

Institution: Glasgow Caledonian University
Unit of Assessment: 12 - Engineering
1. Unit context and structure, research and impact strategy <u>Context</u> <p>UoA12 is embedded in the wider University research strategy and structure, aligned thematically with the UN Sustainable Development Goals 7: “Affordable and Clean Energy” and Goal 9: “Industry, Innovation and Infrastructure”, and influenced by Goal 8: “Decent Work and Economic Growth” and Goal 12: “Responsible Consumption and Production”. All staff are located within the School of Computing, Engineering and Built Environment (SCEBE), but the Unit also benefits from cross-disciplinary input and collaboration, predominantly with UoA11 and UoA13.</p> <p>The Unit’s vision is framed by the University mission “for the common good” and conducts research that delivers significant practical benefits and impact for society as exemplified in the Unit’s Impact Case Studies. The direction and specific activities of the research carried out also aligns with relevant UK and Scottish Government policies. A significant proportion of the research of the UoA is related to energy generation, distribution and efficiency responding to the UK National Energy and Climate Plan (NECP) and the Scottish Energy Strategy, which sets two ambitious targets for 2030: the equivalent of 50% of Scotland’s heat, transport and electricity consumption to be met from renewable sources; and an increase of 30% in the productivity of our energy use across the Scottish economy. Our work also reflects the Scottish Government energy infrastructure policy for large centralised thermal power plants to be replaced by more highly distributed sources of generation, largely from renewable sources.</p> <u>Structure</u> <p>In REF2014, the Unit’s work was co-ordinated by an Institute for Sustainable Engineering and Technology Research (ISETR) as one of three University Institutes. With its new centre-based approach, the University has now established six Research Centres and the ISETR has been largely subsumed into the SMART Technology Centre which reflects the increasing role that AI and Data Science are playing in the development of advanced engineering and manufacturing systems. The research groups working within the Centres provide discipline-specific peer support and exchange, while the Research Centres provide a co-ordinating function that allows the tackling of cross-disciplinary research (and societal) challenges. The groups are designed to be formed from recognised common interest, where staff can belong to more than one group, and new groups can be formed or existing groups evolve to take advantage of emerging technologies and opportunities. It is also feasible for staff members to stay non-aligned with any particular group, preferring to pursue an individual interest.</p> <p>UoA12 consists of 10 Professors and 18 Lecturers or Senior Lecturers, located in the School of Computing, Engineering and Built Environment (SCEBE), coalescing around four thematic groups, primarily working within the newly formed SMART Technologies Research Centre:</p> <ul style="list-style-type: none"> • Applied Engineering Simulation & Analysis (AESAs) • Advanced Manufacturing and Materials (AMM) • Power and Renewable Energy Systems (PRES) • Smart Connectivity and Sensing (SCaS).

Applied Engineering Simulation & Analysis (AESA)

Responding to SDGs 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation and Infrastructure), the AESA research group was formed in 2019 to address the democratisation in digital design, digital prototyping and digital twinning technology with associated AI/ML technologies, where advanced simulation and analysis methods require the tools and techniques for industrial application if SDGs 8 and 9 are to be realised.

The group has seven active research staff and is focused on providing innovative and practical solutions for industry based on applied research, consultancy and knowledge transfer using expertise in:

- Engineering Simulation: Computer Aided Design, Finite Element Analysis and Computational Fluid Dynamics
- Condition Monitoring: applied data analytics for detection and isolation of component / system degradation, integration of condition monitoring and asset design, predictive maintenance
- Multi-phase flow: Instrumentation development and flow modelling.

Recent project titles include:

- Passive Acoustic Diagnostics of Particle Laden Oil and Gas Multiphase Flows
- Development of Maintenance Optimisation, Reliability and Statistical Models and Its Application in Industry
- Design and Development of Prognostics and Health Management Applications for Subsea Production Systems – Physical/Functional Simulations.

Staff in the group working with colleagues in Computing (UoA11) secured a three year, two-associate KTP with Mitsubishi to assist with developments to introduce Smart Factory, Industry 4.0 and Digital Twinning technologies and techniques. Along with knowledge transfer activities, staff in the Group have a strong track record of securing research funding, for example, “Modelling and Measurement for Future Oil & Gas Multi-Phase Flows – Experimental Investigation and CFD Based Simulation”, undertaken in collaboration with the University of Edinburgh and funded by the Energy Technology Partnership and TUV-SUD-National Energy Laboratory.

