ReNU

Renewable Energy Northeast Universities

EPSRC Centre for Doctoral Training

Annual Report

1 April 2022 to 31 March 2023

Engineering and Physical Sciences Research Council

Contents

Foreword

I am pleased to introduce the fourth annual report for the EPSRC Centre for Doctoral Training (CDT) in Renewable Energy Northeast Universities (ReNU). This report covers the period 1st April 2022 to 31st March 2023.

2022-23 has been a very successful year for ReNU that has been characterised by high-quality research, renewed emphasis on in person cohort-based learning and the operationalisation of the complete ReNU doctoral training programme. In 2022-23, we welcomed Cohort 4 to ReNU taking the total number of doctoral candidates to 51.

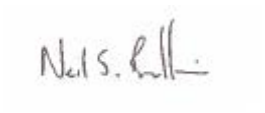
Throughout 2022-23, doctoral candidates have undertaken high-quality research that has resulted in multiple publications in prestigious scientific and engineering journals as well as presentations at international conferences across the USA, Japan and Europe. This is significant progress since 2021-22 and reflects ReNU's growing international reputation for research excellence. I am hugely proud of our doctoral candidates' achievements and also take this opportunity to acknowledge their supervisory teams across Northumbria, Newcastle and Durham universities.

An essential characteristic of the ReNU doctoral candidate experience is cohort-based learning. Following the challenge of the global pandemic, I am pleased to report a substantial increase in in-person cohort training activities including the first all-cohort training in May since November 2019. This was followed-up by the return to an in-person residential induction in October for Cohort 4 and ReNU academic staff at the Centre for Alternative Technology in Wales. This event was an excellent opportunity for doctoral candidate to gain hands on experience of renewable energy technologies and the remaining challenges to mass deployment.

The return to in-person training extended to the 8th North East Energy Materials and Systems meeting in November as part of ReNU's flagship CDT week. This meeting involved doctoral candidates presenting their research to senior research and development leaders from industry and brainstorming skills content for future refinements of ReNU's added-value training programme. Moving towards the later stages of their PhDs, Cohorts 1 and 2 participated in an employability workshop hosted on campus at Northumbria University in January 2023. This training included invaluable sessions such as CV clinics, profile building and a panel discussion on the career pathways of ReNU academic staff and postdoctoral researchers.

In 2023-24, Cohort 1 doctoral candidates will submit their PhD theses and in the same year, ReNU will welcome its fifth and final cohort. These are significant and exciting milestones which occur amidst a dynamic global context that includes economic challenges (all ReNU doctoral candidates received a 10% increase in their stipends this year), disruptive growth in artificial intelligence and an increasingly urgent need for decarbonisation. I am confident that ReNU graduates will be able to leverage their training programme experience and research leadership to make significant contributions in this context and beyond.

Professor Neil S. Beattie



Principal Investigator and Director of ReNU

1. Introduction

In 2018 the Engineering and Physical Sciences Research Council (EPSRC) launched a national Centre for Doctoral Training (CDT) exercise. The result of this exercise was an investment of £446m from UK Research and Innovation to create 75 new CDTs including the EPSRC Centre for Doctoral Training in Renewable Energy Northeast Universities (ReNU).

The EPSRC CDT in ReNU formally started in April 2019 and this document provides an overview of progress from the fourth year of the programme.

2. Aims and Objectives of ReNU

The overall aim of ReNU is to train and equip the next-generation of doctoral graduates with the skills required to drive UK innovation in renewable and sustainable distributed energy applications.

To achieve this aim, the objectives of ReNU are to:

1. create a pipeline of industry-ready doctoral graduates with outstanding problem-solving abilities to enable UK commercial development and exploitation of renewable energy (RE) and sustainable distributed energy (DE) technologies;
2. provide a comprehensive cohort training experience that leverages the unique co-location of the three Universities and is inherently multidisciplinary and international, extending well beyond an individual research project; and
3. add value to the UK economy by fostering a cohort of innovators in a geographical region which offers significant potential for increased productivity and growth.

3. Governance and Management

The organisation and structure of ReNU is shown in Figure 1. The Management Committee (MC), Strategic Advisory Board (SAB) and Delivery Groups (DGs) are all governed by a set of Terms of References that were developed during the first year of operation and approved by the MC. There have been no changes to the MC in 2022-23.

