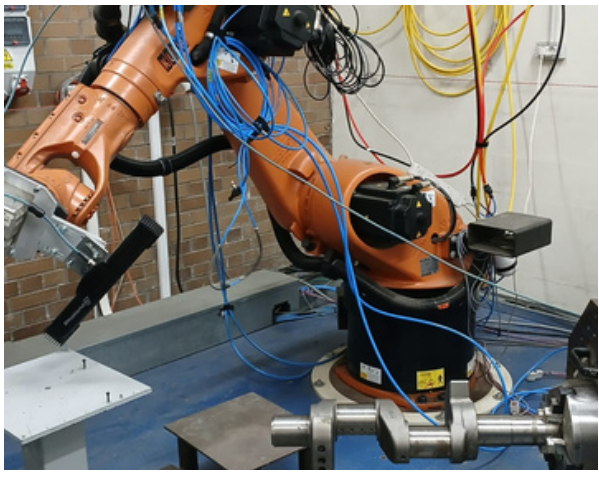
# REMANUFACTURING, REPURPOSING AND RECYCLING ENERGY GOODS THROUGH ADVANCED MECHATRONIC AND DIGITAL TECHNOLOGIES

The R3-Mydas project is pioneering innovative solutions to advance sustainability in key industrial sectors. By leveraging cutting-edge technologies and digital-driven approaches, the project aims to enhance the remanufacturing processes of crankshaft components, EV batteries, and wind turbine gearboxes. These advancements promise to improve precision, efficiency, and environmental impact, setting new standards for cost-effective and high-quality component repair and lifecycle management. Through collaboration with industry stakeholders and integrating automation, digitalisation, and sustainability, R3-Mydas is making significant contributions to the circular economy and the future of sustainable manufacturing.

## Advancing Sustainable Crankshaft Remanufacturing with Digital Laser-Cladding

A new digital-driven approach is set to revolutionize the remanufacturing of damaged crankshaft components, enhancing precision, efficiency, and sustainability. The process begins by defining client requirements for dimensions, tolerances, and materials. A 3D scanner integrated with a robot then captures a high-resolution digital model of the crankshaft. This data undergoes refinement, filtering, and smoothing, generating an optimized CAD model that guides the automated laser-cladding process, eliminating the need for manual programming.



To optimize performance and reduce environmental impact, the workflow incorporates simulation-based process development and physical mock-ups, ensuring minimal thermal stress and distortion. Additionally, a virtual cell (digital twin) replicates the real environment, enabling collision simulations and process validation before physical implementation.

The final stage involves full-scale testing and validation, ensuring the remanufactured crankshaft meets all mechanical and geometric requirements. By combining automation, digitalization, and sustainability, this innovative approach is setting new standards for cost-effective and high-quality component repair in the industry.

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**Advancing the Sustainable Lifecycle of EV Batteries**

As the adoption of electric vehicles (EVs) grows, ensuring the efficient and responsible management of EV batteries is essential for sustainability. The EV battery ecosystem involves multiple stakeholders, from raw material suppliers and manufacturers to recyclers and policymakers, all working to optimise battery performance and longevity. State of Health (SoH) monitoring plays a key role in determining whether batteries should be reused, repurposed, or recycled, maximising their lifespan and reducing environmental impact.

A comprehensive approach to EV battery development is crucial, addressing design considerations, key system components, and safety requirements. This includes cells, modules, housing, cooling, high-voltage systems, and battery management systems (BMS), which regulate energy storage, thermal management, and overall battery performance. Additionally, optimizing manufacturing processes and integrating SoH estimation ensures informed decision-making throughout the battery's lifecycle.

With End-of-Life (EoL) management being a critical aspect of sustainability, strategies for collection, sorting, storage, and transportation are key to safely handling high-voltage batteries. The focus is on reuse, repurposing, and recycling, supported by a novel single-shot SoH estimation method that enables precise battery assessments with minimal testing. Initial results at the cell level demonstrate its potential to enhance circular economy efforts.

