UKRI Engineering and Physical Sciences Research Council

Decentralised Water Technologies

Decentralised Water Technologies

ANNUAL REPORT 2022
YEAR 1

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The Decentralised Water Technologies project is a collaboration between:

THE PROJECT
INTRODUCTION AND BACKGROUND

The project launched in July 2021, with 35 academics and project partners attending the kick-off meeting.

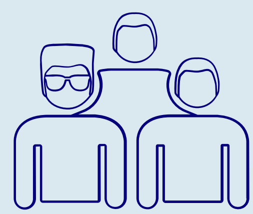
The perfect storm of increasing fuel prices, global insecurity and the climate crisis has brought the need for low-energy, resilient infrastructure into sharp focus. The premise of our research, that decentralised water technologies can contribute to this future structure, opens-up a complex research landscape. We have our own ideas for novel biotechnologies but there is also a plethora of small-scale water technologies on, or near to, the market. Thus, one of the challenges is to develop our own science and engineering solutions whilst, at the same time, thoroughly exploring alternative water and wastewater technologies, all the way from conventional methods to the most cutting edge. There will be no silver bullet technology and there are different perspectives on the need for change so another major challenge is working with communities and government to both alight on the most appropriate and responsible systems and to incentivise change. Water is a vital resource and ensuring equitable access to high quality water and clean environment in a future with decentralised systems presents some interesting challenges for water companies, regulators and government.

In the first 12 months of the project, we have recruited postdoctoral research staff (PDRAs) and started to make progress in each of the main programme themes. When it comes to developing our own technologies, we are probably most advanced with the development of our small-scale drinking water biofilter. On the wastewater side, we have discovered that there has never been a systematic assessment of the greenhouse gas emissions from conventional septic tanks, which are the most prevalent off-grid wastewater systems, anywhere in the world. Thus, in collaboration with Scottish Water and our international partners we have embarked on an extensive survey to measure this. At the same time, we are designing novel small reactors to increase the biodegradation of water and passively capture greenhouse gases. Our energy engineers have now patented their flexible heat pump system, which is significantly more efficient than conventional heat pumps, and the post-doctoral researchers are working in teams to explore the integration of decentralised water and heating technologies. Our sensor development team have invented a novel high-throughput experimental platform that can be used, alongside high-resolution analytical methods, to optimise the 'optical tongue' sensor for applications in water quality. Starting with the island of Barra, our systems engineers have embarked on the most comprehensive study of the full life-cycle energy and environmental costs of existing rural water infrastructure. Our social scientists have been exploring how approaches to ensure ‘energy justice’ when implementing low-carbon decentralised energy systems might be adapted for water systems. Finally, our policy team have been studying existing water law and policy, mapping the complex network of stakeholders in Scotland and are beginning to assess the impacts of decentralisation, while also making significant contributions to the Scottish Government consultations on Land Rights and Responsibilities Statement and the Workplan on Energy, Post and Water 2022-23 for Consumer Scotland.

In addition to publishing 23 academic papers, the team have engaged in a variety of outreach and dissemination activities including, for example, presenting to the Scottish Government's cross party working group on science, hosting a workshop on 'Water and Value' which explored the process of framing the value and meaning of water, keynote presentations at a Royal Society meeting on Engineering Biology, and presentations to the board of Scottish Water and their customer advisory group. We publish a quarterly newsletter in both English and Scottish Gaelic alongside our informative website offgridwater.org.uk. We have also won several additional grants to extend the programme and are now working closely with the Scottish Water Hydronation Chair Team to lead broader initiatives on water research across Scotland.

The rationale for this research being funded by an EPSRC programme grant was that the breadth of research from policy, through social science to technology and the complexity of implementing solutions in a rural communities required PDRAs to work in flexible teams. It is particularly satisfying that the cohort of PDRAs have taken ownership of many of the research challenges and self-organised into teams. They independently initiated monthly plenary workshops around key themes, where invited speakers and stakeholders contribute. Indeed, both the PI and the PDRAs now meet monthly, which is significantly more regularly than we initially proposed. The bi-annual project meetings have been attended by expanding group of stakeholders; our January 2022 meeting was attended by >40 people.

THE TEAM



We adopted an inclusive process to recruit the very best researchers for our Programme. While the process took longer than anticipated, which affected progress, we are proud of our success. We have appointed a group of PDRAS that is diverse in ethnicity and gender. Short biographies of the principal investigators and PDRAs funded by the grant are listed in Appendix A. 48% of the researchers are female, 32% are from BAME groups and the team are assembled from a diverse range of countries in North and South America, Asia, The Middle East and Continental Europe. For one of the PDRA positions, to develop high-throughput experimental platforms, we failed to appoint in two recruitment rounds but were eventually successful and the PDRA will take up the post in July 2022. We have managed to progress some of the research in the associated work package by aligning the projects of existing PhD students with the research. We are supporting the PDRAs in developing their careers and pursuing independent research grants; one researcher has already reached the final interview stage in an RAEng Research Fellowship application.

