Institution:
Glasgow Caledonian University

Unit of Assessment:
13: Architecture, Built Environment and Planning

1. Unit context and structure, research and impact strategy

Context and structure

The Unit's strategic alignment is within one of three societal challenges envisaged by GCU Research Strategy 2020 and 2030: "Sustainable Environments." It is further framed by the UN Sustainable Development Goals (SDGs). Since 2014, the research structure of the Unit has evolved from subject specific research groups and a School-wide single Research Institute into external-facing Research Centres [Research Centre for Built Environment Asset Management (BEAM) https://www.gcu.ac.uk/assetmanagement/ and the Centre for Climate Justice (CCJ) https://www.gcu.ac.uk/climatejustice/]. The UoA's vision is aligned with the University mission "for the common good" to conduct research that delivers significant practical benefits and impact for society (BEAM Centre - resource utilisation in the creation, maintenance and renewal of built assets, by investigating the social, environmental and economic interdependencies of sustainable built environments; and CCJ - health, wellbeing and sustainability in the face of climate change and its in/justice dimensions). The aim is to provide a coordinating function that allows the tackling of cross-disciplinary research (societal) challenges. The Research Centres are subject to a University-wide rigorous approval and re-validation process.

Supported by funding from industry and philanthropic gifts, the BEAM Centre was created in 2015 to explore the social, environmental and economic interdependencies of sustainable built environments in the context of global climate change and natural resource utilisation. Specifically, BEAM research is aligned with SDGs #6 - Clean Water; #7 - Affordable Clean Energy; #8 - Decent Work & Economic Growth (especially labour rights and safe working environments); #9 - Innovation and Infrastructure (built infrastructure); #11 - Sustainable Cities & Communities (smart cities, urban heat island, urban sustainability); #12 - Responsible Consumption & Production (sustainable use of natural resources used in construction); and #14, #15 - Life below water and life on land (environmental impact of construction and built environment).

The Centre for Climate Justice (CCJ) emerged from a partnership with the former President of Ireland Mary Robinson and the Mary Robinson Foundation for Climate Justice (MRFCJ) to address a knowledge gap between climate science and social justice. CCJ is committed to quality action research that addresses climate change within the overarching context of the SDGs of 'leaving no one behind' with special focus on SDGs #1 (no poverty), #2 (zero hunger), #5 (gender equality), #7 (clean energy) and #13 (climate action).

The Research Centre structure is complemented by four peer-supported subject specific Research Groups that straddle the Research Centres. These are staff-proposed, organic and time-limited entities of active staff and associated postgraduate research students, that provide the operational environment for specific research projects. These developments follow the implementation of the GCU 2020 Research Strategy The four groups are: Nature-based Solutions (NbS) and eco-engineering; Water Research; Sustainable Materials and Structures; Construction. External funding and industry engagement are key features of all four groups.

- The NbS group investigates novel, sustainable, and ecologically sound solutions to global environmental hazards and impacts. Its multidisciplinary team brings together soil and plant science, applied ecology, hydrology, geographic information systems, civil engineering, environmental management, ecosystem services, and social science

(community and stakeholder engagement and asset management) to investigate the role of NbS in hydro-meteorological de-risking.
- The Water Research group employs multidisciplinary approaches combining water quality and treatment, environmental technology and management, biology and eco-toxicity, analytical chemistry and community and stakeholder engagement to research water-environment nexus.
- The Sustainable Materials and Structures group covers two areas - construction materials technology (materials durability, prediction of degradation during service life and impact on hygrothermal performance in constructions, environmental impact of durable materials including contribution of re-used and waste materials to more sustainable constructions) and design, analysis and modelling of concrete, timber and steel structures (dynamic performance of structures and structural performance of materials under extreme environmental conditions).
- The Construction Research group specialises in research focused on health, safety and wellbeing; contracts and dispute resolution; and productivity.

Research and Impact strategy

At the REF2014 submission, we identified four critical drivers for our future research. These are now well integrated into our research environment:

- Developing and integrating streamlined construction processes relevant to dynamic construction supply chains - with the establishment of the BEAM Centre, we have enhanced our research, public and industry engagement in Construction Project Risk and Value Management. These are highlighted in Section 4 and in our impact case study on 'Improving 'Safety in Design' Practices in the Construction Industry'.
- Driving forward sustainable built environments in relation to their physical environmental dynamism (bearing in mind climate change imperatives, and to optimise the use of scarce or dwindling resources) - the Unit in its entirety is now fully aligned with the societal challenge of 'Sustainable environment' with both our Research Centres engaging in research and advocacy work on the technical and societal aspects of sustainability (such as our impact case study on renewable energy from wastewater).
- Focusing on zero and low carbon buildings and the impacts on humans through the work of the RICH (Research on Indoor Climate and Health) Centre - the RICH Centre itself is now fully absorbed into the BEAM Research Centre and we have specifically expanded our capacity and impact on societal consequences of low/zero carbon buildings, in particular their unintended consequences (as evidenced by our impact case study on fuel poverty and energy policy).
- Encouraging curiosity-driven research, providing our researchers with the freedom to explore ideas within the strategic priority and emerging areas - the creation of peer-supported subject-specific Research Groups, with input from our Research Centre Advisory Boards have created pathways to pursue a wide array of primary research and to explore their societal implications (as evidenced in Section 4).

