power Systems Laboratory provides a 100 kVA microgrid set integrated with real-time digital simulation to conduct hardware-in-the-loop experimental evaluations for PGRs, industry and international research teams. The Applied Superconductivity Laboratory supports the investigation of state-of-the-art superconductor materials for use in transportation electrification, power networks and medical applications. The cryogenic testing facilities support cable and magnet applications, and an innovative 20 kW rotational cryogenic machine testing-rig for aviation propulsion applications. Similarly, the group manages an Aero Electrical Systems Laboratory and an Advanced Sensors Laboratory, supporting patented DC protection solutions and power systems metrology respectively. An extensive array of modelling platforms complements the laboratories.

AES leads national, international and industry collaborations. Leadership of the EPSRC CDT in Smart Grids and Future Power Networks (EP/L015471/1) and UKERC (co-director, Bell) have contributed to the UK's energy transition. Multiple FP7 and H2020 programmes (e.g. ERIGRID), have sustained successful relationships with leading European centres. The AES group's balancing of academic leadership and industry impact in support of the energy transition is further exemplified by leadership of the £10M Energy Revolution Research Consortium (EP/S031863/1, EP/S031901/1, EP/S031898/1, EP3188X/1) and leadership of the ISCF Driving the Electric Revolution (DER) Scotland Centre (£7M). Similar success is exemplified by an EPSRC Prosperity Partnership (EP/R004889/1) and a UKRI Future Leaders Fellowship (Papadopoulos).

Department of Civil and Environmental Engineering (CEE)

CEE is organised into 3 groups with flexible membership (Table 6c) aligned to the themes of Energy, Advanced Manufacturing and Materials, Health and Enabling Technologies. Supported by contributions from an industrial advisory board and visiting professoriate, the Department's research priorities are reviewed, updated and fed into the Department's annual plan.

Table 6c- CEE Research groups.	
Total CAT A FTE = 30.5	CAT A (FTEs)
Ground Engineering & Energy Geosciences	13
Water, Environment, Sustainability & Public Health	10.5
Intelligent Infrastructure	7

The **Centre for Ground Engineering and Energy Geosciences** comprises 13 PIs supported by 13 PDRAs and 28 PGRs and is the research base of a Royal Academy of Engineering Chair to Prof Lunn MBE. It specializes in research at the boundaries between biology, earth sciences and engineering. The Centre leads on major multi-partner EPSRC and European Commission Research Projects. Key research areas, in partnership with industry, include: development of biomineral technologies for ground improvement; the fundamental behaviour of geomaterials; monitoring and

restoration of flood embankments; nuclear decommissioning; the role of faults in hydrocarbon production and CO_2 storage; well design and integrity; and the use of microseismic monitoring methods for detection of subsurface flow paths. The group maintain a geomechanical laboratory and in partnership with the Water, Environment, Sustainability & Public Health group operate the Department's microbiology laboratory and environmental chemistry laboratories (see section below for more details). In addition, funding from the Oil and Gas Innovation Centre facilitated purchase of a Nikon XT H 225 LC X-ray computed tomography system. This £850k device is located in the AMRL (see MAE) and is fitted with a Deben CT 10kN load cell and environmental chamber providing unique capability to heat, cool and compress samples under CT imaging. The group are instrumental in two EPSRC Prosperity Partnership Awards: EP/R004889/1 Delivering Enhanced Through-Life Nuclear Asset Management (£2.2M, partners – BAM, Babcock, EDF, Bruce Power, Kinectrics, Weir) and EP/S005560/1 Smart Pumping for Subsurface Engineering (CEE led, £2.5M, partners- EGS Energy, GEODynamics, Silixa, Weir) and are engaged in large nuclear decommissioning EPSRC consortia led from the University of Leeds (EP/S01019X/1 and EP/L014041/1).

The **Centre for Water, Environment, Sustainability and Public Health (WESP)** supports the work of 11 principal investigators, 6 postdoctoral fellows and 43 PGR students. The centre is known for its work in environmental engineering to improve public health and plays a major role in advising government strategy in Malawi. The group undertake research in air quality, land decontamination, antimicrobial resistance, atmospheric micro-plastics, pathogen detection in sewage outflow, wastewater treatment, flood prevention/recovery, bacteria/biofilm-pollutant interactions, pollutant control and in research into biotechnologies for cement manufacture. Local research in WESP is supported by CEE's 460m^2 £6M state-of-the-art environmental and analytical laboratories. The facility includes a category-2 microbiology and genomics laboratory, multi-purpose environmental chemistry and analytics laboratories equipped with; full Gas Chromatography, Optical Emission Spectroscopy, High Pressure Liquid Chromatography, Ion Chromatography and nano-analysis. A GCxGC-TOFMS time-of-flight mass spectrometer enables research in environmental forensics giving world-leading capability for the identification of compositional influences on biofuel performance and biologically toxic compounds in contaminated lands. Significant funding from the Scottish Government supports work on water resources in Malawi (£7M) and members are embedded in Malawi in collaboration with the Government of Malawi Ministries and Universities. The group participate in the NERC Oil and Gas CDT led by Heriot-Watt University and have multiple international and industrial partnerships.

The **Centre for Intelligent Infrastructure** is supported by 7 PIs, 5 postdoctoral researchers and 33 PGR students. Its facilities have been formed to support work in the areas of Intelligent Infrastructure, Advanced Materials and Risk & Resilience directed toward the development of resilient infrastructure threatened through climate change and mitigation of seismic hazard risk to the energy assets (nuclear, oil and gas). Specialist facilities include a robotics and 3D printing lab for automated deployment of curable self-sensing materials and for sensor integration into construction components, a corrosion lab including environmental chamber, a cross-disciplinary advanced vibration lab, and atomic force microscopy. The Centre won in excess of £2.5M during the REF period and is a partner in the EPSRC £4.9M DISTINCTIVE consortium (EP/L014041/1) and the prosperity partnerships mentioned under **Centre for Centre for Ground Engineering and Energy Geosciences.** Additional key collaborators include NASA Langley, Lloyd's Register and multiple nuclear, construction and transport agencies.

Department of Chemical & Process Engineering (CPE)

CPE's research is structured in alignment with the University Strategic Research Themes, as shown in Table 6d. Annual research planning is directed toward the growth of the Department and its infrastructure. The Research Committee sets out delivery plans around short- and long-term targets,

facilitates and supports networking and collaborations (internally and externally). The Director of Research manages the Departmental PGR budget and allocations in support of early career researcher development and equality and diversity initiatives.

