ReNU

Renewable Energy Northeast Universities

EPSRC Centre for Doctoral Training

Annual Report

1 April 2021 to 31 March 2022

Engineering and Physical Sciences Research Council

Contents

Foreword

I am pleased to introduce the third annual report for the EPSRC Centre for Doctoral Training (CDT) in Renewable Energy Northeast Universities (ReNU). This report covers the period 1st April 2021 to 31st March 2022.

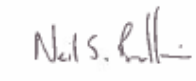
2021-22 has been a successful year for ReNU which now supports and trains 37 doctoral candidates across three cohorts at Northumbria University, Newcastle University and Durham University. After the disruption and challenges of remote working imposed by the pandemic, this year has seen significantly more research and training activities on campuses at the three partner universities. The benefits of a return to in-person interactions within and across the cohorts have been clear to see with doctoral candidates' progress accelerating throughout.

In returning to in-person activities, ReNU adopted a cautious approach and prioritised laboratory access for experimental research projects and social interactions. Major milestones in the latter regard were: a welcome reception for Cohort 3 doctoral candidates with an associated tour of renewable energy installations led by the Carbon Manager at Northumbria University; and an outdoor evening social gathering of all cohorts in the centre of Newcastle. Despite a major easing of restrictions in 2021, ReNU maintained an online learning model for core cohort training through Spring 2022. More generally, we recognise that there are benefits to online learning and will strive to achieve a "best of both worlds" balance for the remainder of the programme.

Further highlights include significant growth in industrial investments in individual doctoral candidates' projects; institutional and grant-funded investments in supporting research infrastructure and people; delivery of a mini-MBA and bespoke innovation training; launch of an Industry Challenge group mini-project; and submission of a joint application for professional accreditation of ReNU's training programme to the Royal Society of Chemistry and the Institute of Physics. The culmination of much of this progress is evidenced by the publication of the first research articles authored by doctoral candidates and their research teams in peer-reviewed scientific journals.

As ever, the ReNU team strives to emphasise the importance of individual doctoral candidates' research projects in the broader regional, national and international contexts for renewable energy. In this respect the three partner universities signed a memorandum of understanding with Britishvolt in June 2021 with a view to supporting R&D, innovation and skills as the market for battery electric vehicles continues to expand rapidly. Similarly, COP26 in Glasgow provided a sharp reminder of the requirements for meeting the criteria set out in the Paris Agreement on climate change. This challenge has become even more demanding following global events in early 2022 and associated increases in energy costs. The combination of these factors confirms, more than ever, the clear need for ReNU doctoral candidates whose capabilities and training are grounded in scientific excellence and high-value transferable skills to tackle some of the world toughest problems.

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 third 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. Following changes to the ReNU MC in 2020-21, there have been no further changes in 2021-22.

