**Institution:** Keele University

**Unit of Assessment:** UoA14 Geography and Environmental Studies

## 1. Unit context and structure, research and impact strategy

### Context, structure and strategic aims

Research in 'Geography and Environmental Studies' at Keele is unified organisationally and thematically through the School of Geography, Geology and the Environment (GGE). Formed in 2017 in response to a review following REF2014, the School is strategically aligned with the University's sustainability agenda and has been instrumental in the leadership of Keele's Institute for Sustainable Futures (ISF) launched in 2018. Our aim is to contribute solutions to the world's most significant environmental and societal challenges and to fulfil our mission to produce research of the highest calibre in geography and allied disciplines, maximise grant capture, facilitate research conduct and optimise research output. Through a new research strategy focused on sustainability science, aligned to the United Nations Sustainable Development Goals (UN-SDGs), we have developed world-leading research in three key areas: (i) Earth systems, including anthropogenic geohazards and climate change; (ii) sustainable energy and environments, including smart energy, environmental science and conservation; and (iii) responsibility and resilience, including migration, mobility, place and health inequalities. Research income since 2014 amounts to almost £3 million, with average income per year increasing by over 90% compared to REF2014. Staff returned to UoA14 have played a major part in Keele's high-impact interdisciplinary national and international programmes of research in sustainability, including the Smart Energy Network Demonstrator (SEND) (£15.5M) – Europe's largest 'at scale' smart energy demonstrator linking multi-vector energy generation, distribution and storage – and HyDeploy (£8.5M), the UK's first hydrogen blended gas network. Underpinning research has been published in a range of prestigious multidisciplinary journals such as Nature, Nature Geoscience, Nature Communications, PNAS, Geology, Quaternary Science Reviews, Social and Cultural Geography and the Journal of Rural Studies.

The formation of the new School and strategic direction has reinforced Keele's long and distinguished history of excellence in geography, geoscience and environmental research, and led to a single submission to REF2021 (UoA14), compared to two separate submissions under UoA7 (Earth Systems and Environmental Sciences) and UoA22 (Social Work and Social Policy) in REF2014.

The rising trajectory of the unit, compared with REF2014, is evidenced by:

- Significant improvement in the quality and scope of our research outputs commensurate with UoA14;
- Total research income (expenditure on grants) of £2,848,154, with increased income from UKRI and EU Horizon 2020, and income per Category A staff FTE 63% higher than the sector median for Geography, Environmental Studies and Archaeology (UoA17) in REF2014;
- An increase of 30% in staff with significant responsibility for research being returned to REF2021 (19.5 FTE) compared to REF2014 (14.2 FTE);
- An increase of 59% in PGR students, facilitated by participation in externally-funded, strategic doctoral training programmes, and a >100% increase in PGR completions, including one professional doctorate;
- Growth through strategic academic appointments, including four Chairs (Fogwill, Healey, Goetz, Scott), seven Lectureships (Glanville, Halama, Law, Lucherini, Meinhold, Rubino, Smedley), a tenure track Research Fellowship (Cao), an Early Career Research Fellowship (Thompson); seven Postdoctoral Research Fellows (Jones, Mendonca, Peacock, Sgouridis, Smith, Toon, Westwood), a Research and Teaching Fellow (Jones) and a Sustainability Project Officer (Briggs);
- Successful academic promotions to Emeritus Professor (Styles), Professor (Pemberton, Robinson), Reader (Gertisser, Knight, McKay) and Senior Lecturer (Cage, George, Oliver, Pringle, Szkornik);
- Investment of >£567,431 in research infrastructure and equipment.

The new research structure of GGE spans the full range of UoA14, drawing together physical and human geographers, geoscientists, those involved with environmental studies, conservation biologists (School of Life Sciences), forensic scientists and chemists (School of Chemical and Physical Sciences (CPS)), and social scientists (Faculty of Humanities and Social Sciences). This has promoted a unique interdisciplinary approach, facilitated by Keele's three multidisciplinary research institutes – notably the Institute for Sustainable Futures (ISF) led by Fogwill, but also the Institute for Social Inclusion, co-led by McKay, and the Institute for Global Health. GGE is a key contributor to the ISF, directing regional, national and international research programmes across its six 'challenge' themes which are mapped onto the UN-SDGs. Highlights include GGE's contributions to the challenge of: (i) 'Clean Energy and Reducing Carbon Emissions', including SEND, HyDeploy, SIMULATE Live-Lab, and leading Keele's contribution to the Midlands Innovation Energy Research Accelerator (ERA); (ii) 'Creating Responsible, Sustainable Communities and Governance', including Zero Carbon Rugeley, led by ENGIE, and NORFACE; and (iii) 'Protecting Air, Land, Water and Ecosystems', including EPOS (€162,275) and SHEER (€291,808). These high-impact projects have enabled GGE to contribute to exciting and diverse research training programmes, including the Centre for Doctoral Training (CDT) in Geoscience and the Low Carbon Energy Transition (GeoNetZero), the NERC CDT in Oil & Gas, the ESRC North West Social Science Doctoral Training Partnership (NWSSDTP), and the Centre for Post-Doctoral Development in Infrastructure, Cities and Energy (C-DICE), funded by the Research England Development Fund in 2020.

**Research and contribution to the discipline since REF2014**

The unit's research strategy aligns to the University Research Strategy. Since 2014, research within GGE has been taken forward through three interdisciplinary **research clusters** that have sustainability science at their core.