The laboratory footprint of the Department exceeds 700m^2 and supports the PIs, 9 of whom were recruited in the current audit period. Significant research activities are also supported through the HPC facility Archie-WEST, the AMRL and the 900m^2 National Facility for Continuous Manufacturing and Advanced Crystallisation (CMAC). Funded through a UK Research Partnership Investment Fund and equipped with world class facilities for research into pharmaceutical manufacturing (primary and secondary processing, materials characterisation, imaging, x-ray diffraction, spectroscopy for process analytics) the facility and Department staff are core to the CMAC research hub consortia (EP/P006965/1, £10.4M) goal to transform pharmaceutical manufacturing processes. The consortia is a global network of academic and industrial partners (GSK, AstraZeneca, Novartis, Bayer, Roche, Eli Lilly, Takeda, Pfizer) comprising more than 130 staff and researchers headquartered within the Strathclyde Institute of Pharmaceutical and Biological Sciences.

Table 6d- CPE Research structure FTE distribution by theme	
Total CAT A FTE = 21.6	CAT A (FTEs)
Advanced manufacturing & materials	6.9
Energy	6.8
Health & Wellbeing	2.5
Measurement science & enabling technologies	3.2
Society & Policy	2.3

CPEs in-house research facilities are summarised in Table 6e and support research on developing novel chemical process solutions for energy generation and storage, water purification, carbon capture, pollution and waste reduction, advanced nanomaterials and diagnostics. The Department works closely with other Departments and centres at Strathclyde, most notably with the Centre for Microsystems and Photonics (EEE) where staff are partners in the LITECS EPSRC programme grant (EP/T012595/1) and the SIPBS led CMAC hub. In response to the March 2020 Smart Sustainable Plastics Packaging UKRI call the Department in keeping the University's sustainability goals and alignment to the Advanced Materials and Manufacturing strategic theme was awarded £800k from NERC (NE/V010603/1) to optimise bio-composite film performance for food packaging applications. The Department also has close links with 25 UK and 40 international academic centres enabled via Newton funds, EU or UK grant funding. Over the REF audit period Fellowship awards have included an EPSRC Manufacturing Fellowship with CMAC, a Leverhulme Research Fellowship, a NERC Independent Research Fellowship and an EPSRC ECR Fellowship.

Table 6e: Chemical Processing Engineering laboratory facilities.	
Laboratory Suite	**Specialist capabilities**
Analytical laboratory	Brunauer–Emmett–Teller surface analysis, Fourier-Transform Infrared Spectroscopy, Intelligent Gravimetric Analysis, Gas Chromatography, high-pressure liquid chromatography, Circular Dichroism and UV-visible absorption spectroscopy, *in situ* static and dynamic light scattering microscopy, Brownian microscopy, High-speed video microscopy and optical trapping facilities.

Laser laboratories	Laser labs for the study of high-temperature reacting flows, including pollutant formation in flames, with specialist intensified cameras, pulsed and wavelength-tuneable lasers and optics required for laser-induced fluorescence, laser-induced incandescence and cavity ring-down spectroscopy.
General Labs	Core facilities and furnaces for materials synthesis experiments, biomass pyrolysis reactions and for the preparation of polymer membranes for gas separation.
Electrochemical Engineering	Core equipment for corrosion testing and monitoring. Facilities include high-temperature, high-pressure autoclaves, electrochemical hardware and characterisation equipment. Large scale electrochemical reactors for removal of pollutants from waste streams and performing electrochemical reactions in ultrasonic fields.
Archie-WEST (Leadership)	High performance computer facility supporting multi-disciplinary research in engineering and physical sciences.

Department of Design, Manufacturing & Engineering Management (DMEM)

DMEM is the academic home to the AFRC/NMIS and staff align closely with the Strategic Research Themes of Advanced Manufacturing & Materials, Ocean Air & Space and Energy. The Department operates a flexible research structure that encourages PI led engagement and collaboration across 3-primary areas of interests: Design, Advanced Manufacturing and Engineering Management (see Table 6f). In addition to AFRC/NMIS, the Department hosts an additional 5 research centres (see Table 6f), each connecting with the AFRC. With management as a core area, the Department's cross Faculty research is linked to groups within the Strathclyde Business School. A Strategic Advisory Group comprising external representatives advise the Departmental Management Board on strategy and performance.

Table 6f- DMEM research structure and centres.

Total CAT A FTE = 20.3		CAT A (FTEs)
Design		7.8
Advanced Manufacturing		10.5
Engineering Management		2
Dept Research Centres	Design Research Group	
	Robotics and Autonomous Systems Group	
	Centre for Precision Manufacturing	
	Sustainability and Remanufacturing Group	
	Engineering Management Group	
Affiliated Research Centre	Advanced Forming Research Centre	

Design research (see Table 6f) is embedded across all research teams within DMEM and general facilities support this expertise to deliver research in computer-supportive collaborative working, intelligent CAD, systems engineering and virtual prototypes as examples. The recent appointment of Arts and Humanities Research Council Design Fellow, Prof Paul Rogers to the Department brings

additional design leadership with expertise on design impact and his appointment builds on a strong portfolio exemplified by multidisciplinary EPSRC awards (EP/M012123/1, £908K) investigating human machine interactions for cognitive based and future predictive CAD design technology (EP/R004226/1, £590K).

The **Centre for Precision Manufacturing (CPM)** research is focused on the following topics: Ultra-precision machining, Micromachining, Nanofabrication, Multi-scales/Multi-physics modelling, Additive Manufacturing, Powder Sintering and Nano-Materials. CPM is led by 3 PIs and supported by 6 PDRAs and 9 PGR students. It operates the Department's Precision Metrology and nanofabrication laboratory (72m^2), the Ultra-Precision Machining laboratory (24m^2) and the Micro-Manufacturing Laboratory (65m^2). The centre collaborates closely with NMIS and has been successful in a range of EPSRC awards (EP/T024844/1 £2.8M, EP/K015345/1 £2.1M, EP/G03477X/1 £1.6M) and 9 successful FP7 and H2020 awards (>€4M).

The **Robotics and Autonomous Systems Group** (RAS) comprises 8 PIs, 9 PDRAs, 36 PGR students and 26 international visiting researchers. The work of the group is directed toward mechatronics, its application in robotics and autonomous systems in space, agriculture, oil & gas, advanced manufacturing and construction. The Group is supported by the Digital Team of the AFRC, and two research laboratories, the Space Mechatronics Systems Technology (SMeSTech) Lab featuring facilities for assembly/test areas for mechatronic and robotic systems, UAV/drones, and the Advanced Food Manufacturing Robotic Lab funded by Innovate UK comprising 3 robots, a conveyor system and a 1000+ axis controller providing applications research in the food, drink and agriculture industries. PGR training in SMeSTech is supported by the Strathclyde Centre for Doctoral Training in Space, in collaboration with MAE and Science Departments. The RAS Group was associated with AFRC's EPSRC Doctoral Training Centre in Advanced Manufacturing through to 2018 and this CDT is now sustained through industrial partners, including Weir, PSA, Space Applications Services and SRPe funding.