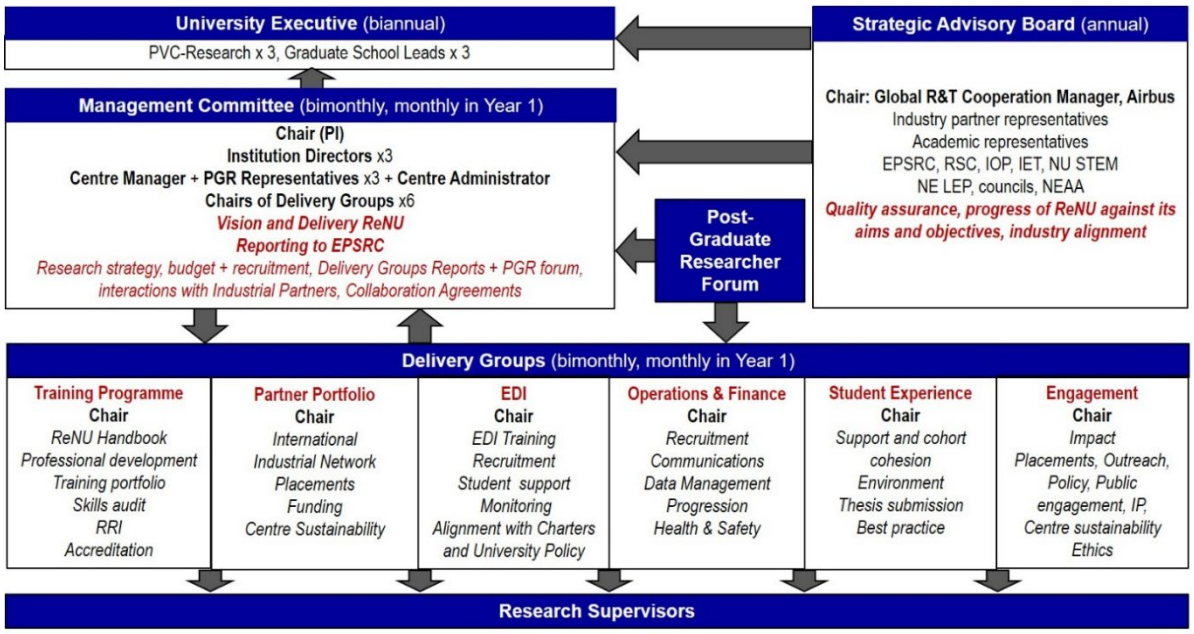


Figure 1: ReNU governance and management structure

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. During the first year of operation the MC met monthly and from March 2021, the MC has met every other month. 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 virtually in both June and November 2021.

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 quarterly MC meetings (standing item). In addition, the ReNU Director holds quarterly update meetings with the Faculty Pro-Vice Chancellor at Northumbria University and annual update meetings with Senior Management at Newcastle and Durham 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

This year has, in general, seen less disruption from the COVID-19 global pandemic. For Cohorts 1 and 2, this has resulted in significant progress across their projects and more in-person academic activity. For Cohort 3, the initial phases of their projects have been relatively normal with the exception of a brief period of working at home in late 2021 due to the Omicron variant of COVID-19.

4.1 General Mitigation Strategies

As a reminder, due to the COVID-19 global pandemic, all ReNU activities were moved online in March 2020. In the summer of 2020, the gradual reopening of laboratories

began, and social distancing measures and local health and safety policies were followed. Access to laboratories was maintained throughout the subsequent UK national lockdowns and the partner universities began a process of regular lateral flow testing for those working on site. We also prepared doctoral candidates and supervisors for potential future lockdowns by encouraging a strong theoretical component of projects. A key opportunity from this period was to allow doctoral candidates to develop creativity and resilience skills which will not only help them in their projects but also their future career directions. Each university continues to consider the impacts of the pandemic and has put in place procedures to take account of the impact of COVID during the final PhD assessments with related communications to students.

Since the publication of the 2021 annual report, ReNU's general approach has been to:

- prioritise activities that support individual students' research projects (e.g. laboratory access, supervisory and research group meetings);
- retain online learning for core cohort training (e.g. Cohort 3 induction); and
- facilitate non-compulsory outdoor social events to promote cohort interaction.

This remains the core strategy up to and including March 2022 and we anticipate some form of online training to be retained throughout 2022 and beyond, where appropriate. At the same time we also anticipate a much greater component of in-person interaction at all levels of ReNU as people across the UK return to university campuses and workplaces.

4.2 COVID-19 Response Group

Following the UK national lockdown in March 2020, the ReNU MC established a COVID-19 Response Group composed of the Director, the three Institution Directors, the Centre Manager and the Chair of the Student Experience Delivery Group. After meeting fortnightly throughout the initial stages of the pandemic, this group met monthly up until July 2021. Thereafter, the activity of the group was moved to a standing agenda item at the bi-monthly MC meetings.

4.3 Communications with Doctoral Candidates

The ReNU MC and academic supervisors regularly solicit student feedback to understand the impact of COVID-19 on individual doctoral candidates. It is clear that students value regular informal interactions with academic staff and we will continue these whilst at the same time prioritising access to key facilities for doctoral candidates to complete their projects to a high standard. This includes laboratory access and use of remote computational facilities.

All ReNU students participate in a 1-2-1 meeting with the ReNU Director at the start of their second year of study. These meetings have allowed us to better understand individual student needs. This is in addition to regular informal meetings of student forums chaired by Professor Douglas Halliday who is a Past Chair of the UK Council for Graduate Education (UKGCE) and an author of the recent UKGCE report, *Covid 19 Impact on Assessment of Research Degrees*. ReNU students were able to benefit from this experience via a workshop for doctoral candidates (June 2021) on how they can ensure that their revised projects will still provide sufficient evidence of original research for successful outcomes. This proved very successful with candidates and follow-up workshops are planned. It was noted that a more focused workshop will be required when Cohort 1 students are close to submitting their theses.

