Sustainable Industrial Futures

Expressions of Interest

Introduction

Following the closing of the Expressions of Interest stage for the Sustainable Industrial Futures funding opportunity, these are being made available in order to enable applicants to facilitate and broker introductions and relationships to create more inclusive and robust full applications, as well as merge and come together where appropriate.

The expressions of interest are below, they are ordered alphabetically by lead investigator.

Contents

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Vision - This is one of three complementary EoIs submitted through The University of Manchester's Dalton Nuclear Institute, this one in collaboration with the National Nuclear Laboratory.

Maximising the sustainability of nuclear energy is only possible by fully understanding the impacts of the whole nuclear fuel cycle and considering the advantages and disadvantages of different options. Factors to consider include minimising emissions, the best use of natural resources, environmental impacts, societal benefits, economic competitiveness, energy security, and security/proliferation concerns.

Nuclear energy is low-carbon and can thus make a major contribution to decarbonisation. Nuclear is somewhat unusual in that the energy generation entity (i.e. the power plant) needs a substantial fuel cycle infrastructure supporting it. Ores must be extracted and processed, fuel enriched and fabricated, and radioactive wastes managed. The latter is a major issue for public acceptability of nuclear, and potentially limits its future role. The fuel cycle is therefore of crucial importance when considering how to improve nuclear sustainability, and a holistic strategy across the energy sector is needed.

As an example of the decisions faced, multiple options exist for handling spent fuel. The current "once-through" approach sends spent fuel directly to storage, with eventual disposal in a waste repository. Many recycling options are possible as alternatives. A "twice-through" approach reprocesses fuel, extracts fissile materials and recycles them into new fuel, reducing the waste volume. Going further would involve multiple recycles in "fast" reactors to maximise the energy from fuel. This could potentially release all available energy from mined uranium, compared to ~1% with the once-through approach.

The current once-through approach was adopted based on short-term economics, and as nuclear energy must be competitive with other forms of low-carbon energy on economic as well as environmental grounds, research is needed to establish which fuel cycle is the best to pursue in the longer term. All practicable options need to be investigated as nuclear plants are long-lived entities and decisions will have consequences for the next century and beyond.

The above example concerns the "back-end" of the fuel cycle (i.e. post-reactor), but questions on the "front-end" must also be answered. Advanced reactor systems will soon be brought online, which may have different fuel specifications as well as waste impacts. Nuclear's biggest environmental impact is from uranium mining, so the impact from finding ways to make this more sustainable would be considerable – and recycling spent fuel would reduce the total emissions/kWh to very low levels.

The vision of the proposed programme is to provide a lifecycle sustainability assessment framework that addresses the wide range of societal, technical, economic and environmental considerations arising from the fuel cycle and identify optimal options. This would focus primarily on fuel cycle technologies and approaches for spent fuel recycle and explore opportunities to integrate with other industrial sectors in resource recovery and materials re-use (e.g. isotopes for medical applications). This will feed into a broader sustainability appraisal of different nuclear futures, incorporating considerations for different reactor systems in line with the holistic strategy needed across the sector.

Opportunities for collaboration - Most of the skills which will be needed exist between NNL and The University of Manchester, however there is a need for data which could come from prospective partners. NNL and Manchester have existing tools which could benefit from such data.

Economics is a significant part of sustainability assessments, so considered assessments and data would be valuable. The Energy Systems Catapult models scenarios for nuclear in the over UK energy mix, and there may be further needs to collaborate in this area to define the nuclear fuel cycle needs.

Nuclear fuel cycles are large and complex and the existing supply chain needs updating. If greater recycling is to be pursued, new parts and infrastructure would need to be created. Insights from members of the supply chain on the practicalities of delivering a functional fuel cycle would be beneficial.

Non-proliferation and security issues play a role in sustainable nuclear, and expertise in these areas would be of value.

Expertise in sustainability assessments focussing on materials recycle and resource recovery in non-nuclear sectors would also be useful.

Relevant Publications:

Dalton Nuclear Institute (2021); https://documents.manchester.ac.uk/display.aspx?DocID=55791

Dalton Nuclear Institute (2023); https://documents.manchester.ac.uk/display.aspx?DocID=68958

K. Dungan et al. (2021); DOI 10.1016/j.energy.2021.119826

K. Dungan et al. (2024); DOI 10.1016/j.nucengdes.2024.113259

R. Taylor et al. (2022); DOI 10.3390/en15041433

R. Taylor et al. (2022); DOI 10.3390/en15072472

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Vision - True sustainability requires a major industrial shift from current feedstocks and supply chains. Adoption of new technologies and regulatory frameworks is essential to drive appropriate outcomes and avoid unintended consequences.

A comprehensive national strategy is needed to translate sustainability concepts into practice. This strategy should ensure the UK hits net zero targets while making it an attractive place for industrial investment and growth.

Previous net zero approaches failed to address scope 3 emissions, leading to complex global supply chains that outsourced the problem, resulting in the loss of R&D-intensive industries, economic growth, jobs, and investment.

Transitioning UK manufacturing away from virgin fossil fuels and feedstocks will be challenging. Existing interconnected systems optimized for price, speed, and flexibility have developed over decades. The necessary transformation will require significant capital investments over the next 20 years, likely increasing consumer prices until new processes are scaled and optimized. Clear government policies and coordination across supply chains are crucial. A national plan should address both current and emerging industries to meet 2050 societal needs.

Key Needs:

- Industry-led application of scientific research and innovations in a coordinated manner to maximize impact.
- Implementation of new tools and techniques (e.g., LCA) through coordinated activities to drive effective and economically beneficial sustainability without losing industry.

How Would We Work?

SCI would establish a Centre for Sustainable Innovations to bring together industry, academia, government, regulators, and regions to develop and implement effective strategies for building a sustainable industry that addresses net zero while also promoting growth and investment in the UK. The centre would:

- Provide a networking forum and facilitate knowledge transfer through conferences, events, and publishing.
- Fund techno/economic studies to assess the best ways to build new supply chains in critical sectors in the UK.
- Convene interdisciplinary research into new feedstocks and systems by connecting academia with potential industrial partners and showcasing technologies from startups and SMEs.

- Build collaborations to drive the adoption of sustainable technologies across existing and new supply chains.
- Support demonstrator projects, such as using captured carbon as an industrial feedstock.
- Shape and draft new regulations to assist both sustainability and economic growth, and develop standard methods for key tools like LCA.
- Disseminate knowledge through conferences, events, workshops, and publishing.
- Provide training and education to the next generation of academic and industrial STEM professionals on achieving sustainability goals.
- Support the scale-up of environmentally beneficial technologies in partnership with industry.

About SCI

- Independent
- Established in 1881
- Scientifically credible (scholarly publisher)
- Industrially credible
- Interdisciplinary
- Significant network in the UK and globally
- Cross-sector
- Established Industrial Strategy Board on Sustainability

Sectors Covered:

- Energy
- General chemicals
- Materials
- Life sciences
- Consumer products
- Transport (including auto/aero)

Disciplines Covered:

- All biosciences and chemistry-related sciences

-	Digital
-	Economics
-	Regulatory

Opportunities for collaboration - We think it is important to start from the challenge, and identify and validate the required science, work to develop into resilient and commercially viable technology and then implement this through our network of companies.

SCI has a broad range of industrial sector coverage – the widest of any other body in the UK. We would utilise our existing partnerships in addition to the co-leaders to help support the centre. Our partnership schemes include other large industrial companies, SMEs, universities and associate organisations such as IP firms.

We would welcome new partners from all industry types however and would like to use this centre to expand the network, partnering with new universities and industry in some of the target areas we have less footprint in such as food and drink (where historically we have focused on agrifood). We already have a strong footprint in chemicals and pharmaceuticals, and on Flue2Chem (an Innovate UK funded demonstrator project) have involved paper/pulp as well as metals and minerals in our community.

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Vision - Title: AI-Driven High-Value Complex Multi-Material (CMM) Recycling and Reuse (AIM-High).

Development of an AI-Driven Autonomous Cell for Robotic Sorting and Disassembly of High-Value Complex Multi-Material Parts to Enhance Circular Economy in the UK

Vision:

AIM-High will revolutionise the recycling and reuse of high-value complex multi-material (CMM) components through the development of an AI-driven autonomous cell that employs advanced robotics for efficient sorting and disassembly. By promoting circular economy practices, AIM-High envisions a future where material recovery is maximised, environmental impact is minimised, and manufacturing processes are inherently sustainable.

Aims:

(1) Enhance Circular Economy Practices: Develop an autonomous system that significantly improves the recycling and reuse rates of CMMs, ensuring that valuable materials are recovered efficiently and reused effectively. Implement a closed-loop design process to optimise component disassembly and recyclability for future iterations.

(2) Integrate Advanced AI and Robotics: Create and integrate AI-driven sorting algorithms and robotic disassembly mechanisms into a cohesive unit capable of handling the complexities of CMM parts.

Implement a Digital Product Passport to maintain quality assurance and traceability across multiple material lifecycles.

(3) Promote Environmental Sustainability: Reduce the environmental impact associated with traditional end-of-life (EoL) disposal methods by optimising processes for material recovery and recycling. Develop sustainable protocols for managing non-reusable components.

Potential applications (Overview of Sectors and Disciplines Covered):

(1) Light industry products - Business-to-Customer (B2C)

- Municipal waste management: Resource recovery to support a circular economy. e.g. Chemical reclamation of small batteries

- Consumer Electronics: Tackle the complexities of disassembling and recycling multi-material electronics, promoting sustainable e-waste management.

(2) Heavy industry goods - Business-to-Business (B2B)

- Automotive: Address the recycling and reuse challenges of components made from diverse materials, such as batteries and composites used in vehicle bodies and interiors.

- Aerospace: Focus on high-performance CMMs, ensuring that valuable aerospace materials are efficiently disassembled and repurposed.

- Large EV vehicles (lorries, trains): Enhance the recycling of complex materials used in large EV vehicles for mining and other heavy industry.

Disciplines:

1. Artificial Intelligence and Machine Learning:

Develop algorithms for identifying and classifying CMMs, leveraging machine learning techniques to improve sorting accuracy.

2. Robotics and Automation:

Design and programme robotic systems to perform precise disassembly operations, ensuring that reusable components are not damaged.

3. Materials Science:

Understand the properties and behaviour of various CMMs to inform the design of effective sorting and disassembly processes.

4. Systems Integration:

Combine AI and robotic technologies into an autonomous cell that operates seamlessly, including software development for integrated control and communication.

5. Sustainability and Environmental Science:

Design for circularity and define feedback mechanisms including the development of Digital Twins (DT) and Digital Product Passport (DPP). Reverse manufacturing capability for the re-utilisation of core components. Develop sustainable recycling protocols and assess the environmental impact of the autonomous cell's operations. LCA & LCC in line with design for circularity assessments.

Methodology:

(1) AI and Machine Learning (ML) Development: Collect and annotate datasets of CMMs. Train and validate ML models for accurate material identification and classification.

(2) Robotic Design and Programming: Design robotic arms and end-effectors tailored for CMM disassembly. Programme robots to perform precise operations for material separation.

(3) System Integration: Develop software for integrating AI algorithms with robotic controls as well as DT. Establish protocols for autonomous operation, including safety measures and feedback mechanisms to influence future component designs. Validate DPP.

(4) Testing and Optimisation: Conduct rigorous testing with a variety of CMM parts. Analyse and optimise system performance to maximise material recovery and recycling rates.

Expected Outcomes:

- A fully operational, AI-driven autonomous cell for sorting and disassembling CMM parts with high efficiency and precision.

- Comprehensive networks addressing input, output, and critical activities for each cell requirement.

- Enhanced design for disassembly and circularity, resulting in improved recycling and reuse rates.

-A scalable solution adaptable to various industries, promoting widespread adoption of circular economy practices.

- A significant reduction in the environmental impact associated with single-use and EoL waste.

Potential Benefits and Societal Impact: AIM-High offers substantial environmental benefits by diverting up to 90% of CMM components from landfills, reducing millions of tons of waste and cutting e-waste by 70%. By enhancing material recovery, AIM-High can lower carbon emissions from raw material extraction and processing by 50% and achieve up to 60% energy savings in manufacturing. The initiative can recover up to 85% of valuable materials, significantly reducing the need for virgin material extraction and lowering energy usage in re-manufacturing by up to 40%. AIM-High's recycling practices can also decrease toxic substance release by 80%. AIM-High aims to boost the use of recycled materials in manufacturing by 30% by 2030 and extend product lifecycles through effective recycling, leading to a 25% reduction in the environmental impact of UK manufacturing processes over the next decade. These benefits underscore AIM-High's role in promoting sustainability, waste reduction, resource conservation, and circular economy practices.

Conclusion: AIM-High will revolutionise the EoL handling of CMM components by integrating cutting-edge AI and robotics with a DPP system. This groundbreaking initiative will substantially contribute to the UK's circular economy by promoting sustainable manufacturing practices and minimising environmental harm.

Opportunities for collaboration - To bolster the AIM-High bid and maximise the programme's impact, we seek strategic partnerships across key sectors. By combining our strengths with complementary expertise, we will accelerate technological advancements, expand our resource base, and expedite the development and deployment of our AI-driven autonomous recycling cell.

(1) Advanced Manufacturing and Robotics: Expertise: We seek partners with expertise in robotics engineering, automation, and manufacturing technology to design and develop the robotic mechanisms for disassembly, sorting, recycling, and reuse within our autonomous cell. Examples: Specialists in industrial robotics, automation systems, and smart manufacturing solutions.

