How circular economy strategies could be considered in Life Cycle Sustainability Assessment of products - conclusions from a literature review

Till M. Bachmann, **Isadora Hackenhaar***, Sophie Huysveld, Rafael Horn, Florian Gehring, Jo Dewulf, Martin Charter

*STEN group, Ghent University

Horizon 2020 European Union Funding for Research & Innovation

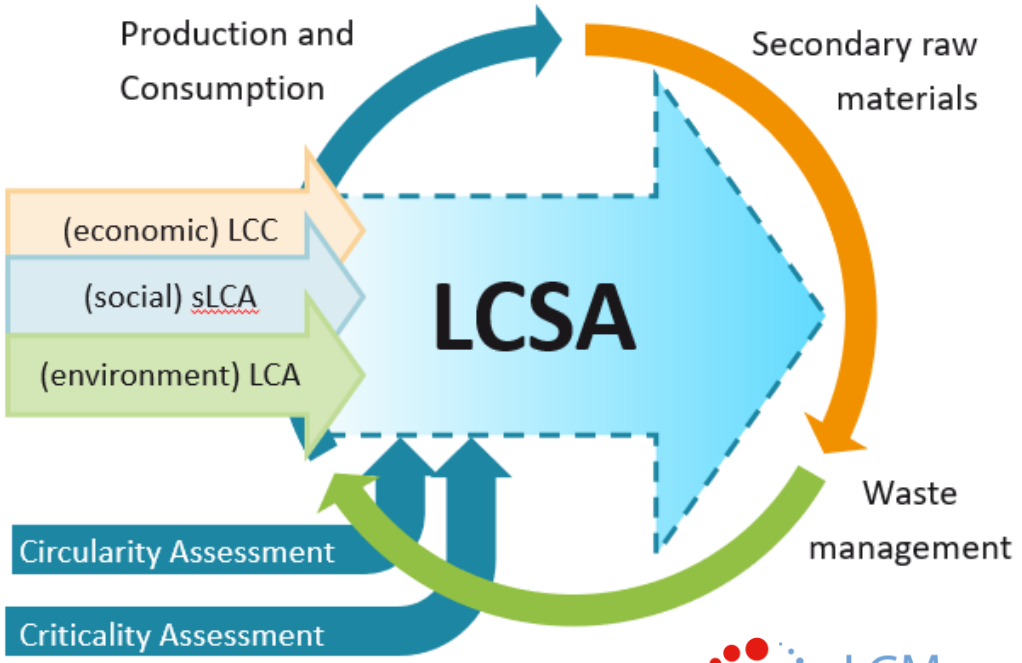
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 958231

Introduction - ORIENTING

Operational Life Cycle Sustainability Assessment Methodology Supporting Decisions Towards a **Circular Economy** (COMPETITIVE, LOW CARBON AND CIRCULAR INDUSTRIES - Materials life cycle sustainability analysis)

Objectives

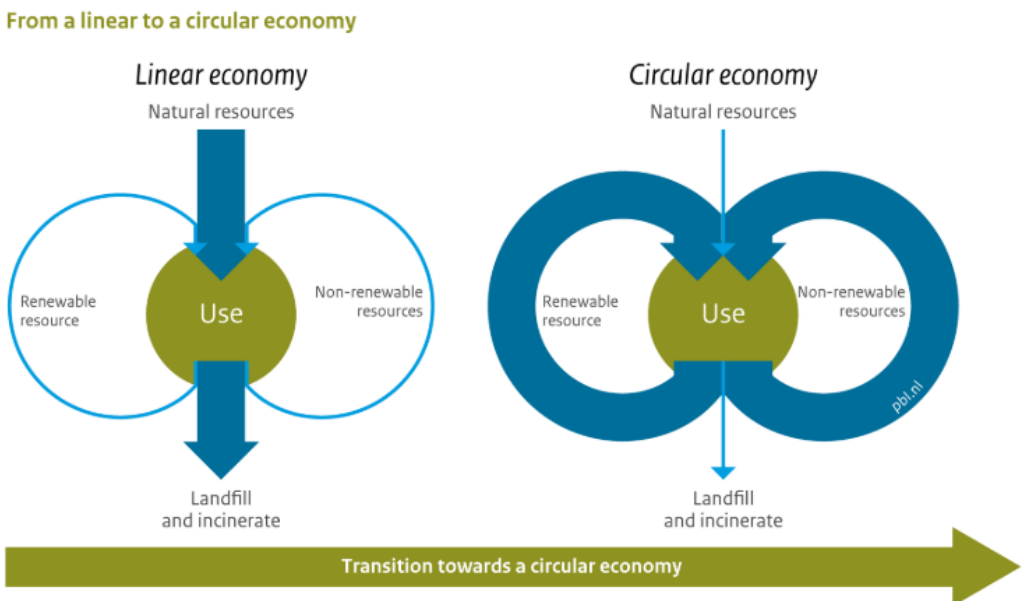
1. To develop a robust and operational methodology for the **life cycle sustainability assessment** (LCSA) of products.
2. To offer a **practical approach** that considers environmental, social and economic impacts in an **integrated** way, as well as material criticality and **product circularity**.
3. To build on **existing initiatives** (e.g., PEF, UNEP/SETAC LCSA) and contribute to a future ***Product Sustainability Footprint (PSF)***

