NICER ECR Summer School - Abstracts

CE-HUB
UKRI National Interdisciplinary Circular Economy Research

NICER PROGRAMME

University of Exeter

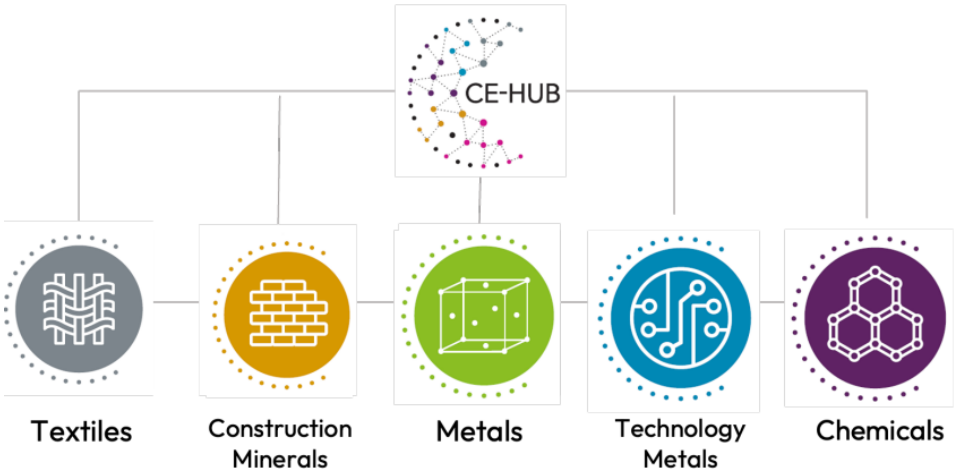
UK Research and Innovation

Contents

About the National Interdisciplinary Circular Economy Research Programme

The National Interdisciplinary Circular Economy Research (NICER) programme is a £30 million four-year investment from UKRI and the Department for Environment, Food & Rural Affairs (DEFRA) to deliver the research, innovation and evidence base needed to move the UK towards a circular economy. Launched in January 2021 and comprising initially of 34 universities and over 150 industrial partners, NICER is made up of five Circular Economy Research Centres each focused on a specialty material flow, and the coordinating CE-Hub:

- The National Interdisciplinary Circular Economy Research Hub (CE-Hub), led by the University of Exeter
- The Textiles Circularity Centre (TCC), led by the Royal College of Art
- The Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials (ICEC-MCM), led by University College London
- The National Interdisciplinary Centre for the Circular Chemical Economy (CircularChem), led by Surrey University
- The Interdisciplinary Circular Economy Centre for Technology Metals (Met4Tech), led by the University of Exeter
- The Interdisciplinary Centre for Circular Metals (CircularMetal), led by Brunel University London



NICER is the largest and most comprehensive research investment in the UK Circular Economy to date. It has been delivered in partnership with industrial organisations from across sectors and DEFRA to ensure research outcomes contribute to the delivery of industrial implementation and government policy. A core aim of the programme is growing the Circular Economy community through a significant programme of outreach and collaboration.

NICER ECR Summer School 2024 – Abstracts

Group 1

Beyond Crack Detection: Non-destructive methods for Early-Stage Fatigue damage detection

Author: Maryam Izadi

Most of the metal's failure happens because of the fatigue which is associated with metal that is subjected to cyclic loading over time. Fatigue damage detection is one of important technological issues in both academic and industrial fields. Early fatigue damage detection promotes circular economy and sustainability by prolonging the lifespan and durability of metals. In most metal, in low and high cycle fatigue, the stages of fatigue are pre-crack nucleation, crack nucleation, micro and macro crack growth, and final failure.

Several techniques have been proposed and developed for detecting fatigue damage in metals. However, comparatively less attention has been given to early fatigue damage detection, specifically targeting the pre-crack nucleation stage. The pre-crack nucleation stage begins with an increase in dislocation density, followed by the formation of dislocation entanglements and, ultimately, the development of slip bands. Subsequently, these slip bands induce intrusion and extrusion, serving as nucleation sites for cracks. The identification of these defects plays an important role as it can facilitate the use of appropriate treatment to either eliminate or mitigate the defects, consequently leading to increase in metals lifespan.

The use of non-destructive methods (NDT) is particularly crucial in this context, given their wide applicability within industrial environments. NDT techniques enable the detection of fatigue damage without destruction of specimen. Techniques such as electrical resistivity and nonlinear ultrasonic testing are employed to detect these defects. The electrical resistivity method operates on the principles of Ohm's law, whereby a current is applied to the metal and the resulting voltage drop is measured to determine the metal's electrical resistivity.

Structural defects including dislocations, entanglements, slip bands, and cracks contribute to scattering and elevation in electrical resistivity. However, to make this method work effectively, we need a sensitive technique with the capability of nano-ohm resolution. The used method is a combination of delta mode and four-probe technique that effectively eliminates thermoelectric voltages resulting from temperature variations in the circuit and minimizes the impact of lead resistance.

Another approach that had been used in this work is nonlinear ultrasonic. In this technique, a wave is propagated through the metal specimen, and upon interaction with defects, higher frequency waves are generated. By detecting and analysing these signals, the presence of defects can be identified. This unique capability enables the detection of early fatigue defects such as dislocations and slip bands, providing enhanced sensitivity and

precision in defect identification. The preliminary findings indicate that both electrical resistivity and nonlinear ultrasonic testing proficiently detect early-stage fatigue defects in metals.

These methods reveal significant changes in three distinct regions prior to 20% of the component's fatigue life. The first drastic change occurring around 0.04% of fatigue life, indicating that even a few cyclic loadings induce a notable change in metal nonlinear parameter and electrical resistivity measurement. This change was confirmed by destructive methods, attributing it to an increase in dislocation density, which further validates the effectiveness of these techniques in identifying early fatigue-induced damage.

Closed-loop and chromium-free leather for the circular economy through refining sustainably available plant food waste

Author: Friedemann Schaber

Currently, 80% (1700 km2) of global leather manufacture is tanned with chromium (III) salts, which are not renewable and problematic to recover at end-of-life (Covington 2007). Commercial vegetable tanning agents are extracted from cultivated stocks, which are insufficient to replace the current consumption of chromium (III) salts. Further expansion of existing plantations is not a sustainable method to generate sufficient tannin extracts to meet current demands. Therefore, alternative bio-based waste sources are required to effectively reuse resources and reduce the need for new fossil-based inputs and reduce the environmental footprint of leather manufacture.

Literature supports the presence of tannins in coffee waste. Low et al (2015) and Bhoite et al (2013) confirm the presence of both condensed and hydrolysable tannins with C13 NMR and MS data. This observation can be extended to many waste streams in the food and beverage sector. Underpinning tanning application has been demonstrated through trials by Baskar at ICLT, which shows the extracted coffee waste replaces conventional veg tannins which includes both tanning and retanning stages. Typical concentrations of tannins required to fully tan are more than 30% of the hide weight, therefore, the use of waste sources has the potential to replace a significant quantity of leather processing chemicals.

Currently at TRL 3, the project aim is to develop a scalable leather manufacturing process with tannins extracted from food and beverage wastes thus replacing Cr and plantation crop tanning agents.

Rationalisation of steel grades and specifications

Author: Sadegh Jalalian

This study introduces a multi-step approach to classification of steel grades with a primary motivation to facilitate reducing the existing number of grades and enhancing recyclability. The relationship between chemical composition and mechanical properties are investigated initially for the case of carbon and stainless steels using the artificial neural network technique.

In addition, the examined group of steels are classified into four distinct subgroups based on their properties, by using the Principal Component Analysis (PCA) and k-means clustering methods. Moreover, we utilise the Shapley Additive Explanations (SHAP) method to identify the most influential features within each group. Finally, we outline an algorithmic method of reclassification that can be applied to steel grades, as well as any other datasets, where the aim is to minimise the number of classes while maintaining the coverage of the property space.

Digital Platform

Author: Linh Truong

Construction is one of the most significant industries that are responsible for the huge extraction of raw materials - 30% of all worldwide – and 40% of energy and process related emissions, including 11% of global greenhouse gases. In addition, during operation and demolition, construction generates about 25% of all waste worldwide along with emitting potentially harmful substances that can lead to drinking water pollution (40%), air pollution (30%) and biodiversity loss.

Recent research has identified barriers and challenges in adopting sustainable constructions in respect of the role of stakeholders, managerial aspects, and technological factors. One of the main challenges is how to promote secondary construction materials and reduce demolition waste at the same time. Many current studies cite digital platforms as an enabler for circular economy and sustainability, by advancing novel solutions based on trust, transparency, visibility, connectivity, security, traceability, and automation. In Industry 4.0, such innovative technologies, for example, BIM, Digital Twin, or AI, are becoming more popular in construction. However, both theoretical and practical implications of digital platforms for circular secondary construction materials are still at an early stage in their development.

There is a need for research which takes a systematic approach to understanding the needs of multiple participating actors for circular material adoption in the construction industry. This research presents the results of multiple stakeholders interviews using AI capture and natural language processing (NLP) for topic modelling. The aim is to propose a conceptual model for digital platform applications for secondary construction materials and a framework to implement successful digital platforms in the future, in this complex setting.

AI-Fixer: AI-assisted consumer electronics repair towards a digital circular economy

Author: Nazli Terzioglu

Electronic waste is a serious global issue that requires an urgent response involving all relevant actors at different levels of the supply chain. Projections indicate that worldwide e-waste will surge from 58 million metric tons in 2021 to 75 Mt by 2030, and further to 112 Mt by 2050 (Forti et al., 2020; Parajuly et al.,2019). These figures underscore the need for circular solutions in the management and lifecycle of electronics. Furthermore, the current economic and marketing dynamics often make replacement seem more appealing than repair (Sonego et al., 2022; Terzioglu et al., 2015; VandenBerge et al., 2023).

To disrupt the current system, the number of legislations such as the new Circular Economy Action Plan (2020), and grass-roots activities such as Right to Repair, Repair Cafes, ifixit.com that promote repairability are growing. Ai-fixer aims to inform and assist national and global activities to address the e-waste problem by stimulating citizen-driven repair to support real change in industrial practices and user behaviour.

We propose a framework for an AI-based tool that guides users through maintaining and repairing consumer electronics using AI-driven design. This tool replaces traditional, underutilised repair manuals with an interactive, user-friendly interface, providing detailed assembly, disassembly, and repair instructions tailored to each product. This approach not only makes the repair process more accessible and manageable for users but also positions businesses as promoters of circular economy.

During the scoping phase, we reviewed the related literature and established a set of criteria for selecting both the product and the repair task. A mobile phone and changing its battery are selected for a case study. We developed a detailed, step-by-step repair framework for the identified product and task. This framework is converted into an initial version of the tool, AI-Fixer. We will conduct co-design workshops with potential users in August 2024 to validate and improve the functionality of the AI-Fixer.

A key aspect of our vision is to scale up citizen-driven repair towards a circular economy. AI-Fixer not only encourages individual action but also has the potential to influence collective behaviour, leading to a community-oriented approach to electronics sustainability. The project empowers communities by providing them with the tools and knowledge to carry out repairs independently. This empowerment fosters a sense of agency among users, making them active participants in environmental stewardship rather than passive consumers.

