

A Procedure to Support Systematic Selection of Leading Indicators for Sustainability Performance Measurement of Circular Economy Initiatives

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Supplementary materials

Appendix A

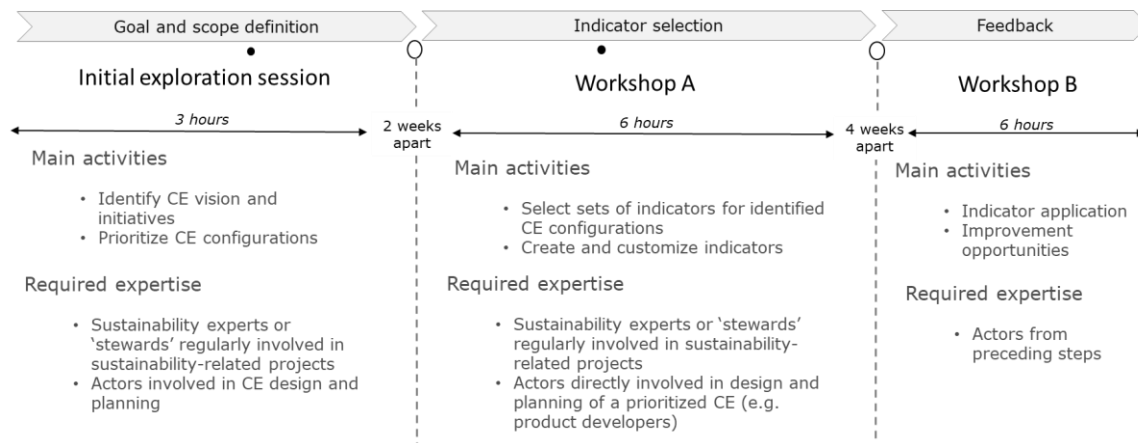


Figure A1. Case study set up: main activities and actors involved.

Appendix B—Application of Indicator Selection Procedure in Company 2 and Company 3

Company 2

Company 2 can be classified as a large enterprise with more than 10000 employees worldwide. The company specializes in the manufacture and service of heavy industrial equipment, thus operating in 'business-to-business' environments. As a large enterprise, the company has a dedicated sustainability department that specializes in corporate reporting, environmental assessments, standardization, company audits and health, and safety aspects. The company has obtained certifications according to ISO 14401, ISO 9001, and compliance with UN Global Compact, ILO guidelines. Furthermore, the standard practice for product development and operations is based on life cycle thinking and UN sustainable development goals. The company has a very strong focus on sustainability with a commitment to continuous development and improvement, including efficient use of resources and the provision of eco-efficient solutions to customers, offering a safe and interesting work environment, creating value for the stakeholders and society. The company provides a wide range of products and solutions, offering preventive, predictive and corrective maintenance, repair and upgrade service, renting program for parts, reverse engineering solutions, among others. Nevertheless, the company is developing new solutions, many of which have a departure point in CE thinking.

Three company representatives participated throughout the engagement workshops: a CSR and HSE specialist, a head of corporate sustainability department and an environmental specialist. During the initial exploration session, the participants raised concerns over single-use packaging, which was used to pack the parts for transportation between the company's own facilities. To address the issue, a CE solution is considered where the packaging would be taken back for internal reuse. The packaging unit consisted of a wooden pallet and a plastic material to wrap the parts in. The main objective of the strategy was to fight waste generation and reduce material consumption, simultaneously being a 'low hanging fruit' solution in