The **Remanufacture Research Group** has 5 PIs and collaborates with staff in EEE and CEE. It was established with £1.45M funding from the SFC and Zero Waste Scotland (2015) and supports 5 PDRAs and 25 PGRs. The group, specialises in interdisciplinary, practitioner-based research in sustainable design and manufacturing with a focus on end-of-life remanufacturing processes. The Group has access to specialist facilities through affiliations with CUE in EEE and the robotics infrastructure and additive manufacturing facilities of the AFRC. In addition to SFC funding, the group secured EPSRC support (EP/N018427/1- £1.9M, EP/P005268/1 - £517K) for autonomous inspection and for non-destructive evaluation in remanufacturing respectively, £223K from the Royal Society to establish affordable remanufacture in Nigeria, and other funding from diverse sources including H2020 and Innovate UK.

Department of Mechanical and Aerospace Engineering (MAE)

MAE delivers its research across four core groups and specialisms led by senior academic staff (Table 6g). Research priorities are annually set through annual planning by the Departmental Management Team (DMT). Reporting to the DMT are the Research Working Group, Laboratory Development Committee and the PGR Committee. The Laboratory Development Committee has the remit to implement continuous improvements to the laboratory fabric and equipment and manage a devolved budget for this. MAE incorporates the Advanced Materials Research Laboratory (AMRL) which provides state-of-the-art facilities in support of materials research across the Faculty.

Table 6g- MAE Research Structure	
Total CAT A FTE = 26	CAT A (FTEs)
Mechanics and Materials Research Centre incorporating Tribology Laboratory Advanced Composite Laboratory Structural Integrity and Life Assessment Research Laboratory Advanced Material Research Laboratory	9.4
James Weir Fluid Laboratory	4.5
Energy Systems Research Unit (3 FTEs returned to UOA 13)	2
Aerospace Centre of Excellence incorporating Advanced Space Concept Laboratories Future Air-Space Transportations Technology laboratory Intelligent Computational Engineering laboratory	10.1

The **Mechanics and Materials Research Centre (MMRC)** include 10 PIs, 5 PDRAs, and 24 PGRs. Research areas include: design, characterisation, manufacture and recycling of advanced composites; erosion, wear and damage; high temperature mechanics, advanced elasticity and plasticity material modelling, novel joining methods for metal matrix composites and structural/plant-life assessment. It provides experimental, theoretical and computational research specialisation in the research areas of Advanced Engineering Materials, Tribology and Tribo-Corrosion, Structural Integrity & Design, Advanced Joining & Surface Engineering and Biomaterials. It hosts a range of state-of-the art micro-to-macro material testing facilities through the AMRL, the Advanced Composite Group laboratory and the Tribology laboratory. Specialist equipment provision include the Weir Advanced Research Centre (WARC) Gigahertz high-cycle fatigue testing machine and a recent £250K upgrade to the corrosion laboratory. Within the AMRL testing to ASTM and ISO standards are available in mechanical testing, thermal analysis, compositional analysis and micro-constructional analysis. MMRC's research has attracted industrial funding from SMEs through to major companies (including Weir Group, Rolls Royce, Terumo Aortic, SSE, Boeing), UK and EU funding bodies. The ongoing relationship with Weir Group through the WARC has generated more than £3M income. European funding includes the Marie Skłodowska-Curie EID APESA award (€1.3M), ERDF Award SPIRE 2 (£1.1M) and Horizon 2020 RIA Da CoMat (£500k).

The **James Weir Fluid Laboratory (JWFL)** supports the work of 5 PIs and the application of computational techniques for the engineering design of complex flow phenomena with applications in space technology, health technologies, energy and manufacturing and multi-scale flow phenomenon focused on solid particle flow, thermal convection instabilities and rheology of complex micro flows. Group laboratories specialise in micro-state flow measurement of complex rheological fluids and gas dynamics with low pressure, high flow capability. JWFL funding is diverse including EPSRC, STFC/UK Space Agency, EU H2020, Innovate UK, medical charities and industry. The group collaborates internationally and are part of the Japanese European Research Experiments on Marangoni Instabilities project; an agreement between the European Space Agency (ESA) and the Japanese Space Agency (JAXA) funding experiments on the International Space Station.

Novel capabilities and expertise in advanced pump engineering are facilitated by funding from the Weir Group including the Prosperity Partnership (EP/S005560/1 see section on CEE) and H2020 APESP programme (Weir Minerals Netherlands, €1.3M). Other non-academic research partners include US Air Force, Proctor & Gamble, QinetiQ, Scotia Gas Networks and Terumo Aortic.

The **Energy Systems Research Unit (ESRU)** has 5 PIs *(N.B. 3 staff members of the Energy Systems Research Unit are returned to UOA13*), 7 PDRAs and 12 PGRs engaged in research on clean energy technologies including marine renewables and the built environment. In support of research on marine renewables, ESRU researchers have access to the Kelvin Hydrodynamic Laboratories (see NAOME) and are partners in the MARINERG-I European Strategy Forum on Research Infrastructures (ESFRI) project forming a pan-European centre of Distributed Research Infrastructures for Offshore Renewable Energy. The group also partner with stakeholders in the Philippines and Mexico on utilising marine renewables for community energy provision and socio-economic development in low-income countries (3 Newton Fund awards approx. £400K).

The **Aerospace Centre of Excellence (ACE)**, founded in 2016 comprises input from 12 PIs and has grown rapidly over the REF audit period. The research has a target horizon of more than 50 years ahead but deploys practical solutions in response to current challenges in space debris, safety, asteroids and comets, space planes and tourism, satellite applications, green and sustainable aviation.

ACE currently operates the Advanced Space Concepts Laboratory (ASCL), the Future Air-Space Transportation Technology Laboratory (FASTTlab), the Intelligent Computational Engineering laboratory (ICElab) and the Concurrent and Collaborative Design Studio (CCDS). The CCDS is a state-of-the-art studio to perform feasibility studies on space missions, end-to-end space mission analysis and design, satellite operations and space environment monitoring. It is also a laboratory with capability to test and deploy innovative software tools for systems design and analysis, resilience engineering, artificial intelligence, and multidisciplinary design optimization. ACE has secured funding from: H2020 (>£8M of grants since 2014) the European and UK Space Agencies, the EPSRC, the French Space Agency. The group are highly collaborative and work with multiple US, European and Asian universities. Industry partners include Airbus, Thales-UK, BAE systems, Lockheed Martin and Space Canada.

Department of Naval Architecture, Ocean & Marine Engineering (NAOME)

NAOME hosts three research groups with affiliated centres led by senior research active academics as shown in Table 6h. The Department's Research Committee, coordinates and monitors research performance and investment across the groups including funding in support of studentships, equipment and conference attendance.