***Sustainable Energy and Environments (4.0 Cat A Staff FTE)***

Led by Robinson (Professor of Sustainability Science), the **Sustainable Energy and Environments** cluster has made crucial contributions to the fields of sustainable energy systems, sustainable systems in organisations and sustainability education (Robinson), biogeochemistry, carbon and nitrogen dynamics and nutrient cycling (Glanville, Oliver, Rubino, Ullah), soil contamination, remediation and ecotoxicology (Oliver), and the impact of anthropogenic change on mammalian communities, genetics, biodiversity and their ecology (Scott). Key contributions in the field of sustainable energy include the delivery of three of the most innovative 'at scale' low carbon energy demonstration projects in Europe: SEND, HyDeploy and Zero Carbon Rugeley. These multimillion-pound projects, funded by European Regional Development Funding, the Department for Business, Energy and Industrial Strategy (BEIS), Cadent Energy and Innovate UK (SEND: £15.5M; 2016-2021; HyDeploy: £8.5M; 2018-2021; Zero Carbon Rugeley: £199.3k; 2019-2022), are leading the UK's ambitions to achieve carbon neutrality by 2050. They have enabled researchers to work with communities and commercial partners on Keele University campus, our 'living laboratory' and the UK's largest campus, and across the UK and internationally to ensure access to sustainable, community orientated low carbon energy. These programmes are fundamental to the UK's Clean Growth and Industrial Strategy policies, and have led to the development of strong collaborative links with commercial partners (e.g. Siemens, ENGIE, Cadent, Northern Gas Networks, ITM, Progessive Energy), community groups (e.g. Chase Community Solar, Sustainable Housing Action Partnership, REGEN, New Vic Theatre), and groups including Energy Catapult, BEIS and regional councils. Furthermore, such activity has promoted the development of Global Challenges Research Fund (GCRF)-facing initiatives, including SOLAR C-FOOD, which, in partnership with the University of Liberal Arts Bangladesh (ULAB) and supported by QR income, aims to explore challenges of zero carbon cooling for fishing communities in Bangladesh.

***Responsibility and Resilience (5.8 Cat A staff FTE)***

Led by Pemberton (Professor of Human Geography), the **Responsibility and Resilience** cluster has made significant contributions to research focused on migration, mobility and place resilience, and health geographies. Critical contributions in respect of work concerned with migration, mobility

and place resilience include new understandings of the mobility and settlement experiences of individuals living in UK superdiverse communities (Pemberton, Leverhulme Fellowship: £49,884), curating development to increase the welfare of Filipino migrant care workers in the UK and Hong Kong (McKay, AHRC: £12,287), facilitating place resilience in cities subject to urban redevelopment (Lau), and the use of ICT in the aftermath of natural disasters (McKay, British Council: £20,300). Research focused on resilience across the life-course has explored challenges of youth entrepreneurship across Europe (Holdsworth, EU FP-7: €299,558), and unique insights into time geographies and issues of 'busyness' (Holdsworth, Leverhulme Major Research Fellowship: £152,657). Related to health geographies, researchers have provided important new contributions to the use of e-cigarettes in shaping health inequities caused by smoking (Lucherini, Cancer Research UK (CRUK): £62,450), health inequalities caused by challenges of access to healthcare in 'superdiverse' neighbourhoods (Pemberton, ESRC NORFACE: £54,442; Lucherini and Pemberton, CRUK: £85,280), the temporalities of alcohol consumption across the later life course (Holdsworth, ESRC: £121,134 (2013-2014)), and the use of global therapeutic networks and digital infrastructure in the provision of health and social care (McKay and Thompson, Leverhulme Trust: £68,427). Overall, such work has been underpinned by grants worth >£650k and with total project costs amounting to £2.4M over the REF period.

***Earth Systems (9.7 Cat A staff FTE)***

Led by Pringle (Senior Lecturer in Geosciences), the **Earth Systems** cluster has made major scientific contributions to: (i) the application of geophysical techniques to environmental, archaeological, anthropogenic geohazards and forensic geoscience (Cassidy, Pringle, Styles); (ii) the dynamics, mineralisation, (tephro)chronology and hazards of igneous and volcanic systems, including their role in the natural carbon cycle (Gertisser, Halama); (iii) environmental and climate reconstructions in 'deep time' (Clarke, Meinhold); and (iv) Quaternary environmental and climate change, and sea-level rise reconstruction and projection (Cage, Fogwill, Law, Nobajas, Smedley, Waller). The latter has been facilitated by the strategic appointment of Fogwill as Professor of Glaciology and Palaeoclimatology and Head of School in 2017 and underpinned by grants worth over £500k from EU Horizon 2020 (EPOS, SHEER) and NERC. Fundamental and applied Earth Systems research has been supported through strong collaborative links with industry and the British Geological Survey (BGS) and by extensive laboratory support, including a geophysical equipment pool worth >£1M, dedicated thin section and ice core analysis facilities, and state-of-the-art geochemical laboratories, funded by HEFCE, NERC, UKRI World Class Laboratories Fund and Keele. These facilities have supported Keele's contribution to high-profile international projects, including the International Ocean Discovery Programme (IODP) and the European Project for Ice Coring in Antarctica (EPICA) – Oldest Ice Project. Linked to Earth Systems research is Keele's membership of the NERC CDT in Oil & Gas, which has provided a new generation of scientists and practitioners with skills to reduce the environmental impact of hydrocarbon exploration and extraction and focus on responsible environmental management to accelerate the process of reducing carbon use in the global economy. GGE is also a member of the GeoNetZero CDT, a programme set up to accelerate the low carbon energy economy transition and address the challenges of achieving net zero. The two CDTs have supported six PGR students.

**Impact case studies, and future strategic aims and goals for research and impact**

Our interdisciplinary research in forensic geoscience and anthropogenic geohazards, which has involved researchers from GGE (Allen, Cassidy, Jones, Pringle, Stimpson, Styles, Toon, Westwood) and CPS (Heaton, Wisniewski), has formed the basis of our two impact case studies (ICS). '**Forensic geoscience to aid the police and community'** has changed Home Office Policy, provided evidence for House of Lords Forensic Science enquiries, changed National Crime Agency operations and impacted many Police searches. These have resulted in convictions in criminal and civil courts, providing closure for victim families and public reassurance that justice will be served. Additionally, the use of innovative geophysical techniques has helped solve two further missing persons cases and led to breakthroughs in cold case investigations. '**Seismic shift: the transformation of UK government fracking policy'** has developed under the EU Horizon 2020 projects EPOS and SHEER. Work carried out by GGE researchers over the past decade has highlighted to national government and industry bodies how fracking-related earthquakes are caused, high-risk areas where fracking should be avoided, and procedures to

minimise fracking-induced earthquake risk. Recommendations from this research have been integrated into UK fracking policy. This includes the introduction of seismic monitoring and establishment of a traffic light system for enforcing magnitude limits that led directly to the moratorium on UK fracking in 2019.

