MANAGEMENT AND PRODUCTION ENGINEERING

Ammin/CRT/DIGEP - LCA Approach for the Recovery of Critical Materials from Automotive Batteries

Funded By	Dipartimento DIGEP Politecnico di TORINO [P.iva/CF:00518460019] FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]
Supervisor	SETTINERI LUCA - luca.settineri@polito.it
Contact	
Context of the research activity	The research integrates the MEIO method with LCA and LCC to assess the environmental, economic, and technical sustainability of critical material recovery from batteries. It aims to provide a comprehensive overview of the process and to incorporate it into a framework for production planning, system design, the selection of sustainable technologies, and the development of low-TRL solutions.
	Project Scope The growing adoption of electric (EV) and hybrid vehicles has led to a parallel increase in the demand for high-performance batteries, particularly those based on lithium chemistries. This trend has raised concerns regarding the sustainable supply and end-of-life management of batteries, with both environmental and economic implications. The recovery and recycling of critical materials contained in such batteries (such as lithium, cobalt, nickel, manganese) represent a key strategy to mitigate resource scarcity risks, reduce environmental impact, and promote a circular economy in the electric mobility sector. However, assessing the sustainability of these processes requires systemic, multi-level analytical approaches capable of supporting informed technological, industrial, and policy decisions. Objectives The project aims to develop and apply an innovative methodological framework that integrates the Multi-layer Enterprise Input-Output (MEIO) model with Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methodologies, with the goal of evaluating the environmental, economic, and technical performance of processes for the recovery of critical materials from automotive batteries. The overarching objective is to support the transition toward more sustainable production systems by providing tools for the design, planning, and scaling of recycling facilities, taking into account sustainability variables across the entire value chain.

Objectives	Specific Objectives: Apply the MEIO method to model the physical, energy, and economic flows within a complex industrial system that includes the collection, treatment, and recovery of end-of-life batteries. Integrate the results of the MEIO analysis with LCA and LCC data to obtain a multi-dimensional view of sustainability, encompassing environmental impacts, life cycle costs, and technical performance. Validate the framework through one or more case studies, analyzing existing or planned recovery facilities, including in collaboration with industrial partners. Develop a decision-making model to support long-term production planning, the selection of sustainable (mature or emerging) technologies, and the optimal sizing of plants. Identify and enhance the potential contribution of low Technology Readiness Level (TRL) technologies, proposing strategies for their integration into future recycling systems. Methodology Description The MEIO method enables a detailed, multi-level description of the relationships between economic actors and the flows of materials and energy between production activities. By integrating this approach with LCA (for environmental impacts) and LCC (for economic impacts), an advanced model can be defined, capable of delivering a comprehensive picture of the sustainability of a production system dedicated to critical material recovery. The model will initially be applied to a representative case study, such as a pilot plant or a regional supply chain, and may subsequently be extended to more complex contexts or scaled up at the national or European level. Expected Results A validated MEIO-LCA-LCC integrated framework based on real-world case studies. Quantitative and qualitative sustainability indicators to support decision-making. Guidelines for the sustainable design of recycling facilities. Identification of promising emerging technologies and related implementation barriers. Contribution to the policy debate on industrial and environmental strategies for the sustainable end-of-life management of batteries. Expected Impact The project aims to provide a methodological and operational foundation for designing more efficient and sustainable battery recovery systems, contributing to national and European goals related to ecological transition, circular economy, and raw material security. The developed model could also be adapted to other high-tech sectors where critical material recovery is strategically important.

Skills and competencies for the development of the activity	The candidate must hold a Master’s degree in Management, Mechanical, Environmental, or Materials Engineering. Preferably, the candidate should have expertise in Life Cycle Assessment (LCA), Life Cycle Costing (LCC), input-output modeling (MEIO), production system analysis, and knowledge of battery recycling technologies. Experience in sustainability and circular economy projects is considered an asset.