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Article

Unraveling Circular Conundrums with a Cheeky Twist: Proposal for a New Way of Measuring Circular Economy Efforts on Product Level within Procurement to Waste System Boundaries

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Abstract: This study addresses the challenge of evaluating circularity within the procurement-to-waste system boundaries, exemplified by single-use in-flight drinking cups provided on SWISS International Air Lines Ltd. flights. A comprehensive review of academic literature, market-based tools, and political regulations highlights the absence of adequate methodologies for assessing circularity within these specific system boundaries. Existing approaches, primarily designed at the product level, are often either excessively complex or focused solely on waste management. To address this gap, the research proposes an extension to the Circularity Mass Utilisation Index (CMU), currently implemented at the European Union level. The traditional CMU does not account for circular inflow, thereby neglecting procurement decisions. In response, this study introduces an extended version of the CMU, expressed as: CMU Extended = (Circular Inflow + Circular Outflow) / (2 * Total Material Use). This modification enables a more holistic evaluation of circularity by incorporating both inflows and outflows of materials in relation to total material use. Empirical testing demonstrated the applicability of this extended CMU in the context of SWISS, allowing for an efficient assessment of circularity for single-use in-flight drinking cups. From these initial results, we hypothesize that this ratio is expected to be broadly applicable beyond the airline industry, providing a valuable tool for businesses seeking to measure circularity within similar system boundaries.

Keywords: Circular Economy; Measuring Circular Economy; Indicator Circular Economy; Sustainability; Procurement; Waste; Aviation Industry

1. Introduction

How can we address the challenge of effectively measuring circularity? As the concept of the circular economy gains momentum, businesses and organizations are recognized as pivotal in driving the transition towards more sustainable and resource-efficient practices. Essential to this endeavor is the need to effectively measure circularity, enabling companies to assess and track their progress in implementing circular economy principles (i.e., Figge et al. 2018, Valls-Val et al. 2022, Vinante et al. 2021). Metrics at the company level can illuminate for example areas where circular practices can be integrated, such as product design improvements for durability and the establishment of recycling and reuse chains for both consumed and produced goods. Understanding their circular economy performance allows companies to align strategies with broader sustainability objectives, potentially enhancing competitiveness, mitigating environmental impacts, and ensuring compliance with current and future regulatory requirements (Kulakovskaya et al. 2023). However, measuring circularity is a complex task requiring standardized methodologies and comprehensive data collection and analysis. Despite efforts by researchers, policymakers, and organizations to develop frameworks and tools, success has been limited due to the intricate nature of the challenge.

This study examines the challenge of measuring circularity within the procurement-to-waste system boundaries, using the example of single-use in-flight drinking cups at SWISS International Air Lines Ltd. (SWISS). In 2019, 22.4 million plastic cups for cold beverages were served on flights,

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all going to waste (SWISS internal documentation). The company does not manufacture these cups or manage their waste treatment itself but procures these services externally. In consequence its influence on the value chain is limited. This is true for many inflight products, such as cutlery, blankets, or hand towels.

The objective is to develop an index tailored to scenarios where the company operates as a B2B buyer rather than a producer. This index must be easily applicable to a range of products, leveraging the company's proprietary economic data to ensure data precision, data validity and data security. Additionally, the index should be adaptable to evolving conditions, such as shifts in policies and regulations.

Following this introduction, the paper proceeds with section two, where the research design is outlined. This is followed by sections three and four, which present a comprehensive literature review and an evaluation of existing market tools, respectively. In section five, the core of our study, we introduce and thoroughly discuss our newly developed circularity metric. This innovative metric addresses the gaps identified in sections three and four and forms the basis for the study's conclusions.

2. Research Method

Thie study employed an explorative research approach to address the challenge of measuring circular economy practices. The methodology comprised a comprehensive literature review, a market analysis of existing tools, stakeholder interviews, and the development of a novel metric.

A systematic literature review was undertaken, utilizing both Google Scholar and the research team's own extensive library. The review aimed to identify and critically analyze key papers and publications related to circularity measurement, thereby establishing a robust theoretical foundation for the study. The search strategy employed a range of targeted keywords, including "measuring circular economy" but also "measuring recycling," with an emphasis on capturing the various cycles inherent to circular economy practices. Further selection criteria involved screening papers for those that employed a mathematical and systematic approaches to measuring circularity. Further screening was carried out to understand in particular the approaches relevant to the by the case study set system boundaries, procurement-to-waste. The objective was to gain a comprehensive understanding of the existing methodologies, metrics, and frameworks utilized in the assessment of circular economy initiatives within the by the case study give system boundaries.

Following the literature review, a market analysis was performed to evaluate current tools available for measuring circular economy. This process involved compiling a list of tools offered to industry and developing criteria to assess their effectiveness, applicability, and limitations, as described in section four. Each tool was analyzed based on these criteria to determine its suitability for addressing the specific system boundaries of procurement-to-waste set by through the case study. To gain deeper insights into the practical application and effectiveness of existing tools, additionally explorative semi-structured online interviews were conducted with selected companies. Additionally, email exchanges were utilized to gather further information and clarify specific aspects of these tools. Further semi-structured interviews with representatives from the Swiss government and the Kanton Zürich were carried out to understand their perspectives on measuring circularity and the context the case study takes place.

Given the identified gap of knowledge through the literature review, market analysis, and interviews, the research team proceeded to develop a new metric. This novel formula, named CMU Extended, was created by adapting an existing circularity metric as described in section five. The development process involved theoretical refinement and practical validation to ensure that the new metric effectively addresses the identified gaps.

3. State of the Art – Literature Addressing Measuring CE within Procurement-to-Waste System Boundaries

The literature review was undertaken within the specified system boundaries procurement-to-waste, focusing on approaches that adopt the buyer's perspective in a B2B situation, reflecting the

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setting of the case study. The primary objective was to identify methods offering directly applicable and quantitative solutions, rather than engaging in conceptual discourse or qualitative assessments. Priority was accorded to literature presenting formulas that could be readily implemented. Additionally, emphasis was placed on recent publications with high citation frequency, reflecting their relevance within the scholarly discourse.

The initial phase involved studying the comprehensive literature review of the work carried out by Parchomenko (Parchomenko et al., 2019), who conducted a detailed assessment and clustering of 63 circular economy metrics. The analysis revealed three primary clusters of metrics, namely, (1) a resource-efficiency cluster, (2) a materials stocks and flows cluster, and (3) a product-centric cluster. For the purposes of this study, particular attention was given to the clusters containing metrics related to materials stocks and flows, as well as product-centric metrics. Using these clusters, we conducted a further analysis of the papers, categorizing them based on the phase they addressed within the product lifecycle relevant to our case: production, procurement, post-procurement, and waste management. This approach enabled us to systematically map how each study contributes to the understanding and advancement of circular economy practices across the various stages of interest. It also allowed us to pinpoint where the existing research is concentrated and to identify critical gaps in the current literature.

Within the materials stocks and flows cluster, a total of nine metrics were identified as interesting for the case. Table 1 presents an overview of the stages covered by these nine metrics. As the table demonstrates, the majority addresses the post procurement and waste phases, with six metrics also encompassing the production phase. Notably, none of the identified metrics address the procurement phase.

