



Circular and Dynamic Manufacturing Supply Chain Orchestration and Optimisation

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Abbreviations

Acronym	Description
CE	Circular economy
LCA	Life cycle assessment
pc	piece
CO2e	CO2 equivalent
GWP	Global warming potential

Executive Summary

This document accompanies the tool developed for the evaluation of the sustainability and circularity performance of processes in Task 3.3. The sustainability and circularity tool, named GRETA (Green Targets), is part of the CIRCULOOS ecosystem, consuming some data from other tools and providing valuable results for an effective decision-making process. Moreover, the document reports on real data (LCI data) from two pilots in the leather and plastic sectors of different countries. In the context of creating new, more sustainable and circular practices, these data will be used in the first phase to calculate CO₂e emissions for optimisation purposes. The integration of GRETA to the RAMP platform for exchanging data is also presented.

1 Introduction

As the global community confronts accelerating environmental challenges, the urgency for adopting sustainable industrial practices has reached a critical moment. The principles of the CE have emerged as a decisive solution to these pressing issues, offering a shift from traditional linear models of production and consumption. The CE emphasizes creating systems that minimize waste, optimize resource efficiency, and foster long-term ecological balance. By embracing circularity, industries can transition from a linear "take-make-dispose" approach to one that promotes continual reuse, recycling, and regeneration of materials. The need for integrating CE principles into business operations is driven by the growing recognition of resource scarcity, environmental degradation, and the adverse impacts of climate change. To effectively implement these principles, businesses must not only adopt new practices but also rigorously assess and evaluate their processes through sustainability and circularity indicators. This involves conducting detailed studies to measure how well current processes align with CE objectives and identifying opportunities for improvement.

Sustainability assessments are crucial in providing businesses with a comprehensive understanding of their environmental impact and the effectiveness of their circular practices. They encompass a range of evaluations, from lifecycle assessments and resource efficiency analyses to waste management and product design for reuse or recycling. By examining these aspects, companies can gain valuable insights into their operational performance, identify room for improvement, and develop strategies to better align with sustainability goals. Moreover, evaluating circularity within business processes is essential for driving continuous improvement and innovation. Such evaluations enable businesses to track progress, benchmark against industry standards, and implement targeted measures to enhance their circular practices. This not only supports environmental objectives but also offers competitive advantages, such as reduced operational costs, improved resource management and brand reputation.

Integrating comprehensive sustainability assessments and circularity evaluations into business operations is fundamental for advancing the CE. By adopting these practices, companies can contribute to a more sustainable future, support ecological balance, and play a significant role in addressing the environmental challenges of our time. Through dedicated efforts in evaluating potential circular practices that can be proposed to stakeholders, businesses can achieve significant progress toward a more resilient and sustainable industrial landscape.

1.1 Project Introduction

The Development of Circularity Enablers within WP3, led by SUPSI, was designed to advance goals of enhancing circularity and sustainability within supply chains and operational manufacturing processes.

The overarching aim of WP3 is to develop a set of tools to facilitate more sustainable and circular practices. This involves creating pilot-ready versions while incorporating valuable feedback received during the development process. The focus will be on customizing these models to meet the practical needs of real-world applications, ensuring their effective integration into operational environments. Additionally, WP3 will provide essential support to stakeholders, enabling them to effectively use and further adapt their business.

A significant aspect of WP3 involves designing and implementing tools for sustainability and LCA. This includes developing a Sustainability & Circularity tool that calculates sustainability indicators. The engine will communicate with RAMP to gather necessary data and ensure integration with other platform components.

Through multi-layered efforts, WP3 aims to significantly contribute to the project's overall goals of promoting circularity and sustainability, utilizing cutting-edge technologies and methodologies to optimize processes and support environmental objectives.