terms of implementation. Thus, the CE solution ‘circular packaging’ was prioritized as a scope to select indicators for in Step 1 (Figure B1). During workshop A (Step 2), the CE configuration for the CE scope consisted of the CE strategies ‘reuse’, ‘reduce impact in manufacturing’ and a BP ‘production and operations’. After applying the corresponding filters in the database, the initial indicator set comprised 34 indicators. Using the guiding questions, the consolidated set of indicators was narrowed down to 13, yet again discussed one-by-one in the group and following the removal of similar indicators, the final set resulted in 8 indicators, of which 3 were customized to better reflect the particularity of the process. The social dimension indicators were opted out by the participants, and the final set comprised of 5 indicators covering economic aspects, 2 covering environmental and 1 being ‘neutral’, i.e., serving the role of a supportive indicator defined by the participants, rather than being a key indicator as others. The participants commented on the final set rather being the one ‘expected’, in that, economic aspects largely dominated by cost aspects (e.g., transport costs). On the other hand, all the participants agreed that “... indicators gave a good overview of data that needs to be collected and registered in their internal database to provide a better overview of the conditions of the current system as well as to introduce and monitor improvements”. Nonetheless, the team also discussed that the scope of circular initiative could be expanded not only to account for take-back routes but also to consider other types of materials for packaging. During Workshop B, the discussion revolved around the data collection process, with participants raising concerns over data acquisition taking into consideration the fact that the transportation aspects of part exchange between factories were being managed by a third-party logistics provider.

Steps	Activities	Outcomes									
Step 1. Goal and Scope definition	<i>Initial exploration session</i> - Defining circular scenarios and circular configurations	Circular scenario: “Circular packaging”									
		Circular configuration: a combination of CE strategy ‘reuse’, CE strategy ‘reduce impact in manufacturing’ and a BP ‘production and operations’.									
‘Leading performance indicator database’ > 270 sustainability-related performance indicators											
Step 2. Indicator selection	<i>Workshop A</i> - Initial indicator set - Refining the initial indicator set	- 34 indicators - 8 indicators: social aspects were opted out									
Step 3: Final indicator set	<i>Workshop A</i> - Composing the final indicator set	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="3" style="text-align: center;">8 indicators</th> </tr> <tr> <th style="width: 33%;">Environmental</th> <th style="width: 33%;">Social</th> <th style="width: 33%;">Economic</th> </tr> </thead> <tbody> <tr> <td> <ul style="list-style-type: none"> • Amount and material type of packaging* • Stock keeping unit* </td> <td style="text-align: center;">- not selected</td> <td> <ul style="list-style-type: none"> • Packaging costs • Total holding cost • Cost of inspection* • Transportation cost from collectors to facility • Cost of disposal of solid waste • Fuel consumption in reverse supply chain </td> </tr> </tbody> </table> <p>* customized indicators</p>	8 indicators			Environmental	Social	Economic	<ul style="list-style-type: none"> • Amount and material type of packaging* • Stock keeping unit* 	- not selected	<ul style="list-style-type: none"> • Packaging costs • Total holding cost • Cost of inspection* • Transportation cost from collectors to facility • Cost of disposal of solid waste • Fuel consumption in reverse supply chain
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Figure B1. Overview of activities and outcomes of the procedure application in Company 2.

The main feedback from Company 2 was to specify who the users of the procedure and indicators should be. Another feedback concerned the importance of having a circular scenario ready to be used as an input for the selection process, in that "... to make filtering meaningful and to be able further narrow down the set of selected indicators". The participants also commented on the 'broadness' of the sustainability screening framework in comparison to, for instance, life cycle assessment methodology, in that, the screening tool accounts for different business processes and allows them to select indicators that cover all three dimensions of sustainability. All the participants acknowledged that because of the comprehensiveness of the database, "it would interesting to have a set of key indicators for each project we initiate and run. Having that, we can collect data that can be used across projects, but also to monitor changes and introduce improvements over time". Furthermore, it was emphasized that some indicators can be used to improve existing performance measurement systems, for instance, the environmental management system because the majority of the company's factories are certified according to ISO 14001. In addition, the participants raised questions about the 'risks' associated with operating with a 'limited' number of indicators or contradictory indicators, commenting about the importance of having boundaries during the indicator evaluation process, so not to select too many, too few or too 'biased' indicators by trying to avoid trade-offs.