Table 1. Stages within CE metrics considering the stack and flow metrics.

Name	Study	Production	Procurement	Post procurement	Waste
How can LCA support the circular economy?	(Haupt and Zschokke, 2017)	**no**	**no**	**yes**	**yes**
Enhanced Landfill Mining in view of multiple resource recovery: a critical review	(Jones et al., 2013)	**no**	**no**	**no**	**yes**
Establishing and testing the "reuse potential" indicator for managing wastes as resources	(Park and Chertow, 2014)	**no**	**no**	**no**	**yes**
A case study of a phosphorus chemical firm's application of resource efficiency and eco-efficiency in industrial metabolism under circular economy	(Ma et al., 2015)	**yes**	**no**	**yes**	**yes**
Modeling the potential impact of future lithium recycling on lithium demand in China: A dynamic SFA approach.	(Guo, Zhang and Tian, 2021)	**yes**	**no**	**yes**	**yes**
Global socioeconomic material stocks rise 23-fold over the 20th century and require half of annual resource use.	(Krausmann et al., 2017)	**yes**	**no**	**yes**	**yes**
Statistical entropy analysis to evaluate	(Laner, Zoboli and Rechberger, 2017)	**yes**	**no**	**yes**	**yes**

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resource efficiency: Phosphorus use in Austria					
Continuous Material Flow Analysis Approach for Bulk Nonmetallic Mineral Building Materials Applied to the German Building Sector	(Schiller, Gruhler and Ortlepp, 2017)	**yes**	**no**	**yes**	**yes**
Dematerialization and the Circular Economy: Comparing Strategies to Reduce Material Impacts of the Consumer Electronic Product Ecosystem	(Kasulaitis, Babbitt and Krock, 2019)	**yes**	**no**	**yes**	**yes**
Total yes	-	**6**	**0**	**7**	**9**

In the realm of product-based metrics, as highlighted by Parchomenko et al. (2019), one notable approach is the longevity-circularity indicator, employing two distinct indices. These indices evaluate both the circular attributes of materials and a metric to gauge the actual lifespan relative to the anticipated lifespan with various reuse options. However, akin to the findings in the previous cluster, the outcomes pertaining to procurement-focused metrics were consistent: None of the identified metrics within this category specifically target procurement or adopt a procurement-centric perspective, as summarized in Table 2.

Table 2. Stages within CE metrics considering product-based approaches.

Name	Study	Production	Procurement	Post procurement	Waste
What gets recycled: An information theory based model for product recycling	(Dahmus and Gutowski, 2007)	**no**	**no**	**no**	**yes**
Triple-C: A Tridimensional Sustainability-Oriented Indicator for Assessing Product Circularity in Public Procurement	(Wurster and Ladu, 2022)	**yes**	**no**	**yes**	**no**
A tool for manufacturers to find opportunity in the circular economy	(Evans and Bocken, 2014)	**yes**	**no**	**yes**	**no**
A multidimensional indicator set to assess the benefits of WEEE material recycling	(Nelen et al., 2014)	**yes**	**no**	**yes**	**yes**
Material Circularity Indicator (MCI)	(EMF, 2019)	**yes**	**no**	**yes**	**yes**
Resource duration as a managerial indicator for Circular Economy performance	(Franklin-Johnson, Figge and Canning, 2016)	**yes**	**no**	**yes**	**yes**
Resource recovery from post-consumer waste: important lessons for the	(Singh and Ordoñez, 2016)	**yes**	**no**	**yes**	**yes**

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upcoming circular economy					
Nano and micro level circular economy indicators: Assisting decision-makers in circularity assessments	(Akanbi et al., 2018)	**yes**	**no**	**yes**	**yes**
Estimating global copper demand until 2100 with regression and stock dynamics	(Schipper et al., 2018)	**yes**	**no**	**no**	**yes**
Longevity and Circularity as Indicators of Eco-Efficient Resource Use in the Circular Economy	(Figge et al., 2018)	**yes**	**no**	**yes**	**yes**
Total yes	-	**9**	**0**	**8**	**8**

In search for the procurement variable, an additional screening of over 40 papers was undertaken, of which only three were found to address procurement directly. For instance, Bai et al. (2022) proposed a group decision-making method integrating various approaches for circular economy and circularity supplier evaluation as well as selection. Despite its intriguing premise, its complexity renders it impractical for application for the case. Atkin and Gergin (2015) emphasized the importance of incorporating environmental, economic, and social dimensions in supplier evaluation, presenting a questionnaire-based approach to assess potential suppliers. However, we found, that the reliance on questionnaire responses poses validity concerns, particularly regarding the accuracy of self-reported data since no standards for such data are in place yet. Sheu et al. (2005) introduced a multi-objective optimization model for a green-supply chain, although its applicability is primarily suited to manufacturing companies rather than service providers like SWISS Airlines.

Regarding waste management, the academic discourse renders around the question of how much detail needs to be considered, the trade-off between methodological detail and data feasibility. Several papers propose simplified approaches, such as calculating the ratio of collected or recycled material to total material, albeit critiqued for overlooking other potentially relevant variables. Pires & Martinho (2019) introduced a waste hierarchy index (WHI) based on parameters like reuse and upcycling, excluding incineration as a circular operation. Park & Chertow (2014) developed a "reuse potential indicator" (RPI), which quantifies the reuse potential of waste materials, emphasizing their resource-like qualities. Anastasiades et al. (2023) progressed with a Circular Construction Indicator framework that incorporates the RPI to evaluate the circularity of construction projects. Other discussions revolve around the waste hierarchy principle, with the European Union establishing a framework comprising prevention, preparation for reuse, recycling, recovery, and disposal.

Also on EU level, we find the Circular Material Use Indicator (CMU) published by Eurostat (Eurostat, 2018) wherein two variables—recycled material and total material used—are juxtaposed in a ratio. The approach quantifies the proportion of material recycled and reintegrated into the economy relative to the total material utilized. The indicator relies on mandatory reporting from all EU Member States, alongside aggregated member state data (Eurostat, 2018). At the national level, the CMU rate is further subdivided by material categories (Federal Statistik Office Switzerland, 2024).

Huysman et al. (2017) and Di Maio & Rem (2015) devised indicators with a more detailed waste classification, aiming to capture various recycling and collection scheme efficiencies. Additionally, Huysveld et al. (2019) and Ardente and Mathieux (2014b) proposed indicators such as the Recyclability Benefit Rate and the Recycled Content Benefit Rate, emphasizing the need for further research on material lifetime, quality, and economic considerations in circular economy assessments.

An interesting contribution comes from Nelen et al. (2014), who aimed to develop a comprehensive set of multidimensional indicators for assessing the benefits of recycling Waste Electrical and Electronic Equipment (WEEE) materials. Their approach encompasses four key dimensions: material cycle closure, critical material recovery, environmental impact avoidance, and

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economic performance. Notably, two indicators, applied in various contexts, assess the mass of recycled and repaired materials in relation to the total material mass. Additionally, an economic performance indicator measures the profitability of recycling and repairing against total material costs. While these indicators reflect a common trend of relating actions to overall quantities, Nelen et al. (2014) introduces an innovative environmental impact avoidance factor. This factor quantifies the environmental impact avoided through recycling and repairing relative to the total environmental impact of the material. Although promising, calculating this metric necessitates a prior Life Cycle Assessment (LCA) to determine the environmental impact of each scenario.

