

Supergen

Strategic priorities for net zero energy
research – a perspective from
Supergen early career researchers



Authors

Ajit Pillai, Santosh Kumar, Rachael Greenhalgh, Amruta Joshi, Oluwafunmilola Ola, Dan Taylor



Abstract

Given the significance of the United Nations Climate Change Conference (COP26) taking place in Glasgow this year, the Supergen (Sustainable Power Generation and Supply) programme identified COP26 as a crucial opportunity to connect UK energy research to wider climate change, net zero and renewable agendas. The six Supergen Hubs collaborated to deliver the Net Zero Conference (NZC) from 1-3 September 2021, demonstrating the impact of UK energy research in achieving net zero, setting out a vision for a net zero energy future and exploring cross-cutting themes such as internationalisation, industrial partnerships and equality, diversity and inclusion. The NZC opened with the Early Career Researcher (ECR) Forum organised by a cross-Hub group of ECRs, focusing on three overarching topics of greening the economy and society, the future of sustainable transport and securing a global transition to clean energy. This briefing paper summarises the outcomes of the flash talk presentations and discussions presented during the ECR Forum and puts forward the current thinking on challenges and opportunities in achieving net zero, from the perspective of ECRs working within energy research.

Foreword

The vast majority of the UK's academic research is carried out by PhD students and post-doctoral researchers. Their perspective on, and understanding of our energy system, state of knowledge and research needs is incredibly valuable. That perspective is even more valuable when it is able to take a view across the different disciplines and energy technologies. Therefore, it is great to see our early career researchers from different disciplinary and technological backgrounds come together to share and compile their thoughts on what our Supergen energy research programme has achieved and what remains to be done. The futures of our energy systems, our climate and our planet lie with them and it is a great privilege to have worked with them on our Net Zero Conference, which has allowed them to synthesise the position and priorities presented here.

Prof. Patricia Thornley, Director of the Supergen Bioenergy Hub

Prof. Deborah Greaves, Director of the Supergen ORE Hub

Prof. Phil Taylor, Co-Director of the Supergen Energy Networks Hub

Prof. Sara Walker, Co-Director of the Supergen Energy Networks Hub

Prof. Yulong Ding, Director of the Supergen Energy Storage Network+

Prof. Michael Walls, Director of the Supergen SuperSolar Network+

1. Introduction

The Supergen Early Career Researcher (ECR) Forum brought together the energy research community to discuss the challenges of delivering net zero, ahead of the crucial COP26, held in Glasgow in November 2021. Insights on how the UK might mitigate climate change and associated challenges ahead from an energy perspective were highlighted during this cross-Hub ECR session, endeavouring to better inform policy, academia, and industry about the UK's net zero energy future.

1.1 The Supergen programme

Funded by the Engineering and Physical Sciences Research Council (EPSRC), the Supergen programme consists of six Hubs furthering the development of sustainable power generation and supply:

- [Supergen Offshore Renewable Energy \(ORE\) Hub](#)
- [Supergen Bioenergy Hub](#)
- [Hydrogen and Fuel Cell Research \(H2FC\) Supergen Hub](#)
- [Supergen Energy Storage Network+](#)
- [Supergen Energy Networks Hub](#)
- [Supergen SuperSolar Network+](#)

1.2 The Supergen Net Zero Conference

During the conference, the Supergen Hubs showcased their research, as well as held cross-cutting panel discussions on topics such as equality, diversity, and inclusion in energy research, international perspectives on Supergen work, our early career researcher activities, and outlining the policy implications of Supergen research for reaching net zero.

1.3 The ECR Forum

Organised by a cross-Hub group of Supergen ECRs, the ECR Forum was split into three sessions, each beginning with a series of flash-talks followed by a panel discussion. The three sessions covered the topics below, and are the basis of this ECR 'Briefing Paper' on delivering net zero:

- Greening the economy and society
- The future of sustainable transport
- Securing a global transition to clean energy

The following sections summarise the key points delivered and discussed via the flash-talks and panel discussions.