Company 3

Company 3 can be classified as a large enterprise with around 500 employees worldwide. The company belongs to the textile sector and specializes in the design of "high-quality textile" for various applications, such as upholsteries, rugs, curtains, home accessories. The customers belong to public, private and commercial segments. The company has a long history of design based on sustainability and life cycle thinking principles. A large number of fabrics are certified according to EU Ecolabel certifications, the headquarter office is certified according to ISO 9001 and ISO 14001 and is operating on 'green' electricity. The company is also working with a circular economy and UN sustainable development goals.

Several company representatives participated throughout the engagement workshops: a sustainability manager, a product developer, a head of design management and a director of a subsidiary company. During the initial exploration session, the participants highlighted the corporate strong focus on resource efficiency and the reduction of environmental impacts. One particular objective set to become a zero-waste company, therefore circular economy was in focus. Indeed, the participants confirmed that there are several circular initiatives the company is looking at with a greater focus on products and reduction of their virgin material input. One of the CE solutions proposed was to focus on pre-user recycling of leftovers in manufacturing to be used as a feedstock for the product. Minimization of raw material input and transportation, reduction of chemical and water usage and manufacturing waste were the intentions behind the solution. Consequently, the CE scope (Step 1) was based on the CE solution 'circular manufacturing', comprised of the CE configuration 'reduce impact in raw material and sourcing' and 'reduce impact in manufacturing'. To this selection, a business process 'production and operation' has been added. This configuration was based on the logic that the closed-loop recycling is to be done internally, i.e., leftovers from the production of a product A would be recycled into product B. Proceeding with the selected CE configuration, the initial set comprised of 46 indicators (Figure B2). The participants then screened the indicators by answering the set of guiding questions (sub-steps under Step 2), selecting 15 indicators to proceed with. Following the discussion in the team, this set has further been refined to contain 7 indicators, 5 of which covered environmental aspects, such as energy, scrap amount, water consumption, while 2 economic indicators addressed the costs of processing and of transport. Likewise, most social and economic indicators were opted out. For instance, the participants stated that for social and ethical issues "... we feel this indicator (the indicator 'Suppliers that have been screened against labor practices criteria') is not for each product, but a core value and basic compliance to become one of our suppliers. This is part

of our code of conduct, a strategic decision". Similarly, most of the economic indicators were de-selected, with participants commenting: "We had a hard time understanding the economic indicators as they are out of our expertise, so we got support from a colleague". For the selected indicator 'Specific solid waste mass', measuring manufacturing scrap amount, which is to be recycled into the product B, the participants stated that it was an interesting indicator, which would allow the company to understand the potential of the CE solution. In order to calculate the indicator, the suppliers had to be contacted to provide the data. During the selection process, the discussion around the indicator 'Product Weight Reduction Ratio' concerned to what extent can the company reduce the amount of a material in the product. As the product designer stated: "... [this indicator] could be taken into account in new product development, but quality [of the current product] is our first priority".

After the final set of indicators was obtained, the participants suggested selecting indicators for another CE initiative that the company was interested in operationalizing. Following the discussion about the zero-waste ambition, another CE solution, B, focused on the leasing model that would allow in retrieving the used product for closed-loop recycling at the end of life. For this solution, two CE configurations were defined. CE configuration A, comprising a business model perspective focused on leasing (circular configuration A under scenario B in Figure B2), and CE configuration B comprising a CE strategy 'reduce impact in raw material and sourcing' and 'recycling' looked from the end of life operations perspective. The initial sets of indicators consisted of 20 indicators for configuration A and 18 indicators for configuration B. It has to be noted that the final indicator set was not selected as this CE initiative was in its 'raw' stage with no details around it. However, the outcome of the screening step allowed us to identify the key aspects that have to be considered when developing the initiative further.