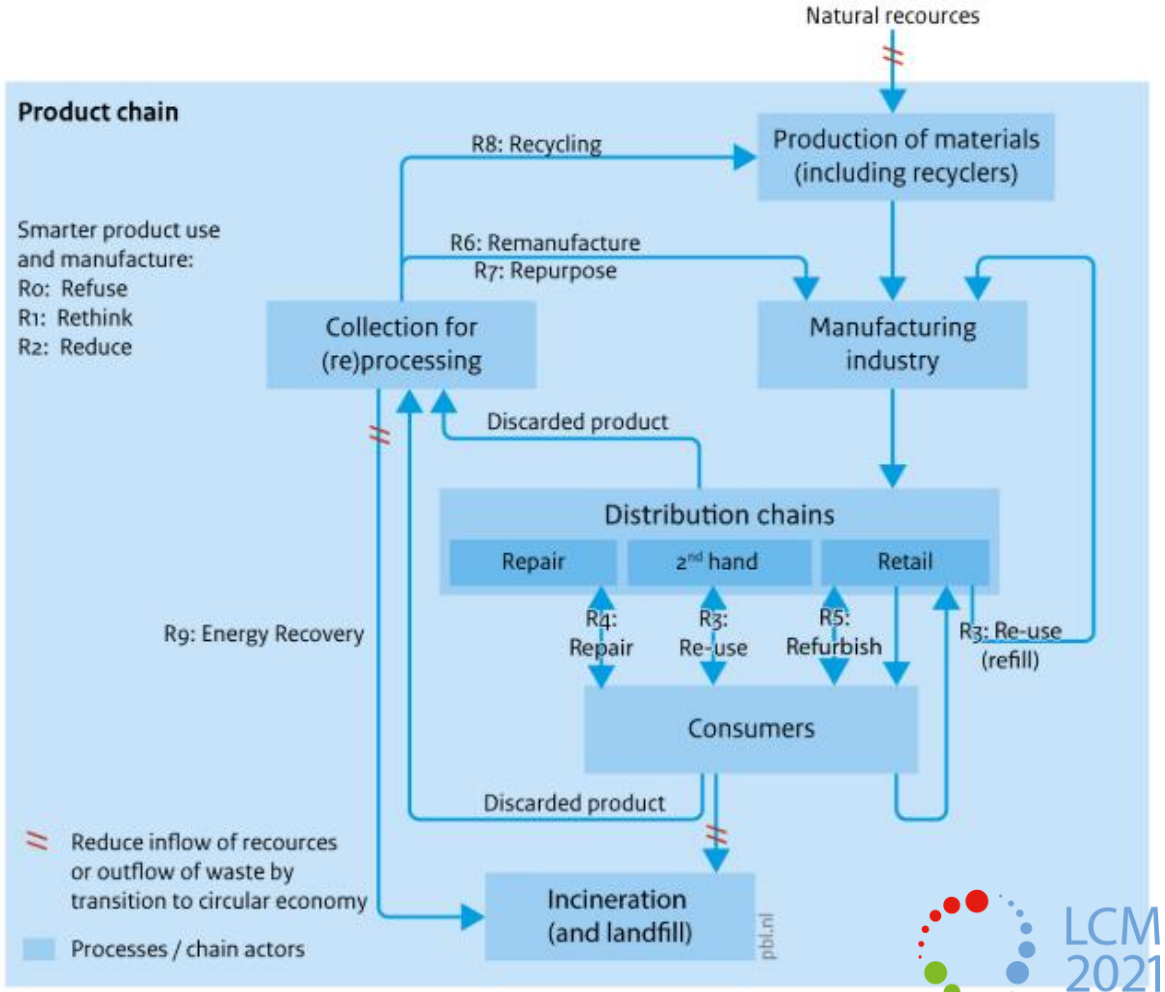


LCM 2021

Introduction - Circular Economy & LCSA

Concept → Practice

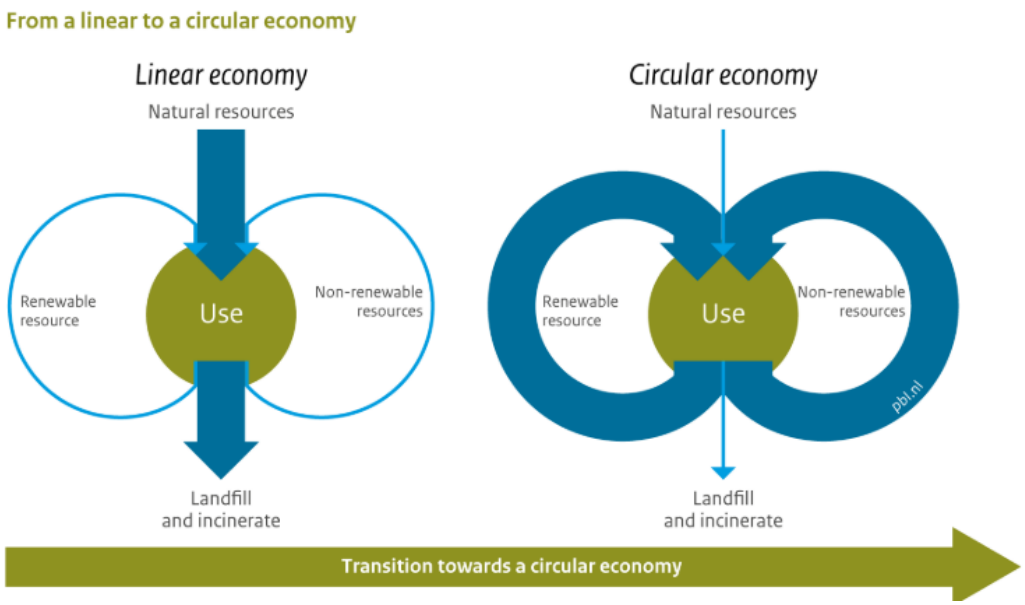


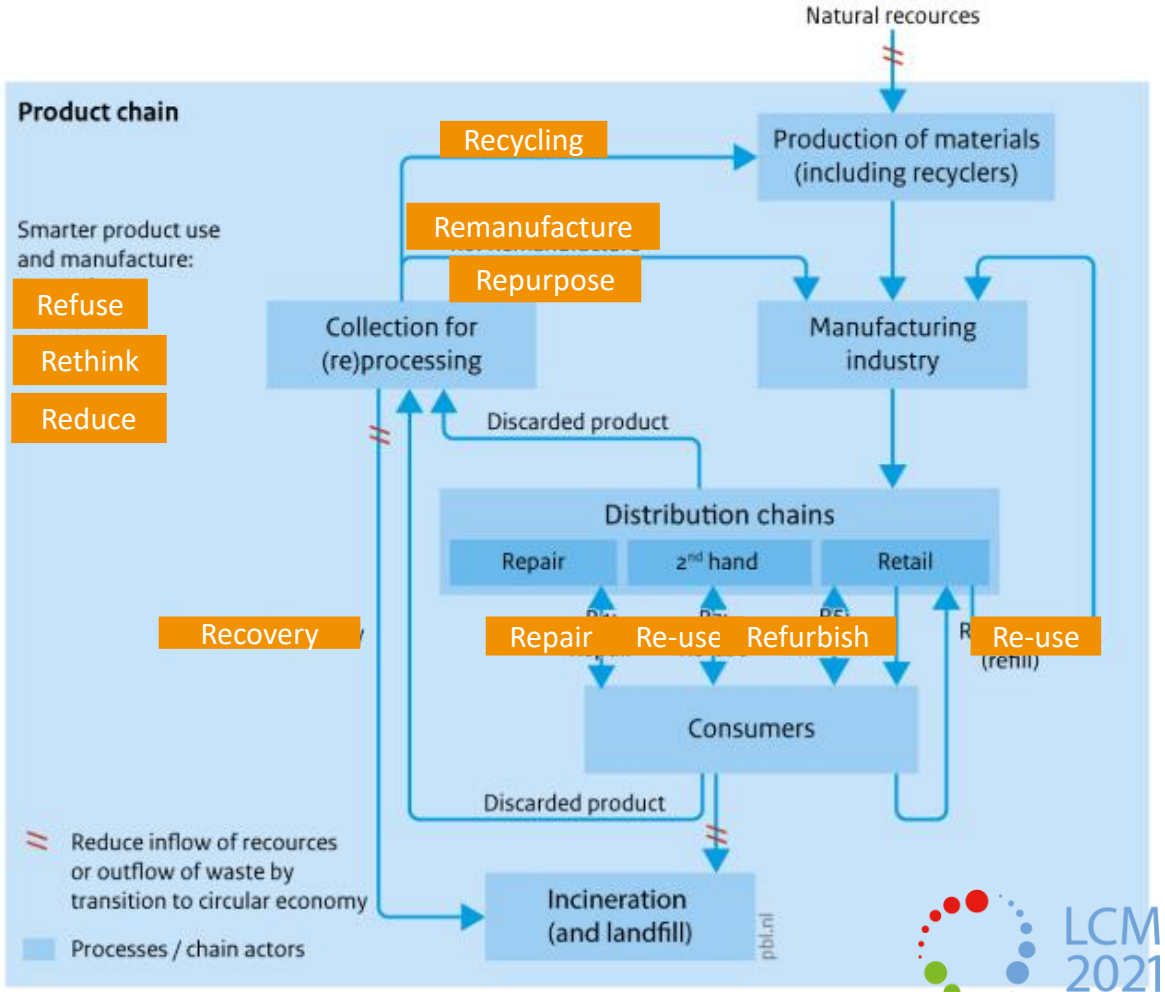


Source of figures:[1]

Introduction - Circular Economy & LCSA

Concept → Practice





Source of figures:[1]

Circular ? = Sustainable

Introduction - Goal and Scope

Goals of research in WP1

1) to identify relevant approaches, concepts, methods and indicators related to circularity of products to be integrated into ORIENTING's LCSA framework;

2) to conduct a critical evaluation of a selection of the most promising indicators for use in LCSA on the basis of the criteria developed in T1.1 in ORIENTING;

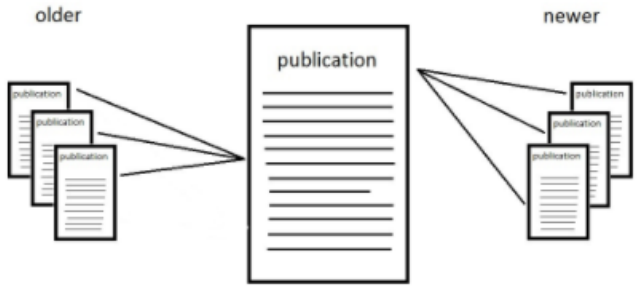
3) and create recommendations for methodological developments in the project.

Scope

ORIENTING = LCSA of products (including components and material)

"CE at a product level focuses on maximising the value in products, components and materials for as long as possible in economic and social systems".