1.2 Deliverable Purpose

The purpose of this deliverable is to present a detailed tool specifically designed to measure sustainability impacts for each process within a given scenario, serving as the initial phase of a more extensive sustainability assessment. This tool will take into account a variety of critical inputs necessary for accurate emission calculations. These inputs include detailed material and energy balances, which provide insight into the resources consumed and energy used during each stage of the process. Additionally, the tool will incorporate geographical data to assess the impact of the location on emissions, considering factors such as regional energy mixes and transportation distances. The type of logistics employed, including transportation methods and supply chain configurations, will also be factored into the emissions calculations, ensuring a holistic view of the process's impacts. Furthermore, the economic value of each raw material used will be integrated into future techno-economic analysis, providing a comprehensive understanding of the cost associated with the procurement and use of these materials. This enables stakeholders to identify key areas for improvement and develop strategies to enhance the sustainability and circularity of their operations. This deliverable provides a significant step towards the CIRCULOOS goals by promoting more responsible practices within industrial processes.

2 Sustainability relevance to CIRCULOOS

In the context of the CIRCULOOS project, “sustainability and circularity” refer to the effort of transforming traditional linear business models into more sustainable and circular ones. A linear economy typically follows a “take, make, dispose” approach, where resources are used to create products and then discarded as waste. The goal of CIRCULOOS is to help, in the first phase, three pilot companies from the wood, leather, and plastic sectors transition to a circular economy, where resources are reused, waste is minimized, and sustainability is prioritized. Through different initiatives proposed by the partners taking part of the CIRCULOOS project, the three pilots are guided to enhance their circularity and sustainability of their operations by reducing waste, reusing materials, and improving resource efficiency. The sustainability and circularity of the different pilots are presented as follows:

PILOT 1 - The wood sector pilot involves Fiction Factory and Herso. Fiction Factory produces modular furniture designed for reuse, and Herso supplies them with recycled materials. Although they have already implemented a circular approach, their focus in CIRCULOOS is to certify the origin of the recycled materials provided by Herso, ensuring that the circularity of their operations is fully traceable and verified.

PILOT 2 - In the leather sector, the pilot involves Khoani and B&A. Khoani primarily uses large leather pieces, while B&A works with smaller fragments. The goal is to increase circularity by allowing Khoani to pass on its leather offcuts to B&A, thus maximizing the use of the leather throughout the production chain. Additionally, both companies will sell any excess leather scraps on a marketplace, ensuring that as much material as possible is repurposed and nothing is wasted.

PILOT 3 - The plastic sector pilot involves Thermolympics and LOLO. Here, the goal is to close the loop by recycling Thermolympics' plastic waste at LOLO's recycling facility. By recirculating plastic waste within their own operations, these companies aim to reduce the amount of plastic waste that ends up in landfills, thereby improving the sustainability of their processes.

3 Sustainability and Lifecycle Assessment tool: GRETA

3.1 Functionalities

GRETA is a web, microservices-based, application designed to assess the sustainability and circularity performances of products and processes in manufacturing contexts. It offers diagnostic and advisory functionalities, enabling users to optimise their manufacturing practices and make data-driven decisions.

GRETA has been tailored to meet the demands of manufacturing companies focused on sustainable early-stage product design. It empowers users to generate and compare different production manufacturing and usage scenarios, leveraging the limited data typically available during the preliminary stages of product design. GRETA can be used to assess the sustainability performances of products (that can be defined using a Bill of Material) and processes and see how the impacts are distributed across different life cycle phases.

GRETA allows the end-user to customise the production processes modelled by the sustainability expert to provide all the specific values needed to perform a life cycle assessment analysis. Once the user has

completed the customisation, the assessment can be executed, and useful insight can be obtained by the assessment charts (Figure 1).

