Applying a Multi-Cycle Life Cycle Assessment Framework to Circular Office Tables and Partition Walls

Authors: Wai Chung Lam and Joren Mijnendonckx

This paper applies the **Multi-Cycle Sustainability and Circularity Assessment Framework** developed by the **Drastic** project to two circular case studies: a remanufactured office table and a demountable internal wall. By testing the framework and comparing environmental performance against a business-as-usual (BAU) scenario, the paper demonstrates how multi-cycle reuse and remanufacturing can significantly reduce environmental impacts over multiple product life cycles.

Although not produced within the Drastic project, this research is directly relevant to Drastic's broader ambitions. It validates the framework that all Demonstrators will use, further supporting the its flexibility in assessing a range of building components and material types across varied national contexts.

The connection to Drastic is strengthened by the involvement of project partner **VITO**, who authored this research paper and also coordinate the Drastic project, including the development of the Multi-Cycle Sustainability and Circularity Assessment Framework. This ensures strong methodological alignment with the tools the Demonstrators will use.

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PAPER

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Abstract

Buildings are among the largest consumers of resources and emitters of CO_2 in the European Union, yet they also hold great potential for circular solutions. This study applies the *Drastic* multi-cycle sustainability assessment framework to two Flemish Living Lab *MASCO* case studies: remanufactured office tables by NNOF and demountable wall systems by JUUNOO. The results show that circular strategies such as reuse and remanufacturing can reduce environmental impacts by 55–66% for furniture and 60% for wall systems compared to business-as-usual construction.

This paper was written for and presented at the 2nd international conference on Circularity in the Built Environment held in Tampere, Finland, 16-18 September 2025. The applied methodological multi-cycle assessment framework has been developed as part of the Horizon Europe project Drastic, under the European Union's Horizon Europe research and innovation framework programme under grant agreement number 101123330. The case studies have been assessed as part of the Flanders Innovation & Entrepreneurship (VLAIO) Living Lab project MASCO, under the VLAIO call "Living Labs Circular Economy 2022". The Circular Value Institute was established during the MASCO project.

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Applying a multi-cycle life cycle assessment framework to circular office tables and partition walls

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Keywords: Built environment, Circular economy, Environmental life cycle assessment, Multi-cycle assessment framework

1. INTRODUCTION

Buildings are responsible for approximately 50% of resource extraction and consumption, 40% of the energy consumption in the European Union (EU), 36% of energy-related greenhouse gas emissions, and over 30% of the EU's annual waste [1]. Of this waste, only about 40% is recycled or reused. Therefore, the built environment has great potential for lowering its resource consumption and decarbonisation by implementing circular economy (CE) principles [2]. Circularity or CE principles, focus on retaining the value of materials for as long as possible through strategies like rethink, reduce, reuse, repair, and recycle – collectively also known as the R-strategies [3]. However, while these R-strategies promote sustainability, they do not offer an assessment of the potential reduction in greenhouse emissions or any other environmental impacts.

Life cycle assessment (LCA) is a widely used, science-based method for quantifying the environmental impacts of products [4]. LCA evaluates the environmental aspects and potential impacts related to a functional unit throughout a product’s life cycle, which starts from raw material acquisition, goes through to production, use and end-of-life (EOL) treatment, and ends with final disposal [5]. The result of an LCA is an environmental profile of the product assessed that includes quantified environmental impact indicators. However, the EN 15804+A2:2019 [6], which is the current European standard for conducting LCAs of construction products, is intended to assess linear life cycles rather than multi-cycle or circular life cycles.

Within the Horizon Europe research project Drastic [7], a sustainability assessment framework has been developed that incorporates multi-cycle LCA (MLCA) while also considering circularity and sufficiency aspects [3]. Five pilot projects that will demonstrate varied circular solutions are currently under development and their level of sustainability will be validated with the developed multi-cycle sustainability and circularity assessment framework by March 2027. To already test and further improve the assessment framework, the Drastic assessment framework has been applied to two circular case studies taken from the Flemish Living Lab project MASCO on circular materials [8]. This paper presents some of the results of the MLCA and circularity assessment of the two MASCO case studies.