Responding explicitly to the societal challenge of 'Sustainable Environments', the UoA's research strategy aims to achieve four goals:

1. An externally funded research base in the area of safe, healthy and sustainable environments (see Section 3)
2. Build research capacity via early career researcher opportunities, post-doctoral fellowships and internships through external funding (including workshops, PDRA opportunities in career development including GCU Crucible Programme, co-hosting of visiting scholars, etc. - see Section 2)
3. Roll out of Continuing Professional Development (CPD) and research-based postgraduate programme provision in sustainable environment and climate change at GCU campuses, through Transnational Education Partnerships and online (See

Section 3); expand and build upon the established Knowledge Transfer Partnerships in the areas of societal, environmental and process management consequences of built environment (See Section 4)

4. Public engagement, advocacy and dissemination in themes associated with 'sustainable environments', including construction safety, building energy performance, environmental sciences, climate justice and stakeholder engagement (See Section 4).

Our approach to impact builds on the expertise of a range of staff submitted for REF2014 in UoA 16 at its core (in the areas of building performance, health and safety in construction, waste management and sustainability assessment), but has evolved to focus on the SDGs in light of the new research talent available for REF 2021 (including built asset management, fuel poverty, nature-based solutions, climate justice and renewable heat). Our industry facing remit facilitates impact through capacity building and innovation events, knowledge transfer activities and policy engagement and advocacy. The Unit benefits from Knowledge Exchange Officers in 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.

Industry engagement and capacity building with external agencies including the Health and Safety Executive (HSE) and the Chartered Institution of Occupational Safety and Health (IOSH) is exemplified by the Unit's Impact Case Study on "reducing construction accidents: saving lives" that provided a gateway process and digital tools to reduce occupational safety and health in construction projects. An exemplar of knowledge transfer is provided by the Unit's impact case study on 'renewable energy from waste water' that turned an environmental problem into a renewable resource for the Strathclyde Passenger Transport (SPT) in Glasgow. Policy-engagement and advocacy is exemplified by the impact case study on 'fuel poverty and energy policy' that led to the inclusion of financial 'uplift' for rural and island households in Section 3(6) of the Scottish Government's Fuel Poverty (Targets, Definition and Strategy) (Scotland) Act 2019.

Furthermore, the Unit envisages enhanced impact through an open and sharing environment. Going beyond the REF requirements of open access, we utilise the external-facing portals of our two Research Centres as repositories (such as https://www.gcu.ac.uk/climatejustice/research/ and https://www.gcu.ac.uk/assetmanagement/researchrepository/) of research that not only disseminate research findings but also act as a testament to the societal benefit of our work, reinforcing the University's ethos of 'common good.'

The combined effect of our research and impact strategy is seen in the following summary changes:

- We have increased the number of staff with significant responsibility for research from 21.6 FTE in REF2014 to 24.8 FTE (approx. 15% uplift) whilst the overall staff strength has remained the same (63 in both years), yet we have secured in excess of £3.7M funding
- Our research outputs have stronger focus on quality journal publications (75% in REF 2014 vs 100% in REF21)
- Widening of our research impact on practice, policy and technology (as evidenced by our impact case studies)
- Growth in the total number of PGR students (63 in 2013/14 vs 77 in 2019/20)
- Research doctoral degree completions have shown an annualised increase of 13% within the REF period, with a total completion during the current period of 52.86 FTE allocated to UoA 13, as opposed to 28 during the previous REF period.

Future aims and goals

Going forward, and in alignment with the GCU Research Strategy 2030, we will focus our research, knowledge-transfer and impact activities on 'social innovation' as it relates to the UN SDG's. The strategy focusses on increasing the income from large grants and further expansion of interdisciplinary collaboration between research groups and units across the University whilst engaging directly with the communities around us both locally and overseas. The strategy is also informed by the Muscatelli Report, which was commissioned by the Scottish Government to describe the economic impact of the Scottish higher education institutions, and to identify the way forward to maximise this contribution particularly in light of post-COVID19 challenges.

Social innovation places beneficiaries and end-users in the conceptual stage of the research process. As applied to the Unit's research activities, this would mean the translation of our research into new products, services and policy advocacy to meet the social needs associated with 'sustainable built environments.' We will specifically focus on public sector innovation, and public service provision and other redistributive measures. We expect future developments to focus on three areas: urban climate mitigation and sustainable development (in partnership with Clyde Rebuilt / Glasgow City Region to influence climate change mitigation at local and regional levels using regeneration and nature-based approaches to mitigate hydro-meteorological change); wellbeing in construction workplace (strategic partnership with Health and Safety Executive (HSE) to aid public sector innovation and best practice guidance); health asset revitalisation (strategic partnership with Health Facilities Scotland, NHS Greater Glasgow & Clyde Heath Board to enhance asset value maximisation and sustainability). It would also include the 'process' dimension of social innovation in terms of governance, empowerment and capacity building dynamics related to nature-based solutions, climate justice and fuel poverty reduction in the built environment.

2. People

Staffing strategy

The UoA's staffing strategy aims to enhance research outputs, income generation in research, contract research and CPD activities. The support and development activities aim to build capacity to enhance external collaborations, and to better capture impact on industry and policy making in sustainable built environment. Such an approach has resulted in greater emphasis on research leadership, as evidenced by the numbers of Professors (six in 2014 to ten now) and Research Fellows (one in 2014 to five now). This was enabled by Research Excellence Grant as well as external funding from Marie Skłodowska-Curie Actions and H2020 projects. These developments reflect our growth in new areas, especially climate justice (SDG #5); geotechnical / structural engineering, GIS applications and nature-based solutions (#11 and 15) and water research (#6 and 14). Furthermore, the Research Centres and Groups are supported by a Research Administrator with an Impact Officer assigned to the School.