Effectiveness of Circular Economy Principles on UK Food Waste

Authors: Mutala Fuseini1*, Vasco Sanchez Rodrigues2 , Laura Purvis3 , Maneesh Kumar4, Renukaben Vyas5

Purpose

This research examines the role of circular economy (CE) principles in addressing food waste. An estimated 10.7 million tonnes of food is wasted in the UK alone in 2021, this has

a value of over £21.8 billion annually and the edible parts of the generated waste associates with 18 million tonnes of greenhouse gas (GHG) emissions, hence a key priority to reduce food waste (WRAP 2023). CE principles aim to eliminate waste and pollution, maximise resource use, and regenerate nature, offering a potential solution to economic, social, and environmental consequences caused by food waste (Ellen MacArthur Foundation 2019). This research investigates the effectiveness of circular economy principles in reducing food waste in the UK food sector.

Research Approach

The study used qualitative data and interview methodology to explore food sector experts' experiences and understanding of CE and food waste. Data were collected through interviews with 11 industry experts and secondary sources included public databases, business reports, and governmental reports.

Findings and Originality

The interviews revealed a lack of awareness and understanding of food waste and circular economy principles among businesses in the food industry, leading to prioritisation of other challenges such as financial constraints. However, large businesses demonstrate good awareness and involvement in food waste management. Collaboration, technology, and supportive policies are identified as key enablers, but limited resources, lack of technology, and lack of collaboration hinder adoption of CE principles. These findings provide unique insights into the enablers and the challenges faced by businesses in implementing CE practices to address food waste.

Research Impact

This research fills gaps in circular economy and food waste literature, providing industry solutions and emphasising the role of awareness, collaboration, technology, and policies in driving positive change. The findings impact policymakers, businesses, and industry associations aiming to promote circular economy and reduce food waste.

Practical Impact

The study highlights the need for technology in the food supply chain for a circular economy. It helps businesses identify key technologies for effective implementation of circular economy principles for reducing food waste in the UK food industry.

Keywords

Circular Economy Principles, Food Waste, UK Food Sector, Enablers, Barriers

Circular Economy Transitions in Resource-rich Regions

Author: Konstantin Born

The accelerating global transition towards net zero carbon economies is intensifying the demand for critical minerals essential for clean energy technologies, such as electric vehicles and renewable energy infrastructure. This shift necessitates a re-evaluation of the mining and metals sector, which is currently under pressure to meet escalating material requirements. Despite efforts in recycling and secondary sources, the substantial reliance on primary mineral extraction persists, exacerbating environmental and socio-economic challenges. My project critically examines this reliance through the lens of economic geography. It investigates the impacts of the energy transition's material intensity on resource use, socio-environmental effects, and the integration of circular economy (CE) principles in the mining sector.

The research addresses the pressing need for a paradigm shift from linear to circular mineral production systems, proposing a system-level approach to mitigate adverse effects such as biodiversity loss, land degradation, and unequal development. It highlights the importance of spatial configurations and local economic linkages in fostering sustainability transitions in resource-rich regions, extending the application of economic geography to the understudied area of mineral extraction. The study underscores the complexity of transitioning towards material-efficient, net zero carbon economies, emphasising that current linear models are unsustainable for a decarbonised future.

The project is structured around two distinct studies. The first study employs a novel dynamic probabilistic material flow analysis (MFA) model to assess the potential of end-of-life (EoL) recycling in meeting future copper demand. The findings reveal that, even under optimistic scenarios, recycling alone cannot fulfil the expected demand, highlighting the necessity of integrating CE strategies into primary production systems. The second study explores the spatial dynamics critical for adopting CE practices, using Northern Chile's mining regions as a case study. It examines how existing production linkages influence the adoption of CE practices and argues for including geographic considerations in CE conceptual frameworks.

The project emphasises the need for context-sensitive investigations into the spatial dynamics of sustainability transitions, particularly in regions dominated by resource extraction. The findings call for increased efforts to transition towards circular modes of mineral extraction, recognising the limitations of current recycling strategies and the importance of tailored solutions for different geographies. It also serves as a call to action for the mining industry and policymakers to embrace CE principles, balancing the need for primary resource extraction with environmental and social responsibility to support the global energy transition.

Quantifying the impact of potential policy interventions on the circular economy of timber in the UK

Author: Chi Zhang

Due to a growing demand for timber products and worries about the sustainability of timber systems, there's an urgent need for suitable policies that regulate resource use and waste management within these systems. This research aims to employ material flow analysis (MFA) to provide a thorough examination of timber stocks & flows in the UK, over the whole life cycle, from growth and harvesting of trees, to waste generation, recycling, recovery and disposal, and use this as a basis for proposing and quantifying the impacts of potential policies to inform decision-making for a sustainable and circular timber sector.

The research is organized into several stages, beginning with a literature review that explores MFA, the circular economy, and the timber system. Following this, an MFA of the UK timber system is conducted, using data from multiple sources to offer insights into the current state of the sector and identify potential areas for improvement. After that, this study will summarise existing UK timber circular economy policies with relevant policies from other parts of the world, to explore the possible upgrading of UK policies. At the same time, this study will also summarise existing approaches to modeling policy scenarios to optimize the ability of future scenarios to reflect policy impacts. After that, scenario modeling of the policies will assess their impacts on the UK timber life cycle and environment. Moreover, the greenhouse gas (GHG) emissions of different flows in different scenarios will be estimated with energy consumption and transport.

The study also discusses research gaps, limitations, and areas for future improvement, as well as the potential implications of the research findings for development of policy to regulate resource and waste management in the timber sector. The findings of this research have the potential to inform future research and policy development for sustainable management of timber.

Group 2

Impact of mineral-based construction materials on soil multifunctionality and provision of ecosystem services

Author: Angeliki Kourmouli

Over half of the world's population live currently in urban areas with future estimates reaching up to 68% by 2050, with an additional 1.2 million km^2 land to be converted to urban areas by 2030[1]. Poor practice or malpractice in the construction industry, lack of established process and lack of practitioners to undertake surveys assessing soils health prior to a development, as well as laws and policies loopholes, are key factors influencing soil loss during construction. Over 90% of the soil coming from construction sites is considered inert, however, millions of tonnes of soils are being disposed of in landfill[2].

Urban soils are often overlooked but they play a major role in human lives as the loss of soil functions can have deleterious consequences (e.g. loss of soil's water infiltration function

can cause increase flooding risk) and huge financial repercussions. Construction impacts soil health and functionality, due to soil loss, compaction, sealing, contamination, reductions in soil carbon, and soil biodiversity loss. The current approach for assessing the effects of a development on land and soil is restricted to the protection of biomass soil function for food, fibre and timber production[3]. Other soil functions that are important in local and national context (such as the hydrological function), as well as in the global context (eg. carbon storage and soil biodiversity), of maintaining healthy ecosystems and mitigating climate change, are completely ignored.

The aims of this study are to assess the impact of three major mineral-based construction materials (concrete, brick and plasterboard) on:

1. soil multifunctionality and ecosystem services under future climate events,
2. plant germination, growth and establishment

To address the first aim, mineral-based construction materials (concrete, brick and plasterboard) were added in seven different concentrations (0, 5, 10, 20, 30, 40 and 50%) to soil. The soils were kept in 25°C in three different soil moisture contents (10, 25 and 50%) and were incubated for 5 months. Measurements of six soil physical and chemical properties as well as four microbial traits took place at the beginning and at the end of the experiment. For addressing the second aim, mixtures of the aforementioned mineral-based construction materials were added in three different concentrations (10, 15 and 20%) to pots and two different plant species were used. The plants were grown in greenhouse conditions for 11 weeks. Both above and belowground biomass were measured as well root architecture and traits.

Although the experiments are not yet completed, interesting patterns and differences across the different treatments have been observed with significant increases in pH, depletion of soil bioavailable nitrogen, as well as stunted plant and root growth.
Our results will shed light to the impacts of mineral-based construction materials on soils multifunctionality, provision of ecosystem services and plant growth. Our findings will assist in changing the business-as-usual soil handling from the construction sector, as well as informing policy and regulatory changes in the UK, introducing greater circularity of soils arising from construction.

References

[1] https://www.worldbank.org/en/topic/urbandevelopment/overview.
[2] Defra (2021) ENV23 - UK statistics on waste data.
[3] IEMA (2022) – A new perspective on land and soil environmental impact assessment

Understanding Bactericidal Mechanisms using Molecular Dynamis Simulations

Author: Caaisha Warsame

The reduction of bacterial transmission is of great importance as it can lead to sever health problems. Bacterial growth and transmission are commonly found in public settings such as transports, health care, offices and door handle due to these surface materials having no inherent or insufficient antibacterial properties. Many studies have been put forward since to understand, reduce and resolve the matter and suggested that natural antibacterial materials such as copper (Cu), silver (Ag) and zinc (Zn) have high antibacterial properties, it

can kill harmful bacteria rapidly (within 2 hours or less) and copper is known to be a great metal coating.

As such, a growing volume experimental studies of bacteria on these metal surfaces have been put forward and reported that the bactericidal activities are mostly cause by the release of ions, affecting the integrity of the membrane and/or the bacterial wall, produce intracellular oxidative stress and are genotoxic, resulting in the death of microorganisms. Although, these studies provide an overall valuable insight on the bactericidal of these metal surfaces, however it is uncertain on what it is happening in a molecular scale to the bacterial structures when in contact with Cu, Ag and Zn metals. Such limited knowledge lies on what initial interaction between bacterial structures and the metal surfaces caused a release of metal ions, how is the integrity of the membrane and/or the bacterial wall affected and when is the oxidative stress generated. Here, in this proposed research on presenting a case study on Cu, Ag and Zn to provide an improved understanding of the bactericidal mechanisms using molecular dynamics simulations can unfold crucial knowledge surrounding the interaction between bacteria and these metals.

Characterisation of solar PV waste – progress in standardising a ‘recyclability index’ for crystalline silicon PV panels.

Author: Matt Burnell

The UK has witnessed a significant increase in solar deployment since 2010, with a cumulative capacity of over 15 Gigawatts (GW) installed by 2024. This equates to over 60 million solar panels now in operation in the UK, or 120,000 tonnes of waste, the majority of which (95%) is crystalline silicon (c-Si).

In 2023, the UK government announced ambitions to increase solar deployment fivefold by 2035. This strategy includes revamping and repowering more efficient solar assets, adding to the exponential growth of PV waste earlier than expected. Therefore, there is an urgent need for the UK to develop the necessary infrastructure and processes to handle large quantities of PV waste.

PV panels contain embedded Critical Raw Materials (CRMs) listed as “high criticality”, including gallium, indium, tellurium, & tin; and other rare metals such as aluminium, copper, germanium, gold, iodine, molybdenum, selenium, steel, and zinc. PV waste also contains embedded materials considered toxic to the environment, such as antimony in PV glass, lead in the solder in electrical ribbons, and fluorine released when PV backsheets are incinerated.

The exact quantities and chemical composition details of various PV waste materials remain unknown, and manufacturers are unwilling to release this information voluntarily due to ‘commercial sensitivity'. This presents a challenge when considering appropriate methods of PV recycling and extracting value from recycled materials.

Consequently, PV waste is incorrectly identified as a homogenous entity and a universal waste stream. However, a pilot study (undertaken by the authors of this paper) undertook

XRF testing on 5 samples of c-Si PV waste dated between 2008-2022, which showed huge variation in their chemical composition.

This study expands on the pilot sample size, taking 50 differing PV modules from the waste stream with strategically varying characteristics, such as manufacturer, model series, country of manufacture, year of manufacture, monocrystalline v polycrystalline, backsheet composition, glass depth, etc.

Method for this study requires slicing the modules into universal sample sizes and dividing the waste into their separated materials (glass, silicon, backsheet, EVA). The materials are tested using SEM, EDX, XRF, ICP, & TGA-FTIR. This enables detailed characterisation of PV waste materials (whole and separated) to be plotted against the variables above, allowing for modelling of predicted materials coming through the waste stream.

