Critical Mass Programmes to Drive a Sustainable Future: Expressions of Interest Invited to Full Stage – Vision Statements

This document publishes the Expression of Interest Vision Statements - by applicants who have provided us with consent – that have been successfully invited to progress to the Full Stage of this funding opportunity. Please note, as part of the Expression of Interest assessment, applicants were also asked to provide EPSRC with a statement demonstrating the complementarity to the current and foreseeable landscape of research in the UK – these components are not being published.

Due to the volume of applications received at the Expression of Interest stage, we are not publishing all Vision Statements. The publication of these selected statements aims to enhance the visibility of successful EOIs, thereby improving the potential for new collaborations between the Project Leads and organisations in industry, the third sector, the public sector, or other academic researchers. These external parties may now directly reach out to the Project Leads to explore collaboration opportunities, with any further engagement being at the discretion of the Project Lead.

The Full Stage Funding Opportunity can be accessed here.

Some Vision statements have been published with redactions, at the request of the applicant / stakeholders, owing to sensitive or technical content which they do not wish to disclose publicly.

We have only attained consent to publish the Project Lead against each of these, and not any details of the applicant team / project partner / stakeholders. We have taken this decision in the light that there may be flexibility between the Expression of Interest and Full Stage bids in terms of the applicant team and co-creation engagements with stakeholders.

Vision Statements

Project Lead and Host Institution**:** Yongliang Li (University of Birmingham)

Vision & Objectives demonstrating call alignment**:**

According to DESNZ, electrifying industrial heating could achieve 15–40% of required carbon abatement by 2050. While direct electrification is costly, integrating it with heat storage allows flexible use of excess renewable electricity to improve cost-effectiveness. Leading industry players are demonstrating this approach, such as AMP Clean Energy, which is developing a 225 MW project integrating a high-voltage electric boiler and pressurized hot water storage to generate heat alongside biomass boilers for the Scotch Whisky industry, while also mitigating wind energy curtailment from grid constraints. This project aims to develop a viable interseasonal energy storage solution for decarbonizing industrial heating, by integrating direct volumetric electric heating with hydration/dehydration-based thermochemical heat storage (TCS). TCS enables long-duration energy storage with minimal standby energy losses, while volumetric electric heating overcomes the heat transfer limitations, resulting in fast reaction kinetics and operational flexibility. Our vision is that widespread adoption of our solution will transform energy-intensive industries into flexible demand response users, enabling them to absorb excess renewable electricity during low-demand seasons and generate heat independently using stored thermochemical fuels. This approach minimizes their grid electricity consumption during high-demand seasons, particularly in winter when commercial and domestic electricity demand peaks for heating, ultimately enhancing grid resilience.This project will be co-led by Profs. Yongliang Li and Stuart Scott, who are leading the only two thermochemical energy storage projects funded under the most recent "Grid-Scale Energy Storage" call (EP/W027887/1 and EP/W027860/1), and Jacopo Torriti who is the Flexibility Theme Lead of the Energy Demand Research Centre (EP/Y010078/1). Our primary objectives are:

(1) Volumetric Electric Heating-Enabled Charging: to investigate the dehydration kinetics and then to develop and optimize flow reactor (which enables energy and power decoupled charging process) powered by various volumetric electric heating techniques.

(2) Manufacture of ‘Thermochemical Fuel’ from Waste: to investigate the impact of impurities and additives in chemical and electrical properties and then to explore cost-effective manufacturing methods using wastes such as cement plant by-products and construction and demolition waste.

(3) Thermochemical Fuel-Powered Discharging: to investigate the hydration reaction kinetics and heat/mass transfer in the flow reactor for rapid, controlled heat release or steam generation.

(4) Financial Viability and Market Pathways: to identify practical pathways for industrial users to achieve financial benefits through actively participating in the grid balancing market, and to explore the design of a hypothetical ancillary service to incentivise interseasonal storage.

Project Lead and Host Institution: Yasser Mahmoudi (University of Manchester)

Vision & Objectives demonstrating call alignment:

Particle-based Interseasonal Long Duration Energy Storage (P2Store)

P2Store aims to revolutionise energy storage sector by addressing the UK's need for 100 TWh of long-duration energy storage (LDES) technologies by 2050, critical for transitioning to a sustainable, net-zero future. These technologies must reliably manage daily, seasonal and extreme weather energy fluctuations. Existing storage technologies, such as pumped hydro and compressed air storage, face geographic and environmental constraints, have low energy density (0.2-15 kWh/m3) with medium discharge durations. Flow batteries with medium discharge duration, have low energy density (10-60 kWh/m3) and high cost £300-£500/kWh. Thermochemical systems enable seasonal storage with energy density of 250-550 kWh/m3, but show moderate efficiency of 50-60% due to charge/discharge losses, complex design, material degradation and limited scalability. P2Store overcomes these limitations by introducing a first-of-a-kind interseasonal LDES solution based on solid particles. Its principle involves converting surplus renewable electricity into high-temperature heat (600-1000°C), transferring it to solid particles (e.g. silica sand), and storing them in insulated aboveground silos. On demand, the hot particles descend into a heat exchanger, transferring heat to supercritical CO2 (sCO2). The recovered heat is then converted into electricity via an sCO2 power cycle, integrated with a compact, fast-response regenerator. P2Store has high energy density 700-1300 kWh/m3. Using available insulation materials (e.g. mineral wool), it can achieve low heat loss <1% per week, enabling 85-90% seasonal heat recovery. By utilising non-toxic and abundant storage media (e.g. silica sand s) and sCO2 power cycle at £0.06-£0.07/kWh, P2Store can achieve exceptionally low cost of £0.02-£0.05/kWh. It is scalable from MWh to GWh with decoupled storage capacity (silo size) and power output, enabling flexible optimisation for diverse storage needs. With discharge durations covering hours to months, P2Store uniquely addresses daily, weekly and seasonal energy fluctuations, surpassing the capability of existing LDES technologies. This transdisciplinary project aims to conduct fundamental studies leading to the development and integration of P2Store's key components which are not commercially available. These include granular particle heater and storage silo (WP1-Manchester), particle-to-sCO2 heat exchanger (WP2-Liverpool), sCO2 power cycle (WP3-Cranfield) and fast-response regenerator (WP4-Birmingham). Through components integration (WP5-All), we will develop and test a P2Store prototype. Whole-system techno-socio-economic, environmental and policy analyses (WP6-

Imperial College) will assess P2Store financial viability, value and regulatory requirements, supporting its grid integration.