Staff development

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.

Most of the Unit's research active staff are involved in teaching and research, with only a minority of staff being research-only. All our researchers 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 career. Individual researchers take, and share, responsibility for being pro-active in engagement within their life-long learning, career, and personal development. Additionally, staff development aims to enhance staff understanding of technical or research process areas that will strengthen 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. Another key skill development of focus is science communication, facilitated by the GCU Digital Communications and Public Engagement team to foster research dissemination to a wider audience. The Unit sees this as a key enabler to achieve impact from staff research (some examples of the outcome of this approach can be seen in Section 4, 'Public engagement' sub-section).

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. The peer review process is aimed at projects over £50,000 in value, 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 an 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 (ADR), three Centre Directors, Senior PGR Tutor, Impact Officer and Senior Research Administrator, overseas the peer review process and formally records peer review outcomes.

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.

Additional support mechanisms available to ECRs in the Unit includes the GCU Crucible programme, a leadership and development programme for early career researchers. Over May/June 2019, one of the BEAM's ECRs attended four Crucible sessions with other ECRs from across GCU, culminating in a visit to the Scottish Parliament to meet with MSPs and parliamentary researchers. The Crucible enabled the ECR to situate their own research in a wider societal context and highlight ways to communicate research beyond academia through media, public engagement and collaboration with policy makers. This further enables the build-up of contacts and tools into the early stages of research and public engagement work thus it had an immediate enhancing effect on researcher development. Additionally, the BEAM Centre supported the participation of one ECR in the Advance HE Aurora programme, a nationwide programme for improving leadership opportunities for female academics from October 2019 to March 2020. The programme provided tools (including the REAL Toolkit) to help develop key and core skills to consider where change could be enacted and advocated within the structures of our own institutions.

Support, training and supervision of PGR students

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) with financial and administrative support by the School, and co-location in a mixed-discipline office environment. This provides 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.

PGR 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 that all PhD students are active members of their Research Group and also satisfactorily complete a transferable (research) skills programme prior to completion.

During the current REF period a total of 52.86 FTE research doctoral degrees were awarded. 81% of the completions were male and 19% female while 50% of the graduates came from overseas. The UoA currently has 77 students registered (47 male, 30 female; 30 Home/EU, 47 overseas; 48 Full Time and 29 Part-Time). This reflects a growth in the number of awarded research doctoral degrees by 89% (52.86 against 28 FTE).

In line with the School policy, each PhD student within the Unit is supported by a nominal budget of £1800 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 recognition of the financial and environmental cost involved in attending international conferences, the School has changed in 2017 its previous practice of offering the students participation in at least 2 research poster colloquia over their 3 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, 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. Students receive feedback from academics, 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.

Additionally, several networking and ideas development initiatives targeted at PhD students are conducted by the Unit. For example, PhD students associated with the CCJ led the organization of seven public seminars between March 2016 and March 2019 on energy and food security, climate migration, vulnerability and adaptation, human right to a decent quality of life, green infrastructure and just transition. While contributing to the public debate and the identification of knowledge gaps, these series also improved the learning experience of the Unit's PhD students. The CCJ also organises a reading group during term time with Masters, PhD students and other interested students on climate justice related topics and offers constructive feedback on discussion points and ideas. This initiative has been hugely popular with students and enhanced their learning experience.

Equality and diversity

Diversity and equality are promoted in all aspects of the recruitment and career management of all of our researchers. Our regular and collegiate progress reviews strengthen the attractiveness and sustainability of research within UoA13. 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. 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. Such actions are coordinated by the local champion (UoA13 Champion Klemm, Postgraduate Research Tutor and Equality & Diversity Champion) who is the main point of contact for postgraduate students in relation to any issues or concerns related to equality and diversity. Specifically, the role aims to listen to Postgraduate Research students who feel that they are not being treated with equality, dignity and respect, independent of the University's formal procedures in an impartial, non-judgmental and confidential manner, as well as to provide information on the University's policies and procedures and to signpost to further information and refer on to appropriate resources to gain help and advice.

The University recognises the importance of maintaining a balance between different academic activities, and this is supported by policies covering flexible working, workload management, sabbaticals, and a Performance and Development Annual Review (PDAR) Scheme in which time allowances are given to engage with research work based on pre-agreed deliverables and line management support. During the COVID-19 pandemic in particular, the University has taken a 'whole-life approach' to flexible working, recognising that some staff have additional caring responsibilities and have been temporarily unable to meet teaching and research responsibilities. In response, workloads have been rebalanced leading to some staff having reduced work hours with no loss of salary. Additionally, the parent School of the UoA has adopted a Research Student Stipends policy during Pregnancy/Parental/Adoption Leave. The Unit is part of the first department in GCU to receive an Athena SWAN Bronze award (2018) where key priorities included: focus on female staff recruitment, support for career development and promotion of female staff and marketing and recruitment to attract more female PGR students. This has contributed to an increase in female staff returning in REF and female professors in the Unit, and a higher success rate of women in promotions (due to the small size of the Unit and data protection, it is not possible to provide exact percentages). We have submitted an Athena SWAN Silver Award application in November 2020.