Coinciding with discussions around Digital Product Passports and the European Critical Raw Materials Act, the outputs of this study are to develop a framework by which a global recyclability index for PV panels is established, based on the chemical composition of materials discovered in PV waste. This paper looks at how characterisation could be automated using AI.

A ‘recyclability index’ will enable transparency for consumers purchasing PV modules, considering their chemical properties, impact on the environment, ease of which to recycle and inclusion of rare critical raw materials.

It is expected that in turn, this will encourage PV manufacturers to divest from using rare materials that are difficult or expensive to recycle at the end-of-life, and better design their products with end-of-life in mind from the outset.

Revisiting the role of impurity elements in microstructure and properties of high strength AA6xxx extruded aluminium alloys

Author: Pavel Shurkin

Aluminium, with an annual production exceeding 100 million tons and contributing 2-4% of global greenhouse gases, plays a crucial role in reaching net zero emissions. Its primary production is the most energy-intensive among metals, producing 4-5 tons of hazardous red mud per ton of aluminium.

In contrast, using environmentally clean post-consumer scrap saves 95% of the energy and produces only about 0.5 tonnes of CO2 eq/tonne of recycled aluminium, compared to 12 tonnes for primary aluminium. Despite aluminium's 100% recyclability, recycling hasn't sufficiently reduced reliance on primary stock. Impurities that accumulate in alloys, even with advanced sorting technologies, limit recycling efficiency. Understanding how the tramp elements influence the performance of alloys was the focus of this study because it is a prerequisite for possible solutions such as alloy design.

The AA6xxx alloys, part of the Al-Mg-Si-(Cu) system, offer excellent manufacturability, corrosion resistance, and mechanical properties after solid solution and aging treatment. The demand for high-strength alloys (YS > 300 MPa) is rising, particularly in the automotive industry for lightweight solutions. With a typical alloying content under 3%, AA6xxx alloys absorb fewer elements compared many other alloys, often requiring dilution with primary aluminium.

A set of impurity elements for this study was chosen — Fe, Zn, Pb, and Ti — because they are considered difficult to remove from scrap. Alloys with single-added impurities were cast into cylindrical billets using industrial-scale direct-chill casting, homogenized, and extruded into flat strips. An extensive work program focused on microstructure-property relationships was developed. Major attention was given to grain size, transformation of intermetallic phases after homogenization preceding extrusion, and characterization of extruded profiles with a focus on intermetallics distribution and grain structure. It was found that the billet's grain size was not significantly affected by impurities; thus, the extrusion speed could be maintained at a high level. Fe impurity had a major impact on the alloy microstructure due to a dramatic increase in the intermetallic fraction.

However, properties were only slightly affected due to a beneficial distribution of particles and a fine grain structure, which was possible due to the compressive and high-temperature nature of extrusion. Zn impurity had no effect on the properties, nor did Pb, though the latter could be present in the extrusion in the form of droplets. Ti impurity was a concern as it is routinely added in the melt in every casting cycle, and if it exceeds a specific level, it could bring faceted Al3Ti intermetallics into the microstructure. One should ensure the correct casting recipe to ensure Ti is dissolved in the melt.

Finally, it was concluded that only Fe could influence the Mg-Si hardening due to the consumption of solute Si, whereas other impurities have no impact on the properties. The results indicate that the effect of impurities on the performance of wrought alloys can be reevaluated so they can be incorporated with a large scrap fraction without impacting alloy performance. Efforts are underway to manipulate the impurities to further diminish their influence on the microstructure during manufacturing.

A Toolbox for Sustainable Metal Recycling

Author: Molly Keal

The global rise in metal consumption is being driven by a growing population, the transition to renewable energy technologies, and the expanding demand for infrastructure development, all of which necessitate significant amounts of metals such as lithium, cobalt, and rare earth elements. To meet this growing demand and minimise waste accumulation in landfill, efficient recycling methods are essential. Current recycling methods, primarily hydrometallurgical and pyrometallurgical processes, require the use of large volumes of toxic solvents and high temperatures, respectively, resulting in harmful secondary pollutants. While these methods can achieve high recovery rates for technology critical metals from end-of-life materials, they are less effective for complex composite materials composed of layers of metals, inorganics, and organics.

A set of physical and chemical tools have been developed for improved recovery of technology critical metals from various waste streams, with an emphasis placed on the

renewable energy sector: wind turbines, solar cells, lithium-ion batteries and catalyst-coated membranes used for hydrogen production [1]. Physical tools include mechanical separation achieved by ultrasound for applications such as delamination of lithium-ion batteries [2, 3] and catalyst-coated membranes. Chemical tools involve electrocatalytic dissolution of the metal or polymer, selective leaching and brine etchants. In some cases, physical and chemical tools can be combined (e.g., electrocatalysis with ultrasound) as a further tool. Finally, comprehensive design considerations must be integrated to facilitate the efficient recovery of metals, ensuring that the recycling process is both economically viable and environmentally sustainable.

1. Zante G, Elgar C. E., Hartley J. M, Mukherjee R, Kettle J, Horsfall L. E., Walton A, Harper G. D. J. and Abbott A. P, A toolbox for improved recycling of critical metals and materials in low-carbon technologies. *RSC Sustainability*, 2024, **2**, 320.
2. US Pat., 17 796 011, 2023.
3. Lei C, Aldous I, Hartley J. M., Thompson D. L, Scott S, Hanson R, Anderson P. A, Kendrick E, Sommerville R, Ryder S. K and Abbott A. P, Lithium-ion battery recycling using high-intensity ultrasonication. *Green Chem*., 2021, **23**, 4710.

Unlocking the potential of logistics service providers in circular economies: Framework development and insights from practitioners

Author: Orsolya-Anna Mate

Logistics Service Providers (LSPs) play a pivotal yet often overlooked role in the transformative journey towards a Circular Economy (CE). Positioned as critical integrators within supply chains, these entities function as cohesive agents, facilitating efficient resource utilisation and promoting circularity across various stages of production and distribution. Furthermore, they operate across various verticals or sectors within the economy. This versatility underscores their relevance to all five Circular Economy Research Centres of the NICER Programme, highlighting their potential impact and applicability across diverse industrial contexts. Despite their fundamental impact, academic discourse has historically underrepresented LSPs in the context of CE initiatives.

The current research endeavours to address this gap through a comprehensive review and synthesis of existing academic literature. This systematic inquiry employs both descriptive and thematic analyses to consolidate knowledge at the intersection of LSP operations and CE principles. By examining a diverse array of scholarly works, the study aims to highlight overarching themes and insights that underscore the role of LSPs in fostering a CE.

In advancing beyond mere synthesis, the research adopts a panarchy theory lens to reinterpret these insights. This theoretical framework posits nested systems of adaptive cycles, offering a novel perspective on the dynamics influencing LSP engagement in circular business models. Central to this approach are propositions delineating conditions conducive to the successful implementation of circular practices by LSPs. Notwithstanding recent scholarly contributions, gaps persist, warranting deeper exploratory endeavours and broader, holistic perspectives. The study advocates for empirical-

qualitative approaches to delve into nuanced scenarios, complementing existing literature and paving the way for rigorous quantitative theory-testing in subsequent phases.

Building on these foundations, the research now embarks on a phase of semi-structured interviews with logistics leaders. This empirical phase seeks to uncover and elucidate best practices that underpin successful circular initiatives within LSPs. By engaging industry stakeholders directly, the study aims to inform and shape industry standards, showcase leadership in circularity, and catalyse systemic change.

Moreover, the insights gleaned from these interviews are poised to serve a dual role: validating and/or refining the conceptual framework derived from the systematic literature review. This iterative process not only strengthens theoretical constructs but also enhances their applicability and relevance within real-world logistics contexts.

In conclusion, the ongoing research represents a concerted effort to elevate the role of LSPs in the discourse on CE. By integrating theoretical insights with empirical findings, it aspires to contribute substantively to both academic scholarship and industry practices. Ultimately, the study endeavours to empower LSPs to navigate the complexities of CE adoption, driving sustainable transformations and fostering a more resilient and resource-efficient future.

Financing the transition to a circular chemical economy

Author: Tom Franklin

UK policies to achieve net zero emissions by 2050 are over-reliant on electrification and carbon capture and storage (CCS). With CCS potentially decades away from becoming a useful method of decarbonisation, this strategy is almost certain to fail. We need solutions that will reduce emissions today and a circular chemical economy is one such proposal of great interest and potential.

Achieving this will require significant political support. This research aims to highlight problems with existing government policy to achieve a just transition to net zero, promote alternative carbon feedstocks focused on CO, residual waste and biomass, and lay out science-based, industry supported, policies to help scale circular chemical economy solutions.

A key challenge in the transition to a circular economy is scaling up suitable technologies within appropriate timescales. Lack of funding opportunities and low investor confidence are significant barriers to scaling up - areas in which policy can provide solutions.

Exploring Critical Factors to Drive Investment to the Circular Economy

Author: Qianqian Ma

Circular economy (CE) transition cannot succeed without sufficient investment from public and private investors. Currently, funding gaps exist and impair the growth of CE. Risk perception of circular-related projects is a significant barrier, leading to potentially massive increases in the cost of the transition for project developers. Although there is a strong momentum of climate-related or sustainability-aligned investments, which often includes CE as one sub-sector, a growing concern is the real impact of these investments on the firm or project level, as well as in society and environment.

Previous literatures have explored barriers, motivations, economic performance of CE projects, and the importance of finance in transitions is incontrovertible, whereas the role of finance and the underlying financing mechanisms are ambiguous. Hence, the research investigates the funding gap phenomenon in the context of CE and takes the chemical sector as example to deepen the understanding on transitions in foundation industries. Research questions are: (1) What makes the CE projects different from conventional projects and other green or low-carbon projects, especially from the financier's perspective? (2) What are the critical factors influencing financing of CE?

The research utilizes a conceptual framework adapted from the Multi-Level Perspectives (MLP) and focuses on the interaction between the finance regime and firms that develop CE-related niche-innovations. The framework adopts fundamental concepts of fit & comfort and stretch & transform strategies to explore research questions. Research around entrepreneurial finance provides fruitful insights on crucial factors that affect securing funding from both firm and financier perspectives as well. The research adopted a qualitative methodology and a case study approach. Ten case studies were conducted to collect data from five chemical firms implementing CE businesses and five financiers investing in CE. The study applied thematic analysis and cognitive mapping approach to identify and extract causal linkages behind thoughts.

The research shows that financiers perceive higher risks of CE projects than firms. Crucial factors that impact financing in CE include capital-intensive business models, high upfront investment, complexity of chemical industry, lack of plants, lack of stable and high-quality recycled feedstock, lack of a secure market and uncertainty of policy and regulations. Financiers prefer capital-light CE business models (i.e., design-based, platform-based, and service-based business models) that can scale quickly and technology providers having niche technical capabilities. While the causal relationships demonstrate that it is feasible to achieve economic viability and increase competitiveness of CE projects. By attracting increased investment into CE businesses to enhance infrastructure and drive innovation, the supply of sustainable chemicals to the market could expand, enabling them to compete more effectively with petrochemicals. To accelerate investment, firms and investors expect government to construct a stable and secure market first.

Group 3

Sustainable circular transformation design approach to advance circular economy and accelerate a transition to net zero in a socially just and equitable way.

