Institution:
Edinburgh Napier University

Unit of Assessment:
Unit of Assessment 12 - Engineering

1. Unit context and structure, research and impact strategy

Unit Context

Engineering research at Edinburgh Napier University (ENU) being submitted to UoA12 is focussed in two main areas:

(i) Smart Technology
(ii) Infrastructure Engineering

The Unit comprises of 27.4 FTE submitted category A staff, all of whom are located within the School of Engineering and the Built Environment (SEBE). SEBE is a vibrant academic unit comprising 68 category A staff. It will also return 12.6 FTE category A staff to UoA13, hence approximately 61% of SEBE academic staff are deemed significantly responsible for research. The comparable submission figure in 2014 was approximately 50% of SEBE staff.

SEBE is one of 6 academic school units at ENU. Its mission is to deliver high quality education and research to add value to the social, cultural and economic capital of the communities it serves. Through alignment with the University's overarching focus on Well-being & Sustainability and the research themes of Environment and AI Technologies, SEBE contributes significantly to the University mission. In 2019/20 SEBE had an undergraduate population of 1,237 and a taught post graduate population of 426. There were 27 research postgraduate students.

The last time SEBE submitted to a general Engineering UoA was to RAE 2001, when it was rated as a 4, ranked between 14th and 21st in a field of 48 submissions. Since then, and especially following REF 2014, the engineering research environment in SEBE has been the beneficiary of significant changes. A review at University and School level prioritised interdisciplinary, high-impact themes. Recent strategic recruitment was successful in the new appointment of 18 talented research staff who can drive high-quality research. Consequently, the 2014 emphasis on civil, construction and transportation engineering, has broadened to include robotics, sensors, human-centred design, and materials, as well as geotechnical, timber, structural, power and renewables engineering. Transportation engineering is now being submitted to UoA13.

These developments have allowed SEBE to revive former strengths, to nurture new ones, and to submit again under Engineering. The scale of the broader scope is significant considering that of the 28 members of staff being submitted now, only 10 were at ENU in 2014 and submitted to REF2014. Moreover, 11 of the 18 newer recruits have been recruited since 2018. Hence we have put in place a group of researchers who are bringing results.

Structure: Centres and Groups

Integration of new appointments into University and School activities has, since 2018, led to an exciting evolution of research strategy and structures in this Unit. Research is now clustered into two themes or centres: (i) Smart Technology and (ii) Infrastructure Engineering.

Within each centre there exist two or three research groups, as illustrated in Fig. 1. The five research groups also provide an internal context for discipline expertise in the Unit (Fig. 1). They are charged with giving staff a sense of coherence and critical mass while remaining alert and open to interdisciplinary and collaborative ventures. The strategic aim of each group is to

achieve impact and sustainability in relevant, applied research. New staff are strategically appointed with this in mind.

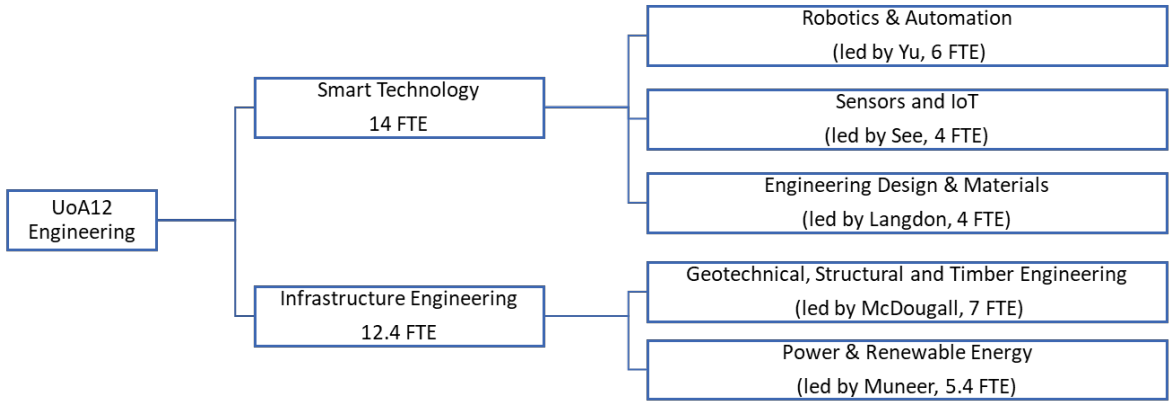

Fig. 1 UoA12 Research Centres and constituent Research Groups together with current FTE

Smart Technology Research Centre (STRC)
As a direct consequence of a revitalised research strategy, excellent research is performed across the three groups that make up the Smart Technology Research Centre; Robotics & Automation, Sensors and Internet of Things, and Innovative Design & Materials. The structure facilitates multi-disciplinary collaborations nationally and internationally.

Robotics & Automation: This group comprises 6 FTE staff: led by **Yu**, with **Guiver**, **McWhinnie**, **Goh**, **Givaki** and **Taylor** (1 professor, 5 lecturers). Brought together following recent new appointments **(Yu, Guiver, Givaki)**, the group has expertise in leading edge digital, control, and AI technologies and methodologies. In robotic solutions, applications concern rotorcraft landing on uneven terrain and under extreme conditions **(Goh, McWhinnie, Yu)**.

Fundamental research is conducted on the intersection of mathematical analysis and mathematical control theory **(Guiver, Yu)**. New techniques are invented in positive state control systems with a view to applications in mathematical biology and ecology **(Guiver)**. Research has also taken place into cyber security of Industrial Control Systems with colleagues in the School of Computing (SoC) **(McWhinnie, Goh, Yu)**.

Yu has undertaken research on SMOOTH-Smart Robots for Firefighting, funded by EU Horizon 2020, and has developed a novel robot-assisted decision-making system in smart firefighting. The team has also just secured an initial award from Scottish Ambulance Service to enhance efficiency of call out operations.

Across the robotics and sensors groups, innovative bicycle sensor systems have been developed and applied in road-surface condition monitoring and human-hand vibration monitoring has led to changes in EU standards **(Taylor, See)**.

Sensors and IoT: This group comprises 4 FTE staff: led by **See**, with **Alwis**, **Kerrouche** and **La Spada** (1 associate professor, 3 lecturers). The recent appointment of **See** and **La Spada** enabled the emergence of this group. Driven by sensor applications, this group has developed innovative telecommunications systems, wireless sensor networks, antennae and sensors (both electromagnetic and acoustic) for healthcare and extreme environment applications (**See**, **La Spada**). It also concerns embedded optical fibre sensors in civil engineering infrastructure for structural health monitoring **(Alwis, Kerrouche)** and water borne pathogen detection **(Kerrouche, See)**.

Engineering Design and Materials: This group comprises 4 FTE staff: led by **Langdon**, with **Vasantha**, **Dorris** and **Sun** (1 professor, 1 senior research fellow, 2 lecturers). This entirely

newly recruited group brings international recognition for work on inclusion, ageing, ergonomics, interaction design and user experience (particularly the analysis of human factors), human machine interface design and the ergonomics of autonomous vehicles from SAE L3-5. It also concerns public opinion on Connected and Autonomous Vehicles (CAVs).

This work is backed up by design informatics analysis into innovation and rapid product development **(Vasantha)**. Expertise also exists around effective design reuse, integrated product and service design, model-based system engineering and analysis, problem-based patent documents clustering, and adaptive crowd intelligence in engineering problem-solving **(Givaki)**.