3. Income, infrastructure and facilities

Research income

During the REF assessment period the Unit secured £3.7 million in research income, which represents a 43% increase over the REF 2014 period. Given the increased length of eligible time (seven years against six years for REF2014), the pro-rated income for 6 years would still represent a 23% increase over the previous period (£3.17 million against £2.58 million in REF2014). A majority of these funds were obtained from EU Govt (£1.49M) and UK Govt (£955k) with significant contribution from industry (£927k) and charitable sector (£232k). In terms of knowledge transfer (contract research and CPD events) the Unit secured £739k from clients ranging from Glasgow Clyde Valley Green Network Partnership, English Heritage (Historic England), Knauf, Scottish Fire and Rescue Service and Local Authorities. Furthermore, GCU coordinates a EUR 7 million Erasmus+ project (over EUR 1.3 million to GCU) as part of research-based provision of postgraduate education (e.g. Master of Urban Climate and Sustainability https://murcs.eu/) to produce high calibre graduates with skills and knowledge to understand, assess and manage climate resilience in cities.

Major projects by the Construction Research Group include Hare who was PI on an international team of researchers, including RMIT (Melbourne), leading a prestigious

£102,800 grant from the Institution of Occupational Safety and Health (IOSH), the world's largest professional organisation for OSH practitioners. The project delivered an innovative system for educating architects and other designers to help them improve H&S for construction workers as well as the occupiers and users of buildings. This important work is integral to the School's research objectives of creating a positive impact to improve sustainability, and also align well with the IOSH commitment to "creating a world of work which is safe, healthy and sustainable." This has led to a CDM app and several international organisations adopting the app per Impact Case Study. Similarly, Hare was awarded £187,000 from Berkeley Group Innovation Fund for the development of a Worker Engagement Maturity Model for H&S, leading to a digital app and guidance on how to improve worker engagement practices (currently in early stages of roll-out for a future Impact Case Study). Additionally, Hare undertook a scoping study for Zero Waste Scotland to update the true cost estimate of waste in a typical 'mixed-waste' construction skip. The scoping study delivered options for methods to collect and calculate the cost of waste items found in skips on various sites across Scotland. The research funding to the Construction Group led to five outputs submitted by Cameron, Hare and Lawani.

The Water Research Group was awarded over €4M in funding from Scottish and European sources. Escudero, Helwig, Hunter, Teedon, Pahl were awarded an INTERREG NWE project to collaborate with 13 EU partners on a study to raise awareness of the presence of pharmaceutical residues in wastewater and explore new methods of reducing them (noPILLS - £1,783,461.00). Additionally, Escudero and colleagues were awarded PHARMAD: Removal of pharmaceutical micro-pollutants from wastewater by anaerobic digestion and its effect on nitrogen recovery from digestate by microalgae. This MSCA IF action (£136,781) addressed the emerging threat of pharmaceutical residues in water bodies by application of a combination of existing and novel techniques for their removal in urban wastewaters. More specifically, the efficacy of anaerobic digestion and microalgae technology for the removal of these pharmaceutical residues were investigated. As an outcome of this research, an innovative system was developed to make use of the microalgae Chlamydomonas acidophila in treating wastewater, which contributed considerably to the success of a further Interreg NWE grant application (Phos4You; 2016 - 2021; 10,810,000 €, total budget to GCU - 896,455 €) a 3-year project aimed at phosphorous recovery from wastewater. The combined outcome of these external funding was 10 outputs by Escudero, Helwig, Hunter, McNaughtan and Pahl.

Jiang obtained grants from Lake Constance Water Supply Board in Germany (£125,114) to systematically examine the end product formation and the corresponding toxicity when water is treated by the oxidation processes. Jiang also obtained grants from Scottish Water to assess a range of filter media within both laboratory and industrial settings. This funding support led to five further outputs from the Water Research Group. Jiang also carried out a knowledge exchange project with UPM Pulp and Paper Ltd to successfully apply ferrate technology in the treatment of pulp and paper industrial wastewater (£23,727.00).

The NbS group were awarded a H2020 Project (Emmanuel, Mickovski, Thomson and Ollauri, €12.26 million total grant over 4 years, €614K to GCU) in 2017. OPERANDUM (H2020, Grant No 776848) aims to reduce hydro-meteorological risks (flooding, landslides, coastal erosion, drought) in European territories through co-designed, co-developed, deployed, tested and demonstrated innovative green and blue/grey/hybrid Nature Based Solutions (NBS), and push business exploitation. The 27-partner consortium has provided science-evidence for the usability of NBS, best practices for their design based on participatory processes achieved through 7 open-air laboratories (OALs), one of which is led and managed by the GCU team. Emmanuel and colleagues from University of Reading, University of Moratuwa, Sri Lanka and research user partners were awarded NERC Science for Humanitarian Emergencies and Resilience (SHEAR) Grant Scheme to work on a 3-year project entitled 'Climate service for resilience to overheating risk in Colombo, Sri Lanka: a multi-scale mapping approach (COSMA)'. External funding to the NbS group resulted in four outputs.

Significant knowledge-transfer activities by the Unit included Innovate UK funding (£193,638) to Mickovski and colleagues in partnership with the Highways Team at Jacobs UK Ltd., to develop innovative and sustainable approaches and processes for protecting the water environment during major highway construction. Hytiris and Emmanuel were awarded £131,841 by Innovate UK to develop innovative solutions for managing the sub-surface water in Strathclyde Passenger Transport (SPT) Subway's tunnel system to provide wider environmental and economic benefits. These KTP initiatives led to four submitted outputs.