4.4 Impacts of COVID-19

The level of COVID-19 impact experienced by students has varied depending on the nature of their research and stage of programme. Projects of an experimental nature and students in Cohorts 1 and 2 experienced the most disruption. Two students (one from Cohort and one from Cohort 2) withdrew from their studies and one student was formally awarded COVID-19 extension from institutional funding allocations. Relative to Cohorts 1 and 2, Cohort 3 has experienced less disruption to their projects

5. Doctoral Candidate Recruitment: Cohort 3

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 2020 with interviews in March 2021. Further rounds of interviews were conducted in the summer of 2021 resulting in a cohort of 16 doctoral candidates enrolling in October 2021.

5.2 Marketing

The ReNU recruitment process prioritised attracting high-quality applicants and direct industry cash contributions to projects. Marketing activities were mostly online due to COVID-19 restrictions.

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 allocation process seeks to balance strategically shaping 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 IDs on behalf of their universities and working as a group for consistency, whilst including the MC step for oversight.

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. The top 8-10 project proposals are taken forward to the MC.
4. The ReNU MC meets to review 26 project proposals and selects 22 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 10 were selected for advert at Northumbria. This increased the studentships at Northumbria from 5 to 8 and 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.
6. Offers are made to the best candidate for each project. If no offer is made, a project is re-advertised.

5.4 Outcome and review

In 2021-22 ReNU recruited 16 students to Cohort 3 who enrolled at one of the three partner institutions on 1st October 2021. Anonymised data was collected for all applications (including ineligible candidates), for statistical analysis including gender, age, ethnicity and disability against EPSRC statistics. These data are shown in Table 1.

Table 1: Recruitment data for ReNU Cohort 3 (2021-22)

Institution	Female Candidates			Minority Candidates			Above 30 Candidates			Total No. of candidates		
	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed	Applied	Shortlisted	Appointed
UNN	41	6	4	136	13	6	50	4	1	152	15	8
DU**	21	6	2	69	14	1	27	3	0	153	24	6
NU	29	4	0	54	4	1	26	3	0	86	12	4
Total	**91**	**16**	**6**	**259**	**31**	**8**	**103**	**10**	**1**	**391**	**51**	**18***

* See section 4.4: 2 candidates withdrew late and could not be re-advertised in time resulting in a cohort of 16.
** 66 applicants had "unknown" for gender, age, ethnicity and disability, hence these were not included but in the total number columns.

ReNU has an aspiration to recruit 33% of any single gender[1] and has achieved this for Cohort 3 for female doctoral candidates. This is consistent with Cohorts 1 and 2 however, ReNU has consistently increased doctoral candidate appointments from minorities from 18% to 44% compared with Cohort 2 which is above the EPSRC average. Note that although ReNU has complied with the UKRI recruitment rules for appointed 30% international candidates, the actual number in Cohort 3 was larger (50%) due to different restrictions for Institution match funded institution and part-industry funded studentships. Overall, Cohort 2 received more applications than for Cohort 1 and in addition to international recruitment, this is attributable to advertising project positions at an earlier stage.

5.5 Balance of projects

Figure 2 shows the balance of ReNU projects across topics in renewable energy. These data reflect increasing diversity of topic and growth in projects associated with renewable energy systems including batteries.