Flying on a different level, Figge, Thorpe and Manzhynski (Figge, Thorpe and Manzhynski, 2021) advocate for a portfolio theory of the circular economy, emphasizing the importance of understanding the trade-offs and synergies among different circularity strategies. The authors posit that circularity should not be viewed as a binary concept but rather as a spectrum of possible configurations, each with varying environmental and economic implications. Drawing on insights from multi-level selection theory, as outlined in Society (2018) by Williams and Pigliucci (Pigliucci, 2009) the authors illustrate how the actions of individual companies can influence the behavior of the broader group, potentially shaping the overall circularity of the system. This group-level perspective offers valuable insights, aligning with the adopted research approach and signaling a promising direction for future research.

The literature review focused on methodologies from procurement-to-waste management, with an emphasis on buyer-centric approaches to identify practical, quantitative solutions. Recent, highly cited publications were prioritized, especially those presenting existing formulas.

Initially, the study analyzed circular economy metrics clusters by Parchomenko et al. (2019), with a focus on materials stocks and flows, and product-centric metrics. Despite addressing post-procurement and waste phases, none specifically targeted procurement. Further exploration revealed a lack of focus on procurement also within the additionally reviewed metrics. Only three papers were found which directly addressed procurement, but their complexity or limited applicability posed challenges. Discussions on the other end of the system boundary, waste management, highlighted the need to balance methodological detail and data feasibility. Overall, none of the approaches we found addressed the system boundaries in a for the case suitable way.

4. State of the Art – Tools on the market

In a first step, market research was carried out to identify tools on the market through common search engines such as Google and MS Bing. Based on a detailed market analysis of currently available tools with categories such as language, active users and availably on the market (see all criteria listed below) in combination with reflections in literature done by Sacco et al. (Sacco et al., 2021), Vinante et al. (Vinante et al., 2021) and Valls-Val et al. (Valls-Val, Ibáñez-Forés and Bovea, 2022), the following tools were selected for further evaluation:

1. Circulytics
2. MCI /Material Circularity Indicator
3. CTI
4. Acodea
5. CEEI
6. CircularTrans
7. Inedit
8. TECNUN
9. CircularityCalculator
10. KMPG

Following the identification of current tools, an assessment was conducted based on the following criteria:

Active Users, Past Users, Europe / Global, Costs, Language, Quantitative, Qualitative, Materials, Water, Waste, Energy, Finance, on the market since, likelihood to stay on the market, potential political impact, product level assessment, company level assessment, education of user. In search

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for a tool which would allow an industry wide comparison on product level now and in the future, priority has been given to the categories:

- Active / Passive Users: Indicator for market acceptance
- Costs: Value for money
- On the market since: Indicator for market acceptance
- Likelihood to stay on the market: Indicator for market acceptance
- Political impact: Indicator to evaluate if the tool reflects current EU / Swiss regulations and will do so in the future
- Product level assessment: Assessment on product level

Discussion Tool Assessment

The analysis of the market reveals the availability of various tools for assessing sustainability metrics. Initial impressions were positive; however, upon applying predetermined evaluation criteria, the pool of viable tools diminished by half. Five tools were eliminated from further consideration due to constraints such as restricted access, unavailability, or language barriers. Additionally, one tool offered by KPMG was excluded as it overlapped with the CTI tool, which was already earmarked for detailed examination.

Subsequently, detailed assessments were conducted on the remaining tools: Circulytics, MCI, CTI, and CircularityCalculator. Discussions were held with the respective providers, either through interviews or email correspondence. Based on the assessment criteria applied as described above, CTI and Circulytics were recognized as the most promising options. The tools showed the most active / passive users, with high market acceptance and, important for the case at hand, what seems with an ability to assess products on product level.

Several conversations were conducted with key figures, including CTI's CEO and its Strategic Director, as well as with a representative of the World Business Council for Sustainable Development (WBCSD), the organization endorsing CTI. In the case of Circulytics, inquiries beyond available documentation were made through email exchanges with the Ellen MacArthur Foundation, the entity behind the tool. Additionally, communication was established with the CEO the MCI tool. Subsequently, a comprehensive discussion of the four tools ensued, incorporating analysis of their online presence, documentation, and qualitative insights gathered throughout the project.

Circulytics

Developed by the Ellen MacArthur Foundation, the tool benefits from the Foundation's established reputation as a leading proponent of circular economy principles. Ellen MacArthur's pioneering contributions to circular economy discourse, including her widely accepted definition of the concept, have cemented the Foundation's influence in both scholarly and practical spheres. Notably, prominent industry players such as H&M, ABB, Coca-Cola, and HP are among the participating companies, underscoring the tool's alignment with prevailing industry standards. Circulytics distinguishes itself by its evaluation framework, which integrates qualitative and quantitative assessments across various organizational dimensions, including innovation, strategy and planning, and personnel capabilities.

Despite its initial promise, the tool's efficacy was compromised in one crucial aspect: its inability to facilitate product-based assessments, a priority criterion for the present study. Subsequent discussions with the tool's developers revealed that the Foundation had discontinued efforts toward standalone product-level assessments as part of its strategic realignment. Previous endeavors in this direction, halted in 2019, now manifest as the MCI tool marketed by Hopkins. Consequently, while Circulytics remains an interesting and powerful tool, its inadequacy for the specific demands of the case study lead to an exclusion of the tool.

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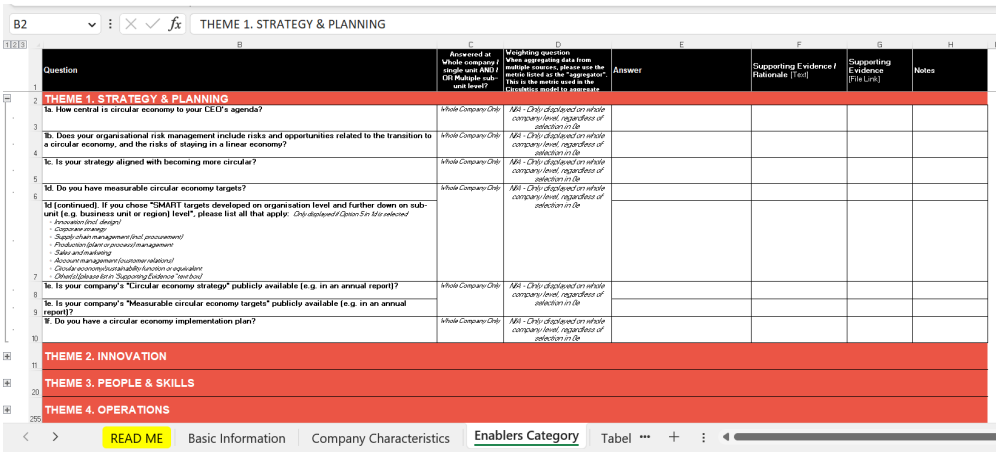

Figure 1. Example from offline data capturing file Circulytics.