The unit's strategic research focus on sustainability science and societal resilience provides a strong foundation for future research, aligned to the UN-SDGs. This will enable us to maximise the quantity, quality, value and success rate of our grant applications, with a particular focus on targeted UKRI, industrial and international funding opportunities. Knowledge exchange, impact-driven research and long-term industrial collaboration are crucial to this strategy, and areas in which we have excelled.

The SEND and HyDeploy programmes, led by researchers in the **Sustainable Energy and Environments** cluster, provide the blueprint for future smart, decentralised energy systems that are key to UN-SDGs 7, 8, 9 and 11: *'Affordable and clean energy', 'Decent work and economic growth',* '*Industry, innovation and infrastructure'* and *'Sustainable cities and communities'*. In this regard, QR SPF funding has been secured for research on consumer perceptions of hydrogen (Robinson) and further work on smart energy will be taken forward through SEND, which will support >240 local businesses, create up to 440 higher value jobs and save ~4,000 tonnes of carbon dioxide each year. Alongside Zero Carbon Rugeley and GCRF-facing initiatives (e.g. SOLAR C-FOOD), such projects highlight our future ambitions and define the role of communities worldwide in the design and development of smart energy systems on our path to net zero.

From a societal resilience perspective, researchers within the **Responsibility and Resilience** cluster will continue to build an international reputation on the social, cultural, embodied and spatial norms of e-cigarette use through working with diverse communities across Europe and beyond, contributing directly to UN-SDG 3 '*Good health and well-being'*. Via ESRC-funded research (JPI Urban Europe 'Urban Migration' programme), members of the cluster will generate new insights into the importance of housing in shaping strategies for socio-spatial integration in urban areas. Such issues directly align with UN-SDG 11, the '*creation of sustainable cities and communities*'. Additionally, work supported by the Leverhulme Trust investigating the impact of new international migration flows on landscapes of care figures heavily in the forward-looking strategy of the cluster, tied to UN-SDGs 3 and 11. Through QR GCRF income, a new strand of research, linked to UN-SDG 12 '*Responsible consumption and production*', is emerging on sustainable consumption and reducing plastic waste in East Asia. Furthermore, work to develop and accelerate innovative solutions in electric vehicle mobility and to create sustainable public transport systems (SDG 11) will be taken forward with industry partners (e.g. Amey) through the SIMULATE programme and funded via the Department for Transport.

Future research and impact of the **Earth Systems** cluster will be generated through new strategic partnerships and collaborative projects across all key themes. This includes research underpinning our ICS in geoforensics in collaboration with the Keele Policing and Academic Collaboration (KPAC) to inform a range of criminal investigations, building on the research impact exemplified in this submission aligned to UN-SDG 16 '*Peace, justice and strong institutions'*. Our partnership in the EU Horizon 2020 EPOS SP (Sustainability Phase) project (2021-2023) - Thematic Core Service - Anthropogenic Hazards (TCS-AH) - will develop research around anthropogenic geohazards and their mitigation, aligned to UN-SDG 11, building on our fracking-related ICS. Recent investment into our Ice Laboratory (>£567,431), GCRF-facing initiatives, and participation in ongoing international projects, including the IODP, the Australian Research Council funded Antarctic ice coring programme (Fogwill), and the EU-funded 'Oldest Ice Project', will further strengthen Keele's growing profile in climate change research aligned to the UN-SDG 13 '*Climate action'*. Finally, aligned to the UN-SDGs 7, 8 and 9, the development of geoscience in the zero-carbon energy transition will be facilitated through the GeoNetZero CDT, which forms a key part of the UK Government's North Sea Tradition Deal (NSTD), and research on carbon capture and storage and geothermal energy (including 'mine water heat-recovery'), linked to SEND and Zero Carbon Rugeley.

**Open research and research integrity**

The unit is at the forefront of developing an open research environment; research outputs are made openly available, which began in advance of the current REF policy and is reflected in its 100% open access compliance for REF2021. We work with partners to seek external funding for open research, have been involved in developing and implementing the University's research data policy, and were early adopters of Keele's digital dataset repository, enabling data from research to be made openly available (e.g. https://researchdata.keele.ac.uk/30/). Data management plans are routinely used and ensure that open research practices are designed into research plans from the onset. Staff target journals with maximum impact in their fields and have embraced the concept of pre-publishing with use of online resources for rapid dissemination of results (e.g. EarthArXiv).

Research within the unit is conducted according to relevant ethical standards and research integrity is at the heart of our activities. In addition to the open research practices outlined above, our research is underpinned by the School and Faculty research ethics committees and a Faculty of Natural Sciences Research Integrity Champion, who supports the delivery of the University's research integrity and reproducibility strategy. Colleagues in the unit are alert and responsive to cultural sensitivities and regulations, ensuring, for example, that international research is conducted in equal collaborative partnerships. Expectations of a positive research culture are promoted at all levels and include a research mentorship scheme and the sharing of best practice.

## 2. People

**Staffing strategy, staff development and support for ECR staff**

GGE employs 44 staff: 34 academic staff and 10 professional services staff, besides seven emeritus professors, two honorary senior research fellows and professors, and four university fellows. 25.2 FTE are employed in research-related roles and amongst these, 19.5 FTE have significant responsibility for research (76.5% of academic staff on research-related contracts) and are included in this submission. The latter includes 1 FTE Category A staff from the School of Life Sciences, where the appointment of Scott as Professor of Mammal Ecology and Conservation and Head of the School in 2019 has built capacity in conservation research and management. Overall, there is an increase of 37% in the number of staff being returned compared to REF2014, in which 14.2 Category A FTE were returned across UoA7 and UoA22.

Research in GGE is strategically led by the School Director of Research (Gertisser), who reports to the Head of School and the Faculty of Natural Sciences Dean for Research through the School's Research Committee. The Director of Research is supported by the three research cluster leads. To build leadership capacity, key members of this unit (Gertisser, Pemberton, Robinson) have completed the AdvanceHE Strategic Research Leaders Training programme based on the importance of their roles to the Faculty of Natural Sciences research mission. Gertisser and Pemberton are also members of Keele's Research Leaders Network, chaired by the Pro Vice-Chancellor (Research and Enterprise).