Steps	Activities	Outcomes											
Step 1. Goal and Scope definition	<i>Initial exploration session</i> - Defining circular scenarios and circular configurations	Circular scenario A: "Circular manufacturing"		Circular scenario B: "Leasing and recycling scheme"									
		Circular configuration A: a combination of CE strategy 'reduce impact in raw material and sourcing', CE strategy 'reduce impact in manufacturing', and a BP 'product development'	Circular configuration A: a combination of CE strategy 'rethink business model' and a BP 'business model'	Circular configuration B: a combination of CE strategy 'reduce impact in raw material and sourcing' and 'recycling' and a BP 'end of life operations'									
'Leading performance indicator database' > 270 sustainability-related performance indicators													
Step 2. Indicator selection	<i>Workshop A</i> - Initial indicator set - Refining the initial indicator set	- 46 indicators - 7 indicators	- 20 indicators - no final set	- 18 indicators - no final set									
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Figure B2. Overview of activities and outcomes of the procedure application in Company 3.

The feedback (Workshop B) included comments on indicator usefulness as well as on improvements the excel database and procedure may need. Firstly, the participants commented on the linkage between the indicator screening process and the competences of the team that screens it. Accurately, the business process view requires a lot of communication between the different departments to understand the ‘value’ each selected indicator can bring. As one participant specifically commented: “looking at the final set, as a product developer, I am already aware of some key performance indicators ... and could easily use them without the need for the database. On the other hand, some indicators (e.g., energy-related) can be very difficult to analyze and interpret due to the lack of [my] knowledge of that area”. Furthermore, the participants suggested to consider “what competencies the user should have in order to work in the database” and “when is it appropriate to use the tool, i.e., in what part of the decision-making process does it bring the most value to”. This comment is supported by a statement from the team that “... there is [in the industrial world] a lot of confusion with the circular economy as a concept, therefore, the practitioners need more help in understanding what circular opportunities are there for a specific sector or specific company, ... and then to focus on how to create a ‘good’ impact”. Thirdly, to aid the decision-making process, “... it is necessary to visualize the common thread between the selected set of indicators and corporate objectives and goals...”.

Appendix C

Table C1. Consolidation of key discussion points at the case companies.

Company 1			
“The process of indicator selection should start with the aligning or defining the organizational sustainability vision and objectives. It is very important to make a company aware of why selection of indicators is important and what indicators can be used for. It is important to connect the final set of indicators to the corporate values”.	“Make the tool user-friendly for those, who may not have an expertise in sustainability assessments, but have passion to work with indicators to make good”.. “.. the procedure requires the facilitator with sustainability expertise to facilitate the team and aid the interpretation of each indicator” (<i>authors: thus making it challenging for (smaller) companies to use the database and select the ‘right’ indicators in a time-efficient manner</i>).	“It is good to have gradual steps in the database (different excel sheets) to obtain the initial set of indicators and then to select the most suitable indicators for the final set using the guiding questions. It gives a good overview of the whole process of the indicator selection, as well as tracks what indicators have been removed from the final set, but initially comprised the initial set”.	“.. (guiding questions) they are very helpful, because they “force” the user to think of each single indicator and reflect on it. Also, the indicator review step helped to understand the internal processes and what matters the most and what are the gaps”.
Company 2			
Important to have a circular scenario ready to be used as an input for the selection process, “... to make filtering meaningful and to be able further narrow down the set of selected indicators”.	‘Broadness’ of the indicators in comparison to, for instance, life cycle assessment methodology, in that, the screening tool accounts for different business processes and allows to select indicators that cover all three dimensions of sustainability.	“Some indicators can be used to improve existing performance measurement systems, for instance, the environmental management system, because the majority of the company’s factories are certified according to ISO 14001”.	Importance of having boundaries during the indicator evaluation process, “so not to select too many, too few or too ‘biased’ indicators by trying to avoid trade-offs” and that “there might be ‘risks’ associated with operating with a ‘limited’ number of indicators or contradictory indicators”.
Company 3			
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