Project Lead and Host Institution: Zhibin Yu (University of Liverpool)

Vision & Objectives demonstrating call alignment:

Interseasonal Thermal Energy Storage (ITES) offers a promising solution for the UK's heat decarbonisation. It is classified into three types: sensible, latent, and thermochemical. Sensible heat storage, such as borehole, aquifer, and hot water pit storage, requires extensive land and favourable geology. With low energy density (0.1–0.3 GJ/m.), high heat losses, and installation costs, deployment is limited. Latent heat storage using phase change materials offers higher density (0.3–0.6 GJ/m.) but suffers from supercooling and low thermal conductivity, requiring costly heat exchangers and limiting scalability. Thermochemical heat storage offers long-duration, low-loss, high-density (1.5–2.5 GJ/m.) energy storage. Current research focuses on for small-scale applications. While salts are inexpensive, the overall system are costly for large-scale ITES. This project develops a scalable thermochemical ITES integrating with large-scale district heating networks. In summer, renewable heat (e.g., solar) is used to drive the reactor, dehydrating hydrated salt. In winter, the produced anhydrous salt is rehydrated to release heat for district heating. The goal of this project is to address the identified challenges and develop the proposed solution through the following objectives:

1) Design and optimise composite materials with higher energy density, stability, and low dehydration temperature for ITES.

2) Develop a novel reactor to overcome the limitations of current systems, such as slow reaction kinetics and material agglomeration, enabling rapid hydration/dehydration, improved heat and mass transfer, and anhydrous salt production for large-scale deployment.

3) Develop a novel flexible heat pump technology to integrate with the developed ITES system and the district heating. It uses solar thermal energy for dehydration in summer and upgrades hydration heat for district heating in winter.

4) Engage end-users, energy companies, and policymakers to ensure user acceptance, co-creation, regulatory alignment.

5) Assess the economic feasibility and life-cycle impact and develop business models for large-scale adoption.

Project Lead and Host Institution**:** Yuehong Su (University of Nottingham)

Vision & Objectives demonstrating call alignment:

The proposed project aims to develop a novel Renewable-Powered Thermochemical Energy Storage (TCES) for Heat and Electricity Generation (RePTES). By maximising the use of renewable energy and minimising reliance on fossil fuels, RePTES supports the UK's long-term sustainability goals towards a net-zero future beyond 2030. This initiative aims to advance renewable energy technologies and enhance existing systems to accelerate the energy transition. Building on prior expertise, the project will develop a novel TCES system integrated with the Organic Rankine Cycle (ORC). This system will enable long term/seasonal storage of renewable energy, generating heat and electricity even when solar power is unavailable and integrating other energy sources such as waste heat and biomass for continuous operation. While primarily focusing on medium-temperature heat storage (200–400°C), the system can also support high-temperature storage (1,000°C+), making it versatile for various power cycles (ORC and air cycles). A key innovation is the TCES reactor, which incorporates new porous encapsulation techniques with optimised air passages to enhance heat/mass transfer. In the system, new composite TCES materials (TCES-Ms) consisting of $Mg(OH)_2$, $MgCO_3$, $Ca(OH)_2$ doped with $LiNO_3$, $NaNO_3$, and KNO_3 will be used. TCES-Ms will be ball milled and use graphite to enhance thermal conductivity and reaction kinetics. Advanced characterization tools like TGA, DSC, and SEM will be employed to optimise the TCES-Ms. TCES-Ms offer significantly higher energy storage densities (100–600kWh/m^3) compared to sensible heat storage (20–50kWh/m^3) and allow long-term storage without heat loss—a challenge for other heat storage methods. The project will explore advanced TCES-ORC integration, employing energy recovery methods, and developing low-global-warming-potential refrigerant mixtures for ORC. Optimisation will leverage computational modelling (CFD, ANSYS) and artificial intelligence (AI) tools. The project involves the Universities–Nottingham, Sheffield, Reading, along with industry partners PCM Products, Arkaya, Solar Ready, and Data Clarity. After initial laboratory testing, a three-year pilot will validate the system. Collaborating with stakeholders, RePTES aims to influence international energy storage policies. The project establishes a strategic vision for seasonal TCES development, uniting academia, industry, and policymakers, addressing challenges in material stability, system integration, and efficiency, while evaluating economic viability. Risk management focuses on material degradation, environmental impacts, safety, and market adoption. This multidisciplinary project combines energy storage, material science, and power generation, aiming for long-term sustainability benefits in the UK. It emphasizes diversity, inclusion, and environmental sustainability, aligning with existing research investments to advance the UK's innovation landscape.

Project Lead and Host Institution**:** Qiuwei Wu (Queen's University Belfast)

Vision & Objectives demonstrating call alignment:

The UK’s net-zero energy system by 2050 has led to a fourfold increase in wind and solar energy over the past decades. However, the transmission grid bottleneck leads to significant wind energy curtailment. As Scottish wind capacity is set to grow five times faster than transmission infrastructure, wind curtailments are expected to become more frequent and prolonged. Additionally, the UK’s energy system lacks optimal coordination with interconnectors, highlighting the need for holistic, cost-effective approach. Energy storage technologies are essential to mitigating curtailment and balancing interseasonal energy demand. Batteries and pumped hydro are either unsuitable for long-duration storage or highly location dependent and capital intensive. Hydrogen electrolysers offer potential for interseasonal storage but remain commercially unproven at scale. In contrast, ammonia (NH3) presents a promising alternative as a hydrogen carrier and zero-carbon fuel. Liquid ammonia has 1.7 times the volumetric hydrogen density of liquid hydrogen and can be stored and transported efficiently at ambient temperature and moderate pressure. Ammonia is well-positioned as an energy carrier with established handling procedures. Several challenges must be addressed to enable green ammonia as an interseasonal storage solution. First, a system-level framework and assessment methodology are missing, which can integrate green ammonia into a cost-effective and reliable net-zero energy system. Second, though ammonia can be locally converted to hydrogen, allowing existing gas or combined-heat-and-power (CHP) turbines to use a hybrid ammonia-hydrogen fuel with minimal retrofits, there is limited availability of ammonia-fired or combined ammonia-hydrogen-fired generators. Third, there is a lack of a robust modeling framework to assess national and local energy market interactions. An AI-powered modeling framework can analyze historical energy data, optimize resource allocation, and inform energy market strategies.

The project aims to:

1. Develop a system-level assessment of green ammonia as inter-seasonal storage, integrating other storage solutions, infrastructure expansion, and inter-regional coordination for a cost-effective net-zero energy system.