MCI Tool

The MCI Tool is offered by a company called Hoskins with the founder, James Goddin, standing behind the tool (Hoskins, 2024). The webpage shows a team with three members presenting itself as a small consulting company. The tool has been further assessed as it was originally based on an initiative from EMA Foundation, as described above and is one of the few tools which allows product level assessment of circularity. The tool is free to download on the website:

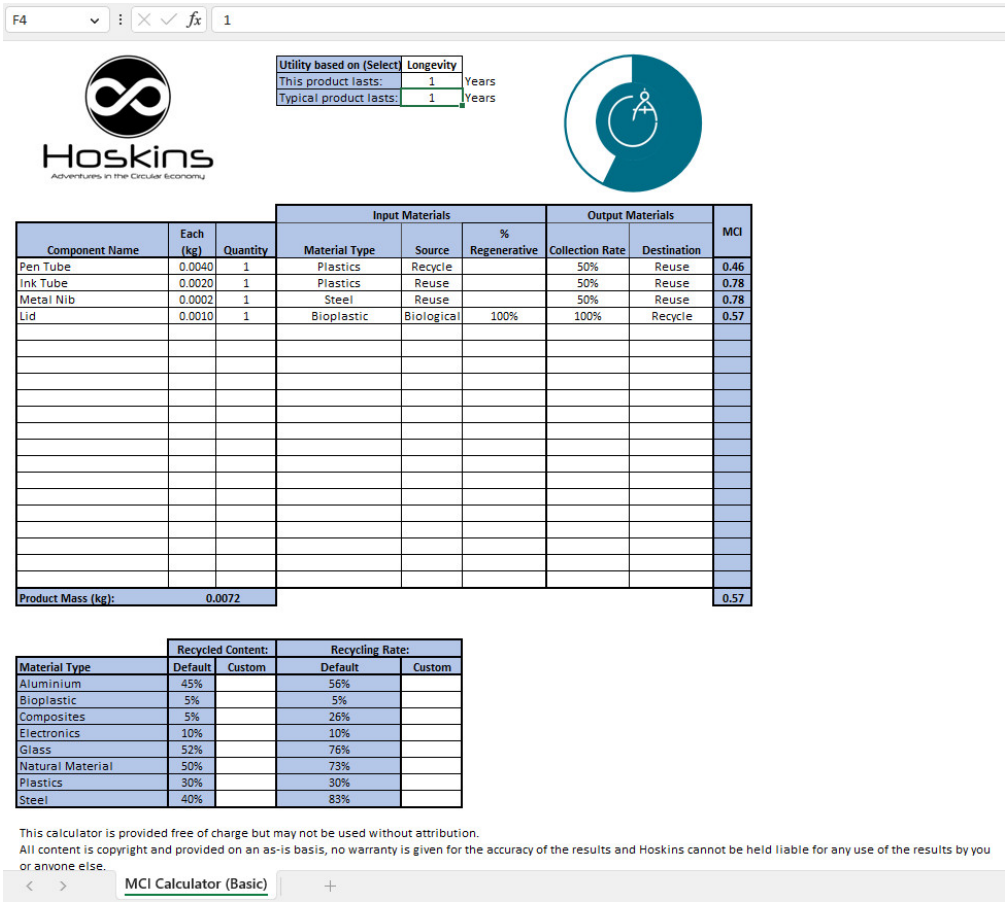

Figure 2. Example from offline data capturing file MCI Calculator.

The tool is provided in form of an Excel sheet (with only one tab as displayed above). The case displayed in the Excel is an example of a biro, provided by Hopkins. Each part of the biro can be assessed individually with a total score showing the MCI factor, ranging from 0-1, one being the

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highest level of circularity. The material types are basic in that for example no differentiation is made on the material level "plastics". The tool is easy to use, however, the Excel itself cannot be modified and the calculations which happen in the background are not displayed in the Excel sheet (only absolute numbers). For the latter argument, following up on an original documentation from EMA (2019) the calculations become clearer, however, the first argument remains, the Excel cannot be modified. For the example of cups with no longevity data, the Excel fails. Any value under 1 year in the category "Longevity" leads to an error for all fields. Additionally, given the low impact the current owner has on the market, this tool is unlikely to reach an industry standard level / reflect future regulations on EU level. For these reasons the tool has been ruled out.

CTI Tool

The CTI tool is provided by a company called Circular IQ with the Word Business Council for Sustainable Development (WBCSD) - a business financed through membership and consulting - standing behind it. In an interview carried out with the CEO March 2023, the CEO claims to also be well connected to the EU influencing policy makers. The tool focuses on supplier data (inflow) as well as the moment of disposal (outflow). The following Excel shows an example of the required data:

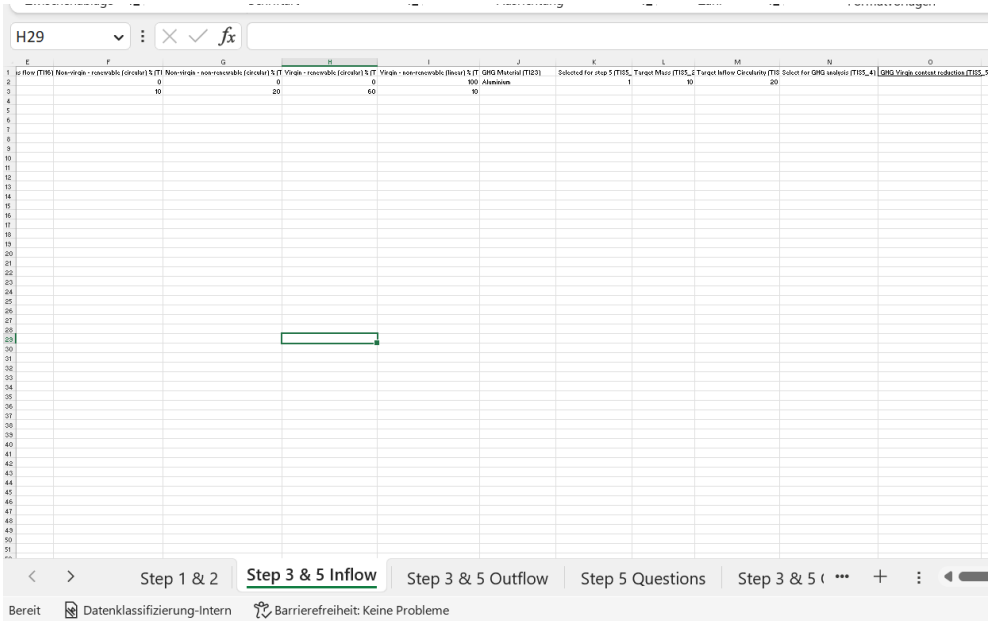

Figure 3. Example CTI tool inflow tab.

Inflow:

As partially displayed above, the inflow data distinguishes between:

Flow type (TI10), Critical material (TI7), Mass (kg) (TI3), Focus flow (TI16), Non-virgin - renewable (circular) % (TI17), Non-virgin - non-renewable (circular) % (TI2), Virgin - renewable (circular) % (TI1), Virgin - non-renewable (linear) % (TI9), GHG Material (TI23), Selected for step 5 (TIS5_1), Target Mass (TIS5_2), Target Inflow Circularity (TIS5_3), Select for GHG analysis (TIS5_4), GHG Virgin content reduction (TIS5_5).