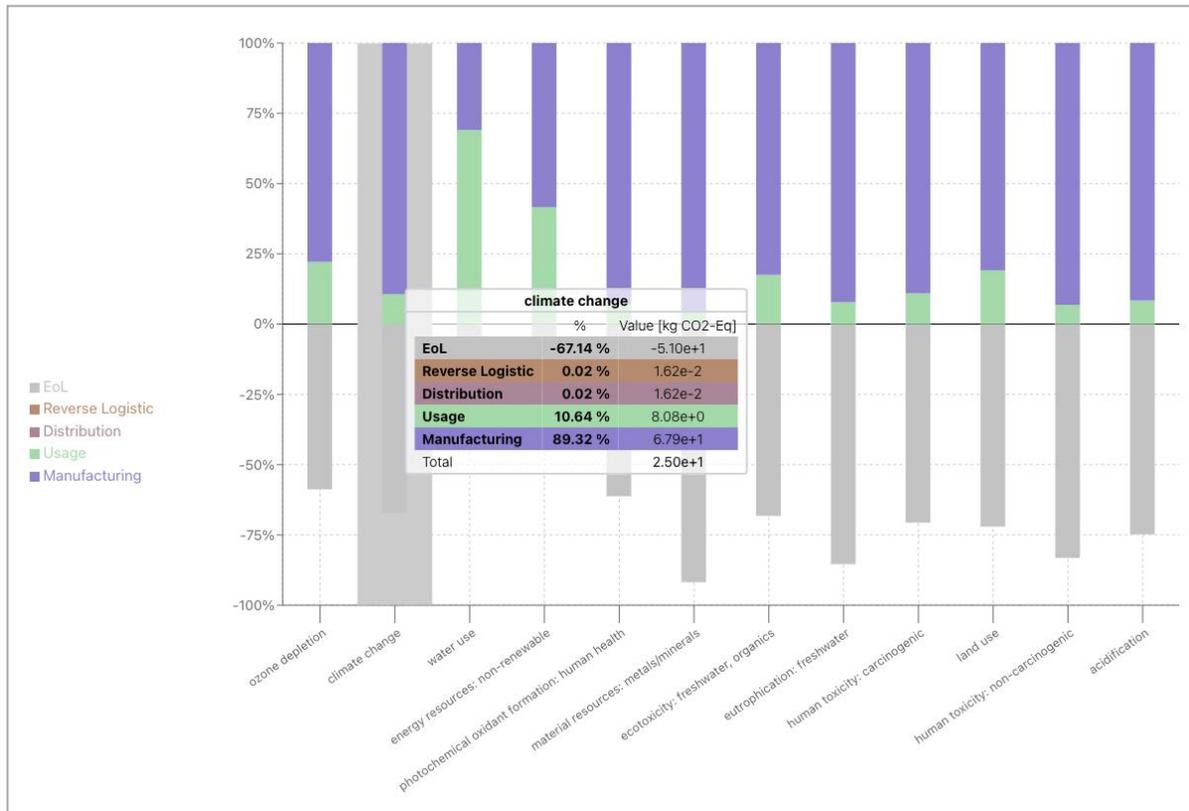


Figure 1 Assessment Chart

GRETA does not allow solely to perform assessment of single products individually but also to compare different product/process alternatives (a key feature for enabling eco-design) or to compare different products to each other, using a radar chart (Figure 2). This functionality is enabled by the real-time calculation engine of the platform; indeed, the manufacturer, during the eco-design process can adjust the scenario parameter to optimize the impacts and compare it to its previous setup or other scenarios through the available radar chart.