2. Validate the technical feasibility and optimize the performance of ammonia-fired generators.

3. Establish an integrated national and local energy market modeling framework leveraging AI and data analytics for optimized resource allocation.

4. Provide techno-economic insights and policy recommendations for scaling green ammonia deployment.

The outcomes will support the UK government, energy agencies, and industry stakeholders in designing national strategies for a sustainable, cost-effective energy future while facilitating industry alignment with these strategies.

Project Lead and Host Institution: Vahid Niasar (University of Manchester)

Vision & Objectives demonstrating call alignment:

Title: Saline Aquifers for Long-term Integrated Compressed Air and Thermal Energy Storage to Decarbonise Heat and Power Sector (SALIENT)

1- Research vision

Transitioning away from unabated natural gas requires alternative long-duration storage to balance intermittent renewables with seasonal energy demand. SALIENT proposes a transformative approach by leveraging saline aquifers for integrated compressed air energy storage (CAES) and thermal energy storage

(TES).

UK saline aquifers offer an estimated 77–96 TWh storage capacity with 54–59% round-trip efficiency. Unlike conventional CAES-TES in salt caverns, aquifer-based systems introduce extra complexities due to the interactions between porous rocks, compressed air, and heat in the presence of saline water. However, they provide orders of magnitude greater capacity and ability to span large geographical areas. This feature is particularly valuable for alleviating electricity network capacity constraints, which remain a major barrier to the cost-effective expansion of renewable energy generation. SALIENT aims to advance fundamental Aquifer-based CAES-TES knowledge, demonstrate feasibility in the lab, and develop policy, sustainability and strategies to utilise aquifers for deep decarbonisation of electricity and heat sectors.

2- Objectives:

A. Aquifer CAES-TES Engineering: Develop AI-enhanced multiscale modelling and laboratorial experiments of multiphase flow, thermodynamics of air/brine/rock systems in saline aquifers for the CAES-TES technologies.

B. Integration of Electricity Network and Subsurface: Develop control strategies and grid integration solutions to optimise the dispatch of energy from SALIENT systems, enhancing grid flexibility and resilience, assess the role SALIENT in decarbonising the GB’s electricity and heat sectors within CleanPower2030 and NetZero2050 targets.

C. Socio-Economic Analysis: Life-cycle analysis and development of a techno-economic assessment framework to evaluate the scalability and cost-effectiveness of SALIENT technology.

D. Policy Development, Stakeholder Engagement and Impact Realisation: Examine appropriate policy frameworks, regulations, identify effective financing mechanisms and incentives to de-risk investment in seasonal storage, innovative business models to ensure commercial viability, open-source modelling tools development.

3. Alignment with UKRI Scope:

SALIENT directly aligns with the UKRI's focus to address the energy transition by combining subsurface engineering, electricity network optimisation, and LCA and policy to develop holistic solutions for grid-scale storage with minimal land use requirements. SALIENT creates a synergistic system that offers significant advantages over individual storage technologies and addresses the highlighted inter-seasonal energy storage challenge beyond hydrogen solutions.

Project Lead and Host Institution**:** Yupeng Wu (University of Nottingham)

Vision & Objectives demonstrating call alignment:

Heating and hot water for buildings account for 40% of the UK’s energy use and 20% of its greenhouse gas emissions. Achieving Net Zero by 2050 requires shifting to electrified heat supply and utilising waste heat. However, this shift is complicated by temporal mismatches between heat supply and demand ranging from daily fluctuations to seasonal imbalances. The UK has 572TWh/year of untapped industrial low-temperature waste heat (<100°C), which, if stored and redeployed, could significantly aid decarbonisation. This project will look at the interplay of energy resource, inter- seasonal & annual storage requirements and a particular long-term stable thermal energy storage technology addressing this challenge of heat decarbonisation. ThermoChemical Energy Storage (TCES) offers a promising solution due to its exceptionally high energy storage density(400–870kWh/m^3)—up to 20–30times greater than conventional thermal storages. Moreover, it provides long-term, safe, environmentally friendly and loss-free heat storage, making it particularly suitable for Interseasonal Energy Storages (IES). However, practical implementation remains limited, with achieved energy densities just above 200kWh/m^3, due to key technical challenges:

a) deliquescence of salts at high humidity, reducing long-term stability,

b) limited discharge efficiency due to water diffusion resistance at the salt surface,

c) low heat transfer coefficients in existing reactor designs, restricting scalability,

d) existing IES require charging temperatures >100°C.

This project will address these barriers by pioneering a low-temperature, high thermal capacity and long-duration TCES system, co-designed with stakeholders for practical feasibility and market adoption. It offers a cost-effective, scalable solution for decarbonising heating and cooling by leveraging industrial low-temperature waste heat and solar thermal energy. The system can be integrated into district heating networks or deployed as modular, transportable units via vehicles and trains, serving communities or individual buildings. This flexibility supports evolving heat delivery systems and advances Net Zero 2050 goals.

Our objectives include:

Material Innovation: Develop a novel stable, millimetre-scale, 3D mesoporous salt hydrate composite TCES with energy density>300kWh/m³, charging temperature<100°C, and long durability, surpassing current limits.

Advanced Reactor Design: Develop a scalable reactor with micro-channels to enhance heat transfer and enable deployment in district heating or modular units.

Circular Economy: Assess the environmental impacts and economic viability of the proposed system, focusing on production, reuse, and end-of-life strategies.

End-User Adoption: Evaluate user acceptance, feasibility, and policy alignment for widespread implementation.

Co-Design with Stakeholders: Collaborate with industry, policymakers, and end-users to tailor solutions and accelerate market adoption.