Author: Susan Evans

Scholars argue to transform organisations for the 21st century requires systemic approaches to design which balance transformation across social economic and natural environmental aspects (further referred to as SystemicDesign). A balanced approach is expected to strengthen and advance circular economy outcomes by improving the wellbeing of people their communities and their natural environments which can lead to thriving society and flourishing humanity. A SystemicDesign approach applies a combination of systems and design methods, to help understand the system and opportunity for change. To achieve this requires new circular economy (CE) theories to understand the hows and whys and new frames to guide a SystemicDesign process at a strategic level to improve both the wellbeing of people, society and the natural environment.

This research suggests, the sustainable circular transformation (SCT) theory, to guide a design and innovation process, advance CE and accelerate net zero transformation by improving the wellbeing of people with conditions of the natural environment . However, while the author has taken a foundational step and validated the theory at a strategic level; knowledge to incorporate this theory into SystemicDesign processes is limited. The theory has been validated through a longitudinal real world Circular bioeconomy transformation and further within graduate design education courses.

The initial findings indicate the SCT can contribute to improve a balanced transition of future CE interventions for outcomes of circularity and sustainability. However, till now the SCT design approach has not been tested or validated among emerging enterprise such as in a workshop environment. In this environment it is expected that productive collaboration and codesign can further improve understandings of design considerations for practical proposals to spur cooperation and advance CE transformation. In adhering to the flow of a systematic research cycle this research proposal aims to investigate the contribution of an SCT SystemicDesign process to emerging enterprise.

The research sector chosen for this study is the food and agriculture system. Emerging enterprise with circular economy technical innovations on the food and agriculture system are to be explored. A SCT SystemicDesign process will be conducted among active enterprise stakeholders as framed by the 12 interwoven design considerations. The process is expected to identify gaps in the system with practical design proposals by evaluating the relationships between humans and non-humans. The food and agriculture sector has been chosen as it is a major contributor and victim to climate change.

Food security is of growing concern presenting a critical issue faced with a growing global population, migration of people to urban environments, inequality of food access, political disruption and war, changing societal expectations and unprecedented change in climatic conditions. Transformation in a CE is vital to this sector as it presents an alternative agricultural model. To achieve this design and innovation are essential to support revitalization of the sector and transition towards more sustainable agriculture.

The research question guiding the research asks: How can SCT SystemicDesign approach contribute to emerging enterprise to advance circular economy and accelerate net zero transformation in a just and equitable way.

Consumer Experience Digital Tools for Dematerialisation for the Circular Economy

Author: Lucie Hernandez

I am a design researcher using participatory tools and methods to understand people's interactions with materials to encourage more sustainable approaches to fashion and textiles. I investigate making practices to examine the interplay between skill, materials and knowledge to generate models and frameworks to reflect people's experiences and use contexts.

In my current role I am working with a team of researchers to design and develop a suite of technologies and digital tools that empower consumers to extend product life. The project supports experiences and services for apparel products that are related to care, repair and upgrade and encourages citizen-consumers to take on the role of 'custodian' of a product, using, looking after and enhancing it. Repair actions for fashion and textile products are positioned to inspire more responsible behaviour that can help the UK apparel-textiles sector to achieve 'zero avoidable waste' as part of a Circular Economy.

One of the core principles of the Circular Economy (CE) is to keep products in use for as long as possible, and one of the main ways to do this is to support people to value their clothing and the materials they are made from. We are innovating *CX Digital Tools* to support experiences and services for apparel products that are related to care, repair and upgrade in order to keep apparel in use for longer, taking advantage of ubiquitous technology such as smart phones or wearable technology.

Textile materials play an important role in the experience of clothing and how it makes people feel. We suggest that creative digital technologies are starting to become key constituents in product experience. The potential exists for these technologies to be used in the creation of immersive, multisensory and multimodal narratives that are highly relevant to consumers' emotions and memories. Material experiences could prove critical in consumption behaviour and decision making, and hence our programme of research is underpinned by our position that experiences and services for products must be constituents of a new relationship between consumers and their clothing.

During our programme of research we have developed three CX scenarios to examine the human experience of materials and to explore the use phases of clothing.

1. 'I repair': Supports consumer-custodians to maintain and repair their garments by accessing mending and customisation techniques and facilitating the development of transferable skills.

2. ‘The Brand repairs’: Investigates changing business models to encourage consumers to participate in textiles circularity and capture information on wear and degradation to inform future material cycles.
3. ‘The Community repairs’: Explores with the community opportunities to collectively share repair and maintenance skills as part of the social refurbishment of garments.

Mapping the Role of Intermediaries in Facilitating Circular Economy Transition in E-Waste Management: A Classification of Key Actors in the Electronics Value Chain

Author: Priya Saikumar

The principal aim of this study is to identify and categorise intermediaries involved in the implementation of circular economy in the electronics value chain. This study focuses on understanding the contributions of intermediaries towards advancing high-R circular economy strategies, which emphasise the prevention of waste and the maximisation of product value beyond traditional recycling methods. Through the analysis of cross-border movements of e-waste, especially between the European Union and the global south, the research seeks to evaluate current practices and identify potential improvements in the e-waste management domain.

This study defines intermediaries as entities that facilitate, support, or enhance the circular economy value chain for e-waste management. These entities act as links between primary stakeholders like governments, manufacturers, OEMs, and consumers, guaranteeing the effective and sustainable operation of the system. This ongoing research aims to classify these intermediaries based on the services they deliver.

Preliminary research and stakeholder interviews have identified several key functions of the intermediaries, including Research and Development, Training and Education, Advocacy and Policy Support, Business Innovation, Compliance Management, Repair and Maintenance, Financial Services, and Logistics and Supply Chain Management. The research utilises the 10R framework for the circular economy, which presents a hierarchy of strategies aimed at optimising the value and durability of products, components, and materials within the economy.

High-R strategies, encompassing Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, and Remanufacture, are prioritised due to their emphasis on waste prevention and the preservation of product value over extended periods. To achieve the research objectives, a systematic literature review was conducted utilizing the PRISMA approach. Following this, there will be a multi-case study analysis of seven EU-funded e-waste management projects. These case studies will be carried out through a series of semi-structured interviews with experts working on these projects.

Although the research is still ongoing and conclusive results are not yet available, the anticipated outcome of this study is intended to highlight the deficiencies in the current policy framework and its implementation that hinder intermediaries from fully utilising these policies to achieve circularity at a systemic level. Furthermore, the research aims to shed

light on critical points where new policies or market interventions could be vital while also highlighting how the operationalisation of existing legislation can be improved to facilitate the shift to high-R strategies in e-waste management. In conclusion, this research aims to provide valuable insights into the role of intermediaries and offer practical recommendations to improve circular economy practices in the electronics value chain, thus contributing to a more resource efficient economic system.

Affordances as tool for mapping in the wool ecosystem to transition towards regenerative ecologies

Author: Chiara Tommencioni

Environmental concerns and the compelling need to operate within planetary boundaries result in the search for novel approaches and solutions to support the transition to materials and processes which are ecological and regenerative to achieve holistic sustainability. Regenerative frameworks suggest the adoption of a holistic vision where all different ecosystems actors' humans and non-humans are comprehensively considered in their interconnections. Concurrently international legislations are urging the world of textiles in taking responsibility along the whole value chain.

Wool is a natural renewable fibre with invaluable intrinsic characteristics produced by sheep whose grazing offers a regulatory service to the ecosystem, if not bred intensively. If sheep are farmed according to regenerative farming standards, the extracted wool can achieve carbon neutrality thus becoming a well-equipped beneficial player in a regenerative context. In addition, wool is one of the purest sources of keratin, a remarkably useful protein. Its recovery from end-of-life and low-grade wool presents worthwhile applications in different industries.

Wool and wool keratin processing cover a vast array of transformation methods ranging from rural and craft-based approaches to cutting-edge biotechnologies, resulting in a plethora of applications which can address different societal needs. All these aspects require a new level of attention to take into consideration the reverberation of action and decision by industry stakeholders in the wider ecosystem, human and non-human, thus including the planet as stakeholder in the process. Ecosystem mapping enables context unpacking and the concept of affordances - due to its broadness - could facilitate ecosystem mapping generation to the level of details necessary to follow a regenerative framework by signposting interconnections between different entities.

The concept of affordances, firstly theorised by Gibson, has been adopted in multiple disciplines. In the field of design, the concept of affordance to date has been applied in Human-Computer Interaction, Design Engineering and in Material-Driven Design both in the technical and biological cycles. By drawing from a literature review across different disciplines, affordances can be defined as relationships between the offering of the environment and the abilities of a form of life to harness them.

As such affordances are characterised for highlighting interconnections and thus generating mapping. To date the concept of affordance has been used as a conceptual model and approach to design artefacts, however there is a knowledge gap in the potential translation

of the concept of affordances into a tool for ecosystem mapping. Hence the first aim of my research is to address this gap by translating the concept of affordances into a tool which can be used for ecosystem mapping - the Affordances for Ecosystem Mapping (AfEM) tool - by testing this tool with wool industry stakeholders through research studies taking the form of workshops. By developing the AfEM tool situated in the wool ecosystem the second aim of my research is to build the AfEM tool to support different actors in mapping their ecosystem to guide informed decision-making process by visualising the wider impact on the ecosystem of potential operations.

Development of high-performance multi-principal element alloys – a computational search for black hole space

Author: Syed Hassan Fatimi

Multi-principal element alloys have attracted attention and resulted in novel concepts of designing metal alloys by exploring a large composition space. Theoretical analysis has predicted regions of composition space where such alloys are resilient to physical changes while undergoing changes in chemical composition. This has led to a data-driven search for this so called “black hole” region by using a combination of advanced machine learning techniques.

In this research, we employ artificial neural network with hyper-parameter optimization to create a search space of alloy compositions and use multi-objective optimization to search for regions of interest by utilizing evolutionary algorithms. Search space generation is designed in this study as a supervised classification problem, where each class is a distinct alloy phase, making this a phase prediction approach. For the complete dataset, we also employ feature subset selection and outlier detection as novel tunable parameters to improve the quality of prediction by selecting suitable features and removing outliers.

Genetic algorithm is utilized for the purpose of hyper-parameter optimization with modified crossover and mutation operators suitable for handling dynamic sized variables. A prediction quality of 88% is achieved with excellent F1 scores. Ablation studies are performed which indicate the importance of using additional hyperparameters in hyper-parameter optimization. In addition to genetic algorithm, a recent nature-inspired technique called Teaching Learning Based Optimization is also used which is a faster and simpler algorithm to implement compared to genetic algorithm but suffers from premature convergence.

For this purpose, three modifications are proposed for Teaching Learning Based Optimization which will serve to slow down the convergence rate and ensure good quality results. Results of hyper-parameter optimization using these modifications indicate that they are comparable to genetic algorithm in terms of testing accuracy but use less computational time and are scalable to larger problems. These novel improvements exhibit the usefulness of our model not only in terms of global optimization of high-dimensional data but also in high throughput design of multi-principal element alloys.

Physicochemical Characterization of Solid Waste in Ouagadougou Using Statistical tools for a higher calorific value Artificial Intelligence mode

Author: Rojosoa Adedeji

One of the major issues in Africa is the lack of access to electricity. Ouagadougou, located in West Africa, specifically faces significant challenges in terms of electrical energy. The purpose of this article is to conduct an experimental study on municipal waste to gain a better understanding of its physicochemical characteristics.

In this paper, artificial intelligence-based models are utilized to determine the net calorific value of each waste type. The parameters considered include moisture, ash content, and volatile matter content. Other parameters are determined through calculations and a literature review.

Artificial intelligence models are employed to predict the net calorific value. To evaluate the model's accuracy, various performance measures are used, including the coefficient of determination, root mean square error, mean absolute error, standard deviation, mean absolute percentage error, and standard error of the estimate.