This group's research is strongly multidisciplinary in scope, recognising the need for comprehensive approaches to climate change, transport and the challenges and opportunities of IoT and communication technologies. As such, it reaches out to other groups within and without this Unit. For example, although his research sits in UoA12, **Langdon** also leads the Transport Research Institute, which is being submitted to UoA13.

Work in materials is led by **Dorris** and has been on two main topics; self-healing industrial coatings for protection of metal structures such as off-shore installations (**Stankiewicz**, now left the University), and harvesting of nano-cellulose from seaweed **(Dorris)**, the latter funded by Zero Waste Scotland.

Centre for Infrastructure Engineering
Infrastructure Engineering is broadly a civil and renewable energy research grouping. There are two groups, with expertise clustered around; geotechnical, structural and timber engineering (including timber resources), and power and renewables (solar, wind and marine).

Geotechnical, Structural & Timber Engineering: This group comprises 7 FTE staff: led by **McDougall**, with **Barreto**, **Dimitriadi**, **Zhang**, **Ridley Ellis**, **Marinelli and Khokhar** (1 reader, 2 associate professors, 4 lecturers). The geotechnics team **(McDougall, Barreto, Dimitriadi)** has notable expertise in the characterisation and modelling of unusual soils (landfilled waste, peat, and rubber soil mixtures), hydro-bio-mechanical formulations with grading entropy concepts implemented via finite elements, finite difference and discrete element methods **(McDougall, Barreto)**, and seismic performance of shallow foundations due to liquefaction and ground improvement **(Dimitriadi)**.

The timber and structures team have strengths in wood science, silviculture, timber properties timber composites and novel engineered-timber structures including bamboo, I beams and oak whisky casks **(Zhang & Ridley-Ellis)**, structural dynamics of timber floors, innovative hybrid cross laminated timber structures **(Khokhar)**, and material characterisation of natural building stones, structural assessment and restoration of historic buildings **(Marinelli)**.

Work in wood science has a strong external presence through the Centre for Wood Science & Technology (CSWT). With large scale testing facilities located in an industrial complex in Edinburgh, CSWT is led by **Ridley-Ellis** and staffed by three research assistants and technicians. Its main aim is to better understand how the management of forests and the climate influence the properties of produced timber, and how these affect its performance in different applications.

The group's commitment to applied research is well illustrated by the impact of work done on the structural integrity of whisky casks by **Zhang** and **Kermani**, and on wood science by **Ridley-Ellis**. Both are submitted as impact case studies to this Unit. **Zhang**, **Kermani** and **Ridley-Ellis** were key to the award of the Queen's Anniversary Prize in 2015, which was also won for timber engineering work in 2009.

Power and Renewables Engineering: This group comprises 5.2 FTE staff: led by **Muneer** with **Vedreno**, **Cai**, **Sola**, **Papadopoulos** and **Tingas** (1 professor, 5 lecturers). The interest of this

group is mainly in electrical and power engineering, including energy and distribution, energy storage, and renewable energy sources (solar). Recent appointments **(Sola, Papadopoulos, Tingas)** have broadened the renewable energy focus to include wind and marine. Additionally, **Muneer** has worked (collaboratively with colleagues in the Transport Research Institute) on the electrification of transportation. A particular strength of the group is solar energy, in relation to CIBSE guides for weather and solar data modelling.

Notable expertise also exists in control and operation of HVDC converters and systems **(Givaki)**, modelling, design and prototyping of Power Electronics Converters and Drives **(Papadopoulos)** and fault diagnostics and condition monitoring for electrical machines **(Vedreño-Santos)**. This expertise is complimentary to work in the electrical and mechanical modelling of wind turbines, power train design and marine energy devices **(Sola, Vedreño).**

Fundamental research in the area of fuel efficiency has recently been added to the group's portfolio following the appointment of **Tingas**. This work concerns the dynamics analysis of reacting flows, and reduction of sophisticated complex chemical kinetics using an algorithmic method for asymptotic analysis.

The impact value of renewable energy research at ENU is well illustrated by the submitted impact case study on solar radiation **(Muneer)**.

Strategy for Next Five Years

SEBE, through alignment with the University's overarching research themes of Sustainable Communities, Information Society and Well-being, has contributed significantly to the University mission over the last 5 years.

The School and Unit are committed to the University's overarching research strategy as outlined in the REF5a. Future school strategies are informed by the institution's five-year focus on staff development, increasing innovation, and developing international research partnerships, and aim to feed into the broad strategic aims of the University. Future interdisciplinary opportunities will be guided by the new University themes.

Following the recent recruitment drive and planned submission to UoA12, we are very well placed to raise the bar and the profile of Engineering research in SEBE. On this basis, a research strategy and objectives for this Unit will drive international recognition for high quality research and build colleagues' careers. These objectives are:

- **Income: to increase income threefold across all categories (research, knowledge transfer, CPD) by 2024/2025**. This is an ambitious target based on the commitment to developing the research base in Engineering as shown by the recent recruitment drive.

- **Research postgraduates: to increase numbers of enrolled PGR students from 22 in 2021 to 32 in 2024/25**. This will be supported by a combination of external funding and continued internal pump priming of selected areas of research (e.g. by internal fee waiver when external funding is won).

- **High-quality outputs (widening staff capability): to increase the number of staff with two 3* or above outputs. Presently 39 category A staff in SEBE hold 3* or above outputs, which is 57% of the category A staff. We aim for this figure to increase to 70% by next REF.** This is objective will be met by promotion of an active research culture within the school, and by mentoring and regular exposure to the discipline base (e.g. by conference attendance).

- **High-quality outputs (consolidating capacity): to grow the number of internationally excellent outputs produced by individual staff.**

- **External funding success rates**: **to increase the proportion of staff who have won external funding from 38% to 50%.**

- **Significant contributions to research base: each research group member to demonstrate at least one activity that can be cited as a significant contribution during the census period.** The Unit will support researchers in undertaking significant activities, including; invited keynote/plenary presentations, journal editorial/editorship roles, and international conference organisation.

- **Public Engagement: at least one event per year organised by the Unit of Assessment.** This objective is to promote openness in our research, and to communicate to communities the type and value of the activity taking place in their local university. It will be supported by the SEBE public engagement champion.

- **Contribution to teaching: at least one case of research expertise driving the teaching programme.** STRC is actively developing research-informed teaching courses, and has already applied funds from Royal Academy of Engineering to fund two visiting professors to contribute the research-informed activities to the engineering subject group. One is Visiting Professor in Control and Instrumentation for the Industry 4.0 age, and the other is Visiting Professor in Developing Professional Skills for Electronic and Electrical Engineers.

- **Contribution to wider society, economy and community**: **generate three 3* impact case studies for UOA12 from the REF2021 submission.** The Unit has already identified 2 possible case study candidates for the next REF period, one in Robotics and Automation for Industry 4.0 and another on energy and power engineering. Work is also underway on the environmental impact of construction on peatlands.

Enabling Impact

Historically, engineering research in SEBE has been strongly applied (e.g. timber engineering, solar energy potential, wood technology, and fibre optics). Recent recruitment into the areas of human computer interaction, robotics, digital healthcare, Industry 4.0, robots for firefighting and manufacturing, have increased the scope of the Unit's application. For example, the recruitment of **Langdon**, whose work on MATSA (Motion Adaptive Touchscreen System for Automotive) has been funded by Jaguar Land Rover. Bringing in new researchers with applied focuses has improved the strong impact potential of the Unit.