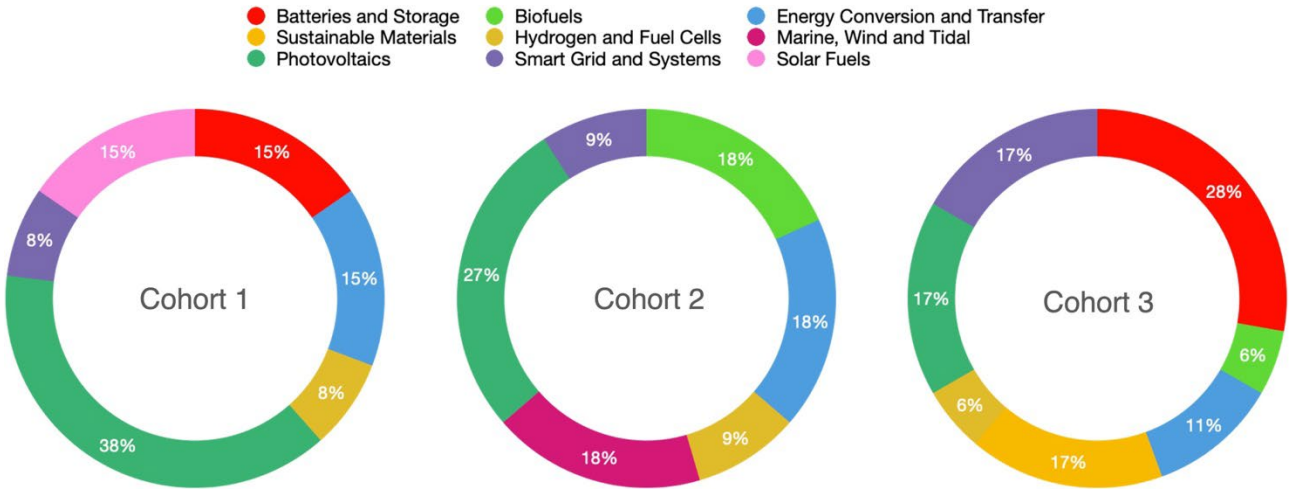


Figure 2: Balance of topics in renewable energy across ReNU projects.

[1] Data from the Higher Education Statistics Agency (HESA) indicates that in 2019/20 41% of undergraduate students studying Physical Sciences were female compared with 18% studying Engineering and Technology. This difference narrows when considering postgraduate research students only where 36% of female students study Physical Sciences and 26% study Engineering and Technology. Aggregating across STEM subjects, this indicates that ReNU's aspiration to recruit doctoral candidates with a minimum of 33% of any single gender is challenging but reasonable.

6. Equality, Diversity and Inclusivity

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. In particular, 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.

For several years now we have been implementing a number of successful EDI policies, including procedures to remove unconscious bias from project selection and the recruitment of doctoral candidates, Mental Health and Unconscious Bias training for both staff and students (provided by the Durham University Counselling Service Team and Northumbria University's NUSTEM programme), Outreach activities and career development opportunities for Early career researchers (through the EPSRC Inclusion Matters Project). This year we also introduced a new EDI element into our training programme, namely the role of energy poverty on social mobility. The training was delivered by National Energy Action, a charity in England, Wales and Northern Ireland that works to eradicate fuel poverty and raise awareness. In response to the EDI challenges highlighted in the recent EPSRC review, we will also create an EDI resource page for ReNU to go live by summer 2022 and are consulting with our student cohorts on the content for this resource.

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 2.

The year 2021/22 saw us welcome the third cohort to the ReNU CDT, bringing the number of ReNU students to nearly 40, as well as the gradual relaxation of COVID restrictions that has characterised the initial stages of the CDT. Throughout all, our aim has been to maximise opportunities for inter- and intra-cohort collaboration and learning, to be responsive to the needs of students, and to add breadth and depth which complements their programme of research. In this section we review the training undertaken this year whilst also highlighting some of the new and developing initiatives within ReNU.