(2) Artificial Intelligence and Machine Learning: Expertise: Collaboration with AI experts is essential for developing sophisticated algorithms for material identification, classification, sorting, and optimising recycling and reuse processes. Their expertise will help refine our machine learning models for improved accuracy and efficiency. Examples: Research institutions, AI software developers, and tech companies focusing on machine learning and computer vision.

(3) Materials Science and Engineering: Expertise: Partners with a deep understanding of material properties, particularly CMMs and batteries, will support the development of effective disassembly and recycling processes, ensuring methods used are safe, efficient, and conducive to material recovery and reuse. Examples: Universities, research centres, and companies with expertise in materials science, chemistry, and engineering.

(4) Sustainability and Environmental Management: Expertise: Experts in sustainability and environmental science supporting the development and implementation of recycling and reuse protocols minimising environmental impact. Promoting circular economy practices and reducing waste. Defining policy & strategy to support future legislation & regulation will enable long-lasting change. Examples: Environmental NGOs, Public Sector, sustainability consultancies, and environmental science academics to influence policy, strategy & legislation.

(5) Battery Technology and Recycling: Expertise: Experience in battery technology, recycling processes, and safe handling procedures will be vital for addressing the battery recovery, recycling, and reuse challenges. Examples: Battery manufacturers, recycling companies, and research organisations focusing on battery technology.

(6) Heavy and Light Industry Supply Chain Partners: Expertise: Engaging with industry stakeholders from a variety of sectors will provide insights into real-world applications and challenges, tailoring our solution to meet industry-specific needs and ensure the scalability of our technology. Examples: Industry associations, manufacturing companies, and supply chain managers within the targeted sectors.

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Vision - Our vision is to facilitate the UK's transition to a sustainable industrial ecosystem, by developing new analytical tools, strategies, and technologies. An ambitious, innovative national systems modelling approach will lie at the core of the work, which we will use to integrate outputs from the centre's diverse workstreams. Ultimately this will provide a new approach for evaluating the benefits, synergies and tradeoffs of different net zero industrial transition pathways across multiple spatial scales and sustainability indicators. We will apply our methodology to regional case studies and to the UK as a whole, working closely with stakeholders to demonstrate its utility as a platform for improving partnerships and engagement among academia, industry, government agencies, the public, and key decision-makers, in designing and evaluating solution narratives.

Specific research aims include:

A1: Develop a novel multi-scale systems modelling methodology broadly based around a Water-Energy-Ecosystem-Bioresources Nexus approach, that can evaluate the impact of industrial transition narratives on multiple sustainability indicators across a range of spatial scales. This will build on previous work focussed on maximising the benefits of decarbonisation interventions by integrating land allocation optimisation approaches with techno-economic and lifecycle models of engineering systems. While quantitative modelling will form a major part of this activity, an important aspect is that we will also develop novel qualitative approaches aimed at incorporating stakeholder constraints and perspectives directly into the model application process. While highly valuable in its own right, the modelling activity will also provide an over-arching integrating function spanning all the Centre's activity. It will also provide a mechanism for drawing in wider set of collaborators, particularly those with policy, planning and strategic investment interests, as we apply the tool to stakeholder defined case studies at regional and national scales.

A2: A workstream entraining key technology domain experts will develop a comprehensive understanding of the capabilities and limitations of key established and emerging sustainable industrial technologies applicable to each sector, along with their potential for improvement. We envision a mix of industrially led activity focussed on the potential for learning-by-doing for more established technologies, with academic-led activity focussed on emerging concepts encompassing both experimental and computational research.

A3: Ecosystem assessment & modelling workstream. Initially this will focus on identifying the most important gaps in understanding of the ecosystem impacts of (presumed) more sustainable industrial approaches, and then transition to characterising poorly understand impacts via a tailored combination of field studies, experimental and modelling research. Activity will be coordinated with that of aims 2 and 4 to ensure coherent technical and environmental datasets across technologies are produced.

A4: Life-cycle, circularity, resources and added-value workstream. Again co-ordinated tightly with A2 and A3, this workstream will focus on data and methodologies for understanding the GHG, materials requirements and added economic value of key sustainable industrial approaches. The emphasis will be on characterising synergies between industrial sectors and the infrastructure, both emerging and established, essential to exploiting them (e.g. heat storage and upgrading, materials recovery). Resource constraints, particularly where there are multiple competing uses across sectors (e.g. UK biomass) or limited global supplies (critical materials) will be accounted for.

A5: Policy, international and stakeholders workstream. Deploying our modelling methodology to develop and evaluate possible narratives for sustainable industrial future in UK will be a key output. This workstream will work with expert stakeholders to formulate and capture possible narratives that will be evaluated as the centre progresses. While the Centre has a UK focus, much of our data and many of our methodologies will have potential application internationally – we will develop international collaboration to demonstrate this.

The integrated approach at the core of our proposed Centre's work has potential to cover all industry sectors, but necessarily the level of detail for each will differ according to available resources, data and expertise. We will finalise the coverage in the light of further discussions with collaborators but as a minimum we plan to include metals/minerals, chemicals, food, paper, ceramics and glass to some degree. We will also include aspects of the energy and transport sectors in our scope, as there are excellent potentials for synergies with the core industrial sectors. Similarly a strength of our proposed Centre's approach is the ability to integrate multiple disciplines in to strategy, investment and other decision making processes. Again coverage will be fully defined as the proposal develops but will include techno-economics, life-cycle analysis, whole systems optimisation, engineering systems/design, environmental economics, land-use analysis and ecosystems analysis.

Opportunities for collaboration - We welcome contact from all prospective partners from across the industrial, policy and academic sectors.

Our consortium has access to a strong set of academic expertise across the disciplines we currently plan to entrain. However our integrative approach is highly flexible, and readily able to bring in relevant researchers from other disciplines who are willing to contribute to our overarching framework in some way.

We are interested in partners with specialist technology expertise that are able to contribute to individual projects fulfilling aims 2 & 4, from both academic and industrial backgrounds. Collaborators with test, demonstration or commercial-scale facilities that are willing to produce and share information are particularly welcome. This extends to sharing experiences of motivations, challenges and benefits in addition to quantitative data on costs, performance and emissions etc.

Similarly with aim 3, we are interested in collaborators willing to share expertise in specialist aspects of ecosystem impacts. This extends both to contributing knowledge from previous research, as well as possessing facilities that can support new projects that might be supported by our proposed centre.

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Vision - Title: Manufacturing FIRST Flagship

(Manufacturing for the Future of Industry and Responsible and Sustainable Technologies)

Background: This flagship has a vision to reimagine and make possible a future industrial system that is technology innovation led, zero carbon, profitable and enables manufacturing growth in the

UK. To achieve this, we are making the supply chain our focus. Material and component suppliers are at the interface between energy intensive primary manufacturers and the technology owners, acting as a cross-sector foundation and this is where change needs to start to drive broader sustainability and circularity. Delivering this vision needs a global, cross-sector, connected system that can link sustainability innovations in design, use, materials, production processes, operations, waste management, supply chain, energy, utilities and digital technologies. This will enable rapid, evidence-based responsible decision making by government, industry and customers. Policies and standards can build on this to firmly incentivise adoption of innovations, circularity and a sharing of risk and value. Right now, the control of change in the UK is at the individual and firm level, with consumers making more responsible choices and champions within firms interpreting and acting on sustainability goals. Internationally, we see more concerted cross-sector initiatives but here there are mostly focused and disconnected clusters. World-leading UK research is also fragmented, found in silos of expertise across management, technology and policy. This limits our ambition for sector-wide change and importantly the rate of change.

Aims: There are three aims for this Sustainable Industrial Futures Flagship.

Firstly, we aim to convene and connect expertise in a whole-system entity that generates world-leading research outputs at the interfaces across the value chain. The UK has invested significantly through the initiatives and programmes named in this call and in many more smaller scale projects. A single flagship will place and link the developed expertise within a new connected system to ensure value capture.

Secondly, we aim to create a flagship that will learn from established firms but prioritise change in new, emerging or rapidly growing manufacturing. The barriers to change for established firms are enormous but the research focus has always been on reducing their emissions and then eventually advising new firms how to translate the learnings. This creates a risk of remaining completely static and being too late to influence manufacturers of the future or to help them consider the broader emerging sustainability goals beyond a reduction in emissions. The Flagship will answer this need through acting as a national convening power for emerging manufacturers. There will be two sector case studies initially, Healthcare and Agri-Food. The supply-chain focused systems approach will enable more effective decision making and lead to framework and model development that will expand to other sectors. With our large network of partner firms, this will ensure progress in linking climate tech, finance, policy, local government and behavioural responses. This is critical to ensure progress towards responsible manufacturing without unintended consequences.

Thirdly, such a significant investment needs to deliver world-leading research, real impact, and inspire the acceleration of change. With our large network of partners, the available knowledge, the technology-focused research that is planned, and our project management toolkits the flagship will deliver a 20% decrease in UK CO_2 (eq.) emissions by 2030. The first noted case study is manufacturing for Healthcare. With the example of medical devices (among other planned areas), there is a target to only procure such technologies into the NHS after 2030 if they meet Net Zero. Secondly, consumed products, end-of-life waste and their supply chain are 70% of the sector emissions, which is almost 6% of UK emissions. This is on the cusp of booming with a strategic growth of the £27bn medical device sector and so change is needed now. The second case study noted earlier is Agri-Food, where agriculture is responsible for 10% of UK emissions but many are highly potent nitrous oxide and methane. Food system emissions are closer to a third of UK emissions overall. These have been identified as high risk high reward challenges to solve where a whole-system research approach is needed, and as a flagship we can drive real change with our cross-sector partners. This target is unique and ambitious among research initiatives and will be an international benchmark to demonstrate the feasibility of translating findings and compressing the timescale of change, and will act as an incentive to convene additional case studies. We plan on further expanding to additional case studies and would highly value expertise in Quantum Technologies, Automotive, and the Rubber, Plastics and non-metallic Minerals sectors.

Opportunities for collaboration - 1. As our first two planned case studies are in the Healthcare and Agri/Food sectors, we welcome additional expertise and experience across the value chain in these sectors.

2. It is especially challenging and important to carry out research into future manufacturing business models with the introduction of technology innovations to support sustainability. We are keen to reach out to complementary expertise in the area of innovative business model development and techno-economic analysis.

3. We plan on further expanding to additional case studies and would highly value expertise in Quantum Technologies, Automotive, and the Rubber, Plastics and non-metallic Minerals sectors.

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Vision - The Coal Authority has the capacity to annually treat 220 million m3 of water in 80 operational treatment schemes and will potentially treat an additional 20 million m3 per annum through expansion of saline and metal mine water treatment programmes. This is approximately 2-3% of total abstracted volumes of surface and groundwater for domestic, energy, agricultural and industrial use in the UK, which was between 8 billion and 12 billion m3 between 2000 and 2018.

As water becomes an increasingly scarce resource and with ambitious decarbonisation plans to reduce industrial emissions by >90% by 2035 relative to 2022 levels there is an opportunity to utilise the Coal Authority's operational capacity, and integrate sectors at a systems level to secure resilient, sustainable, low carbon sources of water, energy and raw materials. This will enable the shift of UK industries to net zero, increasing natural capital and driving the recovery and revival of the country's deprived, post-industrial heartlands through creating new, sustainable employment. The utilisation of these resources prevents them from entering and contaminating current water resources.

The key primary aims of the project are to build a centre of excellence to support industrial decarbonisation by optimising current and developing novel:

- Low or negative carbon, and low or net-energy positive mine water desalination methods, integrate these with waste water treatment, generate by-products for utilisation in green energy production, energy storage, and the manufacturing and agricultural industries
- Hydrogen production, transportation and storage technologies and integrate these into the energy and industrial network, mindfully considering health and safety risks
- Technologies for waste water treatment utilising by-products and sustainable, nature-based solutions to mine water treatment
- Sources and technologies for extraction of sustainable critical and valuable mineral resources through valorisation of mine water, waste water and waste materials from treatment technologies
- Functional, sustainable processes for generating both raw and high-purity materials for energy storage, industrial chemicals, and manufacturing industries including steel, ceramics, glass, paper and vehicles
- Low energy, low carbon routes of resource used by the agricultural industry through utilising mine water, waste water and treatment by-products as sources of water, nutrients and land improvement agents
- Carbon sequestration methods and technologies utilising mine water, waste water and waste materials, and through nature-based solutions deployed in mine water treatment
- Methods of utilising former-mining infrastructure and waste materials for heating, cooling, energy production and storage and integrating these into energy networks for domestic and industrial use

- Modelling and AI water quantification methods for effective planning of water utilisation to appropriately balance industrial needs against natural capital enhancement and preservation, including assessment of social and environmental lifecycle impact
- Decision evaluation and cost-benefit analysis techniques to fully understand circular economic approaches and to maximise profits, industrial integration and environmental management
- Learning opportunities for effective reindustrialisation to maximise Inclusive social, economic and environmental benefits to communities in post-industrial regions

This project will:

- Deliver resilience by reuse of water from the UK's mining heritage and current industry
- Exploit untapped sources of raw materials reducing reliance on imports
- Promote sustainable use of resources for UK industries by developing innovative, low carbon approaches to resource extraction, production and use
- Drive integration of physical assets, processes and information within the wider context of current and nascent industry and infrastructure
- Evaluate processes and requirements at a systems level for maximum economic, environmental and social gain realising benefits across multiple aspects of government policy, over the medium-to-long term.