Research methodology - Literature review & selection of indicators



Cited by or citing Moraga et al. (2019) [2] and Saidani et al. (20199 [3]

Methods/Indicators to be evaluated must*:

- quantitatively evaluate products (micro level);
- workable for any/several product groups/sectors (not only one kind of product) and for any geography;
- three or more "R" strategies.

*according to method's transparency

Research methodology - Literature review & selection of indicators

Cited

25

+

Citing

93

(until 05/03/21)

=

Selected

9

1. Product-Level Circularity Metric (PLCM, C-metric) [4,5]
2. Material Circularity Indicator (MCI) [6]
3. Longevity indicator [7]
4. Circular Footprint Formula (CFF) [8]
5. Product Circularity Indicator (PCI) [9]
6. Circularity index Circ(T) [10]
7. Value-based resource efficiency (VRE) method [11]
8. Sustainable Circular Index (SCI) [12]
9. In-use occupation ratio (UOR) and final retention in society (FRS) [13]

Research methodology - Criteria-based evaluation

Robust

Accepted

Credible

Easy

Relevant

One structure for all ORIENTING topics, adapted to circularity research:

1 Stakeholder acceptance, credibility and suitability	**3 Transparency**
1.1 Acceptance by Policy-makers	3.1 Traceability of the modelling data and model used
1.2 Acceptance by Industry	3.2 Transparency of documentation
1.3 Acceptance by Academia	3.3 Reproducibility
1.4 Acceptance by Civil society	**4 Scientific robustness**
1,5 Credibility among stakeholders	4.1 Peer-reviewed or verification from third party
2 Applicability / Complexity	4.2 State-of-the-art
2.1 Technical feasibility	4.3 Quality of the modelling data
2.2 Data availability and accessibility	4.4 Description of the uncertainties
2.2.a for primary data (activity data)	**5 Completeness**
2.2.b for secondary data (activity data)	5,2 Ability to be applied to specific contexts
2.3 Data-intensity requirement	5,3 Ability to be applied in unspecific contexts (generalization)
	6 Compatibility with life-cycle approach
	6.1.b Takes into account the life cycle thinking/approach