2. Sessions

2.1 Greening the Economy and Society

2.1.1 Introduction

The first session titled '**Greening the Economy and Society**', was chaired by Dr Santosh Kumar (Diamond Light Source/Imperial College London). This session was comprised of four flash talks delivered by Dr Ahmed Gailani (University of Leeds), Dr Joanna Sparks (Aston University), Dr Parimala Shivaprasad (University of Bath), and Dr Kacper Stefaniak (ORE Catapult Ltd). The flash talks were followed by a panel discussion where the presenters were joined by Dr Samuel Perry (University of Southampton) and Dr Evelyn Heylen (Centrica Ltd). Panellists represented a mix of early career professionals from academia, industry and policy.

2.1.2 Flash Talk Summary

The first flash talk presentation by Dr. A. Gailani highlighted the use of a bottom-up models, that although these models are not perfect, they provide a very good approximation which is required to build hydrogen infrastructure. Dr. J. Sparks, a policy research fellow, also emphasised the significance of focused models and their use for effective approximation. She highlighted that if the current use of such models adequately reflected different technological areas, they could provide a solid foundation for policy decision-making, concluding by discussing the role of biomass in the transition to net zero. Dr. P. Shivaprasad, an academic researcher and entrepreneur, discussed her journey from taking her lab work on floral waste to value added chemicals, leaving clean water by designing materials and a scalable reactor. Dr. K. Stefaniak's final flash talk emphasised the importance of strong collaboration with eco-system modellers, because these models are required to define the pathway to net zero, whilst pointing to the role of offshore energy in achieving net zero.

2.1.3 Panel Discussion

A panel discussion moderated by Dr. S. Kumar began shortly after the flash talk presentations, with a brief introduction by each panellist. The answers to key questions highlighted during Session 1 reflect the key points discussed, as well as additional remarks from the authors of this briefing paper.

Question 1 – Is the net zero target ambitious enough, and is the government considering all stakeholders on the path to net zero? How do you see the government's strategy in this regard?

It is debated that the net zero target is not ambitious enough and that it can be achieved more quickly if we actively label the crisis, as a crisis. At the moment, targets are set but no actions are outlined. It's also worth noting that when the Department for Business, Energy, and Industrial Strategy (BEIS) was recently questioned about this, they agreed that we don't have a choice when it comes to achieving net zero. It must be treated as a crisis, and appropriate policies must be put in place. It is understood that government policy is currently slow, especially in the case of carbon capture and storage (CCS), and hydrogen. We must all agree

that it is our responsibility as scientists to give the public the robust scientific data they need, in order to put pressure on the government to act quickly.

Stakeholder engagement is important, but it varies from sector to sector. In recent years, the government has pushed industries by setting up targets and providing funding for research and innovation. Large system change is vital, however individual behaviour also poses a challenge. To reach net zero, we should emphasise the need for individual-level behavioural change and encourage policymakers to collaborate with social scientists and drive societal change.

Question 2 – The government is considering a hydrogen economy, so on the path to net zero, can we develop technology that produces hydrogen using renewables?

It is a positive step that the government has recognised that we cannot rely solely on electricity to achieve net zero. Other contributions, such as offshore energy, bioenergy and hydrogen have an important role to play. In particular, hydrogen has several applications ranging from transportation, the chemical industry and heating, but we need green hydrogen which is currently unaffordable. ECRs recognise the electrolysis process and solar technology as the way forward for green hydrogen production, but there is still much work to be done to achieve scalable and affordable hydrogen production. On the other hand, there is optimism about a breakthrough in green hydrogen production in the near future. One of the most important challenges for hydrogen's widespread use is the safety and skills gap. ECRs advocate for an immediate focus on safety validation, and efforts to reduce the skills gap in order to establish a hydrogen economy.

Question 3 – What areas are most difficult to decarbonise?

The cement industry and solid waste management were highlighted as the most difficult sectors to decarbonise during discussions; however, bioenergy and CCS technologies could be viable solutions in these industries. Biofuels, which use waste as a feedstock, were identified as an extremely important step in the energy transition before electrification. There are concerns that food production and bioenergy crops may compete for limited land space in the UK, however discussions highlighted that bioenergy crops can often grow on land where conditions mean food cannot grow. Discussions concluded that clear government policy and action on land use change is critical for the decarbonisation of particular 'difficult to decarbonise' industries.

Question 4 – Before doing research work, should we think of the sustainability impact?