Opportunities for collaboration - We would seek to gain complementarity by understanding the requirements of chemical and manufacturing industries that would make use of by-products, waste-streams and water generated through desalination, water treatment, component extraction, and feedstock and functional material generation.

Provision of additional expertise would help us to understand:

- The volumes and chemical purity of treated water used by paper, glass, ceramics, fertiliser and steel industries – this would allow us to generate industry-appropriate water types through tailored treatment approaches
- The nature, quantity, and purity of materials required for paper, glass, ceramics, fertiliser and steel industries – this would allow us to generate industry-appropriate feedstock and functional materials through selective metal enrichment, extraction and product-formation processes
- Materials currently used in industry for which there is potential for substitution for lower-carbon, UK-produced alternatives

In order to maximise the potential for circularity, build resilience into the systems level approach and maximise benefits additional expertise would also help us to:

• Link additional industrial waste-streams demonstrating valorisation potential to our processes for technology/process improvement, carbon or energy reduction, and other value-adding opportunities – these would primarily be from glass, ceramics, paper, fertiliser, steel and other manufacturing industries (e.g. agricultural) • Link, where possible, our energy generating systems to local and regional hubs for efficiency – these would include electrical, mechanical/process and civil engineers • Partnering with water companies would enable us to develop applicable low carbon and sustainable solutions to enable them to execute their statutory duties • Understanding the requirements of their domestic and industrial customers would support the practicability of solutions • Reuse of water company waste streams would increase the impact of other relevant solutions.
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Professor Margaret Graham University of Edinburgh

Co-leads - Professor Margaret Graham (Personal Chair in Environmental Geochemistry) - expertise in process-based understanding of contaminant behaviour, fate and impacts upon ecosystems and human health. She has acted as International Expert to the US EPA on the fate of lead in the environment, is the Director of the International Institute for Environmental Studies, and works with water authorities (e.g. Scottish Water) and regulators (e.g. DWQR, SEPA) to inform solutions for climate- and contamination-related problems. She holds NERC Global Partnership funding on Critical Minerals, bringing together key partners and stakeholders in South America, Australia, Canada and South Africa. In addition, she holds Scottish Government and Social Sciences and Humanities Research Council (Canada) funding to bring together leaders of vulnerable communities and researchers across the sciences and arts for inclusive discussions leading to actions around social justice and a globally responsible transition to net zero.

Professor Jason Love (Personal Chair in Molecular Inorganic Chemistry) – expertise in sustainable chemistry and energy, ligand and macrocycle design and supramolecular catalysis. A key theme of his research is on metal recovery from ores and from secondary sources (the “urban mine”). This relies on reagents that can recognise one metal from another and his group develops new reagents based on fundamental coordination and supramolecular chemistries that can recover selectively base, platinum-group, or rare-earth metals from a variety of sources, including e-waste. These new reagents include anion receptors that promote the selective and tailored precipitation of metals from acidic solutions and pre-organised receptors for the highly selective separation and precipitation of rare-earth and actinide anionic compounds. Importantly his group have just published the first application of supramolecular anion recognition chemistry to the recovery of REEs from real-world magnet scrap and ores and demonstrate its integration into a complete recovery process, from raw material through to the purified rare earth oxide product. He holds funding from NERC and EPSRC and his projects have significant input from end-users such as mining companies, refiners, reagent suppliers, and SMEs.

Professor Louise Horsfall (Personal Chair of Sustainable Biotechnology) - expertise lies in synthetic biology and biotechnology with especial focus on how these areas might make manufacturing more resource efficient and help move us towards a more sustainable, circular economy. In addition to funding from IBioIC on bioprocessing scale-up, she also holds awards from UKRI (BBSRC, EPSRC, Innovate UK), Faraday Institution, DSTL, Industry Strategy. She recently won the grand prize in the "Top 10 Global Science and Technology Innovation Awards" at the 2050NOW La Maison's global trends forum.

Professor Charles Cockell (Personal Chair in Astrobiology) – expertise in astrobiology, extreme conditions and the physics of condensed matter. He has carried out research under space gravity systems to develop ways of sourcing metals and minerals essential for survival in space. On the basis that bacteria could one day be used to break rocks down into soil for growing crops, or to provide minerals for life support, matchbox-sized biomining reactors containing small pieces of basalt, a low-grade material submerged in bacterial solution. His research is supported by the UK Space Agency and European Space Agency, The Science and Technologies Funding Council (UKRI) and companies such as Kayser Italia and he is currently exploring the potential knowledge transfer to improve metal recovery methods in terrestrial (including industrial) settings.

Professor Ondrej Masek (Personal Chair of Net Zero Emission Technologies) – expertise lies in developing technologies for biochar production and utilisation of by-products (liquids and gases) for bio-fuels and bio-energy generation and in advanced CO2 capture and storage technologies. He has extensive experience of working in partnership with industry, e.g. using pyrolysis to take commercial apple production to net zero. As Director of the UK Biochar Research Centre, he brings exceptional insight into the status of current markets for biochar and relate carbon removal, key opportunities and potential barriers. These insights include socioeconomic considerations - carbon finance, technology risk, the evolving regulatory context and work related to quality protocols.

Professor Xianfeng Fan (Chair of Particulate Materials Processing) – expertise lies in carbon capture and separation processes and in reaction engineering and catalysis. His recent work focuses on the use of AI to accelerate the development of advanced materials such as metal-organic-frameworks compounds (MOFs) for highly selective separations of carbon-containing gases. His group is exploring the potential applications of pure methane streams for hydrogen generation and connected bioengineering groups are developing methods to produce industrially relevant carbon feedstocks from captured CO2. In addition, he also works on sustainable synthetic methods for hyper-crosslinked polymers (HCPs) as highly stable and low-cost materials for gas storage, catalysis and carbon capture. He holds funding from EPSRC, EU H2020 RISE and from JD New Materials Company Ltd.

Vision - Our vision is to create an internationally leading research-and-industry partnership focused on accelerating the adoption of climate- and environment-smart industrial best practises, to reduce the impacts of carbon emissions and industrial wastes upon our environment and ensure a socially just net zero transition for all.

The UK net zero by 2050 strategy sets out the path to reduce carbon emissions from key sectors including industry. In parallel with the development of hydrogen-based fuels and other renewable energy and storage systems, AI can play a key role in driving the development of efficient, low-cost advanced materials for highly selective carbon-containing gas separations that can be coupled to both hydrogen generation and to bioengineered feedstocks for sustainable industrial developments. For sectors that are more difficult to decarbonise, there is still a need for both nature-based solutions (e.g. afforestation and peatland restoration) and scalable technologies (e.g. enhanced mineral weathering and mineral waste-biochar sequestration) for carbon-offsetting.

The technological changes required to deliver net zero will inherently require a rapid increase in non-carbon resource supply and the demand for technology-critical minerals is set to quadruple by 2040. In just a few decades, this level of demand will also outstrip available mineral supplies and there is an urgent need for upscaling and translation of innovative research to deliver circularity in metal supply chains to secure future industrial and economic growth. There is great potential in both biological and chemical approaches but perhaps even moreso, there is opportunity for shared learning from industry-supported exploratory space biomining where the focus is on high efficiency elemental recovery from low grade resources.

Current linear supply routes generate large quantities of highly complex and potentially toxic wastes, often in locations that are remote from industrial centres. These have an unjust impact on marginalised communities, their water supplies and sensitive ecosystems. There is an urgent need for novel, holistic and integrated approach where research, industry and policy makers work in partnership to deliver sustainable and socially responsible decarbonisation.

At the University of Edinburgh and linked partners (including University of St. Andrews), we have a critical mass of transdisciplinary researchers across the sciences (biology, chemistry, environmental, ecology, informatics, physics and astronomy), engineering, geohumanities and social sciences working together with local scale-to-global industry and agencies, environmental regulators and government partners.

Our aims are to : (i) exploit AI to drive the development of advanced materials (for decarbonisation, new fuels and new feedstocks); (ii) trial nature-based solutions and technologies for carbon-offsetting at scale; (iii) accelerate the wide-scale adoption of fit-for-purpose sustainable biological and chemical methods to support a critical mineral-based circular economy; (iv) explore knowledge sharing from space biomining technologies for adoption as best practise for terrestrial resource recovery; (v) inform environmental monitoring protocols, regulation and policy development through process-based understanding of environmental contaminants and their impacts upon biodiversity and human health.

Opportunities for collaboration - We have expertise across the sciences (biology, chemistry, environmental, ecology, informatics, physics and astronomy), engineering, geohumanities and social sciences working together with local scale-to-global industry and agencies (e.g. Anglo American, UNDO, Rio Tinto, Kingrose, European Space Agency, Kayser Italia, Institute of Mining, Minerals and Materials, Materials Processing Institute, Johnson Matthey, Scottish Water, Sustainable Minerals Institute, Codelco, SQM), consultants (e.g. WSP), environmental regulators (e.g. DWQR, HGH Solutions) and government partners (e.g. Department for Business and Trade, SEPA).

We are also supported by the University of Edinburgh's Edinburgh Earth Initiative team who work across the University and with our external partners to deliver leading edge research, innovation and action and accelerate our response to the climate crisis. University of Edinburgh's investment in an ~1000-hectare Forest and Peatland programme is the largest undertaken by any UK university and affords the opportunity to test carbon offsetting potential and biodiversity gains from restoring natural environments. We are also well placed to engage with the new "Green Port" development of the Firth of Forth and we will look to develop links with industrial partners in renewable energy manufacturing and other green technologies.

We welcome researchers and companies specialising in circular economy, waste management, and green finance to join our partnership. This expertise will help scale up solutions, transforming novel research into practical applications that drive real-world change and improve sustainability of critical minerals from cradle to grave. Additionally, green finance collaboration will develop robust financial models, scaling sustainable projects and technologies, ensuring long-term economic viability. By integrating these sectors, we can enhance our ability to deliver impactful solutions for a sustainable net-zero transition.

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Joe Howe University of Lincoln

Co-leads - Just me... this is an EOI to be part of the programme and be invited to any SIF workshop. I anticipate being a named CL of EoI's from other institutions, I would also want, and expect, to play a leading role as an intermediary between academia and industry - a trusted academic/industrial ambassador.

Vision - The SIF programme will become a dynamic and delivery focussed initiative that brings together the academic partners of choice for the operators, engineering procurement, professional service companies leading on industrial decarbonisation propositions across the UK. It will build upon best practice learned from the UK industrial decarbonisation challenge projects (ie cluster plans, FEED Studies for Track 1 and Track 2 and the UK Industrial Decarbonisation Research and Innovation Centre), other intrinsically related UKRI funded programmes such as the Local Industrial Decarbonisation Plans and Transforming Foundation Industries, utilise the expertise contained within UKRI funded centres such as the BGS and CEH, draw upon international best practice through engagement with Mission Innovation 2 programmes such as clean hydrogen, net zero industries, integrated bio-refineries etc, it will seek to collaborate with with financial industries, regulators; professional and trade organisations; leading consultants and advisory services, UK Government Mission Control and related bodies such as National Energy System Operator, Skills England (and its equivalents across the UK), those leading on Local Growth Plans, engage with Government Departments to inform and ensure alignment with the development of the Government's proposed Industrial Strategy. More broadly this is about ensuring that UKRI becomes a natural partner of choice for knowledge on Sustainable Industrial Futures.

Opportunities for collaboration - There is a pressing need to put the Engineering Construction Development Process at the heart of research, innovation and development on Sustainable Industrial Decarbonisation. Academic expertise and commercial sensitivity in understanding the phasing and complexity of industrial turn around; the nature and interface between onshore and offshore operator requirements; a detailed grasp on the financial/venture bodies who are funding anchor industrial emitters and transport/storage operators; a thorough understanding of the role of engineering procurement and professional services companies; knowledge of the governance of Development Consent Orders etc; an insight and appreciation of the role of bodies such as Crown Estate, water companies, pipeline operators, UK Infrastructure Bank, Natural England, National

Energy System Operator and related organisations; insight and understand of securing consent to operate; mechanisms for enhancing supply chain competence and and so on.
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Professor Aamir Khalid Brunel University London

Co-leads - Professor Zhongyun Fan

Professor Julia Stegemann

Professor Brian Cantor

Ms Teresa Waller

Dr Eleni Lacovidou

Vision - A Centre for Sustainable Industrial Futures (CSIF)

Brunel has formed a team of Senior Industrial and Academic Leaders to co-create a self-sustaining Centre based on the governance and financial model of two of the UK's most successful Membership based RTOs (The Welding Institute, TWI and Manufacturing Technology Centre, MTC, part of the HVM Catapult) to create a partnership between Industry and Academia.

CSIF's aim is to "shift the UK away from environmentally detrimental industries…to more sustainable and circular alternatives".   Our vision is to develop a self-sustaining academic/industrial Centre driving scientific and technological innovations into industrial practice across many sectors.

Industrial Leadership Team consists of:

Current and former Chairs, CEOs and Directors of TWI and MTC as follows:

- Dr Clive Hickman OBE: Chair and CEO of the £100m MTC for 15 years. Chair of Transport Research Laboratories. President of IMechE.
- Professor Aamir Khalid: 15 years as Director and CEO of TWI (£200m Net Worth). Chair of LEP (Cambridgeshire and Peterborough). Non-Executive Director of MTC for 5+ years.
- Professor Tat-Hean Gan: Director of TWI. Won £1.2 Billion of projects from funding bodies.

Academic Leadership Team consists of:

Leading academics involved in UKRI current investments (eg TRANSFIRE, Industrial Decarbonisation Challenge and NICER).