Table 6h- NAOME research groups and centres	
Total CAT A FTE = 27.6	CAT A (FTEs)
Fluid-Structure Interaction Group *Incorporating The Peridynamics Research Centre*	9
Marine Design, Operation and Safety Group *incorporating Maritime Safety Research Centre & Maritime Human Factors Centre*	11
Ocean Engineering Group *incorporating the Offshore Institute*	8

NAOME's research is coordinated through 28 PIs, 40 PDRAs and 142 PGR students working across the themes described below. Over the REF period the Department generated a research income of £12.7M. Main research funders include EPSRC, FP7, H2020, ERC, Scottish Government, British Council (Newton Fund), Department of Transport, Innovate UK, Scottish Enterprise, Oil and Gas Innovation Centre, Wave Energy Scotland, Offshore Renewable Catapult and industries such as

Shell, Lloyd's Register, Oscar propulsion, SSE , Scottish Power, TWI ltd, BAE Systems, and Calmac Ferries.

The **Fluid-Structure Interaction** (FSI) group is based around 9 PIs and researches fundamental experimental techniques and numerical approaches to complex problems including wave and current flow interactions on offshore structures, innovation in hull coatings to reduce biofouling and drag, hull/propeller energy efficiency, green shipping and enhancement of marine structure reliability through advanced structural analysis, experimentation and modelling. The group facilities include the Kelvin Hydrodynamics laboratory (KHL), a unique research centre housing the UKs largest wave/towing tank. The group are also supported by the Peridynamics Research Centre (PDRC) who provide computational modelling capability directed at enhancing the structural reliability of systems using peridynamics and iFEM. The main KHL tank (76m x 4.6m x 2.5m) is equipped with a towing carriage capable of towing to 4.6ms^{-1} under complex wave patterns at variable depths. Equipped with state of art metrology, KHL is used for research into performance of ships, hull and propeller surfaces and offshore structures. Over the REF period upgrades exceeding £0.5M have been made. Upgrades include installation of above and below water 3D optical motion-capture systems, high-speed PIV systems for non-intrusive flow measurement, a state-of-art ultrasonic wave measurement system, an ADV system for measurement of turbulence in flow and a high stiffness six-axis load-cell and amplifier. New instrumentation also includes a Fully Turbulent Flow Channel as part of the KHL to support computational work on hull and propeller roughness, biofouling and coatings. In support of the facility a new large 3-axis CNC milling machine is available for model-making and manufacture of complex mechanical parts. In 2020, FSI were awarded H2020 funding of €5M (RUDDER) to lead on research to reduce shipping costs and improve the environmental sustainability of the shipping industry.

The **Marine Design, Operation and Safety Group** comprises 11 PIs and leads on maritime safety, stability and human factors research through two recently formed centres; the **Maritime Safety Research Centre (MSRC)** and the **Maritime Human Factors Centre (MHFC)**. The group's work has supported international regulatory developments through the UN's International Maritime Organisation and through its many H2020 awards it has expanded its research to support developments in green shipping and operational factors spanning marine engines and emission reductions technologies, fuel cells, voyage optimisation and weather routing. Facilities available to the group include the Small Marine Engineering Lab, a Full Mission Ship Bridge Simulator and a Virtual Reality Laboratory.

The £200K Full Mission Bridge Simulator (Wartsila-NTPRO-5000) is the only full-mission human factors research simulator in UK. It is equipped to measure navigational performance of seafarers and systems in 40 different sea regions using 50 different ship models or models of specific ships. The simulator includes audio-visual recording systems and integrates wearable technologies to monitor and measure human–system interactions, team work, situational awareness, emergency procedures and quantifications of human error risks. A Virtual Reality laboratory was recently commissioned to conduct research aimed at measuring/enhancing crew performance in safety critical situations.

The **Ocean Engineering Group** (OEG) incorporates the Offshore Engineering Institute and comprises 8 PIs focusing on offshore engineering research for the oil and gas sector and marine renewables, including design of fixed and floating assets, computational fluid dynamics, operations/maintenance modelling, logistics & management, safety and reliability, decommissioning, carbon capture and storage. Significantly, the group are active in researcher training including a H2020-MSCA-ITN (ENHANCE) programme and the EPSRC CDTs in Renewable Energy Marine Structures (REMS, EP/L016303/1), Wind and Marine Energy Systems and Structures (EP/S023801/1, Oxford and Edinburgh) and the NERC/EPSRC Industrial CDT in Offshore

Renewable Energy (IDCORE) with Edinburgh, Exeter and the Scottish Association for Marine Science.

Department of Biomedical Engineering (BME)

BME operates a flat structure across the 3 research areas each representing a community of interest comprising independent principal investigators (Table 6i.) Departmental research strategy and delivery planning is coordinated through a Research Committee reporting to the Department's Management Committee. A key function of the Research Committee is local targeted communication to ensure awareness of emerging research opportunities and to promote networking and collaborations within the life sciences, industry, clinical and community-based centres. The Department operates a Departmental Ethics Committee which has authority to approve non-invasive research on healthy human volunteers. Research involving invasive procedures are considered by the University Ethics Committee or submitted to the Research Ethics Service in Scotland.

Table 6i- BME- Primary Research Communities of Interest	
Total CAT A FTE = 21.6	CAT A (FTEs)
Cell, Tissue & Organ Engineering	4.6
Rehabilitation Engineering	6
Medical Devices &Diagnostics	10

BME has a long track record of translating research and collaborating with clinical sites, industry and communities in low-income countries. BME hosts 21 PIs, 17 PDRAs and 115 PGR students. Its research and facilities cover 3 communities of interest centred on Rehabilitation Engineering, Medical Devices & Diagnostics and Cell, Tissue & Organ Engineering. In late 2017, a £16M refurbishment of its Wolfson Centre commenced. New upgraded research laboratories and specialist workshop/medical device prototyping services will cater for the growing accommodation and research needs of the Department and will compliment additional facilities developed within TIC for wearable medical sensor research.

In the new Wolfson there are 22 multiuser research laboratories specialised for research in healthcare technologies including biomechanics/motion analysis, advanced assistive technologies, medical robotics, cell & tissue engineering, biomaterial & tissue testing, computer modelling and point-of-care diagnostics and toxicology. The Wolfson Centre's tissue and biomaterial testing suite is part of the AMRL and dedicated to study of hard and soft biomaterials and is licensed for work with human tissue. The Wolfson Centre also supports dedicated workshops with metallic 3D printing for rapid prototyping.

Studies involving human volunteers are conducted in co-located laboratory space with disability access. Facilities include a Motek CAREN 6-DOF motion platform and interactive virtual environment. This facility is complemented by a large open environment motion capture laboratory incorporating activity monitoring and multi-channel non-invasive neurophysiological measurement and neuromodulation capabilities. BME was recently awarded £500K from the Jules Thorn Charitable Trust to purchase advanced rehabilitation equipment for disability research focused on co-produced research with clinical partners and patients to be housed in this space. This funding follows from Scottish Government support over the REF period of £1.6M for research in rehabilitation engineering facility and staff. Specialist manufacture, fitting and evaluation of prosthetic and orthotic devices is supported through workshop and clinical facilities in the National Centre for Prosthetics and Orthotics (a clinical training centre within BME).