Panellists discussed that as ECRs, we should try to use experimental design to reduce the number of planned experiments as much as possible, and it was noted that artificial intelligence could play a critical role here. It is also critical to reuse solvents and recycle waste chemicals and plastics. There should also be a requirement for sustainability assessments in proposals, to examine and declare the impact of undertaking research on people and the environment. We should learn from our past experiences and use these experiences to shape the future. For example, the use of dichlorodiphenyltrichloroethane (DDT), an insecticide discovered by Swiss chemist Paul H. Müller, who was awarded the Nobel Prize in Physiology or Medicine (1948) for this discovery, was banned in 1972 due to public outrage over its negative environmental impact. Therefore, sustainability assessments should be mandatory in future research.

Question 5 – What is the role of ECRs in delivering net zero target?

The role of ECRs varies depending on the field of study. Today's ECRs are future leaders and role models for the next generation of researchers, so they have a significant role to play in the journey to net zero. It is critical that ECRs receive the necessary support and motivation to take up new technologies to market, whilst ECRs themselves must think outside of their comfort zones and engage in broad collaboration with industry and policymakers. Unfortunately, many surveys have shown that since Covid-19, ECRs have been hit hardest by the impact of pandemic restrictions. UK Research and Innovation has taken steps to motivate and support ECRs such as the future leadership fellowships, however, more must be done in order to engage ECRs and direct their potential and talent to achieve net zero.

2.2: The Future of Sustainable Transport

2.2.1 Introduction

The second session of the ECR forum was focused on the theme '***The Future of Sustainable Transport***'. The session was chaired by Dr. Hui Luo (Imperial College London) and comprised of three flash talks by Dr Luis Badesa (Imperial College London), Dr Amruta Joshi (University of Birmingham) and Dr Santosh Kumar (Diamond Light Source/Imperial College London). The flash talks were followed by a panel discussion in which the presenters were joined by Dr Yousif Al-Sagheer (University of Birmingham).

The flash talks and panel discussion in this session underlined the importance of different approaches towards sustainable transport employing electricity and hydrogen, as well as active modes of transport such as walking and cycling. Various dimensions for attaining future sustainable transport were discussed including material level studies for solar biofuels, system level integration using vehicle to grid (V2G) technology, as well as life cycle assessment (LCA) methodology for evaluating emission saving potential.

2.2.2 Flash Talk Summary

The different pathways to accomplish sustainable transport in future were elucidated in the flash talks using electric vehicles (EV) with V2G technology by Dr L. Badesa, active transport using e-bikes by Dr A. Joshi and artificial photosynthesis for production of useful chemical or fuels including H₂, syngas and hydrocarbons using biomass or organic waste by Dr S. Kumar. Thus, the flash talks in this session covered wider spectrum of approaches for sustainable transport emphasising criticality of multi-modal transport.

The first flash talk highlighted the supplementary use of EV for grid services in addition to its primary purpose of transport through V2G technology. The demand for infrastructural changes required to address increasing share of EVs along with widespread adaption of renewables in power generation could be handled efficiently by accounting for the uncertainties in travelling patterns. The capability of cost-effective decentralised grid support by EVs obviating the requirements of building assets was presented through outcomes of economic optimisation model. The second flash talk provided glimpses of recognition of active travelling modes for the UK's transport system in the policy frameworks. The emission saving potential of e-bikes for personal and commercial applications in comparison with other vehicles was illustrated through the case-studies, with different daily mileages and various percentage of power assist from batteries of e-bikes using LCA methodology. The third flash talk demonstrated the circular

economy-based approach to synthesize chemical fuels including hydrogen and other low carbon fuels such as methane, carbon monoxide, methanol through artificial photosynthesis. The research efforts for solar biofuels using sustainable materials, probing their characteristics at the atomic level and interfaces were illustrated, with emphasis on a collaborative approach for scaling up the technology.

2.2.3 Panel Discussion

The panel discussion was coordinated by Dr. Hui Luo with brief introductions by panel members about their research areas. Since the panellists were from diverse backgrounds, the discussion covered a range of different net zero technology alternatives for sustainable transport. The panellists provided their views on various approaches for sustainability of future transport, barriers or potential risks in implementation of these approaches as well as how ECRs can contribute to addressing these issues. A brief summary of the panel discussion is presented here.