- Professor Brian Cantor FREng FRS: Vice Chancellor at York and Bradford (Net Combined Worth £600m). Chair/Director of 2 Science Parks (Net Worth £750m). Member of York, Leeds and Bradford LEPs. Director of UN International Centre of Excellence (ICE) in Circular Economy
- Professor Zhongyun Fan. Director of BCAST. Won and delivered £100m of projects in the field of circular metals in the past 10 years.
- Professor Julia Stegemann: Director of UKRI Circular Economy Centre for Construction Materials at UCL.
- Ms Teresa Waller: Director of Research Support and Development at Brunel with over 30 years experience in running large scale R&D Centres.

The financial and governance model for the Centre (based on Industrial Membership) will work as follows:

- The investment of £26m will set-up and fund the Centre to carry out new research and apply existing research as a system to support the transition to more sustainable industrial processes and operations.

- The 45 Industrial Members from the 7 sectors described in the Call (Industrial Steering Committee) will contribute £75m funding towards transitioning the academic research to develop products and services to meet the objectives of the Climate Change Committee monitoring map.

- The above entities will form consortia to target additional funding streams to further leverage the research into products and services resulting in another £38m of funding for this work.

The Centre leadership team has already achieved all of the above targets in their former jobs as Chairs, CEOs and Vice Chancellors of major UK RTOs and Universities.

We have already achieved industrial support from companies of over £5m. Our university partners are prepared to support our bid to a total of £3m.

In the first 7 years; an investment of £26m will create a self-sustaining Centre that will generate a further £116m of funding from industry and other funding bodies.

Opportunities for collaboration - Academic Partners

Our bid has strong academic representation from many of the 7 sectors described in the call, which include Metals and Minerals, Food and Drink, Energy and Ceramics.

To further strengthen our bid; academic coverage across the Glass, Oil Refineries, Paper and Pulp sector would be advantageous. Industrial Members Our bid has strong industrial representation (Industrial Members) from many of the 7 sectors described in the Call (Industrial Steering Committee). This includes coverage with a number of Industrial Members in each of these sectors. We will reach £75m of industrial funding with our existing sectors covered. If we grow academic coverage into Glass, Oil Refineries, Paper and Pulp, we then have the opportunity to increase the industrial leverage. Additional Support Expansion of our capacity for the development and deployment of environmental monitoring, reporting and validation technologies would be advantageous. We strongly believe that we can establish CSIF (based on 2 of the UK's most successful RTOs ie MTC, part of the HVM Catapult and The Welding Institute, TWI with a team that includes past CEOs of these organisations) that is fully aligned with the SIF funding call that will provide the core operational and management structure. The Centre will secure significant industrial funding and support and will grow and expand to support all the cross-sector research challenges involved in the industrial decarbonisation of UK manufacturing.
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Prof Anna Korre (AK) Imperial College London
Co-leads - Our consortium building efforts have focused on bringing together a team of diverse disciplinary expertise covering all sectors considered in the call, extensive industry experience and close engagement with the industrial clusters, industry associations, the range of stakeholders influencing and directing relevant policies and regulations, as well as geographic, career stage and EDI characteristics. Alongside the centre Director, five Deputy Directors have come forward to coordinate disciplinary direction and sectoral engagement as follows. Prof Mark Jolly (MJ), Cranfield University Prof Jin Xuan (JX), University of Surrey Prof Rebecca Lunn (RL), University of Strathclyde Prof Frances Wall (FW), University of Exeter Prof Sue Black (SB), University of Durham

We are implementing an agile approach to the centre management informed by our experience of leading and co-leading large international programmes together with industry (UKRI, EU Horizon, Accelerating CCS Technologies programmes; AK/RL/MJ/FW/SB); catapults, industry and industry associations' innovation programmes (MJ, academics and several partners in our team); research and innovation programmes in Industrial Decarbonisation (IDRIC; AK), Transformation of the Foundation Industries (TransFIRe; MJ/SB) and Circular Economy (NICER; FW/JX).

At this point in time over 100 prominent academics and researchers from 26 institutions eligible for UKRI funding are supporting this effort exclusively. They are from the following universities/institutions (in addition to the six listed above, presented alphabetically):

Bangor University, British Geological Survey, Brunel University London, Cardiff University, Heriot-Watt University (the Global Research Institute for Net-Zero and Beyond, iNetZ+), Newcastle University, Northumbria University, Sheffield Hallam University, Teesside University, University College London, Bangor University, University of Aberdeen, University of Cambridge, University of Coventry, University of Edinburgh, University of Oxford, University of Sheffield, University of St Andrews, University of Warwick, University of Wolverhampton, University of York.

Several industry associations, leading industry partners, engineering and management firms heavily invested in the sectors of the call are partnering directly in SIF Unlimited, providing tangible support.

Vision - Focusing on industry, as defined in the Industrial Decarbonisation Strategy, the vision for the proposed virtual centre Sustainable Industrial Futures (SIF) Unlimited is to make world leading advances in research and innovation required to address the challenges associated with industrial emissions and to drive a sustainable industrial future in the UK and beyond.

Our overall strategic plan, mission and objectives will guide all SIF Unlimited centre activities. Our aim is to accelerate and upscale solutions and technologies by forging strong links between academia, industry, regional and local stakeholders, regulators, government, professional organisations, and technology and innovation centres in the UK and internationally. We specifically aim to inform the development of UK's Industrial Strategy. With the strongest expertise in systems analysis amongst our partners, we will untangle and evidence the interdependencies, interactions and consequences between decarbonisation, circular economy, resource & energy efficiency and environmental net gain in industry and manufacturing sectors, so these are truly understood and optimised. We are committed to deliver outstanding, world leading and measurable outcomes and impacts, which are sustainable and inclusive.

Our consortium includes exceptional innovation and delivery partners for industry and the manufacturing sectors. We are committing our excellent technical expertise, experience in managing large scale academic and industrial investments and offer access to substantive piloting and demonstration infrastructure facilities, to co-create a strategic programme that is very large in scale and comprises complimentary and integrated research that leverages UKRI's investment GBP 26M offer very significantly. Our focus is to address in analytical and quantified ways large scale sustainability improvements in the following sectors:

- metals and minerals
- chemicals
- cement

- food and drink
- paper and pulp
- ceramics
- glass
- oil refineries
- less energy intensive manufacturing including vehicle, wood products, pharmaceuticals and electronics, among other industries.

Our cross-cutting systems projects will address:

- infrastructure (CO2 capture transport, utilisation and storage networks, electricity, hydrogen, other liquid and gaseous fuels) operability, logistics;
- digitalisation and security in process and systems integration;
- value chain circularity, resource efficiency and sustainability;
- socio-economics and just-transition;
- policy, sustainable investment and finance;
- EDI and knowledge exchange

Thematic projects developed through co-creation will be cross-institutional (several co-leads), include industry, associations, local and regional government and other relevant stakeholders in leading/active roles. Our projects will be defined and selected through a transparent co-creation process, conducted mostly live and led by senior industry, technology and policy executives, prioritising efforts that deliver tangible world leading outcomes, designed for quantifiable impact. Our aims for the industry sectors selected are:

- to shift their products, systems and services to clean alternatives, which in turn will lead to sustainable skills, jobs and wealth creation;
- to reduce associated carbon emissions nationally and internationally;
- to provide technological solutions to address security of UK supply of feedstocks, materials, and fuels;
- to create value from recovery, reuse and recycling of critical materials through greater modular design and circularity of resource streams;
- to create new jobs, businesses, supply chains and industries that exploit (or leverage and build upon) UK resources and research strengths,
- to develop and ensure uptake of sustainable solutions and products that will be of significant value to the UK through both domestic and export markets.

Accelerating impact through genuine engagement between academia, industry and local communities is a specific focus in SIF Unlimited, facilitated by dedicated funds. This will be achieved by devising industrial / commercial placements, academic/policy secondments, and other mechanisms that secure intimate collaboration between early career researchers, academics, field engineers, scientists and decision makers.

Opportunities for collaboration - We recognise that, due to inherent disciplinary, physical, geographic, scale and structural constraints, several of the industry and manufacturing sectors included in this call have had limited opportunity to engage actively in research and innovation activities together. In SIF Unlimited, we integrate geoscience, materials, chemistry, engineering, social sciences, and business expertise in a common platform and with clear focus to reduce the whole lifecycle costs and environmental impacts of the industrial-scale manufacturing processes. We perceive that distinct sector's experience in discovery might helpfully inform other sectors. Likewise, in developing strategy, implementation plans, or even use of facilities that the active engagement through the centre life will bring about, there will be new insights and opportunities. We welcome the engagement and joining efforts with like-minded, collegiate teams. We expect that our consortium will expand and become stronger through the open and continuous co-creation processes planned both in preparation to the full proposal submission in December 2024 and throughout the life of SIF Unlimited.
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David Lennon University of Glasgow
Co-leads - Professor Stewart Parker (ISIS Facility, STFC Rutherford Appleton Laboratory); Dr Andy York (Johnson Matthey Technology Centre, Sonning Common); Dr Paul Collier (Johnson Matthey Technology Centre, Sonning Common) Dr Emma Gibson (School of Chemistry, University of Glasgow) Dr Hamish Cavaye (ISIS Facility, STFC Rutherford Appleton Laboratory).
Vision - Decarbonisation is at the centre of the global Net-Zero agenda for sustainable chemical manufacturing and the commissioning of new chemical process operations. Central to the delivery of this goal is the provision and ready access to hydrogen. The proposed project seeks to examine the role of ammonia as a chemical vector for the transportation of 'green hydrogen'. The emphasis of the study will be on the ammonia decomposition stage, with the research team evaluating the effectiveness of heterogeneous catalysis formulations that feature earth-abundant metals. The novelty of the proposed workplan resides in the application of neutron scattering techniques to interrogate the catalysts but also different reactor configurations.
Opportunities for collaboration - The proposal is centered at the interface of two industrial sectors: (i) catalyst manufacturers and (ii) chemical manufacturing organisations. Johnson Matthey are world leaders in catalyst technology provision. This includes the supply of industrial grade catalysts for a wide variety of chemical processes but also the engineering knowledge connected with reaction engineering. This skills-set ensure the right catalyst is used with the right reactor design. The academic component (U of G) of the consortium provides experience in applying neutron scattering techniques to examine a range of heterogeneously catalysed reactions. The Central Facility connection (ISIS) provides the know-how and expertise in the operation of neutron scattering instrumentation and methodology that can provide new insight on catalyst performance. Johnson Matthey provide a portal to engage with the chemical manufacturing sector.
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Francis Livens University of Manchester
Co-leads - Francis Livens, Adrian Bull, Juan Matthews, Gregg Butler, Fiona Rayment, Laurence Stamford (all University of Manchester)

Vision - Beyond Electricity- Completing Decarbonisation with High Temperature Nuclear Heat.

This is one of a set of three complementary EoIs submitted through the Dalton Nuclear Institute, The University of Manchester

Vision for the Programme.

High temperature (550-950°C) nuclear heat offers the prospect of decarbonising some sectors of industry where there are few, if any, other options. High Temperature Gas-cooled Reactors (HTGR) have been identified by Government as a way of addressing this problem, and our vision is, through the Sustainable Industrial Futures Hub, to define how HTGR technology can be delivered and integrated into a decarbonised society.

Background.

While nuclear fission is widely seen as supporting baseload electricity generation in a decarbonised grid, an all-electric energy system is not viable. In particular, energy intensive industrial processes (metal, glass, ceramics, synthetic fuels) require high temperatures (500-1500°C) [1], while potentially important future fuels (e.g. synthetic aviation fuel, hydrogen, ammonia) will benefit from plentiful supplies of high temperature heat. It is postulated that advanced nuclear fission, particularly HTGR, can provide a low carbon solution to this problem and Government is exploring the demonstration of HTGR in the UK by the 2030s [2].

Research Aims

The use of nuclear heat is a new way of 'doing nuclear power' and many questions remain about the integration of the nuclear heat supply with the end use process and the wider energy system, as well as the possible roles of heat storage, hydrogen production by High Temperature Steam Electrolysis, and thermochemical cycles in implementation. Beyond these technical questions, such a novel deployment of nuclear power raises issues of planning, siting, regulation, and social license to operate which all need to be addressed.[3]

Interfacing HTGRs with end uses of nuclear heat will require smart reactor manifold designs to manage reactor heat outputs at different temperature ranges required for different steps in the process, heat exchangers and heat exchange media modelling, e.g. gas-gas or gas-to-molten salt heat exchange, as well as innovation in design and manufacturing for all components attached to the reactor. Research on both heat storage technologies and the associated heat network transmission media is also needed. The HTGR technology itself requires research into fuel (High Assay Low Enriched Uranium (HALEU; typically in the range 15-20% U-235) fuels, coated particle fuels) and core materials (structural materials and graphite), advanced manufacturing; modelling, simulation, and design. Implementation of HTGR and integration into the energy systems requires research related to planning, siting, and regulation, especially the interaction of HTGR with associated industrial plants, and into the societal aspects of deploying HTGR as envisaged.

