

Institution: Robert Gordon University (RGU)
Unit of Assessment: 12 - Engineering
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 Content & structure</p> <p>Research at the Engineering unit is creating a vibrant, sustainable and expanding community with the vision to be recognised internationally for our impactful research in our core themes:</p> <ul style="list-style-type: none"> • Advanced Materials (Faisal, lead): focus on materials, manufacturing, testing and condition monitoring (10 academics, 2 RFs, 15 PhDs). Research includes development of novel, new, functional materials and their applications, nanomaterial safety in consumer products, coatings, improved understanding of damage, failure envelopes mitigation and fracture mechanics in commercial products, circular economy and waste management solutions. The team has established partnerships in Oil & Gas, Energy, Transport, Chemical, Processing and other safety-critical industries. • Environmental Engineering (Lawton, lead): focus on developing technologies and processes in treatment of water, soil and waste oil using chemistry and electrochemistry (4 academics, 4 RFs, 5 PhDs). Research includes development of biotechnologies for algae detection and generation of bioproducts, environmental sensors and tracers detection of a range of compounds in air, water and soil. This includes development of reference materials and monitoring regimes, including novel photocatalytic reactors and new methods of wastewater treatment. • Energy (Hossain, lead): theme encompasses diverse activities in flow modelling, oil and gas, membrane technology and renewable energy (12 academics, 35 PhD students). The group is problem-focused including development of tools and techniques for the energy sector including oil and gas, energy transition and the renewable energy (hydrogen, wind, tidal and solar) sector. The key topics include multiphase flow induced vibration, hydro cyclone separator, multiphase flow assurance, integrated sand management, geo-mechanics, enhanced oil recovery, hydrogen production and purification, carbon capture and storage, and battery technologies. • Instrumentation & Sensors (Prabhu, lead): recently developed following an investment in the expansion of the Unit's Electrical and Electronic Engineering expertise and knowledge base (11 academics, 2 PDRAs, 12 PhD students including 7 new early career researchers (ECRs)). The research in instrumentation investigates the design, modelling, control, simulation, communications and development of autonomous systems and devices. Research in sensors covers wide range of fields including photochemistry, environmental tracers and sensors, clean technology, photocatalysis, photonics, spectroscopy, biosensors, instrumentation, environmental sensing, and monitoring. <p>1.2 Research Strategy</p> <p>The Unit's strategic aims are:</p> <ul style="list-style-type: none"> • To develop research that has long-term, transformative and sustained impact on our society in its core themes: Advanced Materials, Environmental Engineering, Energy, and Instrumentations & Sensors. • To be recognised as the source of knowledge and technical expertise for industry, governments, and society, in our core themes. • To sustain the growing volume, quality and impact of research carried out. <p>Our research made steady progress from RAE2008 to REF2014 (GPA 2.10 to 2.85 overall). However, following the REF2014, the Unit has experienced a high turnover of staff (52 staff left, including 16 due to retirement), which means the process of rebuilding the Unit's capacity is still in progress. In parallel, the University implemented major structural and operational changes following REF2014 with the dissolution of Research Institutes in 2015 and the Academic Faculties in 2016, moving to a School-based structure that has enabled the increase in cross-School, interdisciplinary activities, and the alignment of research to teaching and the establishment of a single Graduate School.</p>

Research leadership has also been consolidated through the appointment of an Academic Strategic Lead (**Njuguna**) to develop and implement the research strategy at Unit level. The core strategic achievements during the REF2021 period have centred on:

- Increasing the number of PhDs (from 36/yr to 60/yr) and improving PhD completions (from 26 to 53)
- Supporting career progression of research staff (nine ECRs to Senior Researchers and 12 to independent researchers; and seven postdoctoral Research Fellows (RFs) to Lecturers) plus growing the number of mid-career researchers (four to 14).
- Increasing the volume of high-quality publications (from 33/yr in 2014 to 70/yr in 2021)
- Growing research and commercialisation income. Four start-ups created by research staff. Research activities have engaged over 80 business, around 30% of which are start-ups developing innovative technologies, six KTP projects and supported >20 now commercialized industrial engineering products.

Additional significant strategic achievements over the REF period include:

- Contributing to national emergencies by redirecting resources to manufacture PPE and face shielding for Grampian NHS and securing Scottish Funding Council (SFC) funding for designing advanced PPE to tackle the COVID-19 pandemic.
- Supporting the creation of National Subsea Centre (NSC), a £40 million RGU partnership with the Oil and Gas Technology Centre (OGTC) and industry, as a part of the Aberdeen City Region Deal. Launched in 2020, the NSC aims to tackle challenges in subsea engineering; to deliver cost-effective, faster, smarter and cleaner technology which will be developed with, and deployed across, the industry.
- Developing new strategic collaborations with Scottish Research Partnership in Engineering (SRPe) that has led to partnerships with other universities in two European Regional Development Fund (ERDF) funded initiatives (£3.7M for the Medical Devices Manufacturing Centre) and a collaboration with University of Strathclyde in Digital Manufacturing Skills Academy (£3M) delivered through National Manufacturing Institute Scotland (NMIS).
- Building a strong foundation for industrial collaboration to increase income with demand-led applied research as evidenced by the growing number of projects with industrial collaborations (see, Section 4.2).
- Continuous leadership and management of the Sand Management Network, a group of over 30 organisations (including BP, Shell, Chevron, Baker Hughes, Total among others) with interest in Research & Development to tackle problems in Oil and Gas (O&G) exploration and production to meet regional, national and international research challenges.
- Institutional and departmental Investment of ~£10m in improvement of engineering laboratory facilities through major projects and collaborations, including the Materials testing Lab, Manufacturing facilities, Membrane Processing Lab, Composites Lab, Multi-phase flow loops, ROV pool and Wavetank, Laser Lab, CyanoSol Lab and joint venture between KCA Deutag Ltd/RGU DART® training facility; £500,000 Wood Group Foundation investment to develop Energy Transition Institute (previously named 'Oil and Gas Institute').
- Establishment of four start-ups (d-Finger Ltd, SafeInflux Ltd, LITESTAT Limited, neoSome Ltd); two US Patents awards, five non-disclosures and Materials Testing Services consultancy business.
- Hosting/organising international conferences, including SPIE's "Counterterrorism, Crime Fighting, Forensics and Surveillance Technologies"; IEEE's 'Sensors'; MTS/IEEE 'OCEANS 2018' International Conference on Structural NanoComposites Series (NANOSTRUC 2014, 2016,2018), Hydrogen Forum; and hosting 46 visiting researchers, nine of international standing.