The Unit has prioritised engagement with industrialists, entrepreneurs, consultants and innovators. A dedicated KTP facilitator has been used to support certain projects. A business development manager, with both regional and sector expertise, has been recruited to establish contacts. An enterprise lead has been appointed to guide future commercial strategy. In addition to this recruitment, group leaders in this Unit actively encourage staff to make use of University Commercial Engagement managers. Two colleagues working in the area of self-healing coatings **(Stankiewicz)** and Bamboo/timber composite beams and torsion testing **(Zhang)** have been helped by our Commercial Engagement manager in the Research, Innovation, and Enterprise Office to apply for patents.

Recognition of the priority given to impact is evidenced by our success in 2020 in securing two Industrial Visiting Professor Awards from the Royal Academy of Engineering. Visiting professors improve knowledge and understanding of key subject areas, as well as connecting research with the needs of industry and society. They also have a positive impact on graduates and research students by contributing to teaching and learning, as well as employability and skills. Visiting professors support SEBE engineering graduates and research students to strengthen external partnerships with industry during their studies.

This commitment to supporting applied research, with input from KTP and commercial experts, has strengthened colleague's readiness and capability to engage in impactful research. This approach underpins the Unit's three impact case studies:

Solar Radiation: Enabling International Innovative Design Applications for Professional Practice (Muneer)
Muneer's research into solar radiation and daylight was undertaken for organisations such as with the Chartered Institute of Building Service Engineers, and technology company Delta-T. By responding to the needs of these organisations, his research has impacted international standards, professional practice guidelines and products.

Improving Whisky Cask Performance to Benefit Distilleries (Kermani and Zhang)
Kermani and Zhang's research was a part of a KTP with one of the world's largest producers of spirits and beers. It has shown that improved knowledge of cask performance can benefit both the distiller and the sector as a whole by doubling cask lifespan, with improved methods of cask rejuvenation and a reduced need for replacement casks, and reduced liquor losses during maturation due to better bung design. This has led to high estimated savings for the producer.

Timber properties, grading & standards for sustainable modern construction (Ridley-Ellis)
The "Strategic Integrated Research in Timber" (SIRT) and allied projects have led to the creation of The Centre for Wood Science and Technology (CWST). The commercial support provided to this centre has led to funded projects from stakeholder groups, such as the Forestry Commission Scotland. The research has increased knowledge of key physical and mechanical properties of UK and Irish grown timber, resulting in improvements in standards for production and sustainable use of timber construction products, which has benefitted UK and Irish growers and sawmills.

Supporting Interdisciplinarity

Figure 2 shows schematically the interdisciplinarity of this Unit's work, both between research groups within UoA12 (intradisciplinarity), and between UoA12 and other schools or external bodies (interdisciplinarity).

Both intra- and interdisciplinarity have been nurtured by strategic recruitment. Recent arrivals, such as **Yu** and his work on robotics and automation, offer rich interdisciplinary gains, in this case in the medical arena and especially in digital healthcare. The strength and potential for interdisciplinary work are underlined internally with the Schools of Computing and Health Sciences, and externally with various organisations on topics such as smart robots for firefighting (e.g. impact of COVID-19 on Scottish Manufacturing Sector and investigation of an Industry 4.0 framework).

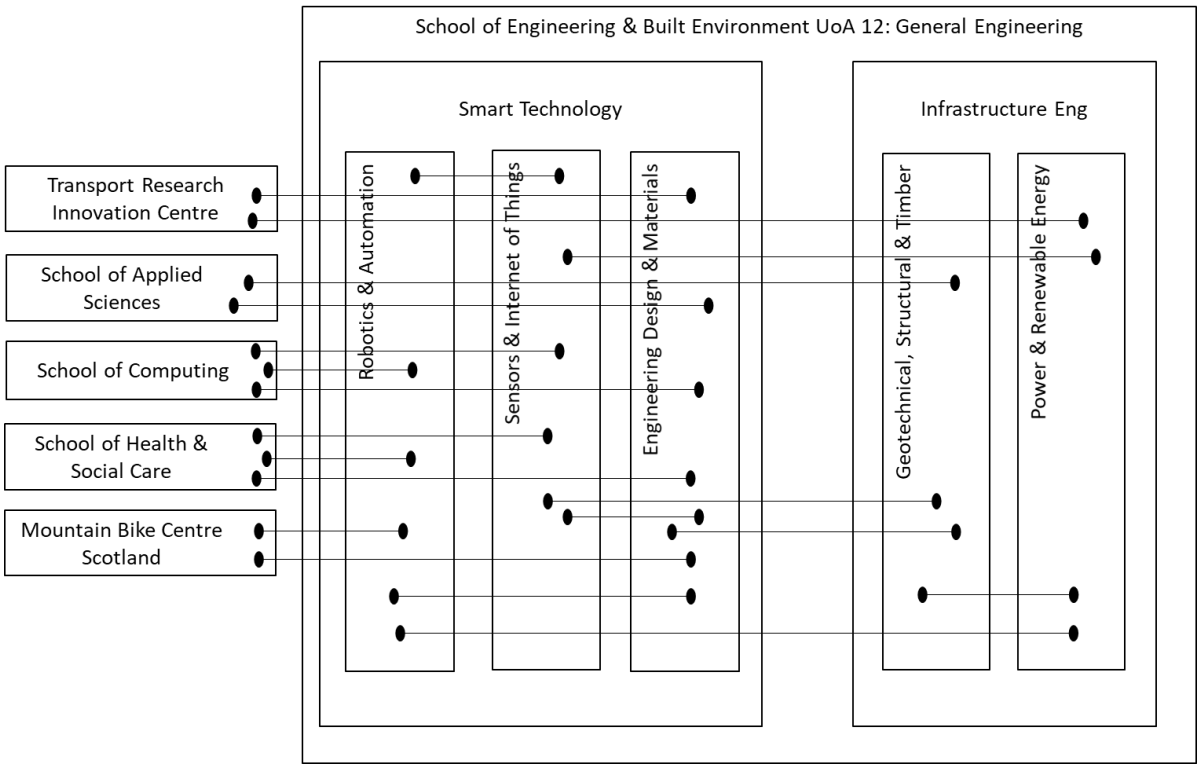

Fig. 2 Interdisciplinarity (between UoA12 and other research entities outwith SEBE) and intradisciplinary (within UoA12) research activity.

Professors **Yu** and **Langdon** bring establish reputations in Statistical Machine Learning, Machine-Learning, and Robotics, especially when applied to practical technology. This tranche of new expertise will be used to develop STRC/TRIc multi-disciplinary bids for funding. Novel research into technology in transport and infrastructure will be prioritised to respond to the growing needs of transport in a context of climate change, as well as addressing inequalities and lack of inclusion in the population. As a result, Human Centred Design will be closely linked to work by the TRIc and the Robotics and Sensors Technology group **(Yu)**.

Open Research

UoA12 at ENU is committed to making research findings public and freely available. The Unit follows University open research requirements, and outputs are held in the University repository and are compliant with the Concordat on Open Research Data. The School Head of Research is charged with ensuring compliance **(Yu)**. For REF2021, UoA12 will return 69 outputs, all of which are available from ENU or another university repository. 13 were published by gold route.

Regarding promotion of the open data agenda, the School is incorporating data management plans into the established funding peer review process. In addition, school research leaders, following engagement with the University Lead for Research Data, provide advice and mentorship to staff during pre-application stages. Exemplar data management plans are also made available to staff where appropriate.