Off-campus research facilities include access to research space at the Spinal Injuries Unit (Queen Elizabeth University Hospital), the Glasgow Clinical Research Facility (Royal Infirmary, Glasgow) and Coathill Hospital NHS Lanarkshire. In 2020, BME were awarded SFC funding to develop rapid COVID-19 diagnostics based on lab-on-a-chip diagnostic technologies developed for sepsis, cancer and drug resistant TB (MycoChip) detection in low-income counties (Corrigan, Newton Fund). Other medical device innovations with reach to disabled communities in low-income countries include the development of the Portable Eye Examination Kit (PEEK), and the Google supported Legbank project ($1M) to develop and field test Magicast, a unique non-expert casting process for prosthetic limb manufacture in territories lacking limb-fitting expertise.

BME are involved in two EPSRC CDTs; the CDT in Medical Devices & Health Technologies (EP/L015595/1) which has received continuous EPSRC support since 2004 and the CDT in Prosthetics & Orthotics (EP/S02249X/1). BME also collaborate with the CDT in Future Ultrasonic Engineering (EP/S023879/1) and three SCDTs focused on health technologies. UKRI awards to BME include STFC and BBSRC awards to Reid (£3.1M) and collaborators at the Universities of Glasgow and West of Scotland (£1.8M) on novel bone regenerative studies and research on advanced sensor development as part of the global LIGO Scientific Collaboration (https://stfc.ukri.org/news-events-and-publications/features/on-the-ground-at-ligo-and-around-the-world/).

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

4.1 Research Base Recognition, Contribution and Influence

***Selected Learned Society Recognition, Fellowship Awards, and Notable Prizes*.**

In October 2019, our Principal (Prof Sir Jim McDonald) became President of the RAEng. Prior to this he chaired the RAEng Research Committee (2016-2019) and held presidency (2017-2019) of CESAER (https://www.cesaer.org/), a consortium of 60 leading European science and technology institutions. In 2019 he joined China Premier Li Keqiang's Foreign Experts Advisory Group (http://english.www.gov.cn/premier/news/202001/18/content_WS5e22ce85c6d0db64b784cc34.html). Further recognition of his research leadership is his work as co-chair of the Scottish Government's Energy Advisory Board, his chairing of the SFC research pooling initiatives (see section 3) and of the Glasgow Economic Leadership Board. In 2019, his contributions to energy research were acknowledged with the award of the Energy Institute's Melchett Medal. Prof Sir McDonald is also the Honorary President of IET (Scotland), a Presidential Fellow of New York University and Honorary Professor at Peking University.

During this audit five staff became Fellows of the RAEng (Connolly, Lunn, Haas, Vassalos, Wren) and seven became Fellows of the Royal Society of Edinburgh (RSE) (Bell, Connolly, Lunn, Haas, Reid, Shipton, Uttamchandani). Lunn became a RSE Trustee and Council Member and four staff were elected on five-year terms to the RSE Young Academy Scotland (Mulvana, Kazakidi, Macdonald, Reid). This Academy is chaired by Prof S Reid (BME) who in 2016 won the RSE President's Medal for his contribution to the Laser Interferometer Gravitational-Wave Observatory (LIGO) partnership. Prof M Macdonald (MAE/EEE), also part of the RSE Young Academy, was awarded the Sir Thomas Makdougall Brisbane Medal (2016) for early career achievements and Prof Lunn (CEE) was further honoured with MBE (2017) for her contribution to engineering and supporting equality and diversity. In addition, Profs McArthur and Ridgway were notified in 2020 of the IEEE Richard Harold Kaufmann Award and the IET Mensforth Manufacturing Gold Medal respectively.

Building from REF2014, 21 staff achieved Fellowship status across engineering and multidisciplinary areas. Notable examples include; IEEE (McArthur, Uttamchandani), IET (Haas), IMechE (Athanasios, Chen, Qin), American Society of Mechanical Engineers (Chen), IChemE (Roy), Royal Society of Chemistry (Hamilton, Price), the Institute for Materials, Minerals and Mining (Hamilton), Royal Microscopical Society (Windmill), Royal Institution of Naval Architects (Boulougouris), Royal Aeronautical Society (Macdonald), Royal Society of Medicine (Gourlay, Connolly), Institute of Physics and Engineering in Medicine (Black, Conway, Giardini), and the Institution of Engineers and Shipbuilders in Scotland (Jalalvand, Oterkus) amongst others. Our largest membership groupings rest with the IEEE and over the REF period a further five staff acquired senior status (MacGregor, Camos-Gaona, Stankovic, Clemente, Blair).

4.2 Funded Research Chairs, Fellowships & Named Lectureships

Prestigious RAEng personal research awards made during this REF cycle include 2 Research Chairs (Lunn with BAM Nutall, Pierce with Spirit Aerospace), 1 RAEng/Leverhulme Senior Research Fellowship (Chen), 3 RAEng Research Fellowships (Bauer, Weijia, Min), 1 Industry and 1 Enterprise Fellowship (Liu, Carroll).

Success in UKRI research Fellowships include 3 EPSRC fellowship awards (Browell- Innovation; Panagiotis- Future Leaders; Price- Manufacturing), 1 NERC Fellowship (Dobson) and a AHRC Design Fellowship (Rogers 2014-21). Additional research Fellowships include 5 awards from the Royal Society (2 Newton International Fellowships, 3 Industrial Fellowships), 2 Leverhulme Early Career Fellowships (Haw, Reid, A), 2 Marie Sklodowska-Curie Individual Fellowships (Tubaldi, Kazakidi) and a Weir Industrial Fellowship (Yang).

In addition to personal Fellowships, 34 staff hold Visiting Professorial (VP) positions with a further 8 holding Honorary Research Fellow status in collaborating institutions across the Americas, Europe, UK and Asia. Honorary NHS contracts have been held by 7 faculty from BME.

Newly endowed chairs were established in BME (Shu, Hay Chair of Biomedical Engineering) and EEE (Stewart, Xilinx Inc Industry Professor of Signal Processing; Bell, ScottishPower Chair in Smart Grids).

4.3 Prizes (excluding Journal/Conference Awards)

Staff have also been recognised through different UK and international prizes above those mentioned previously.

Our Energy theme and focus resulted in a number of prizes. Roberts (early career researcher) won the 2015 Scottish Energy Researcher of the Year for her work on Energy Infrastructure & Society. In 2014, Booth won the Energy Innovation Award for Best University Technology in recognition of the spin-out Synaptec. Weijia (2014) was awarded an IEEE Van Duzer Prize and in 2017 and 2019, Min received separate Jan Evetts Superconductor Science and Technology awards.