- Improving research KPIs compared to REF2014, with a total research income of £4.67m (42.7% increase), 493 outputs produced (50% increase, and new revenue stream in commercial research income (from £0 to £2.9m).
- Growth in research-led teaching, more alignment of research expertise with teaching programmes; and development of biomedical, manufacturing & design courses aligned with research knowledge base including formation of a new Advanced Materials and Instrumentation & Sensors research groups.

Our future strategic goals for the next five years are briefly stated as:

- Increase research active staff number through large/midsize externally funded projects and doubling the research staff time allocation FTE to 18.
- Develop competitive, sustainable critical mass of researchers through our interdisciplinary research groups by investing in PhD studentship and attractive staff retention plan.
- Significantly increase research/commercialisation income (from UK/International) to £3M annual turnover by 2024 and £4M by 2026, by creating a culture of grant writing through provision of training and mentoring, fostering productive collaborations.
- Achieve an overall research excellence recognized to be in top 30 in REF2028 for the relevant unit of assessment, by increasing the number of staff producing nationally and internationally recognised high-quality outputs (3*/4*) to 30.
- Increase the number of RFs (six), PhD/EngD registered students (≥80) and completion of (20/yr) PhD/EngD students by 2024.

1.3 Impact strategy

The Unit recognises the importance of impact, which remains a strategic priority and a core driver for its research activities. To sustain and maximise the impact of our research, the Unit aims to:

- Provide specialist training to broaden staff knowledge of research impact.
- Continue our work with partners in developing countries to sustain the impact of our research in advancing drinking water quality worldwide.
- Sustain existing activities with industry stakeholders, such as the Sand Management Network, Materials and Engineering Testing Services, Interface, and the National Subsea Centre, and establish new partnerships as a route to deliver impact.
- Develop a series of public engagement events to promote the impact of our research and to encourage further collaboration for future activities with potential for further impact to the wider society.
- Enhance business engagement and enterprise through the KTP network, Interface, and Scottish Enterprise.
- Develop a more effective process for collecting impact evidence of our research projects.
- Increase transparency and reduce current barriers in IPR permitting, licensing, and insurance support.
- Engage with Schools, Colleges, and Institutes to develop training and guidance, including through the Aberdeen Festivals and Science Weeks.

During the REF2021 assessment period, we have undertaken several initiatives to support and stimulate the development of impactful research within our Unit. In 2019, several research staff attended the Impact Workshop organised by the University's Research Strategy & Policy office. This has enabled staff to consider impact from the inception stages of our research projects. In addition, we have capitalised on commercial projects to foster long-term partnerships with industry collaborators, as well as enabled student placements. Furthermore, research active staff are encouraged to and have participated in industry and professional events such as Offshore Europe, SubseaExpo, Euroforum (organised by SMN), SPE and IEEE conferences and collaborated/co-designed research projects with engaged industrial and academic collaborations companies (examples in Section 4).

Our research impact is achieved through working directly with end users, which is one of our key strengths. This can be evidenced by, among others, our research into improving toughness of

materials to enhance functional performance that has driven economic growth and cost-saving innovations in engineering products worldwide (*Impact Case Study 1*). This study has led to the development of novel materials and technologies, which have since been successfully applied in new commercialised pipe and pipeline products in the O&G sector, as well as in improvements in building safety and cost-effectiveness in the Construction industry in Dubai, Singapore and Far East Asia. Furthermore, research led by our Environmental team has supported the development of World Health Organisation (WHO) guidelines, and underpinned international detection methods and water treatment strategies worldwide (*Impact Case Study 2*). Our in-house algal biotechnology generates the world's largest supply of cyanotoxins (17 individual toxins, c. 50 products) (transfer price >£2 million since 2009) used by stakeholders worldwide establishing and maintaining monitoring programmes, optimising water treatment and establishing health benefits.

1.4 Interdisciplinary Research

Research staff in the Unit have extensive opportunities to interact with specialists in other disciplines, including internal and external seminars, and the development and delivery of cross-school courses such as the BEng/MSc Biomedical Technology. Furthermore, our research staff also have access to shared facilities with other schools, including the School of Pharmacy and Life Sciences, Scott Sutherland School of Architecture and the School of Computing. This has enabled several interdisciplinary projects, including but not limited to:

- Research on safety of nanomaterials looking at safety regulation and policy in occupation health, toxicology and ecotoxicology, materials science and engineering, which involved Technalia and Inkoa (Spain), CSIRO (Australia), Cranfield University, RGU and Imperial College and Vito (Belgium).
- Study on fuzzy logic application into value of information assessment in O&G projects, a collaboration between the School of Engineering and the School of Computing.
- A collaborative research between control engineering and computational sciences on innovative solution for UAV swarms which mimic the chaotic dynamics of ant colony.
- Research on drilling fluid waste between chemists, analytical sciences, materials science and engineering to address circular economy challenges, in partnership with Dundee University, Northumbria University, University of South Africa (S Africa) and Cracow University of Technology (Poland).

The Unit does recognise, however, a requirement to develop more incentives to allow more researchers to continue their research in fields complementary to their own. This would include:

- Creating mechanisms for interdisciplinary work to be evaluated by panels on which multiple disciplines are represented.
- Providing collaboration opportunities for researchers to learn from scholars in other fields.
- Funding sabbaticals and visiting-scholar grants for researchers to work in multidisciplinary groups.