For the outflow section, which is on the next tab, called "Step3&5 Outflow" as visible in the figure below, the following categories must be filled in:

Flow name (M18), Flow type (TI10), Mass (kg) (TI6), Recovery Potential Percentage % (TI4), Actual Recovery Percentage % (TI5), Selected for step 5 (TIS5_6), Target Mass (TIS5_7), Target Recovery Potential (TIS5_8), Target Actual Recovery (TIS5_9).

Only considering the data requested for the outflow and inflow, it becomes clear that first, we need to collect a lot of data and second, we can (hopefully) expect a detailed assessment once we have filled in the data. Additional data can be collected and filled in to also display water and energy usage:

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	A	B	C	D
1	**Renewable Energy**		Swiss Cup	
2	Renewable Energy Amount (TIS3_1)	80		
3	Total Energy Amount (TIS3_2)	100		
4	Energy Unit (TIS3_3)	kwh		
5	**Renewable Energy Improvement**			
6	Renewable Energy Amount Change (TIS5_30	5		
7	Total Energy Amount Change (TIS5_31)	-5		
8	**Water**			
9	Total circular water withdrawal (TIS3_4)	100		
10	Total water withdrawal (TIS3_5)	500		
11	Total circular water discharge (TIS3_6)	300		
12	Water Unit (TIS3_7)	m3		
13	**Water Improvement**			
14	Total circular water withdrawal change (TIS5_	50		
15	Total water withdrawal change (TIS5_33)	-50		
16	Total circular water discharge change (TIS5_3	-50		
17	**Water Use**			
18	Water Use (TIS3_8)	750		
19	**Revenue**			
20	Revenue (TIS3_9)	5000.25		
21	Revenue Currency (TIS3_10)	$		
22				
23	**Circular material productivity**			
24	revenue obtained from beverages			
25	avg cost per serving	CHF		
26				
27				
28				
29				

Step 3 & 5 Outflow | Step 5 Questions | Step 3 & 5 Other

Figure 4. Example CTI tool.

The report, which is created based on the input data, is available as HTML display on the website or as PDF download (several pages). An example is displayed below:

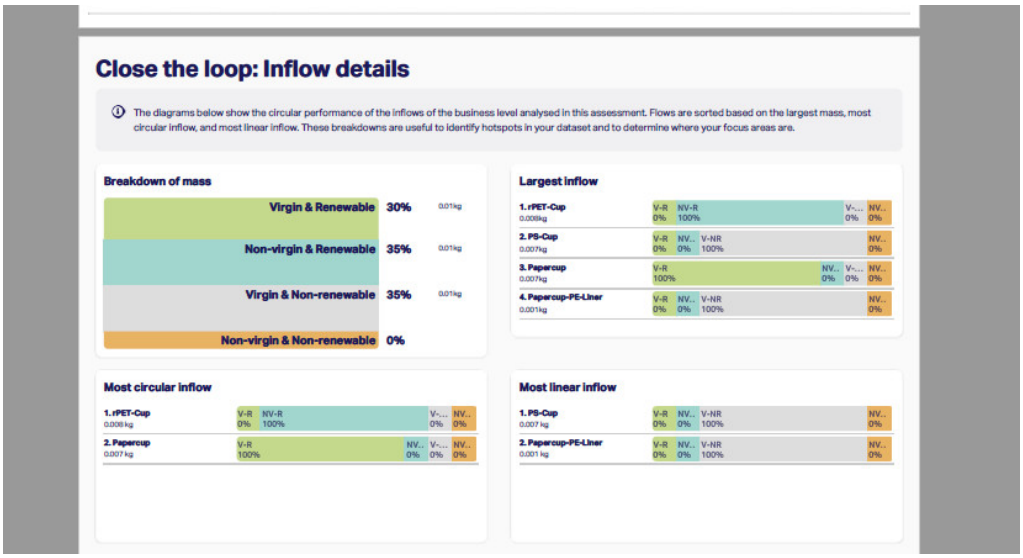

Figure 5. Example CTI report.

Discussion CTI Tool

Since the tool was considered as very promising at the beginning of the project, it deserves a separate discussion: Early on, our aim was to identify a standardized instrument for assessing circularity, with potential application within the aviation sector. Subsequently, we engaged in

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extensive discussions with the tool provider to explore the feasibility of further developing their solution to suit industry-specific needs.

However, our experience with the tool revealed a significant challenge in data collection over time. This challenge is deeply rooted in our case context: SWISS operates as a user rather than a producer of the product (cups), thereby lacking direct control over the cup supply chain. Consequently, data acquisition from suppliers proves to be laborious and, in some instances, unattainable, as the companies supplying SWISS may not possess the necessary information. Moreover, the data provided by suppliers often pertains solely to their production processes, omitting crucial details regarding the cradle-to-gate aspects of material production.

Another critical issue arises from our reliance on externally sourced data, which hampers our ability to verify its accuracy effectively. While established ISO standards could potentially mitigate this issue by aligning supplier obligations with those of B2B consumers, no such standard currently exists for measuring circularity. Despite inquiries with the ISO Standardization body regarding the development of such a standard, specifics regarding ISO/CD 59020 remain undisclosed as of spring 2024. Unfortunately, requests for insight into the standard's direction were met with refusal. With no standard available yet, no company certified (which again will take time even once ISO will have published their ideas), there is a risk, that a supplier who naturally wants to keep SWISS as customer will report in his / her own favor with no neutral body to check upon the data.

Circularity Calculator

The Circularity Calculator has been developed in the context of an EU research project and is now offered by Ideal&Co, a small Dutch design company with, according to the webpage, five members. The tool is interesting in that it reflects the different circles of circularity and offers indicators, which put in relation the variables material / production effort / money and with this shows money saved by keeping things in the loop.

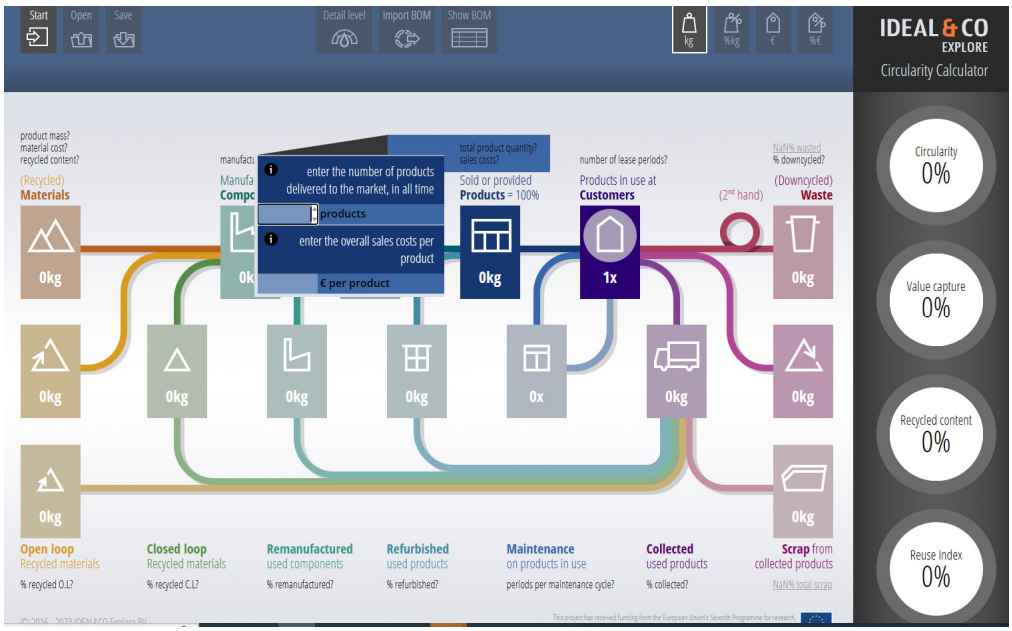

Figure 6. Example Circularity Calculator.