Multiple Dynamic Spectrum Alliance awards from 2016 have gone to Stewart and his team for bringing connectivity to rural communities and businesses work that underpins the growth of our 5G Cluster. Our activities in the Measurement and Enabling Technology theme resulted in Uttamchandani receiving the IEEE Sensors Council Technical Achievement Award (2017) and Pierce was awarded The John Grimwade Medal (2015, British Institute of Non-Destructive Testing). Fundamental research advances were recognised through the 2016 Gruber Cosmology Prize (USD500k shared through LIGO) and a IMechE top innovations prize in 2017 (both Reid).

Other themes have also seen significant recognition for our academics. In Health there have been two Longitude Prizes (Corrigan- antimicrobial resistance microplate tests, Giardini- smartphone based eye diagnostics). A Design Museum, Design of the Year Award from for the Portable Eye Examination Kit (Giardini, 2015), and a Google Impact Challenge Disabilities award ($1M) for the social enterprise Legbank project (Buis, 2016). In Ocean, Air and Space Day was awarded the Royal Institution of Naval Architects Medal of Distinction (2014), Vassalos the Society of Naval Architects and Marine Engineers Gold Medal (2016), Kurt the Maritime Safety Award from the Royal Institution of Naval Architects (2017) and Incecik was granted an Honorary Doctorate by Chalmers University of Technology in recognition of his research on green shipping and environmental sustainability. In 2016, Clemente was named as overall winner of the EU sponsored European Satellite Navigation Competition and in Advanced Manufacturing Luo won the 2015 IMechE Ludwig Mond Prize.

4.4 Notable Advisory and Committee Memberships (excluding conference organisation)

Within this submission, 95 (45%) contributed to over 250 different advisory groups or committees reflecting our commitment to sharing our research insights, influencing key organisations and driving impact in our field. Limited examples from each Department are listed in Table 7.

Table 7. Examples of staff engagement and contribution to committees serving varied interests

Dept	Name	Contribution
BME	Connolly	BME review panel, Hong Kong Polytechnic University
	Conway	Trustee; IPEM, Dunhill Medical Trust & Medical Research Scotland.
		Member (-2015) Glasgow Universities/NHS Biomedicine Governance Board
	Reid	Co-chair; Einstein Telescope Instrument Science Board.
		International advisor to the Stanford-led Centre for Coatings Research
CEE	Dobson	Lead: Diamond II synchrotron upgrade for imaging in Geosciences
	Douglas	Member Advisory Group Observatories & Research Facilities for European Seismology
	Kalin	Advisor to Government of Malawi on water resource management
	Knapp	Advisor to Public Health Scotland on Control of Antimicrobial Resistance in Scotland
	Lunn	Member (-2015) UK Gov Committee on Radioactive Waste Management
		Member of the Scottish Government Geothermal Energy Expert Group
	Morse	Advisor to Malawi Government on National Community Health Strategy
	Renshaw	Advisor to Welsh Government, Nuclear Task and Finish Group
		Member & Hon Sec, Royal Society of Chemistry Radiochemistry Group Committee
	Roberts	Member of the UK Energy Research Centre Research Committee

	Shipton	Member, Scottish Gov Independent Expert Scientific Panel on Unconventional Gas.
	White	Member- Scottish Public Voice Committee, Inst of Civil Engineers. Vice President, International Commission on Coupled Land–Atmosphere Systems
CPE	Price	Member of an AstraZeneca Scientific Advisory Board
	Burns	Committee Member, IoP Combustion Physics Group
DMEM	Duffy	Member of DfT's Clean Maritime Council Member BAE Systems and University partner Board.
	Ijomah	Member BSI product specification committee for secondary market products. Member-The Social, Economic & Environmental Case for Remanufacturing (UK gov)
	Ion	Board Member High Value Manufacturing Catapult Board Member Oil and Gas Technology Centre (OGTC) Academic Panel Member Greater Glasgow Economic Leadership Forum Manufacturing Group
	Rodgers	Trustee of Research in Specialist and Elderly Care
	Whitfield	Member of Advisory Board – The Design Society
	Yan	Chair- Executive Committee of Robotics & Mechatronics, IET UK GovAdviser on Space Robotics and Autonomous Systems (UK Space Agency).
EEE	Andonovic	Board Member, SFC-funded Innovation Centre 'CENSIS'
	Bell	Expert Witness House of Commons Science and Technology Committee, Clean Growth. Technical Advisor to Ofgem - electricity supply interruptions Advisor- BEIS- National Infrastructure Commission. Co-Chair, Scottish Gov Technical Advisory Group, Energy & Climate Change Analysis Member of the Climate Change Committee (est. by Climate Change Act 2008)
	Browell	Advisor to Renewable UK Wind Advisory Group Member of International Energy Agency, Wind Task 36 (Forecasting)
	Burt	Board member & Spokesperson, European assoc. of Distributed Energy Laboratories Steering Committee, Eur Energy Research Alliance Joint Programme for Smart Grids Member of Governing Board for UK Aerospace Research Consortium

	Dysko	Technical advisor to National Grid Workgroup GC 0079
	Gachagen	Academic Chair, UK Research Centre in Non-Destructive Testing
	Haas	Chair of NATO Workgroup on Optical Wireless Communications
	Holliday	Member Advisory Board, UKRI Driving the Electric Revolution
	Leithead	Member of Energy Technology Institute Strategy Advisory Group Steering Committee, European Energy Research Alliance Joint Programme Wind Deputy Chair of Offshore Renewable Energy Catapult Research Advisory Group
	MacGregor	Member of the Glasgow Chamber of Commerce
	Macleod	Member – BSI, non-destructive testing (NDT) technologies of DED manufactured parts
	McArthur	Member of the Scottish Enterprise Smart Grid Industry Leadership Group Scottish Power Retail, Wholesale & Renewables External Stakeholder Advisory Forum
	Michie	Member IEEE IES Sub-Tech. Committee on Smart Agriculture
	Pierce	Research Advisor to Spirit AeroSystems Ltd. Board member, UK Research Centre in Non-Destructive Evaluation
	Siew	Member of the UK National Committee for CIRED and CIGRE SC S4 Advisory Group.
	Stewart	Adviser to Scottish Development International (Scottish Enterprise) IEEE DEIS Membership of Member.
MAE	Cartmell	Deputy Chair of the AIAA Technical Committee on Space Tethers
	Macdonald	Non-Executive Board Member, UK Space Agency Member, COSPAR Task Group on Establishing a Constellation of Small Satellites Committee Member, Achieving Science Goals with CubeSats, National Acad. Sciences.
NAOME	Boulougouris	Standing Committee Member of UN International Maritime Organisation
	Brennan	Member- Offshore Renewable Energy Catapult Research Advisory Board Member of the Energy Technology Partnership Advisory Board;
	Day	Board of Society of Naval Architects & Marine Engineers
	Incecik	Member of Lloyd's Register Marine Technical Committee
	Kolios	Vice-President Elect, European Academy of Wind Energy
	Lazaklis	Advisor at British Standards Institute