PROJECT PARTNERS

The contributions and support of our project partners has been invaluable. The commitment of Scottish Water's staff time and resources to the project has been vital to the achievements of the research so far. The research and innovation team has been the main link between the academics and Scottish Water staff. They (Susan Lee in particular) have managed to collate one of the most comprehensive and self-consistent databases of assets, water and energy flows, emissions, and logistics for any rural community in the UK and thus our systems engineers have been able to produce a thorough examination of the greenhouse gas emissions and energy usage, and deliver life cycle analyses that are both revealing and vital for evaluating alternative technologies. They have also facilitated links to the Scottish Water Horizons and the process engineers who are supporting trials of our technologies at their development centre in Bo'ness and at a wastewater treatment plant in Fife. Scottish Water have enabled us to speak directly to their Stakeholder Advisory Group and their Independent Customer Advisory group. SEPA have also provided data for the programme and all the project partners have made important contributions at our plenary meetings and have, or will be, interviewed by the policy and social science researchers.

With thanks to our partners:

Scottish Water
Drinking Water Quality Regulator for Scotland
Welsh Water
Scottish Environment Protection Agency
Barra and Vatersay Communities Ltd.
Arran Eco Savvy
Iona Renewables
Jura Development Trust

THEMES & WORK PACKAGES

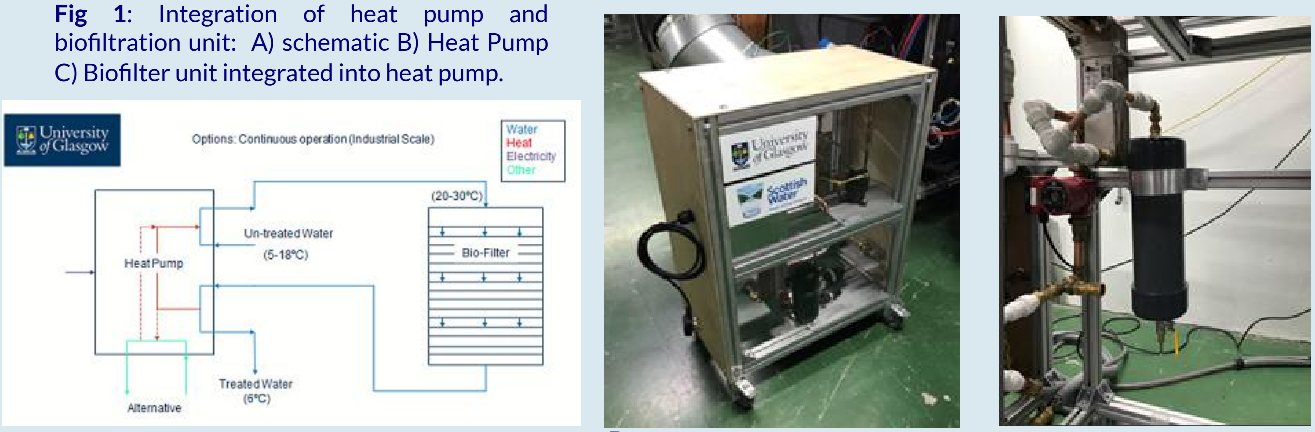
The research is organised into three connected research themes and seven work packages.

WORK PACKAGE 1: TREATMENT TECHNOLOGIES

Biologically Enhanced Biofilters. We are working towards the development of enhanced biofiltration units for deployment in rural areas for small scale drinking water treatment. The aim is to incorporate engineering interventions to increase the activity of the microbes and enhance biofiltration. Heat can effectively increase biological activity. By integrating a heat pump with our biofilters, the aim is to increase the biological activity of the biofilter (20C) and simultaneously cool the treated water (6C) to prolong biological stability. To progress this, we have undertaken the following:

1. Designed and built an operational heat pump and integrated a biofilter. The unit can take raw water with a temperature range 5 to 18C, heat it to 20C to pass though the biofilter and subsequently cool the treated water to 6C **(Fig 1).** We are currently testing the integration of the unit. We have also established a method to monitor the biologically stability of the treated water based on assimilable organic matter (AOC).

Fig 1: Integration of heat pump and biofiltration unit: A) schematic B) Heat Pump C) Biofilter unit integrated into heat pump.



A B C

2. Completed a detailed meta-analysis of the current literature on biofilter microbial communities (12 studies) to explore global patterns in influent, effluent and biofilter community composition (currently in preparation for submission to Water Research). This work has aided inform core biofilter microbes (Fig. 2) and the temperate selection for the biofilter temperature experiment, which aims to identify the cross over point for potential pathogen proliferation balanced with increased biofilter performance.