1.5 Open Research Environment

Engineering research embraces an open research culture including sharing of research data, delivery of academic seminars, newsletters and staff-student activities. A core strategy is that all research supported by the Unit must be collaborative. All staff are required to ensure publications which conform with requirements for open access, and institutional support is also provided. We monitor open access compliance via three-monthly reports, reviewing and discussing compliance at the research committee meetings. Our submission open access compliance (96,2%) reflects this commitment. Sharing of raw data is managed at institutional level with input from the Unit. Every project and PhD student must create a data management plan. Data is stored and regularly backed up using Institutional data repository (RGU OpenAir) hosting over >5000 outputs.

1.6 Integrity

The School of Engineering has a Research Ethics & Integrity Committee chaired by the Research Lead (**Njuguna**) and comprised by senior researchers (**Faisal, Steel, Mamdud, Prabhu**) and support staff (Shanks and Stevenson (secretary)). Environmental Engineering research is overseen by the School of Pharmacy and Life Sciences Ethics Committee. The individual Committee meets quarterly, and its remit is to ensure all ethical aspects of the School's research activities are in accordance with RGU's Ethics Policy (2017) and the Concordat to Support Research (2019).

In addition to the above mechanisms, all University's research funding applications are required to undergo a meticulous process of internal authorisation, which includes the review and approval of Ethics self-assessment questionnaires. This process is overseen by the Research Strategy & Policy office.

2. People

2.1 Staffing strategy

All academic staff within the Unit are on Teaching & Research contracts, in accordance with Scottish employment law for post-1992 institutions. The distribution of teaching and research workload is determined by the line managers within the Unit. They allocate duties through the annual Employee Performance Review (EPR), a transparent process that enables academics to discuss their priorities and objectives, which include their time allocation for research.

In this Unit submission, 16 of the academic staff are active researchers, of which four are ECR, seven are mid-career researchers and five are at Professorial grades. The current submission consists of 15.8 FTE, and the Unit highly supports researchers to become independent researchers through the provision of a strong collaborative environment. All submitted staff are on permanent contracts.

At RGU, research is managed under the leadership of the Vice-Principal for Research, through the Heads of School and Academic Strategic Leads (ASLs). In this Unit, the latter is responsible for developing and updating our research strategy as well as the development of staff. Our ASL organises bi-monthly research meetings with the theme leads to cement the foundations of our strategy, and the Engineering Research Committee meets quarterly to review implementation and progress of the strategy, reporting back to the Unit/University Senior Management Team.

Succession planning is at forefront of our strategy to develop future research. Since REF2014, a significant number of ECRs have been recruited to replace a high volume of staff who have retired and to cover Unit expansion. Each ECR follows a probationary process under the guidance of a line manager, being appraised annually through their EPR and being supported through collaboration with other academic colleagues.

ECRs are allocated to one of the thematic areas under the theme lead and supported through mentoring and in producing high-quality publications and encouraged engage in research projects with senior researchers as Co-PIs. Whilst during this assessment period many ECRs did not meet the requirements of independent researcher as set out in the RGU Code of Practice, the Unit is currently setting out plans to create effective mechanisms to support and guide them towards research independency status.

In 2018, new role profiles were implemented for Reader and Senior Lecturer giving progression to higher grades as well as well-defined routes to Professorial grades. In the Unit, staff are supported through mentoring, guidance, and networking opportunities. This has led to two Professorial (Edwards, Njuguna) and three Reader (Hossain, Prabhu, Faisal) promotions since 2018.

2.2 Staff development

Our EPR process allows a degree of flexibility in allocating research duties and direction of career at different stages of career progression. Our staff are set clear objectives related to grant income,

publications, and postdoc/PhDs supervision in their appraisals and have ring-fenced time to achieve these objectives. However, it has been challenging to relieve staff from teaching and administration duties (a matter the Unit plans to address in its strategy). Staff at all career stages can apply for Sabbatical leave (institutional policy) with the support from the School.

We offer an excellent support platform for staff to collaborate with industry. We work closely with research networks such as Scottish Innovation and Technology Centres; O&G Innovation Centre (OGIC); Industrial Biotechnology Innovation Centre (iBioIC); Sand Management Network; Innovation Centre for sensing; Imaging and Internet of Things (IoT); Oil and Gas Technology Centre (OGTC); and Energy Technology Partnership (ETP). Moreover, extensive networks with industry have been built through participating in industry events such as Offshore Europe, Subsea Expo, All-Energy and professional body events IMechE, SPE, IOM3, IMarEST, and EI. Professional body events are held at RGU and our staff volunteer in their committees.

Our staff also have access to leadership and professional development programmes supported by RGU. Several our staff have taken part in these programmes (see below), and we will continue to support such involvement.

- Pioneer: RGU Future Leaders' Programme - 3
- Voyager: RGU Middle Managers' Programme (ILM Level 5 Certificate in Leadership and Management) - 4
- Discoverer: RGU First Line and Aspiring Managers' Programme (ILM Level 3 Award in Leadership and Management) - 4
- Aurora: Women in Leadership Programme - 5
- The RGU Manager (for new managers) - 4
- Pedagogical training programme– All staff
- PhD supervision training programme – All PhD supervisors
- Staff Wellness (physical and mental health) programmes – All staff
- Research Ethical and Integrity programme – 1
- Health and safety training programme – all staff
- Innovation and research commercialisation – 6
- RGU Skills4Success - 9

The Skills4Success portfolio of staff development workshops help staff with professional and interpersonal skills such as time management, communication, and personal effectiveness. The Unit also offers staff individual coaching sessions with experienced leadership coaches, team development, facilitation, and other bespoke development interventions.

2.3 Research Students

The Unit has made significant investments in attracting excellent PHD/EngD students through offering fee-only and full-stipend studentship. Furthermore, to address the skills gap resulted from the departure of senior staff, the Unit has supported the development of 20 ECRs as co-PhD supervisors, guided by experienced researchers. Looking ahead, the Unit aims to focus investment on ECRs towards research independency.

Since, REF2014 the School has offered studentships to a total of 28 students, investing £1.3 million on fees and stipends. These students published 29 journal articles and participated in 50 conferences, with 100% completion within 3.5 years. The Unit will continue to support this initiative through further investment.