The tool is designed to capture cradle-to-cradle or cradle-to-grave considerations and boasts a well-crafted interface. Yet, its application to our case study reveals significant limitations. SWISS lacks ownership of the requisite data concerning sourcing and production, and the company has no detailed information necessary for meaningful application of the looping criteria displayed within the tool. Moreover, the tool does not adequately address the need to evaluate products within system boundaries extending from procurement decisions to waste management. Instead, it primarily

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supports design decisions in the early stages of product design, aligning with the target audience identified by the tool provider.

Ten tools were initially identified for evaluation, five were excluded due to restricted access, unavailability, or language barriers, with KPMG's tool building on the CTI tool, leaving four tools under investigation. Our analysis indicates that none of the currently available tools are adequately suited to our case study. While Circulytics stands out as a potentially influential tool, its scope, assessing the entire company, exceeds the project's objectives whilst the tool falls short when it comes to product-based assessment. The MCI tool, while offering simplicity, lacks applicability for products lacking longevity data and is unlikely to make a significant market impact. Moreover, its Excel format prohibits modification. The CTI tool falters due to SWISS's lack of ownership over necessary data. The Circularity Calculator boasts a well-designed interface and comprehensive documentation elucidating its mathematical underpinnings. However, on early-stage product design guidance as well as strength in differentiating on various types of loops, limits its usability for our project.

Overall, the tool assessment demonstrates a lack of solutions tailored to companies operating in a procurement position without ownership of the product's value chain. Common challenges across all tools include a lack of cost-revenue structures, data governance issues, reliance on product suppliers, and standalone functionality without integration with existing tools. These findings resonate with existing literature, highlighting the absence of standardized approaches and the conundrum of balancing analysis depth with data collection requirements.

In evaluating the tool's applicability, we examined also the relationship between the tool provider and political institutions, as described above, recognizing that political regulations heavily influence corporate actions. Given SWISS's headquarters in Zurich and its affiliation with the Lufthansa Group, we focused on both regional (Canton Zurich) and broader regulatory environments (Switzerland and the EU). We conducted three interviews with relevant departments in Canton Zurich and the Swiss government, aligning these discussions with the recent G7 summit's push for plastic waste neutrality by 2040 (World Economic Forum, 2024). Given the absence of legislation requiring circularity metrics at the company or product level in Switzerland, Canton Zurich, or the EU, we inquired specifically about the potential impact of the G7 summit's decision on companies headquartered in Switzerland that operate within the EU. Both Swiss government and Canton Zurich representatives suggested that mandating such metrics at the EU level is improbable due to significant enforcement challenges.

The specific regulatory changes resulting for example from the G7 summit's plastic waste neutrality initiative remain uncertain, as no official drafts or hints have been published by the involved governments yet. Initial drafts are expected by 2024, but the form and impact of these regulations are still speculative. The overall learning is, that companies must adopt a metric-based approach that is adaptable to the evolving regulatory landscape to remain compliant and competitive in the future.

5. Development of a Circularity Factor

Given the absence of viable approaches in existing literature, tools, or regulations to address the system boundaries from procurement-to-waste decision within a B2B consumer context as set by the context of the case study, we undertook an iterative process to re-examine all available information. Through these iterations, which also encompassed an analysis of measures implemented by the Swiss government and the EU, we arrived at a familiar metric utilized at the country level, namely the Circular Material Use Indicator, CMU (Eurostat, 2018). As described in the literature section, this approach bears resemblance to the basic metric described in waste management literature, wherein two variables—recycled material and total material used—are juxtaposed in a ratio leading to the following equation: Circular Material Use Indicator (CMU) = Circular Use of Material (U) / Overall Material Use (M). This metric is applied at both the national and EU levels. An example published by the Swiss government on country level is shown in the figure below.

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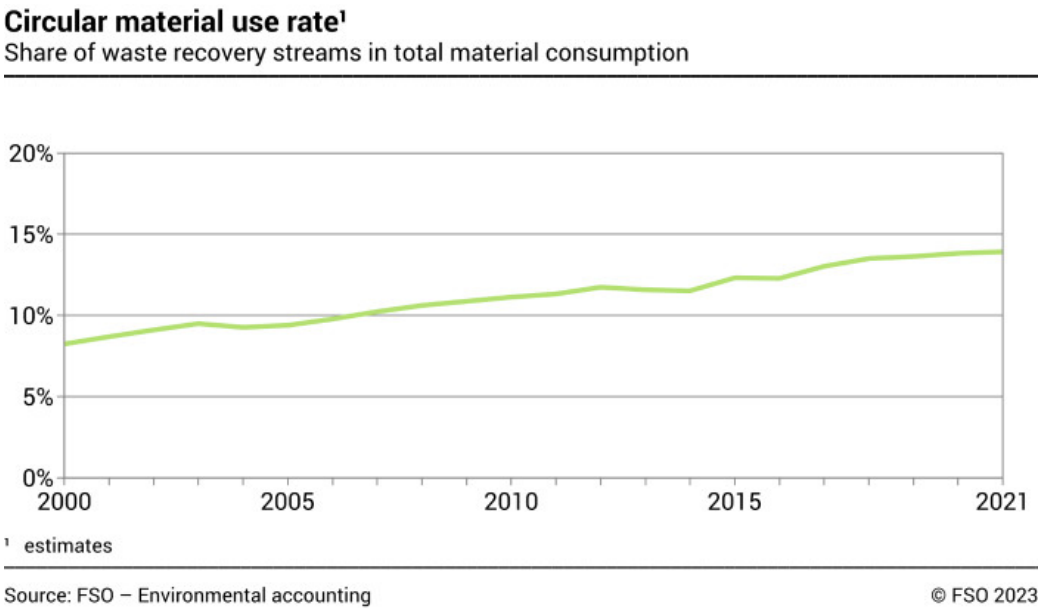

Figure 7. CMU displayed and published by the Swiss government (Federal Statistik Office Switzerland, 2024).

Upon closer examination, this indicator offers interesting benefits across multiple dimensions. It is recognized both in Switzerland, where SWISS is headquartered, and in key target markets like the EU and EU-associated countries, making it familiar to both policymakers and the informed public. Moreover, its communication simplicity as a percentage enhances its accessibility. Furthermore, data availability poses no hindrance as values for the requisite variables must be compulsorily reported by each EU and EU-associated government, including Switzerland.

However, the application of this metric within a country context is subject to several limitations. Firstly, the quality of data provided by member states dictates the reliability of the indicator; disparate data quality may compromise its accuracy, resulting in a rough approximation. Secondly, the indicator exclusively encompasses materials officially designated as waste, thereby excluding on-site loops such as internal recycling within companies. Thirdly, the focus solely on the disposal phase introduces similar challenges encountered in literature and within the tool market, including issues of data availability, data quality, the complexity of data capture and analysis versus granularity in results, and the absence of reflection on the procurement phase.

