



Regenerative bioeconomy systems: Reimagining how society makes, uses and renews resources

The LIFE Research Institute is developing regenerative bioeconomy systems that integrate biosciences and biotechnology to transform waste and biological resources into high-value products, addressing environmental challenges

THE CHALLENGES facing society today are increasingly interconnected. Climate change, biodiversity loss, resource depletion, pollution, food security and human health can no longer be addressed through isolated technological solutions. Instead, they require integrated systems capable of continuously creating, recovering and regenerating value.

Building regenerative systems for the health and wellbeing of people and planet

At the LIFE Research Institute (LIFE RI) at the Technological University of the Shannon (TUS), researchers are developing precisely such systems. Working in tandem with nature, LIFE RI combines expertise in biosciences, biotechnology, circular

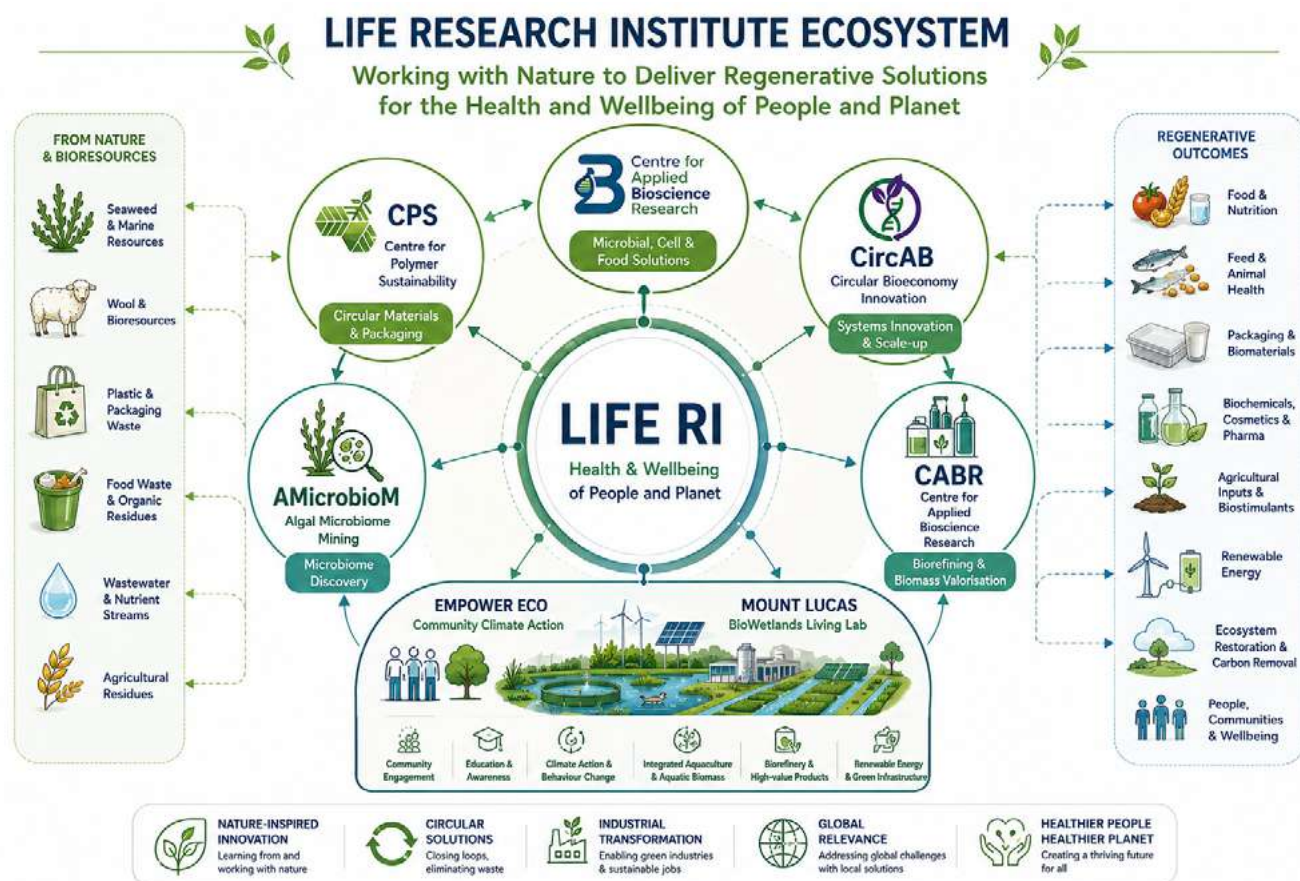


Fig 1: LIFE RI integrates bioscience, biotechnology, circular manufacturing and regenerative systems through interconnected centres and living laboratories that work together to deliver solutions for the health and wellbeing of people and planet



manufacturing, health, agriculture, environmental sustainability and bioeconomy innovation to develop solutions that support both people and planet.