Applying a system’s thinking approach to circular economy transition; insights from the use of a sociotechnical systems approach within the UK hospitality sector

Author: Danielle Farrow

Despite more than twenty years of research into sustainable tourism, the environmental impact of the UK hospitality sector remains high. A growing body of research into the concept of a circular economy (CE) demonstrates transitioning to this way of working has significant benefits both for the environment and business outcomes but has yet to be applied to the hospitality sector. In this paper, we adopt a Socio-Technical Systems Thinking approach to propose and test a novel, practical framework for CE implementation within the hospitality sector. Data is gathered via a cross-sectoral, multi-stakeholder engagement programme to develop evidence-based, sectoral specific CE implementation plans. Specifically, we draw out the characteristics of the current system, identify challenges to CE implementation, potential future opportunities for the sector, and enabling factors. Theoretical and practical implications are discussed for researchers, practitioners, and governance bodies interested in facilitating the implementation of a CE.

Assessment of Circular Economy Adoption in Food industry in Nigeria

Author: Tawakalitu Funke Adedeji

The discussion to preserve our environment has been on top gear to all stakeholders across board especially now that SDG goal 2030 is only six years away, and the effect of waste generated by industries has begun to affect our environment most especially in the

developing countries. Circular Economy CE deals with ways to improve the quality of the environment and human life by increasing production efficiency. In the future, it is intended to replace the linear economy, in which a large percentage of products, in the first place, end up unnecessarily after consumption in landfills or incinerators.

The concept Circular Economy CE hold huge promise in industrial solid waste management if the key element to adopt an institutional framework, holistic stakeholders' involvement, innovation capabilities can be adopted by all enterprise that generate this waste. The advocacy for alternative use of biodegradable packaging materials holds promise environmental sustainability management. This research aims to assess the current level of adoption of CE model by the food entrepreneurs in Nigeria, specifically in the food industries.

It also seeks to identify the factors influencing their adoption of the model, evaluate its effect on their performance and make recommendations for improving its adoption. This is with the view of ensuring that idea of sustainability is embedded in food industry packaging to save the African continent. The study will use the mixed study approach that is qualitative and quantitative method. At least 300 enterprises in the study area within the category of large, medium and small enterprises will be surveyed in the food industry. Data collected will be analyzed using both descriptive and inferential statistics.

Group 4

Measuring the Circular Economy: (de)coupling behaviours during strategic organisational transitions

Author: Margo Raynolds

Phenomenon: A problem arises when transitional initiatives, i.e. socio-ecologically conscious institutional and regulatory developments, are not successfully implemented, embedded, governed and evaluated within organisational business strategy and as a result, there is an evident gap between what the businesses are doing (i.e., policies and practices) and what they are achieving (i.e., meeting intended outcomes). A leading reason for the disconnect between the adopted policies and practices and the actual outcomes in this context is that there is still "a lack of consensus on the conceptualisation and operationalisation of circularity principles and measures" (Nikas et al., 2022). In practice, the role of systems thinking in CE transitions is still emerging, and it is "often times not highlighted that CE necessitates a systemic shift" (Kirchherr et al., 2017). There is a clear need to further substantiate the claim that this disconnect is occurring in CE transitioning businesses and to examine real-world transitions to understand how to best bridge the gap with effective implementation and monitoring.

Theoretical Position: To meaningfully assess and promote the real-world implementation and monitoring of circular principles, policies, practices, and related outcomes, the research primarily combines insight from the emerging circular economy literature, alongside established institutional theory within the management and organisational studies literature. Primarily, the research draws upon 'means-ends decoupling' institutional theory that explains the act of implementing "practices (and associated ways of evaluating practices)

that have an opaque relationship to outcomes" (Bromley & Powell, 2012). As well as Gond and colleagues' (2017) 'coupling' theory, as work by organisational actors to strategify issues of importance, i.e. whichever issue is perceived within organisations as necessary (e.g. enabling CE practices) leads to internal attention and resources, and ultimately, embeddedness within the overall business strategy. The research specifically calls upon 'material coupling', i.e. strategic measurement tools, as a means to strategify CE within business strategy.

Aim and Objectives: The overarching aim is to contribute to the growing literature on the CE concept by theorising the role measurement plays in enabling organisations' successful transitions to systems-centric circularity, resulting in practical implications for application by industry. To achieve this aim, there are three primary objectives:
1. To substantiate means-ends decoupling in the CE context with empirical evidence.
2. To evaluate measurement (i.e. material coupling) as a mechanism to strategify CE within organisations to increase the chances of newly implemented practices (i.e. means) achieving their intended outcomes (i.e. ends) via a multiple embedded case study.
3. To utilise findings to determine factors that enable (and inhibit) the dissemination and governance of measurement systems in organisations attempting systems-centric CE business strategy transitions.

Upon consideration of the state of the literature and the challenges identified industry practice, the proposed overarching research question is: To what extent does the employment of measurement systems enable transitioning organisations to embed CE within their overarching business strategy?

Methodology: The research has a primarily interpretivist philosophy, associated with a relativist ontology and social constructionist epistemology. The research adopts an inductive approach to theory development and the research design is a qualitative multi-method study with a case study strategy performed cross-sectionally across three MNCs in the packaging, fashion and food industries. Data is collected primarily via semi-structured interviews, supplemented by documentary evidence and research feedback sessions, ensuring participant validation. Data is analysed through employment of Gioia's coding methodology and thematic analysis.

Circular Chem Cross cutting research project: A circular economy of chemicals roadmap for the UK

Author: Miriam Fsadni

To support the UK's pledge to achieve net zero carbon emissions by 2050, a pathway to a circular economy of chemicals, with detailed strategies and meaningful milestones, is required. The aim of this research project is to prepare a roadmap, showing the current status and future prospects of the circular economy of olefins. A whole systems approach is used to identifying the challenges and opportunities association with the transition from a linear to a circular model. This involves taking into account not just the availability of new technologies, but also business, economic, societal and political considerations. The

roadmap draws on consultations with stakeholders for a holistic view of the chemical industry and related supply chains.

Within this framework, the roadmap looks at fostering resource efficiency, reducing carbon emissions, replacing petrochemical feedstocks and reducing waste. This includes identifying new technologies and comparing these with established technologies; identifying products or feedstocks from circular routes that could replace linear ones, and where new standards and testing are required; as well as understanding where conflict or competition with other sectors (e.g. Energy) may arise.

The roadmap also aims to highlight where policy change is planned & needed in order to make the transitions in the required time, and provide a structure on which to compare progress and impact internally and externally. The outcomes from this work will be disseminated through workshops, press releases and online content to support and inform research and funding decisions, as well as public engagement.

Lithium-Ion Battery Circular Supply Chain: An Agent-Based Model

Author: Krishna Mohan Thazhathu Valiyaveettil

Lithium-ion batteries form the essential component of electric vehicles. They are composed of technology metals such as lithium, cobalt, nickel, etc. that are rated critical due to the uncertainties in supply as the ores are located only in some countries. Hence, for many countries such as the UK, establishing a circular economy of lithium-ion batteries is essential. This may be performed by many activities such as recycling, remanufacturing, repurposing, reusing, etc.

This research models the circular ecosystem as an agent-based model, considering the different elements in the circular supply chain as different agents of the system. The agent decisions that prioritize the reverse loops in flow materials give rise to economic and environmental trade-offs. The regulatory decisions and market forces form the environment for the agent-based model influencing the agent's decisions. This research analyses the evolving nature of the circular supply chain through the agent-based model.

Carbon emissions and circular economy in new build projects in the construction sector: The role of accounting and accountability

Author: Sue Harris

The field of the PhD study is how circular economy (CE) principles are used to reduce carbon emissions in new build construction projects. The study will focus on the role of Sustainability Control Systems (SCS), and the facilitators and inhibitors to sustainability accounting and accountability in this area. It will consider the extent to which these CE and carbon SCS are or are not integrated with Management Control Systems (MCS) decision-making relating to new build projects.

This PhD is funded by the UKRI Interdisciplinary Circular Economy Centre for Mineral-Based Construction Materials (ICEC-MCM). I am delighted to come to this research from 20 years in industry, most recently as Technical Director of the international Circular Economy Centre of Excellence at Anthesis Group.

Sustainability assessment of novel low carbon cement and concrete technologies

Author: Donald Nwonu

Amid the persistence of climate change renowned as the most pressing of the triple planetary crises, legally binding net zero commitments illuminate the path to a sustainable horizon. Efforts by the cement and concrete industry to decarbonize has led to various market-ready and forthcoming emission reduction measures, but cement substitution remains the most widely adopted in blended cement concrete. Yet, it is unclear what would be a “low carbon concrete” required to achieve the climate target of the Paris Agreement. Thus, this research aims to provide insight in this regard by adopting a multidisciplinary approach.

First, the challenges in carbon accounting for concrete structures are investigated because accurate accounting underpins the emission reduction potential for any low carbon technology. In the second objective, a multi-criteria decision support framework is developed to consider all circular economy strategies for concrete. Then, the framework is hypothetically tested via a case study to support decision making for the fate of concrete at end-of-life. The framework also supports the creating of digital product passport due to the material information resulting from the framework application. The decision process is critical for consideration of carbon accounting of concrete structures from a whole life perspective.

In the third objective, we investigated the ready-mix concrete designs available in the UK concrete industry arena to understand the best available technology (BAT) that can achieve a durable concrete robust against carbonation and chloride induced deterioration mechanism. Then we modelled to 2050 the decarbonization potential of the BAT for cement substitution by considering a full combination of three technologies and three decarbonization paths, including dematerialization. Importantly, we found that dematerialization can be leveraged to significantly cut emissions even with low cement substitution.

The last objective aims to systematically analyse 148 policy documents from the UK public and private sector related to the built environment using text machine learning to understand how “low carbon” is defined for the built environment to provide insight on the right path towards defining a low carbon concrete.

Tackling climate emergency in capital project organising through circular economy: Empirical evidence from flood risk management project.

Author: Mayank Jain

Capital projects often intersect with socio-technical systems, where societal needs such as flood protection, transportation, and other infrastructure are facilitated through engineering led infrastructure delivery process. Environmental damages and economic (funding) challenges have historically been part of infrastructure delivery. However, the climate emergency and targets such as net-zero have compounded these existing challenges, as infrastructure projects are among the largest consumers of resources and significantly contribute to carbon emissions.

In this research, we address these challenges and provide empirical evidence on how adopting a circular project organizing framework can deliver infrastructure assets at lower cost, with higher material productivity, lower carbon emissions, and reduced impact of future climate change risks. We adopt a multi-method approach. First, based on a literature review, we develop an asset-agnostic circular project organizing framework comprising six phases of the asset lifecycle and sixteen circular economy interventions spanning these phases.

Second, using a case study of an executed and commissioned flood defence project, we analyse data on costs and carbon emissions to develop a material flow model, using Sankey diagrams, for the executed project and future interventions required over 100 years, assessing its material footprint. This provides baseline quantitative data on material footprint, carbon emissions, cost, and benefit-cost ratio (BCR) as project performance indicators.

We then operationalize circular economy interventions from our project organizing framework, relevant to the case study, validating the technical feasibility of these interventions using practitioners' data (interviews) and secondary literature. We present evidence of the impact on project performance in two scenarios: "Circular Now" and "Circular Future." The "Circular Now" scenario models technically feasible circular interventions using currently available technological solutions at material and asset levels. To address feasibility uncertainty and bias, we present our results with three sub-scenarios: conservative, most likely, and optimistic.