2. METHODOLOGY

As described above, the Drastic sustainability assessment framework [3] has been applied to this study. The framework defines a multi-life cycle approach as “*an approach that enables cascading scenarios based on the R-strategies regarding a circular economy to preserve and*

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prolong the service life of buildings, components, and materials, thereby reducing resource demand (water, energy, and materials)". The modular structure of the EN 15804+A2:2019 forms the basis for the MLCA in which cascading scenarios based on the R-strategies are included in the different life cycle information modules, as visualised in Figure 1.

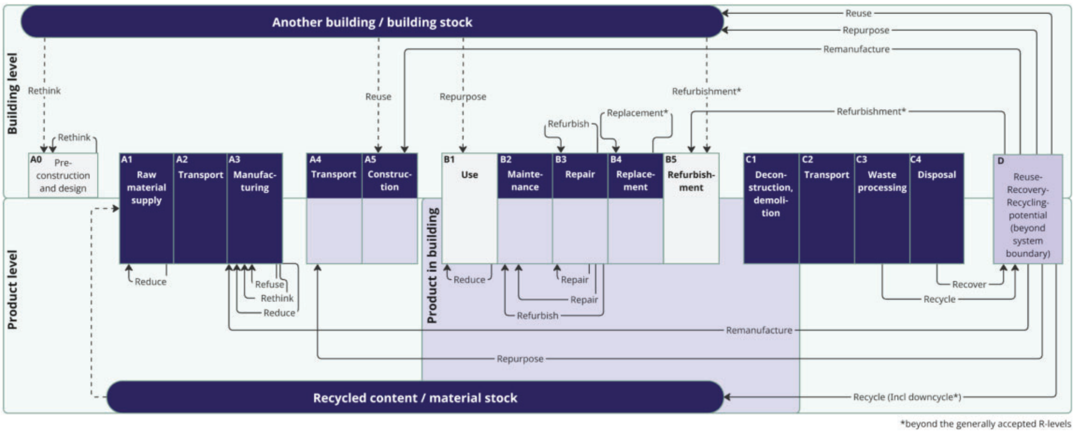

Figure 1: Mapping of the interaction between the R-strategies and information modules [9].

The core and additional environmental impact categories as included in the EN 15804+A2:2019 (e.g., the impact category climate change expressed in the unit kg CO_2 equivalents, and particulate matter expressed in disease incidence) are used to calculate the characterised life cycle impact assessment results. All 19 categories have been considered to minimise burden shifting. Furthermore, normalisation and weighting have been applied to allow aggregation of the assessed impact categories into a single score. While the uncertainty level associated with a single score is greater than that of the individual indicators, it facilitates better univocal decision-making compared to presenting several individual indicators side by side.

The EN 15804+A2:2019 standard does not provide guidelines for normalisation or weighting. Therefore, the Environmental Footprint (EF) weighting approach [10] developed by the Joint Research Centre of the European Commission is used, as the impact categories and impact assessment methods of EN 15804+A2:2019 align with those of the EF method. The normalisation and weighting in accordance with the EF method results in a single score expressed in environmental milli-points (mPt). This article presents only the single score results. To calculate the environmental impacts, the LCA software SimaPro Craft, version 10.2, and the generic life cycle inventory database ecoinvent 3.11 are used. Furthermore, the components from the Drastic assessment framework related to multi-cycle life cycle costing and circularity from a sufficiency perspective are excluded from the scope in this paper.

3. CASE STUDY DESCRIPTIONS

This paper presents two circular case studies: an office table remanufactured and sold by NNOF, and a demountable, reusable internal wall solution by JUUNOO. Both case studies consider an office building located in Brussels, Belgium as the location of the client.