A key to our societal benefit/common good engagement efforts is contract research with practical applicability to industry, government and the third sector. For example, Teedon and Helwig (with the James Hutton Institute) delivered the Sustainable Rural Communities: Community Pilots project for CREW (Scotland's centre for expertise for waters) engaging communities to investigate the potential and actual impacts of private water supplies on individuals, owners, communities, individual businesses (particularly around tourism, agriculture and small business start-ups), the rural economy, and consequently population distribution) (£56,715.00). This was interdisciplinary project carried out with GCU members of UoA20.

Thomson was the Principal Investigator for Sustainability Benchmarking Tool for Buildings project, funded by Energy Technology Partnership Knowledge Exchange Project working with Whole Life Consultants Ltd, in 2015/'16. The research provided the underlying framework for a Sustainability Benchmarking Tool for helping evaluate a buildings sustainability performance against 1) current regulations and best practice guides, and 2) against a data base of other buildings. The foundation of this stemmed from joint research during the EPSRC funded SUE-MoT and this funding provided the opportunity to provide expertise to the development of their commercial tool. This has followed on to secure £6,000 of funding from Scottish Construction Innovation Centre for an MSc student to work with them on a marketability assessment of the toolkit and its potential.

Jafry collaborated with the Environmental Research Institute at the University of the Highlands and Islands on a Scottish Govt. funded initiative to develop the "Scottish Government Arctic Policy: Mapping Report" in 2019, authored by Jafry, Mikulewicz and colleagues.

Infrastructure and facilities

The Unit has access to a full-scale Environment Chamber facility and three laboratories aligned with the Research Groups. The Chamber facility consist of a workshop and three environmental chambers (full scale testing chamber to test the effects of temperature, relative humidity, driving rain and infra-red radiation with independent parametric controls; smaller materials testing chamber and a thermal property test rig).

Nature-based Solutions (NbS) Lab has access to a wide selection of laboratory equipment for testing soil mechanics (e.g. soil shear strength, soil water retention, soil particle size distribution, soil density, soil organic matter, soil liquid and plastic limits, soil compaction), chemistry labs in which the basic chemical composition of soil, water, and gas samples can be analysed (e.g. total Kjeldahl nitrogen, phosphorous, heavy metals, TOC, carbon dioxide, and methane). The lab also has access to two environmental chambers, where plant-soil interaction experiments can be developed under controlled environments. The lab possesses an array of soil monitoring sensors (e.g. soil moisture sensors, soil temperature probes, and tensiometers), data loggers, GPR, DAQs, penetrometers, shear vanes and boxes and related equipment for the deployment of field-based research stations looking into plant-soil-atmosphere interactions.

Sustainable materials and soils laboratories have the following facilities: Mercury Intrusion Porosimetry, Scanning Electron Microscopy, universal compression machine, concrete and mortar mixers, Automated Vicat Apparatus, PUNDIT, Schmidt Hammer.

Water Lab has established major laboratory facilities and instruments including FTIR Spectrometer, Flame Atomic Absorption Spectrometer, Fluorescence Spectrometer, Raman Spectrometer, Electronic Scanning Microscopes, Gas Chromatography-Mass Spectroscopy (GC-MS), High Performance Liquid Chromatography-Mass Spectroscopy (HPLC-MS), Autoclave, Total Organic Carbon Analyser, Kjeldahl distillation unit, Anaerobic digesters, Palintest heating block and Spectrometer, Temperature controlled incubator.

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

The Unit's collaboration and wider contribution to research base is coordinated by the two Research Centres and supported by the research groups in discipline specific information and exchange both inwards and outwards.

Interdisciplinary collaboration

Our researchers in construction safety, building energy performance, environmental sciences, climate justice and stakeholder engagement collaborated with a wide variety of disciplinary experts.

Working with occupational therapists and epidemiologist, Hare built on previous research using visual methods of communication (pictograms) to use body mapping for Musculoskeletal Disorder risk assessment, which in turn was identified by the Institution of Occupational Safety & Health (IOSH) for national news coverage, influencing local authorities to change waste collection systems to wheeled bins.

Collaborating with social scientists and poverty alleviation specialists, Baker helped to reconceptualise fuel poverty as a complex problem and proposed a new framework for assessing the condition that incorporates dynamic risk-based measures.

Together with community regeneration specialists, engineers, social scientists and education specialists, Jafry explored ways to embed universal access to water as a right and associated responsibilities.

An inter-disciplinary group of hydrologists, analytical chemists, waste and environmental chemistry specialists (Helwig, Pahl, Roberts, Hunter, McNaughtan, Escudero) highlighted important considerations on source attribution, as well as providing an up-to-date risk ranking of pharmaceutical pollutants. It is particularly relevant at the moment as changes to prescribing are being considered in Scotland, which will take into account for the first time the environmental impact of pharmaceutical compounds.

Our environmental scientists (Pahl and Hunter) collaborated with environmental engineers and waste management specialists to develop novel models to accurately estimate the efficacy of anaerobic co-digestion process for biogas production.

Teedon collaborated with experts from occupational medicine, toxicology and pesticide control that highlighted community researchers' abilities to build and sustain trusting relationships with participants, which enhanced the rigour of the study as a result of their on-the-ground responsiveness and flexibility resulting in data collection beyond expected targets.

Furthermore, Emmanuel collaborated with researchers in Computing and Interactive Systems to develop Low Power Wide Area Wireless Network for Smarts Cities and Remote Health

Monitoring which forms the basis of an Impact Case Study underpinning the REF 21 submission by a neighbouring UoA within our School (UoA11).