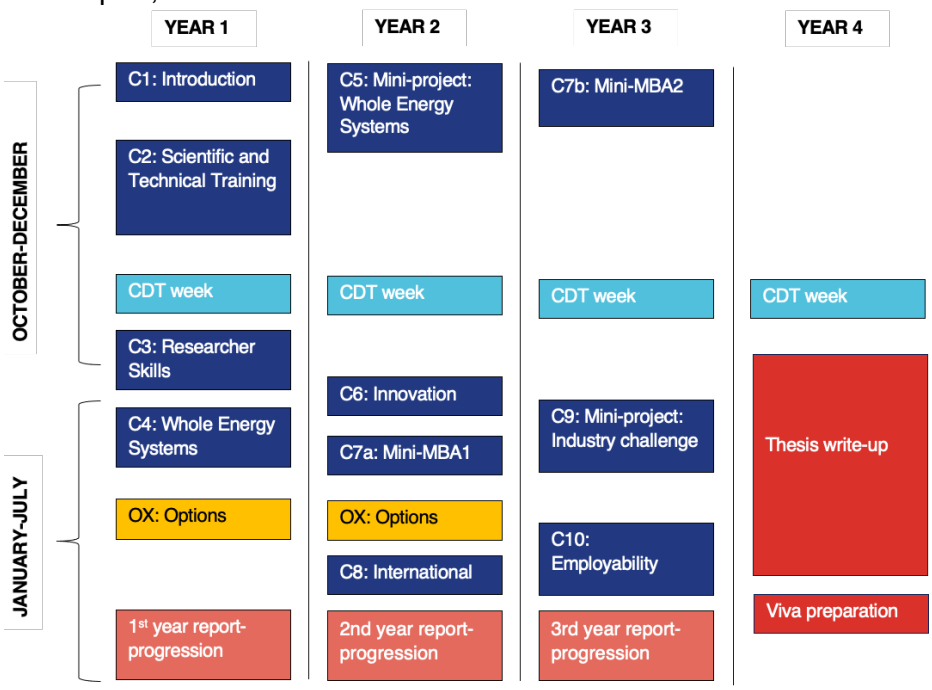


Figure 2: ReNU training programme schematic

7.1 Finding a "new normal"

The end of legal COVID restrictions in the UK marked a significant change to what modes of training are possible as compared to the early life of the CDT. This was both positive and posed a challenge to the university sector generally in finding a balance between in-person teaching, the EDI issues related to those who may be vulnerable, and not losing the benefits that have been uncovered by online working.

Our approach within ReNU was as follows:

- Adhere to national and local regulations related to COVID should they be re-introduced, and likewise, to follow policies of the three partner universities in the event of further restrictions or lockdowns.
- Re-introduce in-person teaching where practicable from Easter 2022.
- Retain the benefits of online learning and communication where this will expand the range of training opportunities offered by ReNU.
- Prioritise optional in-person social events to promote interaction.

For the first time since March 2020, ReNU students met in person to welcome Cohort 3 and at an evening social event both in autumn 2021 and a meeting of all three cohorts is planned for May 2022 at training event and dinner at the Gateshead quayside.

"The first face-to-face event was quite uplifting, seeing and hearing from others in the cohort about their experiences so far."

"Meeting people face-to-face during the site visit. Listening to presentations from cohorts above me was also interesting to see how your PhD develops"

Example of positive feedback, ReNU training 2021

7.2 Leveraging the benefits of online learning

While there is no doubt that ReNU students and staff benefit from in-person meetings, the ReNU MC has striven to preserve and maintain the benefits of online learning. Two

specific examples of this are: (1) the creation of an online industry seminar series with speakers from both the USA and Europe giving valuable talks; and (2) a joint workshop on the conversion of CO_2 to useful products with the University of Calgary's CREATE ME2 postgraduate programme (see section 10).

7.3 Review of modules

Cohort 3 received training in core modules C1 (Induction), C2 (Renewable Energy Fundamentals), C3 (Researcher skills) and C4 (Whole Energy Systems). These modules were delivered online in addition to online social events for cohort integration, due to COVID-19 restrictions. From previous student feedback on C2, the ReNU team understood the importance of making this training more accessible to a wider range of disciplinary backgrounds and research topics. We thus adapted this training and also included a contextual introductory lecture on the Energy Landscape from the ReNU Director. Students' feedback to these changes was overall very positive.

A key objective of the ReNU training programme is to provide students with the broader skills and knowledge required to tackle decarbonisation. Module C3 covers researcher skills and included contribution from a Deputy Editor of the Royal Society of Chemistry journal, *Energy Advances*. Together with sessions on data analysis and data acquisition, these sessions were well received by ReNU students. Even more broadly, ReNU's training programme helps students contextualise their research in the context of the whole energy system with positive feedback.

"Pursuing a project which focused on whole energy systems, I found the content of C4 quite relevant and fascinating. I was most intrigued by the presentation on decarbonisation of heating and cooling industries as this also can be further investigated in my project."

"I most enjoyed lectures on Glaciers and Climate Change and the anthropology and case study lectures."

"The anthropology lectures were such a breath of fresh air and it was great to see how a transition to renewables needs to be broadened to countries beyond the global North. Developing countries and isolated communities also need to be brought into focus."

Students were able to build on their whole energy systems training with a group project (C5) that culminated in a presentation to peers and guests at CDT week in November.

ReNU's training programme also emphasises the importance of entrepreneurship and innovation and these are addressed through a mini-MBA at Durham University and external innovation training by specialists. Both of these involved business and design briefs designed to simulate real-world situations with "Dragon's Den" type pitches to investors and mock client meetings. 2022 also saw the kick-off of ReNU's Industry Challenge mini-project in March 2022 with client briefs generously provided by ReNU's industry partners. For this project, ReNU students work in teams across cohorts with a designated project manager and academic mentor to help navigate the brief and meetings with clients over an intensive 2-week period that is not necessarily related to their individual project.