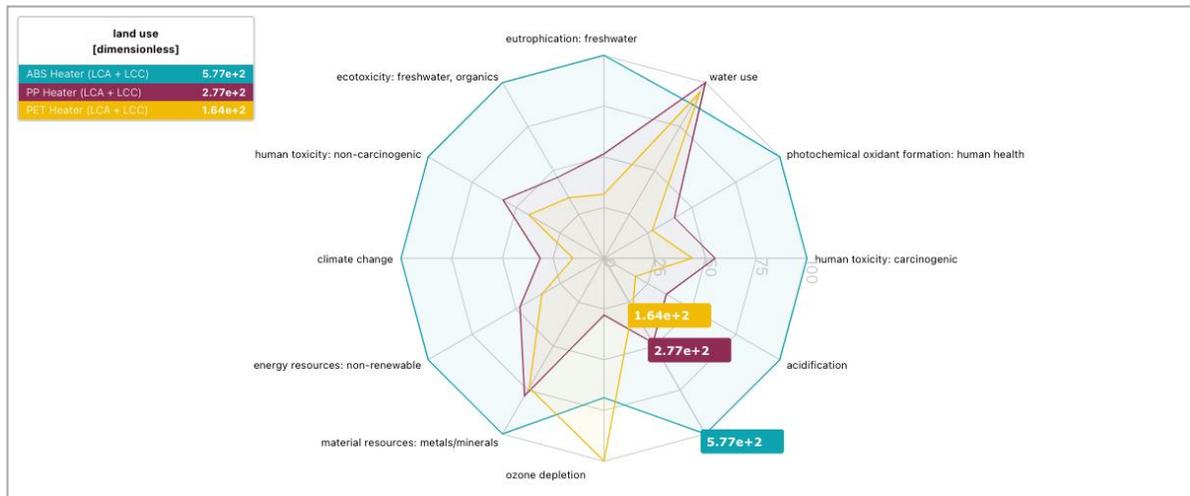


Figure 2 Radar Chart

The result of the assessment or the one produced by the comparison can be used to automatically generate a PDF report that contains all the alternatives included, including the list of sustainability parameters and the list of indicators produced by the assessment calculation.

3.2 Integration with RAMP platform

One important feature of GRETA that needs to be highlighted in this context is its flexibility, indeed includes an integration layer that can be exploited in different scenarios of integration:

- GRETA can (automatically) gather IIoT data as **input** to fill customization parameters and execute the assessment exploiting those data gathered in near real-time from external data sources. One interesting thing is that the source that produces the data can be an IoT device, a MQTT broker, a REST API, a database, and so on. For example, the data can be gathered from the CIRCULOOS platform.
- GRETA allow the end user to export assessment data to external data sources. Moreover, in that case the data can be exported to external platforms, in a database or to an MQTT broker, and so on. The environmental indicators obtained by the assessment can be sent to the CIRCULOOS platform in a JSON-LD format exploiting the semantic context defined.

The functionalities of GRETA are exposed by means of a set of REST API, in that way other services can exploit those API for integration purposes, using GRETA as a sustainability service.

This integration mechanism can be used in the context of the CIRCULOOS project, for example receiving or providing data to RAMP, MPMS, SCOPT and SCDT tools.

3.3 Indicators selection

So far, each operation within the established system boundaries will return data on the equivalent CO₂ emissions for that specific boundary. These calculations of CO₂e emissions will then be sent to the RAMP platform. CO₂e emissions refer to a metric that combines the impact of different greenhouse gases into a single value expressed as the amount of CO₂ that would have the same global warming potential over a certain time period. This metric is crucial for assessing the sustainability of a process, as reducing CO₂e emissions directly contributes to mitigating climate change and its environmental impact.

The GRETA tool, developed by SUPSI, is capable of calculating not only CO₂e emissions but also a variety of other environmental, economic, social, and circularity indicators. All those indicators, after the assessment, will be sent to RAMP but at this stage, only the CO₂e emission (GWP indicator) is taken into account. This is because CO₂e is the key metric being targeted in the current optimization tool. The goal is to identify alternative solutions that offer a more sustainable outcome compared to the existing process. Therefore, the objective function in the optimization will focus solely on minimizing CO₂e emissions.

4 Conclusion

In response to pressing environmental challenges, the CE offers a transformative approach to industrial practices, shifting from linear models to systems that emphasise minimization of residues and improve resource efficiency. The CIRCULOOS project aims to facilitate this transition by helping pilots in the wood, leather, and plastic sectors adopt more sustainable circular practices. By focusing on sustainability assessments and circularity evaluations, businesses can gain valuable guidelines into their environmental impacts and identify opportunities for improvement. These evaluations, which include LCA and resource efficiency analyses, are required for driving continuous improvement, optimizing processes, and achieving competitive advantages through improved resource management and reduced operational costs.

The GRETA tool within WP3, led by SUPSI, plays an important role in this transformation by developing a tool that supports sustainable and circular practices. This deliverable introduces a tool designed to perform sustainability and circularity assessments for various processes, integrating critical inputs such as material and energy balances, geographical data, and logistics factors.

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