Advanced Manufacturing and Materials (AMM)

Responding to SDGs 12 (Responsible Consumption and Production), 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation and Infrastructure), the AMM research group was also formed in 2019 to undertake research to develop advanced materials and manufacturing methods including robotics. This group aims to impact the Scottish economy through contributions to the Made Smarter initiative and SDG 12, 8 and 9.

The group has five active research staff with expertise in:

- Materials Characterisation (Metals, Composites and Plastics)
- Advanced Manufacturing Techniques (Electro-machining, Welding and Cold Forming).

Recent projects from this group include:

- Environmentally sustainable manufacturing process development
- Development of metal matrix composites using tungsten inert gas technique.

The aim of the group is to increase research funding by continuing and increasing engagement with industry and by aligning with collaboration opportunities available through, for example, the Scottish Research Partnership in Engineering key theme “Advanced Manufacturing”. Two members of this group have recently secured a KTP project with a local company, Precision Tooling Services Ltd, to improve manufacturing efficiencies titled “Optimisation of Smart Precision Electrochemical Machining (OSPECM)”.

Power and Renewable Energy Systems (PRES)

The PRES has evolved from the Diagnostic Systems and Energy & Power Systems groups that were submitted in REF2014 and deploy significant computational work using AI/ML with an expected contribution to SDGs 7 (Affordable Clean Energy) and 9 (Industry, Innovation and Infrastructure). This group of 12 staff brings together researchers from different departments whose interests involve the renewable energy and power sector. These interests include:

- Power generation
- Energy distribution
- Sources of energy
- Materials for energy applications
- Power and energy applications
- Asset health

In the conventional power area an example of a recently awarded research project is “High precision fault localisation in buried power cables based on wireless charging” funded by the Energy Technology Partnership and Scottish Power Energy Networks. The group has secured ongoing support and research funding from industry partners Doble and EDF. The staff are also working in the areas of non-conventional and renewable power, such as small-scale network integration and power from wind farms.

The staff have internal collaboration with colleagues in computing (UoA11) particularly in the application of machine learning and strong international academic collaboration and joint publications with colleagues from Europe, China, Africa and the Middle East. This group has arguably the strongest and most sustained track record of securing funding and producing high quality research output and impact of the groups in this UoA. Two of the Unit’s three impact case studies originate from work from staff in this group. The strategic importance of the Group is recognised and supported by senior management with the appointment of Prof Farrag from this group as Director of the SMART Technology Centre.

Smart Connectivity and Sensing (SCaS)

Aligned with SDGs 7 (Affordable Clean Energy) and 9 (Industry, Innovation and Infrastructure), the SCaS research group aims to advance sensors, networking and IoT for societal benefit. This group of 10 staff from different academic disciplines undertakes high quality and high impact research in the fields of smart connectivity and sensing, and contributes to UoA11.

Key research projects include:

- Integration and Evaluation of LoRa Sensor Technology for a Flood Early Warning System
- A KTP with SST Sensing on the Development of Fluorescent Polymers
- LED-Based Indoor Tracking for People with Dementia
- Low Energy Consumption Illumination Sources based on Collimating Optics
- Development of HV Condition Monitoring Systems.

While the group works closely with the SMART Technologies Research Centre, with key developments in wireless communications for the Internet of Things (IoT) and Industrial Internet of Things (IIoT) seen as potential growth areas, there is good interdisciplinary collaboration with colleagues in Health and Life Sciences and again, staff have strong international collaboration in publications in academic journals.

All four groups represent coherent academic discipline sets, however the staffing boundaries of the research groups are not fixed and staff may belong to and contribute to more than one group. The research group leaders co-ordinate the activities of the group and report these activities and achievements to the SCEBE Research Committee and Research Management Group.

Impact Strategy

The Unit benefits from the Knowledge Exchange Manager in the Research and Innovation Office (RIO) to support the planning and management of its impact as well as from an Impact and Knowledge Exchange Officer appointed to the School in 2017. They have provided significant guidance to researchers about approaching stakeholders for planning, collecting and curating evidence of impact. SCEBE has a business partner in the Communications & Engagement Directorate that is also very helpful in targeting media outlets and explaining the research and its impact to suit each media outlet's target market.