Supporting Research Integrity

In accordance with University guidelines and requirements, research in the Unit is encouraged to be conducted to the highest levels of integrity, including appropriate research design and frameworks. To ensure that findings are robust and defensible, SEBE underpins its integrity and data protection commitments via its ethics committee. Chaired by **Langdon** and comprising 10 researchers and stakeholders, the committee meets on a quarterly basis. **Langdon** is a specialist in Research Ethics and Data Management.

The School is currently operating a pre-award requirement for new projects that may require the storage of any personal data. The aim of this is to ensure compliance with University regulations, UK Law and GDPR. This comprises of a researcher checklist, data management plan, privacy assessment, and informed consent and briefing document. The researcher's checklist is structured as a sequence of screening questions that identifies areas of ethical and integrity risk. Post award, projects will be required to get ethical approval from the SEBE ethics lead where items of potential sensitivity will be referred to the SEBE ethics committee.

2. People

Strategy

In 2018 SEBE made the strategic decision to re-establish engineering research at ENU by recruitment. As a result there has been a concerted effort to recruit into key areas. Of the 28 category A staff being submitted, 18 were appointed after the date of the last REF, which represents a threefold increase on the pre-existing 10 staff members. The submitted staff profile is: 71% lecturers, 11% associate professors, 11% professors, 4% senior research fellows, and 4% readers.

All staff members are on permanent contracts. Two of the new appointments were professors, recruited to lead in the areas of robotics, intelligent control & emerging technologies **(Yu)** and inclusive design, ergonomics and human factors **(Langdon)**. These individuals were targeted to lead these areas based on extensive publications records and success in grant capture. Nine of the lecturers in the Unit are early career researchers. Leadership capabilities in two of the research groups, plus succession planning in Infrastructure Engineering mean further recruitment to the Unit is still planned.

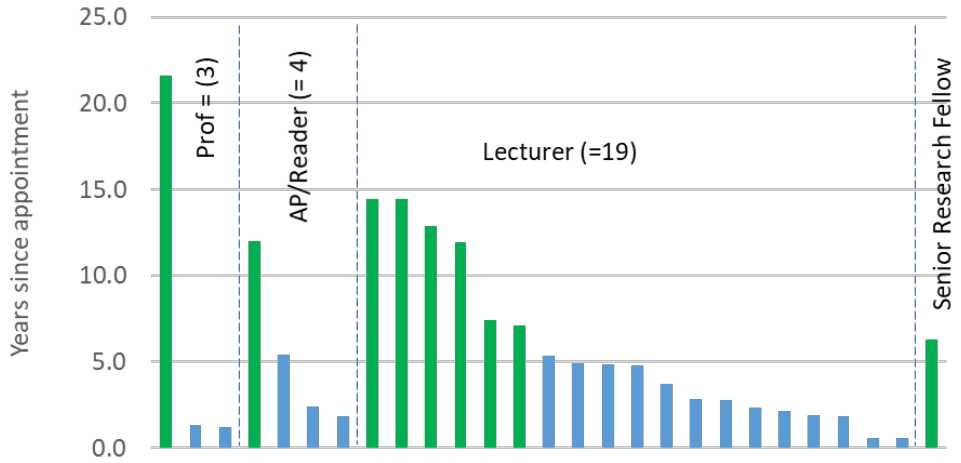

Fig 3. Length of service since appointment to ENU; post REF2014 shown in blue.

Staff Development

As described in REF5a, all staff are part of a newly-implemented career development scheme called '*My Contribution'*. In SEBE and UoA12 a portion of REG funding is made available for staff development. In the period, this has typically supported attendance at external training courses that are aligned with research training needs as identified through the My Contribution process.

SEBE uses the *My Contribution* process to ensure staff in the school from all backgrounds and experience are able to develop a research career. A good example of how the career development scheme has worked for this Unit is the case of **McWhinnie**, who has been on the

lecturing staff for over 25 years. Through more targeted and relevant mentoring, provision of research time, and development, **McWhinnie** is now being submitted to REF as significantly responsible for research.

More broadly, the number of category A staff in SEBE holding what have been internally assessed as two or more internationally excellent outputs is 39 out of 69. This is planned to increase to 48 by the next REF. As in the case of **McWhinnie**, other staff have been identified as developing for REF, and are provided with protected time and mentor support to ready them for the next submission.

It is recognised that sabbatical leave provides an opportunity for staff to develop links and enhance the national and international profile of their teaching and research. This Unit is committed to University sabbatical policy as set out in REF5a.

The Unit provided a semester sabbatical for **Barreto**, who organised a 4-month residency at Zhejiang University, one of China's foremost research institutions. He worked with Professor Zhongxuan Yang on the cyclic behaviour of driven piles in sand for offshore installations. This visit, provided by The Royal Academy of Engineering's Research Exchanges with China and India Programme, led to publication of several conference and journal publications, the co-supervision of 1 MSc student and 1 PhD student, and the award to **Barreto** of the title of Visiting Scholar at Zhejiang.

The impact of **Barreto's** visit was managed by adopting a collegiate and reciprocal approach to sabbatical cover, drawing on the benefits of team-teaching. Indeed, such an approach is now a key part of University policy on sabbatical leave.

Staff Recruitment Policy

UoA12 has made strategic appointments at lecturer level in geotechnics **(Dimitriadi)**, electronics **(La Spada)**, structures **(Marinelli)**, mechanical engineering **(Givaki, Sola, Papadopoulos)**, interactive design **(Vasantha)**, and engineering mathematics **(Tingas, Guiver)**. The Unit has also attracted experienced staff and postdocs from strong European research institutions (e.g. **Langdon** from University of Cambridge, **Papadopolous** from University of Nottingham). At associate professor level, one appointment has been made in electronics **(See)** and at professor level, three have been made (**Yu**, **Langdon** and **Keates**, Keates has now moved on). One research assistant has been promoted to a lectureship **(Sun)** and one staff member has been promoted to associate professor **(Zhang)**.

Plans to recruit at professor level in civil engineering and in mechanical engineering were delayed by COVID-19, although an individual has now been recruited to the mechanical engineering professorship.

This strategy has been a major factor in the significant increase in outputs eligible for REF submission, experience in grant success, doctoral student supervision capacity and importantly, what has internally been judged to be the improvement in the quality of outputs. Recruitment to all new academic posts will continue to emphasise the need for all successful candidates to understand and demonstrate support for the indivisibility of research and teaching, as well as having strong research track records.

Early Career Researchers (ECR)

To allow the long-term sustainability of research in UoA12, ECR's are provided with a number of opportunities to develop and access funding. UoA12 has 9 staff who are early career researchers.

Specific encouragement and support to help build ECR careers is given in a number of ways:

(i) **Mentoring.** ECR's are allocated a mentor to support them in developing skills and identifying training needs across the academic role. Mentors advise on publications strategy and support ECRs in considering external early career research grant opportunities. A school-wide peer review scheme is in place to support the application process.

(ii) **PhD supervision**. UoA12 aims for each ECR to have minimum of one PGR student for whom they are director of studies, to improve their experience of supervision.

(iii) **Preferential consideration in internal funding**. In 2020/21, a call for bids into SEBE 'seed-corn' funds saw ECRs submit 10 out of a total of 15 applications, 4 of which are in this Unit. They secured £30,000 from a total £94,000.