[1] Peakman A. & Merk, B. (2019). The Role of Nuclear Power in Meeting Current and Future Industrial Process Heat Demands. Energies, DOI 10.3390/en12193664

[2] BEIS (2021) https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies#amr-research-development--demonstration-programme

[3] NIRAB (2024). Research, Development and Innovation required for a High Temperature Gas Reactor Demonstrator. https://www.nirab.org.uk/cdn/uploads/attachments/NIRAB_Report_and_Appendices_Digital.pdf

Opportunities for collaboration - Our foci are on 1) delivery of HTGR technology at pace; 2) integration of the nuclear heat source with the end use; and 3) the societal context of the HTGR and its utilisation. The following topics are of particular interest:

Societal context- techno-economic assessment; regulation; siting; licensing and permitting; planning; social license to operate

Evaluation of potential end uses for nuclear heat- hydrogen manufacture by high temperature steam electrolysis; thermochemical processes for hydrogen; synthetic fuels manufacture

Integration of the nuclear plant with end use processes- smart manifolds; heat transfer; thermofluids

Manufacturing- advanced manufacturing; modular design and construction; qualification and regulation; codes and standards

The nuclear technology- high assay uranium; coated particle fuels; core materials, particularly graphite

Modelling and simulation- reactor and core design, digital control and instrumentation; digital twin; system models

We are therefore interested to make contact with partners with expertise in any complementary area, but especially:

Techno-economic analysis

Social sciences (e.g. economics, planning, social anthropology)

Digital control & instrumentation;

Modelling & simulation (digital twin, in silico);

Materials, manufacturing, qualification, codes & standards

Systems approach and integration

Engineering design

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Prof Mercedes Maroto-Valer Industrial Decarbonisation Research and Innovation Centre (IDRIC), Heriot-Watt University
Co-leads - Our inclusive and diverse consortium currently comprises the following co-leads. We are in discussions with other potential co-leads for further coverage of the call thematic areas. Prof Fiona Charnley, UKRI National Interdisciplinary Circular Economy Hub - NICER, University of Exeter Prof Ian M Reaney, UKRI Transforming Foundation Industries Network+, University of Sheffield Dr Mark Sutton, UK Centre for Ecology & Hydrology (UKCEH) Prof Marcelle McManus, University of Bath Prof William Sampson, University of Manchester Dr Maxine Akhurst, British Geological Survey (BGS) Prof Benjamin Sovacool, University of Sussex Prof Mohamed Pourkashanian, University of Sheffield Prof Cameron Pleydell-Pearce, University of Swansea Prof Michael Shaver, University of Manchester Prof Hussam Jouhara, University of Brunel Prof Iain Todd, University of Sheffield Prof Peter Hopkinson, University of Exeter Prof Markus Zils, University of Exeter Prof Tony Roskilly, University of Durham Dr Lindsay-Marie Armstrong, University of Southampton Prof Peter Taylor, University of Leeds Prof John Andresen, Heriot-Watt University Prof Jon Maddy, University of South Wales Prof John Barrett, University of Leeds Prof Amanda Crawley-Jackson, University of Arts London Prof Nashwan Dawood, Teesside University Prof Jonathan Radcliffe, University of Birmingham Christine St John Cox, Energy Systems Catapult Prof Joe Howe, University of Lincoln Dr Sudhagar Pitchaimuthu, Heriot-Watt University

Prof Jim Watson, University College London

Prof Kirstie Simpson, University of Chester

Prof Justin Perry, University of Northumbria

Vision - The vision of the Sustainable Industrial Futures (SIF) Hub is to realise a sustainable future for UK manufacturing, driving a systemic and lasting shift away from environmentally detrimental practices toward circular and sustainable alternatives, resulting in demonstrable and scalable cross-sector environmental, economic and social benefits.

In 2021, the UK Committee for Climate Change (CCC) published its projections of carbon abatement based on existing and potential mitigation strategies to achieve net-zero within the industrial and construction sectors by 2050. The recent 2024 CCC report highlighted that although the Third Carbon Budget was met, urgent action is needed for the UK to meet its 2030 targets. Average industrial reductions are behind the pace needed and are not driven by sustained programmes for deeper decarbonisation essential for future competitiveness of UK manufacturers.

Many technological interventions will be needed to enable this sustainable transition: Carbon capture, utilisation and storage (CCUS), hydrogen, Negative Emission Technologies and electrification, as well as the adoption of circular approaches to the reduction, recovery, reuse, repair and remanufacture of existing assets must all be enabled to fully address the emissions directly arising from the supply and use of materials, products, components and systems across sectors. Therefore, a whole-system, cross-value chain approach is required to ensure that technological advances are not implemented in isolation, to uncover and quantify associated economic, environmental and social impacts, and to better understand the trade-offs between technologies and approaches that will underpin transformational systems change.

Aims of the programme:

- Address ‘cross-sectoral’ industry-led challenges through cross-cutting research themes, so the SIF-Hub impacts on as diverse a range of industries in a timely way to achieve environmental net gain.

- Unite the wider UK community through supporting network activities, conferences, workshops, marketing, webinars and on-line resources.

- Establish and embed throughout the Hub’s lifetime a culture of inclusion, equity and diversity, including active engagement and nurture of early career researchers.

- Support the development of effective policy, regulatory frameworks and standards for sustainable manufacturing industries.

Overview of sectors and disciplines covered:

The SIF-Hub vision will be achieved by uniting, leveraging and expanding upon >£500m of strategic investments, including: Industrial Decarbonisation Research and Innovation Centre (IDRIC), National Interdisciplinary Circular Economy Research Programme (NICER), Transformation Foundation Industries Challenge (TFINetwork+), SUSTAIN Hub, Henry Royce Institute, Sustainable Materials Innovation Hub, Translational Energy Research Centre (TERC), Heat Pipe and Thermal Management Research Group (HPTMRG), Made Smarter and MAPP

Hubs, Green Industrial Futures CDT, the Foundation Industries Sustainability Consortium (FISC, including Economiser I and II), Glass Futures, and Net Zero Industry Innovation Centre. The SIF-Hub consortium is also well connected with other major relevant UKRI research centres, including Hydrogen and CCS Hubs, Supergens, UKERC, EDRC and GGR Demonstration Programme. Led by the Directors of IDRIC, NICER CE-Hub and TFIN+, the SIF-Hub integrates globally leading and diverse expertise, covering engineering, physical and environmental sciences, to enable a whole system, interdisciplinary cross-sector approach to achieve scientific excellence and quantifiable impact. We are uniting successful networks, academic experts, industry partners and RTOs to co-create sectorial and cluster approaches to enable transformation within the manufacturing industries as identified by the UK Industrial Decarbonisation Strategy, namely metals and minerals, chemicals, food and drink, paper and pulp, ceramics, glass, oil refineries and less energy-intensive manufacturing. Together, our SIF-Hub will be unique in addressing cross-sectoral research challenges and transforming the sustainable transition of UK industrial manufacturing processes and operations to net zero.
Opportunities for collaboration - We have built an exceptional consortium of academic and industrial partners to develop true systems approaches, including complimentary and unique expertise in industrial decarbonisation, circular economy and resource and energy efficiency to ensure environmental net gain of the SIF-Hub outputs. We have already run two co-creation workshops to shape our vision. As we continue co-developing our vision and the programme, the next step for us is to run partner workshops to scope further the focus areas of strategic interest. This also includes to identify and bring in complimentary partners and academic expertise (engineering, physical and environmental sciences) to support the co-delivery of the programme, including through our participation in the UKRI facilitated workshop in September.
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Vision - Key to the acceptance of any net-zero technology is noise and vibration performance. For example: light-weight materials for automotive and aerospace applications must perform acoustically to avoid detrimental noise problems; quieter wind turbines will produce more energy if they can be operated continuously without upsetting local residents. To manage noise and vibration performance, there is an increasing demand for fast, reliable, and accurate simulation for vibro-acoustic behaviour of complex engineering structures. Designs for transportation (electric vehicles, drones, etc.), domestic products, and building services such as heat pumps, increasingly require accurate models to efficiently prototype and validate performance. This avoids over or under design, reduces reliance on physical prototyping, and makes best use of material resources, all of which contribute towards net-zero targets.

The only practical way to model the vibro-acoustic performance of complex systems is to break the problem down into its components. By measuring and/or modelling the individual components, the behaviour of the assembled system can be synthesised and used to optimise designs or verify the performance of new technologies. It is widely understood that certain component types, for example vibration sources (motors, pumps etc.) but also novel materials, etc., are too complex to be modelled accurately by numerical means. And so, it is essential that advanced experimental methods are available to characterise components through testing, and that these methods are able to integrate with numerical simulation to form so-called hybrid models.

Currently, the most well established hybrid simulation framework for vibro-acoustics is the frequency-based Component Transfer Path Analysis (CTPA). The culmination of over 4 decades of research and development, CTPA is now deeply embedded within the product development process across various sectors, most notably the automotive (https://webinars.sw.siemens.com/en-US/component-based-transfer-path-analysis/?pk_vid=9d507ce14e22f25517230278000542be). As new net-zero technologies are developed, new applications of CTPA are found, though with them new limitations. As an example, the move towards electric vehicles has introduced new e-motors that generate noise and vibration at frequencies much higher (up to and above 10kHz) than their combustion counterparts. CTPA cannot be relied upon to tackle such high frequency problems. Similarly, as new lightweight materials become increasing sensitive to vibration amplitude, non-linearity becomes an integral part of system design. However, CTPA cannot deal with non-linear systems.

Though a powerful tool, as new technologies are developed CTPA increasingly finds itself unable to solve the problems before it. To overcome these limitations, a paradigm shift is required. As part of this call we would propose a programme of work to develop new hybrid methodologies, better suited to high frequency and non-linear use cases, for emerging net zero technologies. This will involve developments in the disciplines of acoustics, structural dynamics, computer simulation and algorithm design.

Opportunities for collaboration - We would seek research partners in the fields of computer simulation and algorithm design, particularly related to high frequency and non-linear time domain problems.

We would also be interested to provide support for partners who would like to extend their own proposals to include studies on noise and vibration.

With regards to sectors, we see the automotive, rail, aerospace, domestic product and building service industries being the greatest beneficiaries of the proposed work. Though we would welcome collaboration from other sectors that have identified noise and vibration to be important for their technologies.

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Vision - A Sustainable Future for the UK Semiconductor Industry – SUSTAIN-SEMI Synopsis: The global semiconductor industry underpins all modern technology and will be a central pillar in the societal challenge of achieving Net Zero. The semiconductor sectoral challenge is two-fold: i) how do we create the technology that will deliver Net Zero; and ii) how do we do so in sustainable manner, driving circularity and reducing emissions intensity and environmental impact. The UK Semiconductor Sector is growing rapidly, both in response to the Net Zero imperative, and a move towards sovereign security and improved national resilience for key technologies such as telecommunications, AI computation, quantum tech, electrification of power and clean energy. The semiconductor industry – although not visibly producing emissions like (for example) metals and minerals processing, fossil fuel refining or plastic production – is next cab off-the-rank for emissions reduction as a major polluting manufacturing industry. Legislation is being rolled out across the globe dealing with (for example) reducing all scopes of emission (including electrical power), reduced reliance on critically endangered raw materials, replacement or mitigation of harmful process solvents and gases (such as SF6), and increased embedding of circularity in manufacturing. We at Swansea University are deeply committed to helping our regional and indeed national semiconductor industry understand and solve the imminent challenges facing our sector in achieving future sustainability. We have a built a new £55M RD&I facility called the Centre for Integrative Semiconductor Materials (CISM) which mimics a full manufacturing environment – but has been designed to incorporate what we term 'Semiconductor Innovation for Net Zero' – a comprehensive infrastructure and operational innovation programme that seeks to do the research now that will create the sustainability solutions that will be mandated in the industry within the next 5-10 years. We are closely connected with other RD&I and industrial organisations throughout the UK and EU (our top university facilities and programmes, industry bodies such as SEMI EU and SEMI UK, global initiatives such as the US CHIPS and Science Act and EU Chips Framework, and the majority of the major players in UK semiconductor manufacturing such as KLA, Vishay, Microchip, etc.). In our proposition and potential contribution to a Sustainable Industrial Futures Centre of Excellence SUSTAIN SEMI – we seek to be the conduit through which the UK semiconductor

manufacturing sector can partner with other industries of national importance to the UK in delivering Net Zero. Our foci will be: i) rolling out a practical and transdisciplinary RD&I programme to address major 1st order sustainable challenges such as the high embodied energy in semiconductor component manufacturing and the replacement and mitigation of the worst processing practices; ii) 'test bedding' of promising interventions in our manufacturing-mimicking facilities (such as CISM, but also at partner universities); iii) learning from and adopting the best practices in circular manufacturing now rolling out across multiple cognate sectors, but which are nascent in semiconductors; iv) engagement in the development of legislation and policy reflecting state-of-the-art and UK priorities, plus assessing the impact of change; and v) being the vehicle to roll out monitoring frameworks such as SEMI S23.

The UK semiconductor sector must be part of any national sustainable industries strategy.

Opportunities for collaboration - The semiconductor materials and components manufacturing supply chains interact with multiple cognate supply chains across a wide spectrum – for example mining and refining of raw materials, the provision of bulk process chemicals, and the upstream recipient manufacturing industries such as automotive and aerospace, electronic goods, stationary energy, information and communication technology, etc. Many of these sectors are implementing core circular economy principles including (for example) the future requirement to passport constituent components in their products (take the example of batteries in EVs) to increase recyclability, measure and reduce emissions and environmental impact, and also to validate responsible raw material sourcing. These are nascent principles in semiconductor manufacturing and thus we would like to connect our industry through a proposition SUSTAIN-SEMI with:

1. Practitioners from other sectors that are more advanced in implementation of sectoral circularity adoption and this includes experts in the development and implementation of policy;

2. Industries such as mining, bulk chemicals, energy generation and provision which intersect semiconductor manufacturing in order to connect all elements of the semiconductor manufacturing supply chain and understand how to construct full end-to-end frameworks;

3. End user industries such as automotive and aerospace who will impose sustainability measures down their supply chains – our sector needs to understand future requirements substantially before they are imposed.