The aim of the Unit's impact strategy is for its research to be translated into demonstrable impact for the benefit of the different communities that it serves. The strategy objectives are to:

- Raise understanding of the scope of impact and empower our research staff to undertake interdisciplinary research with meaningful impact in local, national, and international publics / communities
- Embed Impact Thinking across the research project lifecycle and to encourage researchers to engage with planning pathways to impact as early as possible in the research process
- Develop a shared resource base to collect and curate ongoing impact and to develop research support infrastructure and target resources to strengthen existing mechanisms to promote stakeholder engagement, as well as develop systems and processes to gather robust evidence of impact
- Provide opportunities for the Unit's researchers from PhD student to Professoriate level to gain the appropriate knowledge, skills and resources to plan and evidence research impact through carefully planned knowledge exchange and patient-public involvement programmes
- Increase the number of projects with external partners having clear pathways to impact.

Through SCEBE, the Unit has collaborated with the University's Graduate School and Communication & Engagement Directorate to run training and development seminars for researchers that cover impact management, stakeholder engagement, public engagement and media training. Colleagues are also pointed to publicly available online resources.

Beyond the researcher training and development programme, researchers are strongly encouraged, through the peer review and mentoring processes, to consider impact early and often, during grant preparation, post-award implementation and post-project reflection.

Achievements over the REF period

Since 2014, the Unit has consolidated and enhanced its research position and international status through:

- Greater clarification of its strategic direction situated with alignment to the SMART Technology Research Centre
- The formation of research groups in order to develop a more cohesive approach
- Increased staff resources with new appointments in manufacturing, materials, and electrical engineering
- Improved career development pathways for its staff resulting in an increase in staff submitted from 21 FTE to 28 FTE (including 10 professors and four ECRs)
- An increase in research doctoral degrees awarded from 30 in REF2014 to 67.57 FTE this period
- Enhanced researcher recruitment, development and peer review processes
- Strategic investment in laboratory facilities (e.g. in chemical analysis and multi-phase flow)
- Stronger international and national collaborations particularly with industry (e.g. Doble (USA), TechnipFMC, EDF (UK), TUV SUD NEL Ltd (UK), Mitsubishi Electric Ltd (UK), Wuhan Electrical Power Company (China), Woodward L'Orange GmbH (Germany) and many SME's) and actively engaged in research pools such as the Scottish Research Partnership in Engineering and the Energy Technology Partnership
- Richer impact engagement and interactions with industrial sectors, policymakers, government, schools and the general public.

Future Strategy

The Unit's strategy looking to the future draws on the experience and expertise of staff working in partnership with industry to improve efficiency, introduce new technologies and drive sustainability and align with the University's ambitions in social innovation. The Unit has therefore a commitment to innovating for social and economic impact, and engaging globally in line with the Universities values. The staff of the Unit are actively engaged with relevant local research pools, industry bodies and innovation centres and intend to be increasingly responsive to UK and Scottish Government policy direction through increased interaction with Holyrood. The growing importance of AI and ML in engineering is a key driver for strategy of the Unit's development in staff training and activities which will result in increasing the impact of the research output. The requirement for the democratisation of science and the open research initiative require staff to be ever more open to collaboration and dissemination of research data and results and the School will invest in data collation and sharing facilities and policies. It is envisaged that significant new opportunities for external collaboration and impact may be derived via the open research agenda. The Unit currently shares data with colleagues nationally and internationally, however, in the future the Unit is committing to share appropriate data and information on an open platform, accessible to fellow academics and citizens around the world. A current example is the code developed for a project concerned with modelling and simulation of superalloy under extreme environments which is open and available on GitHub [<https://github.com/jeffenhuang/MSM-MD> and <https://github.com/jeffenhuang/lammps>].

Aligned with the mission outlined in the Muscatelli Report, staff submitted in UoA12 have been successful in securing funding from Industry partners through sources such as KTPs, and support of doctoral studentships either fully funded or as a contribution to schemes available through Innovation Centres e.g. the Energy Technology Partnership and CENSIS.

The Unit's plan for the next five years will be to both continue to re-align effort in support of advances in research activities associated with Industry 4.0 technologies, e.g. IIoT and Digital Twins which has increased the need for instrumentation, sensors and software-intensive

systems in existing labs and re-aligned technician support, and maintain current level of investment in areas of success, through internal investment in new laboratory facilities and staff appointments aligned with research groups. These developments are planned in collaboration with colleagues in the SMART Technology Research Centre which has a budget to facilitate innovative developments.