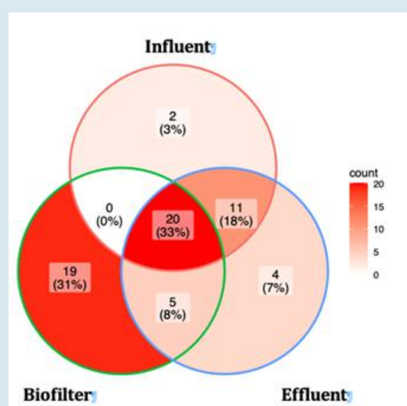
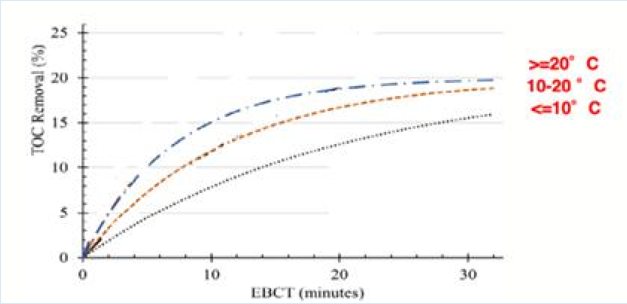


Fig 2: Ven Diagram of the core microbiome identified in 85% of all samples in the influent water, the biofilter and the effluent water

3. We are planning a suite of temperature experiments to determine the appropriate temperature at which to operate the biofilter balancing biofilter operation with pathogen growth (Fig 3).

A



B

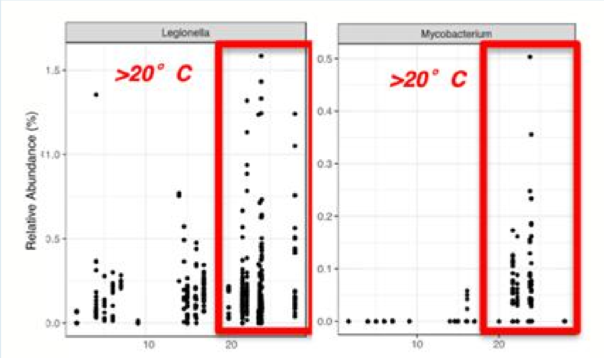


Fig 3: Increases in temperature A) Total Organic Carbon (TOC) removal B) but also pathogen proliferation (data from our global metanalysis).

Wastewater Reactors. It transpires that most domestic wastewater in remote rural communities in Scotland, and indeed the rest of the world, is managed via septic tanks. Our systems engineers have demonstrated that the collection, treatment, and disposal of septic tank sludge represents the greatest source of greenhouse gas (GHG) emissions from the existing rural water infrastructure. In addition, poorly managed and failing septic tanks are widely reported to SEPA, cause localised pollution and are the source of disputes. Thus, our wastewater research has focused septic tanks. The received wisdom is that septic tanks merely collect the solid waste, undertake minimal treatment and therefore, only emit biogas at low concentrations. This has never been empirically tested for temperate climates. Thus, our first task is to characterise the treatment and emissions from existing septic tanks and add that to them to the inventory of cost and benefits of the existing infrastructure. We are doing this in controlled conditions at Scottish Horizons Water's Bo'ness development centre. To achieve this, we have developed a suite of instruments to measure, for example, the temperature distribution, methane emissions, pH and degradation rates, that relays the data and can be controlled over a 4G network. The instruments can then be deployed in real septic tanks.

If we could half the sludge then we could, potentially, half the cost and emissions from managing it. By integrating the flexible heat pump technology with an insulated septic tank, such that the tank provides the necessary heat reservoir, we can simultaneously enhance the activity of the microbes that degrade the waste. Our energy engineers have designed an integrate heat-pump wastewater systems. In addition, we are about to begin a trial where septic tanks operate at a range of temperature fed by real wastewater at a wastewater treatment plant in Fife to assess the efficacy of raising the temperature. These will be controlled and observed remotely.

Building and testing the enhanced septic tank and internet of thing monitoring system at the development centre in Bo'ness.

If we successfully degrade more of the carbon in the waste, then we will increase the amount of biogas, predominantly methane, which is a potent greenhouse gas. Thus, we are developing a novel bioreactor where methane consuming microorganisms consume the methane and generate heat which can be fed back into the septic tank to further enhance the synergy between the heat pump and wastewater treatment.

Heat pump technology development: The prospect of combining heat and water technologies is a direct consequence of the new heat pump technology developed by our energy engineers. It is more efficient and flexible than the current heat pumps in the market. More importantly, it is specifically designed with the flexibility to utilise and manage multiple heat sources and sinks and thus presents may opportunities for integration with water and wastewater systems.

The team has conducted comprehensive numerical analysis to develop the new concept. They have also built a prototype as shown in the figure and proved the concept for energy saving. The team is now refining the design to optimise the heat pump system to fully demonstrate its wide benefits for energy recovery and power saving.

WORK PACKAGE 2: DESIGN TOOLS

The development of design tools has been hindered by difficulties in recruitment. We have offered a PDRA position associated with this work package in three rounds of recruitment where, after initially accepting, the candidates have pulled out for a variety of reasons. Nonetheless, working with PhD students we have delivered some truly innovative engineering design tools. Thus, we have pioneered combining computer simulation with 3-D printing to rapidly design plastic structures to optimally carry biofilms. Biofilms are sticky layers of bacteria that can consume water pollutant and can be used to treat drinking and wastewater. We have also begun to implement a massively parallel bacterial culturing technology where we hope to rapidly evolve the mix of different species of bacteria in communities that are best suited to treating site specific waste streams.