Teedon led the Water Environment Micro-pollutants Scientific Initiative (WEMSI) Project engagement activity undertaken in Brazil both in São Paulo and Curitiba around understandings of and attitudes towards aquatic (micro) pollution. Engagement was undertaken with both members of resident communities e.g. adjacent to Billings Reservoir in São Paulo and policy and regulatory stakeholders. This interdisciplinary project funded by the British Council - Newton Fund Institutional Links Programme on monitoring and mitigating micro-pollutants in Brazilian waters: source attribution, environmental risk, community and stakeholder engagement. It investigated water micro-pollutants in two urban areas to prioritise micro-pollutants in Brazil's Billings Reservoir (São Paulo) and Belem River (Curitiba) through the engagement of appropriate regional, scientific and regulatory stakeholders and communities adjacent to these water sources.

Networks for the common good

The Unit has wide-ranging networks from professional bodies, technical committees, national and international scientific committees to community groups and external events organization. SDGs form the basis for these engagement activities:

- SDG3 - Good health and wellbeing: Enhanced Cod Removal and Drinking Water Treatment, (partnership with Lake Constance Water Supply, Jiang); EDPHiS - Environmental Determinants of Public Health in Scotland (Partnership with Public Health Scotland, Teedon); Development of a worker engagement model (The Berkeley Group, Berkeley Group, HSE, CITB, Morgan Sindall, Mitie, Galiford Try, CALA, Joseph Gallagher, Laing O'Rourke, Sodak, Arcadis, EDF Energy, Unite: Hare)

- SDG9 - Industry, innovation and infrastructure: Improving Designers on Preventing Hazards (IOSH, Glasgow Institute of Architects, HSE, AMEY, Allford, Hall, Monaghan & Morris Ltd. Architects; Hare); Crane Erect OSM (Stewart Milne Group, Tong)

- SDG 13 - Quality of education/climate action: MUrCS Project (Lahti University of Applied Sciences; University of Huelva, ES; six other Associate Partners from Brazil, Sri Lanka, Israel, South Africa and industry/local authority partners) (Emmanuel, Thomson)

- SDG14 and 15 - Life on land / below water: Changes to Agricultural Land Bank (Scottish Environment Protection Agency, Mickovski); KTP Project (Jacobs UK Ltd, Mickovski); ECOMED Project (TU Madrid, Istanbul Uni, EmmaTech, Astrolabe, Sangalli y Coronel, Naturalea, INRA, Jemmbuild, ITC Formia, UoEvora, ICE Klaus Peklo, Geing; Mickovski, Thomson); OPERANDUM (https://www.operandum-project.eu) (University of Bologna, Italy plus 26 academic, industry and NGO partners from the EU and beyond; Emmanuel, Mickovski, Ollauri and Thomson); EU COST TU1401 - Renewable Energy and Landscape Capacity, resulting in publication of Glossary on Renewable Energy terms and Landscape Quality (http://www.tajokologiailapok.szie.hu/pdf/2018_SpecialIssue2/2018specialissue2.pdf) (Mikulewicz).

Membership of organisations and committees

- Hare is currently International Coordinator of CIB W099 (H&S) and conference chair, as well as chair of CIOB H&S Special Interest Group
- Baird held the Presidentship of Chartered Institution of Wastes Management (CIWM) 2015-2016

- Emmanuel was Secretary, International Association for Urban Climate (IAUC - www.urban-climate.org), the largest international network of urban climate researchers (2012-2016)
- Klemm is Council member of the Institute of Concrete Technology; Construction Industry Research and Information Association (CIRIA); member of RILEM Technical Committees and working group leader within TC 260 RSC - Recommendation for use of Superabsorbent Polymers in concrete construction as new internal curing agents
- Mickovski is member of ISSMGE TC307 - Sustainability, resulting in journal publication in a special issue of the Engineering Sustainability journal; member of CIB W120/TG91 preparing the roadmap of natural disasters research capacity and networks (2018- current); participated in EU COST TU1202
- Helwig represents One Health Breakthrough Partnership, subgroup on contaminants of emerging concern
- Zhang is a member of the UK Timber Design Code Committee and other European Standard Committees - B/525/5 Timber Design Code Committee and CEN/TC124/WG1 Timber Structures/Testing Methods for Construction Supervisors (In-kind contribution to project funded by CITB) (2017 - 2019)
- Thomson has been a member of the Association of Researchers in Construction Management (ARCOM https://www.arcom.ac.uk) since 2016.

International events and conferences

- CCJ hosted a prestigious Elsevier Conference, the World Forum on Climate Justice, in June 2019 (https://www.elsevier.com/events/conferences/world-forum-on-climate-justice). Addresses including Rt. Hon Nicola Sturgeon MSP, First Minister of Scotland, Mary Robinson, MRFCJ, Penelope Endersby, Chief Executive of MetOffice; Prof Sir Andrew Haines, London School of Hygiene & Tropical Medicine explored pressing topics in climate justice advocacy, research, policy and practice as we adapt to reach the 1.5°C goal
- In January 2017, the BEAM Centre co-hosted the “Overcoming obstacles to high density resilient cities” event with the Chartered Institute of Building Services Engineers (CIBSE) and University College Dublin. The event explored the interdependent relationships between built form, energy, climate and health and wellbeing in the context of dense urban environments and led to an output submitted for consideration for REF21 (DOI: https://doi.org/10.1080/09613218.2018.1499995 and https://doi.org/10.1016/j.uclim.2020.100642)
- Mikulewicz obtained support from The Royal Geographical Society (RGS) to host a Climate Change Research Group (CCRG) development workshop in January 2020 to develop key skills for critical climate change research
- Thomson hosted the 35th ARCOM Annual Conference in September 2020.