Our research students are a diverse group, of whom 80% are international students. The cohort is predominantly male (76%), which is not unusual in this discipline. Looking ahead, similarly to our staff recruitment approach, we aim to actively encourage applications from female students. During the REF2021 period, the completed PhD students have been funded through e.g. The Carnegie Trust (1); Commonwealth Scholarship (1); Research Pooling Energy Technology Partnership/Northern Research Partnership (ETP/NRP) (2); The Petroleum Technology Development Fund (PTDF) (7); Niger Delta Development Commission (NDDC) (3); Sonatrack (1); PTQI (1); Kuwait Petroleum (1); School funded studentship (28); Engineering staff (3) and self-funding. The Unit is a major recipient of PTDF studentship funding for being a well-regarded centre for O&G related research.

PhD students are recruited following success application and interview. The progress of the research journey is managed by the School and the Graduate School. After induction, students attend a week-long PgCert module (the first of two modules) in Research Methods. Within three months of enrolment, students submit their PhD/EngD registration form indicating a supervisory team.

The supervisory team consists of first and co-supervisors. Within two months of attending the first PgCert Module, students submit a report setting out a Research proposal, a RESSA form and a personal development plan (PDP), which are marked and returned with detailed feedback. After one year, a student attends the second module on Research Methods and submit a progress report with a RESSA form and a PDP plan, following which the report is marked and feedback provided. After 12-15 months, students submit a transfer proposal and attend a transfer viva conducted by an independent assessor, following which the successful students move on to the PhD phase, while unsuccessful student get an opportunity for a resit or work towards MPhil/MSc by Research.

Each year, student's fill an annual review form which gives an opportunity to student to voice any concerns independent of the supervisory team. Following the meeting, a detailed plan of action is drawn and in difficult cases, the issue is raised to the Graduate School Lead (GSL). Students have opportunity to meet with the Head of School and the GSL on a one-to-one basis or through Student-Staff Liaison Committee meetings. The PhD students' representative is also a member of the respective School Academic Board. The School provides funds for PhD students to attend international conferences. The Unit has made presenting at the School Research Seminar mandatory before attending international conferences.

Attending the School Research Seminar Series is also mandatory for PhD students. Since 2014, 44 research seminars were organised by the School. These seminars included presentations from research students (53), academic staff (13) and external speakers (32), providing the students an opportunity to learn and interact with international and national researchers.

In addition, the Graduate School runs Researcher Training Programme throughout the year and online training materials are provided through the RGU Campus Moodle (VLE portal) to develop their skills for their future career. The Graduate School organises Residential Retreats Days for the research students with extensive training on thesis writing, facing viva and career planning. Research students co-develop data management plan with their supervisory and upon approval are allocated data repository.

Health and Safety training is mandatory for research students who often work as demonstrators in tutorial and lab sessions and can join the training programme to become Associate Fellow of the Higher Education Academy. Since 2014, four PhD students joined the Unit as Lecturers. Furthermore, research students often work part-time as a research assistant in short-term funded projects.

Research students are required to produce a career development plan using Research CV planner in their PgCert Research Method Reports. The Research Degrees Co-ordinator is involved throughout a student's PhD journey from admission, registration, progress monitoring, transfer, and PhD examination. We have implemented a strategy for monitoring and managing student progress which resulted in time completion rate within the registration period improving from 30 % to 47%.

Our PhD students won several prizes including SPE Student Bursary, SPE European Regional Student Paper Contest and Best Conference Presentations. PhD student interviews are featured in the quarterly School Research newsletter, where students discuss about their research project, motivation and career aspirations. Social events are organised through Research Students Association. PhD students have been supported throughout the COVID-19 period with extension of registration, hardship fund and well-being support as well as individual needs regularly assessed by the Graduate School to minimise disruption. Recent survey shows that 85% of Engineering PhD students are satisfied with overall research degree experience with 98% satisfied with their supervision. Furthermore, 86% are also satisfied with the support provided during COVID-19.

2.4 Equality and Diversity

Our Unit comprises a diverse group of researchers drawn from a wide cross-section of society, provides support and a conducive environment to enable them to progress with their research career. We are the most diverse Unit in RGU. We embrace a positive attitude towards the promotion of equality and diversity and take pride in creating a working, educational and social atmosphere that is inclusive of everyone. We share the belief that equality is a way to ensure successful team performance by increasing its diversity, acknowledging the fact that organisations with a diverse workforce are more progressive in terms of innovative ideas and skills than those without it. This is not limited to gender equality but covers age and cultural diversity.

Unit has 78/22 male to female academic staffing ratio and stands at 77.4% to 22.6% in current PGR cohort, with overall 12.9% White, 66.1% Black and 21% Asian representation. In this Engineering submission, 12% of submitted staff are ECR, 19% of submitted staff are female, 44% submitted staff are white; 56% BAME.

As part of the University's Equality and Diversity Policy, all staff are expected to be aware of and comply with the policy's principles and complete the mandatory training in Equality and Diversity.

Our policies support flexible working patterns as well as working from home and part-time working, through the implementation of University policies such as Family Friendly, Flexible Working and Sickness Absence Policies. The Sabbatical Policy is also made available to all research staff at any career stage. The success of this policy is clearly demonstrated by accomplishments of Prof Edwards, who during her sabbatical has successfully applied as a Principal Investigator for funding of £1,18 million (BBSRC/NERC Safe and Sustainable shellfish consortium grant), plus a further £250,000 from industry 2018-2021, and £160,000 from KTP with Scottish Bioenergy on valorisation of algal material 2018-2020. Prof Edwards was also awarded £1,281,487 on the 'In-reservoir destruction of Blue-Green Algae and their toxins' project as a Co-Investigator.

Staff and students' wellbeing is also well supported. Balance of teaching and research work is managed through workload modelling with annual EPRs allowing staff to review workload with line managers to facilitate a favourable working environment. RGU has dedicated wellbeing webpage (WorkLife) with support made available to staff and students (for example, 24/7 helpline).

To promote diversity from the onset, research students and ECR staff are encouraged to join the RGU early career researcher (ECR) Network which is managed by the Research Strategy & Policy Department and the Graduate School. Another important network is the Engineering Female staff supported through the Aurora programme and a developing 'Woman in Engineering Group' of about 70 members (staff and students).