WORK PACKAGE 3: LOW-COST SENSORS

The goal of WP3 is to develop and deploy low-cost, low-maintenance sensors for the regular and routine monitoring of the treatment systems developed in WP1 and WP2. These sensors must be integrated inline, capable of warning of imminent system failures, and able to be used by non-experts.

The outputs from the treatment systems are complex mixtures containing a variety of molecules that need monitoring. Rather than developing multiple sensors to monitor the levels of each possible molecule, we have chosen a label-free sensor design that mimics that of the biological system of taste. This type of sensor allows for a simple measurement using a small sample size that can provide the non-expert with a single output to monitor. The sensor is comprised of nano-tastebuds, each providing a different response to the same sample. The combination of signals from each nano-tastebud will create a unique fingerprint for each sample, and these fingerprints can be used to build a model.

To fabricate the sensors, we must (1) determine the layout and design that is able to support the highest density of sensors, (2) develop multistep fabrication protocols to produce the sensor
chips, and (3) determine the surface chemistry modifications that provide the best partial-selectivity.

We have now iterated through 5 different sensor layout designs, developed fabrication protocols for each design, and created a protocol using a droplet-on-demand printer that has allowed us to pattern custom-made inks of specific surface chemistries for each nano-tastebud of the sensor. Through this development, we have determined the maximum density of nano-tastebuds. Currently, we are in the process of developing an automated measurement system for the sensor. Our next step is to begin measuring samples from Scottish Water to validate the surface chemistries selected and from the filtration experiments of WP1 and WP2 to corroborate sensor readings with analytical chemistry and AOC experiment results.

To validate and interpret the fingerprints produced by the low-cost sensor we need a detailed analysis of the water chemistry. The chemistry of dissolved organic carbon (DOC) is of particular interest, but this is complex mixture of components , such as acids, sugars, proteins, and lipids, which varies depending on a range of parameters, including molecular weight, pH, aromaticity, and hydrophobicity. We have developed methods to characterise these chemical signatures, which we have been testing on the influent and effluent from our biofilters (WP1). With additional chemical analysis of a range of Scottish Water samples we will be able to calibrate the signals from out biosensors.

THEME 2: PARTNER COMMUNITIES

WORK PACKAGE 4: COMMUNITY CONTEXT & PATHWAYS OF IMPLEMENTING SYSTEMS CHANGE

Understanding people and place is essential in planning for socio-technical transition such as water system change, and this understanding must be developed at an early stage of planning and implementing change. Research under Work Package 4 investigates how to ensure that both decision-making processes about new systems - and the new systems themselves - are fair, equitable and best fit for the places they will be used. Our initial desk-based research focussed on the policies and priorities for Island communities in Scotland, the current context in terms of community involvement in decision making around water systems and justice issues, and initial stakeholder engagement to understand key challenges and priorities. In addition, given there is a great deal of work taking place around sustainability and just transitions in relation to rural communities in Scotland, we have been building a network in this area amongst researchers and other coordinators of community activities and are looking at opportunities for collaboration and adding value to existing work.

Early insights from WP4 research find that island communities have strong ambitions to increase sustainability, achieve net-zero, and find routes to climate resilience. We have identified tensions and challenges that need to be explored, including concerns about who will carry the cost or responsibility for change, and whether the change will be appropriately situated alongside the drive to tackle other pressing community issues - around transport and housing, for instance. We've also been able to draw on learnings from the shift to decentralised energy systems to identify technology-specific issues that will need to be considered in ensuring a just transition, for example, the need to appreciate the consequences of new monitoring processes being developed in the Programme and how that data will be accessed and used. We've noted that there is also a significant need for further research and recommendations for improvement in the way communities are involved in change: although best practice principles for decision-making and change processes are available, they are not often implemented or if they have been implemented it is not clear why they have been successful. Similarly what is meant by 'place based' decision-making is poorly defined. These insights have shaped the development of our detailed research plans, and we are examining these issues in more detail as a priority in the next stages of our research.

Our first phase of empirical research is currently taking place (Summer 2022), after which we will publish the first of several planned 'insight briefs' (Community matters: values, practices, and aspirations for water services and community co-benefits for Scottish islanders) to inform the technologies and systems under development within the programme. Finally, we have recruited a PhD student (starting March 2023) to respond to emerging research themes of 'Just transitions through decentralised utility services, systems, and infrastructure'.