Our strategic objectives are to:

1. Increase the scale, quality and impact of the Unit's activities through greater industrial collaboration. The SMART Technology Research Centre will provide a focus for this activity.
2. Enhance the research environment, culture and structure to underpin internationally excellent research through an employment strategy to attract high calibre ECRs and support their progress. This will be achieved by forming collaborations with research intensive institutions through both formal means such as the Scottish Innovation Centres and the Energy Technology Partnership and through natural alliances, by supporting inward and outward visiting professors and researchers and by adopting sector best practice in research management.
3. Increase the volume of research income from UKRI and the EU by increasing collaboration with research intensive institutions and improve the quality of applications through an internal peer-review college.
4. Increase the number of postgraduate research students and their subsequent successful completion and transition them into a positive career destination. This will be achieved through greater success in securing research funding to support studentships, investment at University and School level and support provided to postgraduate students by the Graduate School.
5. Strengthen our international collaborations in order to address problems that require solutions that work in multiple cultural contexts, for example in the solar energy area where techniques developed may be applied in developing countries in line with the University Mission.
6. Strategically engage with beneficiaries and research users to ensure that the Unit's work achieves maximum impact through active engagement with major industrial or civic partnerships in applied research to solve real world problems, and embedding the impact paradigm within the Unit and impact management through dedicated staff functions.

2. People

The Staffing strategy of the UoA working through the SMART Technology Research Centre aims to enhance research outputs, income generation in research, contract research and CPD activities, as well as research impact on technology development and practice and to build capacity to enhance external collaborations and better capturing of impact on industry. All UoA staff will enhance their understanding of technical or research process areas that will play to strengthening the Unit's capability, particularly as it moves into new areas e.g. Data Science, unconscious bias training, and culture training to enhance international collaborations. The UoA fully endorses and utilises 'The Concordat to Support the Career Development of Researchers' and gives due recognition to the importance of recruiting, selecting and retaining researchers with the highest potential to achieve excellence in research. In doing so, researchers are openly recognised and valued as an essential part of the human resource pool and vital components in achieving the University's overall strategy for development and delivery of world-class research.

During this REF period, five of the 28 staff submitted are newly recruited to GCU to contribute to teaching and enhance specific targeted research areas. Examples of staffing strategy and staff

development within UoA12 are: Gomez was recruited as an ECR, and Munoz de Escalona as a lecturer in the Department of Mechanical Engineering to replace retired staff in the specialism of materials and manufacturing. Dr Gomez was given a reduced teaching commitment and assigned an academic mentor, Prof Anjali deSilva, and has been a PI in a successful KTP application. Dr Munoz de Escalona is a more experienced academic and has been supported to gain promotion to Senior Lecturer within two years and make valuable contributions through published output.

All the Unit's staff are involved in both teaching and research, with no staff being assigned "research-only" duties. However, all our researchers – irrespective of their job-mix – are valued for their contribution to our research activities and are supported in their efforts to be flexible and adaptable in what is an increasingly global, diverse, and mobile research environment. Their personal and career development and lifelong learning is recognised and promoted at all stages of their valued career. Individual researchers take, and share, responsibility for being pro-active in engagement within their lifelong learning, career, and personal development. This is managed through the University's Performance and Development Annual Review (PDAR) process to set workload, training and performance indicators.

Researchers submitting work for external consumption engage in our (School) Peer Review process, which seeks to aid them in ensuring their work is of high standard.

In terms of career development support, ECR's are supported through Research Groups (support and mentoring by established staff) and a School-wide ECR Group; their Head of Department will actively seek appropriate relief from normal duties to allow the ECR to focus on their research development and outputs.

Whilst the University actively enhances support for the PGR student community via the institution-wide Graduate School (<https://www.gcu.ac.uk/graduateschool/>), PGR students are embedded in their relevant Research Group as well as having ample opportunity for cross-discipline discourse via the annual student-led RiSE (postgraduate Research in Sustainable Environments conference) and co-location in a mixed-discipline office environment.

Starting in 2017 the PGR Student body has organised conferences, with financial and administrative support by the School. This provided a safe and welcoming environment for the School's PGR students to practice presentation skills in a professional context, to learn about their peers' work and form a closer-knit student community. From September 2019 onwards, the PGR conference (RiSE) was opened for presenters from other Scottish universities and further afield, thus providing a wider platform for exchange and peer network formation.