In addition, we need to connect with expertise who can provide new technology options for reducing the emissions intensity of our manufacturing processes, for example:

1. Providers of new waste handling technology from the chemical processing industry;

2. Expertise in monitoring and managing complex industrial infrastructure (the controls industry);

3. Suppliers of industrial-commercial-scale clean energy and carbon capture technology;

4. Techno-economic expertise to construct predictive life cycle analysis models to help validate and test potential policy, infrastructure and operational interventions in semiconductor manufacturing.

We would thus welcome partnerships with cognate transdisciplinary groupings and organisations such as IDRIC, NICER, UKERC, Sustainable Manufacturing Hubs, IKCs, the relevant Catapults, the UK Energy Demand Research Centre, etc. – many of whom are now connecting to our industry as it becomes a prominent part of the UK landscape.

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Dr Jason Palmer UCL

Co-leads - Dr Jason Palmer

Vision - Transitioning the UK industry to net zero carbon emissions is a critical endeavour, requiring urgent action and coordinated research effort. We believe four pillars are essential:

1. Understanding the Landscape: Research efforts should begin by comprehensively mapping the current state of the UK industry. This involves assessing emissions across sectors, identifying key contributors, and understanding technological and operational challenges. Researchers should collaborate with industry partners, government agencies, and consultancies to collect data, analyse trends, and model potential pathways. By creating a detailed baseline, we can prioritize interventions and allocate resources effectively.

2. Innovation and Technology: Research should focus on developing and scaling low-carbon technologies. This includes advancing renewable energy sources (such as wind, solar, and hydrogen), improving energy efficiency in manufacturing processes, and exploring carbon capture and storage solutions. Collaborative projects between universities, industry players, and research centres can accelerate innovation. Additionally, interdisciplinary studies that combine engineering, materials science, and policy expertise are crucial for translating research findings into practical applications.

3. Carbon in Building Materials: Given the new Government's push for housing-led growth and streamlining planning decisions, embodied carbon in construction materials is likely to grow as a proportion of overall UK GHG emissions. There is a very strong case for targeted research aimed at reducing emissions from new homes.

4. Policy and Behaviour Change: Beyond technology, research must address policy frameworks and human behaviour. Engineers and researchers from other disciplines can evaluate the effectiveness of existing policies, propose new regulations, and assess their impact on emissions reduction. We will also explicitly consider SMEs, who consistently face barriers to decarbonisation. But this is not enough we must also work to understand consumer behaviour, supply chain dynamics, and workforce transitions. Research should inform targeted policies that incentivize sustainable practices, encourage circular economy models, and foster a just transition for workers. By integrating science, technology, and policy, we can drive the UK industry toward net zero while helping to reverse the decline in UK industry and addressing social equity.

This vision is consistent with the Government's Net Zero Research and Innovation Framework, published in March 2023 (https://tinyurl.com/NZ-Innovation-Framework), which gives detailed actions and timelines for action that is needed in different industrial sectors.

Opportunities for collaboration - Ideally, collaborators with stronger links to industry - especially high-emissions parts of industry, with excess thermal energy that could be re-deployed. We are particularly interested in developing links with glass manufacture, chemicals, cement, other building materials, and current and prospective battery manufacturers (which are likely to experience high growth, due to expansion of EVs and increased electrical storage on the national grid).

We have a very detailed understanding of energy use in buildings, but less knowledge about industrial processes - perfect partners for us would be those with strong process-energy experience, but more limited knowledge about carbon emissions from buildings. We also have gaps in knowledge relating to (green) hydrogen, industrial energy storage
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Vision - UK Centre for Industrial Decarbonisation (UKCID): Humber Living Laboratories for Energy Infrastructure. The Humber region is the UK's largest CO2-emitting industrial cluster; its decarbonisation is pivotal to meet national targets. The Humber hosts almost all high-emitting sectors (Chemical & Process Engineering, Steel, Paper & Pulp, Oil & Gas, Glass, Food & Drink, Shipping/Logistics), but faces significant societal challenges across people skills, disconnected systems, and the environmental landscape. The Humber Industrial Cluster Plan (HICP) and Deployment Projects (which recognise the national importance of decarbonising the Humber) highlight the region as an ideal "living laboratory" to demonstrate decarbonisation technologies (TRL 4-7) and promote Knowledge Exchange (KE) across the UK and internationally.

UKCID focuses on the urgent need for commercially viable, low-carbon energy solutions. We offer physical space, industrial appetite, workforce, and facilities (both on- and offshore) necessary to develop IP/know-how and demonstrate pilot plants mature enough for mass-market take-up (TRL 4-7). This will enhance the UK's industrial competitiveness, open new commercial opportunities for UK oil and gas assets, support industry goals, and boost industrial productivity.

The University of Hull (UoH), together with CATCH (who led the HICP development, and whose 50+ industry members span all key decarbonisation sectors) possess the academic excellence, energy-intensive industry networks, connectivity with government bodies and professional leadership experience to maximise UKCID's potential for UK benefit. In partnership with stakeholders, we envisage a hub-and-spoke model, with UKCID serving as the national hub, supported by regional industrial clusters and academic units across the UK, acting as spokes.

Our Vision:

UKCID will showcase UK excellence, driving both demonstration and deployment of decarbonisation solutions through holistic and systematic approaches. The lessons captured from previous UKRI initiatives, will help accelerate wider UK opportunities. Moreover, UKCID will inform, influence and promote key government drivers of change such as supporting GB Energy in effective investment decision-making, space and physical pipeline planning for the Crown Estate Bill, alternatives for the Sustainable Aviation Fuel (Revenue Support Mechanism Bill) investment, and water security, to help deliver responsibly on the Water (Special Measures) Bill.

Aims:

1. Partner with UK industry, academia, policymakers, and communities to overcome challenges in demonstration, speedy deployment, scaling-up, data exploitation and management, and policy integration.

2. Accelerate net-zero/negative emissions transitions of high-emitting industries via systems thinking and transdisciplinary research, ensuring sustainable and inclusive growth, resilience, and energy security.

3. Navigate risk, reward and cost, optimising the rapid decarbonisation of UK industry for economic, environmental, and societal benefit, with sustainable resource use.

4. Secure industry and local community buy-in to expand activities across high-emitting sectors.

5. Identify industrial symbiosis opportunities/sectorial requirement synergies through a whole-systems approach.

6. Establish transparent governance frameworks, monitoring impact and evaluating projects, affording reliable reporting and validation of outcomes.

7. Build a robust network of industry, academic, local community and policy partners to embed KE benefits through other initiatives, such as Local Industrial Decarbonisation Plans (LIDP) and Transforming Foundation Industries. 8. Forge a national capability in decarbonisation through inclusive communities-of-practice, ensuring long-term, sustainable growth of a skilled workforce, whilst cultivating a culture of applying and embedding research excellence to address priority challenges.
Opportunities for collaboration - Our Expertise and How We Complement Others. UKCID is uniquely positioned to deliver national capability in sustainable industry, serving as a live, test-bed, demonstration laboratory for the UK, whilst acting as a global showcase. The Humber can deliver 8-16 MTe of negative emissions annually, and has Track 1 and Track 2 licences for advancing CCU(S) - the ideal environment for R&I of key technologies and second-generation deployment, including energy and water-efficient solutions. We already partner with private sector investors in the energy-intensive, energy-producing, and energy-storing sectors, including importers. We recognise that, given our size and diversity, other SIF proposals and also the UK Infrastructure Bank (UKIB) may require our collaboration. The Humber has access to substantial CO2 and hydrogen storage, offshore wind power, and existing low-carbon energy off-takers. We attract investments and provide solutions for enhancing energy efficiency, industrial symbiosis, supply chain analysis, skills interventions, water for industry, adapting public perception, and collective lobbying for faster UK net-zero progress. Key UK trade associations, including CCSA, Crown Estate, NSTA, Environment Agency, HSE, Natural England, NESO, DNOs, ECITB, and Cogent, have strong relationships with both Humber Energy Board and Humber Freeport. As well as the UoH VC chairing Yorkshire Universities, we are recognised by our SIF-relevant research, KE and impact in: • Hydrogen Production and Storage, • Low-carbon Energy (The Aura Innovation Centre, and CDTs), • Carbon Capture, Sustainable Materials (EPSRC PBIAA), • Industry 4.0, Digital Twins, Cyber Security, Data Science and AI (DAIM), • Circular Economy, • Community Engagement, Participatory Action Research, Environmental policy (EEI), • Human Factors and Sustainable Culture Change, and • Energy policy. Through our partner CATCH, we access a network of 50+ businesses focused on workforce development for sustainable industry.
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Vision - The construction industry faces a critical challenge to achieve net zero by 2050 that extends across its entire supply chain and ecosystem. Transformative approaches must be developed to reduce its overall environmental footprint. Its basic materials rely on high-carbon foundation industries - steel and concrete. In tandem, England generated 53.6 million tonnes of non-hazardous construction and demolition waste in 2020, with no improvement in the recovery rate since 2010. The government's Resource & Waste Strategy goal of 'maximising the value of resources and minimising the environmental impact of waste' means that innovative developments are urgently needed.

Alongside this sustainability issue, the UK's construction and housing industry grapples with a heat decarbonization challenge. Reaching London's targets alone will require ~40% reduction in total heat demand from its buildings, requiring >2 million homes and 75% of non-domestic buildings to be properly insulated, 2.2 million heat pumps installed, and 460,000 buildings connected to district heating. Current heat pump installations hover at only 11% of the 2028 government target of 600,000/year, and energy-efficient installations via government schemes fell by 55% in 2022. While landlords and homeowners desire greener practices with 84% considering or taken action to improve energy efficiency, they face financial constraints and knowledge gaps in emissions reduction strategies and new technologies.

The built environment imposes challenges on and is challenged by the natural environment. The waste generated must be managed, biodiversity must be respected, noise and pollution must be minimised for planetary and human health, while the climate emergency necessitates resilience to extremes in temperature and flooding.

Developing a sustainable and environmentally compatible and adaptable construction industry and achieving heat decarbonisation requires acceleration of the transition towards retrofitting, design for deconstruction/intelligent demolition to stimulate reuse/remanufacture of materials and the rapid development and deployment of a range of technologies.

Our vision brings a whole-system response that integrates research on new technologies with systems thinking to inform policy, regulations, health, natural and social co-benefits, and skills while ensuring synergistic research for nature-positive solutions and environment protection.

Our aims are to: (i) develop and connect early-stage technologies with demonstrator projects and evaluation environments to inform and develop long lasting solutions with positive impact on the environment and all its inhabitants; (ii) provide new ways of leveraging green finance/ carbon economy; (iii) improve the evidence, communications and community structures for trust and faster adoption of solutions; and (iv) engage insurers, regulators and policymakers in the longer-term changes needed

Our proposed programme's disciplines include mechanical, civil, design, electrical, materials and manufacturing engineering, physics, chemistry, systems science (systems thinking, systems engineering and systems dynamics), social, operational, environmental, climate, geography, health and business sciences. Sectors and partners include the construction and building infrastructure industries (e.g. Arup, Delancey, RESustain, Exergy), complemented by the Manufacturing Technology Centre Catapult, banks and green-tech accelerators, and local authorities.

Opportunities for collaboration - We would welcome new partners that enhance and complement the skills we currently have including those in academia and industry working in solutions for decarbonising the foundation industries related to the construction sector. We are looking to collaborate with those that work with new and innovative approaches to waste and environmental management, those with expertise in building codes and materials certification for new materials and technologies, experts in sustainable urban planning and climate resilient design (we have already reached out to colleagues within King's Centre for Urban Science and Progress (CUSP) London), new approaches in systems science, biodiversity, especially as related to the built environment, acoustics and the impact of noise on wildlife, soil and water science. We would like to reach out to new policy and local authorities to enhance the reach of our current group and charities and social enterprise that relate to our vision.

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Vision - The UK has a diverse industrial economy, accounting for over 11% of annual CO2e emissions. Achieving net zero or negative greenhouse gas emissions, along with boosting economic and societal resilience, job growth, and resource and energy security, is crucial for the UK's future. This programme aims to drive sustainable industrial transformation, advancing the UK towards greener industries and processes, and delivering wider socio-economic and environmental benefits. Each industrial sector faces unique challenges, requiring tailored approaches to decarbonisation, feedstock sustainability, and moving towards a circular economy. Strong industrial engagement and the co-creation of research challenges will be key to the programme's success. For early-stage technologies (TRLs 1-3), impactful research and development can significantly reduce CO2e emissions and enhance sustainability. For example, sustainable chemical feedstocks could revolutionise the chemicals industry while enabling mass decarbonisation in other sectors, such as green hydrogen for steelmaking. Similarly, Carbon Capture, Utilisation, and Storage (CCUS) technology can reduce emissions from sectors like cement, chemicals, iron, and steel, enabling net-negative carbon emissions when combined with other low-carbon technologies. By targeting these cross-sectoral technologies and working with stakeholders to tailor them to specific industries and processes, we seek to maximise overall learning and translation of knowledge. Addressing both well-known and unforeseen challenges in deploying new sustainability improvements is critical. For instance, producing key chemicals efficiently requires effective use of energy (thermal, electric, or solar) and sustainable use of rare elements, along with novel feedstocks like biomass and waste valorisation. Additionally, exploring sustainable methods for

manufacturing important technologies, such as hydrogen-related materials, metal-organic frameworks for chemical filtration, and catalysts, can significantly improve process efficiency and reduce waste. These innovations will lead to cleaner manufacturing processes with lower environmental impact and better use of critical resources like rare and rare earth metals.