3. Income, infrastructure and facilities**3.1 Income:**

Overview of Research income during the assessment period:

Income Sources	2013 - 14	2014 - 15	2015 - 16	2016 - 17	2017 - 18	2018 - 19	2019 - 20
BEIS Research Councils, The Royal Society, British Academy and The Royal Society of Edinburgh	39.55%	29.54%	18.83%	28.77%	21.32%	31.31%	51.23%
UK-based charities (open competitive process)	0.31%	0.36%	0	0	0.73%	1.26%	0.11%
UK-based charities (other)	0	0	0	0	0	0	0
UK central government bodies/local authorities, health and hospital authorities	12.34%	12.12%	31.57%	32.3%	14.92%	13.02%	11.41%
UK central government tax credits for research and development expenditure	0	0	0.21%	0	0	0	0
UK industry, commerce and public corporations	20.98%	19.03%	15.26%	14.21%	16.76%	19.42%	13.51%
UK other sources	0.05%	0.72%	0	0.66%	14.45%	13.54%	0.39%
EU government bodies	1.67%	2.69%	2.61%	0.62%	0	0	0
EU-based charities (open competitive process)	0	0	0	0	0	0	0
EU industry, commerce and public corporations	0	0	0	0	0.15%	0	1.57%
EU (excluding UK) other	0	0	0	0	0	0	0
Non-EU-based charities (open competitive process)	0	0	0	0	0	0	0

Non-EU industry commerce and public corporations	25.1%	23.05%	17.88%	18.78%	28%	20.76%	20.18%
Non-EU other	0	13.11%	13.64%	4.66%	3.67%	0.69%	1.6%

The Unit also attracted additional direct industrial funding (80 projects, worth £2.9m plus in-kind contribution). The Sand Management Network which is after 20 yrs is now moving on to Phase 10, has had an impact on the dissemination and implementation of best practice across the O&G industry in relation to new techniques, products, health and safety and the environment. This has led to the development of sand management technologies and workflows to improve the economic viability and enable safe operation of sand prone fields in the North Sea. Many of our ECRs have successfully obtained grants (41 projects, worth £537k cash & in-kind) through Innovation Vouchers from the Scottish Funding Council, directly working in collaboration with industry.

Our Wave Tank has attracted funding to develop innovative wave energy solutions to power subsea small pool developments (£100K from the OGIC). A wind tunnel has been used to develop and test innovative vertical axis wind turbines. Material testing facilities attracted consultancy worth £200k and mostly leading to research projects. Our research has also benefitted from institutional Pump Priming funding to develop lab facilities for electrochemical testing focussing on solar energy harnessing and vertical axis wind turbine testing. As part of the continuous work in collaboration with our Environmental Engineering team, we have supplied Enzo Life Sciences commercial bioactive compounds resulting in funding of £1.5 million since 2014.

3.2 Infrastructure:

Administrative support at the Unit is provided by two dedicated staff, with each PhD student being supported by a technical staff. Investment in IT infrastructure includes High-Performance Workstations, Virtual Computing Machine, and a new streamlined data repository (Worktribe). Research is well supported by the Library with online access to all major journals and, where not available, through inter library loan. Staff and students have 24/7 access to the Library during the exams period, to support those with caring responsibilities and other personal/professional priorities. Our research dissemination is supported through RGU's Open Access.

The Unit's research also benefits from access to shared facilities with other HEIs, such as access to the FlowWave tank at Edinburgh and UK National Supercomputing ARCHER. We have secured Neutron beam time (total 17 days, worth £300k) at ISIS Neutron and Muon Source (Engine-X) at Rutherford Appleton Laboratory (Didcot, Oxford) for carrying out research to study spatial and directional distribution of strains in materials. An EPSRC Digital Surface Manufacturing grant, allowed access to the air plasma spray (APS) facility at the University of Nottingham.

Our project SIRENA got access and use of the unique particle emission measurements facilities at the Flemish Institute for Technological Research (VITO) in Belgium, (through European Commission funded 'QualityNano Transnational Access') to research nanoparticle aerosols release and mechanisms for occupation health workers safety protection.

3.3 Facilities

The Engineering Unit is based at our £135 million Garthdee Campus in Aberdeen. The Unit shares facilities mainly between School of Engineering and School of Pharmacy and Life Sciences. Strategic investment has been made to support the research development within the four core themes of the Unit.

3.3.1 Energy Facilities

Recent investment to set up the National Subsea Centre (NSC) will significantly benefit the Unit's research, providing access to state-of-the-art Subsea Engineering and Computational facilities.

Recently 2 new professors have been appointed in NSC with engineering and computational backgrounds, who will help the development of cross-disciplinary research activities.

Current facilities include:

- (i) **Hydrodynamic Multi-Phase Flow laboratory:** The facility includes a customised large-scale multi-phase flow loop instrumented that supports the Unit's sand management research. The lab also has a Remote Operated Vehicle (ROV) Pool (a 3m-deep test tank for underwater robotics and subsea projects), a 1Hz Wave Tank (1600mm water depth, 500mm wide and 1300mm length to the beach end), and a Plint TE 44 subsonic model Wind Tunnel (up to 20 m/s). The lab is complemented with computational fluid dynamic modelling and simulation tools such as Ansys Fluent and CFX, Comsol and OpenFoam. A well engineering lab undertakes research on ultradeepwater and unconventional shale and heavy oil fields; and the Power lab hosting AC induction machines, DC machines and respective drives and transformers to support research in power generation. We also have an actuated solar energy harnessing plant, a research facility hosted at the roof top of Sir Ian Wood Building that supports solar energy research.
- (ii) **Process Integration and Membrane Technology laboratory:** This facility had very high impact in REF2014 and has recently seen further significant commercial investment after a change in focus from Oil & Gas towards Carbon Capture and Storage (CCS), Hydrogen, and alternative fuels. The lab is equipped with gas chromatography mass spectrometry (GC-MS) systems and Quantachrome nitrogen adsorption analyser (BET), and low and high-temperature multi-gasses reactors. The lab possesses 20 novel, fully automated catalytic membrane reactor-separators pilot units evaluated (at different operating process parameters and real treatment conditions) to study gas and liquid mixture separations and for catalytic processes.
- (iii) **The DART (Dynamic Advanced Response Training) simulation suite:** The DART is a multimillion-pound investment unique in Europe that provides realistic, real-time training within a virtual drilling environment. This includes the latest DS6000 simulator which is used in the research and development of new drilling technologies. It also includes older simulators for training in the technology used to support future decommissioning work in the North Sea.