Question 1 – Is it more beneficial to take multi-vector approach for the decarbonisation of transport, or should we focus on electrification, which requires new infrastructure?

All the panel members unanimously suggested that multi-vector approach is indispensable for decarbonisation of transport. Singular focus on electrification would not be successful in addressing all modes of transport considering electricity infrastructure limitations. Thus, the existing transport network of other fuels can be utilised for hydrogen; however considerable attention must be given to research efforts towards the source of hydrogen and fuel cell technologies. While number of solutions should be considered based on their technology readiness level, a least regret approach employing electrification would be essential considering ‘urgency’ of net zero targets. Also, for any of the technological vectors, LCA determining emission contributions in various phases such as manufacturing, use-phase and end-of-life must be contemplated. It was noted that during LCA studies, the economic aspects or cost-benefits of the technology tend to get more attention than the entire LCA.

Question 2 – What are the different pathways for sustainable transport?

The active modes of transport such as walking and cycling, as well as public modes of transport, will be playing a key role in decarbonising transport; however, they will demand infrastructural support such as the safety of cycle riders. The policy level measures such as the “Cycling and Walking Investment” strategy by UK government were highlighted. However, the new low carbon modes of transport would also need to compete with the incumbent fossil-based solutions; in this case, the high polluting modes should be disincentivised by actions such as implementation of clean air zone. Contrarily, the affordability of transport for vulnerable sections of society must be ensured for fair transition while applying carbon taxes.

Question 3 – What business models are there to incentivise public transport use?

Public transport may be provided with some support, in the form of subsidies to reduce tariffs. Also ‘Mobility as a service’ which cumulatively charges for travel from source A to destination B using number of different modes of transport.

Question 4 – How can hydrogen help the ‘difficult to decarbonise’ sectors, such as aviation and shipping? Are there any barriers?

Hydrogen is considered to be significantly critical technology for aviation, shipping and other heavy-duty vehicles. It is available in different forms such as compressed gas or also liquid organic forms; the important characteristics are volumetric/gravitational energy density deciding space/weight limitations. Also, barriers such as the current status of renewable hydrogen production in terms of efficiency, as well as safety of different hydrogen carriers for transport, were emphasised as critical areas of research. The discussion also highlighted the key factor of the assessment of sustainability across all technological solutions for future transport.

2.3: Securing a Global Transition to Clean Energy

2.3.1 Introduction

The third panel of the Supergen ECR Forum was focused on ‘**Securing a Global Transition to Clean Energy**’. This session, chaired by Dr. Robin Preece from the University of Manchester included flash talks by ECRs from the Supergen community: Dr. Gregory Gregori (Imperial College London), Dr. Stuart Walker (University of Exeter), Dr. Anurag Roy (University of Exeter), Dr. Matyas Daboczi (Imperial College London), and Mr Simon Ighofose (PyroGenesys), who were joined by Dr. Wei He (University of Warwick) for the panel discussion.

Across the flash talks and the panel discussion, the speakers identified that there was no technological silver bullet to ensure the global transition to clean energy and that a variety and range of developments were required to support all renewable energy technologies. The panel identified important research areas that ECRs must consider in order for their research and work to contribute positively to this transition.

2.3.2 Flash Talk Summary

A common theme throughout all the flash talks was the importance of material science and the development of not only novel materials, but sustainable materials that take a systems approach which consider these technological developments as part of the ecosystem. The four flash talk speakers highlighted the importance and impact that novel sustainable materials can have with respect to storage (Dr G. Gregori), tidal energy blades (Dr S. Walker), solar energy and passive cooling (Dr. A Roy), and solar energy (Dr. M. Daboczi). Common challenges with novel materials highlighted by all the speakers included the compromise between cost, efficiency, and sustainability and often displacing a non-sustainable, but low-cost incumbent was a major barrier that all these technologies would face as they simultaneously seek to become more cost effective, efficient, and increase the sustainability of the technology.