Nevertheless, if applied at the company level, will these limitations persist? Additionally, could the inclusion of the procurement phase by introducing an additional variable enhance the comprehensiveness of this otherwise straightforward yet potent metric? These questions merit further exploration and will be addressed in subsequent discussions.

Transfer of an Existing Approach

We embarked on a quest to address two fundamental questions:

1. Can we adapt this approach to measure circularity at the company or even product level, focusing on the outflow of materials?

2. Is it feasible to modify the factor to incorporate both the procurement and waste decision phases, thereby encompassing the system boundaries pertinent to our case study?

In pursuit of the first question, we conducted two tests, the details of which are delineated below.

Testing of the Indicator Circular Material Use Rate

Example 1: We have two products, one, the plastic glass large, and secondly, the r-PET Cup. We assume that the plastic glass large as well as the r-PET Cup are not going into any circular loop and that we have 100 units in total:

U (circular use of material)= 0 (nothing is looped)

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M (total material) = 100
CMU=0/100
CMU=0%

Example 2: We assume that 80 units of the plastic glass large as well as 80 units of the r-PET Cup are going into recycling and that we have 100 units in total:

U (circular use of material)= 80 (80 units are looped)
M (total material) = 100
CMU=80/100
CMU=80%

Cup Type	Circular Use of Material	Overall Material Use	CMU
Plastic Glass Large (LX31.020)	0	100	0%
r-PET Cup	0	100	0%
	Nothing recycled		

Cup Type	Circular Use of Material	Overall Material Use	CMU
Plastic Glass Large (LX31.020)	80	100	80%
r-PET Cup	80	100	80%
	80 untis will be recycled		

Figure 8. Testing of CMU on company level.

What we can see is that in its simplicity to calculate, we can translate the approach to the current case and with this at company and even product level. The figure below illustrates the advantages and disadvantages if we were to follow this approach and use this equation for the case of SWISS:

Pro	Contra
Allows quick assessment of circularity within in-house (available) data	Applied only on country level until now
Easy to communicate	Does not explicit reflect loops
Easy to measure	Does not reflect km/weight/CO2
Governance	Does not reflect cost/revenue of action
Similar measurement is used by other organizations too (Example: Weleda)	Does not reflect procurement decisions

Figure 9. Summary of advantages and disadvantages of CMU application on company level.

Having established the feasibility of translating the circularity metric to the moment of waste on product level, our attention turned to assessing its viability for external communication and its potential utility as a marketing instrument. While this translation offers a simplified representation of circularity and lacks the granularity to capture all possible loops, its simplicity may render it more accessible for external stakeholders. In literature, we encountered primarily critical perspectives on such non-complex approaches, yet we questioned whether this perspective truly aligns with real-world applications.

Subsequently, we embarked on an explanatory analysis of approaches adopted by other organizations and came across the case of Weleda, a brand well known for its efforts in all categories of sustainability:

Weleda's annual report features a succinct overview titled "Selected Numbers," depicted in the figure below on the left. Alongside metrics such as the number of employees, this section provides insights into the company's sustainability endeavors. Given that Weleda manufactures its products internally, attention is also drawn to metrics such as organic proportion of plant-based resources, renewable energy proportion, and proportion of recycled materials in packaging. Of relevance to our

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case, wherein we do not possess the entire value chain of the product and do not manufacture the cups, is the metric pertaining to waste management: Proportion of waste that is reused: 97%.

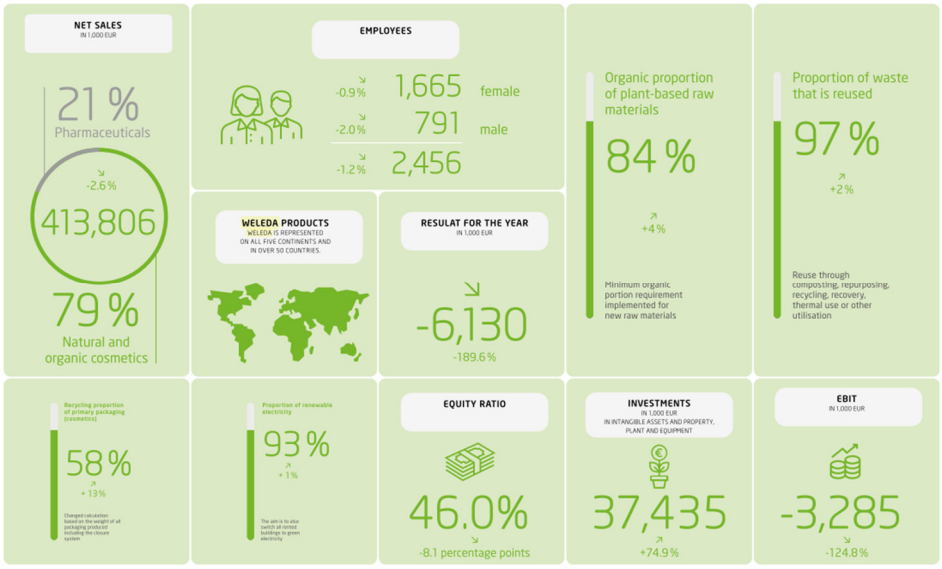

Figure 10. Selected key figures of Business Year 2022 (WELEDA GROUP and WELEDA AG, 2023).

By indicating that 97% of all waste undergoes recycling of various forms, Weleda's reporting highlights two key aspects: firstly, it underscores waste as a focal point of metric, and secondly, it signifies that the metric serves as a comprehensive summary of all waste management activities, encompassing reuse, recovery, and energy retrieval through incineration. Notably, the inclusion of an additional category labeled "other utilization" adds further nuance to the reporting, albeit in a less specific manner. Thus, Weleda's example demonstrates that even companies esteemed for their sustainability practices utilize metrics akin to the CMU in their public disclosures.

The metric and what stands behind seeming to be an accepted measure, CMU could offer a compelling approach for our case, if we can address the procurement challenge. Subsequently, we shifted our focus to addressing the second question:

1. Can we adapt this approach to measure circularity at the company or even product level, focusing on the outflow of materials?

2. Is it feasible to modify the factor to incorporate both the procurement and waste decision phases, thereby encompassing the system boundaries pertinent to our case study?

Further Development of the Circular Material Use Rate

To reflect the procurement decision, we modified the model such that it shows in- and outflows of material as displayed in the equation below:

$$CMU\ Extended = \frac{Circular\ Inflow + Circular\ Outflow}{2 * Total\ Material\ Flow}$$

Definition Outflow

The current definition of outflow in the established CMU equation on country level would be, that everything which is declared as waste and goes into recycling thereafter is counted in. Recycling is defined by the European Union as

"Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into

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materials that are to be used as fuels or for backfilling operations." (Official Journal of the European Union, 2008)

Two points stand out: First, incineration with energy recovery common also in Switzerland is not considered (contrary to the Weleda example) and secondly, as previously mentioned, outflow is the moment when waste is declared officially as waste. That means, any kind of recovery / looping on a company level is not considered in the current CMU.