3.3.2 Advanced Materials Facilities

As part of their ongoing research activities, this group regularly makes use of facilities and resources at ARCHER, STFC Rutherford Appleton Laboratory, Henry Royce Institute, Diamond Light Source (Didcot) and SALSA (Grenoble, France). The current facilities are:

- i) **Nanocomposites & Composites Labs:** This facility was developed after REF2014 and recent investment was made in a composites manufacturing lab to support our growing research in this field. Equipment available include extruder for materials compounding, Fiaxell's Solid Oxide Fuel Cell (SOFC) high temperature electrochemical device for energy materials research, nanomaterials synthesis lab supporting inhouse synthesis of graphene oxide, polymer blending, polymer synthesis, and nanoparticles modification research.
- ii) **Materials testing and characterisation:** although it still requires further investment, significant development has been demonstrated in this area since REF2014. It has become central to the Unit's Materials Testing consultancy business to industry. It includes Instron (x4) and Denson (x1) Universal Testing Machines, thermal conductivity, engine test beds for fuel nano additives testing, ballistic impact testing, microscopy, and spectroscopy (X-Ray Photo Spectroscopy, UV (Ultra-violet) spectrophotometers etc), a corrosion testing lab and related testing/sample instrumentation capability. Cross-university equipment pool offers access to analytical equipment such as Zeiss EVO Scanning electron microscope

(SEM), Oxford Instrument system energy dispersive X-ray analyser (EDXA), Fourier Transform Infrared Spectroscopy (FT-IR) and GC-MS systems.

- iii) **Design and Manufacturing:** these facilities include a Manufacturing workshop with a series of CNC machines comprising a Vertical Machining Centre (XYZ 710 VMC) as well as manual machines and a welding lab. The Unit has recently invested in industrial scale 3D printing equipment (Intamsys FUNMAT Pro) enabling further inter-school access to 15 fused deposition modelling rapid prototype machine, Metal additive machine (an EOS m100), vacuum forming machine, textile fabrication and two Laser and direct metal laser sintering machines. Also host a series of engineering softwares (ANSYS FEA suite, Solidworks, data mining etc) to support manufacturing and design.

3.3.3 Environmental Engineering Facilities

Research within this theme is benefitted through access to the following facilities:

- i) **CyanoSol Lab:** these state-of-the-art facilities for algal/cyanobacterial production, downstream processing and supporting analytics are essential to facilitate research and sustainable revenue (*Impact Case Study 2*). RGU is equipped with water and wastewater treatment research state-of-art analytical, microbial and molecular facilities.

The RGU team has a long-standing international reputation for excellence in the field of cyanotoxins. Allied with their extensive expertise and experience in the subject, the impact of their research is enabled by access to cutting-edge facilities including gas chromatography-mass spectrometry (GC-MS); multiple high-performance liquid chromatography (HPLC) systems with a wide range of detection capability (photo diode array, fluorescence, evaporative light scattering); and ultra-performance liquid chromatography coupled to quadrupole time-of flight mass spectrometer (UPLC-QTOF) to support untargeted metabolite analysis and ultra-performance liquid chromatography, coupled to triple quadrupole mass spectrometer (UPLC-MS/MS) for targeted metabolite analysis. The team have bespoke facilities for algal culturing (>1200 L), downstream processing, and automated flash and high-performance liquid chromatography purification systems (mass/UV/VIS guided).

This capability currently supports two GCRF projects (BBSRC 'Bio-based Solution to Eliminate Cyanotoxins in Drinking Water' and EPSRC 'In-reservoir destruction of Blue-Green Algae and their toxins'), a BBSRC/NERC project on Safe and Sustainable Shellfish, and industrial funding from Enzo Life Sciences. The team are actively involved in networking hubs, such as UK Harmful Algae (UKHA) and UK Algae, all of which present excellent opportunities for training, funding and networking for ECR development.

In addition, RGU's membership of the SFC-funded Industrial Biotechnology Innovation Centre (IBiolC) facilities gives access to two resource centres, based at Strathclyde and Heriot Watt Universities. Bespoke technologies such as Next Generation Sequencing facilities are normally outsourced to Scottish Universities Life Science Alliance (SULSA), a research pooling partnership between Scottish Universities and supported by the Scottish Funding Council, providing cutting-edge technologies at centres of excellence.

- ii) **The Centre for Research in Energy and the Environment (CREE):** laboratory facilities include Perkin-Elmer absorption spectrometer, fluorescent spectrometer, Edinburgh Instrument's fluorescent lifetime spectrometer, Raman spectrometer, optical spectrograph, a range of UV, visible, NIR lasers including nanosecond & femtosecond lasers, high temperature glass melting furnaces, electrochemical analyser and photocatalysis lab.

These facilities have attracted collaborative research projects with international and national universities as well as research organisations and industries. These include funding from Innovate UK, Knowledge Transfer Partnerships (KTP), EPSRC, UK-India Education and Research Initiative (UKIERI), Scottish Funding Council and Scottish Innovation Centres - Centre for Sensor and Imaging Systems (CENSIS), IBiolC (Industrial Biotechnology Innovation Centre), SAIC

(Sustainable Aquaculture Innovation Centre), CSIC (Construction Scotland Innovation Centre) and the Data Lab.