WORK PACKAGE 5: MEMBRANE TECHNOLOGIES & MOBILE DEMONSTRATION UNIT

Membrane filtration will be used as post-treatment for biofilter effluent polishing, in order to remove contaminants, including bacteria and bacteria by-products grown in the biofilter. The water quality achieved in the biofilter effluent will, however, dictate which membrane process is most appropriate. The membrane processes which will be considered to start off with are microfiltration and ultrafiltration, as the former removes bacteria and the later removes bacteria and viruses. It will be assumed that NOM and other contaminants such as metals will be removed entirely in the biofilter, and hence nanofiltration is not required. Microfiltration membranes have the advantage of requiring lower energy (up to 3 bar), hence gravity can be considered for this process, which would be an advantage for remote areas. However, the membrane pores being larger than UF, imply they retain contaminants which are larger than the ones UF can remove, hence the importance of knowing what effluent quality is produced in the biofilter.

As fouling and biofouling is the biggest issue in membrane processes, in parallel, we are developing novel membrane materials which physically vibrate with shining light, in order to efficiently remove fouling and biofouling from the membrane surface.

Outreach / Testing Facility. We proposed the development of a mobile technology testing facility in collaboration with Scottish Water. The planning for this was delayed by a combination of the COVID pandemic and maternity leave for Dr Semiao but began in earnest in May 2022. It immediately became apparent that a much more careful and nuanced assessment of the ultimate aims for such a facility, its long term sustainability and the practicalness of implementation was required. We need broad buy-in from Scottish Water, other stakeholders and potentially many universities to ensure the longterm success. Thus we are implementing a series of workshops to address questions such as: Are outreach and testing compatible in one facility? What are the health and safety implication of outreach to , for example, schoolchildren? Would a suite of activities that could be unpacked and delivered in existing spaces with the support of local professionals be more safe and sustainable? The PDRAs will brainstorm a suite of alternatives for broader discussion in a workshop starting 5th September 2022. It is imperative that we have a clear, longterm operating plan before commissioning a facility or suite of activities.

WORK PACKAGE 6: INTEGRATED OFF-GRID SOLUTION

As an initial step, a detailed understanding was developed for the drinking and wastewater treatment works (DWTW and WWTW) in the partner community islands, i.e., Arran, Barra, Iona, Jura, and Vatersay. This was done via frequent communication with the Scottish Water Net-zero program manager and process operators. The baseline environmental footprints (such as energy usage, water usage, and carbon emissions) of the drinking and wastewater treatment works of the islands were mapped using the approach of life cycle assessment (LCA). The LCA analysis quantifies emissions from individual processes associated with water treatment works and allows the identification of environmental hotspots. Sensitivity analysis was also carried out to understand the influences of various model parameters and input data uncertainty on the LCA results. The gathered results will facilitate the exploration of alternative technologies and scenarios, which could offer carbon footprint abatement for the DWTWs and WWTWs.

As a collaborative effort with the Heat and Energy Team of the program grant, a process integration between a heat pump and anaerobic digestion (AD) was performed. The integrated design was based on the utilisation of the heat recovered from domestic wastewater via a heat pump, which was used to control the thermal condition of the AD reactor. It is expected that a temperature swing in the AD reactor will affect the biogas production rate, and significantly impact the economics and emissions of the entire system. The thermodynamic model of the heat pump was integrated with a data-driven model of the AD reactor to quantify biogas generation under various waste input and thermal conditions. Furthermore, this model will be incorporated with the cost-benefit analysis and LCA to quantify the financial feasibility and environmental footprints of the integrated design upon its application in the islands. To summarise, the specific outputs include:

1. We created a process database about the existing drinking and wastewater treatment works in the islands;
2. We carried out a series of LCA to quantify the energy usage, water usage, and carbon emissions of the existing treatment works in the islands;
3. We are preparing a report to summarise the LCA study;
4. We are developing models for a heat pump and AD-based integrated design by working with the Heat and Energy Team;
5. We published >7 papers on the topic of LCA of environmental and energy systems and process modelling, by which relevant experiences about LCA-based parametric study and decentralisation designs were accumulated.

THEME 3: POLICY AND IMPLEMENTATION

WORK PACKAGE 7: REGULATION AND POLICY

In Work Package 7, the researchers have been engaged in mapping the relevant policy stakeholders and policies related to the technologies being developed in the grant. This initially involved meetings with key stakeholders such as Scottish Water, Drinking Water Quality Regulator and Scottish Environment Protection Agency in order to determine their priorities in relation to water services. We now have a comprehensive overview of the relevant policy actors and are building good relationships with these actors.

The researchers have also been taking the opportunity to respond to policy consultations and develop engagement strategies in order to begin to influence policy direction. Relevant recent developments in the Scottish context include the implementation of the EU drinking water directive and the carbon neutral islands initiative.

Finally, the researchers have been considering potential options for international comparisons, with the jurisdictions of Denmark, Switzerland and Ireland being recommended as models of decentralised water management which will be useful to explore.

