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Automated Life Cycle Assessment in Scalable and Flexible Manufacturing

Abstract: Traditional Life Cycle Assessment (LCA) processes are time-consuming and rely heavily on manual input. In collaboration with Mirka, a Finnish manufacturing company producing abrasives, we integrate real-time data flows between production databases and LCA tools. This collaboration is ideal due to Mirka's extensive product portfolio, containing thousands of different products, providing a strong foundation for demonstrating the scalability and versatility of the automated LCA framework. We utilize a data lakehouse architecture to enable seamless handling of diverse datasets often required for LCA and supports near real-time updates to sustainability metrics. This automated solution minimizes manual effort, adapts dynamically to operational data changes, and delivers a continuous overview of environmental performance.

Keywords: Life Cycle Assessment, Data Lakehouse, Real-time Data Integration, Automated LCA, Manufacturing

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1 Introduction

Life Cycle Assessment (LCA) evaluates the environmental impacts of a product throughout its entire life cycle. LCA plays a key role in driving sustainability, supporting frameworks like Environmental Product Declarations (EPDs) and Digital Product Passports (DPPs), both essential for complying with circular economy (CE) principles. Yet, traditional LCA methods remain manual, time-consuming, and static, [1] which limits their usefulness for current sustainability needs. With the European Union's Corporate Sustainability Reporting Directive (CSRD) requiring transparent reporting on sustainability, [2] companies are pushed towards more sustainable production, and could benefit from implementing more dynamic and automated processes in calculating sustainability metrics.

For companies with extensive product portfolios, often containing over thousands of products, automation is essential to make the LCA process more effective. Additionally, automating LCA calculations unlocks further benefits, such as real-time visualization of emissions during production, supporting data-driven management and continuous performance monitoring.

In this study, we implement an automated life cycle assessment (ALCA) process at Mirka. The goal is to demonstrate how automating LCA calculations can reduce manual effort and enhance the scalability of sustainability assessments. By leveraging a data lakehouse architecture, we enable near real-time integration of production data with LCA tools, allowing for dynamic updates to sustainability calculations. This approach could improve efficiency and provide Mirka with continuous insights into environmental performance, promoting data-driven decision-making for more sustainable production.

2 Background

2.1 Automated Life Cycle Assessment

The main challenge for automated LCA for complex products are defined by [3] as the conflict of objectives between accuracy and efficiency, the manual workload for mapping input data against life cycle inventory (LCI) datasets, the lack of flexibility in LCI modelling, and the missing application in commercial LCA software.

There is currently no framework supporting fully automated LCA calculations. However, commercial LCA software solutions, such as SimaPro Synergy [4], and Sphera [5], have recently released application programming interfaces (APIs), enabling programmatic communication with their systems, underlining the need

for automated solutions in industry. Additionally, the framework proposed by [1] presents an ALCA process for manufacturing companies, and [3] solved their defined challenges by developing an LCI modeling approach, allowing automated assignments of a component's attributes to pre-defined LCI models using commercial LCA tools, indicating that research efforts are also in progress.

2.2 Mirka Ltd

Mirka is an essential partner for this project due to several key factors. First, their broad product portfolio provides the perfect test case for demonstrating the scalability of the ALCA framework. With thousands of distinct products, the system can be tested for its ability to handle diverse materials, processes, and environmental impacts at scale.

Second, Mirka's established data infrastructure supports integration capabilities with real-time LCA tools. Their existing systems ensure that the automated framework can access reliable and well-organized data for seamless processing. Additionally, Mirka's strong sustainability focus, including initiatives like transitioning to fossil-free electricity and reducing emissions, shows willingness to adapt to sustainability efforts.

This combination of complexity, data readiness, and sustainability alignment makes Mirka an ideal collaborator for implementing and showcasing the ALCA system.

3 Aims

The aim with this study is to implement an ALCA process that integrates real-time production data into LCA tools, validate the scalability and flexibility of the ALCA framework by applying it to Mirka's extensive product portfolio, and demonstrate continuous sustainability monitoring through real-time visualizations of key environmental indicators.

4 Methods

The ALCA workflow implemented in this study is illustrated in Figure 1. The ALCA framework at Mirka integrates real-time data from ERP, MES, and sensor systems into a centralized data lakehouse, acting as a storage repository, to enable automated, dynamic LCA updates. Python scripts process and map data to OpenLCA models, with results like carbon emissions fed back into the storage repository to be used in for example dashboards for near real-time monitoring. The system supports version control for traceability and will be tested for scalability and performance across Mirka's products.

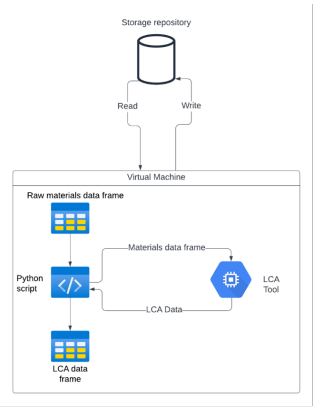

Fig. 1. ALCA Workflow

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