3.3.4 Instrumentation & Sensors Facilities

The Instrumentation & Sensors Research Group shares facilities with the other three groups. It also hosts its dedicated Laser Lab with equipment includes Ar Ion, Diode Lasers He-Ne, Nd YAG (1064 nm) Tunable Nd YAG (190-1500 nm), Optical Fibres and Solid-State Lasers (450 nm, 472 nm, 488 nm). The Biomedical Laboratory development is currently at early stages and will capitalise on existing facilities at onset. We will focus on Minimally Invasive Surgery using Robotic assisted systems, hyperspectral imaging, and fibre sensors. This will be aimed to provide reliable and affordable diagnostic development with high sensitivity, fast response, low cost, and real time sensing.

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

4.1 Academic Research Collaboration Examples

The Unit's research on nanomaterials safety looking at nanoparticles release from nanoproducts, and both toxicology and eco-toxicology has contributed significantly to academic, standards, protocols and industrial practices. This is a collaboration with Technalia (A Egizabal, Spain); VITO NV (E Frijns, Belgium), Cranfield University (V Marchante), University of the Basque Country (MP Cajaraville, Spain), Imperial College (H Zhu) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (JA Schutz, Australia). This collaboration has also led to PhD graduates being appointed to key roles in the industry (incl. S Sachse as Materials Product Manager at Lego/ECCO; A Irfan as Toxicologist at BASF/Shell; A Nassiopoulos as Head of Composites at Prodrive; F Silva as Critical Failure Analyst at Rolls Royce, L Gendra as Research Fellow at WMG). The outcomes of this collaboration were widely published (>20 Journal papers and two textbooks on 'Health and Environmental Safety of Nanomaterials') and have attracted funding from EC Life+ H2020 QualityNano Project; Nanosafety Stream of the Advanced Materials Transformational Capability Platform (Australia) and the Basque Government.

Polymer nanocomposites research collaboration focused on materials design at a nanoscale level, surface modification of inorganic nanoparticles and hybridization to achieve macroscale properties. UKIERI collaboration with University of North Maharashtra (India) funded by DST-UKIERI; Rajiv Gandhi National Junior Research Fellowship; and Newton-CONFAQ funding. It has also been industrially exploited by Shapoorji & Pallonji Pvt. Ltd (Indian multinational) in the development of new ballistic protection products using the new resin grade/composites (*Impact case study 1*). Lithium-Ion Battery (LIB) based on the bipolar material-MXene is central to the research collaboration with Yanshan University (China), Southwest University of Science (China), Beijing Engineering Center for Hierarchical Catalysts (China), University of Houston (USA) and University of Western Ontario (Canada).

A collaboration network of Scottish Universities (RGU, Glasgow, Edinburgh, Strathclyde, West of Scotland) initially under the CombGen Consortium funded by the Carnegie Trust and EPSRC has been focusing on biomass waste for gasification and combustion process. The collaboration has expanded to create The Farm Waste Utilisation Group comprising farms in Forfar, Inverurie, Peterhead and Dingwall. The network has received funding from Interface Food and Drink (IFD GBER Scheme). Collaboration with Dr Claribelle Nwogu at University of Owerri (Nigeria) has focused on <mailto:>Membranes and Process and led to creation of a new Africa Centre of Excellence in Future Energies & Electrochemical Systems (ACE-FEES) at the Federal University of Owerri (Nigeria), a \$6 million project funded by the World Bank.

The research on wastewater treatment involves collaboration with researchers at Cranfield University and University of Bath. Research focusing on Cyanotoxin was undertaken in collaboration with Jagiellonian University (Poland). The water treatment collaboration research has attracted funding from EPSRC; EPSRC Impact Acceleration; UK Water Industry Research; BBSRC/NERC (£1.2 million) Joint Call in Aquaculture, EC's Erasmus Mundus, Scottish Government Hydro Nation Scholars Programme and EPSRC/GCRF. Research in partnership with

water utilities companies such as Northumbrian Water, Scottish Water, Wessex Water, Anglian Water, Severn Trent Water, Yorkshire Water and United Utilities has identified, for the first-time, activated sludge operational conditions for enhanced micropollutant removal from wastewater. In addition, Cogeh, a Brazilian water company, has adopted the work detoxification on the cyanotoxins and design of TiO₂-photocatalytic water treatment, in development of routine use of TiO₂ photocatalysis close.

The Unit has hosted a series of visits from experienced and young researchers. Examples including Dr Josef Hlinka & Dr Roohi Haghpanahan who carried out experiments related to corrosion of anodized titanium/ hydroxyapatite & analyse electromagnetic properties of materials and led to a journal and conference proceeding output. Dr C Hu (South China Agricultural University) visited the Unit for 12 months working on 'Distributed Video Coding. Dr Renganathan, Vellore Institute of Technology, India provided new skills training to RGU on using Open Source CFD, and OpenFoam.

As part of research staff and students UK-India collaboration research, Prof S Mishra and his PhD student have visited RGU (for over 12 months) and RGU staff and student visited North Maharashtra University funded by DST-UKIERI. Prof R Grose and Prof B Praveen (India) on sensors embedding technology, Mr O Skar (Norway) for Shell on oil and gas applications and on new materials impact on food science safety with Prof M Younes (Ex-Director, World Health Organisation, WHO).

4.2 User/Industry Collaboration examples

Co-developing research ideas with end users in Orkney Islands is a unique initiative that led to solving waste management problems. The Unit's research activities also supported a number of SMEs through Innovation Voucher to take company innovation and entrepreneurial work to the next stage. DART simulator has been used to train industry staff in realistic, real-time within a virtual drilling environment. The team has engaged significantly with industrial businesses.

Examples include subsea pipeline structural integrity and insulation materials with Subsea 7, high-power cables insulations and pipe installation products with Technip FMC Ltd, materials behaviour evaluation with Stork Engineering (a Flour Company) and thermal spray coatings with Saudi Aramco (Saudi Arabia). KTP projects also evidence our growing applied research with Rubber Atkins Ltd on downhole drilling tool elastomer seals and HarperUK on subsea autonomous systems. Research with Shapoorji & Pallonji (India) has focused on novel composite materials and manufacturing challenges in products development for construction industry.