Broader themes explored in the flash talks included the importance of geospatial analysis to understand both the temporal and spatial relationships between energy sources and demand centres to improve energy distribution. The importance of the developing technologies that are flexible, and able to adapt to different needs and different use cases, was highlighted by Dr S. Walker during this session. Mr. S. Ighofose presented his work developing flexible technologies and programmes aimed at improving energy independence and energy literacy

in rural communities in Africa. Another important factor raised by the flash talks was the development of systems to inform the wider public and support the adoption of clean energy technologies. The discussion centred around the need for clean technologies to be inclusive, identified that it is vital to use gender-neutral language, as well as employ educational materials that are accessible to all demographics and devices.

2.3.3 Panel Discussion

Following the flash talks, all presenters were joined by Dr. Wei He (University of Warwick) and moderated by Dr. Robin Preece in a panel discussion. Key questions and themes discussed are summarised below.

Question 1 – How do we ensure that decisions being made around net zero are appropriate globally?

In discussing the transition to net-zero and sustainable energy generation, it is easy for researchers in the UK to take a euro-centric view and often focus on solutions that are suitable for the UK and Europe. The panel raised that it was vital to ensure that decisions made surrounding net-zero and the global transition to clean energy appropriately considered the needs of the global population, in particular individuals and communities living in areas with limited resources. Mr. S. Ighofose discussed about his experiences of working in Africa where flexible solutions for different rural communities were required. Simon identified that each rural community was unique and that solutions needed to be flexible in order to cater for the specific needs of different user groups. The discussion here highlighted the importance of optimising the use of local resources and allowing local communities to solve their needs using resources available, while leveraging experience and expertise globally. Tidal energy is a great example where certain locations geographically have a vast potential to exploit tidal resources, but this is very localised. Therefore, it is important that nations and regions that do have these resources exploit them efficiently, while other regions focus on alternate technologies that suit their geography, demand profile, and economic situations.

The panel highlighted the importance of considering the localisation and differences in not only renewable energy resources, but also factors such as population density and energy demand profiles in developing appropriate solutions.

Question 2 – What is the role of large energy companies, such as BP and Shell, in this shift?

Dr. R. Preece led the discussion on the role of major engineering entities such as BP or Shell in the transition given their potentially complimentary experience. It was mentioned that key oil and gas companies such as BP were rebranding and emphasizing their expansion into cleaner technologies. The panel identified that a major barrier for decarbonising specific sectors was the financial perspective, and so ensuring that private industries that are financially motivated are incentivised to drive the transitions towards clean solutions, is vital. Carbon credits and offsetting could be one potential option to enable the transition through financial incentives, and existing large engineering firms are well placed to lobby governments and policy makers in order to establish this. The panel also queried if the major players were in fact necessary for the energy transition and if it might be more effective to support smaller rapidly growing renewable energy specialists, rather than enabling oil companies to extend

into renewable energy solutions. Although established companies are expanding into renewables it is not necessarily these companies that are driving the change or innovation in these spaces.

Question 3 – What do you perceive as the major threats in achieving a transition to net-zero?

The panel closed the session discussing the major threats and dangers to a global transition to clean energy. The discussion was centred around material sustainability and the importance of considering the entire life cycle, especially end of life, to reduce and eliminate e-waste.

The panel identified the following research areas that ECRs and the Supergen community should focus on and urge policymakers to act on, in order to support the transition to net-zero and clean energy:

- The need for sustainable materials that don't compromise technological viability;
- The importance of cost reduction for all renewable energy technologies and the need for mechanisms to adequately promote sustainable solutions such as carbon auditing;
- Developing local solutions for local problems while leveraging global inter-disciplinary expertise; and
- Balancing the compromise between cost, efficiency, and sustainability.

3. Concluding Remarks

The general consensus of the ECR Forum was that the net zero by 2050 target is not ambitious enough. At the moment, goals have been established, but few national plans for action have been developed.

Greening the economy and society: ECRs further recognised the importance of hydrogen as a green economy asset after renewable electricity but advocated for an immediate emphasis on safety validation, and efforts to close the skill gap, in order to establish a hydrogen economy. Social science is important when considering how to incentivise individuals through policy to change their behaviour, whilst acknowledging that wider system change is vital to achieving net zero. A major barrier for decarbonising specific sectors is the financial perspective, and so ensuring that private industries that are financially motivated are incentivised to drive the transitions towards clean solutions, is vital.