7.4 Accreditation of ReNU training programme

In late March 2022, the Royal Society of Chemistry and the Institute of Physics performed a joint panel (virtual) visit for an accreditation visit. Our ambition is to become accredited such that ReNU students will be able to apply for *Registered Scientist* status at the end of their second year. Central to this process are mentoring and maintaining a Professional Development Record as well as staff training from the Professional Bodies. The panel

visit was positive and at the time of writing and the ReNU team has submitted their response to the panel's comments.

7.5 Responsible Research and Innovation (RRI)

ReNU's approach to RRI is to train academic supervisors and this is a condition of becoming a ReNU doctoral candidate supervisor. Following this, ReNU now has 23 academic supervisors that formally hold Registered Practitioner status.

Our approach to Responsible Research and Innovation was highlighted by the professional consultancy ORBIT as good practice and in September 2020, ReNU's Director was invited to share ReNU's approach to RRI with all UK CDT Directors and EPSRC in a virtual meeting.

8 Student Experience

The support offered by ReNU for its students and supervisors has continued to evolve as the team seeks to offer a positive and further enhanced experience to all ReNU students. Over the last year, research laboratories and facilities have reopened and candidates have been supported by supervisory teams to adjust to new working practices. Lessons learned from the enforced shift to online working have been incorporated into new working practices with the use of some online meetings offering a good opportunity to engage with the full ReNU cohort across all three institutions. With the admission of the third cohort, the sense of community in ReNU continues to grow with interactions across all three cohorts. Students were positive about the opportunity to interact and learn from those at different stages in their PhD during the intensive CDT Week training activity. Students were particularly positive about the emergence of in-person activities.

The ReNU Student Experience Group has continued to meet regularly four times a year to gather feedback from students, listen to their views and feed this into the planning for ReNU. The focus on the training offered in C2 (scientific and technical training) has been adjusted in response to student feedback to make it more representative of the breadth of PhD projects in ReNU. A concern raised by students was to understand how the pandemic might impact the final assessment of their PhDs. In response, a discussion workshop was organised in June 2021 covering doctoral assessment criteria, exploring what examiners look for in assessing a PhD and the implications for individual PhD projects. In responding to student feedback, the ReNU training program has included more on the societal and anthropological aspects of energy, as part of C3 training. For example, a consideration of energy poverty and anthropological case studies from developing countries which proved to be very popular (see section 7.3) with students who have welcomed the opportunity to develop a broader understanding of the context of the energy challenge, and how their individual research projects might fit into the wider energy landscape. Alongside the C7 "mini-MBA" offered by ReNU through the Durham Business School, this helps students to develop a broad range of high-level energy-related skills and insights in preparation for a career in distributed energy systems. Plans are underway to offer ReNU students further training and support on possible careers related to the scope of ReNU with input from industrial and other partners. The Whole Energy Systems project (C5) and Industrial Challenge Project (C9) give students an opportunity to work in small teams with a range of different expertise, thus furthering their professional employment skills.

At the recent Student Experience meeting, all student reps were positive about the progress on their individual PhD projects and were able to report positive ongoing research activity with their PhD projects, a number are now able to present work at

conferences and be co-authors on papers. The ReNU team continues to build and develop a leading program of training to support the PhD students across the full range of activity in ReNU. This important activity is supported effectively by the ReNU student reps who play a key role in providing input to support the development of the ReNU program.

9 Partners

ReNU continues to strengthen its relationships with existing external partners while also establishing connections to new partners this year. This year, ReNU has seen significant growth in industry-sponsored projects with investments totalling ~£250,000 across a range of areas in renewable energy. This growth reflects ReNU's growing reputation for excellent research that drives impact. In addition, in-kind support from regional, national, and international partners has steadily increased in the last year to over £170,000 from more than 30 industrial partners in a variety of ways including: delivery of ReNU training via specialist lectures and workshops; cohort site visits and training; and access to facilities and laboratory equipment.

In 2021, ReNU achieved significant growth in industry contributions to doctoral candidate projects totalling approximately £250,000 across a broad range of topics in renewable energy. We believe this growth reflects ReNU's growing reputation for scientific excellence and impact.