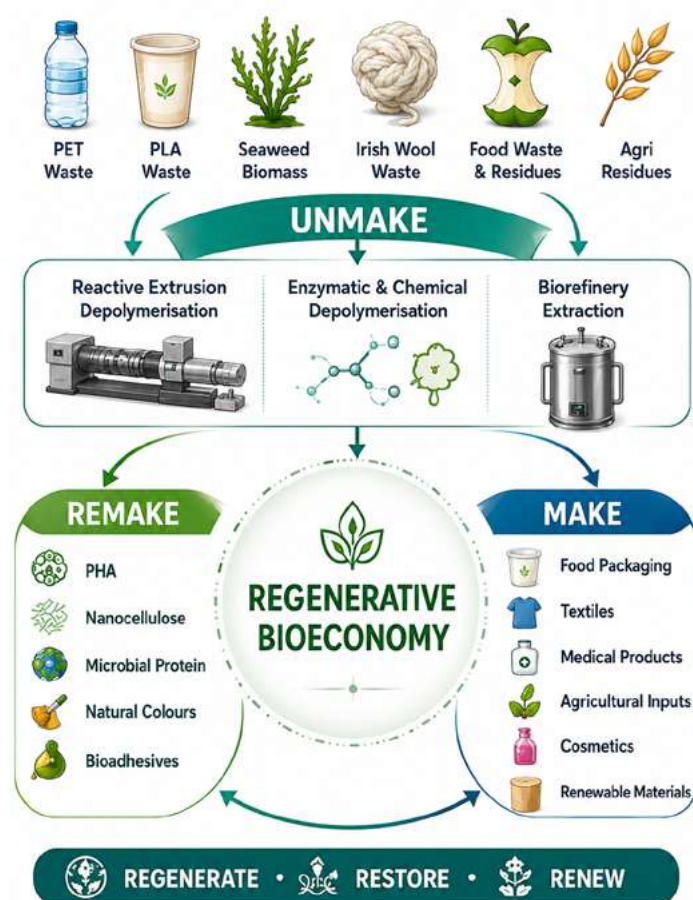


Fig 2: The TUS CPS and LIFE RI Make-Unmake-Remake framework establishes regenerative manufacturing loops that continuously recover, regenerate and remake materials and products

Through a network of centres and groups including the Centre for Polymer Sustainability (CPS), Centre for Applied Bioscience Research (CABR), CircAB, AMicrobioM, Empower Eco and the SHE Research Centre, LIFE RI is creating technologies that transform waste streams and biological resources into high-value products, materials, services and regenerative ecosystems.

From circular plastics to regenerative manufacturing

Traditional manufacturing systems follow a linear pathway of extraction, production, use and disposal. LIFE RI is demonstrating a fundamentally different model inspired by natural systems, where resources circulate continuously within regenerative loops.

At the heart of this approach is the CPS Make-Unmake-Remake framework. Through advanced depolymerisation, bioconversion and manufacturing technologies, post-use materials are transformed into new feedstocks and regenerated into high-value products.

This framework now extends beyond plastics and encompasses biological resources, agricultural residues, wool, food waste and aquatic biomass, establishing a comprehensive platform for regenerative bioeconomy innovation.

Transforming waste carbon into living materials

One of LIFE RI's most significant advances has been the development of technologies capable of transforming plastic waste into biological resources.¹



Fig. 3: PerPETual, Twinn4MicroUp and EcoPlastiC technologies convert waste plastics into valuable biological feedstocks and sustainable materials



The PerPETual platform uses reactive extrusion depolymerisation to recover high-purity monomers from PET waste streams, including difficult-to-recycle packaging, textiles and mixed materials. These monomers can be returned directly into virgin-equivalent PET production or utilised as feedstocks for microbial manufacturing.