3.1 NNOF

NNOF (Nearly New Office Facilities) is a Belgian company specialising in sustainable design and transformation of professional workspaces [11]. They offer relocation services for companies, including remanufactured or reused furniture to fit the new office space. For this case study, an office table is selected, made of a particle board panel supported by powdercoated steel legs. The panel, measuring 0.9 by 1.8 meters, is covered in melamine and finished with PVC edging. During the remanufacturing process, NNOF mechanically removes the melamine and PVC edging from the table surface, before applying new melamine and PVC edging. Additionally, a new powder coating is applied to the steel legs. When a table is suitable for reuse, it only requires a manual cleaning with water and soap. Both the remanufacturing and reuse process include transport from the client to the NNOF warehouse and from the NNOF warehouse to the client of the next use cycle. For remanufacturing, there is also transport between the NNOF warehouse and the NNOF workshop.

3.2 JUUNOO

The Belgian company JUUNOO designs and develops modular and reusable internal wall systems for workspaces [12]. Their BaseClick wall is an alternative to conventional non-load-bearing internal walls, which generally use a metal framework and gypsum board finishes. The BaseClick consists of a clickable metal frame that allows for endless reuse. It is filled with glass wool insulation and covered with fibreboard panels, which are secured using nylon tapes. The insulation, fibreboard panels, and nylon tape can be reused twice. When these components are disassembled for a third time, they will need to be replaced, i.e., a refurbish activity in terms of the R-strategies.

4. RESULTS

The next sections describe the results per case, addressing the environmental impacts per scenario, cycle, and information module. While the net impacts in module D –representing the potential benefits and loads beyond the system boundaries that result from waste processing in module C– are included in the graphs for completeness, they are not discussed in the next sections. This exclusion is to ensure clarity and prevent any double counting of potential avoided impacts.

4.1 RESULTS NNOF

Figure 2 illustrates the MLCA results of the NNOF case study. It shows the environmental profile based on the single score (mPt) of an office table for four different scenarios. Each scenario is separated with a thick vertical line, and each scenario considers three cycles separated with a dotted line. Each scenario starts with a first business-as-usual (BAU) production (A1-A3), transport (A4), and installation (A5) in cycle 1, and ends with a final EOL (C2-C4) in cycle 3. The first scenario represents the traditional linear “take-make-waste” economic model, where each cycle ends with an EOL (C2-C4), and each cycle begins with a full product and construction process stage (A1-A5). This BAU scenario serves as a baseline for comparison for the remaining three scenarios that reflects NNOF’s approach, incorporating the R-strategies remanufacture and/or reuse in cycles 2 and 3.

One BAU module A, including production, transport to and installation at site, account for 2.09 mPt, while a BAU EOL (module C) accounts for 0.78 mPt. In the first scenario, these impacts occur three times, once per cycle, totalling to 8.62 mPt. The second scenario considers one BAU module A (2.09 mPt) followed by two remanufacturing cycles at NNOF (0.50 mPt each), and a final EOL (0.78 mPt), resulting in a total environmental impact of 3.87 mPt over three cycles. This corresponds to a 55% reduction in environmental impact compared to the BAU baseline scenario. The third and fourth scenarios consider one and two reuse cycles, respectively. The environmental impact of one reuse cycle is 0.05 mPt. Therefore, in the third scenario still with one remanufacture cycle, the total environmental impact over three cycles is 3.42 mPt, while in the fourth scenario with two reuse cycles, the impact is reduced to 2.96 mPt. These correspond to reductions of 60% and 66%, respectively, compared to the BAU baseline scenario.