ReNU's annual CDT Week still plays a key role in connecting the cohorts with industry partners. During this week, students benefit from a wide range of scientific presentations and follow-up conversations as a result of their communications with academics and industrial representatives. As a result of the relatively limited opportunities for networking, CDT Week in November had a stronger focus on doctoral candidate presentations for an academic audience and we anticipate a return to greater industry engagement during an in-person CDT Week in 2022.

In 2022, ReNU surveyed its industry partners on employability skills and outcomes of the survey were fed back to the Training Programme Delivery Group. This valuable feedback from industrial partners helped to shape ReNU training activities to improve the employability of our graduates, increasing the chances of securing high-skill jobs and succeeding in their future careers.

A further exciting development this year has been the launch of the Industry Challenge group mini-project (C9) in March. In this core module, doctoral candidates respond to a client brief set by one of ReNU's partners. We are extremely grateful to our partners for setting these briefs and engaging in client meetings with the ReNU teams which self-determine a Project Manager role and are assigned an academic mentor. Through these and further projects for subsequent cohorts, ReNU students have the opportunity to experience tackling an industrial R&D problem.

10 Internationalisation

Opportunities for international travel in 2021-22 have continued to be severely restricted by the pandemic. However, the indications in early 2022 are that these restrictions are easing and we anticipate travel opportunities both nationally and internationally for ReNU students and academic staff in the second half of 2022. For many ReNU students, the nature of this travel will be to present their results at academic conferences – a key part of developing their profile and networks. These events include for example, the 49th IEEE Photovoltaics Specialists Conference in Philadelphia and the 41 International Conference on Ocean, Offshore and Arctic Engineering in Hamburg.

As well as encouraging ReNU students to attend international conferences where possible (and respecting any individual COVID-19 constraints), we continue to promote submission to online conference and workshops. These have proven valuable throughout the pandemic and facilitate inclusive and sustainable opportunities for attendees.

ReNU's originally planned visit to the Institute for Clean and Renewable Energy at Huazhong University of Science and Technology in Wuhan remains paused indefinitely as a result of COVID restrictions and Cohort 1 students have been supported to seek alternative opportunities. In 2021 ReNU worked with programme partner, the University of Calgary, to jointly host a UK-Canada CO_2 Conversion Research Workshop. This was a collaboration between ReNU and the National Sciences and Engineering Research Council (Canada) Collaborative Research and Training Experience (CREATE) in Materials for Electrochemical Energy Solutions (MEE). This collaboration proved very successful as evidenced by the creation of a joint seminar series. More generally, ReNU has built on partnerships in Canada with the award of a second UKRI UK-Canada Globalink doctoral exchange scheme and a placement in summer 2021 at a Canadian University.

11. Outlook

In summary, 2021/22 has seen significant progress across ReNU, particularly in the context of the challenges and impacts of COVID. Looking ahead, we see continued opportunities for accelerating progress through research and cohort-based learning. Throughout summer 2022, we anticipate a return to international travel for many within ReNU and the opportunity to present their latest results. In October, we welcome Cohort 4 involving new opportunities for in-person activities both within Cohort 4 and across cohorts. In November, we plan a return to an in-person (and augmented by remote joining where practical) CDT Week and associated opportunities for networking. Early 2023 sees the launch of ReNU's last core module: Employability Skills training which Cohort 1 will take to develop skills and experience relating to securing high-skill employment in either industry or the public sector. All of these exciting training events will be augmented by rich discussions with supervisors, mentors, research groups and colleagues and complement many further high-quality scientific publications and presentations.

Appendix 1 – ReNU team

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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

Prof. Guillaume Zoppi - Operations & Finance Chair

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ReNU topics: Earth abundant materials, photovoltaics, transparent electrodes

Dr Budhika Mendis – Equality, Diversity and Inclusion Chair

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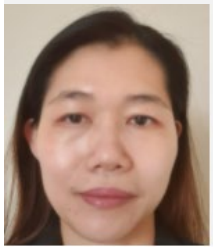
ReNU topics: Molecular and solid state chemistry and metal complexes



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Appendix 2 – List of Publications

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

1. **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, accepted.
2. Ioanna Pallikara, **Prakriti Kayastha**, Jonathan M. Skelton and Lucy D. Whalley, The Physical Significance of Imaginary Phonon Modes in Crystals, *IOP electronic structure*, 2022, accepted.
3. 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, https://doi.org/10.1021/acsaem.1c03247
4. **Elisangela Jesus D'Oliveira,** 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
5. 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
6. 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