GCU Academic Development and Student Learning (ADSL) hosts a series of Graduate Teaching Assistant (GTA) workshops aimed at PhD students considering lecturing as a career. Topics that have been covered in the series include teaching to small groups, teaching international students, blended learning, teaching through simulations and managing disruptive behaviour in the classroom.

The Unit greatly values the contribution made by researchers studying for MPhil and PhD awards to the culture, output, dissemination and promotion of the research work conducted within the Unit. All PhD candidates have a Director of Studies and supervisory team appointed before the start of their studies and all supervisory teams have at least one member of staff being entered to REF2021. All Directors of Study and Supervisors have secured PhDs, or have significant industrial experience in their own cognate areas and undergo initial and on-going training in the management of PhD candidates. The Unit has secured several externally funded studentships which are aligned with the Unit's research areas. The Unit's forward strategy is to target increased collaboration with research-intensive universities, industry and the public sector through the research pools e.g. Scottish Research Partnership in Engineering. All new research student appointments are made following interview in accordance with the University Equality and Diversity procedures.

Research students are encouraged by their supervisory team to disseminate their research to the wider academic communities by publishing in a range of refereed journals and through attendance and presentations at national and international conferences. The School provides approximately £1,800 per student over their course of study to underpin their project and development; the students, together with their supervisors, agree on the most beneficial use of this budget, for example whether to support laboratory consumables, specialist IT equipment or generic skills development and attendance at conferences.

In 2017, in recognition of the cost involved in attending international conferences, the School changed its previous practice of offering students participation in at least two research poster colloquia over their three year PhD tenure, to the student-led organisation of a postgraduate research conference, where the students can practice conference presentations in a supportive and peer environment and showcase their research work to the wider School research community. Each student benefits from presentation feedback and the opportunity to engage with other research students from different discipline areas within the School.

In response to PhD student feedback on office space (closer proximity to relevant labs, supervisors and Research Groups), the School is in the process of co-locating PGR students in close proximity to the Research Centres. The longer term plan includes the establishment of a central research hub on the 5th floor of the George Moore building in the Glasgow campus, whilst allowing for specific needs of some research students for extended opening hours (e.g. for complex computer processing work) to be located elsewhere with extended office hours.

Training and development of PhD students is facilitated by a learning development plan developed by students themselves, with input from their supervisors. This is a combination of courses offered by the Graduate School, including graduate teaching roles as required, and students receive feedback from academics and construct a reflective log so that their personal development can be self-evaluated and provide feedback on the students' progress. The Graduate School plays a significant role in the general developmental needs for research students by providing a developmental research training framework. The topics covered include research skills, methodologies and techniques, research management and information collation, research ethics, language skills and academic writing, networking, team working and career management.

Whilst the University actively enhances support for the PGR student community via the institution-wide Graduate School, PGR students are embedded in their relevant Research Groups as well as having ample opportunity for cross-discipline discourse via the annual student-led RiSE (postgraduate Research in Sustainable Environments conference) and co-location in a mixed-discipline office environment. The UoA discipline specific and School-wide Equality and Diversity Postgraduate Research Tutors work with all supervisory teams to plan and deliver research training programmes aligned with the Vitae Researcher Development Framework and to ensure that all PhD students are active members of their Research Group and satisfactorily complete a transferable (research) skills programme prior to completion.

Researchers submitting work for external funding engage in our (School) Peer Review process, which seeks to aid them by ensuring their work is of high standard. The Peer Review Process is aimed at larger projects (over £50,000), or those where GCU takes a lead role within a consortium, and is enhanced by internal review and support. The peer review college is a virtual group of experienced researchers and project leaders, who are selected based on their personal and professional experience to provide internal review of proposals. The peer review process is conducted as an ongoing support mechanism, where researchers are encouraged to involve peer review as early as possible in the proposal development, rather than a gate keeping scrutiny at point of submission. The School's Research Management Group, which is made up of the Associate Dean Research, three Centre Directors, Senior PGRT, Impact Officer and Senior Research Administrator, oversees the peer review process and formally records peer review outcomes.

During the current REF period a total of 67.57 FTE research doctoral degree completions were recorded under UoA12, where a staff member from UoA12 acted as a supervisor. 79% of the completions were male and 21% female while 64% of the graduates came from overseas. The UoA currently has 53 students registered (44 Male, 9 Female; 28 Home/EU, 25 overseas; 23 Full Time and 30 Part-Time). This reflects a growth from a total of 42 registered students reported in REF2014.