Engagement with research users, beneficiaries and audiences

Members of the Unit have been engaged with research users in three ways: actionable research that focuses on social innovation, engagement with legislators, regulators and decision-makers, and impactful research targeted at specific organisational audiences:

- Thomson undertook to look at how collaboration and greater and more effective pathways of communication can be fostered with stakeholders and communities involved in active travel infrastructure projects. In collaboration with Glasgow City Council they were able to directly embed the PhD-developed CoCo Toolkit into the planning of a major active travel infrastructure project. Working with stakeholders, the toolkit underpinned a proposal for funding from the Scottish Government for developing a cycling village in the Yorkhill and Kelvingrove area of Glasgow

(https://ayecycleglasgow.org.uk/yokecoco-secure-13m-to-create-cycling-village-in-west-end/). thus providing both validation for the research but also helping to secure the funding of £13 million from the Scottish Govt in a competition across Scotland for such projects.

- Hare's appointment by the Scottish Government as 'Senior Advisor - Buildings and Construction' for the Independent Review into the Queen Elizabeth University Hospital Infections of 2018/19, commissioned by Jeane Freeman, MSP Cabinet Secretary for Health and Sport.
- Jafry and colleagues provided research-informed evidence to shape public policy - including International Development Committee Inquiries on the topics of "UK aid combating climate change" and "climate change and disability". Their evidence was featured in the committee's reports titled "11th Report - UK aid for combating climate change" and "13th Report - DFID's work on disability - inclusive development" published in July 2019.
- Baker provided evidence to Scottish Parliament Local Government and Communities Committee; Black Commission on Housing and Wellbeing (Baker) - verbal evidence to government and stakeholders, which led to changes in Fuel Poverty Act (2019) (see our impact case study on fuel poverty and energy policy by Baker and Emmanuel).
- Emmanuel acted as an expert advisor on the content and analysis contained in the Final Assessment Report of the First Scottish Climate Change Adaptation Programme by the Adaptation Sub-Committee of the UK Committee on Climate Change in March 2019.
- Under the leadership of Thomson (and coordinated by the BEAM Centre) an embedded researcher (subsequently awarded a PhD) in Health Facilities Scotland (HFS) evaluated the performance measurement system used to manage health care estate. Findings were developed in collaboration with HFS and report is being used now to improve the system as part of a strategic review and to underpin a wider policy and management review of performance measurement. Additionally, BEAM Centre researchers engaged with the NHS Greater Glasgow and Clyde (GG&C) Board at its flagship hospital (Queen Elizabeth University Teaching Hospital) in 2017-2019 to identify and overcome overheating issues in this and other Scottish Hospitals.
- Teedon engaged with health-related research users via membership in NHS Health Scotland Public Engagement Advisory Group. The Group's role was to advise NHS Health Scotland on its public engagement activities and to deliver strategies and priorities for this (Teedon was the only academic member of the group). Additionally, Teedon's work was commissioned by a government department to inform its own reflections on the pesticide regulatory regime.
- Emmanuel collaborated with the Glasgow Clyde Valley Green Network Partnership (GCVGNP) and the Glasgow City Council to provide evidence to the likely cooling effect of strategically placed green infrastructure to mitigate the expected urban warming till 2050.
- Baker's work via contract research for key stakeholders including the Scottish Government, ClimateXChange Scotland, the Eaga Charitable Trust, Citizens Advice Scotland, Calor Ltd, Scarf, and Ricardo-AEA led to better understanding of the needs of fuel poor householders (as evidenced by the impact case study submitted by our Unit).
- Lawani and colleagues (funded by Construction Scotland Innovation Centre, CSIC, £56k) explored, site productivity enhancement through an in-depth longitudinal case study to measure and improve site productivity in house building. This was achieved through the implementation of timber kit off site manufacturing (OSM) with the crane-erect build method that identified opportunities for improvement in terms of process efficiencies (accurate schedule management and improving the planning of work packages and logistics management), crane optimisation (exceptional crane downtime and recommendation for productivity improvement).

Contributions to the research base

Members of the Unit contributed to the research base in built environment via keynote addresses, journal/special issue editorships, peer review colleges and external examination of PhDs internationally.

Keynote addresses include:

- Hare - 'Safety in Design' research for CDM Regulations at ICE Conference London (2016), IOSH CPD Gretna (2017), Scottish House builders & Glasgow Institute of Architects, 2019
- Baker - Rethinking Fuel Poverty as a Complex Problem - Holyrood Communications conference
- Mickovski - 6th Geotechnical Seminar UFRN-PEC, Natal, Brazil, 2017, Invited panelist at the ICE/BGA debate - BIM in Geotechnics of the Northern Geotechnical Group, 2016, Session Chair CIB World Building Congress, Hong Kong 2019 - Natural Disasters (WG119) session; SEMC Cape Town 2019 - Soil and Water Bioengineering session
- Thomson - Engineering, Procurement and Construction Conference
- Klemm - 1st International Conference on Construction Materials and Structures, Johannesburg, South Africa, 2014, 11th International Symposium on Brittle Matrix Composites, Warsaw, Poland, 2015, 2nd International Congress on Materials & Structural Stability, Rabat, Morocco, November 2017, 12th International Symposium on Brittle Matrix Composites, Warsaw, Poland 2019; Emmanuel - Architectural education in a time of climate emergency, CASE/KSA Keynote address, University of Kent, 2019.