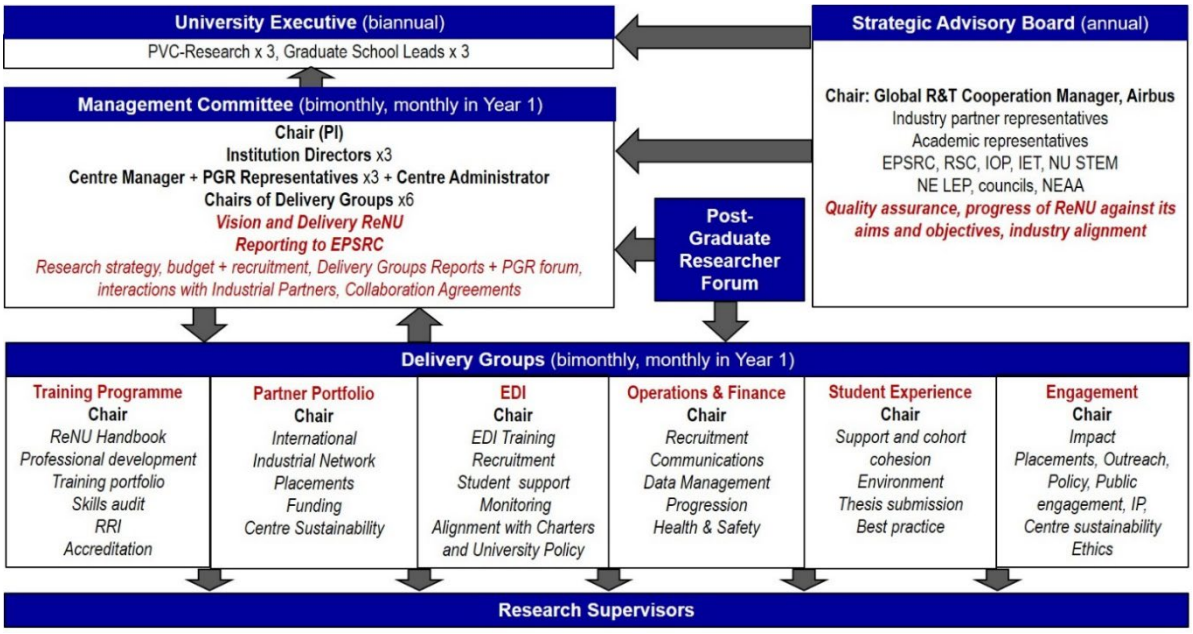


Figure 1: ReNU governance and management structure

3.1 Management Committee (MC)

The ReNU MC is composed of the named investigators, the Centre Manager, the Centre Administrator and doctoral candidate representatives. It has responsibility for the vision and operation of the CDT consistent with the project proposal. Note that the EPSRC Project Liaison Officer is formally a member and has access to all documents and the right to attend any meeting of the MC. The MC meets every other month and following the pandemic, has returned in 2022-23, to rotating this meeting around the partner university campuses with a remote joining facility available at every meeting. The MC responsibilities are defined in a Terms of Reference according to: Strategy and Policy Development; Operational; Approval; Monitoring and Review; and Reporting Relationship with Other Bodies.

3.2 Strategic Advisory Board (SAB)

The ReNU SAB is chaired by a Global Research and Technology Coordination Manager from Airbus and is composed of the MC, industry representatives, the North East Local Enterprise Partnership, an EPSRC Project Liaison Officer, external academic advisors and non-profit organisations. The SAB met in both May and November 2022 with an acting Chair (due to absence) from the Energy team at the North East Local Enterprise Partnership.

3.3 Delivery Groups (DGs)

There are six delivery groups overseeing operational aspects of ReNU and these are shown in Figure 1. These involve a named investigator as Chair as well as academic supervisors and doctoral candidate representatives. The DGs meet on average every two months and are governed by a Terms of Reference ratified by the MC.

3.4 ReNU Manager and Academic Support Coordinator

ReNU has a Centre Manager and Academic Support Coordinator. The Centre Manager position is a 1.0 FTE permanent academic position in the Department of Mathematics, Physics and Electrical Engineering at Northumbria University. This post has an 0.5 FTE secondment to the CDT for its duration that is funded by EPSRC. The administrator position is a 0.5 FTE post funded entirely by EPSRC.

3.5 Risk Management and Mitigation

A project Risk Register detailing project risks, controls, risk rating, mitigation actions, timescales and owners is reviewed at MC meetings. In addition, the ReNU Director holds annual update meetings with the Senior Leadership teams at the partner universities.

3.6 Systems and Tools

A ReNU Microsoft SharePoint site hosted at Northumbria University is available to all ReNU investigators, Professional Support Staff and Graduate Schools across the three institutions. This site includes terms of reference for the delivery groups and minutes of the MC meetings. This site is also linked to a ReNU Microsoft Teams site which is accessible to doctoral candidates and provides a single virtual location for all training materials used in the training programme.

4. COVID-19

Relative to the previous 2 years, 2022-23 has been relatively normal in the context of COVID-19 with little disruption to the operation of ReNU. The majority of the doctoral training programme has been in-person although we continue to use remote options where there is a sensible case. A significant highlight from the training programme was a dinner at the Baltic Centre for Contemporary Art in Newcastle in May 2022. This followed technical training for all cohorts from industry partner, the Offshore Renewable

Energy Catapult, on the next-generation of wind turbines. This was first time since 2019 that all ReNU doctoral candidates and the MC were able to meet together in person.

After careful consideration, the ReNU MC is recommending extensions to PhD projects as a result of the pandemic only in exceptional circumstances considered on a case-by-case basis. This recommendation is aligned to institutional policies at the partner universities. In reaching this decision, the ReNU team made reference to *The Impact of Covid 19 on Doctoral Assessment* produced by the UK Council on Graduate Education which was co-created by ReNU Co-Investigator and MC member Professor Douglas Halliday (Durham). Drawing on this resource and expertise, the ReNU team is supporting doctoral candidates and supervisors (particularly Cohort 1) in the preparation of a COVID impact statement for inclusion in their theses.