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- Gupta, R., Miller, R., Sloan, W., & You, S. Economic and environmental assessment of organic waste to biomethane conversion. *Bioresource Technology, Volume 345, (2022), 126500*
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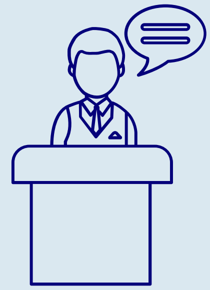
EVENTS, CONFERENCES, INVITED LECTURES & IMPACT ACTIVITES



Meetings and Events

Date / Frequency	Title
Monthly	PI/Co-I's Monthly Meeting
Monthly	PDRA Monthly meeting
9 July 2021	Programme Grant Start-up meeting
18 November 2021	Visit to Scottish Water Horizons' Water Development Centres
27 January 2022	Research Team Technical Meeting - Research Showcase
28 January 2022	EPSRC Programme Grant on Off-Grid Technologies Plenary Meeting
29 April 2022	PDRA team day
13 May 2022	Living Sustainably with Water: An Interdisciplinary Challenge / Water & Value Workshop
21 - 23 June 2022	EPSRC showcase 'Engineering Net Zero Solutions'
16 August 2022	PDRA Sci-Comm Training Event
30 August 2022	Research Team Technical Meeting - Research Showcase
31 August 2022	EPSRC Programme Grant on Off-Grid Technologies Plenary Meeting
5-8 September 2022	PDRA Workshop (Outreach mobile facility)

Conferences and Invited Lectures

Date	Title	Event	Speaker
10 February 2022	Understanding microbial communities through In-situ omics data synthesis	BBSRC's EBNet Webinar	Dr Umer Ijaz
28 March 2022	Engineering biology is a broad church that is united by the need for predictive population biology models	Microbial ecology for engineering biology - The Royal Society	Prof. William Sloan
28-31 August 2022	Sustainability through ESG	2022 Global ESG Forum, South Korea.	Dr Siming You

Impact Activities

Date	Details	Responsible
26 November 2021	Presentation of preliminary framework for the governance of de-centralised water technologies in Scotland at the (online) Annual Ius Commune Conference organised by the University of Maastricht, The Netherlands. Dr Robbie presented at workshop on property law and resilience, and received feedback from a variety of researchers from The Netherlands, Belgium, Canada, Iceland and England.	Dr Jill Robbie
26 May 2022	Presentation on the progress of the research to Scottish Water's Independent Customer Group.	Prof. William Sloan & Dr. Jill Robbie

ADDITIONAL FUNDING / GRANTS

- Dr Marta Vignola / BBSRC EBnet grant for research on biofiltration (Value £50,000).
- Caroline Gauchotte-Lindsay / BBSRC EBNet grant for Proof of Concept on Fluorescent Microbiofilter Assay for Rapid Real-time Monitoring of Organic Micropollutants Biodegradation (Value: £50,000).
- Dr Anastasiia Kostrytsia / University of Glasgow Engineering Biology Workshop / £10,000 towards her research project.
- Professor Zhibin Yu / EPSRC grant / An Adsorption-Compression Cold Thermal Energy Storage System (ACCESS) (Value: £1,022,621).
- Dr Siming You / Supergen Bioenergy Hub Rapid Respond Funding Programme 2022 / Consortium for Waste-to-Hydrogen utilisation and betterment (C-WtHub) (Value: £19,949).
- Dr Siming You / Royal Society International Exchange Scheme Grant / Microwave-based nanofiltration (Value: £12,000)

CONCLUSION AND YEAR 2 AIMS

Based solely on the academic metrics (23 international journal papers, 5 presentations and £200K of supplemental related income) the first year of this programme grant was highly productive. We have published in areas from the fundamental microbiology of bacteria to novel water quality sensors and life cycle analyses of biohydrogen production. We have contributed to public consultation on water policy, held international workshops, and begun to interact and exchange ideas with partner organisations. Thus, for example the information flow with Scottish Water and SEPA has been invaluable in our baseline assessments of existing water infrastructure. Our network of collaborator has expanded through, for example, the independent customer group for Scottish Water.

The aims for the next year are three-fold. *Firstly*, to bring our partners, in rural communities and stakeholder organisations, into closer collaborations. We have a programme of interactions between the researchers and various policy and community groups ready to roll out over the next year. *Secondly*, we want to bring some of our initial scientific, engineering and policy studies to fruition and disseminate the results. Thus, our baseline assessment of existing water infrastructure, our mapping of the policy and institution framework surrounding rural water provision, the assessment of emissions from septic tanks, the analysis of the microbial ecology of biofilters, should all be completed and ready to convey to both stakeholder and academic audiences. *Thirdly*, we will begin to tailor both systems of existing water technologies and our own novel developments to the needs identified through our engagement programme and our systemic quantitative analyses.

APPENDIX A: TEAM BIOGRAPHIES

Academic Investigators

Professor William Sloan FRSE has grown a multidisciplinary water and environment group at UoG with a mix of skills that is tailored for tackling grand challenges. He holds a Royal Academy of Engineering (RAEng) Chair in Emerging Technologies. His expertise is in developing theory on the dynamics of microbial communities used in biotechnologies.