Project Lead and Host Institution: Robert Dryfe (University of Manchester)

Vision & Objectives demonstrating call alignment:

Several electrochemical technologies could contribute to interseasonal energy storage (IES). This programme will develop and evaluate two competing technologies, and a hybrid system, within a sustainability framework for UK IES. Our specific aim is to explore synergies between these technologies. First, we will consider the electrolytic generation of methanol (Cobb) and power generation through fuel cells (Holmes). Secondly, we will evaluate redox flow batteries (RFB) (Dryfe) as a single solution to IES through novel formulations of zinc/halide chemistry. Electrolyser/fuel cell combinations have benefits of higher energy density, but lower round trip efficiency, while the converse is true for RFBs. Parallel techno-economic and life-cycle analysis (LCA) will benchmark and compare these technologies for UK IES. We will evaluate methanol production from multiple CO2 sources as part of the sustainability framework. Methanol is chosen as the energy storage medium due to its high energy density, ease of storage as a liquid at room temperature and reasonable round trip energy efficiencies. Complementary RFB approaches will be developed to optimise the cell chemistry. Crucially, optimisation of the CO2 to methanol reactor and the halide half of the flow battery will allow their combination to develop a hybrid “redox fuel cell” (or hybrid battery). This synergistic approach has the advantage of eliminating the potentially “high barrier” counter-electrode reactions (conventionally, water electrolysis to oxygen, which is simply vented) from the CO_2 reactor, and the non-flow based Zn electrode from the RFB. Hybrid technologies have been reported but are normally based on hydrogen, which has inherent disadvantages for IES. Key complementary challenges of the combined technologies will be explored with advanced characterisation applied to understanding electrode, membrane and electrolyte degradation (Haigh). We will co-develop the programme with industrial collaborators (bp, JM, Technical Fibre Products, Ineos, Haliogen Power) and engage with the Energy Innovation Agency (Greater Manchester based) to ensure our solutions are scalable and economically viable. Sustainability will be integrated throughout the development and deployment of the methanol, RFB, and hybrid routes (Stamford). LCA will assess all technologies from cradle to grave, against 18 environmental impact categories, to inform their development. Concurrent life cycle costing workstreams will evaluate costs at scale in collaboration with our industrial partners. Later, the absolute sustainability framework will be used to optimise deployment scenarios for the storage technologies to simultaneously minimise costs and emissions in net zero energy futures. This approach will ensure that the innovative electrochemical IES technologies developed in this work are aligned with the core principle of enabling a sustainable future.

Project Lead and Host Institution: Robert Steinberger-Wilckens (University of Birmingham)

Vision & Objectives demonstrating call alignment:

WINTER AMMONIA will trail-blaze a route to highly effective inter-seasonal energy storage. On average, UK wind turbines produce 2.4x more energy per day in mid-Winter vs. mid-Summer. UK solar panels generate 9 times more mid-Summer than mid-Winter. Present electricity demand rises ~+20% rise in Winter. Electrifying space-heating will considerably grow this seasonality. Balancing supply and demand seasonally suggests a wind:solar mix >90:10. Downsides are: (1) wind power is much more variable than PV between years, so high wind penetration drives inter-annual storage. (2) PV may become much cheaper per kWh than wind — even in GB. Using ammonia (NH_3) to “store electricity” is not optimal. WINTER-AMMONIA explores interseasonal storage with 4 components: (i) forming NH_3 from renewable energy (RE) when abundant, (ii) driving CHP engines for Winter heating new developments, (iii) deploying aqua-ammonia (A-A) for retrofittable Winter heating and (iv) selling/sourcing NH_3 abroad. Flexible production of NH_3 from RE is already being demonstrated by project partners STFC and needs further work on cost-reduction and durability. Novel NH_3 compression to >12bar for storage is underway at Nott’m and Durham. NH_3-fired engines are being mastered by current projects involving Nott’m and Cardiff and require customisation for variable-load engines running at fixed (synchronous) speed where all heat rejection has value. Nott’m developed the concept of A-A for heating in which A-A is delivered via the existing gas network to replace gas-fired heating with a safe, sustainable, zero-carbon and low-disruption solution. Preliminary work indicates this is surprisingly feasible; a batch process is already proven at Nott'm, and a continuous separation unit is devised. Two gas networks are taking this very seriously and considering support for trials. Exergy from >600degC combustion temperatures can drive an absorption heat pump using methodologies polished at Imperial (CM) and Durham to boost heat delivery. That could be done also with CH_4 or H_2 as fuel, but water separated from A-A (containing <50 ppm NH_3) provides a rich source of low-grade heat (always >= 0degC) that is cheap to collect. Nott'm is demonstrating this "latent heat pumping" concept with electric heat pumps. NH_3 transportability potentiates international energy exchange much studied at B'ham (including geo-political aspects) and solves worldwide flexibility challenges. NH_3 storability (esp. as A-A) brings resilience advantages and additional flexible power paths. Using A-A for some heating retrofits would flatten GB electricity demand, improve grid utilization, reduce upgrades and leverage existing gas networks. NH_3-fired CHP plant would offset power drawn by electrical heat pumps. System benefits from correlating generation with heat requirements are studied extensively at Imperial (IS) and B'ham (JR). WINTER AMMONIA is unique and may be transformative.

Project Lead and Host Institution: Thomas James Cherrett (University of Southampton)

Vision & Objectives demonstrating call alignment:

ERFLOG: Electrifying Road Freight and Logistics by 2050 through Understanding and Integration - UK Road Freight employs 1.9m people in 60,000 companies, generating 7-8% of national carbon emissions. It is difficult to decarbonise and highly sensitive to climate risk. Electric propulsion is now the only viable route to decarbonising logistics. Hydrogen-powered lorries are unaffordable due to their high capital and running costs. Electrification of road freight contains three major techno-economic challenges: 1)UK electricity consumption will increase by about 30%, requiring 11GW more power and substantial distributed grid reinforcement. 2)Battery-electric freight vehicles (BEVs) are significantly heavier than diesels, reducing payload requiring additional EV loads and cost. 3)EVs have limited ranges. To minimise downtime and additional logistics costs, 'opportunity charging' must fit into times when vehicles are loading/unloading requiring fast chargers with electrical supply connections up to 20MW, at 20,000 logistics facilities. Our vision is for an orderly, optimal transition of the road transport system to low-carbon, electric propulsion by 2050. This will benefit the environment, industrial efficiency, national prosperity and develop a well-trained, resilient, efficient and competitive logistics industry. The 5-year project will deliver this vision by assembling a diverse, trans-disciplinary team of world-leading researchers, vehicle manufacturers, logistics and energy industry leaders and policy makers, who will co-create a systems-based approach to predicting and informing the logistics system’s transition.

Objectives: 1) Create and validate a comprehensive ‘dynamic roadmap’ (emergent agent-based model) of the complex, adaptive electric road freight system. (Model long-haul and urban logistics operations, the evolution of vehicle technology, land use, power and energy systems and charging infrastructure). 2) Answer essential questions for the transition: vehicle choices; energy requirements and infrastructure (power needs, connection sizes and locations, grid reinforcement, static vs dynamic charging); land use (for charging, energy generation, logistics facilities); business models and finance needs; economics and optimal policy requirements; and environmental outcomes. 3) Build capacity in industry and Government (prepare them for implementing an optimal electric logistics system by 2035-2040). We will validate and exercise the dynamic roadmap ‘in the loop’ in a wargaming environment and co-create and pilot the training systems needed by industry and government to educate participants in all roles: from drivers to the C-suite. 4) Maximise impact. Develop insights, robust decarbonisation pathways and decision-support tools for all stakeholder groups.