(iv) **Training workshops**. ECR's are provided preferential support to attend specialist workshops (e.g. **Vedreno** at TechEx).

(v) **Conference attendance**. ECR's are supported in attending conferences to make direct contact with the research base. It is also a valuable opportunity to create, to cultivate, or to seek to join networks that are active in research fund bidding. We are keen to support early career academics to attend conferences (e.g. **Alwis**, IEEE Sensors, **Turnbull** and **Melia**).

(vi) **School ECR forum**. This is a school-based discussion group led by an academic who has only just 'graduated' from ECR status and is an active researcher **(Alwis)**.

The two research centres have directly invested in ECRs over the period via core funding, pump priming initiatives and bridge funding between projects. The Unit has 5 post-doctoral research assistants/fellows.

Exchanges with Business

As has been mentioned regarding impact, the Unit supports applied research as a matter of course. This has led to exchanges and collaborations with a number of businesses, for instance, a KTP with a large spirit producer has led to an impact case study.

A Royal Academy of Engineering Industrial Secondment was won by **Zhang** in 2019. The secondment was 0.5 FTE for 12 months at Intelligent Wood Systems (IWS), part of the Glenalmond Timber company in Perth, Scotland. IWS had equipment and corresponding engineered wood product expertise to support **Zhang**'s work on pre-stressed bamboo-timber composite beams.

The industrial secondment has since led to the appointment of IWS staff (Cleverly) as a visiting professor, thereby enhancing industry and research-led teaching.

The Unit has also formed a number of research groups, whose collective expertise and industry profile has led to a high number of exchanges.

CWST is a large-scale testing facility housed in an industrial complex. By placing the centre in an industrial setting, the findings from this research group have led to frequent exchanges with industry.

STRC is another group which allows strong links with companies and international partners through its Advisory Board, Honorary Research Fellows and Associates. For example, STRC has recently appointed Dr Carol Marsh (FIeT, Deputy Head of Electronics Engineering, Leonardo) as an industrial visiting professor.

Postgraduate Research Students (PGR)

In 2019/20, there were 22 PGR students in SEBE. Staff in UoA12 have supervised 8 ENU PhDs to completion in the period. The year by year breakdown is shown in Fig. 4 (and should be read in conjunction with the relatively large number of recently appointed Category A staff, as depicted in Fig. 1).

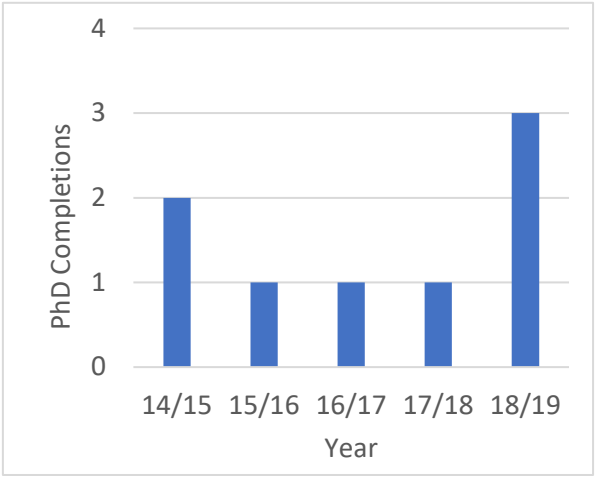

Fig. 4 Number of PhDs completed at ENU by staff aligned with UoA12 by year.

As a key part in the creation of a vibrant research environment, we plan to grow our PGR student population by 10% per annum over the next period. The new strategy and focus of research in UoA12 has already led to a rise in PhD applications. An interim target of a SEBE PGR population of 29 has been set for 2022/23, with a proportionate increase in this Unit of approximately 10% p.a.

PGR Recruitment

In the period, the unit has aimed to increase student numbers, to provide more student finance support, and to increase international PGRS collaborations.

PGR student recruitment has enjoyed internal support via 7 Anniversary scholarships for fees and stipends between 2015-2019. The Unit has also had success in achieving a number of specific, project related PGR students (Forestry Commission Scotland, Energy Technology Partnership Data Lab, SEPA), and more recently has recruited to unfunded positions through direct contact and advertising on FindaPhD, marking the desirability of PGR study with UoA12 staff.

International PGR student activity has been facilitated through a memorandum of understanding with Ningbo University in China to jointly supervise PhD students (registered at ENU) in the field of transport. The students receive a 50% fee waiver.

This is the first of a number of strategic partnerships that the School plans to broker with other international institutions to boost PGR student numbers. For example, we have begun research student collaborations with another five Chinese universities, all of which will operate under ENU research degree regulatory and supervision frameworks. In this scheme, research students are jointly supervised by both our staff and faculty staff at the partner institution. Fee income is shared while the award remains an ENU degree.

One of the benefits of these international collaborations is the potential for more extensive academic cooperation between the two institutions, for example joint publications assume greater importance. At this stage we have joint supervision agreements with Shanghai University of Engineering Science (SUES), Dongguan University of Technology (DGUT), Guangxi

University of Science and Technology (GXUST), Shanghai Normal University (SHNU) and Zhongkai University of Agriculture and Engineering. We have already welcomed two PGR students to the scheme, one each from SUES and DGUT.

Muneer secured competitive funding for a PhD student from the Energy Technology Partnership, which is an alliance of thirteen independent Scottish universities and the largest power and energy research partnership in Europe. Led by ENU, the award was won in conjunction with the Wood Group and Heriot-Watt University.

Support and Development for PGR Students

Monitoring and support mechanisms have been introduced in response to feedback received both directly and via the institutional PRES survey. They target subject specific research capabilities and more generic skills needed by a successful research leader.

Monitoring of research student progress is managed locally by a school-wide Research Degrees Committee, chaired by **Fonzone**, the PGR lead for the School. Progression protocols are handled under a University-wide scheme, as set out in REF5a.

SEBE holds an annual two-day PGR conference, usually at an external education or team-building facility. Research supervisors are active participants. It also holds a School research seminar every fortnight, at which PGR students give presentations on their work to their peers, staff and external visitors.

SEBE organises writing groups and 'off campus' research retreat weekends. These events are part of a wider initiative to mentor and support PGR students to co-author papers with their supervisors, and have led to students publishing two or more refereed journal papers, supporting thesis submissions. SEBE has also instigated an annual paper-writing prize competition to encourage high quality authorship.

We have also awarded monies from a hardship fund (£8,000 in 2020) in response to COVID-19, and previously to assist students in financial difficulty (**Donker, Du**; c £14,000), to ensure talented researchers can realise their ambitions.

SEBE uses RPG funds to support PGR attendance at external courses, for example training in the use of SPSS. Resourcefully, two research students **(Gharavi**, **Islam)** requested to attend a course on LaTex with the intention of delivering the same course to the entire SEBE PGR student population. SEBE supported them in this endeavour.

Research students can also access funds for conference attendance, and supervisors help PGR students to select the most useful events based on the quality of the conference, the likelihood of a subsequent publication, and years into the registration period (priority being given to students closer to submission) (e.g. **Livingstone, Turnbull, Melia, Bernal**).

Equality & Diversity

SEBE and UoA12 are committed to ensuring all staff and PGR students have equal access to research opportunity, and both abide by University policies as set out in the REF5a. Within the Unit, research group leaders ensure that sufficient staff can cover others with caring responsibilities/maternity leave. There is also a School Inclusion Monitoring Committee, charged with monitoring and reporting on equality and diversity matters.