Recent research has demonstrated the biological conversion of PET-derived carbon into polyhydroxyalkanoates (PHAs), bacterial nanocellulose and microbial oils. These technologies transform waste plastics from an environmental burden into a valuable carbon resource capable of supporting the manufacture of next-generation sustainable products.

Together with the Horizon Europe **Twinn4MicroUp** initiative, these developments are creating new opportunities to integrate plastic circularity with industrial biotechnology and microbial manufacturing.

Sustainable packaging inspired by biology

Nature has evolved highly efficient material systems over billions of years. LIFE RI researchers are harnessing these principles to create sustainable alternatives to conventional petro-based polymer packaging.

Using microbial fermentation and industrial side streams, researchers have developed protein-rich biomass

materials capable of forming packaging films and trays with excellent oxygen barrier properties. These materials offer a microplastic-free and potentially biodegradable alternative to conventional multilayer packaging systems.

Complementing these developments, the **CicloSeal** platform is creating plastic-free bioadhesives and heat-seal coatings suitable for paper cups, fibre packaging and food-contact applications. **CicloColour** extends this approach by transforming agricultural side streams, including spent turmeric biomass, into natural colour systems for packaging and consumer products.

Together, these technologies provide the foundations for fully regenerative packaging systems capable of operating within continuous circular lifecycles.

Nature-inspired innovation from the seaweed microbiome

Nature remains the world's greatest innovator.

Through the **AMicrobioM** programme, LIFE RI researchers are investigating the vast diversity of microorganisms associated with marine seaweeds. These microbial communities, known as holobionts, produce a wide range of bioactive compounds that may support plant growth, enhance resilience and reduce dependence on synthetic agrochemicals.

SCP BARRIER PACKAGING PLATFORM

High Performance. Biobased. Plastic-Free.