Our approach involves building a multidisciplinary, inclusive team, fostering innovation across engineering, physical, and environmental sciences. Thematic groups will cover various sectors and technologies, each led by an early career researcher to develop and coordinate strategy. This structure will facilitate industrial co-creation of research challenges and the translation of technology from the lab to demonstration and full deployment. The University of Nottingham team will leverage its extensive experience in leading large-scale projects. This includes EPSRC CDTs in carbon capture and storage, sustainable hydrogen, cleaner fossil energy, resilient decarbonised fuel energy systems, sustainable chemistry, the Future Composites Manufacturing Research Hub, and EPSRC programme grants in sustainable chemistry and catalysis, additive manufacturing, and ammonia for heavy-duty transport.

Policy frameworks must support industrial decarbonisation while avoiding carbon leakage and job losses. Establishing appropriate business models, governance arrangements, stakeholder interactions, and capacity building is crucial for sustainable decarbonisation under various technological, socio-economic, market, and environmental conditions. Effective policy will need to balance creating a consistent institutional framework for planning security with enough flexibility to adapt to new developments.

Our programme will deliver significant outcomes, including technological advancements, economic growth, job creation, and environmental benefits. By influencing both UK and global markets, we aim to export sustainable solutions, contributing to a global reduction in industrial greenhouse gas emissions. Through a systems approach, we will maximise the sustainability of industrial processes, achieving environmental net gain, social cohesion, and economic resilience.

Opportunities for collaboration - • Wider involvement with the food and drink sector – particularly drink

- Paper and pulp links
- Alternative feed stocks particularly from waste (we have good expertise but due to breadth more would be welcome)
- Ceramics
- Wood products – sustainable use
- Mining waste – as alternative feed stocks, breadth of field
- Fission
- Greater breadth and depth of industrial contacts
- Policy and business expertise – again, breadth of field means while we have an extensive business school, more is welcome

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Vision - AEONS: Advanced Evaluation Of Nuclear new-build Sustainability

This is one of a set of three complementary EOIs submitted through the Dalton Nuclear Institute at The University of Manchester.

The overall vision of this programme is to offer a nationwide cohort of expertise dedicated to the development and evaluation of innovations that maximise the ability of nuclear fission to enable economy-wide industrial sustainability. The proposal envisages a research cluster producing outputs which will inform and influence the design, deployment, operation and integration of these technologies to support the delivery of Net Zero. It aligns with UK Government plans for new nuclear reactors as a national endeavour, and bridges the aims of Great British Nuclear and Great British Energy by developing nuclear's role in non-nuclear parts of the energy system such as hydrogen, carbon capture and synthetic fuels. AEONS has the ambition of forming a national centre of excellence offering opportunities for many institutions to collaborate and contribute via open research calls. Development and retention of skills will be a focal point to ensure expertise for an expanding sector of energy new-build activities both nuclear and non-nuclear.

AEONS will frame its research around interlinkage between five themes (carbon and air quality, water, circular economy, biodiversity, and socioeconomics) and five cross-cutting areas (construction, operation, electricity use, heat use, and methodological innovation). Pilot-scale experimental work will include the application of nuclear heat and potential surplus electricity to a) improve the efficiency and cost profile of electrolysis at low and high temperatures, b) develop alternative heat usage options including waste heat for food production, c) progress thermally assisted direct air carbon capture, d) advance catalysis for synthetic fuel production, and e) design novel heat exchange systems for nuclear plants to maximise utilisation. This will enable nuclear to improve the sustainability of multiple sectors beyond electricity.

A programme length of 10 years is envisaged, structured in two phases progressing from lab- to pilot-scale experimentation, with sustainability assessment applied at all stages to maximise sustainability during TRL progression. In each phase, funding calls will be released to receive and fund research proposals relevant to the overall aims of AEONS. This timeframe aligns with the anticipated construction schedules of Sizewell C (2025 to ~2035) and the likely deployment timeline of small modular reactor (SMR) technologies (early-mid 2030s). The centre will investigate technical opportunities applicable to all these advanced nuclear options, across small and large pressurised water reactors (PWRs) and advanced modular reactor (AMR) designs that will secure the longevity of AEONS beyond the 10-year programme.

All technological innovations will be explored with sustainability assessment as a core driver to establish carbon implications across the full life cycle alongside a broader suite of methods to consider multiple environmental impacts and socio-economic barriers and opportunities. Scenario analysis will be used to understand how to accelerate the adoption of these technologies and their roles within the broader system. Skills development will be embedded in the programme with PhD scholarships and flexible funding for early-career researchers.

Opportunities for collaboration - Our proposal includes personnel across The University of Manchester, spanning chemical engineering, nuclear engineering, energy policy, climate change, catalysis and sociology. Additionally, we have interest from contacts in other institutions linked to economics, digitalisation and environmental sensing.

We are keen to make contact with others, particularly in (but not limited to) the following areas:

Biodiversity – innovations in plant construction or utilisation of heat/electricity to improve biodiversity (terrestrial and aquatic), and the impact assessment thereof.

Planning and construction – social issues and policy issues, key barriers and enabling innovations

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Professor Mike George, Chemistry, U of Nottingham

We also have a large number of other university investigators who have already agreed to contribute. This will be expanded as the process continues. Currently this includes but is not limited to:

Professor Sir Martyn Poliakoff FRS, FREng (Nottingham)

Professor Rachel Smith (Sheffield)

Professor Matthew Roseinsky FRS and Professor Alex Cowen (Liverpool)

Professor Chris Hardacre (Manchester)

Professor Paul Webb (St Andrews)

Dr Alberto Rodan and Professor Sir Richard Catlow (Cardiff)

Vision - As energy transitions towards decarbonisation, so the chemicals and pharmaceutical industries need to transition towards de-fossilisation of the carbon supply chain. The chemical-using industries contribute ca. 24% of the UK GDP and value of global annual chemical production is set to double by 2030. Although only 5-7% of oil production is used to make chemicals, those chemicals contribute ca. 50% of revenue from oil which is vital to the economics of the oil industry. Therefore, the economic viability of fossil carbon will become untenable for the current petrochemicals industry, and we need to become custodians rather than consumers of carbon. Key factors will be (i) sustainable supply chains including raw material sourcing and minimal environmental impact; (ii) circular economy with reuse, recycling, and regeneration of materials and implement closed-loop systems, (iii) energy efficiency to invest in energy-efficient technologies and processes and utilize renewable energy sources and (iv) provenance. Equally important will be process optimization, implementing new advanced process control and monitoring systems using real-time data analytics to enhance efficiency, reduce waste, to enable control of the production process in real-time, ensuring consistent quality and reducing waste. We must move away from the concept of waste to the idea of valuable nth generation carbon feedstocks. These will include CO2 from point source capture (PSC) as well as direct air capture (DAC), municipal solid waste, plastics and biomass.

Our Strategy: Conversion to value added petrochemical replacements e.g. CO, methanol, ethylene and H2 amongst others will require a multifaceted approach including thermo, bio, photo, electro and plasma chemical approaches, and hybrids among these. Availability of H2 will be a critical bottleneck for industry and catalytic methods must focus on intensified and atom efficient reduction processes without molecular H2. There is unlikely to be a silver bullet, but there may be silver buckshots. The ethos of Great British Chemicals will be to investigate complete system supply chains. There will be an element of risk, but equally a large element of reward. Furthermore, other carbon recovery technologies including selective extraction, pyrolysis and chemical degradation will be explored.

Methodology: We will create the necessary interplay between fundamental and applied chemistry, process analytics and modelling, digitalisation and Industry 4.0, engineering and systems approaches. We will bring together the necessary expertise in business, policy social science for stakeholder engagement culture of sustainability within the whole chemistry using enterprise. While Great British Chemicals will be virtual, we will ensure that there will be an active exchange of knowledge, equipment, and facilities. This will be established by a collaboration agreement between the parties within Great British Chemicals. Social sciences and policy development will be integrated into the centre as well as psychological approached to behavioural change. Carbon deduction facilities will also play an important role in the decarbonisation of stranded communities and air quality measurement to determine the effectiveness of technologies will be integrated.

Achieving Success: Great British Chemicals will engage both industry and policy makers. We will build on the successes of the Circular Chemicals Network and more generally NICER, SUSTAIN and the Flue2Chem TFI consortium and the manufacturing and PAT innovations of recent Photo-Electro EPSRC Programme Grant and the current Sus-Flow EPSRC accelerating the medicines revolution with the extensive network of industrial partners to develop the centre according to the needs of industry. In this way we can address needs in a fast and efficient manner so that we can develop the new industrial approach without hesitation. Demonstrator technology and plants will be made available to help accelerate the R&D journey. This will include the CCUI Innovation Centre that will provide access to solvent/amine-free CO2 capture from emitter sites and bottled captured flue gas for use by investigators. All will be monitored by an independent strategic advisory board.

Opportunities for collaboration - Partnership: Great British Chemicals currently comprises 7 universities, a database of 100+ interested international companies (many FTSE listed) and foundation industries including paper & pulp, steel, pharma, glass, construction and chemicals production.

We will work to unite the activities of existing centres and hubs (for example Flue2Chem, Idric, NICER, CircularChem), We need a strong multidisciplinary approach to aim to meet net zero and to do this we need gtoups that can produce innovative, step-change research. We need not only academic expertise but also outstanding project management capabilities in order to effectively deliver an innovative flexible funding programme.

We are actively seeking further expertise in ceramics, pharmaceuticals, bio-transformations/engineering and supply/blockchain analysis. While we will already have access to world leading carbon dioxide reduction demonstrators and pilots we are open to extending this to novel facilities. There is an essential need for environmental scientists and engineers with expertise in air, water and land expertise and to a range of social scientists from politics and economics to behavioural psychologists and change management experts.

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The simplest way is by email (p.strying@sheffield.ac.uk) in the first instance. We can then arrange Zoom/Teams calls as appropriate.

Group Zoom meetings will be scheduled throughout the Full Proposal development phase and beyond. In person meetings can also be facilitated as required.

Paolo Tasca University College London

Co-leads - Paolo Tasca (Lead) – A serial entrepreneur in the blockchain space and is also the founder and Executive Director of the Centre for Blockchain Technologies at University College London (UCL CBT)

Nikhil Vadgama (Co-Lead) – The Deputy Director of the UCL Centre for Blockchain Technologies, as well as the Programme Director of the MSc Financial Technology at UCL

Jiahua Xu (Co-Lead)

Juan Ignacio Ibañez (DeepTech sustainability)

Walter Hernandez (AI Sustainability)

Vision - To create a Sustainable DeepTech Centre that will conduct both fundamental and applied research at the cutting edge of climate and sustainability applications of emerging digital technologies, notably artificial intelligence and distributed ledger technology.

The specific verticals to be explored are:

Establishing a global carbon price.

Making climate finance auditable.

Scaling sustainability markets' validation and verification.

Making sustainability reporting credible.

Boosting Supply chain transparency

Quantifying carbon sequestrated using artificial intelligence

Establishing a methodology for tokenising carbon credits

Sustainability reporting

Enhancing the renewable energy industry and increasing low carbon energy dominance through DeepTech.

Improving the state of the art of climate modelling in the face of emerging digital technologies such as AI and DLT.

For an integral perspective that is able to deliver in these fronts, the Centre will be comprised of leading experts in the fields of:

Climate science

Carbon Sequestration

Artificial Intelligence

Computer Science

Distributed Ledger Technology

Economics

Supply chains

These experts will:

Produce research publications in Tier A academic publications

Issue policy recommendations and cutting-edge workshops and conferences that can set the agenda in these crucial fields

Introduce an extensive methodology which turns carbon sequestrated into blockchain token credits

Support PhDs around the world, notably the Global South, conducting research in these key verticals.

A cohort of 15 experts would be assembled in the first quarter, with an additional 5 members per year henceforth: 2026 PhD support would start for the first 3 candidates, which will be 8 by 2027 and 16 by 2029. We aim to make the UK a centre for climate and regenerative technologies globally.

Opportunities for collaboration - To complement our expertise in artificial intelligence and blockchain technology, we will need domain experts in regenerative agriculture. This will be to effectively quantify carbon sequestrated and jointly create a methodology for tokenising carbon credits. We will also need experts in renewable energy, supply chain sustainability and regenerative agriculture.

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Dr Romain F H Viguier Scottish Carbon Capture and Storage, at the University of Edinburgh

Co-leads - Co-lead 1: Prof Mohammed Pourkashanian, The University of Sheffield

Co-lead 2: Prof Mathieu Lucquiaud, The University of Sheffield

Co-lead 3: Dr Ignacio Tudela-Montes, The University of Edinburgh

Co-lead 4: Dr Giulio Santori, The University of Edinburgh

Vision - Vision and Aims of the Centre for CO_2 Utilisation and Conversion Technologies

The Centre for CO_2 Utilisation and Conversion Technologies envisions a future where carbon dioxide (CO_2) is harnessed as a valuable resource rather than a waste product or a liability for its emitter. Our goal is to establish a virtual hub that fosters innovation and collaboration in the field of CO_2 conversion, facilitating the development of innovative technologies that transform CO_2 into useful products. We aim to bring together experts from various sectors and disciplines to create scalable and economically viable processes that contribute to a sustainable and circular economy. Our vision is to close the carbon loop, significantly reducing greenhouse gas emissions and mitigating climate change.