Diversity and equality are promoted in all aspects of the recruitment and career management of all our researchers and PhD candidates. We strive to ensure that our regular and collegiate progress reviews strengthen the attractiveness and sustainability of research within UoA12. The University's Equality and Diversity and Dignity at Work policies and practices are deployed across all aspects of the recruitment, career management and exit of all of our researchers and PhD candidates. The policies ensure that each person is treated equitably and with respect and that decisions made are transparent and sound. All staff subscribe to these policies and undergo engagement and training to ensure that individual and collective approaches to such matters are robust. Local champions lead the implementation and raise awareness of the policies and contribute actively to bottom-up and top-down initiatives such as Research Group lead, Athena Swan group, Internationalisation group, ECR group, PGR conference organising committee or PGR tutors. Dr Boutaleb is chair of the School Equality and Diversity Committee and chair of the University Tackling Racism Short Life Working Group. The UoA is committed to the specific goal of ensuring that "Minority ethnic people experience better outcomes in completing further and higher education, and in transitioning to the labour market after completion" [The Scottish Government's Race Equality Framework (2016)].

3. Income, infrastructure and facilities

Following the merger of two academic schools in 2014, and a refresh in 2018 to form the School of Computing, Engineering and Built Environment (SCEBE), the increase in physical facilities and central support service has enabled researchers to focus on specific work and to utilise these enhanced facilities e.g. laboratories, technicians, funds. The staff complement has been bolstered by recruitment of specialist researchers in electrical power.

With a shift in the structural composition of the three Units within the School and the prevalence of interdisciplinary projects, the Unit has seen a drop in total funding over the REF period from £3.68m in REF2014 to £2.58m in REF2021. This may have been in part due to the re-structuring of the Unit and the creation of the SMART Technology Centre and consolidation of staff into more research groups. Furthermore, several recent large awards were delayed or did not realise their full income potential within the REF period due to the recent upheaval caused by Covid-19. In the later part of the REF period, the Unit is realising the benefit of the recruitment of new staff, staff re-training in AI/ML and the strategic direction of the research groups, which has resulted in a number of successes: a KTP with Mitsubishi awarded in 2020 with a total value of £493,080.00 (Alkali and McGlinchey in collaboration with researchers from UoA11); a KTP with Precision Tooling Services Ltd. on the optimisation of smart precision electrochemical machining awarded in 2020 with a total value of £211,244.00; a EUR900k EU funded Capacity Building project on Renewable Energy Technologies in Sri Lanka with a total value of £123,742.00 (Farrag, in collaboration with researchers from UoA13).

There have also been two substantial rounds of funding from Doble Engineering during the REF period to form the Doble Centre for Innovation which has supported a KTP and several PhD studentships. This has resulted in a new advanced technology product range for Doble Engineering. The research work in the Electric Power area is the basis of two of the Impact Case Studies included in this submission.

The staff in the Unit have traditionally been very successful in working with industry partners, and we have currently running KTPs with: Mitsubishi Electric Air Conditioning Systems Europe Limited, in a major investment project to embed understanding of IIoT, predictive and prescriptive analytics, to allow development and implementation of a model for monitoring and

optimisation of production processes, that will translate into higher manufacturing yield, productivity and capacity, and with Precision Tooling Services Limited to develop and embed expertise in electrochemical machining to deliver enhanced capability of precision component manufacture for the aerospace, automotive and renewable energy sectors.

Several KTPs completed within the REF period include:

- MAHLE Engine Systems UK Limited: To apply a surface characterisation and metallurgy knowledge to identify factors influencing integrity of bimetallic strip bond delamination. To develop testing and process monitoring tools, techniques and procedures for the assessment of bimetallic strip bond integrity and monitoring of critical process parameters. Grant Amount: £132,377.
- First ScotRail Limited: To review existing maintenance practices, develop condition monitoring products on passenger trains and identify optimal cost-effective maintenance strategy and periodicities. Grant Amount: £131,240.
- Doble Powertest Limited: To develop the capability of ElectroMagnetic Interference for diagnostic condition assessment of generators, motors and cables to support the power generation industry. Grant amount: £157,904.
- SST Sensing Limited: To embed chemistry expertise to develop the next generation of gas sensor solutions. Grant Amount: £140,884.
- James Howden & Company Limited: To undertake dynamic modelling of oil injected screw compressor systems, leading to improved control system design and performance optimisation across a wide range of operating environments and fluid characteristics. Grant amount: £160,637.