Project Lead and Host Institution: Conchúr Ó Brádaigh (University of Sheffield)

Vision & Objectives demonstrating call alignment:

Aerospace is a strategic pillar of the UK economy, driving exports, innovation, sustainability & national security, with a turnover of $35 billion p.a. & 120,000 highly skilled jobs. Although sustainable aviation fuel (SAF) reduces aircraft environmental impact, it still emits CO2. The Aerospace Technology Institute’s (ATI) FlyZero project identified liquid hydrogen (LH2) as the most viable energy source for zero emissions from future aircraft. This is the biggest technological challenge to aerospace since the gas turbine and challenges the UK’s dominance in aerospace fuel systems & gas turbines. Lightweight composite materials are critical for the UK’s Jet Zero strategy and are potential alternatives to metals for storage & distribution of LH2 on aircraft. The ATI-HCN has completed a Materials Landscaping study (unpublished) which identifies a lack of fundamental knowledge on composites performance in LH2. State-of-the-art carbon fibre reinforced composites can exhibit x10 higher permeability to hydrogen than metals & suffer from thermal residual stresses between fibres & polymer, causing accumulated damage. This is a major barrier to the development of LH2-fuelled aircraft, as metal storage solutions are likely to lead to aircraft which are too heavy to be competitive. New composite material configurations, tailored for significantly reduced H2 permeability & improved long-term durability at 20K will be developed. Novel hybrid barrier liners & manufacturing processes will be developed for the multi-wall tanks & pipes to contain & distribute LH2 safely in aircraft. Multi-scale mechanics understanding will be developed to find the optimum reinforcement microstructure, bulk material & interface development for safe long-term durability in LH2. Trade-offs between functional performance, manufacturability, maintainability & recyclability, and benchmarking against metallic solutions will be investigated. Transdisciplinary supply chain research will investigate the future-proofing of environmental sustainability & resilience of the UK composites manufacturing supply chain for LH2 storage. It will use a future systems approach to 1) compare materials manufacturing supply chains, model different raw material suppliers & solutions to recover/recycle the end of life materials; 2) predict how external factors: CBAM regulation, carbon leakage, tariff uncertainty & net-zero energy may influence where composite materials are sourced & components manufactured to reshore the supply chains to the UK. This project brings together the UK's leading experts on polymer composites, manufacturing, cryogenic materials testing & supply chain development in a transdisciplinary approach to developing lightweight materials capable of storing and distributing LH2 on aircraft. Alignment with industry key knowledge, skills gaps & priorities will be achieved through a steering group including OEMs, primes & supply chain, ensuring rapid technology transfer into industry.

Project Lead and Host Institution: Meysam Qadrdan (Cardiff University)

Vision & Objectives demonstrating call alignment:

Title: Repurposing Existing Gas Infrastructure for a Net Zero future (REGAIN)

CONTEXT

Great Britain's gas infrastructure is approaching a critical transition phase as the shift to net zero reshapes its future role away from the transport of fossil natural gas. Infrastructure changes could differ markedly between various pressure tiers and geographies depending on the complex interplay of multiple factors including national and regional decarbonisation pathways for electricity, industry and heat. Sections of gas infrastructure could be repurposed to transport alternative molecules such as hydrogen, CO2 and biogas; adapted for energy and non-energy purposes such as compressed air storage, flood water collection, conduits for cabling; or mothballed/decommissioned. The 2030-2050 timeframe will see significant change across gas networks, yet substantial knowledge gaps persist around the environmental and economic trade-offs for different use cases beyond fossil gas.

Britain requires a substantially expanded knowledge base to better inform its regulatory determinations for the price control period beginning in 2031 and beyond. For a sense of scale: the regulated asset value of Great Britain's gas networks stands around £26 billion and an NIC report published in late 2023 suggests transition total costs could range from £45-74 billion by 2050.

VISION AND OBJECTIVES

The vision of the REGAIN programme is to establish an integrated programme that combines cross-disciplinary knowledge to address the complex challenge of gas infrastructure transition, and to be at the forefront of this research globally. By bringing together a critical mass of UK expertise and building international research leadership, we will deliver innovative and transformative research into the re-use or decommissioning of gas infrastructure beyond fossil gas. Our programme will significantly expand the evidence base in this critical area, directly contributing to the shift away from environmentally detrimental fossil fuels toward more sustainable alternatives that accelerate clean energy transitions and enable circular material flows, such as CO2 utilisation.

REGAIN's objectives are to:

Create a deeper evidence base for policy decisions regarding gas network futures

Develop methodologies for evaluating transition pathways against multiple criteria

Identify region-archetype options for gas infrastructure, acknowledging geographical and socioeconomic variations

Build modelling tools to understand system-wide implications of infrastructure changes

Establish a platform for stakeholder knowledge exchange and scenario testing.

A detailed research programme will be co-created with research theme leads, policy makers and gas sector stakeholders; at the EoI stage major gas sector stakeholders including National Gas, IGEM, WWU, NESO, DNV and Energy Systems Catapult have expressed in principle support for the programme.

Project Lead and Host Institution: Matt Carnie (Swansea University)

Vision & Objectives demonstrating call alignment:

SPiCE will advance the huge potential of next-generation photovoltaics (PV), delivering transformative systems-based solutions to enable the UK to transition to a new era of clean energy. Addressing the urgent challenge of decarbonising energy generation while ensuring resource efficiency, SPiCE will develop high-performance, scalable and integrated PV technologies that directly contribute to Net Zero. Building on strategic applications identified in EPSRC Program Grant (ATiP - EP/T028513/1), SPiCE will focus on two applications identified as having the greatest potential to drive sustainable energy transitions: 1. Agrivoltaics (Agri-PV): Developing durable PV for dual-use, ensuring energy generation complements rather than competes with agricultural productivity, enhancing food and energy security. 2. Indoor PV: Advancing low-light and indoor (IPV) technologies for energy-autonomous IoT devices, reducing battery reliance and enabling smart, efficient infrastructure.