We aim to advance the design and synthesis of catalytic materials that can efficiently convert CO_2 into valuable products. This includes the creation of innovative heterogeneous catalysts, biocatalysts, and enzymes that enable high conversion rates and selectivity under energy-efficient conditions.

The Centre will encourage the exploration of alternative CO_2 conversion methods, including electrochemical and biological pathways. Our focus will be on developing electrochemical cells for fuel and chemical production, as well as leveraging engineered microorganisms and enzymes to convert CO_2 into bio-based products. These technologies have the potential to be directly integrated with renewable energy sources, further enhancing their sustainability.

A comprehensive evaluation of the environmental and economic impacts of CO_2 utilisation technologies and processes is crucial for their successful implementation. Part of the centre's activities will include conducting life cycle assessments (LCAs) and techno-economic analyses (TEAs) to determine the feasibility, sustainability, and market potential of the developed technologies. This will include assessing energy consumption, carbon footprint, and overall cost-effectiveness.

The Centre aims will be to serve as a platform for collaboration and knowledge exchange among industry, academia, and government agencies. By facilitating interactions, workshops, and joint research initiatives, the centre will accelerate the translation of fundamental research into practical applications. Our goal is to address technical, economic, and regulatory challenges through a multidisciplinary and cross-sectoral approach, ultimately paving the way for commercialisation.

Overview of Sectors and Disciplines Covered

- Chemical and Process Industries: Focus on synthesising chemicals and materials from CO_2, including fuels, polymers, and specialty chemicals.

- Energy: Development of renewable fuels and energy carriers, such as hydrogen and synthetic hydrocarbons.
- Environmental Technology: Innovations in Direct Air Capture (DAC) with direct conversion to products.
- Materials Science: Advances in catalyst design and the development of novel materials for CO_2 conversion.
- Food and Drink: Utilising CO_2 in food preservation, carbonation, and as a feedstock for biotechnological applications, including the production of food-grade chemicals.
- Oil Refineries: Exploring CO_2 conversion processes to enhance refinery operations and create value-added products from waste gases.

The disciplines covered include:

- Chemistry: Catalysis, reaction engineering, and materials chemistry.
- Chemical Engineering: Process design, optimisation, and scale-up.
- Biotechnology: Enzyme and microbial engineering for biological CO_2 conversion.
- Environmental Science: Life cycle assessment and environmental impact analysis.
- Economics: Techno-economic analysis and market assessment.

Opportunities for collaboration - To strengthen our bid and ensure the successful establishment of the Centre for CO_2 Utilisation and Conversion Technologies, we seek partners with specific expertise and experience in the following areas:

- Experts in Advanced Catalysis and Reactor Design: We are looking for partners who can offer innovative solutions for catalyst development, reactor optimisation, and integration into industrial processes. Their expertise will be essential for enhancing the performance and scalability of CO_2 conversion technologies.
- Experts in Electrochemical Processes and Materials Development: We aim to collaborate with specialists who can advance technologies such as CO_2 electroreduction and energy storage systems. Their role will involve developing novel electrodes, electrolytes, and cell designs to improve the efficiency and sustainability of electrochemical CO_2 conversion technologies.
- Experts in Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA): Partners with skills in LCA and TEA will be crucial for evaluating the environmental and economic impacts of CO_2 utilisation technologies. Their expertise will support comprehensive assessments of the technologies' ecological footprint, resource efficiency, and market viability.
- Experts in Industrial-Scale Process Development and Implementation: We seek partners with experience in scaling up processes from the laboratory to industrial scale. Their knowledge will help address operational challenges and optimise the integration of CO_2 conversion technologies into existing industrial infrastructure.

•   Experts in Policy and Regulatory Frameworks: We require guidance from experts who understand the policy and regulatory landscape related to CO_2 emissions and utilisation. Their insights will help ensure compliance with current regulations and contribute to shaping future policies, facilitating smoother technology adoption and deployment.

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Stephen Wallace   University of Edinburgh

Co-leads - Prof. Susan Rosser

Prof. Louise Horsfall

Prof. Dominic Campopiano

Dr Joanna Sadler

Dr Diego Oyarzún

Dr Christopher Ness

Dr Tyler Shendruk

Prof. Helen Hailes

Dr Jack Jeffries

Prof. Paul Freemont

Dr Jose Jiménez

Dr Mark Corbett

Dr Neil Dixon

Dr John Heap

Dr Jose Munoz

Dr Vinod Kumar

Prof. Jin Xuan

Dr Jhuma Sadhukhan

Vision - The UK Centre for Carbon Recovery & Re-entry (C2X) led by the University of Edinburgh will bring together seven UK HEIs and 40+ industrial partners to pioneer the accelerated co-creation, co-development, scale-up and deployment of novel sustainable bio-upcycling manufacturing processes. Through a synchronised hub-and-spoke model, C2X will nucleate key industrial waste sources from across the UK through state-of-the-art analytical chemistry facilities, advanced AI-driven data analytics, with established global leading UK engineering biology infrastructure and bioprocess scale-up facilities at the Edinburgh Genome Foundry, London BioFoundry, Biorenewables Development Centre (BDC), IBioIC Flex-Bio and Centre for Process Innovation (CPI) to create an accelerated technology pipeline for the re-entry of carbon embedded within abundant UK waste streams into sustainable products for which there is a key global demand. Centre industrial partners and academic spokes have been chosen from across the UK, based on demonstrated expertise in engineering biology for microbial upcycling: Edinburgh (plastics, lignin, carbohydrate, wool); Manchester (municipal); Nottingham (CO2), Northumbria (plastics), Cranfield (CO2, carbohydrate), UCL (sugar beet pulp) and Imperial (food, PAH) alongside lifecycle assessment experts (Surrey), bioprocess engineers (Edinburgh, UCL) and technology scale-up partners (IBioIC, CPI, BDC) to accelerate TRL progression towards industrial end-use. With a coordinated pipeline of ongoing and planned research activities aligned with diverse UK waste feedstock providers and end-users from across seven industrial sectors (food&drink, pharmaceuticals, packaging, logistics, materials, fashion, automotive), C2X will embed experts in bioprocess optimisation, technoeconomic analysis and lifecycle assessment throughout all Centre activities to ensure rapid de-risked biotechnology scale-up and industrial translation to generate maximum UK economic and climate gains.

Through ongoing engagement with national resource mapping exercises, C2X will also monitor and rapidly react to changes in industrial supply and demand. It will work closely with environmental scientists to assess the ecological impact of current and future UK waste disposal practices by sequencing prolific waste sites to discover new biological tools that will catalyse the development of future biotechnologies for the circular economy.

The C2X Centre has four aims:

- Recover. Facilitate the identification and chemical characterisation of abundant organic waste sources from UK commercial and industrial partners and quantify the associate climate impacts of existing waste disposal processes to ensure net-zero benefits.
- Recycle. Identify new degradation tools and approaches for waste recycling and engineer highly active chemical and biocatalysts for industrial waste remediation.
- Re-enter. Apply emerging engineering biology methods to develop novel bio-upcycling processes to re-enter carbon-based waste feedstocks into the UK circular economy to create higher-value industrial products.
- Redesign. Design new industrial products that are functionally comparable, sustainable and recyclable-by-design to ensure a future bioeconomy that can deliver improved technological solutions in addition to products that replicate existing industrial and consumer demands.

Overall C2X brings together leading UK experts in engineering biology with allied disciplines in chemistry, physics, engineering, social science and an extensive global network of commercial partners from across the entire value-chain to de-risk and accelerate the adoption of new cutting-edge biotechnologies that will enable transition to a more sustainable, circular and net-zero UK industrial future.

Opportunities for collaboration - C2X is seeking additional academic and industrial partners with expertise in the design and scale-up of industrial bioprocesses that can be utilised to remediate and upcycle organic waste feedstocks. We also seek new industrial partners to join our extensive and growing network of companies who either (i) generate waste that is currently disposed via UK landfill or incineration, and/or (ii) currently manufacture industrial end-products from petrochemical feedstocks and wish to explore sustainable bio-based manufacturing solutions using engineering biology.

C2X also seeks additional scientific expertise in the following areas:

- machine learning and artificial intelligence for the accelerated design and optimisation of industrial bioprocesses to join Centre Co-Is with existing expertise in deep learning for strain design, systems and control engineering, and whole-cell modelling.
- upstream pre-processing methods for the separation of complex organic mixtures
- novel downstream processing methods for product isolation
- high-throughput analytical techniques for small molecule identification in complex mixtures and rapid bioprocess analysis
- metagenomic sequencing and biocatalyst discovery from environmental samples
- metabolic engineering in non-model organisms and the use of C1 feedstocks
- green chemistry methods for waste feedstock depolymerisation and/or upcycling to create products that cannot be accessed via biocatalysis
- public engagement in biotechnology, climate change and circular economy topics

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Professor Brad Wynne University of Strathclyde

Point of contact: Mark O'Hare University of Strathclyde

Co-leads - PI – Prof. Brad Wynne (University of Strathclyde)

Co-I – Dr. Avril Thomson (University of Strathclyde)

Co-I – Prof. Karen Turner (University of Strathclyde)

Co-I – Mr. Stephen Fitzpatrick (University of Strathclyde)

Co-I – Prof. Kerry Kirwan (University of Warwick)

Vision - In the next 10 years, the UK faces a critical challenge of reducing an expected 500 million tonnes of materials, (with 45% of UK emissions comes from manufacturing) to be extracted for high-integrity, high-value sectors (renewables, nuclear, aerospace, marine and space), producing gigatons of waste destined for landfill.

70-85% of UK emissions are tied to material extraction and primary processing often conducted offshore. This leaves the UK economy vulnerable to global market fluctuations, lacking resilience and depending heavily on imports. The UK also has an opportunity to develop resilience through circular economy solutions, addressing going to ground for new materials, implementing reduce-reuse-recycle at a national scale and delivering sustainable economic growth and prosperity.

Vision and Aim:

Our vision positions the UK as a global leader in circular manufacturing, transforming high-integrity, multidisciplinary sectors by maintaining the highest value in products. This transformation will be driven by innovation and establishment of new standards through the following strategies:

1. Innovative Product Design: Develop methods to reduce/rethink/refuse, designing products and systems for 'end-of-use', and enabling secondary feedstocks and industrial symbiosis
2. Maximise product value: Unlock 'value retention processes' (Enhanced life, Reuse, Repair, Refurbishment and Remanufacture) in new and existing products/systems alike, maximising economic, environmental and social opportunity
3. Maximise material value: Develop high-value recycling methods, processes, and material characterisation, repurposing recycled materials into higher value applications
4. Technology: Methods development, control/monitoring systems, novel material dev, and automated repair

The project will leverage HVMC investment and the UKRI funded Remake Value Retention Centre (RVRC) project (£4.5m 2024-2028). This initiative will focus on a system-level approach to end-of-use products in high-value, high-integrity sectors.

Investigators will address high-integrity sectors, creating tighter loops of circularity for existing and new products. The project will address multi-faceted barriers to adoption including, lack of cross-sector collaboration, a need for new technologies, and novel business models. These solutions will deliver design, materials and manufacturing, lifecycle modelling, energy policy, and data-driven approaches across sectors to impact emissions.

Building on existing research, the project aims to move the UK from environmentally detrimental processes to sustainable alternatives. Collaboration with industry and policymakers, will drive scale up, translation of research, ensuring the entire system contributes to a potential 99% reduction in CO_2e for products through its processes. This could lead to a reduction of up to 60 $MtCO_2e$ from existing sectors and a further 925 $MtCO_2e$ reduction from new sector products. This initiative is projected to create 20,000 jobs in the UK renewables sector, contributing ~£1.6billion GVA for the sector.

A comprehensive dissemination plan establishes a research/industrial steering group, cross sector specialist working groups and raises awareness across diverse groups within the STEM community. The key research challenges to be tackled include:

- Overcoming siloed approaches that hinder comprehensive solutions
- Developing supply chains for recycled materials
- Designing high-performance parts for maximise life extension
- Deploying new materials, manufacturing and automation processes across sectors
- Establishing standards and business models for value retention processes
- Address cost/risk/skills gaps associated with circular practices

Opportunities for collaboration - Investigators will focus on high-integrity, high-value sectors at a product level, particularly in metals and composite materials, across design, advanced manufacturing, remanufacturing, and high value recycling. We seek additional expertise at a liquid material level and across different sectors such as electronics, healthcare/bio-medical, and plastics.

The project is linked to the NICER programme, the Remake Value Retention Centre (RVRC), and £9m of strategic investment from HVM Catapult themes in Net Zero: Industrial Sustainability, Clean Energy programs, and National Resilience: National Security and Healthy Living programs. We also seek partners through Foundational Industries to engage and disseminate materials requirements upstream, developing material properties at a ‘product’ level; ensuring the full value chain is covered. The project will leverage private investment from the HVMC network, building a consortium from across sectors in energy recovery methods, standards, policies, circular business models, digital-twins activity.

The project must be transdisciplinary and, driven by the findings of the EPSRC-TERC report, we see opportunities for forming disruptive and innovative groupings across disciplines. The project will build a robust ecosystem that supports innovation, collaboration, and widespread adoption of circular economy practices across high-integrity sectors. This collaboration aims to overcome the multifaceted barriers to adoption, such as large risks, lack of cross-sector collaboration, and low awareness of circular business opportunities, ensuring successful implementation of the project’s vision and aims. There is a unique opportunity to create a ‘Big Picture’ of the challenges to uptake and business change for critical UK sectors, which in turn will allow successful future interventions.

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