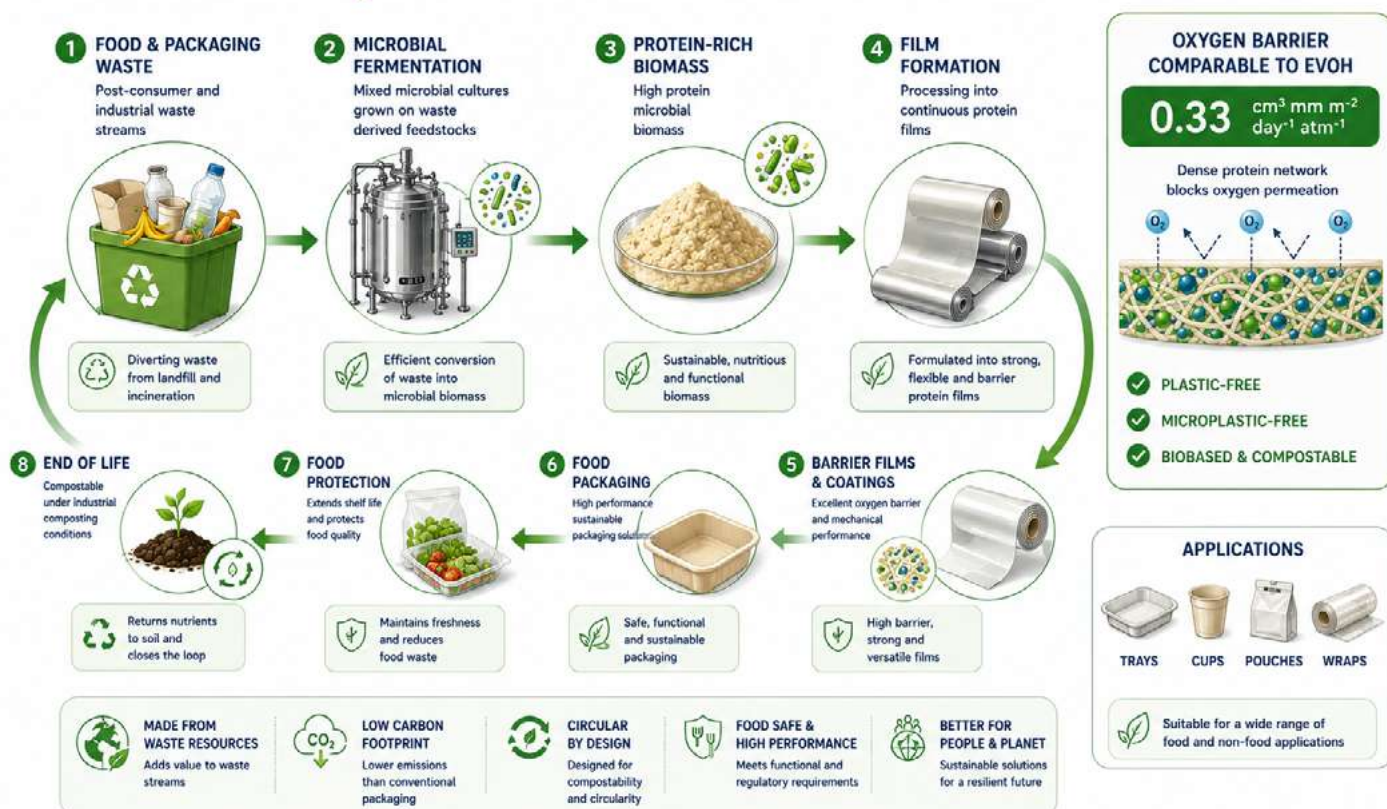


Fig. 4: Protein-rich microbial biomass can be transformed into high-performance packaging materials with oxygen barrier properties comparable to conventional fossil-derived materials