In 2022, ReNU's COVID Response Group was formally dissolved with any remaining issues delegated to the Student Experience Delivery Group (reporting to the MC) and the ReNU Centre Manager.

5. Doctoral Candidate Recruitment: Cohort 4

5.1 Principles

In recruiting doctoral candidates, we considered several strategic principles including: quality; industry involvement in projects; balance across the partner universities; diversity; balance across technical themes; and alignment with UKRI rules on international eligibility. Following a review of the proposed projects by the SAB in November, advertisements were placed in December 2021 with interviews in March 2022. A second round of interviews was conducted in June 2022 resulting in a cohort of 15 doctoral candidates enrolling in October 2022 across the three partner universities.

5.2 Marketing

The ReNU recruitment process for Cohort 4 prioritised attracting high-quality applicants and direct industry cash contributions to projects. Marketing activities were carried out via networks and promoted across undergraduate and postgraduate programmes in each university.

5.3 Project allocation and selections

ReNU projects are allocated according to an annual target of 5 at Northumbria, 4 at Newcastle and 4 at Durham. The final number of appointments may vary depending on the number of collaborative studentships (with direct contribution from industry) and any unappointed studentships from previous recruitment rounds. The allocation process seeks to balance themes strategically shaping the breadth of the portfolio across ReNU topics and investigators whilst ensuring the appointment of quality doctoral candidates and industry involvement. The process also seeks to devolve management to the three individual Institution Directors (IDs) on behalf of their universities. The IDs can select an allocation panel for shortlisting the projects to be advertised, while also working as a group between IDs for consistency. The shortlist is presented to the MC for oversight prior to final presentation to the SAB for confirmation.

The process is described in the following steps but it is important to note that the offer of an individual studentship is devolved to each institution where the doctoral candidate will be enrolled as a student and registered for a PhD.

1. Three IDs agree a consistent approach to applications, interviews and offers consistent with the three University processes.
2. All proposals checked for linguistic gender bias using software http://gender-decoder.katmatfield.com.

3. IDs and co-investigators within an institution meet to review and rank project proposals using quality and fit to scope as the main criteria. Typically, the top 8-10 project proposals are taken forward to the MC.
4. The ReNU MC meets to review project proposals and selects a subset for advertisement after consideration of the principles listed in section 5.1 (Note that 6 projects were each selected for advert at Durham and Newcastle while 12 were selected for advert at Northumbria. This increased studentships at Northumbria was the result of additional funding from industry partners and the University.)
5. Following an advertisement period of ~6 weeks, interviews held virtually at each institution with the host ID attending all interviews as Chair. In cases where the ID is a potential supervisor, another member of the team takes the role of Chair.
6. Candidates are ranked across projects and studentships are allocated according to set criteria. If no offer is made (or if offers are rejected) and there are studentships remaining to be allocated, a project (or set of projects) is re-advertised into subsequent rounds.

5.4 Outcome and review

For the 2022-23 academic year, ReNU recruited 15 students to Cohort 4 who enrolled at one of the three partner institutions on 1st October 2022. Anonymised data was collected for all applications (including ineligible candidates), for statistical analysis. A subset of these data is shown in Table 1. For comparison, the accumulated data is provided in Table 2 for cohorts 1-3.

Table 1: Recruitment data for ReNU Cohort 4 (2022-23)

	Female Candidates			Minority Candidates			Total no. of Candidates		
	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed
UNN	17	1	1	81	20	3	107	31	8
DU	69	11	2	146	10	1	184	26	4
NU	20	3	0	61	4	0	78	9	3
Total	**106**	**15**	**3**	**288**	**34**	**4**	**369**	**66**	**15**

Table 2: Aggregated recruitment data for Cohorts 1-3

	Female Candidates			Minority Candidates			Total no. of Candidates		
	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed
UNN	62	17	7	142	23	6	219	48	18
DU	24	8	4	91	18	2	199	46	11
NU	47	11	3	76	6	2	136	33	12
Total	**133**	**36**	**14**	**309**	**47**	**10**	**554**	**127**	**41**

ReNU has an aspiration to recruit 33% of any single gender and has surpassed this over the last 3 cohorts with 34% of its recruitment identifying as female. However, in cohort 4, the percentage has dropped to 20%, despite having a larger number of female applicants when compared with previous years. Whilst Newcastle University did not appoint any in this cohort, it is worth noting that at Durham University, 50% of the appointed candidates were female. In terms of recruiting minorities, although lower than cohort 3 (44%), cohort 4 was 27% which is greater than the aggregated recruitment so far (24%). In view of this analysis, ReNU is achieving diverse cohorts which exceed EPSRC benchmarks. In addition to the data in Table 1, at Northumbria and Newcastle universities[1], 27% of cohort 4 were >30 years old and 27% have identified as disabled.

[1] *DU data unavailable as it was deleted due to data retention policy.

ReNU has an aspiration to develop ECR and mid-career academics as PhD supervisors and across all cohorts 1-4, these account for 80% of doctoral candidates' projects (note for cohort 4, this is 93%). ReNU is further committed to increasing under-represented groups as supervisors and 25% of supervisors across all cohorts are female (27% for cohort 4). We will continue to review recruitment practices with the aim of fair and diverse representation across supervisors and doctoral candidates who have the opportunity to carry out world-leading research in renewable energy.