SPiCE will embed principles of sustainable design and scalable manufacturing across whole-system lifecycle. The key challenges include enhancing PV efficiency, durability, and whole system power management, accelerating deployment into real-world applications.

Research objectives (RO) have been co-created with partners such as PolySolar and the NFU for the Agri-PV strand and partners such as Epishine, E-peas and Logitech for the IPV strand:

RO1: Optimise PV technologies such as perovskite and organic PV for Agri-PV and Indoor PV, enhancing efficiency and stability.

RO2: Develop low-impact manufacturing using roll-to-roll processing, non-toxic solvents, and sustainable materials for scalability.

RO3: Integrate PV into real-world systems, optimising energy harvesting for smart sensors and low-light agricultural applications.

RO4: Establish end-of-life strategies for material recovery, recyclability, and circular design to enhance sustainability.

RO5: Drive adoption through co-creation with industry, farmers, policymakers, and stakeholders for rapid deployment and impact.

SPiCE will take a transdisciplinary, co-creation approach, integrating materials science, device engineering, IoT, and environmental and social sciences to drive real-world impact.

SPiCE aligns with EPSRC’s Energy and Decarbonisation priorities by developing low-carbon PV solutions that contribute to net-zero energy generation and more efficient energy use. While not the main focus of the project, SPiCE will embed circular principles throughout to enhance PV sustainability.

By mentoring Early Career Researchers and fostering interdisciplinary collaboration, SPiCE will build the next generation of PV and energy experts, ensuring long-term research capacity and innovation. This will position the UK as a leader in sustainable, high-performance PV, accelerating the transition to a resilient, low-carbon society that supports long-term energy security and Net Zero goals.

Project Lead and Host Institution: Nick Baker (Newcastle University)

Vision & Objectives demonstrating call alignment:

SemiWave will establish the UK as a global leader in sustainable wave energy by developing technology that has been optimised for performance, economic viability and social acceptance, whilst being environmentally benign. It supports the UK's transition to a clean, circular energy economy and the need for diversified renewable energy sources. The amount of electricity that can be generated from waves is similar to that from offshore wind. The two resources are complimentary, but the slow speed of waves means large dedicated electrical machines and power converters are required. This power take off (PTO) technology affects device reliability, efficiency and lifetime cost of energy. PTO performance is dependent on a diverse range of raw materials, supply chains and manufacturing techniques. A generator using rare earth permanent magnets is likely to be more efficient and lighter than one which is rare earth free. Encapsulation in epoxy improves thermal performance, offers environmental protection and increases overall reliability. However, the use of epoxy and rare earths increases the carbon footprint whilst adding challenges to the supply chain and end-of-life material recovery. There is hence a conflict between wave energy converter performance and embedded environmental and social impact. This is best resolved at the design stage with a system level transdisciplinary collaboration. This challenge is amplified by the need to rapidly scale up renewable energy deployment. The total value to the UK of wave energy is estimated to be £2.32bn-4.37bn by 2050. In the same time frame, offshore wind turbines will use 93,000 tonnes of rare earth magnets, placing significant strain on the supply chain and raising environmental and political concerns. SemiWave is a collaboration between electrical, electronic and civil engineers, hydrodynamicists, wave energy developers, environmental modellers and industrialisation centres. There is excellence in developing and deploying power electronics, electrical machines, wave energy devices and life cycle assessment tools. Two wave platform companies, local construction and marine service contractors, motor and converter component suppliers, and academic policy developers ensure research is grounded in real-world challenges.

Objectives

• Quantify interplay between device hydrodynamic performance, electrical efficiency, material use and manufacturing techniques of the electrical components of three classes of wave energy converter (heaving buoy, hinged multi-PTO device, and flexible attenuator).

• Design, simulate, build, deploy operate and decommission a fully operational wave energy converter and PTO.

• Develop a life cycle inventory system for material stocks and flows and their economic, social, environmental and technical values.

• Develop guidelines and best practice on incorporating environmental, economic, and social impacts when evaluating PTO technologies for wave energy.

Project Lead and Host Institution: Clive Roberts (Durham University)

Vision & Objectives demonstrating call alignment:

Integrated Decarbonisation Across Transportation Sectors (iDARTS)

Transportation is the largest contributor to CO_2 emissions and energy consumption in the UK, accounting for 618 TWh of the 1,706 TWh energy used in 2023. Road and rail transport consumed 408 TWh, with over 90% sourced from petroleum. Nearly 100% of shipping and aviation energy relied on fossil fuels, with sustainable aviation fuel making up just 0.28%. Decarbonising the transport sector is essential to achieve net-zero emissions by 2050 and unlocking economic and social benefits. While progress has been made through existing hubs for specific transport modes, a critical gap remains in harnessing system level synergies across the sector to drive comprehensive and sustainable change. Decarbonising transportation presents complex systemic challenges, whilst requiring diverse carbon-free energy vectors tailored to specific mobility needs. Although core technologies, such as batteries, hydrogen engines and fuel cells are common, their adoption varies due to differences in design, regulation, and investment needs. Safety, scalability and environmental considerations further impact feasibility. Considering technologies in isolation limits their broader adoption, making an integrated approach essential for effective transport decarbonisation. Critical questions will be addressed 1) How can sectoral boundaries be transcended to maximise cross-mode synergies in technology deployment? 2) How to boost zero-carbon energy penetration in multi-energy vector transportation systems via cross-mode technological synergies? 3) How to holistically assess the competitive-cooperative dynamics between renewable-electrification technologies and low carbon fuel solutions across modes? 4) How can lifecycle carbon and non-carbon emissions accounting, along with circular economy principles, be leveraged to assess and enhance the system level impact of scaling core decarbonisation technologies across sectors? 5) How to ensure technologies are accepted and are integrated into the broader transport system? Driven by the consortium's trans-disciplinary expertise in powertrains, infrastructures, operations, systems modelling, logistics, economics, human factors and policy across road, rail, maritime, and aviation, iDARTS will serve as the lead hub for cross-sector transport research. By actively engaging with industry stakeholders, policymakers and researchers, we will generate robust evidence to inform strategic decisions and accelerate the transition toward an integrated, sustainable transportation future. iDARTS will take a systems approach, combining divergent thinking (disruptive technology innovation and impact analysis) with convergent thinking (cross-sector multi-energy system analysis). This approach will untangle the complexities of multi-mode transport, define key challenges, timelines, and interdependencies, and integrate decarbonisation solutions for trans-sector applications.