AMicrobiOM DISCOVERY PLATFORM

— Unlocking the Power of Seaweed Microbiomes for a Sustainable Future —

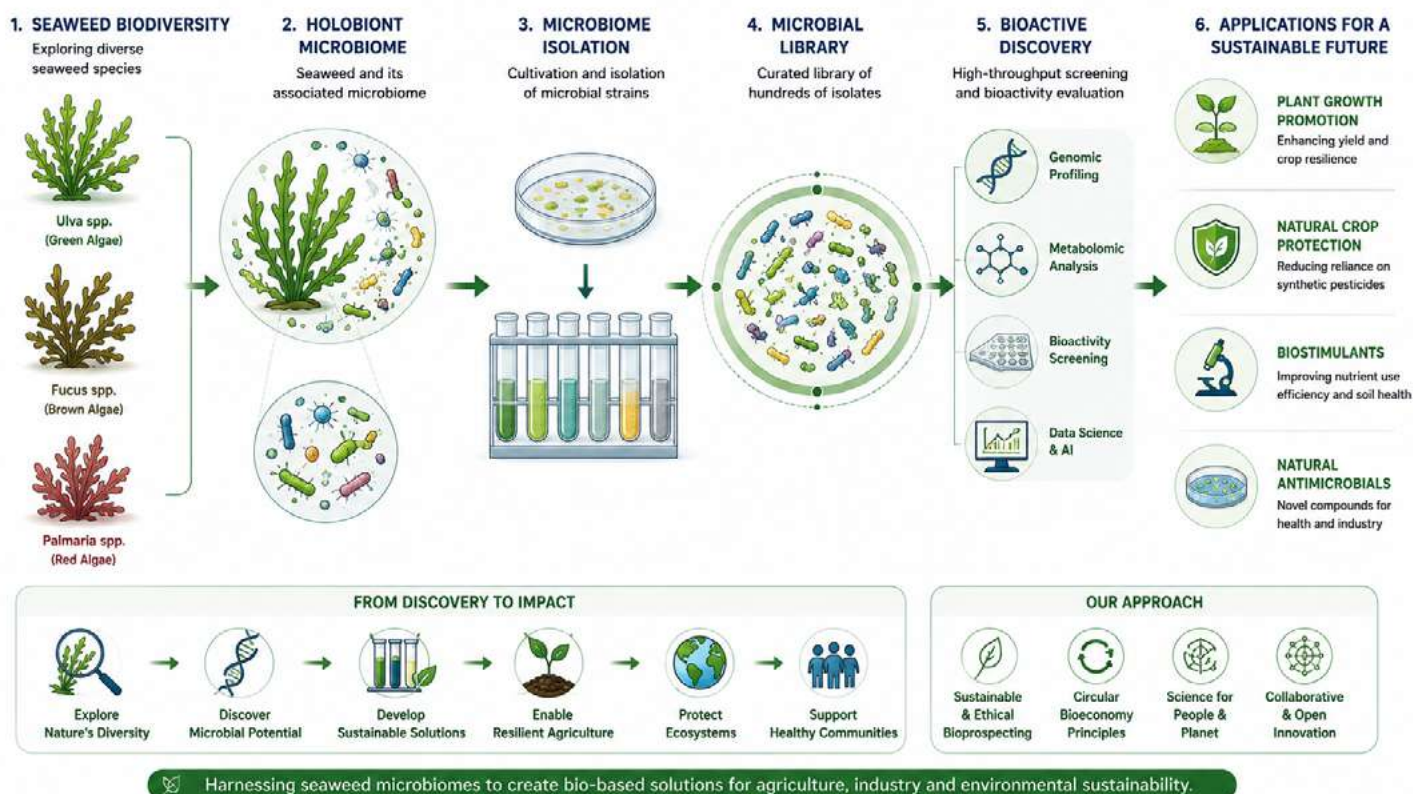


Fig. 5: AMicrobiOM is exploring seaweed-associated microbiomes as a source of novel bioactive compounds for sustainable agriculture, environmental protection and industrial biotechnology

FROM FLEECE TO FIELD

— Transforming Irish Wool into High-Value Bioeconomy Products —



Fig 6: SPRINGWOOL and RevEire are developing new circular value chains that transform Irish wool into high-value biomaterials, cosmetics, medical products and agricultural resources



By combining advanced DNA sequencing, microbiology, analytical chemistry and plant science, AMicrobioM is creating a unique microbial resource platform capable of supporting future developments in sustainable agriculture, environmental remediation and biotechnology.



The future of sustainability lies beyond waste reduction and recycling"

The programme demonstrates how nature-inspired discovery can create entirely new opportunities for innovation while supporting more resilient and sustainable food production systems.

Unlocking value from overlooked bioresources

Not all valuable resources are recognised as such.

For decades, Irish-grown wool has experienced declining economic value despite its significant biochemical potential. Through the **SPRINGWOOL** and **RevEire** projects, researchers at **CABR** and **CircAB** are demonstrating how wool can become a cornerstone of a new circular bioeconomy.

Advanced extraction technologies are being used to recover keratin, ceramides and other high-value compounds for applications spanning cosmetics, medical devices and advanced biomaterials. Residual

fibre streams are being investigated for textiles, bioplastics and agricultural applications, while composting pathways ensure nutrients can be returned to the land.

This cascading biorefinery approach exemplifies LIFE RI's commitment to extracting maximum value from biological resources while supporting rural enterprise and regional development.

Mount Lucas: A living demonstration of the circular bioeconomy

Perhaps the most ambitious demonstration of LIFE RI's integrated approach can be found at the **Mount Lucas Bioeconomy and BioWetlands Living Lab**.

Located within a unique peatland environment, the site combines integrated aquaculture, duckweed cultivation, macroalgae production, renewable energy generation and advanced biorefining technologies within a single circular ecosystem.

Nutrients from aquaculture support aquatic biomass production, while renewable energy and digital monitoring technologies create a living demonstration of climate-resilient bioeconomy systems. Outputs include food ingredients, animal feed, packaging materials, biofertilisers, biostimulants and renewable fuels.

The Living Lab serves as a real-world platform for demonstrating how biological resources can be transformed into sustainable products while supporting environmental restoration and regional development.



Fig 7: The Mount Lucas BioWetlands Living Lab integrates aquaculture, aquatic biomass cultivation, renewable energy and biorefining systems within a circular peatland ecosystem



Fig 8: LIFE RI is creating integrated regenerative systems where waste streams, biological resources and industrial processes continuously create, recover and renew value

From waste streams to regenerative value systems

The future of sustainability lies beyond waste reduction and recycling.

LIFE RI's vision is one of regeneration, where biological resources, industrial processes and natural ecosystems operate together to continuously create value while restoring environmental health.

Plastic waste becomes feedstock. Seaweed becomes a source of bioagents and crop biostimulants. Wool becomes biomaterials and medical products. Aquatic biomass becomes food, feed and packaging. Industrial side streams become high-performance materials.

By integrating biotechnology, bioscience, circular manufacturing, digitalisation and nature-based solutions, LIFE RI is helping establish the foundations of a regenerative bioeconomy capable of delivering healthier ecosystems, stronger communities and more resilient industries.

The future belongs to systems that work with nature rather than against it. Through its growing portfolio of

technologies, demonstration platforms and industrial partnerships, LIFE RI is providing models to help to build that future today.

References

1. Upcycling Depolymerized PET Waste into Polyhydroxyalkanoates and Triacylglycerols by A Newly Isolated *Rhodococcus* sp. Strain



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