The focus on sustainability science has informed **strategically aligned appointments** since 2014. Recruitments to the **Sustainable Energy and Environments** cluster have included Healey (SEND Professor in Practice), Scott (Professor of Mammal Ecology and Conservation; Head of School of Life Sciences), Glanville (Lecturer in Physical Geography), Rubino (Lecturer in Environmental Science), Cao (Tenure Track Research Fellow in Energy and Sustainability), Peacock and Sgouridis (Postdoctoral Research Fellows), and Briggs (Sustainability Project Officer). The appointments of Lucherini (Lecturer in Human Geography), Thompson (Leverhulme Early Career Fellow) and Smith (Postdoctoral Research Fellow) have built capacity in health geography in the **Responsibility and Resilience** cluster, while the MSCA Fellowship of Mendonca supported Holdsworth's EU FP-7 programme-funded work focused on youth entrepreneurship. The **Earth Systems** cluster has seen growth through the appointments of Fogwill (Professor of Glaciology and Palaeoclimatology; Head of GGE), Goetz (Professor of Geology), Halama (Lecturer in Petrology), Law (Lecturer in Geography), Meinhold (Lecturer in Geoscience), Smedley (Lecturer in Physical Geography) and Jones (Research and Teaching

Fellow in Geology), who have strengthened areas of expertise in geoenergy, anthropogenic geohazards, environmental change in 'deep time' and magmatic and volcanic processes, and helped develop strategically-important research in climate change. Earth Systems research has also been strengthened by the appointments of Jones, Toon and Westwood as postdoctoral research fellows in the multi-institutional EU Horizon 2020 EPOS and SHEER projects, headed up by Styles, then Pringle. Furthermore, research capacity has been enhanced through an institutional strategic change that allows staff to move from teaching fellow roles to lectureships in education and scholarship (Allen, Moolna, Rogers) or education and research (Law).

The unit's approach to staffing is aligned to Keele's People Strategy. All staff are supported towards **academic promotion** through annual appraisals, research plans, and promotion workshops. Promotions and appointments based on 'Research and Enterprise' depend on nationally and internationally-recognised excellence in research, which was a factor in the promotions to **Emeritus Professor** (Styles: Applied and Environmental Geophysics, 2015), **Professor** (Pemberton: Human Geography, 2017; Robinson: Sustainability Science, 2019), **Reader** (Knight: Geography, 2015; McKay: Human Geography, 2018; Gertisser: Mineralogy and Petrology, 2019), and **Senior Lecturer** (Pringle: Geoscience, 2014; Szkornik: Physical Geography, 2015; George: Sustainability, 2019; Oliver: Environmental Science; Cage: Physical Geography, 2020). In total, five female and six male academic staff have been promoted since 2014. Existing staff develop their research careers through involvement in Keele's staff development programme and discipline specific CPD via professional bodies. All Research Fellows on fixed term contracts are supported in developing their careers, and several early and mid-career staff have secured prestigious appointments at other institutions, including Cassidy (Professor; Birmingham University), Rubino (Lecturer; University of Campania, Italy), Smedley (Lecturer; Liverpool University) and Ullah (Senior Lecturer; Birmingham University).

Management of research time is monitored through Keele's Workload Allocation Model, with new lecturers having their research time protected for the first three years. Early career academics are mentored by a senior staff member and attend a structured staff development programme. In line with the University's Academic Role Expectations, individual research plans (which report on research activities, outputs and grant applications) are reviewed by the Head of School and Director of Research and discussed in the formal annual appraisal process. The plans inform allocation of research time, research support and mentoring. Advice on research outputs and grant applications is also provided via individual mentoring, research cluster leads and an internal peer-review system, which allows all outputs and grant applications to be overseen by the School Director of Research and research cluster leads.

**Equality, diversity and inclusion**

Operating within the Keele University Equality, Diversity and Inclusion (EDI) Strategy (2018-2022) and framework, and holding a Bronze Athena SWAN Award, the proportions of women academic and professional services staff in the school has grown since 2014 to 38% (13 staff) and 60% (6 staff), respectively. The proportion of female staff FTE submitted has increased from 28.2% (4 FTE) in REF2014 (UoA 7, UoA 22) to 43.6% (8.5 FTE) in this submission. Several of our latest recruitments have been women, including Glanville, Scott (School of Life Sciences) and Thompson. All staff who sit on recruitment panels undergo selection and recruitment training, including Unconscious Bias training. Women who are returning to research after a period of maternity leave are supported by the Academic (Maternity) Returner's Fund. Women have been supported through external leadership programmes such as Springboard and Aurora. There are flexible and remote working arrangements in place, which support colleagues with childcare responsibilities and those involved in field courses. Keele holds a Bronze Race Equality Charter award. GGE prides itself for its diverse workforce, with staff and ~1/3 of our PGR cohort coming from Europe, Africa, North America, Australia and Asia. Of our PGR completions since 2014, 36% have been female and 19% had a BAME background.

**Postgraduate research (PGR) students**

PGR FTEs have steadily increased, with 143 FTEs enrolled in GGE since 2014. This amounts to an average of 20.36 FTEs per year, compared to 12.8 FTEs in 2012/13, a 59% increase. PGR

awards (29 awards; Table 1) have more than doubled compared to our REF2014 submission (14 awards), with the average number of awards per year increasing from 2.8 to 4.0, an increase of 43%. Funded PGR student recruitment has been strategically aligned with our key research areas and the strategic priorities of Keele's research institutes. To recognise the diverse needs of PGR students, we advertise opportunities internally and externally to UK, EU and international students on a full- or part-time basis. Positive action statements are used to encourage applications from under-represented groups, and to ensure a fair process, all applicants are interviewed prior to offer to confirm project suitability.