Project Lead and Host Institution: Panagiota Angeli (University College London)

Vision & Objectives demonstrating call alignment:

Electronics are integral to modern, digital societies, empowering businesses and improving quality of life. According to InnovateUK's 'Electech sector' report, the electronics sector employs >1 million people in the UK in >45k businesses, generating £100 billion. Unprecedented levels of electronics consumption, compounded by short lifecycles, result in piles of e-waste (>80Mt by 2030), often containing non-biodegradable plastics. E-waste not only poses health and environmental risks but represents a missed opportunity: it is rich in critical (e.g. rare-earth) elements, essential in electronics and net zero technologies. Redefining e-waste as a high-value resource can support growth, secure UK's critical elements supply chains, and promote circular economies. Our ambition is to overhaul the current electronics paradigm. We propose a critical mass programme with the vision to embed sustainability in the next-generation electronics, by keeping products and materials at their highest utility and value with minimal waste. We will adopt a whole systems-based approach to address the numerous challenges for the circularity of electronics, delivering innovations in the design of electronic products and processes, for recycling, refurbishing/reuse and remanufacturing. To balance longevity with recyclability we will develop and integrate: agile separation technologies to retrieve valuable elements from variable waste streams; novel recyclable/degradable materials (e.g. biopolymers, green conductive inks); advanced manufacturing approaches to integrate recycled and new materials, while maintaining functionality. To catalyse our vision a highly synergistic, transdisciplinary Critical Mass Programme is proposed among 4 Universities spanning 3 UK regions and uniting expertise on multi-criteria decision making, processing, electronics design, materials and circularity. We have co-created our vision with our partners across the value chain, in electronics (WEEE, In2tech, BAE, Quantum), metals recovery (Johnson Matthey, BASF), advanced manufacturing (Xaar, Domino), policy makers, innovators and end users (Newham Council).

Our Objectives are:

•Conduct transformative research on:

1. Digital decision support framework for sustainable product and process systems design, enabling electronics circularity

2. Intensified separations for efficient materials recovery from e-waste

3. Novel materials balancing longevity with recyclability or biodegradability

4. Advanced manufacturing (inkjet, 3D, screen printing) for sustainable electronics (PCBs, wearables, plastic components) from recycled and new materials.

• Lead technology translation/exploitation activities

• Nurture young researchers

• Promote dissemination/outreach activities to inform policy makers, local authorities and the public.

The programme will address the lack in UK of e-waste recycling capability and create a strategic advantage on innovative electronics manufacturing.

Project Lead and Host Institution: Jason Hallett (Imperial College London)

Vision & Objectives demonstrating call alignment:

Our vision is to provide a roadmap for a large-scale UK-based integrated biorefinery designed to deliver multiple intermediates and products to industry from locally sourced sustainable feedstocks. We will identify the key technological, logistical, market, socio-economic and sustainability barriers to delivery and perform cutting-edge research to meet these challenges and enable several UK industries (transport, fine chemicals, pharma, FMCG, construction and manufacturing) to meet 2050 Net Zero targets by replacing fossil feedstocks with renewables. This work will move beyond sector-specific improvements, driving a transformative, whole-systems approach to sustainable manufacturing that enhances the UK's bioeconomy leadership.

Objectives:

1) Develop and integrate the key technologies for a large scale biorefinery through effective and scalable technologies, meet the needs of current UK manufacturing and anticipate the needs of future industries (e.g. energy storage materials).

2) Evaluate the potential economic and environmental impacts of the integrated biorefinery through integrated modeling approaches to assess systemic impacts by combining process modeling, risk models, resource flow and life-cycle sustainability analysis, techno-economic and circular economy models to optimise scalability, multi-sectoral integration, and policy alignment.

3) Develop efficient chemical and biochemical transformations through a process systems engineering approach based on renewable energy (including electrification) and capable of delivering the intermediates UK industry needs. Examples will include sustainable cellulosic packaging, lignin-based resins for renewable composites and fermentation routes to emerging products (e.g. alternative proteins).

4) Develop a dynamic system-wide UK biomass allocation decision support framework to map and optimize sustainable feedstock selection (considering UK forestry, agricultural and waste sectors), cascading use, and sectoral trade-offs, addressing seasonal variability, competing demands, decarbonization potential and logistics to maximize efficiency at scale.

5) Develop interdisciplinary co-creation bubbles with industry, policymakers, researchers, and other stakeholders, to identify future technological pathways, business models, regulatory frameworks, and supply chain adaptations needed to bridge the gap from fundamental research to scalable deployment.

Link to a sustainable future

Sustainable bioresources are critical to reducing the UK's industrial reliance on fossil carbon, particularly in chemicals, materials, and fuels. However, with sustainable biomass supply projected to remain limited at 40-60 EJ/year by 2050, a highly optimized allocation strategy and modular, multi-input/output biorefineries are essential. The UK chemical industry generates >£60 billion and >160,000 jobs, produces >20 MMtpa of products and contributes ~10% of CO2 emissions. To achieve Net Zero this sector must transform.

Project Lead and Host Institution: Muhammad Imran (Aston University)

Vision & Objectives demonstrating call alignment:

The UK's transition to net-zero manufacturing demands a fundamental shift in material synthesis, process engineering, & circular economy integration. While some industries can decarbonize via electrification & hydrogen, sectors reliant on carbon feedstocks—such as building materials, plastics & polymers, & chemical-based consumer products—face a deeper challenge: reducing embedded carbon & keeping carbon in circulation. The 1st requires biogenic & renewable carbon alternatives to replace fossil feedstocks, while the 2nd necessitates closed-loop material recovery to extend lifetimes & prevent re-emissions. The proposed Programme (CIRBIO) will transform material manufacturing, developing scalable, low-carbon alternatives by replacing fossil-based feedstocks with biogenic, DAC-derived, & circular carbon materials. It will pioneer high-performance biogenic composites, CO2-derived materials, & novel carbon conversion pathways, delivering structurally robust, cost-effective, & industrially viable alternatives. CIRBIO will advance CO2 electrochemical reduction, enzymatic polymerization, & biochar-CO2 composites to create sustainable materials. It will develop high-selectivity catalysts, continuous-flow reactors, & solvent-based processing to integrate DAC & bio-based feedstocks into industrial processes. CIRBIO will optimize depolymerization, enzymatic recycling, & CO2 mineralization for recyclable plastics, carbon-sequestering materials, & closed-loop systems. It will establish LCA models, techno-economic assessments, & policy frameworks to support net-zero compliance & industrial adoption. This extends Aston's work on Supergen Bioenergy Hub, Loughborough's on CircularChem, & Edinburgh's on UKCCSRC, addressing market-relevant products not previously studied yet vital to UK prosperity. CIRBIO will fully evaluate DAC for material synthesis while providing a cross-technology framework to identify the most sustainable pathway for various product sectors. Industry partners Croda, Breedon Group, Unilever, & McBride will support material validation, supply chain integration, & industrial adoption. CIRBIO will also engage Birmingham City Council & regulatory bodies to align innovations with policy incentives, carbon credit mechanisms, & circular economy regulations. London Green City will support incubation & commercialization, connecting research outputs with investors & pilot-scale manufacturing. CIRBIO will deliver pilot-scale validation of DAC & CO2-to-material processes, demonstrating biogenic & CO2-derived materials in industry while developing scalable models for construction, polymers, & consumer supply chains. A multi-criteria decision framework will guide material substitution, integrating LCA-driven sustainability metrics & techno-economic feasibility assessments. CIRBIO will also co-develop policy recommendations to support net-zero materials while advancing workforce training in circular manufacturing & carbon-negative materials.