		Member of Lloyd's Register Technical Committee
	Vassalos	Member of Council of the Royal Institution of Naval Architects
		Advisor to UN International Maritime Organization
		Chair of the Group of Experts for Domestic Ferry Safety Regulations.
	Tao	Member of Arctic Technology Committee, Int Ship & Offshore Structures Congress

4.5 Engagement with UKRI and other funding agencies

Over the REF period the majority of established staff have engaged as grant reviewers covering all UKRI councils and multiple UK and international funding agencies. In addition to recognising the calibre of our staff, this is pleasing because it allows our research insights to be used to shape future research and research agendas. The EPSRC is our most significant UKRI funder and engineering has 31 full members of the EPSRC electoral college and 28 are associate members. Two staff from CEE are members of the NERC electoral college (Phenonix, Shipton) and Rodgers (DMEM) is a member of AHRC peer review college.

Notable advisory engagements with EPSRC over the REF period include 3 current members and 1 past member of EPSRC Strategic Advisory Teams (McArthur- Energy; Haas- ICT; Lunn- Engineering; Conway- Engineering to 2014) and multiple repeat appointments to EPSRC prioritisation panels. In addition, recognising their expertise, a number of staff have supported UKRI and wider strategic grant decision making through the senior roles in panels as summarised in Table 8, with further notable contributions to other grant awarding panels listed in Table 9.

Table 8. EPSRC grant panel senior roles (2014-2020).

Dept	Name	Funder/Panel
BME	Conway	Director & Chair, Sandpit in Assistive, Adaptive and Rehabilitative Technologies. Panel Chair EPSRC Health Technologies Impact Fellowships- interview panel Panel Chair EPSRC/UKRI Innovation Fellowship Sift Panel
CEE	Renshaw	Panel member: EPSRC/Korea Civil Nuclear Research Programme Phase 2; Panel member: EPSRC /Japan Civil Nuclear Research Programme Phases 2 & 4;
EEE	McArthur Uttamchandani	Chair EPSRC Panel for the Trustworthy Autonomous Hub programme Chair of EPSRC Engineering Fellowships Interview Panel

Table 9: UOA12 staff contributions to notable grant awarding committees (excluding EPSRC)		
Dept	Name	Funder/Panel
BME	Connolly	Royal Academy of Engineering Research Awards Panel Royal Academy of Engineering Newton Fellowships
	Conway	-2019. Chair International Spinal Research Trust Scientific Committee and Panel Deputy Chair, Medical Research Scotland, Research Awards Committee Deputy Chair, Dunhill Medical Trust, Research Grants Committee (chair from 2020) Member (Chair from 2020), Wellcome Trust Programme Advisory Group (Innovation Flagship Programme - budget £300M).
	Gourlay	Panel Member Science Foundation Ireland – Covid19 Response Panel Member, Covid 19 Rapid Response, Chief Scientists Office Scotland
	Reid	Panel Member, Royal Society Grants Panel (Physical Sciences).
	Rowe	Panel Member, Translational Medicine Grants, Chief Scientists Office, Scotland
DMEM	Rogers	Member of the UKRI Future Leaders Fellowship Funding Panel Panel member AHRC
EEE	Ahmed	Chair and member of award panels at Research Council of Norway`
	Andonovic	Vice-Chair & Panel Member, European Research Council Advanced Fellowships
	Leithead	Member of Royal Society Newton Advanced Fellowships Assessment Panel
	Uttamchandani	Member Science Foundation Ireland Grant Awarding Panel
MAE	Macdonald M	Panel member, UK Space Agency 'Science Experiments on Sub-Orbital Flights'. Chair, ARIEL (ESA M4 Candidate mission) SPRP Review Panel, UK Space Agency
NAOME	Incecik	Panel member of The Research Council of Norway Panel member of The Research Council of Sweden
	Kolios	Panel member NERC
	Lazakis	Panel Member Royal Society UK Newton Fund research projects Member of grant funding panel of Norway Research Council national projects

		Member of grant funding panel of The Netherlands Research Council national projects Member of grant funding panel of European Commission Research projects

4.6 Contributions to Conferences and Academic Publications

As part of our strategy to communicate our research in high quality and appropriate publications, we supported and encouraged leadership in this area. This has resulted in seventy-five staff holding editorial board appointments, covering 145 titles, with nine having served as Editor-in-Chief for titles including: Journal of Sound and Vibration (Cartmell), Journal of Engineering Design (Duffy), Ocean Engineering (Incecik). A further 35 staff report commissions as Guest or Special Edition Editors for 54 peer reviewed journal titles. All staff participate in peer review.

91 staff in UOA12 contributed to the organisation of 300+ conference events as chair or members of organising committees (representing all Departments and staff grades). 245 of these events were international, part of a recurring world or international conference series or hosted abroad. 57 staff were named as conference/session chairs at 141 events over the period. 180 keynote presentations were delivered from 61 faculty and 29 Plenary Lectures from 14 staff over the census period. A further 267 invited talks were presented at various conferences from 64 staff.

4.7 Contribution to Economy and Society

Staff who have formed start-up companies or maintain company appointments or advisory roles include Booth, Niewczas- Synaptec; McArthur- Bellrock Technology; Johnstone- Nautricity; Ault- Smarter Grid Solutions, Zagnoni- Screenin3D; Shu- Organlike, and we have seen the spin-out ETS/Silent Herdsman being acquired by Afimilk Ltd. We encourage spin-out and commercialisation activities through a range of Faculty interventions in terms of authorising staff time in the commercial ventures and supportive arrangements for laboratory and office accommodation.

Our ability to translate research expertise into impact is demonstrated through Non-Executive Director (NED) appointments held at the Weir Group, Scottish Power, Scottish Power Energy Networks, the Offshore Renewable Catapult, the National Physical Laboratory (all McDonald), UK Space Agency (Macdonald M), the HVMC (Ion) and Maritime Innovations (Vassalos). Vassalos was also Chairman of the Brookes Bell Group and Delta Marine before stepping down in 2015. At Scottish Enterprise, McDonald served as a NED to 2016.

Public engagement is part of our commitment to useful learning and our identity as a socially progressive organisation.