Our analysis of circular now scenario shows a potential decrease in material inflow between 32-43%, carbon emission reductions between 20-45%, cost reductions between 10-28%, and an improvement in BCR between 10-43% compared to baseline performance. Furthermore, speculating on a "Circular Future" scenario that relies on a developed circular economy ecosystem, we anticipate potential material reductions of 35-66%, carbon reductions of 40-65%, cost reductions of 25-53%, and BCR improvements of 15-66%. Additionally, we identify a series of unaccounted costs and benefits, suggesting a future research agenda for additional benefit modelling.

Through the case discussion, we argue that this circular approach to project organizing also reduces the impact of hydrological uncertainties arising from climate change, which would require multiple interventions over the 100-year design life of the assets. Grounded in literature and empirically validated through case study analysis, our project organizing framework contributes to the body of knowledge in project management by proposing a pathway for circular economy-led innovation to tackle the climate emergency and deliver higher performance. As a contribution to practice, the framework provides a strategic, circular, whole-system innovation pathway for managing appraisal, design, delivery, asset use, and end-of-life stages with improved performance indictors and better manage future risk of climate change.

Paint Recycling for End-of-life Construction Cladding

Author: Anna Voytyukova

European production of prepainted metal amounts to 1.5 billion square meters annually, with 75% of it used in construction. The coil coatings used for prepainted metal significantly contribute to the coating industry's carbon footprint, which needs to be dramatically reduced to meet the net zero target by 2050. Understanding the specifics of the coating industry's carbon footprint is crucial to achieving the target: 98% of the emissions fall under Scope 3. This includes those from the extraction and production of raw materials, the use of sold products, waste disposal, and the disposal of products at the end of their life cycle. Therefore, circularity must be introduced to link the stages of extraction and disposal, close the loop, and reduce the carbon footprint.

Currently, when end-of-life construction cladding is recycled, the metal is remelted and recast, but the organic coating is incinerated with no recovery of materials from the residue. Closing the loop not only for the metal substrate but also for the organic coating is the aim of this research.

The project is structured around two primary goals. The first aims to investigate methods for the removal and collection of paint from prepainted metal with minimal environmental impact. Research is being conducted on various paint removal methods and their combinations, targeting different coating chemistries and metal substrates. The methods being investigated include laser ablation, molten salt cleaning, dezincing with KOH and HCL, ultrasonication, cryogenic treatment, and electrochemistry. These processes are then analysed with life cycle assessment (LCA) to quantify their environmental impact.

The second goal is to develop a route to extract the paint constituents for reuse. The fragments of organic coatings are manipulated to separate organic and inorganic components: coloured or anti-corrosive pigmentation, organic polymers etc. The constituents are prioritised according to their environmental impact. For example, titanium dioxide comprises up to 60% of the paint's carbon footprint. Depolymerisation for binder

recovery is performed to make thermoset recycling economically viable and environmentally sustainable. Additionally, the presence of lead and chromium (IV) in end-of-life construction cladding, manufactured before the enforcement of REACH regulatory standards, is considered.

The recycling of organic coatings from end-of-life prepainted metal is crucial for the reduction of the industry's emissions. The research project aims to integrate circular economy principles into the coating industry and contribute to keeping global warming below the 1.5-degree Celsius threshold.

Enabling mechanisms for the evolution of circular supply networks

Author: Lisa Rossi

Aims

Unsustainable natural resource consumption is irreversibly affecting the balance within the natural ecosystem. By encouraging the reuse of materials at their highest value the circular economy addresses current concerns. Nevertheless, its success relies on digital technologies and platforms providing the necessary information on resource flows between actors and across the life cycle of a product service system. We explore how digital supply chain technologies and platforms can support the transition to a circular economy.

Methods/Approach

By conducting cross-industrial case studies among leading examples of circular ecosystems, we explore: (i) supply network configuration and stakeholder evolution; (ii) operating and business model transformation; and (iii) supporting digital infrastructure. In-depth interviews and workshops enabled visualising (i) net material, financial, and information flows, (ii) supply network and institutional actors and (iii) different supply network configurations.

Results/Findings

We develop a supply netting and pooling map and identify three circular ecosystem archetypes, namely material identification, product monitoring, and platform collaboration. Findings suggest circular configuration evolution from material passport pre-competitive collaborations to platform ecosystems for continuous reverse-forward material exchanges across competing and non-competing actors.

Relevance / Implications for practitioners and academics

The research uniquely brings together three bodies of literature, namely supply network configuration, stakeholder, and digital platform theory, to explore the circular evolution context and define the key attributes for creating circular ecosystems. Second, it distinguishes distinct circular platform archetypes across three dimensions of analysis.

Third, it sheds light on different transformation pathways by analysing and comparing cases of circular ecosystem evolution.

Group 5

Impacts of implementing Circular Economy practices on the environment and social impacts of MCM life cycles

Author: Irene Josa

My project aimed to assess the consequences of implementing CE practices on the environmental and social impacts of MCM life cycles. This objective was divided into three main tasks, namely:
- to review of indicators to assess environmental impacts of MCM supply chains
- to develop the environmental impact assessment models, also to identify the impact hotspots for these supply chains with respect to CE practices
- to do the same for social impacts

As for the review of indicators, the PRISMA standards were followed in conducting a systematic review of the literature. Three key categories comprised the taxonomy that was constructed after indicators were taken out of the literature that was chosen for examination. These categories included the type of indicator, the level of assessment and the area of assessment.

The review's findings demonstrated the wide range of indicator sets that have been proposed and used in the literature, some of which are presumably used more frequently than others. This study advances the area by providing a comprehensive taxonomy of indicators specific to the construction industry, which makes it easier to take environmental system complexity into account when choosing an indicator set.
Regarding environmental impacts, an LCA model was built that allows assessing the impacts (e.g., CO2 emissions, resource depletion, water consumption) of the concrete supply chain at different levels, from the production of 1 ton of cement and 1 m3 concrete to the construction of a building.

An evaluation of the effects of cleaner production practices was conducted using this model. Three alternative scenarios were evaluated in addition to the business-as-usual scenario. These included cleaner electricity, which examined the effects of using five different electricity grid mixes; cleaner transportation, which examined the effects of using battery electric trucks and varying transportation distances; and cleaner fuels, which examined the effects of utilising different fuel combinations in the cement kiln.
The findings demonstrate that combining various solutions can result in notable reductions in CO2 emissions. On the other hand, some approaches might result in a rise in other effect categories, such as land use, ionising radiation, and stratospheric ozone depletion.

Regarding social impacts, the first work conducted involved identifying limitations in S-LCA, as well as demonstrating how behavioural science approaches can improve the social impact assessments. This study, which was done in collaboration with Met4Tech, allowed underscoring the potential that the behavioural science has in advancing S-LCA. The

second piece of work conducted as part of the social impact assessment was a case study which used S-LCA for the comparison rebuilding of a building as opposed to its retrofitting.

Three scenarios were established: the baseline case, in which the building remains unaltered; the new building scenario, in which the original structure is totally demolished and rebuilt; and the circular scenario, in which the old building is renovated.

National Policy for a Circular Economy: Institutionalisation of Circular Strategies in the UK's Agri-Food Sector

Author: Omorinola Akeredolu-Ale

The UK's transition to a circular economy (CE) contributes to the UK's ambition to be world leaders in responsible environmental stewardship. The devolved administrations have proposed several policies; however, doubts have been raised about the effectiveness of traditional public policy in achieving the normative goals of the CE and its break with business-as-usual. Studies that have assessed enablers and barriers of circular strategies have mostly focused on CE imperatives which support optimal use of existing materials e.g. recycling. However, in a CE, recycling is considered a last resort. More research is needed to develop policies relating to more sustainable product manufacture and more preferable CE imperatives such as 'Refuse', 'Rethink' and 'Reduce'.

While comparatively little CE scholarship focuses on it, the agri-food sector has the potential to significantly reduce UK carbon emissions. The sector has the advantage of being able to directly "regenerate nature", the principle of the CE to which the literature and policy appears to pay the least attention. The sector faces limited growth potential due to the constraints of consumer intake capacity and can accommodate only minor direct innovation. Furthermore, food production is already being negatively impacted by the effects of climate change; increasing the factors to consider in pursuing sustainability. However, opportunities for improvement lie in enhancing efficiency. Circularity in agriculture encompasses such considerations of resource efficiency, sustainability, and regeneration. Emphasizing the concept of regeneration, establishing circular production models requires the integration of regenerative systems that close nutrient loops, reduce leakage, and maximize the long-term value of each loop.

Combining these opportunities for research, this study explores the bi-directional links between macro-level factors (national policies) and micro-level dynamics (organisational change) in the agri-food sector, within the context of the UK's transition to a CE. The project is underpinned by institutional theory, which postulates that organisations are not self-contained entities but are instead shaped by social expectations from relevant parties as well as shared beliefs, structures, and conventions (DiMaggio & Powell, 1983; Scott, 2005). Within this framing, the project seeks to understand the formation and content of relevant policies, as well as how organisations adapt to external pressures such as these policies, shifting societal norms, and consumer behaviour.

The study employs a multiple-case design (MCD) to examine the institutionalisation of CE practices (refuse, rethink, reduce, etc.) in all four UK home countries (each country being a case), with particular focus on the role of public policy and governance in their transition. Insights from this study could be applicable for improving CE strategy adoption in the sector, with transferable lessons across home countries and in other regions globally. Data collection is from multiple sources; review of national policy documents and semi-structured interviews with policy makers, subject experts and stakeholders in the agri-food sector who are impacted by the identified policies. Thematic and content analyses will reveal the patterns and pressures driving CE policy development and organisational responses.

The role of the Circular Economy strategies in creating resilient SMEs in conflict zones: The case of Palestine.

Author: Bassem Abudagga

Abstract: Small and Medium Enterprises (SMEs) operating in conflict zones face formidable challenges. However, resilient SMEs owe their survival to circular economy (CE) strategies, which not only bolster their resilience but also facilitate internationalization—a crucial driver of economic development.

The research seeks to explore the gap of how CE strategies benefit Palestinian SMEs in conflict zones, particularly in terms of resilience for internationalization. It evaluates the impact of CE principles and indicators on SMEs, investigates how CE strategies affect internationalisation, and considers contextual factors like culture, politics, economy, and environment.

The research aims to explore the concept of circular economy and its implications for SMEs in conflict zones. It analyses Palestinian SMEs' current practices related to resilience, internationalization, and circular economy adoption. Additionally, the study evaluates how circular economy strategies impact SME resilience and internationalization. Contextual factors influencing these aspects are also compared. The research objectives include reviewing existing literature on circular economy principles, analysing resilience dimensions for conflict zone SMEs, conducting case studies on Palestinian SMEs' awareness of circular economy principles, comparing motivations and barriers for internationalization, measuring circular economy impact on performance, and identifying best practices for implementation.

Existing literature provides various definitions of SME resilience, but many fail to adequately address the unique context of conflict zones (Aall and Crocker, 2019). While most definitions focus on SMEs' ability to adapt, maintain positive performance, and recover from disruptive events, they overlook the specific challenges faced by SMEs in conflict zones, such as political instability, violence, and unexpected risks. Considering this context is essential for defining resilience in such environments.

Circular economy principles—reduce, reuse, recycle—offer a lifeline to SMEs (Madaan et al., 2024). By embracing CE, SMEs optimize resource usage, minimise waste, and adapt their business models. These circular practices enhance their ability to withstand adversity. Resilient SMEs owe their success to CE strategies, which not only ensure survival but also contribute to economic development within conflict zones.