Table 1. Number of research doctoral degrees awarded.

| Year | Research doctoral degrees | PhDs | Professional doctorates |
|---|---|---|---|
| 2013-14 | 3 | 3 | - |
| 2014-15 | 7 | 7 | - |
| 2015-16 | 2 | 2 | - |
| 2016-17 | 5 | 4 | 1 |
| 2017-18 | 4 | 4 | - |
| 2018-19 | 2 | 2 | - |
| 2019-20 | 6 | 6 | - |
| **Total** | **29** | **28** | **1** |

Since 2014, six PhD studentships have been secured through internal funding by the Faculty of Natural Sciences/ACORN (Fogwill, Gertisser, Glanville, Halama, Pemberton, Pringle). Additionally, two studentships have been supported by the ESRC NWSSDTP (Holdsworth), and it is expected that further studentships will be secured in these areas by establishing a new Human Geography and Environmental Studies pathway to support doctoral research. As associate partner of the NERC CDT in Oil & Gas, established in 2013, and the GeoNetZero CDT, which commenced 2019, six studentships have been secured (Clarke), while a further NERC Industrial CASE studentship was obtained via the 2017 National Productivity Investment Fund alongside '4Recycling-Ltd' (Oliver). Further twelve international PGR students have been funded through Commonwealth Scholarships and competitive funding schemes, including the Higher Committee for Education Development in Iraq and TET Fund Nigeria. First destinations of our PGR students have included lectureships (41%) and other positions (7%) in academia, employment in discipline-related industry (38%), discipline-related teaching positions in schools/colleges (7%), and others (7%).

All PGR students are members of the **Keele Doctoral Academy (KDA)**, launched in April 2020, which provides a unified platform for PGR support, including implementation of the Postgraduate Code of Practice. Student progress is overseen by the Faculty of Natural Sciences Postgraduate Research Committee, attended by School Director of Postgraduate Research (Meinhold), with decisions ratified by the University Research Degrees Committee. Progress is monitored formally via six-monthly progress reports completed by students and lead supervisors, doctoral progression (after 12 months) and a pre-submission review stage (after 30 months). No student may progress to formal PhD status without completion of all formal progression-relevant requirements. All PGR students have at least two supervisors, chosen to provide subject-specific and methodological expertise. Only academic staff who are research active, have undertaken supervisor training or can demonstrate a track record of successful supervision may act as lead supervisor. Early-career staff may act as co-supervisor to develop supervisory experience. PGR skills are developed at Faculty and School level through accredited Keele modules, with emphasis on a student-led training programme, set together with lead supervisors and the School Director of Postgraduate Research. All PGR students are required to develop a training plan, and the skills acquired, and training completed are recorded within a 'Personal Development and Learning Plan'. Training is also provided via existing NERC and ESRC training partnerships, where students have access to specialist training workshops provided at participating institutions, and by the KDA. Subject to project requirements and university regulations, the unit's PGR students have given

guest lectures and run seminars on undergraduate courses, mentored by experienced academic staff. Most PGR students have also acted as demonstrators for undergraduate classes, gaining invaluable teaching experience and skills of benefit to their future careers.

GGE PGR students have contributed to our vibrant research environment by presenting in the School's seminar series and through Keele's research institutes. They have taken part in the annual Faculty of Natural Sciences' Postgraduate Research Symposium and the postgraduate conference of Keele's **Institute of Liberal Arts and Sciences (ILAS)** to showcase their research, and have given presentations at leading conferences (e.g. AAPG, EGU, Goldschmidt). A postgraduate support fund held by the Faculty of Natural Sciences (up to £600/year) has facilitated attendance at Vitae, and other external training courses, conferences/workshops and events. This has led to seven outputs in this submission with GGE PGR students as named authors, including two publications in Nature Geoscience (Harris, Hepworth).

In the recent Postgraduate Research Experience Survey (PRES 2019), Geography and Environmental Studies achieved an excellent overall satisfaction score of 92%, which is in the top quartile of 28 participating HEIs in this subject area, outscoring the sector average of 79% and the University's score of 86%. Top quartile results were also achieved for supervision, resources, research culture, progression and attainment, and professional development, highlighting the unit's excellent postgraduate research provision.

**3. Income, infrastructure and facilities**

**Research income**

Compared with REF2014, the unit has successfully increased its average research income per year by over 90% (£406,879 compared to £213,392 in the previous REF period). In total, we have generated £2,848,154 in research income. Research income per Category A staff FTE for GGE has increased by 63% compared to the sector median for Geography, Environmental Studies and Archaeology (UoA17) in REF2014. Significant research grant successes range from esteemed individual awards to large-scale regional, national and international projects with academic partners, industry and policymakers. The former includes a prestigious Leverhulme Research Fellowship (Pemberton), a Leverhulme Major Research Fellowship (Holdsworth) and a Leverhulme Early Career Fellowship (McKay for Thompson). The latter includes several EU Horizon 2020 (Holdsworth, Styles and Pringle) and Innovate UK (e.g. Fogwill) awards, two Cancer Research UK grants (Lucherini, Pemberton), a NERC Urgency grant (Gertisser) and a British Council grant (McKay). Other funds have been secured from the British Academy, Higher Education Academy, Joseph Rowntree Foundation, Spanish Science, Innovation Ministry, the Australian Research Council and in-kind awards from NERC scientific facilities (e.g. NEIF, IMF).

**Major grant successes include:**

**Sustainable Energy and Environments**

- EDRF/BEIS: Smart Energy Network Demonstrator (SEND) (Fogwill; Project total: £15.5M)
- OFFGEM: HyDeploy (Robinson; £871,330; Project total: £8.5M)
- Innovate UK: Zero Carbon Rugeley (led by ENGIE): a major new development as a catalyst for a town wide smart local energy system (Fogwill; £199,332; Project total: £3M)
- Research England Development Fund: Centre for Postdoctoral Development in Infrastructure, Cities and Energy (C-DICE) (Fogwill; £4M available for partnership activities)
- ADEPT – SIMULATE: Smart, Infrastructure and Mobility Urban Laboratory and Test Environment (Fogwill; £1.975M available for research and partnership activities)

**Responsibility and Resilience**

- EU FP-7 (MSCA Fellowship, Mendonca): Youth Entrepreneurship in UK and Portugal (Holdsworth; €299,558)
- Leverhulme Trust: The Social Life of Busyness in an Age of De-acceleration (Major Research Fellowship to Holdsworth; £152,657)

