



Introduction

In the transition towards Net-Zero, there is significant interest in phasing out fossil fuels as both the energy source and precursors in the chemical sector. With a circular economy mindset, one attractive solution is getting the fossil fuel alternatives from the accumulated waste stream, such as biomass from food and agriculture waste, plastic waste and industrial pollutant water waste. Electrochemical conversion has emerged as a promising approach over the years for such application, due to its highly efficient process and low carbon emission when coupled with renewable electricity. The limitation currently is the design of efficient and stable catalyst materials, and the scaling up feasibility. Therefore, this original, multi-disciplinary research workshop aims to bring together researchers to share their cutting-edge discoveries on replacing petroleum feedstocks with waste materials in energy and chemical production.

This research topic on waste upcycling for energy and chemical production is highly aligned with Surrey's Research and Innovation strategy on sustainability. It is closely linked to the research activities within the Institute for Sustainability, especially the programme of "Energy and Environment" and "Plastics in a Circular Economy". At the national scale, this topic aligns with UKRI's vision for a greener future, and the UK's net-zero research framework. It will be linked to a few national wide networks for a broader impact, such as UKRI Interdisciplinary

Centre for Circular Chemical Economy, Supergen Energy Storage Network⁺, Supergen Bioenergy Network and UK-HyRes.

Event Aims

The event was designed to facilitate communications of multidisciplinary research in the areas of energy conversion and circular economy. The objectives include:

1. Enable participants to understand other aspects in this research theme that are outside of their main research expertise.
2. Simulate discussions among participants that would lead to innovative collaborations and further funding for cross-disciplinary research.
3. Showcase Surrey's academic excellence, forge strong connections with other world-leading institutes.

Organising Team

The workshop was organised by Dr Hui Luo, who oversaw the planning, scheduling of the workshop and inviting guest speakers. Dr Luo is a Surrey Future Fellow from School of Mechanical Engineering Sciences, and a Fellow of the Institute for Sustainability. Her research interests include developing and up-scaling efficient electrolysis and chemical recycling technologies to convert biomass and plastic wastes into green hydrogen and high-value commodity chemicals. Working on such interdisciplinary research, she identified the need to bring different expertise and voices together to solve the grant challenge faced by our climate, and hence designed the workshop. With the UGPN Research Collaboration Fund she won in 2023, she was also able to invite partners from University of Sao Paulo to share their cutting-edge research on biomass valorisation.

The workshop is also co-organised by Ms. Ellie Wang from School of Mechanical Engineering Sciences, who was in charge of event logistics and financial budgeting, and supported by Ms. Louise Jones from IAS.



Event Themes

The workshop started by a welcome note from Professor Jin Xuan, Associated Dean of Research & Innovation from Faculty of Engineering and Physical Sciences. He addressed the importance of untied efforts in building a Net-Zero Circular Economy. Following this, 11 talks are scheduled throughout the day in four sessions focusing the following main themes: Green Hydrogen Production and Utilisation, Biomass Valorisation, CO₂ Capture, Storage and Utilisation, Theoretical and Fundamental Insights.

Green Hydrogen Production and Utilisation

Professor Germano Tremiliosi-Filho from University of Sao Paulo provided a general overview of the hydrogen market in Brazil and the work they lead on electrochemical biomass reforming for maximising H₂ production.

Dr Bahman Horri from University of Surrey introduced their recently patented a hybrid water-splitting process, the so-called SurreyH₂ technology, for sustainable hydrogen production by combining the thermochemical and electrochemical routes.

Professor Joelma Perez from University of Sao Paulo provided a summary of deep understanding of the reactions involved in noble metals nanocatalysts for fuel cell anodes, using advanced techniques combining online electrochemical mass spectrometry (OLEMS), ion chromatography (IC), and high-performance liquid chromatography (HPLC). And the insights received may facilitate the catalyst use as a source for energy storage and conversion.

Biomass Valorisation

Professor Magda Titirici from Imperial College London introduced her pioneer research on biomass hydrothermal carbonisation to produce advanced carbon materials for battery and electrocatalysis, as well as using biomass to produce green hydrogen and high-value biochemicals.