5.5 Scope

Figure 2 shows the distribution of ReNU projects across topics in renewable energy. These data reflect the diversity of technical work across decarbonisation which in 2022-23 included a notable increase in projects relating to hydrogen.

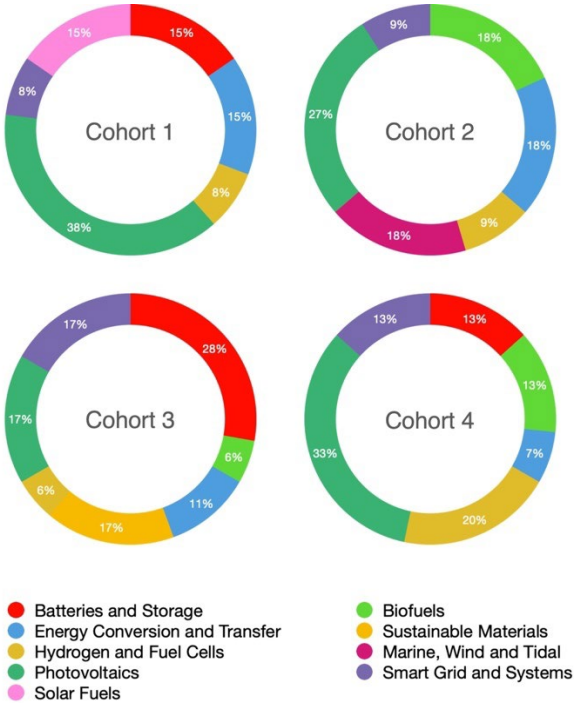


Figure 2: Balance of topics in renewable energy across ReNU projects.

6. Equality, Diversity and Inclusivity (EDI)

The three Universities in ReNU all hold Athena SWAN awards at Institutional Level. Newcastle University holds a Silver Award, and Durham and Northumbria hold Bronze Awards. ReNU takes seriously its responsibility to offer equality of opportunity to all staff and doctoral candidates and is keenly aware of the challenges facing STEM subjects in increasing diversity.

The work of the EDI Delivery Group is guided by the recently published 'Review of EPSRC-funded Doctoral Education' and the EDI challenges outlined in that document. After consulting with our student representatives we have created a dedicated EDI webpage for ReNU (https://renu.northumbria.ac.uk/?page_id=1847) highlighting our commitment to diversity, and listing various sources of disability and care support. Students within ReNU also continue to receive excellent training in EDI, such as Mental Health and Unconscious bias (provided by the Durham University Counselling Service Team and Northumbria University's NUSTEM programme) and the role of energy poverty on social mobility (delivered by National Energy Action).

7. Training Programme

The philosophy of the ReNU training programme is to provide doctoral candidates with both the deep knowledge of the science and engineering for energy as well as the broader business and innovation skills to allow our graduates to succeed and lead in industry. A schematic diagram of ReNU's training programme can be found in Figure 3.

The year 2022/23 saw us welcome the fourth cohort to the ReNU CDT, bringing the number of ReNU students to 51. In this section we review the training undertaken this year whilst also highlighting some of the new and developing initiatives within ReNU.

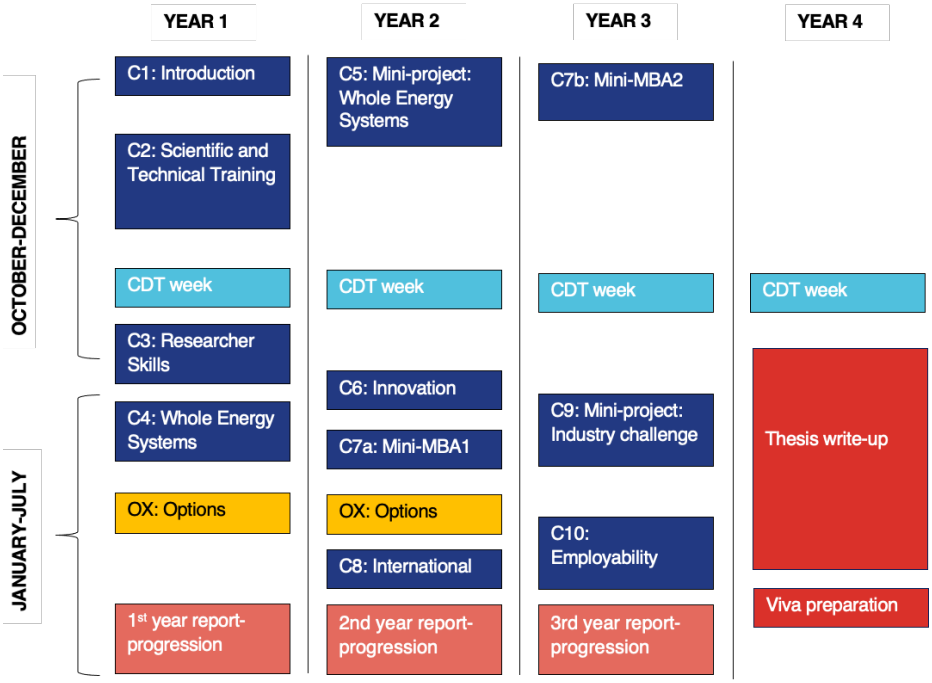


Figure 3: ReNU training programme schematic

2022-23 has been a year of progress and success for the ReNU training programme. We were proud to be formally accredited by the Royal Society of Chemistry (RSC) and Institute of Physics (IOP), meaning all ReNU doctoral candidates will be eligible to apply for Registered Scientist (RSci) status from the end of their second year. Further, our training programme has continued to adapt in response to student feedback, whilst taking forward positive initiatives already implemented, including lecture capture developed during COVID now providing flexibility for those who may be ill or have disabilities. This year also saw cohort 1 enter their final year, meaning that for the first time, all years of the training programme are active. Below we summarise the training together with feedback from doctoral candidates.