We use ‘Engage with Strathclyde’, an annual week-long event, to allow multiple opportunities for the public and industry to find out about our research. It also serves as showcase on how we create benefit for industry, the public and third sectors. We have enjoyed long standing collaborations in the support of public engagement events and permanent exhibits within the Glasgow Science Centre, through the annual H2020 funded Glasgow Explorathon. We have also created interest in engineering from communities with poor access rates to higher education. The “ReallySmallScience” workshops were inspired by research in nanomaterials (CPE) and consist of hands-on engagement workshops. The initiative was ‘Highly Commended’ in the Education and Training section of the IChemE Global Awards (2015), and has been supported by grants from the Royal Society of Chemistry (Outreach Funding, 2016-19, £15K), RAEng Ingenious Funding scheme (2013-20, £60K)

and has been replicated by City University New York, the SENA National Training Service (Colombia) and the Universidad Católica de Temuco (Chile).

Significant public talks have included the 2014 BBC-TV Royal Institution Christmas Lecture by Haas (EEE) and a TED Global Talk by Haas in 2015, “Forget Wi-Fi: Meet the New Li-Fi Internet” (2.8M views).

4.10 Impactful Research not Recorded in Impact Case Studies

Supporting the UN Sustainable Development Goals

Through embedded collaborations in Malawi, research led by CEE and funded by the Scottish Government Climate Justice Fund and others (https://www.gov.scot/publications/scottish-government-contribution-international-development-report-2018-19/pages/13/) has led to improving infrastructure, planning and management of water sources throughout the country. Through development of a Malawi National Management Information System for water, resilience and access to clean water has improved. Public health has been safeguarded by contributions in creating an Integrated Water Resources Management Policy through rapid remediation of at risk or contaminated water supplies. An example of impact from this work was the ability in 2019 to prevent a major cholera outbreak (https://www.gov.scot/news/disasters-emergency-committee-appeal) in response to a major flood disaster resulting from Cyclone Idai.

Also in Malawi, CEE together with the University of Malawi Polytechnic, Government ministries, WaterAid, UNICEF and others (https://www.strath.ac.uk/malawi/projects/chikwawaproject/) concluded important trials of an environmental hygiene intervention involving 1000 households yielding a 62% reduction in diarrhoeal disease and a 51% reduction in respiratory infections in children under five. Based on this outcome the public health intervention and training method is now implemented through national public health policy and campaigns. Current estimates predict the success of this work contributes to 250000 fewer diarrhoea cases in under-fives at any given time. In the last year the impact has expanded through adoption within the Malawi government’s COVID prevention strategy and through community health programmes of major NGOs including Pump Aid and Water Aid (https://www.pumpaid.org/covid-19-response/).

Research quantifying and raising awareness on the environmental and health damage stemming from unregulated ship recycling in LMICs has generated impact such as the introduction of UN adopted green ship-recycling regulations and European certification requirements (see https://www.imo.org/en/OurWork/Environment/Pages/Ship-Recycling.aspx). In turn, this has enabled researchers from NAOME to support the ship-recycling industry in Spain and Turkey improve worker safety, efficiency and reduce pollution. By developing a culture of health and safety management and worker training, NAOME in collaboration with the Bangladesh ship recycling industry, has assisted yards achieve the international standards necessary to access international contracts thereby maintaining local work economies, reducing child labour and critically improving worker life-expectancy whilst reducing the toxic environmental impact of unregulated yards. The Bangladesh ship recycling industry is now better placed to maintain employment of over 100,000 people, is close to self-sufficiency in steel requirements and generates foreign currency in excess of £500 million per year.

Our expertise on environmental disaster prevention (CEE) was called upon following the MV Wakashio breaching off Mauritius (July 2020) helping to protect important wildlife sanctuaries and coastal regions from a potential 4000 tonne oil spill (https://digit.fyi/glasgow-scientists-use-data-modelling-to-tackle-the-mauritius-oil-spill/). The work in collaboration with the Mauritian IEEE and NGOs used rapid predictive modelling and advice on oil-boom construction and deployment

contributed to minimise the environmental impact of the spill, protecting the sensitive coastal ecosystem and economy of the region.

CEE and partners (10.1016/j.jhazmat.2013.11.053) contributed scale-up and successful commercialisation of a laboratory based combustion land remediation technology: Self-sustaining Treatment for Active Remediation (STAR https://www.savronsolutions.com/star/). Commercialized by licence to Savron Solutions, STAR achieves 99.9+% destruction of contaminants to soil depths of 11m reclaiming viable land use at cost savings over alternate approaches. In 2017, the Savron project team were presented with American Academy of Environmental Engineers and Scientists Superior Award for "the Evolution of STAR from Laboratory Concept to Full-Scale In Situ Implementation" acknowledging the collaboration from Strathclyde in achieving restoration and reuse of multiple toxic industrial sites (https://www.savronsolutions.com/wp-content/uploads/2019/09/savron-case-study-in-situ-former-site-nj-2019.pdf).

Through research focused on the fundamentals of materials by DMEM and AFRC a foundational body of research, termed the AFRC Validation Cycle, has been applied to design manufacturing processes to maximise material strength and durability of manufactured parts. By enhancing resource efficiency and product resilience, research on behalf of industry has created new intellectual property and enabled more than 25 organisations including multinationals (Rolls-Royce and Boeing), manufacturing SMEs and social enterprises to improve their products, profitability and intellectual property rights (https://www.strath.ac.uk/research/advancedformingresearchcentre/whatwedo/industrycasestudies/). The successes achieved through the AFRC were central to the Scottish Government's investment of £75M toward NMIS and AMIDS (https://www.gov.scot/news/national-manufacturing-institute-for-scotland/).

Synaptec, formed in 2014, protects power system infrastructure through novel optical sensing and has created high value employment, achieved multiple awards form UK Energy Innovation, secured significant investment for growth and is deploying its technology across high- and low-income economies. With technology that enables real-time analysis of energy networks, Synaptec is partnering globally with system operators and renewable developers to save costs and maintain grid supply at a time where the complexity of energy supply creates a high outage risks (https://synapt.ec/applications).

Embedded Technology Solutions (ETS) has pioneered the introduction of wearable technology in the agri-tech arena. Through the development of an Internet-of-Things inspired decision support platform to optimise animal husbandry within dairy farms research in collaboration with Scottish Agricultural College and The Royal Dick School of Veterinary Studies resulted in ETS achieving a £3M investment in 2014 to market the technology (Silent Herdsman). This wireless sensing collar provides monitoring of multiple animal health indicators and the machine learning capabilities assist farmers to maximize productivity through increased milk yield, improved animal welfare, reproduction success and reduced operating costs. Acquired by Afimilk Ltd in 2016 (https://agfundernews.com/vc-backed-uk-dairy-technology-silent-herdsman-acquired-by-israels-afimilk5382.html) and now sold globally (https://www.afimilk.com/cow-monitoring) Silent Herdsman has been central in stimulating investment in precision farming through the adoption of Internet-of-Things technologies within the Agri-food sector, and helping farms achieve the highest standards of welfare for their animals.