To further improve battery lifecycle management, automation in battery dismantling is being explored through robotic systems, computer vision, and AI-driven processes. These innovations aim to streamline disassembly, improve safety, and support the transition to a more circular and sustainable EV battery ecosystem.

**Enhancing Wind Turbine Gearbox Longevity Through Advanced Remanufacturing**

Wind turbine maintenance costs significantly impact the Levelized Cost of Energy (LCOE), with repairs accounting for up to 25% of expenses. As turbines grow in size, repair costs rise due to material waste, energy losses, and production guarantees, highlighting the urgent need for more sustainable solutions.

Traditional gearbox remanufacturing is limited to minor wear repairs, but additive manufacturing (AM) introduces a transformative approach by enabling the reuse of failed components with updated technology, reducing failure rates and extending product lifecycles.

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The R3-Mydas project focuses on addressing three major failure modes in wind turbine gearboxes, integrating cutting-edge simulation models and validation techniques to assess the benefits of remanufacturing. By combining high-quality material testing, advanced heat treatment evaluations, and AM-based repairs, the project aims to minimize costs, reduce downtime, and enhance gear strength. Field data and test bench trials will validate the effectiveness of these new repair strategies, ensuring high-quality standards are met.

The validation framework ensures that stakeholder expectations are met, translating them into measurable targets and key performance indicators (KPIs). Through rigorous demonstrations, data collection, and performance evaluations, the project will establish confidence in the feasibility of remanufacturing wind turbine gearboxes, fostering cost savings, sustainability, and circularity in the wind energy sector.

**Facilitating Sustainable and Circular Value Chains in the Manufacturing Industry**

The R3-Mydas project is accelerating the manufacturing industry's transition towards more sustainable and circular value chains. To ensure lasting impact, a Safe and Sustainability by Design (SSbD) assessment is conducted on the new circular value chains. The project includes SSbD assessment for the Oil&Gas and wind energy industries, covering:

- Environmental Dimension: Conducting a Life Cycle Assessment (LCA) of the remanufacturing process, including Carbon Footprint, following ISO14040 guidelines.
- Socio-economic Dimensions: Performing a Life Cycle Cost assessment to ensure economic viability and a Social Life Cycle Assessment to identify potential social issues.

For EV batteries, the project also considers the safety dimension to identify and minimise hazardous substances and situations. The SSbD framework supports decision-making towards safer and more sustainable chemicals and materials over their life cycles, aiming to prevent pollution and reduce the environmental footprint.

Standardisation plays a vital role in ensuring consistency and quality across industries, creating a common framework that enables products, services, and systems to work together seamlessly. In the R3-Mydas project, standardisation plays a key role in integrating new technologies and findings, reducing duplication of effort, and fostering innovation. It accelerates the transfer of knowledge from research to industry, enhancing the efficiency and impact of R&D projects. The project involves assessing the standardisation framework by collecting and verifying the suitability of existing standards for the developed technologies

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## R3-Mydas Marketplace: Unique Features and Vision

The R3-Mydas marketplace is a central component of the project, designed to facilitate and accelerate the adoption of sustainable and circular value chains in the manufacturing industry. This innovative platform stands out with two key functionalities: promoting remanufactured components and products and offering remanufacturing resources and services to a broad range of customers.

Built on the MARKET4.0 platform developed by NCI, the marketplace leverages advanced functionalities such as matchmaking and bidding to support remanufacturing tools, materials, infrastructure-as-a-service, and other services. These features ensure businesses can access the necessary resources to optimise their remanufacturing processes, reduce downtime, and enhance production efficiency.

The marketplace also plays a crucial role in making underutilised business models actionable. By aligning with Circular Economy (CE) principles, it emphasises sustainable remanufacturing value chains and accounts for stakeholder relationships, interaction mechanisms, value propositions, and revenue models. This holistic approach ensures that the business models are economically viable and sustainable. By integrating these advanced functionalities and business models, the R3-Mydas marketplace is set to become a cornerstone for promoting sustainable manufacturing practices, fostering innovation, and driving the transition towards a circular economy.


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