- Cancer Research UK: Exploring the implications of new and novel alternative nicotine products in superdiverse areas for health inequalities (Lucherini and Pemberton; £85,280)
- Leverhulme Trust: Global therapeutic networks: mapping the new disconnects between place and care (Early Career Fellowship to Thompson; McKay; £68,427; Fellowship total: £86,159)
- Cancer Research UK: Vaping, smoking and evolving norms (Lucherini; £62,450)
- ESRC NORFACE: Understanding the practice and developing the theory of welfare bricolage in super-diverse neighbourhoods (Pemberton; £54,442; Project total: £1.2M)
- Leverhulme Trust: Residential mobility in super-diverse neighbourhoods (Pemberton; £49,884)
- British Council: UK Philippines ICTs in Disasters Consortium (McKay; £20,300; Project total: £300k)
- AHRC-GCRF: Curating Development: Filipino migrants' investment in Philippine futures (McKay; £12,287; Project total: £110k)

**Earth Systems**

- EU Horizon 2020: Understanding, preventing and mitigating the potential environmental impacts and risks of Shale Gas Exploration and Exploitation (SHEER) (Styles and Pringle; €291,808; Project total: £2.68M)
- EU Horizon 2020: European Plate Observing System: long-term plan to facilitate integrated use of data, data products, and facilities from distributed research infrastructures for solid Earth science in Europe (EPOS) (Styles and Pringle; €162,275; Project total: £31.0M)
- NERC urgency grant: The 3 July 2019 paroxysm at Stromboli volcano (Italy): is Stromboli playing by new rules? (Gertisser; £21,628; Project total: £64,657 (fEC))

Additionally, GGE staff have been involved in major international research programmes held at institutions elsewhere, as co-investigators or project partners. Examples include:

- Beyond EPICA – Oldest Ice Project: Impurities Consortium (Fogwill; Award: €2.54M; EU Horizon 2020)
- Sediment-related disasters following the 2010 eruption of Merapi volcano, Indonesia (Gertisser; Award: €520k; AXA Foundation)
- Back to the future: Interglacial warming and the West Antarctic Ice Sheet (Fogwill; £323,818; Australian Research Council (ARC))
- Expedition 382. Iceberg Alley and subantarctic ice and ocean dynamics (Fogwill, Cage; International Ocean Discovery Programme)
- Mass migration and real estate in European cities (Pemberton; Urban Land Institute)

**Strategies for generating research income**

The unit's three research clusters perform a strategic role in setting the direction for research activity and generating research income allied to GGE-wide and institutional priorities. The clusters meet quarterly to identify funding opportunities, develop collaborative approaches responding to funding calls, and peer review grant applications before formal submission. This has led to an increase in the number, value and award of grant applications secured, including EU Horizon 2020, UKRI (ESRC, NERC, GCRF) and the Leverhulme Trust. A total of £95k has been made available by the School to support cluster activities geared towards research development, impact and dissemination. For research requiring seed-corn funding for significant research grant development and for bringing together wider groups of academic researchers, the Faculty of Natural Sciences has provided support through the strategic allocation of a Research Development Fund (RDF). In total, £66k has been secured by GGE for developing 19 projects, including research on the impacts of climate change on oceans, mapping atmospheric pollution, thermal imaging of burial sites and the development of new smart energy infrastructure. Institutionally, support has been provided for applications to the GCRF through the Global Challenges Research Network at Keele. To date, GGE staff have received £99k for co-creating projects with international collaborators from DAC countries, including SOLAR-C-Food, a project that seeks to protect the blue economy and support equality and education in coastal communities, and INTEGRITY, a project that aids mitigation and adaptation planning for coastal communities

for sea level rise. Both projects involve university and community partners in Bangladesh and Indonesia.

**Infrastructure supporting research and impact**

Through investment since REF2014, a strong infrastructure has been built, including state-of-the art laboratories, computing facilities and field equipment that have underpinned our strategic research. Analytical laboratories and PGR facilities in the William-Smith Building have been refurbished at a cost of >£360k to provide cutting-edge research facilities for geochemistry, water chemistry, sedimentology, mineralogy/petrology and near-surface geophysics. GGE Staff and research students also have access to shared research facilities in the Lennard-Jones Laboratories (CPS), housing Chemistry, Physics and Forensic Science. Coupled with continued use of the University's £3.5M Sustainability Hub, which, since 2011, has been home to our sustainability activities, the completion (in 2019) of the University's £34M Central Science Laboratories and the Horwood Energy Centre to support Keele's SEND project, such investment has strongly underpinned our strategy for generating research income.

Further investment of >£567,431 in the unit's Antarctic and climate change research has been supported through the development of a dedicated Ice Laboratory, which provides high-precision water chemistry, stable isotope analysis and fluorescence spectrometry capability for dissolved organic matter analysis within bespoke freezer, water and ice sample laboratories. The Laboratory provides new capacity in the UK for ice core and water research, driven by the need to understand climate change across polar ecosystems. Investment into sample preparation facilities for tephra has built capacity for tephrochronological research, while environmental research has benefitted from a portable $CO_2$ flux analyser, a cell imaging multi-mode reader, and investment of £97k for a liquid TOC and portable FITR analyser from the UKRI World Class Laboratories Fund 2020-21, which provides the platform for future cutting-edge research in biogeochemistry, carbon and nitrogen dynamics, and soil science. High-specification computer hardware has built capacity in environmental and climate research in 'deep time', while new multi-frequency ground-penetrating radar and LiDAR systems have been fundamental for our impact case studies in forensic geoscience and fracking. The newly acquired equipment complements existing research facilities, including a substantial geophysical equipment pool worth over £1M, dedicated thin section and ice core analysis facilities, and geochemical laboratories equipped with, for example, a portable X-ray fluorescence spectrometer, a scanning electron microscope, petrological microscopes, a particle size analyser, organic elemental analysers and a heating and freezing microscope stage. These have supported externally funded projects on the dynamics and hazards of igneous and volcanic systems and soil science. Additionally, GGE has benefitted from investment into some of the best UAV technologies in the country, equipped with both RGB cameras and multispectral capability, which have been used to inform research projects with Staffordshire Police to identify burial sites through forensic geomorphology, and for managing historic heritage sites.