Definition Inflow

We suggest extending the current model for SWISS by this variable to allow the presence of circular procurement decisions. The circular inflow is expressed by using the quote of recycled material in a purchased product (see example below).

Total Material Flow

The total material as denominator is consistent with the original definition; however, due to the inclusion of the inflow variable, it is necessary to multiply the denominator by 2 to ensure the equal weight of both variables (normalization).

Testing

Having extended the equation to include the procurement decision, we tested it on the example of cups as displayed below:

Cup Type	Recycling Rate Purchasing (inflov	Circular Use of Material (outlfow)	Overall Material Use	CMU
Plastic Glass Large (LX31.020)	0	0	100	0%
r-PET Cup	50	0	100	25%
		Nothing recycled		
Example 2				
Plastic Glass Large (LX31.020)	0	80	100	40%
r-PET Cup	50	80	100	65%
	Contains 50% recycled material	80% will be recycled		

Figure 11. Application of CMU Extended to the cup case.

Two examples are given in the table above:
Circular Inflow (procurement): 100 kg cups contain 50kg recycling material
Circular Outflow: 80 kg of the 100kg are recycled after being declared as waste
Total Material: 2*100kg
CMU Extended: (50kg + 80kg) / 2*100kg = 0.65

The example illustrates that the devised CMU Extended formula effectively incorporates the procurement decision while retaining the benefits associated with the original CMU approach. Below, we present a table outlining the advantages and disadvantages, now supplemented with new insights stemming from the variation of the equation:

Pro	Contra
Allows quick assessment of circularity within in-house (available) data	Applied only on country level until now
Easy to communicate	Does not explicit reflect loops
Easy to measure	Does not reflect km/weight/CO2
Governance	Does not reflect cost/revenue of action
This type of measures is used by other organizations too (Example: Weleda)	Not industry standard (there is none)
Connects inflow with outflow -> reflects procurement decision	~~*Does not reflect procurement decisions*~~
Provides a good starting point for decision making based on flows that Swiss can control	
Can easily be adapted to more detailed analysis	

Figure 12. CMU-extended pro / contra.

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In italic, additional advantages gained through the extension of the model are highlighted. On the contrary side, we could eliminate one main point, that the approach does not reflect procurement decisions and thus solve a major problem in literature and industry: Finding an indicator which addresses the system boundaries of procurement-to-waste with reasonable effort.

Research Limitations and Next Steps

We propose the utilization of the CMU Extended as an initial framework for measuring circularity within organizations aiming to address the procurement-to-waste boundaries. To address the aforementioned disadvantages, we recommend not further extending the equation but rather integrating additional variables separately and correlating them with the CMU Extended indicator:

1. Introduce a metric demonstrating the economic costs associated with the decision-making process, such as varying procurement costs and disposal costs per material unit (and destination in the case of the airline industry).
2. Contextualize the CMU Extended within the framework of CO2 emissions, focusing on a product or material basis in accordance with current CO2 emissions reporting.
3. Relate the CMU Extended to CO2 emissions resulting from the weight per cup per kilometer flown (only for the case of the aviation industry and in-flight products).

Such comparative analyses, presented perhaps in the form of a matrix, could facilitate informed decision-making at the level of each flight. In the case of the aviation industry, such an approach might result in instances where SWISS selects cups made from less expensive non-recyclable materials for certain destinations where landfill disposal is the predominant outflow. Conversely, for other destinations exhibiting a high recycling rate in the waste stream, SWISS may opt for a more costly alternative. Through this strategy, overall circularity could be enhanced without incurring additional costs or CO2 emissions on the level of km flown per cup, as SWISS optimizes the performance of all flights within the specified categories. Material flow and life cycle assessment (LCA) categories could be incorporated into this matrix where available, potentially integrating them into the existing IT infrastructure. The entire model or matrix may undergo testing with various products and product categories, and subsequently be implemented across the company.

6. Conclusion

The analysis highlights a significant gap in the existing literature, tool availability, and policies regarding circularity metrics within the procurement-to-waste system boundaries, particularly for companies operating as Business-to-Business (B2B) consumers. Even in Parchomenko et al. (2019) comprehensive literature review, no paper addressed these system boundaries and non the procurement phase. On the latter, further exploration identified works such as Bai et al. (2022), which however proved overly complex for practical application, Atkin and Gergin (2015) with a questionnaire-based approach raising credibility concerns, and Sheu et al. (2005), which is suited to a different sector. On the waste management side, more approaches were found, including the Circular Material Use (CMU) methodology (Eurostat, 2018). However, approaches covering the entire procurement-to-waste phase were notably absent.

In seeking a market-based solution, within the project, we analyzed ten tools marketed as circular economy measurement tools. Only four passed the initial screening, as the others were either unavailable, not in English, or had restricted access, reflecting a broader issue of functionality. Of the four remaining tools, three addressed the product level but were ultimately ruled out due to either high costs, data availability issues and/or complexity, making them unsuitable for practical implementation. Regulatory approaches also fell short in helping with SWISS pursuit to find a way to measure circularity. Interviews with authorities in County Zürich and the Swiss government revealed no plans for regulations specifically targeting circularity metrics on product level. Likewise, EU legislation does not yet focus on circularity metrics at the product level.

Despite these challenges, this research took a positive turn when we re-evaluated available literature and tools, revisiting the Circular Material Use (CMU) Index (Eurostat, 2018), widely recognized and used in Switzerland, the EU, and associated countries. Originally designed to

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measure circular material use as a percentage of total material consumption, we hypothesized that this index could be adapted to the company and product levels. Initial results confirmed this hypothesis, showing that the CMU is indeed adaptable beyond its original scope.

Building on these findings, we refined the CMU to include the procurement variable, resulting in the development of the CMU Extended formula: (Circular Inflow + Circular Outflow) / (2 * Total Material Use). This enhanced equation provides a more comprehensive view by incorporating both circular inflow (procurement) and circular outflow (waste treatment) in relation to total material use. Our successful testing of the CMU Extended in the context of the case study validated its effectiveness as a robust metric for evaluating circularity, offering valuable insights into procurement-waste management decisions at the product level with on company level available data.

For future research, we propose the testing of the hypothesis that the newly developed approach will not only enable SWISS International Air Lines Ltd. to measure circularity effectively but will also be applicable to a diverse range of enterprises, including large, small, and medium-sized businesses, irrespective of their industry. Based on our findings and further informal testing, we assume this may be the case. We hypothesize that by utilizing the CMU Extended formula, organizations regardless industry and size can effectively assess their circularity performance across their business-to-business (B2B) operations, encompassing the entire procurement-to-waste spectrum, and leveraging existing internal data. This approach may eliminate for any type of company the need for additional software solutions or external data collection, offering a straightforward, adaptable and easily comprehensible metric for stakeholders.

We also recommend further investigation into organizational decision-making processes when employing the CMU Extended formula in conjunction with other tools, such as life cycle assessment (LCA) data, key performance indicators (KPIs), and economic metrics. Specifically, it would be valuable to observe how companies incorporate multiple decision-making factors on-site and whether the introduction of a circular economy (CE) metric—providing a quantifiable measure of CE efforts—truly affects their strategic decisions. Will it really shift priorities in the light of newly available data?

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