Professor Jhuma Sadhukhan from University of Surrey gave an overview of the multi-level assessment of biorefinery, and stressed the need for a country-wide bioeconomy plan to optimise renewable and bio-based resources (biomass) to produce products from food and pharmaceuticals through consumer chemicals to biofuel and bioenergy.

CO₂ Capture, Storage and Utilisation

Professor Edson A. Ticianelli from University of Sao Paulo introduced a number of electrochemical processes investigated in our group, including (i) reduction of protons or water for hydrogen generation and water oxidation for oxygen production in water electrolyzers; (ii) reduction of oxygen for electrical energy production from hydrogen in fuel cells; (iii) reduction of carbon dioxide, mostly aimed to syngas syntheses.

Dr Melis Duyar from University of Surrey gave an overview of the essential role of CO₂ capture and utilisation in decarbonising all sectors to reach a net zero emission future. She discussed approaches to develop novel adsorbent materials for CO₂ capture, catalytic materials for the production of sustainable chemicals and present strategies to effectively combine these approaches to yield an integrated CCU system.

Dr Lei Xing from University of Surrey presented the advent of machine learning and AI has for the promise of digitalising the CO₂ capture and utilisation processes and systems. Through the amalgamation of data-driven and physics-based modelling, alongside the integration of AI-based adaptive control strategies, there is a substantial enhancement in the efficiency and performance of these processes.

Theoretical and Fundamental Insights

Professor Hamilton Varela from University of Sao Paulo introduced his work on characterizing kinetic instabilities in electrochemical reactions, and demonstrated how fundamental studies of such dynamics can inform and improve the electrocatalysis of small organic molecule oxidation.

Dr Santosh Kumar from Diamond Light Source illustrated how soft X-ray spectroscopies (including X-ray photoelectron spectroscopy (XPS) and Near-edge X-ray absorption fine structure (NEXAFS)) at B07 beamline are powerful element selective techniques that help understand the electronic and geometric structure of (photo)electrocatalysts under operating conditions.

Professor Georg Kastlunger described how the combination of constant-potential DFT approaches and transition state theory-based considerations allow us to explicitly study the potential, pH and electrolyte dependence of multistep reaction networks relevant for the green transition. Further, he discussed general trends in the kinetic characteristics of the competing elementary reactions in electrocatalytic reductions and their consequences on the potential and pH response of the product selectivity.

The workshop was concluded by a closing remark by Dr Luo, thanking all the speakers and participants, as well as encouraging all attendees to stay in touch for future collaborations.

Delegate Feedback

The reception of the workshop was extremely positive, with delegates commending the organising and theme of the event:

“It was lovely meeting many old and new faces, and new collaborations. Thank you for the invitation and wonderful hospitality.”

“It was so much fun to be part of this workshop. Thank you for the perfect organising and the opportunity to connect with others in the field.”

“I learnt many new techniques that are very beneficial for my PhD study, I will for sure explore the chances to use them.”



Next steps & Outcomes

The workshop stimulated many discussions around shared interests, and this has already facilitated activities beyond the workshop itself:

- The introduction of B07 beamline at Diamond Light Source raised good interests among researchers on catalysis. Joint beamtime proposals are currently being developed to apply in the next call in Sep 2024.
- The importance of combining experimental studies with theoretical modelling is also well received, and researchers from University of Surrey, Technical University of Denmark and Diamond Light Source are planning to combine efforts in revealing fundamental mechanisms in catalysis. Collaboration projects are currently under discussion.
- This workshop concludes Dr Luo's UGPN Research Collaboration Fund with University of Sao Paulo, but the fruitful results from the binary visits will be shaped into a scientific publication on plastic electrolysis, from there a bigger grant proposal will

be developed in the near future targeting UK-Brazil partnerships, such as EPSRC-FAPESP joint research grant.

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Finally, this event would not have been possible without the fabulous invited speakers, therefore the final acknowledgement goes to all the speakers for their attendance and sharing their excellent research in Sustainable Energy and Chemical Conversion.