**Organisational support for research and impact**

At School level, support has taken the form of: (i) strategic academic staff appointments to research-focused positions within GGE linked to the three research clusters; (ii) appointment of Lecturers in Education and Scholarship to free up research time of academic staff with significant responsibility for research; (iii) allocation of ≥20% research time for staff with significant responsibility for research; (iv) appointment of research leads who strategically direct the three research clusters, manage their research budget and report to the School Director of Research; (v) appointment of a School Director of Postgraduate Research, who strategically manages and develops, together with the School Research Director, all aspects of PGR research; (vi) the launch of a Research Laboratory Committee, which oversees the strategic development of GGE's research laboratories and facilities; (vii) implementation of a research mentoring scheme for staff at all career stages; and (viii) support and an internal peer-review system to enhance research grant applications, managed by the School Director of Research. Together, such support has informed the work of each research cluster and facilitated cross-cluster research linked to our overarching theme of sustainability science. For example, the formal partnership with ULAB has led to a programme of innovative cross-cluster research in sustainable energy for off-grid fishing communities, responding to contemporary national and international initiatives and GCRF

opportunities related to UKRI (ESRC) calls for 'Building resilience for remote communities in small island developments' (George, McKay).

At Faculty level, funding support has included: (i) launch of a competitive scheme for funded PhD scholarships to support investment in major strategic areas; (ii) implementation of a Research Development Fund (RDF) for developing larger grant applications focused on interdisciplinary and external partnership working, public engagement and impact; (iii) a Return to Research Fund to support staff who have not been able to carry out research for a period of time due to career breaks, including maternity leave and/or teaching and/or administrative duties; and (iv) an expanded Research Recovery Fund to support researchers or to re-establish strategically important research programmes that have been delayed due to Covid-19 and associated control measures.

Institutionally, the Research and Innovation Support Enhancement (RaISE) team draws together professional services staff with expertise in research development, governance, integrity, ethics, contracts, public engagement, partnerships, commercialisation, and impact. The team supports the development of research and innovation projects involving Keele and external partners and has enabled a combined approach to research and innovation support, enhancing the quality and effectiveness of our research proposals, their implementation and impact. Support from the three institutional research institutes has informed our strategy for generating funding, including interdisciplinary research activity around clean energy, sustainable governance and communities, and communicating sustainability (Institute for Sustainable Futures); migration (Institute for Social Inclusion); and health (Institute for Global Health). Development of impact from research has been supported through an impact development programme of impact workshops, an annual, week-long impact and engagement festival, and launch of an 'Impact Acceleration' funding scheme. The latter has supported GGE staff involved in the organisation of impact workshops and meetings linked to the EU Horizon 2020 EPOS and SHEER projects.

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

**National and international collaborations, networks and partnerships** have been crucial to the delivery of our research strategy. Institutionally, the RaISE team has supported GGE in identifying strategic research partners and has worked to develop and deliver high-impact research programmes integral to building capacity, and delivering knowledge exchange and impact to research, economy and society.

**Regionally**, GGE is leading Keele's contribution to the ERA programme of Midlands Innovation, the grouping of eight research-intensive universities in the Midlands to drive cutting-edge research, innovation and skills development that will grow the Midlands' and UK's high-tech, high-skilled economy (Fogwill, Glanville).

**Nationally**, GGE has collaborated on several innovative programmes that are crucial to the UK's ambitions for net zero (SEND, HyDeploy, SIMULATE, Zero Carbon Rugeley) and underpinned by collaboration with UK academic, commercial, community, and governmental partners who have been fundamental to the unit's success. Examples include industry partners (e.g. Siemens, ENGIE, Cadent), community groups (e.g. Chase Community Solar, Sustainable Housing Action Partnership, REGEN, New Vic Theatre), and policy-facing collaborators (e.g. BEIS, Energy Catapult, BGS, regional councils).

**Internationally**, GGE has led major research programmes, including the EU Horizon 2020 EPOS and SHEER projects (Styles, Pringle), the NORFACE-funded project on welfare bricolage in superdiverse areas (Pemberton) and an EU Horizon 2020 project exploring youth entrepreneurship (Holdsworth). We have also participated in major international research programmes; examples include Pemberton's co-investigator role in the Urban Land Institute-funded project 'Mass migration and real estate in European cities', McKay's co-investigator role within the AHRC-GCRF 'Filipino migrants' investment in Philippine futures' project, Gertisser's involvement as work package leader in the AXA Foundation research consortium 'Sediment-

related disasters following the 2010 eruption of Merapi volcano, Indonesia', and the co-investigator roles of Fogwill and Cage in the International Ocean Discovery Programme 'Expedition 382: Iceberg Alley' and the EU-funded 'Beyond EPICA – Oldest Ice Project'. As one of only three UK-based members of the International Institute for Environmental Studies (GGE lead: Oliver), we have provided opportunities for students and researchers to be involved in international environmental research.

Establishing a School Internationalisation Director role has been instrumental in developing **new international partnerships**, including concordats and memoranda of agreement with Guangzhou and Tongji universities (China), the University of Northern Sumatra (Indonesia), Narxoz University (Kazakhstan), the University of Campania (Italy), the British Council South Africa Programme, and ULAB. Since 2014, GGE has welcomed thirteen **research-focused academic and industrial visitors** from nine countries, supported through several prestigious Keele ILAS Fellowships.

**Our strong national and international collaborations, networks and partnerships** are crucial to maintaining **high-quality, high-impact publications.** This is evidenced by publications in prestigious journals, including Nature (Fogwill), Nature Geoscience (Fogwill, Gertisser, Cage, Rubino), Nature Communications (Halama, Waller), PNAS (Fogwill, Rubino), Geology (Meinhold, Smedley), Quaternary Science Reviews (Gertisser) and Journal of Rural Studies (Pemberton) on topics that attracted significant media interest, ranging from Antarctic ice melt (Fogwill) and volcanic processes (Gertisser) to the impacts of international migration on urban and rural communities (Pemberton) and alcohol and vaping practices (Holdsworth, Lucherini). International recognition of GGE staff is highlighted by the award to Styles of the Medal of Merit for contributions to European Geoscience in 2015, and in relation to our Green Gown Awards and Nominations in 2016, 2018, 2020 and 2021.