Editorial roles of our members include:

- Mickovski - Associate Editor, Arabian Journal of Geosciences, Springer; Member of Editorial Board - Environmental Geotechnics, ICE Publishing, Innovative Infrastructure Solutions, Springer; Guest Editor of a Special Issue of Ecosystem Services, Elsevier, Procedia-ESEM journal (vol. 4, iss. 4)
- Klemm - International Journal of Computational methods and Experimental Measurements, Journal of Building Physics in Theory and Practice
- Emmanuel - Building Research and Information (vol. 46, iss. 8, 2018).

Our peer review college involvement includes:

- Klemm - H2020, FORMAS (Swedish Research Council), National Research Foundation (South Africa), Caixa Foundation (Spain)
- Emmanuel - UKRI - Peer Review College, FLF Scheme, NSF (Portugal), MIUR (Italy), GACR (Czech Republic), NWO (the Netherlands), ISF (Israel), Erasmus+ (CBHE), IILG Scheme (USA) and EPSRC
- >40 external PhD examination in Europe and Asia.

Public Engagement for wider societal and economic benefits

Our engagement with the wider society is in line with the mission of our University, 'for the common good' and targeted specific areas of our research that has wider societal benefit - including climate change and climate justice, fuel poverty in the built environment, geotechnical engineering, water research, health, safety and risk management.

- Recognising the benefit of CCJ's research to change lives, policy and practice, Jafry and a PhD student in Climate Justice were invited to a reception at the House of Lords

on access to safe water in a celebration of the work of Village Water, an NGO in Zambia, which strives to provide safe water and transform the lives of people living in rural Zambia, where CCJ collaborated on the Water for ALL project.

- In the area of fuel poverty in the built environment, Baker's work on the rural uplift in fuel poverty is a common theme in his engagements with Scottish Parliament's Cross-Party Group on Housing / Renewable Energy and Energy Efficiency, Energy Poverty Research initiative, European Energy Poverty Observatory - Advisory Board and UK Fuel Poverty Research Network. These engagements were key to his work being taken up by the Fuel Poverty (Scotland) Act as demonstrated in one of our Impact Case Study on Fuel Poverty and Energy Policy.
- Water Research Group members coordinated and promoted public engagement activities, including the Glasgow Science Festival for 3 years running, Smart STEM events for 4 years, the Dippy on Tour Event at the Kelvingrove Museum and GCU's community days amongst others. Through these public outreach activities, the Group raised awareness of water pollution, Over the past 5 years, the group engaged with > 250 professionals, > 1000 members of the public and >1000 children on the broad topic of water pollution and monitoring, as part of research activities, research dissemination and promotional activities relating to water science. Furthermore, research projects by the group (such as Phos4You) garnered considerable media attention on the use of microalgae to recover phosphorus (BBC News Scotland, "New research into recovering phosphorus from sewage": https://www.bbc.co.uk/news/uk-scotland-41374541).
- Similarly, geotechnical engineering research by Mickovski and colleagues assisted the Stonehaven and District Community Council to develop an Independent Hydrology Audit scheme to respond to planning applications submitted to Aberdeenshire Council. The IHA scheme was developed and six developments were assessed in the 2016. The IHA development including a case study was published in Wiley's Water and Environment Journal.

Further public engagement for societal benefits were provided by members of the Unit in the form of independent expert opinion for the media when news stories break:

- Hare - Glasgow School of Art fire (2018): 17th June TV interviews: BBC World Service, BBC Scotland, Ch. 4; generated 151 reports nationally/internationally; with estimated 765 million worldwide views/readers. Forecast £100m rebuild cost 'The Scottish Times' Front Page 18th June 2018 - subsequently confirmed by GSA insurers as an accurate estimate (additionally, two articles in 'The Conservation' to discuss the severity and the lessons for other cities elicited 13,622 and 2,091 reads respectively by Jan 2019).
- Jafry - STV programme Scotland Tonight to discuss Extinction Rebellion demand for zero emissions by 2025 (April 2019) as well as writing an opinion article for the Journal of the Law Society of Scotland on the climate emergency (https://www.lawscot.org.uk/members/journal/issues/vol-64-issue-08/opinion-tahseen-jafry/).
- Helwig et al. - Appearances on national TV and Radio (Radio show contribution: https://www.bbc.co.uk/programmes/p0281ylg; BBC News Scotland) to promote new research into recovering phosphorus from sewage": https://www.bbc.co.uk/news/uk-scotland-41374541.

Recognition of our public engagement came in the form of awards, prizes and inclusion in research agenda setting:

- Jafry - Elsevier Atlas Award (Mar 2017).
- Hare, Lawani and Cameron, won the prestigious Hinze Prize for their Conference Paper, titled: "Developing worker engagement maturity model for improving occupational safety and health (OSH) in construction" subsequently published in the Journal of Construction Project Management and Innovation, Vol 7, pp 2116 -2126.

- Hare won the Institution of Civil Engineers Parkman Medal twice in 2017 and 2019 for best paper of the year in their peer-reviewed proceedings.
- Mickovski was awarded the International Innovation & Research Awards (Premier Award) by Chartered Institute of Building, 2016 for the research paper 'Implementation of eco-engineering design into existing slope stability design practices.'
- Jafry was one of 107 authors selected from 40 countries, to be included in the World Social Science Report 2016, that sets the research agenda for the next 10 years in inequalities research.