Professor Cindy Smith holds the RAEng-Scottish Water Research Chair. She has been PI on a diverse portfolio of research projects in molecular biology methods, fish microbiomes, nitrogen cycling and drinking water microbiology.

Professor Zhibin Yu leads the thermal energy technologies research group at Glasgow and is pioneering the exploitation of low-grade heat sources in a variety of EPSRC, GCRF and ETP projects. His low carbon heating and cooling technologies have found wide application.

Dr Jaime Amezaga is a Reader in Environmental Sustainability at Newcastle University and has an international reputation for his research on the interface between technology, policy and institutional analysis in sustainable water challenges.

Dr Andrea Semiao is a Senior Lecturer and directs the world-leading research on novel membrane technologies at the University of Edinburgh and her research extends into novel application of membranes in bioengineered systems and resource recovery with the support from RCUK and other funding bodies, including Scottish Water.

Dr Jen Roberts is a Senior Lecturer and Chancellor's Fellow in Engineering at the University of Strathclyde. Her interdisciplinary applied research addresses the social and environmental risks of low-carbon energy and water technologies. Ultimately her work aims to inform how the net-zero transition can be implemented in a way that is acceptable to society and to the environment.

Dr Rebecca Ford is a Senior Lecturer and Chancellor's Fellow at the University of Strathclyde in both the politics and electrical engineering departments. She explores how the interaction of people energy and water systems can affect infrastructure, policy, business models and culture. She is research director of the EPSRC EnergyREV consortium which explores the role of decentralised energy systems in a net-zero future.

Dr Jill Robbie is a Senior Lecturer in private law at the University of Glasgow and a qualified solicitor and leads the Glasgow Water Network. Her research is on the reform of private water rights. Jill collaborates across Northern Europe, North America and South Africa. Her monograph "Private Water Rights" was recently published by the Edinburgh Legal Education Trust.

Professor Alasdair Clark is a Professor in Biomedical Engineering at the University of Glasgow and former RAEng research fellow. He develops low-cost photonic sensors, including the much publicised 'optical tongue' that tests for fake whisky.

Dr Stephanie Connelly is a Lecturer in Environmental Engineering, previously a recipient of an EPSRC doctoral prize fellowship, who specialises wastewater treatment in developing world settings. She holds a number of UKRI GCRF grants on novel sanitation technologies.

Dr Umer Ijaz is a Reader in Engineering Informatics. His research aims to develop novel bioinformatic pipelines and statistical methods for genomics data derived from complex microbial communities in any environment. In recognition of his research achievements, Dr Ijaz has received a number of honorary appointments.

Dr Caroline Gauchotte-Lindsay in a Senior Lecturer in Environmental and Analytical Chemistry who is an expert in marker discovery for environmental biochemical processes and is the Principal Investigator on two GU funded chemical sensor design projects. She is a recipient of the Brownfield Greening award for her practical research in remediation

Dr Siming You is a Senior Lecturer who deploys systems engineering approaches to the design and optimization of bioenergy systems. His research has been applied in practice for decentralised waste management in Singapore and his recent perspective in Science calls for a more generally distributed yet orchestrated response to waste management in the light of the COVID pandemic.

Dr Marta Vignola holds a Royal Academy of Engineering for Development Research Fellowship on the development of Eco-engineered biofilters for the sustainable removal of pesticides from drinking water in Brazil.

Project Support

Fiona Lees is the Project Manager for the grant and supports the project's financial reporting and monitoring processes, and co-ordinates the project administration. Fiona has experience in managing and coordinating projects and brings strong technical, financial and organisational skills to the role.

Valia Tavoulari-Matthiopoulos is the Project Administrator, providing support to the Project Manager and the research team. Valia has many years experience within the University sector, particularly in data management and analysis, event organisation, finance, website maintenance, and supporting new initiatives in research and higher education.

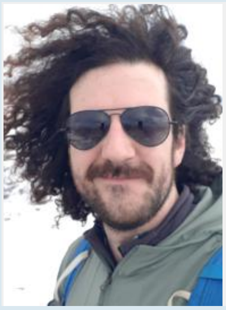
Research Associates and associated PhD students

Tania Gomez-Borraz is a Research Associate at the University of Glasgow with a PhD in Environmental Engineering and a background as a biochemical engineer. Tania has experience in waste treatment technologies for water and air pollution control.

Fabien Cholet is a Research Associate in Microbial Ecology. Fabien completed a PhD at the University of Glasgow in 2020, under the supervision of Prof. Cindy Smith, entitled 'Optimising and applying RNA based approaches to identify active nitrifiers in coastal sediments'.

Andy McKeown is a Research Associate within the energy group of the School of Engineering at the University of Glasgow. His background was initially in small scale organic Rankine cycle systems for power generation but his main focus is on refrigeration and heat pumps.

Anastasiia Kostrytsia is a Research Associate within the Water & Environment group at the School of Engineering, University of Glasgow. Anastasiia has been working on an RAEng: Scottish Water 'Biofiltration by biological design' fellowship to optimise water biotechnologies; and revealing active ammonia-oxidising microorganisms in variable salinity coastal sediments.