C1: Welcome Event and Induction Week (7th -14th Oct 2022)

A programme of induction activities during the first weeks of the programme to welcome cohort 4, with the highlight of a 3-day field trip to Centre for Alternative Technology (CAT) in Wales. This trip provided students with the opportunity to interact with each other as well as ReNU staff. The field trip emphasised the urgent need for greater adoption of renewable energy as well as allowing doctoral candidates to experience a wide range of energy installations at CAT including biomass, wind turbines, hydroelectricity and PV.

'It was a valued opportunity to hear about political and other wider aspects of the energy challenge from those who had been working in this area for many decades.'

C2: Renewable Energy Fundamentals (17th October-21st October at Northumbria), (5th-9th December at Durham)

This training was specifically designed to provide an overview of a broad range of renewable energy technologies and how different research areas fit into the wider energy landscape. A broad range of themes and topics, including energy materials, renewable energy technologies, energy system and materials modelling, materials characterisation were delivered by ReNU supervisors to introduce students to different aspects of the energy system. All students responded that they considered the organisation and support for training to be good or excellent.

'The lectures on different topics of physics were interesting.'

'This series of training was vital to students in broadening our horizons and empowering us not only in our field of specialization but also in other multi-disciplinary areas.'

C3: Research skills (7th -11th November)

This module covered critical transferrable research skills relevant to future careers. A one-day introductory workshop on coding in Python helped students to develop key computational skills for research including data analysis and programming. Sessions on energy poverty and societal responsibility provided wider context around the importance of renewable energy conversion. Additionally, a Conference Abstracts & Posters workshop was well and helped students to generate a focused abstract and then use this to guide the development of an inspiring scientific poster.

'The whole week was good but the poster session experience was unique.'

CDT Week (21-25 November 2022)

For the first time since the pandemic, we were able to run an in-person CDT Week involving both industry and academia, with Cohort 2 opening proceedings by highlighting the different work going on within ReNU. Students found CDT week beneficial through the opportunity to learn more about the challenges faced by different sectors including manufacturing and water. A ReNU doctoral candidate chaired a panel discussion on careers and was commended by both students and partners. More ReNU candidates chairing and introducing sessions will be considered for further CDT weeks. Two site visits were also organised to Northern Gas Networks Hydrogen House in Gateshead and to rooftop solar PV installations on campus at Northumbria University.

'I enjoyed the networking aspect and discussions with industry.'

'Was very interesting to attend the Hydrogen House visit. It was nice to go and see the site in person and was a good break from studying.'

'It was exciting to hear the projection of the industry experts on relevant and critical industry skills of the future such as lifecycle analysis, programming and development of a business case.'

C4 and C5: Whole Energy Systems and Group Projects

The Whole Energy Systems and Group Projects play a key role within the ReNU CDT training programme as they provide the opportunity broaden students' perspectives on energy beyond their immediate research. This year, it involved cohort teaching and informal discussion on policy, economics and society, followed by a group project in teams of 3 to address a particular challenge or question (e.g. *Are sand batteries the next clean energy revolution?)* over a two week period. At the end of the project, each team submitted a written non-technical summary of their findings and gave a 15-minute presentation on the project in CDT week.

'The project scope was enjoyable and a reasonable workload.'

'Good topics and good presentations.'

C6: Innovation training (24-26 April 2022)

Cohort 2 students participated in an online workshop focused on innovation techniques and skills followed by the application of these to a hypothetical problem in the transport sector. Doctoral candidates worked in multidisciplinary groups and received feedback on their mock client presentations.

RSC/IOP Accreditation

ReNU was accredited by both the RSC and the IOP in June 2022. All ReNU students are now able to apply for Registered Scientist (RSci) status at the end of their second year. RSci is a mark of excellence show personal and professional integrity and highly regarded internationally. All ReNU doctoral candidates who wish to pursue RSci status are assigned a mentor (who is not their supervisor) at the beginning of their programme to support their development of the application. Additionally, two accreditation workshops were organised to discuss the process and included input from the RSC. These have been highly effective and we hope to see the first ReNU doctoral candidates achieve RSci in 2023-24.

C7: Mini-MBA

Both Cohort 1 and 2 have now completed mini-MBA training provided by Durham University in March 2021 and June 2022 respectively. 8 students submitted their assignment for a Strategic Management Project with the Chartered Management Institute. Cohort 3 & 4 will start their mini-MBA this June 2023.