We have contributed to the **research base of the discipline** through **journal and scientific book editorships and editorial board memberships of international journals**, notably: Scientific Reports, Antarctic Science and PAGES Magazine (Fogwill), Journal of Mineralogy and Geochemistry and Geochimica et Cosmochimica Acta (Halama), Frontiers in Earth Science – Volcanology (Gertisser), and Social and Cultural Geography, and Population, Space and Place (Holdsworth). An example of our book editorships is Elsevier's Stratigraphy & Timescales series (Montenari). We have provided **expert reviews for high-impact academic journals** including Nature, Nature Geoscience, Nature Communications, Scientific Reports, Bulletin of Volcanology, Journal of Applied Ecology, Health and Place, Urban Studies, Environment and Planning, Social and Cultural Geographies, Regional Studies, and Journal of Ethnic and Migration Studies, and have assisted regularly on national and international postgraduate research examination panels. We have served as **council and committee members** and **fellows of learned societies and professional bodies**, including RGS/IBG, Rural Studies Research Group, Association of Southeast Asian Studies, BGS, EuroGPR, NSGG, RICS, Metamorphic Studies Group, Forensic Geoscience Group (chaired by Pringle 2016-18), the Geological Society Accreditation and Chartership Panels, and the British Ecological Society, including its Public Engagement Working Group.

We have provided **expert advice** through **knowledge exchange** on the UK Burial Expert Panel and Home Office START group (Pringle), Earthwatch Institute (Scott), the IUCN Global Mammal Assessment (Scott), the Higher Education Academy Education for Sustainable Development Advisory group (Robinson), and the Intergovernmental Panel on Climate Change as expert editor (Fogwill) and contributor (Law). We have served on **technical and scientific review panels** and **as scientific session convenors of major national and international conferences** such as AGU, IGARSS, IEEE, EGU and EAGE, where we have also given **invited or keynote presentations** (e.g. Goldschmidt – Gertisser, Halama; Geological Society (NSGG-FGG – Pringle). We provide **service to major national and international funding agencies** through: (i) memberships of the NERC (Glanville, Halama, Oliver, Pringle), ESRC (Holdsworth, Pemberton, McKay), British Council (Oliver); (ii) research grant assessors on ESRC panels (Holdsworth, Pemberton), the UKRI Future Leadership Fellows panel (Holdsworth) and the European Research Council's Peer Review College (Holdsworth); and (iii) regular reviews of UKRI and international

grant proposals for NERC, ESRC, AHRC, GCRF, EU Horizon 2020, and research councils in the USA, Canada, Australia, South Africa, France and Germany. Furthermore, we have **supported UKRI's Research England council** through McKay's appointment as outputs assessor to the REF Main Panel D (Sub-Panel 25 - Area Studies), and hosted **important events and workshops**, particularly the 2015 EU COST Management Committee and Training School focused on intergenerationality and resilience across the life course (Holdsworth). We have also hosted the EPOS training course and three NERC-funded 'Geophysical Skills for Environmental Scientists' advanced training courses for PGR students, ECRs and graduate-entry geophysicists in industry (Pringle, Stimpson).

Our **research impact on practice, policy, economy and society** is demonstrated by Styles' collaboration with the Department for Environment, Transport and Rural Affairs (DEFRA) and BEIS, transforming UK government policy on fracking, Stimpson's role as Vice-Chair of the EPOS SP TCS-AH Consortium Board, and Pringle's provision of expert evidence for a House of Lords forensic science enquiry and expert search support for the National Crime Agency, exemplified by our impact case studies. We have collaborated with the Environment Agency and the Angling Trust on issues of otter predation (Allen, Pemberton), and with ecological consultancies and NGOs (e.g. Royal Society for the Protection of Birds, Environment Agency) on wetland birds and mammals. This has led to publications and guidelines linked to management practices and mitigation (Scott). We have been engaged in the **public understanding of science** through: exhibitions, including 'Subversive Plasticity' involving local artists and the ESRC Festival of Social Science in partnership with London-based Filipino community Kanlungan (McKay); outreach events via Keele's award-winning Higher Horizon Stardome programme (Gertisser), 'Pint of Science' (Fogwill, Pringle) and Stoking Curiosity (Fogwill, Holdsworth, McKay); media impact via live interviews by, for example, BBC, Sky News, ITV, TRT World and the Press Association; and 64 articles in The Conversation, with over >2.5M reads since 2014. We have featured on national and international television productions as experts, including BBC Springwatch, Channel 4 and ARTE-TV (Scott, Gertisser), and have been involved in citizen science-based initiatives, including a project funded by the Earthwatch Institute in Estonia, working with >150 citizen scientists to survey and monitor wetlands, and BBC Urban Mammals (Scott). Researchers have also **established links with key stakeholders,** including policy makers and members of parliament, leading to the first reading of the Pet (Theft) Bill in the House of Commons, following launch of a government petition on pet theft as a specific crime (Allen). Such links have also added to the development of the SEND project, and along with the School of Computing and Mathematics (SCM) and commercial partner Siemens, are jointly responsible for programme implementation and delivery (Fogwill, Healey, Cao). Furthermore, Robinson, with academics from CPS, is responsible for directing research and development of HyDeploy, working with commercial partners (e.g. Cadent) to establish the potential for blending hydrogen into the gas supply to reduce carbon dioxide emissions, and has been invited with the HyDeploy Consortium to provide expert evidence to the House of Commons Science and Technology Committee. Building on the SIMULATE project (2019-2021) – a Department for Transport-funded programme led by Robinson with academics from SCM, the Keele Business School and School of Psychology – to support innovation and R&D in future transport systems, we are leading work on a Keele Smart Transport Demonstrator Partnership (Robinson). Our global reach is exemplified by our work with the UN Environmental Programme and UN Climate Change Commission through the School's SEND Professor in Practice (Healey), who has advised government on the clean energy transition and serves on the BEIS Energy Innovation Programme advisory board. Healey is also Industry Advisor to the joint CENELEC/ETSI task force developing EU energy data network and Demand Side Management standards, and 'Industry Expert' at the United Nations Committee for Europe (UNECE) that develops the UN strategy on sustainable energy to realise international agreements on climate change.