The future of sustainable transport: An emphasis on a multi-vector approach towards sustainable transport was highlighted. ECRs reiterated the need for strong policy measures and infrastructure on the active modes of transport such as walking, cycling as well as public modes of transport that could play a key role in decarbonising transport.

Securing a global transition to clean energy: ECRs emphasised the importance of considerations for wider ecosystems, impacted by the availability of up-to-date data to make accurate approximations and define the various pathways to reach net zero. Fundamental research on sustainable materials and technology development could play a bigger role and should be well supported.

The impacts of Covid-19 are not equal, and surveys have shown the ECR community have been hit hardest by the restrictions imposed that have interfered with collaborative work. It is critical that ECRs, who are future leaders and role models for the next generation of scientists, receive the necessary support and motivation to bring new technologies to market and contribute to the net zero target. Policymakers, research organisations, and universities should establish stable platforms and provide extensive support for ECRs following this period of uncertainty. Furthermore, funding bodies must develop a diverse portfolio in order to provide opportunities for all ECRs to participate in collaborative, whole-systems interdisciplinary research activities. Focus on multi-disciplinary research supports and encourages ECRs to collaborate with one another across disciplines, enabling them to go beyond technological niches, and consider the wider implications of their work. From the beginning of their careers, ECRs are in a position to be able to build multi-disciplinary approaches into their research philosophy, if supported to do so.

Within the ECR Forum, the quality of talks and constructive discussions on a wide range of issues (often beyond an ECR's core area of research or focus), indicated that ECRs are ready to play a bigger role in the net zero journey.

4. Authors

The authors of this briefing paper who represent various Supergen Hubs, are also the organisers of the ECR Forum at the Net Zero Conference.

Dr Santosh Kumar

Diamond Light Source, Harwell Campus, Oxfordshire, Didcot OX11 0QX, United Kingdom

Department of Chemical Engineering, Imperial College London, London, SW7 2AZ, United Kingdom

E-mail: santosh.kumar@diamond.ac.uk or santosh.kumar@imperial.ac.uk

Dr Ajit Pillai

Renewable Energy Group, College of Engineering, Mathematics, and Physical Sciences, University of Exeter TR10 9FE, United Kingdom

E-mail: a.pillai@exeter.ac.uk

Ms Rachael Greenhalgh

Centre of Renewable Energy Systems and Technology (CREST), Loughborough University LE11 3TU United Kingdom

E-mail: r.c.greenhalgh@lboro.ac.uk

Dr Amruta Joshi

Energy Systems and Policy Analysis Group, School of Chemical Engineering, College of Engineering and Physical Sciences, University of Birmingham, B15 2TT, United Kingdom

E-mail: a.p.joshi@bham.ac.uk

Dr Oluwafunmilola Ola

Advanced Materials Research Group, Department of Mechanical, Materials and Manufacturing Engineering, University of Nottingham, NG7 2RD, United Kingdom

Email: oluwafunmilola.ola1@nottingham.ac.uk

Mr Dan Taylor

Supergen Bioenergy Hub, Energy and Bioproducts Research Institute, Aston University, B4 7ET, United Kingdom

5. Speaker and Panellist Information

Thank you to all of the organising teams, speakers, panellists, and participants for making the Supergen Net Zero Conference an engaging and interactive platform for exploring the role of energy research in delivering net zero.

The list of speakers, panellist and chair for all sessions are given below.

Session 1

Santosh Kumar (Chair) (Diamond Light Source/Imperial College London)

Ahmed Gailani (University of Leeds)

Joanna Sparks (Aston University)

Parimala Shivaprasad (University of Bath)

Evelyn Heylen (Centrica)

Samuel Perry (University of Southampton)

Kacper Stefaniak (ORE Catapult)

Session 2

Hui Luo (Chair) (Imperial College London)

Luis Badesa (Imperial College London)

Amruta Joshi (University of Birmingham)

Santosh Kumar (Diamond Light Source/Imperial College London)

Yousif Al-Sagheer (University of Birmingham)

Session 3

Robin Preece (Chair) (University of Manchester)

Gregory Gregori (Imperial College London)

Stuart Walker (University of Exeter)

Anurag Roy (University of Exeter)

Matyas Daboczi (Imperial College London)

Wei He (University of Warwick)

Simon Ighofose (PyroGenesys)