C9: Industry Challenge Group Mini-Project (Spring 2022)

In April 2022, the Industry Challenge Group Mini-Project was developed by inviting Industry "clients", including the Offshore Renewable Energy (ORE) Catapult and renewable energy specialist, Discerna, provided projects that investigated by 6 groups of cohort 1 and 2 students over a 4-week period. Two projects were converted into case studies which are now available on ReNU's website. Cohort 3 and 4 students will start their mini-project in March 2024.

C10: Employability training (9-10 January 2023)

A two-day employability workshop was delivered to cohorts 1 and 2 students by the Employability Partnerships Team at Northumbria University in early January 2023. This involved sessions on personal branding and networking, preparing for interviews, and resilience. One highlight was a panel discussion from academics at different stages to provide students with perspectives on graduate employment in academia and industry. The workshop also included a valuable CV and cover letter clinic.

'The personal branding/networking session (Day 1) was really useful; the panel session (Day 2) was also very interesting and it was good to hear from academic speakers.'

'The panel discussion was also good, helpful to understand the different career paths.'

Writing retreat (1-3 March 2023, Alnwick, Northumberland)

Supported by Durham Centre for Academic Development, this three-day writing retreat was well received by cohort 1 students, who are at the concluding stages of their PhD wrap and will write-up their PhD theses this year. This event also included a workshop to help students prepare for their viva and was well-received.

'I enjoyed the whole experience. The timed sessions, working alongside others were very helpful! It was also nice to get to know the other non-ReNU students from Durham university. The setting of the hotel was very peaceful and made the stay both productive and restful at the same time.'

'Hotel (and the people running it) was nice, and the grounds were easily accessible during breaks; food was good and plentiful. Viva preparation session was useful.'

'This retreat was invaluable for me - it really helped me get the space, clarity and focussed time to write away from pressures of daily life. I came away with a rough draft for a paper and it was morale boosting to see what I could achieve in a short space of time with dedicated focus & peer support.'

Additional ReNU training

As well as the core training modules described above, the ReNU training programme includes optional modules focused on practical sessions and workshops to support doctoral candidates' individual research projects. These included sessions on X-ray diffraction, thin film processing and electron microscopy. In 2022, ReNU introduced an industry seminar series (approximately monthly) supported by new and existing industry partners.

8. Student Experience

As ReNU expands to four cohorts, the student experience offered to ReNU doctoral candidates continues to develop and build on the important legacy of previous years. Inter-cohort interactions are now fully embedded into the ReNU training and wider student experience opportunities, particularly in whole CDT events such as CDT Week. This year, CDT Week was held fully in person and offered an important opportunity for students to enhance their own skills, network, and showcase the outstanding research in ReNU. A number of sessions were led by students, including an excellent plenary discussion involving experts from across the energy industry. Part of CDT week was devoted to a series of round table discussions on the strengths and opportunities offered by ReNU and how these can be further enhanced, giving students an opportunity to input directly into the longer-term planning for ReNU.

ReNU has an active group of committed student representatives who meet regularly in the ReNU Student Experience Group with ReNU supervisors to provide direct comments and feedback on all aspects of the ReNU training, ReNU activities and ReNU research projects. Student input has led to further enhancements in many aspects of ReNU training (including C3, C4, C4, CDT Week). Feedback from student reps has revealed a desire among ReNU students to learn more about wider societal and political aspects of energy including: green energy and green economics, degrowth, more anthropological and societal perspectives. Work is underway to develop these requests as another example of how student input enhances the training and wider experience offered by ReNU in preparing students to fulfil the vision of ReNU to make a positive impact on the UK future energy system while addressing the systemic challenge of climate change.

A notable success this year has been the accreditation of the ReNU training program by the Institute of Physics and the Royal Society of Chemistry. Students who complete the first two years of ReNU training can submit an application and reflective account of experience leading to professional recognition as a Registered Scientist (RSci). The RSci status is recognised by many of the professional bodies and offers an accelerated route to full chartered status, for example CChem or CPhys. This recognition is a testament to

the quality of the training offered by ReNU. More importantly it has provided opportunities to discuss the process with ReNU students and enable them to understand the importance of:

1. professional development;
2. creating a record of training;
3. reflection on practice; and
4. professionally recognised competencies.

These skills will be invaluable in helping students secure important and influential roles in the energy industry upon completion of their PhD and ReNU training. This illustrates the positive impact that the experience offered to PhD students in ReNU can have, and how student input has enabled this experience to continue to develop. As we approach the completion of the first cohort, we wait with expectation to see what our ReNU graduate will achieve in terms of a positive impact on decarbonising energy to create a better future for all.

9. Partners

This year, ReNU has further expanded its network of partners and direct cash contributions to projects from industry reached approximately £450k (cumulative). We anticipate that this figure will exceed £500k in 2023-24. In addition, in-kind support to projects was approximately £260k and included training through expert lectures and workshops; hosting cohort site visits; providing access to facilities and laboratory equipment; and providing client briefs for Industry Challenge group mini-projects.

CDT Week in November included the 8th North East Energy Materials and Systems (NEEMS 8) meeting and was the first time that this event was held in-person since 2019. This event involved senior R&D leaders from over 20 companies, doctoral candidates, the ReNU management team and EPSRC. In addition to scientific and industry presentations, a key activity during the NEEMS 8 meeting were breakout sessions focused on the skills and attributes of high skill postgraduates to drive decarbonisation.