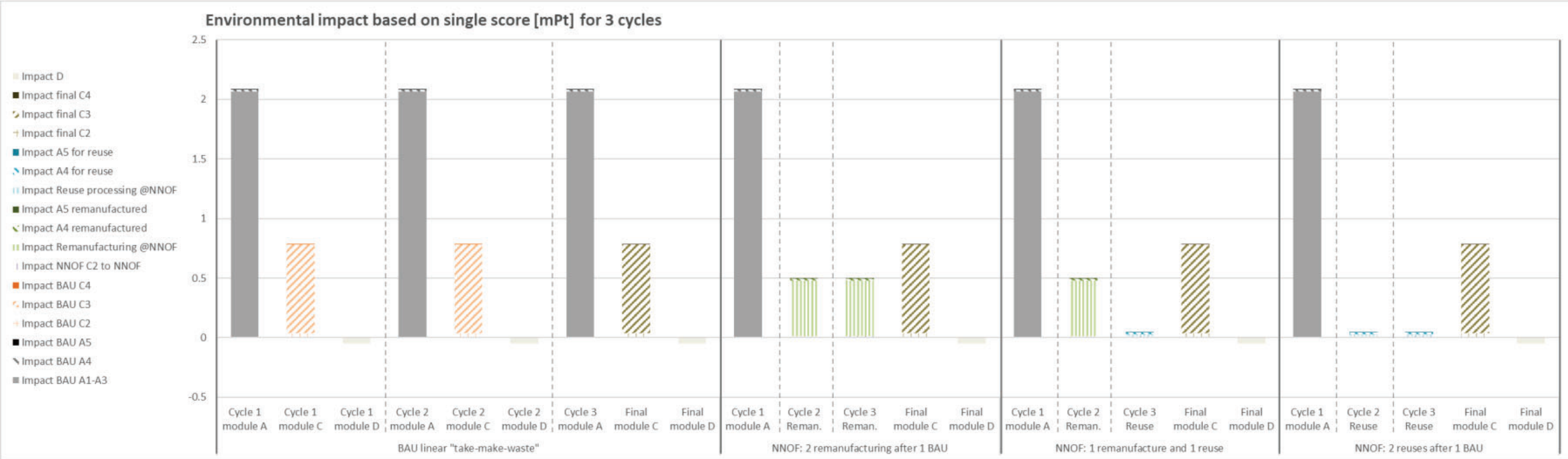

Figure 2. Comparative MLCA of a BAU office table and NNOF table for three cycles, environmental profile expressed as single score [mPt].

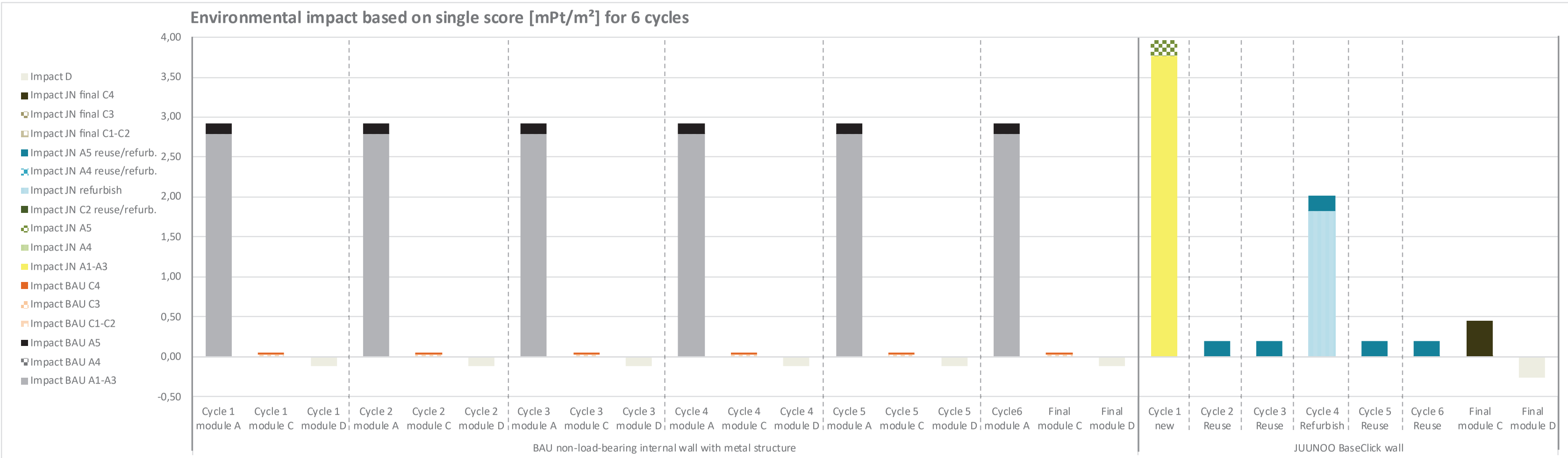

Figure 3. Comparative MLCA of a BAU internal wall and JUUNOO BaseClick wall for six cycles, environmental profile expressed as single score [mPt].