Project Lead and Host Institution: Abed Alaswad (Aston University)

Vision & Objectives demonstrating call alignment:

Concrete production plays a significant role in making the construction sector a major contributor to GHG emissions. This programme aims to 1) explore the potential of integrating biochar, a carbon-rich material derived from biomass, into concrete, and 2) develop a smart monitoring system to enhance durability, understand maintenance needs and inform policies. The potential benefits of biochar-concrete include improved physical and mechanical properties, longevity, beside significant environmental benefits.

By integrating fundamental investigations into biochar production, biochar-concrete interactions, fibre optic sensing, environmental assessments, circular economy and evidence-based policies, this transdisciplinary programme will lay the groundwork for innovative, low-carbon construction.

Research Objectives:

1. Biochar Production and Characterization for Concrete: Investigate the properties of biochar produced from different feedstocks and pyrolysis conditions, analysing chemical composition, porosity, and carbon capture potential.

2. Biochar-Concrete Interactions: Explore how biochar interacts with concrete, investigating microstructural changes, hydration, and bonding at the nanoscale. This will provide insights into its interaction with cement, fine aggregate, and supplementary cementitious materials.

3. Development of Fibre Optic Sensing Framework: Develop a conceptual and experimental framework for embedding fibre optic sensors into concrete, ensuring flexibility, immunity to electromagnetic fields, and high-resolution measurements.

4. Data Analysis for Structural Health Monitoring: Extract real-time data from sensors and analyse parameters like strain, temperature, and crack propagation using machine learning algorithms. This will help understand defect formation and provide a robust data-driven decision-making process for optimisation.

5. Environmental Impact Assessment: Conduct comprehensive assessments throughout the lifetime of the programme to maximise environmental benefits, including carbon capture, GHG reduction, and reduced resource extraction.

6. Circular Economy Integration: Explore biochar-concrete’s role in a circular economy by valorising waste streams and promoting resource efficiency, while achieving broader benefits to society and economy.

7. Policy and Regulation Development: Work with stakeholders (e.g., OPSS, KIER, Cemex, Tarmac) to maximise the impact of the programme and co-create evidence-based policies, regulations, and standards for biochar-concrete, aligning with UK Net Zero strategies.

Building on the team’s expertise in the Biochar CleanTech Accelerator, the UK Biochar Research Centre, Institute for Sustainable Building Design, Aston Institute of Photonic Technologies and expertise from (10055261, MR/Z505419/1, EP/Z000742/1, EP/J010413/1, EP/T01962X/1), this programme will position the UK as a global leader in sustainable construction, driving systemic change toward a sustainable future.

Project Lead and Host Institution: Manish K. Tiwari (University College London)

Vision & Objectives demonstrating call alignment:

Vision: Industrial food and agri-waste are untapped resources for sustainable chemical feedstock. Our vision is to set up a critical mass centre BENIGN, using a systems-based approach to integrate bio/chemical catalysis and nanoengineering for food/agri-waste derived new surface treatment products. Our ambition is to enhance functionality while eliminating harmful per- and polyfluoroalkyl substances (PFAS) from surface treatments. The centre's high-level objectives include:

1. Systems Approach as the Core Driver – From waste feedstock to application-specific surface treatments, integrate systems-based life cycle and techno-economic analyses with data-driven materials research to remove PFAS.

2. Enhanced Resilience – Improve durability and longevity of built environments, transport vehicles, and infrastructure.

3. Energy Efficiency & Poverty Alleviation – Develop passive heating, cooling, and energy-harvesting surface treatments to reduce energy poverty.

4. Innovative & Recyclable Coatings – Improve adhesion control for marine biofouling prevention, enhancing material circularity and energy efficiency.

Co-Creation and Partnerships: The centre's vision was shaped in a March 2024 workshop with 15+ UK partners. BENIGN partners include Newham Council, Thames Estuary Growth Board, and UK industry leaders: Tate & Lyle, Eco Research Ltd, C-MAT, BASF, Johnson Matthey, IBioIC, Graphenestone, and AkzoNobel. End-users include NSG (glass panels), Altro, Engie, TFL, and Airbus. UKRI and partner support will establish a critical mass in sustainable surfaces to advance the circular economy.

Research Innovations and Deliverables:

1. Sustainable Coating Constituents – Manufacture cyclodextrins, biopolymers, MOFs, and COFs from industrial food and agri-waste using a systems approach.

2. PFAS-Free Coatings & Films – Develop scalable MOF/COF-based coatings via bio/chemical catalysis and nanoengineering to:

o Prevent contamination (fouling, ice accumulation, corrosion).

o Enable passive radiative cooling and mechanical energy harvesting.

o Support solar energy harvesting to address energy poverty.

3. Machine Learning-Enabled Material Discovery – Use systems modelling and AI to optimize MOF/COF coatings for urban pollution control, including CO_2/NO_x-capturing transparent windows.

4. Life Cycle & Techno-Economic Analysis – Assess sustainability metrics such as GWP, carcinogenic index, and life cycle costing.

5. Use-Inspired Prototyping & Recycling – Validate the systems-driven approach through prototyping, stakeholder feedback, and circular material innovations.

Market Potential and Impact: Beyond underpinning PFAS transition in $200B global coatings industry, films for passive cooling/heating, and biofouling prevention will create new markets. BENIGN drives circularity through a systems-driven initiative, converting agri/food waste into high-performance, PFAS-free surface treatments that support Net Zero targets.