In June, the ReNU team participated in EPSRC's Engineering Net Zero event held in the Advanced Research Centre at the University of Glasgow. In total, 6 academic staff and 9 doctoral candidates represented ReNU at this event over 3-days. This included hosting a ReNU stand with live demonstrations and interactive activities relating to Net Zero impact from ReNU research.

10. Internationalisation

Opportunities for international travel increased significantly in 2022-23 mainly through doctoral candidate attendance and presentation at international conferences in the USA, Japan and Europe. Throughout the year, ReNU students attended and disseminated their research at over 25 national and international conferences.

In designing the ReNU programme, our original intention was for all students to participate in a short placement to ReNU partner, Huazhong University of Science and Technology (HUST) in Wuhan, China. Given the impacts on travel imposed by the pandemic, the ReNU MC took the difficult decision to cancel this particular aspect of the training. All doctoral candidates were informed of this decision at the earliest possibility and have been advised that they can reallocate their research training and support grant towards other travel and dissemination activities. We will also continue to explore the potential for virtual events with international partners.

A notable international success for ReNU was the award of another scholarship from the UKRI-Canada Globalink Doctoral Exchange Scheme. When coupled with other collaborations including with ReNU partner, the University of Calgary, 3 ReNU doctoral candidates have now taken up short placements in Canadian research institutions.

11. Outlook

In summary, 2022/23 has been an excellent year for ReNU that has been characterised by many more opportunities for in-person training and cohort-based learning as well as high-quality research. Looking ahead, Cohort 1 will submit their theses and ReNU will welcome its fifth and final cohort.

Appendix 1 – ReNU team

Prof. Neil S Beattie - ReNU Chair and Principal Investigator

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ReNU topics: Photovoltaics, earth abundant materials

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ReNU topics: Smart grid and systems, photovoltaics

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ReNU topics: Solar fuels, photovoltaics

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ReNU topics: Energy conversion and transfer, photovoltaics

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ReNU topics: Earth abundant materials, Photovoltaics

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ReNU topics: Power electronics and control, wireless power transmission

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ReNU topics: Conversion technologies, green hydrogen, biofuels

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ReNU topics: Earth abundant materials, photovoltaics, transparent electrodes

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ReNU topics: Earth abundant materials, photovoltaics

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ReNU topics: Earth abundant materials, photovoltaics

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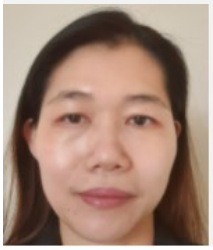
ReNU topics: Molecular and solid state chemistry and metal complexes



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Appendix 2 – List of Publications

The article publications are given in reverse chronological order. ReNU contributors are highlighted.

1. **Dominic Shiels**, Magda Pascual-Borràs, Paul G. Waddell, Corinne Wills, Josep-Maria Poblet and **R. John Errington**. A thirty-year old mystery solved: identification of a new heptatungstate from non-aqueous solutions, Chemical communications, 2023. https://doi.org/10.1039/d3cc02061d
2. **Anotidaishe Moyo**, Muhammad Wakil Shahzad, Jonathan G. Terry, Stewart Smith, Yoshio Mita, **Yifan Li**. Test Structures for Studying Coplanar Reverse- Electrowetting for Vibration Sensing and Energy Harvesting, 35th International Conference on Microelectronic Test Structure (ICMTS), 2023. 10.1109/ICMTS55420.2023.10094057
3. **Ewan D. Matheson**, Xinya Xu, **Yongtao Qu**, **Guillaume Zoppi**, **Vincent Barrioz** and **Neil S. Beattie**. A structural, optical and electrical comparison between physical vapour deposition and slotdie deposition of Al:ZnO (AZO), MRS Advances, 2023, 1-6. https://doi.org/10.1557/s43580-023-00554-w
4. Ana Carolina Coutinho Dutra, **George E. Rudman**, **Karen E. Johnston** and **James A. Dawson**. Defect chemistry and ion transport in low-dimensional-networked Li-rich anti-perovskites as solid electrolytes for solid-state batteries, Energy Advance, 2023, Advance Article. https://doi.org/10.1039/D3YA00075C
5. Mehdi H. Biroun, **Luke Haworth**, **Hossein Abdolnezhad**, Arash Khosravi, **Prashant Agrawal**, Glen McHale, **Hamdi Torun**, **Ciro Semprebon**, Masoud Jabbari and **Yong-Qing Fu.** Impact Dynamics of Non-Newtonian Droplets on Superhydrophobic Surfaces, Langmuir, 2023, 39, 16, 5793–5802 https://pubs.acs.org/doi/full/10.1021/acs.langmuir.3c00043
6. **Luke Haworth**, Deyu Yang, **Prashant Agrawal, Hamdi Torun**, Xianghui Hou, Glen McHale, and **Yong-Qing Fu,** Reduction of Ice Adhesion on Nanostructured and Nanoscale Slippery Surfaces. Nanotechnology and Precision Engineering, 2023, 6, 013007. https://doi.org/10.1063/10.0017254
7. **Prakriti Kayastha**, **Devendra Tiwari**, Adam Holland, **Oliver S. Hutter**, Ken Durose, **Lucy D. Whalley**, **Giulia Longo**, High temperature equilibrium of 3D and 2D chalcogenide perovskites, Solar RRL, 2023, 2201078. https://doi.org/10.1002/solr.202201078
8. **Udari Wijesinghe**, **Giulia Longo**, Oliver S. Hutter*, Defect engineering in antimony selenide thin film solar cells, *Energy Advances*, 2023,2, 12-33 https://doi.org/10.1039/d2ya00232a
9. **Anotidaishe Moyo**, Muhammad Wakil Shahzad, Jonathan Terry, Yoshio Mita, **Yifan Li**. A facile coplanar reverse electrowetting-on-dielectric configuration for more flexible and integratable force/motion sensing applications, IEEE Sensors, 2022, 1-5. 10.1109/SENSORS52175.2022.9967283
10. **O.M. Rigby**, T. Richards-Hlabangana, Q.M. Ramasse, I. MacLaren, R.A. Lomas-Zapata, M.S. Rumsey, K.P. McKenna, **B.G. Mendis**, Structure and electronic properties of domain walls and stacking fault defects in prospective photoferroic materials bournonite and enargite, Journal of Applied Physics, 2022, 132, 185001. https://doi.org/10.1063/5.0095091