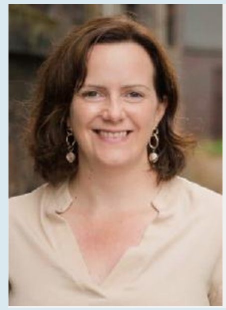
Baptiste Poursat is a Research Associate with a PhD in Environmental Chemistry. His research focuses on the removal of organic micropollutants, such as medicines and pesticides, by microbial communities in drinking water and wastewater treatment plants. His objectives are to improve the biodegradation and treatment activity of microbial communities and to understand the underlying mechanisms leading to the development of enhanced catabolic activity.

Zahra Hajabdollahi Ouderji is a Research Associate and obtained her PhD in Energy and Power Engineering from the Huazhong University of Science and Technology. Her research is concerned with developing novel enhancements for the thermal performance and heat transfer rate of energy systems through alternative applications of renewable energy, multi-purpose systems, and technologies such as heat recovery to advance the efficiency.

Calum Cuthill is a Research Associate. As an Electronics Engineer he is skilled in remote datalogging, system prototyping, software and circuit design. Previous work includes monitoring of mountain rivers with Edinburgh University, and as Senior Applications Engineer at chip design company Cirrus Logic.

Laurie Savage is a Research Associate and obtained his PhD in Biological Sciences from Queen's University Belfast in 2018. He is an environmental and analytical chemist with a focus on using mass spectrometry techniques, including targeted and non-targeted methodologies. His current focus is to further understand the composition of dissolved organic carbon in water.

Justin Sperling is a Research Associate at the University of Glasgow with expertise in nano and microfabrication of metamaterial sensing devices. His work involves the design, production, and testing of novel nanophotonic devices for regular and routine monitoring of the decentralised water technology systems being developed in the project.



Laura Major is a Research Fellow and Anthropologist based in Engineering at the University of Strathclyde. She specialises in the study of material culture, justice, and community. Her research investigates how relationships between people and objects, or landscapes, affect their lives and the choices they make. Her work aims to help in the design of better, fairer, practices and systems.

Pritam Das is a Research Associate at the University of Edinburgh, developing an environment friendly approach, based on visible light responsive membrane cleaning, to mitigate bacterial fouling in wastewater treatment. He has more than 7 years of experiences, working in Polymer chemistry and Chemical engineering in well-known research sectors for wastewater treatment and biomedical applications.

Rohit Gupta is a Research Associate working on Integrated Systems. His current research efforts highlight carbon, water, and energy footprint assessment for existing water treatment systems in partner community islands

Ayo Ogundero is a Research Associate primarily focussing on using novel and multidisciplinary approaches like flow cytometry for rapid quantification and assessment of key microbial interactions (such as predation and biofilm growth) in water treatment systems. Through this we can exploit the growth of microbial communities to perform specific tasks.

Elizabeth Lawson is a Research Associate, and part of the environmental engineering research group at Newcastle University. Her interdisciplinary research focuses on the interaction of people and water systems, with a specific focus on how tangible changes to policy and governance can create more sustainable and resilient water systems.

Xiang Shi is a Research Associate at the School of Engineering, University of Glasgow. He has a PhD in Geomicrobiology, an MSc in Petroleum Engineering and a BSc in Biology. His research interests focus on understanding the dynamics of diverse microbial populations in engineered and natural porous media ranging from small-scale biofilters to large-scale subsurface reservoirs.

Uzma Khan is a Research Associate at the University of Glasgow. As a bioinformatician, she focuses on the analysis of 18S rRNA datasets originating from the biofilter project and examines shotgun metagenomics datasets originating from the nitrifiers, biofilters and microbial community surveys of (solar) septic tanks.

Mel**issa Bruns-Moore** is a Research Associate and a multidisciplinary Environmental Scientist focused on anaerobic digestion and biogas production from the perspective of chemistry, microbiology, and engineering. Melissa acted as the process chemist for the commissioning of the GRREC waste to energy facility in Glasgow, Scotland. Currently, she is completing her PhD studying the effects of amoxicillin in anaerobic communities.

Tymon Herzyk is a PhD student. His research is primarily focused on describing the abundance of individuals within microbial populations using computational models that account for ecological drift and selection. Specifically, tackling the question of whether we can accurately derive population dynamics through calibration of these models when using time series data.

Jade Liu is a final year PhD student. Her research is focused on the feasibility of Waste-to-Hydrogen technology for sustainable waste management and green public transport in Glasgow, Scotland. The study involves using life cycle assessment, cost benefit analysis and optimisation techniques to assess the viability of Waste-to-Hydrogen conversion technology and systems in the production of hydrogen.

Linghui Shi is a PhD student. Her research focuses on antimicrobial resistances and in decentralised wastewater treatment systems, especially how wetland and lab-scale study of diversity of microbial community drives the change of growth rate when exposed to different amoxicillin concentrations.

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