Partnership with Saudi Aramco, AWE plc (UK), Oil Technics Ltd, Xi Engineering and Sand Monitoring Services SMS Ltd in oil and gas sector. We collaborate with Petroleumsoft Ltd in developing new innovative approach for the accurate quantification of vertical transverse isotropy (VTI). Further, McAlpha Inc (Canada) is committed to our research in membrane and process for compact catalytic systems for three-phase chemical reactions (gas-solid-liquid). It builds on and extends the reach of our Patent US8501151 licensed to Gas2 Ltd (RGU spinout company) that generated £17.5 million in inward capital investment (2008-2013).

Research on micropollutants in water has involved collaboration with Northumbrian Water, Anglian Water, Severn Trent Water, Yorkshire Water and United Utilities using pilot-scale wastewater treatment plant (WTP) to inform operation of their WTPs to achieve micropollutant discharge limits, mitigating the need for expensive tertiary treatments. Further research collaboration is with Wessex Water and Scottish Water reed bed systems for sustainable low-cost treatment of emerging pollutants. Research on the fate of cyanobacteria in drinking water treatment plant lagoon has been a focus of collaboration with South Australian Water Corporation (Australia) and detoxification of the cyanotoxins with a Brazilian water company Cogeh (Brazil). A collaboration with CEFAS (Centre for Environment, Fisheries and Aquaculture Science), West Country Mussels, Cromarty Mussels and Association of Scottish Shellfish Growers has enabled the detection of potent cyanotoxins, in water, shellfish and health food supplements ensuring these products are safe for human consumption.

Research on waste oil treatment is central to our KTP industrial collaboration with SureClean Ltd (now NCR). We have had an industrial contract with CNOOC international to develop tools for predicting pressure drop in a Buzzard Water Injection Flowline for slurry flow and designing an innovative de-aerating nozzle for filling bottles for Foodmek; and development innovative capsule dishwasher in partnership with Loch Electronics Limited.

4.3 Wider influence, contribution to and recognition by the research base

RGU is represented by **Steel** on the Board of the Energy Technology Partnership ETP, a Research pooling partnership in Scotland focusing on Energy and funded by the Scottish Funding Council (SFC). **Steel** is the Chair of Sand Management Network. The Scottish Research Partnership (SRPe) is another research pooling in Engineering where **Njuguna** represents RGU in the Manufacturing Thematic Committee. Both the ETP and SRPe have recently each co-founded a PhD studentship. Further **Njuguna** and **Steel** represent the Engineering Unit engagement in the National Subsea Centre collaboration with Oil and Gas Technology Centre (OGTC) and action groups leadership with Energy Institute (**Oluyemi, Steel**); Society of Marine and Underwater Engineering (Iyalla).

Our research contributes to scholarly work including Editor-in-Chief (**Oluyemi**) of Petroleum Engineering (Springers) book series; Associate Editor of "International Journal of Condition Monitoring and Diagnostic Engineering Management" (**Asim**); Editorial Board membership in Energies, MDPI (**Hossain**) and **Njuguna** in the Polymer and Composite Materials (Springer Book Series), Open Engineering (De Gruyter), Frontiers of Materials (Frontiers), Polymer (MDPI), Journal of Heat and Mass Transfer (Praise Worthy Prize), Current Nanotoxicity and Prevention (Betham Science);

Our researchers have held Guest Editorship in Special Issues including Monitoring and Simulation for Battery System, Processes: Electrochemical Materials in Batteries (**Fernandez**); "Micromechanics and Surface Engineering of Metals" (MDPI, 2021) (**Faisal**); Journal of Nanomaterials (Hindawi, 2015) on 'Materials Properties Characterization by Molecular Dynamics Simulation Techniques' (**Faisal**); Surface Functionalization and Applications of Organic/Inorganic Hybrid Nanomaterials (**Fernandez**). Water (**McCullagh**); "Sensing in Oil and Gas Applications" (2018/19, **Prabhu**); Advancements in Wind Turbine Technology (**Asim**), Multiphase Flow Modelling for Renewable Energy, Energies' (**Hossain**); Fibers, 2019 (**Njuguna**) and Journal of Materials on 'Futuristic Materials' (2014,2016; 2018; **Njuguna**).

They are also involved in both national and international grants peer review process including the EPSRC Reviewer College Full membership (**Edwards, Lawton, Asim, Njuguna, Faisal, Prabhu, Hossain**); BBSRC (**Edwards, Prabhu**); MRC (**Prabhu; Njuguna**); IBioIC (**Edwards, Njuguna, Prabhu**), Scottish Institute of Re-Manufacturing (**Njuguna**), OGIC and ETP (**Steel**) and SRPe (**Njuguna**).

Researchers are also involved in international activities as regular reviewers for Commonwealth Scholarship Commission (**Hossain**); UKIERI (**Prabhu, Njuguna**), GIAN, India (**Hossain**); Bangladesh Energy & Power Research Council (**Hossain**); SIFT panel for round 5 for the UKRI Future Leaders Fellowship (**McCullagh**); EC H2020 Batteries 2019 (H2020) (**Fernandez**) and Israel Science Foundation (**Prabhu**). **Njuguna** is involved in various European Commission programmes, M.NET, Nanyang Technical University (Singapore), FCT Portugal, Kazakhstan National Center of Science and Technology, South Africa STC and Singapore's A*STAR Group. Our researchers are also involved in learned communities through conference organisations such Conference Chair for SPIE conference on "Counterterrorism, Crime Fighting, Forensics and Surveillance Technologies" as part of the SPIE symposium on Security and Defence, 2020, 2019, 2018 (**Prabhu**); Technical Chair for the IEEE OCEANS'17 conference at AECC, Aberdeen, June 2017 (**Prabhu**); the International Webinar on Modeling Thermo-Fluids, organized by School of Mechanical Engineering, Vellore Institute of Technology, Chennai on 8th August 2020 (**Hossain**); International Webinar on Computational Fluid Dynamics and Energy Efficient Technologies, 11th December 2020 (**Hossain**). **Njuguna** has organised and co-chaired the NANOSTRUC bi-annual

conference series (2014, 2016, 2018) while **Oluyemi** is part of technical organising committee of SMN/SPE Euro Forum bi-annual conferences (2014, 2016, 2018, 2020).