The Unit has a wide range of specialist apparatus and dedicated laboratory facilities supported by trained and experienced technical staff. These include a High Voltage Laboratory with two 100kV transformers, a Water Purification and Remediation Facility, Sustainable Energy Laboratory integrating micro-renewable sources and a Gas-Solids and a new industrial scale Gas-Liquid-Liquid Multi-Phase flow facility as detailed in the forward plan from the REF2014. The multi-phase flow facility was utilised in an Energy Technology Partnership funded studentship in partnership with TUV SUD NEL Ltd and the University of Edinburgh and the recently awarded CENSIS research project Developing a Smart Venturi Wet-Gas Meter to Foster Efficient Gas Production and Digital Transformation in partnership with TUV SUD NEL Ltd.

In addition, the Unit's spectroscopic and microscopic equipment supports activities across all School research themes. The equipment includes Gas-Liquid Chromatography, High Performance Liquid Chromatography, Gas Chromatography-Mass Spectrometry, Liquid Chromatography-Mass Spectrometry, Fluorescence Spectrometers, FT-IR Spectrometer, Raman Microscope, Laser Scanning Confocal Microscope, Atomic Force Microscope (AFM) with STM capability, Scanning Electron Microscope (SEM) with EDX and Transmission Electron Microscope (TEM). Within the Unit this equipment is utilised in the support of materials research and sensor development.

The Unit has been successful in securing funding and in producing outcomes for the two research areas indemnified in REF2014 for investment and development: (i) securing energy supply with an aging infrastructure through the development of novel diagnostic tools and sensors, and (ii) the development of diagnostics and sensors for water quality monitoring and remediation. In both areas the work has developed with industrial collaboration.

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

The UoA is actively engaged with, and contributes to, the wider research base and beneficiaries; much of this activity is co-ordinated and supported by the Research Groups, who provide a focal point for discipline specific information and exchange both inwards and outwards, and the SMART Technology Research Centre as a strategically guiding support mechanism.

UK-based collaboration

The staff in the Unit work collaboratively with research colleagues in universities across the UK which has resulted in joint research funding and co-authored outputs with institutions such as: University of Strathclyde, University of Glasgow, University of Edinburgh, University of Nottingham, Northumbria University, Robert Gordon University, University of the West of Scotland, Cranfield University, University of Sunderland, University of Cambridge, University of Leeds, University of Bath, University of Sheffield, Queen's University Belfast, University of Exeter, Cardiff University, University of Portsmouth.

International Collaboration

The Unit has developed a number of capacity building projects, especially with ODA countries, through GCRF and EU funding, including:

- EU-funded E-Stem project with the Arab Academy for Science and Technology and Maritime Transport and Alexandria University (Egypt)
- Development of Smart optical wireless communications projects with University of Novi Sad (Serbia)
- A Water Treatment Device for Hybrid Clean Water/Energy Transferrable Platforms with Alexandria University and Addis Ababa University
- A visiting fellowship from National Autonomous University of Mexico to investigate the effect of vibration on the loss of function of refrigerator doors
- Knowledge exchange activities with Dedan Kimanthi University of Technology (DeKUT).

The Unit also maintains a close relationship with institutions across the world through joint publications and other academic collaborations: Yildiz Technical University (Turkey), Vellore Institute of Technology University (Tamil Nadu, India), Wuhan University (China), Université du Québec (Canada), University of Paris-Sud XI (France), University of Electronic Science and Technology of China (Chengdu, China), University of Oslo (Norway), Delft University of Technology (The Netherlands), Shahrood University of Technology (Iran), National University (Oman), Texas A&M University (Qatar), Eötvös Loránd University, Shiga University of Medical Science (Japan), Łódź University of Technology, Universiti Kuala Lumpur British Malaysian Institute, University of Malaya, Universiti Teknologi MARA (Malaysia), Jubail Industrial College (Saudi Arabia), Qatar University (Qatar), Université Grenoble Alpes (France).

Staff within the Unit contribute to a wide range of activities across their respective research disciplines, such as board members of committees of national and international professional bodies, conference scientific and organising committees, academic journal reviewers, funding application reviewers, external examinerships, and public engagement and outreach activities to schools and colleges through, for example, Primary Engineer.