The West Bank in Palestine serves as a compelling case study. Despite ongoing conflict, Palestinian SMEs have displayed resilience through CE practices. However, the concept of resilience in SMEs remains multifaceted, lacking consensus among scholars. Definitions, measurements, and influencing factors vary widely. Investigating SMEs' resilience in conflict zones is essential to uncover hidden themes and inform practical strategies.

This research employs qualitative methodology, including semi-structured interviews, focus groups, and ethnographic research. Participants include SME owners, managers, employees, policy makers, practitioners, and experts in Palestine. The study aims to explore motivations, challenges, outcomes, and contextual factors related to circular economy strategies. Secondary data sources include statistical reports, academic literature, policy documents, and media articles relevant to SMEs and circular economy practices in Palestine.

The potential output of this research project is likely to align with the researcher's vision. It is evident that SMEs surviving in conflict zones have adopted and emphasized resilience. This achievement can be facilitated by implementing circular economy strategies, which can effectively support SMEs in their internationalisation efforts, ultimately contributing to economic development although of the conflict and Palestine serves as the targeted context of the study.

Welsh Government Net Zero and Climate Policy on Consumption

Author: Dan Thorman

A series of 'Roundtables' were held with a selected group of key actors, each focussing on a key area of policy; one of which was material consumption and the circular economy. The discussions centred around the role this sector has to play in mitigating climate change and reducing carbon emissions in Wales. Through inviting different stakeholders from organisations and local communities across Wales, across policy and practice, and asking them to deliberate information about the main policy objectives, this research gains insight into the workings of how policy might be put into action.
For policy relevant themes, there was a need to avoid the siloing, to reconceptualise metrics for progress away from the economic, and to encourage co-production and engagement between government, local authorities, business, and citizens. There were good examples of smaller projects such as sharing/fixing hubs that need to be scaled up, with more consideration in planning and infrastructure that can facilitate the flow of resources, with better integration with public services and procurement. The importation of products and raw materials brought about concerns for those working to reduce wasteful consumption, where global international policy differs.

Material Flow Analysis of Glass in the UK: Pathways for Sustainable Management

Author: Leonel Tchadije

The UK glass industry, a vital part of the manufacturing sector, faces significant sustainability and resource efficiency challenges. This research presents a material flow analysis (MFA) of glass in the UK for 2021. Data was collected from various sources including the UK Minerals Yearbook, Eurostat, British Glass, UK Trade Info, WRAP, Glass for Europe, and UK Statistics on Waste. Key metrics such as material import dependency, recycling rates, and circularity rates were evaluated.

The analysis shows an 18.1% dependency on imported raw materials. Container glass has a recycling rate of 74.7% and a circularity rate of 63.3%. In contrast, flat glass exhibits lower rates, with 29.6% for recycling and 25.1% for circularity. Fibre glass shows even lower performance, with recycling and circularity rates at 12.2% and 10.3%, respectively. Domestic glassware and other glass products indicate no recycling or circularity.

The overall glass recycling rate in the UK stands at 52.0%, with a circularity rate of 54.1%. Although over half of the glass is being recycled, significant potential for improvement remains. The data indicates that 47.8% of recycled glass is utilised in closed-loop systems, whereas 52.2% is down-cycled into lower-value products. This inclination towards down-cycling highlights opportunities for enhancing closed-loop recycling to retain more value within the process. Additionally, the analysis underscores the import and export of cullet. The UK imports 187 kt of cullet while exporting 372 kt, resulting in a net positive trade balance. This suggests potential missed opportunities for domestic recycling, which could further reduce reliance on imported raw materials and enhance circularity.

To improve sustainability and resource efficiency, several key recommendations are proposed. Enhancing domestic recycling capacity to reduce reliance on imported raw materials. Investment in advanced recycling technologies and infrastructure is crucial to improve efficiency across all glass sectors. Prioritising closed-loop systems over down-cycling can preserve more value within the recycling process. Furthermore, increasing the domestic use of cullet can address the trade imbalance and promote circularity.

Impacts of circular economy measures on the global steel industry and economy

Author: Serguey Maximov

The steel industry is essential for infrastructure and the manufacturing of various finished goods, but it is also a significant consumer of primary materials and a leading source of greenhouse gas emissions, topping CO2 emissions among heavy industries. Steel is also crucial for global decarbonisation as an integral component of many of the infrastructure

that would make possible transitioning towards a Net-Zero future, such as wind turbines and electric vehicles. Over the past 50 years, global steel demand has more than tripled and is expected to continue rising in the coming decades to support economic growth, the consumption of goods and new infrastructure.

Depending on the product, steel remains in use for few years, around 13 years in vehicles and more than 50 years in construction. After this period steel may be reused or recycled. The main source of CO2 emissions from the steel industry comes from the use of coal for iron and steel production. The increased use of scrap for electricity based secondary steel production is seen as a greener alternative to meet the future demand for steel. However, the limitations and interactions of this alternative within the broader global economy are yet to be understood.

In this work, we present the recently updated Material version of the Environmental Global Applied General Equilibrium (ENGAGE) model. ENGAGE-Material is a global CGE model which uses recursive dynamics to project the behaviour of the global economy to 2050 and beyond. It is based on the GTAP11-Power database and features up to 160 regions, which can be aggregated according to the user's requirements. For each of these regions the model accounts for the production, consumption and interregional trade of 37 goods and services.

This new version of the model includes a detailed representation of the iron and steel supply chain which is based on physical input-output tables provided by PIOLab (Wieland et al. 2020). ENGAGE-Material differentiates the production, consumption and trade of iron ore from other minerals. It also distinguishes production of primary iron and steel by traditional routes: blast furnace, direct reduction, blast oxygen converter and electric arc furnace. Furthermore, it includes new primary clean steel production routes, such as direct reduction with hydrogen and considers an explicit representation of different types of scrap (i.e. home, prompt and end-of-life).

These new features enable a detailed analysis of the role of different types of iron and steel products in the economy and allows assessing interactions between material use efficiency, and circular economy and decarbonisation policies. We assess the economy-wide impacts of different policy measures that aim to promote the adoption of less carbon intensive production routes. Such of these measures are: import duties on iron ore, taxes to primary steel production; subsidies to secondary steel production; mandates on secondary steel use in specific sectors; incentives to scrap production; and carbon taxes, among others.

Group 6

Circular Supply Chain Design (CSCD) Strategies for Business Models (BMs) in the Metals Industry for 2050

Author: Xinyu Liu

• Introduction and background

Metallic materials are the fuel for economic growth and the metals industry underpins the competitive positions of every industrial sector. The transformation of the metals industry from the current largely linear economy to a Circular Economy (CE) will play a critical role in realising clean growth, doubling resource productivity, and reaching net zero carbon emissions in 2050.

We believe that without a vision of the future, our actions become mere short-term reactions, lacking the power to effectively shape our trajectory. To realise the transformation of the metals industry into a circular one, this research aims to create shared futures for the metals industry in the UK by speaking with business organizations, policymakers, industry associations, academia and other stakeholders related to the metals industry ecosystem.

In addition to metal materials development, the ways how businesses and supply chains are operated are also vital. To support Circular Business Models (CBMs), Circular Supply Chain Design (CSCD) Strategies can play a significant role.

• Research question and objectives

Therefore, the research question for this research is:

How to develop CSCD Strategies to support CBMs?

The objectives include:

1)Develop CSCD Strategies framework;

2)Test the framework with three case studies.

• Methodological approach

The approach adopted is mainly case study. Three case studies will be done (three companies in total, each case study is in correspondence with one of the companies). For each case study, there will be three steps. The first step is a workshop for the company to choose from 60 developed CBMs applicable to them in 2050. The second step is semi-structured interviews, from which insights will be obtained about how CSCD Strategies can support the successful adoption of the chosen CBMs from step 1. The third step is the validation workshop, by which the results gained in the former two steps will be shared and validated.

• Preliminary findings

The CSCD Strategies framework has been developed, also sharing the same structure with the Circular Product Design framework.

• Practical implications

This research will provide CSCD Strategies for the metals industry to achieve CE in 2050.

The broken promise of triple bottom line approach in circular economy

Author: Vinayak Sharma

This research primarily calls upon the theoretical claim of the significant stabilizing role of business model design in businesses tackling/incorporating new strategic issues (Bocken et al., 2019). Thereby, we initially scope the role business model design is currently playing in strategizing the Circular Economy (CE) in transitioning organizations. The research will further query the various business model design and innovation framework that have been developed in academia and practitioner tools to strategize the transition toward CE principles and embed circularity into the business strategy of existing organisations.

This enquiry is not intended to interrogate the specific use of framework or tools, but instead how these tools or frameworks engage, include, and develop the three dimensions - economic, environmental, and societal dimensions in its process as part of the Triple bottom line approach (Elkington, 1998). Initial analysis showed that these tools and frameworks are not paying attention to the social dimension by not integrating it in their design process. Furthermore, this research is also particularly important to future research, as there has been no agreement to measure how effective an industry/product is in making the transition from linear to circular approaches, particularly those that affect society (Rivera et al, 2020).

Keywords: Circular Economy, Sustainability, Business Model Design Innovation, Triple Bottom Line, Social Dimension

Foregrounding Political Convictions in the Circular Economy: Social Dimensions and Just Transitions

Author: Jamie Plaatjes

In the last two decades, the Circular Economy (CE) has been a central topic of conversation among academia, governments, policymakers, and corporations. More recently, the focus has shifted to include social issues alongside environmental ones, emphasizing that the transition to a CE must be fair and equitable for all. This paper sets

out to better understand and categorize the prevailing research discourses on the social dimensions of circularity and identify pathways for future research.

By employing critical integrative awareness and adopting the role of a ‘prospector,’ this review synthesizes insights and transfers theories across domains. Findings show that while the social dimension literature addresses important issues like consumer health and safety, human dignity, workers' rights, and food security, it neglects to consider the heterogeneity of political convictions that inform many ideas of just circular transitions. This paper critiques the dominant depoliticization of the circular transition and supports the call for repoliticization. It also examines how a political spectrum helps to understand the diverse conceptions of ‘just transitions’ and uses Amartya Sen's idea of justice to conceptualize these transitions, integrating political, social, and economic perspectives.

Global Circular Economy Trends: Upstream and Downstream Practices Across Sectors

Author: Halid Abu-Bakar

This study examines global trends in circular economy practices, focusing on the "Rs"—Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Recycle, and Recover—and their associated sectors. Data reveals that over 60% of initiatives remain recycle-oriented, with waste management being the dominant sector. Despite the emphasis on recycling, a shift towards upstream practices such as Rethink, Reduce, and Reuse is imperative for achieving a sustainable circular economy.

Analysis of various countries' initiatives highlights significant investments and outcomes. Germany's €73 million investment in circular construction and efforts in packaging to save 4 million tonnes of CO2 by 2050 exemplify effective Rethink and Reduce strategies. The Netherlands' 50 new urban circular projects and Paris's target to recycle 300,000 tonnes of textiles by 2025 underscore the potential of Reuse practices.

Sector-specific trends show advancements in certain industries. The construction sector in the Netherlands focuses on sustainable city planning, while the global textile industry sees significant efforts to reduce landfill waste. Key policy recommendations include tax incentives, subsidies for circular practices, robust waste reduction regulations, and global collaboration to share best practices.

Comparing the costs of recycling versus upstream interventions reveals that upstream initiatives offer greater resource efficiency and long-term savings. Investments in redesigning products and processes reduce raw material needs and environmental costs. Emerging sectors like biotech and energy are also identified as ripe for innovative circular solutions, supported by significant investments such as the EU’s €200 million in biotech projects.