4.2 RESULTS JUUNOO

Figure 3 presents the MLCA results of the JUUNOO case study. It outlines the environmental impacts, expressed in mPt/m² of wall area, for two scenarios: the BAU baseline scenario, which considers a gypsum metal stud wall, and the JUUNOO BaseClick wall. Both scenarios are assessed over six cycles. The chosen number of cycles allows for a complete assessment of the JUUNOO wall's circular potential.

The BAU scenario involves six identical cycles, each comprising of production, transport to site, and installation in module A, followed by deconstruction, waste treatment, and disposal in module C. The impact of one BAU module A is quantified at 2.93 mPt/m², while one BAU module C accounts for a significantly smaller impact of 4.87×10^{-4} mPt/m². The relatively minor effect of module C is so small that it is almost not visible on the graph. The BAU scenario results in a total impact of 17.85 mPt/m² when assessed over six cycles.

The first cycle of the JUUNOO scenario comprises of the production, transport, and installation of the BaseClick wall, which accounts for an impact of 3.96 mPt/m². Cycles 2 and 3 represents reuse cycles, where the wall installed in the previous cycle is manually disassembled and transported to JUUNOO (C2 reuse/refurb. –which is too small to be visible on the graph), followed by transport (A4 reuse/refurb.) and installation at another office location (A5 reuse/refurb.), resulting in a relatively small impact of 0.20 mPt/m² per reuse cycle. Cycle 4 is the refurbish cycle, in which the insulation, fibreboard panel, and nylon tape need to be replaced, while the clickable steel frame can still be reused. This refurbish cycle has an environmental impact of 2.02 mPt/m². Cycles 5 and 6 are also reuse cycles like cycles 2 and 3; however, at the end of cycle 6, an EOL is considered with an impact of 0.45 mPt/m². Overall, the JUUNOO scenario results in a total impact of 7.21 mPt/m² when assessed over six cycles, which corresponds to a 60% reduction compared to the BAU scenario.

5. CONCLUSION

The MLCA results of both cases highlight the environmental benefits of transitioning from a linear economy to circular strategies such as remanufacturing and reuse. In both cases, the BAU baseline scenarios leads to the highest environmental impact due to repeated full-cycle production and EOL stages, emphasising the inefficiencies of the conventional "take-make-waste" model.

The NNOF case study demonstrates how integrating remanufacturing and reuse strategies can significantly lower environmental burdens. The comparison between the different scenarios demonstrates that reducing the need for new materials and extending the lifespan of existing furniture leads to meaningful environmental savings. In this specific example, a reduction ranging from 55% to 66% is feasible over three cycles. Moreover, increasing the number of remanufacturing or reuse cycles would further enhance sustainability gains, reinforcing the value of circular design principles.

Similarly, the JUUNOO case study shows the possible effectiveness of reusable non-load-bearing internal wall systems. Despite a higher initial impact in the first cycle, total environmental impacts can be reduced across multiple cycles with refurbishing and reuse processes. The break-even point between the assessed BAU gypsum wall and the JUUNOO system is reached by cycle 2, demonstrating possible gains of circular construction practices. These findings emphasise the importance of designing demountable, long-lasting products that minimise waste and optimise material use across multiple cycles.

It is important to acknowledge that this assessment assumes BAU products remain unchanged throughout different cycles. However, future advancements in technology, production methods, and energy infrastructure—including decarbonisation efforts—could lead to lower environmental impacts over time. Therefore, incorporating prospective LCA approaches into multi-cycle assessments would provide a more dynamic and forward-looking perspective on the MLCA framework.

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