Editorial Roles

- Dr Ibrahim Kucukdemir: Journal, (SCI-E) Editorial Board Member and Associate Editor, Turkish Journal of Electrical Engineering and Computer Sciences, Editor of the Proceedings 13th IFAC Workshop on Time-Delay Systems, (49), 10, 2016, Editor of the Proceedings 6th IFAC Symposium on System Structure, (49), 9, 2016, Invited Editor, Measurement and Control, 2020
- Professor Chengke Zhou: Associate Editor of SCI indexed journal "High Voltage", 2016
- Dr Ahmed Aboushady: Associate Editor of IEEE Access Journal (IF=4.098), 2019-date. Associate editor of Renewable Energy and Sustainable Development Journal, eISSN: 2356-8569, Editorial board member of Journal of Electrical Engineering, David Publisher, ISSN: 2328-2223.

Keynote and Plenary Presentations

- Professor Chengke Zhou: Keynote speaker to international conference on condition monitoring and diagnostics (CMD2016)
- Dr Ahmed Aboushady: Plenary talk at Scottish Renewables Solar Conference, Edinburgh 2016.

Professional and Industry Body Engagement

- Dr Ibrahim Kucukdemir: Senior Member IEEE (2019), IEEE UK and Ireland Section, Control Systems Chapter, Committee Member and Membership Secretary, Turkish National Committee on Automatic Control, IFAC Technical Committee Member (2.5) on Robust Control, IFAC Technical Committee Member (2.2) on Linear Control Systems, IFAC Technical Committee Member (2.6) on Distributed Parameter Systems, IFAC Technical Committee Member (7.1) on Automotive Control
- Dr Ahmed Aboushady: Member of JWG 11 “Performance of voltage source converter based high-voltage direct current transmission” linked to SC 22F of the PELS/022 British Standards Institution (BSI) and International Electro-technical committee (IEC), 2019-date. Member of International Council on Large Electric Systems (Cigre) Working Group B4.81, 2019-2021, Senior member IEEE, Aug 2017-date. Technical program co-chair of the 53rd International Universities Power Engineering Conference (UPEC) 2018 conference, GCU, Sept 2018
- Professor Babakalli Alkali: Member Rail Research UK, Fellow of Operational Research Society
- Professor Don McGlinchey: European Federation of Chemical Engineering, Working Party Member – Mechanics of Particulate Systems, NAFEMS CFD Working Group Member, Editor of NAFEMS Journal of Industrial CFD Case Studies
- Professor Chengke Zhou: Author of international guideline, CIGRE brochure 706 - The use of statistics and statistical tool for analysis of life data.

The research of the staff in the Unit is informed and enhanced through collaboration with Industrial partners and this important aspect is exploited through personal and professional networks (e.g. IMechE, IEEE and IET) and is typically financially supported through direct funding and knowledge transfer partnerships. Doble Engineering have invested approximately £1 million in supporting the research in high voltage condition monitoring systems at GCU during this REF period. EDF Energy has also made significant investment in the Unit's research activity which has changed the way power cables and motors are monitored and asset life redefined in EDF Energy's nuclear power stations and Scottish Power in the UK. Further industrial collaboration in the form of KTPs has been undertaken with companies including Mitsubishi Electric Ltd, Doble Powertest Ltd, and SST Sensing Ltd which has contributed to the financial health of the companies and the economic sustainability of the UK, through sustainable quality employment for workers.

Industry Engagement and Collaborations

Scottish Power Energy Networks, Technip Umbilicals, ZF Lenksysteme GmbH, UVEX Arbeitsschutz GmbH, Ernst & Young GmbH, Kuwait Petrochemicals Industries [PIC], Voith GmbH, Abellio ScotRail, Aalen Institute of Materials Research, Pilz Optics, Oman Oil Refineries and Petroleum Industries Company [ORPIC], Robert Bosch GmbH, Raptor Oil Ltd, TUV-SUD-NEL Ltd, Mitsubishi Electric Air Conditioning Systems Europe Ltd., Precision Tooling Services Ltd, Doble Powertest Ltd, SST Sensing Ltd.

Summary

In summary, the staff in the Unit are committed to making a meaningful contribution to the wider University strategic research alignment with the UN Sustainable Development Goals. The Unit recognises that engineering is a fast-evolving and increasingly cross-disciplinary area where an agile approach is required to address the current and future needs of society. The benefits from the formation of new research groups and the Smart Technology Centre, the recruitment strategy and training of staff, and targeted partnerships nationally and internationally with academic colleagues and industry are beginning to be realised and give a positive future direction for the Unit.