Equality and Diversity Policy
Defined at University level, the Unit is committed to E&D policy in relation to:

(i) **Selection for REF submission (staff members).** This is guided at University level by the Code of Practice.

(ii) **Selection for REF submission (outputs).** This Unit has considered only refereed journal outputs. Selection from this pool of journal outputs is determined at University level by an impartial automated algorithm. The algorithm has been devised to maximise aggregate output score within REF and Code of Practice guidelines.

(iii) **Maternity leave (including returning from).** One member of staff has taken maternity leave from December 2020. The Unit is committed to covering the individual while away and will consider their reintegration carefully based on their needs following their return.

(iv) **Study leave**: As mentioned, **Barreto** has been permitted study leave in this period, and has been appropriately covered in his absence.

(v) **Disability.** The Unit is committed to ensuring relevant support is in place for those with listed disabilities.

(vi) **Protected characteristics.** The Unit is committed to ensuring all individuals have the support for their specific needs to allow them to perform research.

(vii) **Flexible working.** Although no individuals are currently working flexibly, the Unit is open to suggestions to support its staff.

(viii) **Timings of meetings.** We avoid early and late meeting times. We have one member of this Unit for whom such consideration is important as that colleague has caring responsibilities.

Equality and Diversity Profile
Selected characteristics of the submitted staff in UoA12:

Gender: 14% identify as female, and 86% identify as male. All female members of staff are at lecturer level. SEBE is keen to encourage women in engineering, having a representative **(Pantsi)** on the local Women in Engineering Society, and being one of only two Schools in the University to hold an Athena Swan Bronze Award (awarded 2017).

Ethnicity: 14% identify as Asian, 54% identify as White, 25% identify as Other, and 7% are Unknown.

Disability: 4% identify as having a disability, 92% identify as having no disability, 4% are Unknown.

Age Profile: 14% are 25-35, 46% 35-45, 18% 45-55, 18% are 55-65, 4% are 65-75.

3. Income, Infrastructure and Facilities

Income

Since 2014, £5.3m of research, commercial and consultancy (RC&C) income has been won by 23 SEBE academic staff working in engineering. It is evident from Fig. 5 that this income is predominantly EU industrial funding, mostly income from the South African Paper Products Industry, secured by **Turner** in the period 2015-2017. UK central government bodies are the second largest source of income.

Of the 23 staff members to achieve funding in the period, 9 have retired or left ENU. The 14 who remain are aligned with and contribute to UoA12. These 14 staff members brought in £1.56m. The main sources of income are now UK central government and the Research Councils (see

Fig.6). The yearly income for the 14 UoA12 staff contingent is seen from Fig. 7 to be variable from year to year but with relatively constant average trend over the period.

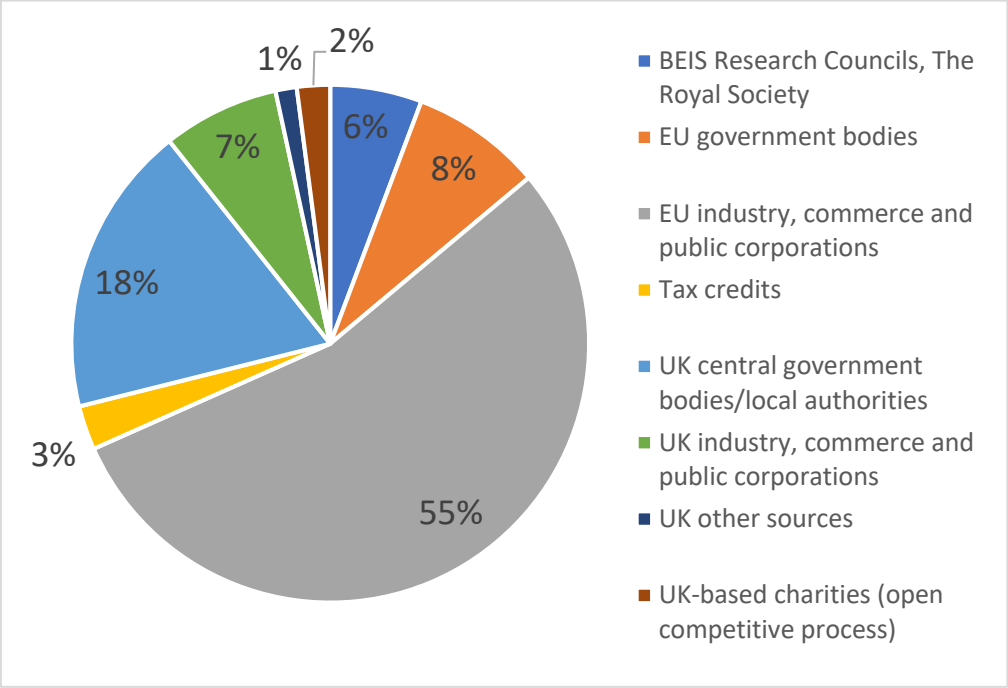

Fig. 5. UoA12: Income by busitype, 2014 -2019 (all engineering staff). Total income = £5.3m.

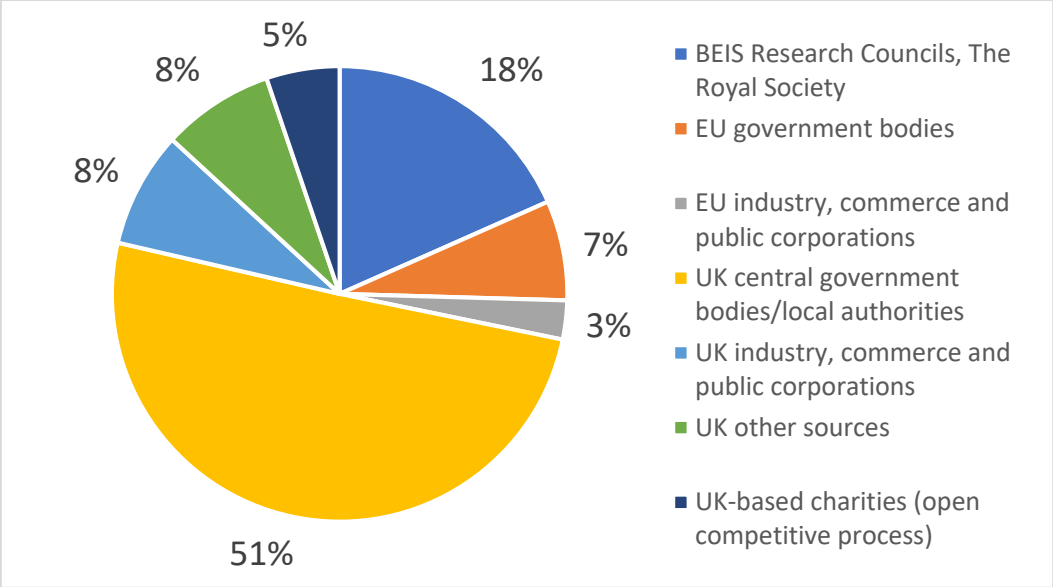

Fig. 6. UoA12: Income by busitype, 2014 -2019 (only staff currently at ENU. Total income = £1.56m).