11. Deyu Yang, **Luke Haworth**, **Prashant Agrawal**, Ran Tao, Glen McHale, Hamdi Torun, James Martin, Jingting Luo, Xianghui Hou*, and **YongQing Fu***, Dynamic Mitigation Mechanisms of Rime Icing with Propagating Surface Acoustic Waves, Langmuir 2022, 38, 37, 11314–11323
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12. Melissa Orr, **Glen R. Hebberd**, **Emma E. McCabe**, and Robin T. Macaluso, Structural Diversity of Rare-Earth Oxychalcogenides, ACS Omega 2022, 7, 10, 8209-8218. https://doi.org/10.1021/acsomega.2c00186
13. **Michael D. K. Jones, James A. Dawson**, Stephen Campbell, **Vincent Barrioz, Lucy D. Whalley, and Yongtao Qu**, Modelling Interfaces in Thin-Film Photovoltaic Devices, Frontiers in Chemistry, 2022, 10:920676
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14. **Ian Brewis**, Rana-Faisal Shahzad, Robert W. Field, Abdesslem Jedidi, and **Shahid Rasul**, Combining experimental and theoretical insights for reduction of CO2 to multi-carbon compounds, *Discover Chemical Engineering,* 2022, 2:2.
https://doi.org/10.1007/s43938-022-00009-y
15. **Matthew C. Naylor**, Devendra Tiwari, Alice Sheppard, Jude Laverock, Stephen Campbell, Bethan Ford, Xinya Xu, **Michael Jones, Yongtao Qu**, Pietro Maiello, **Vincent Barrioz, Neil S. Beattie**, Neil A. Fox, David J. Fermin, **Guillaume Zoppi**, Ex-situ Ge-doping of CZTS Nanocrystals and CZTSSe Solar Absorber Films, Faraday Discussions, 2022, 239, 70-84.
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16. Ioanna Pallikara, **Prakriti Kayastha**, Jonathan M. Skelton and **Lucy D. Whalley**, The Physical Significance of Imaginary Phonon Modes in Crystals, *IOP electronic structure*, 2022, 4, 033002.
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17. Stephen Campbell, Martial Duchamp, Bethan Ford, **Michael Jones**, Linh Lan Nguyen**, Matthew C. Naylor**, Xinya Xu, Pietro Maiello, **Guillaume Zoppi, Vincent Barrioz, Neil S. Beattie, and Yongtao Qu**, Recovery Mechanisms in Aged Kesterite Solar Cells, *ACS Applied Energy Materials,* 2022, 5, 5, 5404–5414.
https://doi.org/10.1021/acsaem.1c03247
18. **Elisangela Jesus D'Oliveir, Sol Carolina Costa Pereira**, Dominic Groulx, **Ulugbek Azimov**, Thermophysical properties of Nano-enhanced phase change materials for domestic heating applications, *Journal of Energy Storage*, 2022, 46, 103794. https://doi.org/10.1016/j.est.2021.103794
19. **Simon Doherty**, Julian G. Knight, Hussam Y. Alharbi, **Reece Paterson**, Corinne Wills, Casey Dixon, Lidija Šiller, Thomas W. Chamberlain, Anthony Griffiths, Sean M. Collins, Kejun Wu, Matthew D. Simmons, Richard A. Bourne, Kevin R. J. Lovelock, Jake Seymour, Efficient Hydrolytic Hydrogen Evolution from Sodium Borohydride Catalyzed by Polymer Immobilized Ionic Liquid-Stabilized Platinum Nanoparticles, *ChemCatChem*, 2022, 14, e20210172021. https://doi.org/10.1002/cctc.202101752
20. Mehdi H. Biroun, **Luke Haworth**, Prashant Agrawal, Bethany Orme, Glen McHale, Hamdi Torun, Mohammad Rahmati, and **YongQing Fu**, Surface Acoustic Waves to Control Droplet Impact onto Superhydrophobic and Slippery Liquid-Infused Porous Surfaces, *ACS Applied Materials & Interfaces*, 2021, 13, 38, 46076–46087. https://doi.org/10.1021/acsami.1c09217