The study concludes with a call to action, emphasising the need for governments, businesses, and consumers to prioritise upstream Rs. Achieving this shift is essential for creating a sustainable, waste-free world, mitigating environmental impacts, and fostering

economic resilience. The overarching message is clear: prioritising upstream Rs is crucial for realising the full potential of a sustainable and efficient global economy.

Over half of the world's population live currently in urban areas with future estimates reaching up to 68% by 2050, with an additional 1.2 million km2 land to be converted to urban areas by 20301. Poor practice or malpractice in the construction industry, lack of established process and lack of practitioners to undertake surveys assessing soils health prior to a development, as well as laws and policies loopholes, are key factors influencing soil loss during construction. Over 90% of the soil coming from construction sites is considered inert, however, millions of tonnes of soils are being disposed of in landfill2.

Urban soils are often overlooked but they play a major role in human lives as the loss of soil functions can have deleterious consequences (e.g. loss of soil's water infiltration function can cause increase flooding risk) and huge financial repercussions. Construction impacts soil health and functionality, due to soil loss, compaction, sealing, contamination, reductions in soil carbon, and soil biodiversity loss. The current approach for assessing the effects of a development on land and soil is restricted to the protection of biomass soil function for food, fibre and timber production3. Other soil functions that are important in local and national context (such as the hydrological function), as well as in the global context (eg. carbon storage and soil biodiversity), of maintaining healthy ecosystems and mitigating climate change, are completely ignored.

The aims of this study are to assess the impact of three major mineral-based construction materials (concrete, brick and plasterboard) on:
1.soil multifunctionality and ecosystem services under future climate events,
2.plant germination, growth and establishment
To address the first aim, mineral-based construction materials (concrete, brick and plasterboard) were added in seven different concentrations (0, 5, 10, 20, 30, 40 and 50%) to soil. The soils were kept in 25°C in three different soil moisture contents (10, 25 and 50%) and were incubated for 5 months. Measurements of six soil physical and chemical properties as well as four microbial traits took place at the beginning and at the end of the experiment. For addressing the second aim, mixtures of the aforementioned mineral-based construction materials were added in three different concentrations (10, 15 and 20%) to pots and two different plant species were used. The plants were grown in greenhouse conditions for 11 weeks. Both above and belowground biomass were measured as well root architecture and traits.

Although the experiments are not yet completed, interesting patterns and differences across the different treatments have been observed with significant increases in pH, depletion of soil bioavailable nitrogen, as well as stunted plant and root growth.
Our results will shed light to the impacts of mineral-based construction materials on soils multifunctionality, provision of ecosystem services and plant growth. Our findings will assist in changing the business-as-usual soil handling from the construction sector, as well as informing policy and regulatory changes in the UK, introducing greater circularity of soils arising from construction.

References
1 https://www.worldbank.org/en/topic/urbandevelopment/overview.
2 Defra (2021) ENV23 - UK statistics on waste data.
3 IEMA (2022) – A new perspective on land and soil environmental impact assessment

Closing the circularity gap in tourism through policy co-design

Authors: Ciara Taylor, Dr Susann Power, Professor Una McMahon-Beattie, Dr Bronagh Magee

The tourism industry has proven to be a catalyst for economic growth, with over 969 million tourists generating over US$7.7 trillion for the global economy whilst simultaneously contributing 7.6% towards global GDP in 2022 (Statista, 2023). Concurrently, the tourism industry has provided great societal benefits, with the creation of 22 million jobs in 2022, a 7.9% increase on 2021 (WTTC, 2023). However, despite its success, Casagrandi and Rinaldi (2002) argue that it is at the environment's expense. Despite the United Nations (UN) calling for the more sustainable development of all sectors through the Sustainable Development Goals (SDGs) (UN, 2015), the continual disregard for the environment suggests that the current linear economic system is outdated (Zhong et al., 2011), with interest peaked towards a circular economic system which promotes resource minimisation (Andersen, 2007).

Circular economy literature has roots in industrial ecology which is the study of material and energy flows through industrial systems (Andersen, 2007). However, the circular economy is mainly referred to in industrial ecology literature within a manufacturing context; and with regards to practice, only three countries have begun to embrace this new economic structure: China, Japan, and Germany (Ogunmakinde, 2019). Despite this advancement, the circular economy remains under-researched within a tourism context (Korhonen et al., 2016), with a keyword search of terms relating to circular economy and tourism yielding only 69 results within nine reputable databases.

In Northern Ireland (NI), tourism spend exceeded £1 billion in 2019 (Tourism Northern Ireland, 2022). However, despite this economic growth challenges to environmental and societal wellbeing, such as pollution, climate change (DAERA, 2019) and low spending on transport remain (Torrance, 2022). To combat this, the NI Department for the Economy published a report – "The Circularity Gap" – highlighting a significant circularity gap within NI. Only 7.9% of the NI economy is currently deemed circular, with the report identifying the tourism sector as one of the most offending culprits of linearity (DfE, 2022). However, the report remains vague on how to improve circularity.

Therein lies the aim of this research: to develop a policy framework for a circular economy within the NI tourism industry; and thus, contribute to the development of circular economy research within tourism literature. It is noted in literature that a circular economy demands a holistic approach, therefore this research intends to adopt a co-design methodology, which is particularly beneficial in a governmental context (Blomkamp, 2018). The data collection will comprise of a range of qualitative methods, including an extensive analysis of relevant NI policy documentation and a series of nominal group technique workshops with policymakers and agents of change within the circular economy and tourism space in NI. The analysed data will then be discussed within a consensus workshop with the aim of co-designing a tourism circularity conceptual framework, which will support the narrowing of the circularity gap within NI and will also be applicable to comparable destinations.

Expanding the Circular Economy: Integrating Rural and Semi-Rural Communities into Meso-Level Sustainability Initiatives

Author: Jessica Robins

Meso-level circular economy (CE) initiatives predominantly focus on urban areas due to superior connectivity and a high density of people, making consumer-facing circular activities more feasible. However, nearly half of the population in England and Wales resides outside of cities, in rural and semi-rural areas. These regions are often neglected in meso-level CE considerations by governments, industry, and academics. Recent studies reveal that individuals in these non-urban areas typically have higher carbon footprints than their urban counterparts. This disparity is primarily attributed to inadequate public transportation and the necessity to travel longer distances for accessing services and leisure activities.

This research investigates the intersection between different community types and the circular economy, aiming to render the often-intangible circular loops within communities more visible. In the UK, a growing movement of community repair initiatives spans cities to villages, serving as pivotal points for grassroots CE efforts. These repair centres not only foster community engagement but also reduce waste by prolonging the life of products through repair and reuse.

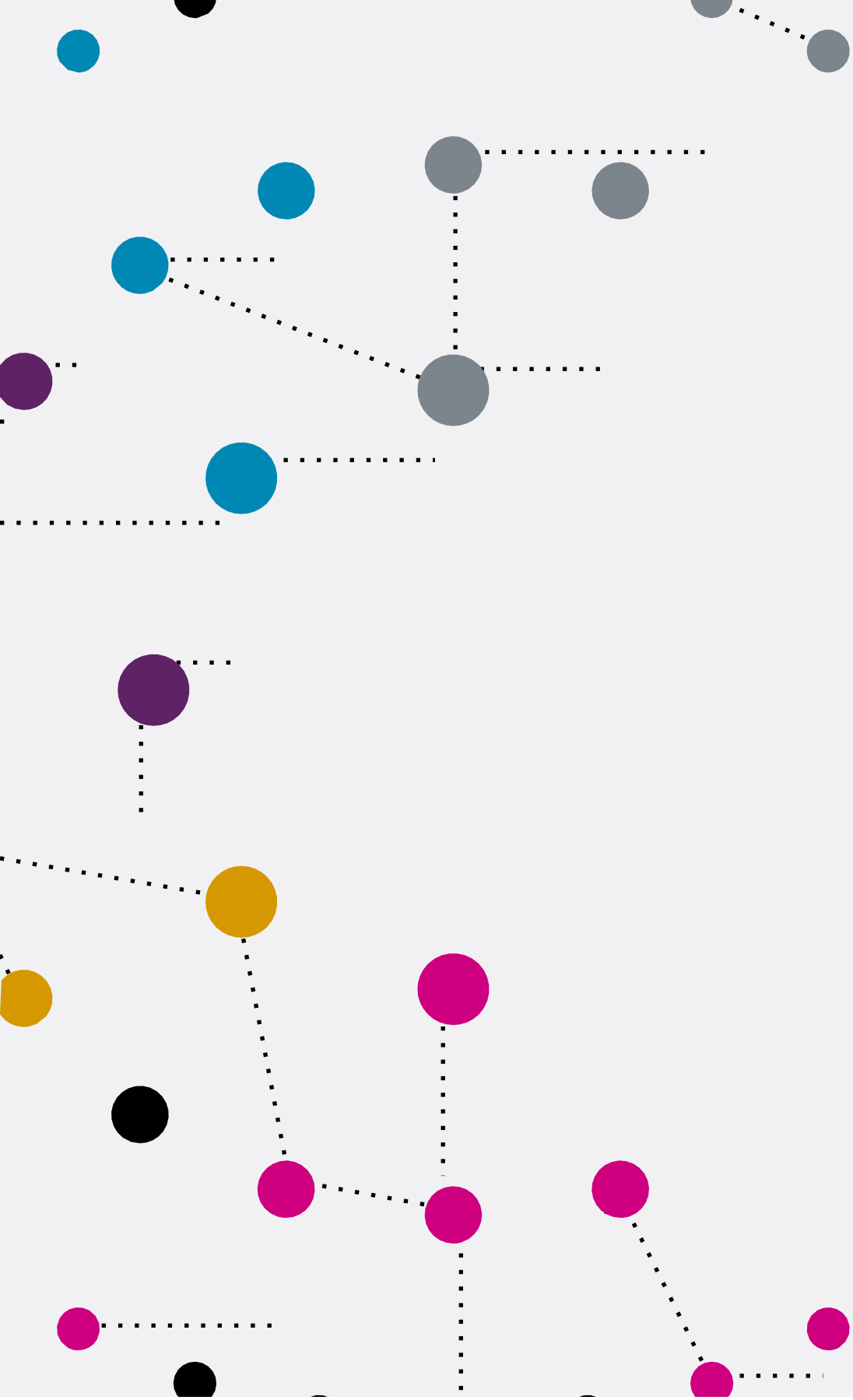
Starting with an in-depth examination of community repair centres, this study will expand to identify other circular and sustainable initiatives within rural and semi-rural regions. The objective is to collaborate with these communities to map out their local circular economies, highlighting their contributions and potential for growth.

The initial phase of the project involves a comprehensive survey targeting volunteers at community repair centres across the UK. This survey aims to uncover details of the volunteers' interactions with the repair centres including motivations for participating in these initiatives, and to identify other existing circular economy activities in their local areas. The survey will gather data on the types of items being repaired, the frequency of repairs, and the demographic characteristics of both volunteers and users of these services.

Based on the survey results, key individuals or gatekeepers in regions with a high concentration of CE initiatives will be approached to participate in a detailed mapping exercise. This exercise will delineate the connections among businesses, organisations, and community groups focused on the circular economy. It will also identify gaps and opportunities for enhancing local CE activities.

The research will employ participatory research methods, to gain deeper insights into the dynamics of these initiatives. By understanding the challenges and successes experienced by rural and semi-rural communities, the study aims to provide a comprehensive view of how these areas contribute to and can further develop sustainable practices.

The findings of this research will be instrumental in informing policymakers, industry leaders, and academic researchers about the potential for expanding circular economy



CE-HUB
UKRI National Interdisciplinary Circular Economy Research

NICER PROGRAMME

University of Exeter

UK Research and Innovation