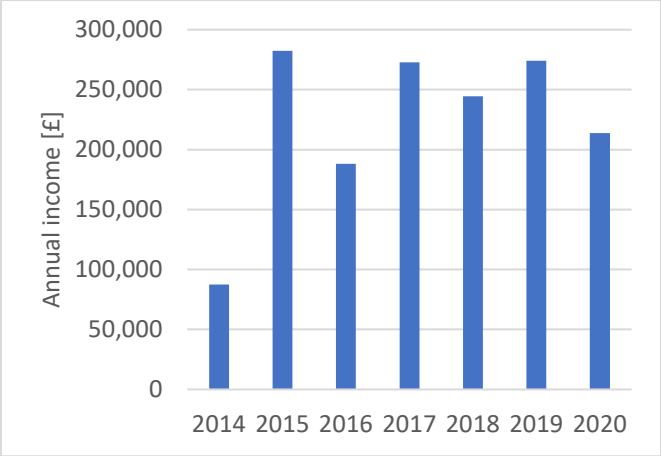

Fig. 7. UoA12: yearly research, commercial and consultancy income brought in by current UoA12 category A staff.

Research Income Strategy

UoA12 has enjoyed the influx of 18 new staff members in the period, who have transformed a small group of independent scholars into a vibrant and active research unit. This recruitment has allowed us to move into a number of new research areas via new staff members research interests. Balancing past performance of established academic staff in UoA12 (see previous section) with the enthusiasm and early evidence of potential success of new recruits, we are targeting **research income of £0.5m p.a. for UoA12 in 2020/21** and an annual increase of 10% thereafter.

We will seek to achieve these targets by increasing the number of KTPs across the School, and through targeted support of academics with strong links to industry. School innovation managers have been appointed to support this, with responsibility for building industry and other external relationships, increasing KTPs and identifying opportunities to generate external research income **(McCarthy, Harris)**. Recent successes from these appointments include the award of £10,000 from Scottish Ambulance Service for innovation metrics for AI and ML on data sets, and robotics in emergency medical services.

Planned increases in the number and/or value of funding bids will be incorporated into staff annual reviews as a part of constructive *My Contribution* discussions. New academics will be encouraged to benefit from REG funding to an internal competitive process that encourages and rewards the development of good quality research proposals. In 2019/20 exchequer funds were allocated using a new approach and 22 proposals were funded from the 36 submitted, with priority given to supporting ECRs.

Funding has also been ringfenced to support networking opportunities, training and conference attendance. All academics will have the opportunity to attend at least one conference a year, subject to having a paper accepted for presentation.

Infrastructure and Facilities

The School is further developing its organisational structure of groups, centres and institutes, as set out in Section 1. These structures will clarify the context and ownership of research targets such as outputs, income and impact.

Research management across UoAs, is headed up by a School head of research **(Yu)** supported by the directors of the two research centres and a school research and innovation

officer. This group makes strategic decisions about the allocation and focusing of internal research funds to support conference attendance, small research projects, and PhD studentships and research fellow appointments. It also monitors outputs and steers the allocation of research time on the basis of what staff have achieved in the previous year. Support for knowledge exchange (KE) activities, public engagement and commercial contract research activity, is provided centrally through the Research, Innovation and Enterprise Office (RIE), and by the school public engagement (PE) champion (professorial level) and KE admin staff. This support has led to a significant increase in PE, KE and diverse media engagement by staff since REF 2014.

During 20014-19 the University invested over £5 million in specialist labs and equipment, the major contribution being the new purpose test laboratory facilities at Seven Hills on the west side of Edinburgh. The Seven Hills facility houses the Centre for Wood Science and Technology (CWST), which provides strategic structural test facilities for timber construction, wood science, offsite construction prototypes and material analysis.

UoA12 is the principal user of the School's physical infrastructure and resources. There are 8 laboratories spread across two sites (Merchiston and & Seven Hills), the former supported by 5 technical staff **(Laing, Dhonju, Wilson, Campbell, Best)**. All accommodate staff and postgraduate research and undergraduate teaching or project work.

At the main (Merchiston) site there are laboratories dedicated to heavy electricals, manufacturing (including FMC), heat control, fluid mechanics, materials (including scanning electron microscope), geotechnics (including cyclic triaxial rig and earthquake shaking table), environmental travel (including motorcycle rolling road), large scale structures, fibre optics, fabrication and machines.

Materials Lab: Tescan Vega LMU with Secondary Electron, Back Scatter Electron, Energy-dispersive X-ray Spectroscopy and Electron Backscatter Diffraction detectors; Cyclic Corrosion Cabinet.

Nanomaterials Lab: PSI-20 Microfluidiser; LabRAM Acoustic mixer; LAMBDA™ 750 UV/Vis/NIR spectrophotometer; AR1500 Rheometer; DSC Q2000 Differential scanning calorimeter; Zetasizer - Dynamic Light Scattering; Freeze Dryer.

Geotechnics Lab: Wykeham Farrance Dynamic Triaxial rig; Quanser Shaking Table.

Structures Lab: Large-scale (3 m x 3 m) Racking Rig; Zwick Rowell Multi Actuator (100kN, 200kN, 300kN) Servohydraulic (2 m) universal testing frame.

Timber Lab: Zwick 050 Universal Testing Machine; (5 m x 2 m x 2 m) Moisture conditioning chamber; Microtome sectioner.

Robotics & Automation Lab: Festo FMS (Flexible Manufacturing System) Scaled Festo Flexible Manufacturing System (FMS) with 9 networked Siemens S7-1500 PLC's, Mitsubishi Robot Controller and SCADA; NXTone distributed controllers; Festo Robotic and Vision Cell; Mitsubishi SCARA Robot Cell, Festo process control rigs with Siemens S7-1500, (vi) Festo pneumatic platforms with PLC S7-1200 controllers, Festo (Robotino) Autonomous Robots from; Quanser Q-bots.

Electrical/Electronics Lab: Specialist electrical equipment includes: (i) R&S ZNB40 Vector Network Analyzer; LPKF Protomat E44 Rapid PCB prototyping machine; Yokogawa DL850E Scopecorder DL850E-Q-HE Portable mixed signal oscilloscope and data acquisition recorder; Yokogawa AQ6370D Optical spectrum; Micron SM125 Optical Sensing Interrogator; Anrithsu MS2711B Spectrum Analyser up to 6 GHz.

Most laboratory spaces are on the ground or basement floor of Merchiston, all of which are accessible to wheelchair users.

At Seven Hills, we have a 700 m^2 high ceiling, pillar-free, wood science and timber research facility. The Centre for Wood Science and Technology is based at 7 Hills. Specialist test equipment includes large scale beam bending and torsion test rigs and conditioning chambers, optical microscopes, and NDT equipment (including sonic and ultrasonic acoustic tools for 3D tomography).

Diamond Light Source, the UK's national synchrotron facility, located at the Harwell was used by researchers in materials group to look at effects of intra- and inter-crystalline swelling agents on cellulose nano-fibril production.

The School has linked with and established new industry and external sector advisory panels, involving both private and public sector organisations. These have advised and mentored new research and innovation developments towards impactful outcomes. Examples include strategic partnerships with the industry-led Construction Scotland Innovation Centre, Forestry and Timber Industry leadership group, and the regional transport partnership SESTrans.

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

Collaborations with Other Institutions

The Unit has benefited from a number of inward visiting academics in the period. These include; Professor Claudio Mahler (Federal Universidad Rio de Janeiro), Joan Esteban (Universidad Jaume I), Paride Tamburrini (Politecnico di Torino), Marina Miranda, (Universidad de Cantabria), Zixuan Li (IAESTE, University of Macau), Associate Professor E J Gago (University of Granada), Prof Peiliang Wu (Yanshan University), Prof Qui Yuan (Chinese Academy of Science), and Suphitcha Chanruerang (Mahidol University).

Engagement with Key Research Users

McWhinnie works with Wyman Gordon (consultants in the aero-space sector) on advanced automation control systems. **Kerrouche** collaborates with Pyreos (a consultancy service) for testing and characterisation of novel infrared sensors. **Zhang**, works closely with Intelligent Wood Systems (specialists in bespoke engineered wood products) and has benefitted from access to advanced manufacturing capabilities. Recently he has had success in engaging the IWS technical director as a Royal Academy of Engineering visiting professor. **Dorris** has led work on nanocellulose production and application with Scottish Enterprise under the High Growth Spinout Fund, and development of rheology modifiers funded by IBioIC.

Contributions to Economy, Society, and the Sustainability of the Discipline

Infrastructure Engineering
Work in the area of Infrastructure Engineering covers timber engineering, geotechnical engineering, structures, power and renewable engineering. A number of accolades and measures of esteem have been garnered, and evidence of influencing the sector accumulated over the census period.

Ridley-Ellis, who heads up the Centre for Wood Science and Technology, and **Zhang** made a key contribution to the award of the 2017 **Queens Anniversary Prize** for Timber Engineering. **Barreto** is the UK representative on the **ICSSMGE Technical Committee**, TC105.

Barreto has sat on five **editorial panels**, including Geotechnique (2019-), Computers & Geotechnics (2017-2020), Proc. ICE Geotechnical Engineering (themed) (2019), and Proc ICE Geotechnical Engineering International (2018). **Zhang** has been on the editorial panel of the ASCE, Journal of Civil Engineering since 2018. **Muneer** has been on the editorial Board of

Future Cities and Sustainable Cities & Society. **Ridley-Ellis** has sat on European Journal of Wood Products since 2018.

Invited lectures and/or conference **keynotes** have been given by **McDougall** at IISc Bangalore (2018), Precipitation & Dissolution at KAUST (2016), Fukuoka University (2016) and by **Zhang** at HKUST (2019). **Zhang** also won a RAEng Industrial **Fellowship** for a collaborative project with Intelligent Wood Systems on engineered timber products in 2019, and best paper prize at **Wood Science** (2017). **Cai** is a visiting scholar at Queens, Belfast. **Ridley-Ellis** was invited to give Royal Forestry Society's Lawrence Pilling Lecture in 2019, and a lecture at the Ecole Superieure du Bois in Nantes.

An increasing contribution to the research base is evident from the more than 20 **external examinations of PhDs**, at both UK and overseas institutions, undertaken by Infrastructure engineering staff. These include; **Marinelli** with National Technical University of Athens (2016), **Barreto** with Edinburgh (2019), Sheffield (2018) and Bristol (2017), **McDougall** with Southampton (2015 & 2019), Delft (2016), Bristol (2017), Cantabria (2017), IISc Bangalore (2020) and for a professorial appointment panel at King Saud University (2016). Also, **Zhang** with Andhra University (2019), Hong Kong University of Science and Technology (2019) and University West London (2017).

There has been an increase in **conference organisation** activities in the period, either as lead organiser, session chair or scientific committee roles. These include; **Barreto** via Geoteknik (2019), Micro-Macro, Atlanta (2018), Granular Matter, Glasgow (2018), Rains & Rivers, Edinburgh (2016), MTGS (2016), GM3 (2019), EMI (2020) and IS-Geo Micro to macro (2019). **McDougall** was session co-chair at XVI ECSMGE International Conference (2015). **Zhang** has maintained a steady involvement with a number of timber/structural engineering conferences, including Civil, Structural and Environmental Engineering (2015 & 2019) and Timber Structures (2015 & 2019).

Advisory/expert witness steering group activity have been undertaken by **McDougall** on the Dutch Sustainable Landfill Management Project (2018), **Ridley-Ellis** on North European Network for Wood Science, and TRADA (Timber Research and Development Association) and **Zhang** on Chinese Ministry of Science's Plan 111 (2017). Many staff **(Barreto, Ridley Ellis, Tingas, Cai, Vedreno)** have been **reviewing grant** proposals for EPSRC, COST Actions and the Carnegie Trust.

Infrastructure Engineering research has also provided a basis for **outreach** activities. For example, **McDougall** was invited to present on seismic protection using rubber soil mixtures to a special session on the developing World at Edinburgh Science Festival (2019). **Ridley-Ellis** has been instrumental in the Bright Club's Science Comedy night, and is frequently called upon by news media, such as BBC World Service, to comment on timber source quality matters. All staff regularly review papers for a wide range of civil engineering journals and in one case, **Barreto** has been awarded 'Outstanding Reviewer' status by the American Society of Civil Engineers for four consecutive years (2015-2018).

Smart Technology

Work in the area of Smart Technology covers Robots and Automation, Sensors, and Engineering Design & Materials. As is the case in Infrastructure Engineering, significant changes following new appointments have occurred. Only four members of this 14 strong group were returned to REF 2014 at ENU **(Yu, Langdon, Dorris)**, and four staff are early career researchers. Accolades and measures of esteem have been garnered and evidence of influencing the sector has accumulated over the census period.

Yu won the International Exposition Geneva **prize** (2015) for his invention on haptic robot control. In 2017, **Alwis** won Australian Water Association award for research innovation. **See** won Bolton University's Jenkinson Research Award in 2017.

Yu has been **guest editor** for 3 special issues on smart manufacturing, and non-linear controls in journals such as Energies (2017), and Journal of Mathematical Problems (2014 & 2016). **See** was guest editor for International Journal Antennas and Propagation. **Alwis** was guest editor for MDPI Applied Sciences and Sensors (2019). **La Spada**, an ECR, is on the editorial panel of Journal of Physics D.

Invited lectures and/or conference **keynotes** have been given by **Taylor** as part of Windesheim University's Applied Science Week (2016), and by **Yu** at Smart Industry Workshop on Robotics and Automation in 2019.

More than 15 **external examinations of PhDs**, have been undertaken by smart technology engineering staff. For example, **Yu**, with Sussex (2014, 2015, 2018) De Montfort (2014), Liverpool John Moores (2016), Northumbria (2016), Southampton (2017) and Central Lancashire (2017), and **See**.

Researchers in the Unit have been Involvemed in **conference organisation** activity. This includes; **Kerrouche**, who was part of local organisation of IEEE World Congress on Computational Intelligence, and **Givaki**, who was session chair at Grid Integration (Universities Power Engineering Conference) in 2018. **Vasantha** was on the scientific committee of International Conference of Engineering Design, Delft, in 2019, and **Yu** was General Chair of the International Conference on SKIMA, 15-17/12/2016, General co-chair of the International Conference on Advanced Mechatronic Systems in Japan 10-12/08/2014 and China 22-24/08/2015, and IPC Chair of the EPSRC Network Plus: Industrial Systems in the Digital Age Conference 2017 & 2018.

Advisory/expert witness steering groups. Taylor has recently been appointed to BSI Committee GME/21/6 on Human Vibration & Shock. **Yu** is an EPSRC college member. **See** and **Alwis** have been **reviewing grant** proposals for EPSRC.

Our research has also provided a basis for **outreach** activities. For example, **Taylor** has been active in the Construction and Built Environment Challenge for local high schools, and **Kerrouche** has put on a Microfluidics show at another local school.

All staff regularly review papers for a wide range of smart technology journals.