Based on [14], [15], among others, adapted within the ORIENTING project

Results of the evaluation

#	Criterion	PLCM	MCI	Longevity	CFF	PCI	Circ(T)	VRE	SCI	UOR/FRS
III	Source	(Linder et al., 2017) [4] [5]	(EMF & Granta, 2019) [6]	(Franklin-Johnson et al., 2016) [7]	(Zampori et al., 2019) [8]	(Bracquené et al., 2020) [9]	(Pauliuk et al., 2017) [10]	(Di Maio et al., 2017) [11]	(Azevedo et al, 2017) [12]	(Moraga et al., 2021) [13]
XVII	Final score	A-	A	A-	A-	A-	B	B	B+	A-
1	Stakeholder acceptance, credibility and suitability	C	A+	B	B	B+	C+	D+	B	B+
2	Applicability / Complexity	A+	B	A	A	B	C+	A	B	B+
3	Transparency	A+	A	B	A	A	B+	C+	A	A+
4	Scientific robustness	A+	B	B	B+	B	B+	B	B+	A
5	Completeness	A+	A+	B+	B	A+	B+	A+	B+	C+
6	Compatibility with life-cycle approach	C+	A+	A+	A+	A+	C+	B+	C+	A+

Results of the evaluation

The highest score (A) has resulted for the MCI by EMF, followed by PCI, PLCM, Longevity, the CFF and UOR/FRS (all A-) while the lowest score (B) was obtained for the three methods Circ(T), VRE and SCI.

#	Criterion	PLCM	MCI	Longevity	CFF	PCI	Circ(T)	VRE	SCI	UOR/FRS
III	Source	(Linder et al., 2017) [4] [5]	EMF & Granta, 2019) [6]	Franklin- ohnson et al., 2016) [7]	(Zampori et al., 2019) [8]	(Bracquené et al., 2020) [9]	Pauliuk et al., 2017) [10]	(Di Maio et al., 2017) [11]	(Azevedo et al, 2017) [12]	Moraga et ., 2021) [3]
XVII	Final score	A-	A	A-	A-	A-	B	B	B+	A-
1	Stakeholder acceptance, credibility and suitability	C	A+	B	B	B+	C+	D+	B	B+
2	Applicability / Complexity	A+	B	A	A	B	C+	A	B	B+
3	Transparency	A+	A	B	A	A	B+	C+	A	A+
4	Scientific robustness	A+	B	B	B+	B	B+	B	B+	A
5	Completeness	A+	A+	B+	B	A+	B+	A+	B+	C+
6	Compatibility with life-cycle approach	C+	A+	A+	A+	A+	C+	B+	C+	A+

Results of the evaluation

The highest score (A) has resulted for the MCI by EMF, followed by PCI, PLCM, Longevity, the CFF and UOR/FRS (all A-) while the lowest score (B) was obtained for the three methods Circ(T), VRE and SCI.

#	Criterion	PLCM	MCI	Longevity	CFF	PCI	Circ(T)	VRE	SCI	UOR/FRS
III	Source	(Linder et al., 2017) [4] [5]	EMF & Granta, 2019) [6]	Franklin-ohnson et al., 2016) [7]	(Zampori et al., 2019) [8]	(Bracquené et al., 2020) [9]	Pauliuk et al., 2017) [10]	(Di Maio et al., 2017) [11]	(Azevedo et al, 2017) [12]	Moraga et ., 2021) [3]
XVII	Final score	A-	A	A-	A-	A-	B	B	B+	A-
1	Stakeholder acceptance, credibility and suitability	C	A+	B	B	B+	C+	D+	B	B+
2	Applicability / Complexity	A+	B	A	A	B	C+	A	B	B+
3	Transparency	A+	A	B	A	A	B+	C+	A	A+
4	Scientific robustness	A+	B	B	B+	B	B+	B	B+	A
5	Completeness	A+	A+	B+	B	A+	B+	A+	B+	C+
6	Compatibility with life-cycle approach	C+	A+	A+	A+	A+	C+	B+	C+	A+

Accounting for CE beyond dedicated indicators

Circular “R” strategies at life-cycle stages:

- 3 main LC stages: design; use phase, and end-of-life;
- most of the indicators measure the implementation of strategies at the end of life of the products and are mainly focused on recycling;
- doing without indicators = LCSA as a means to assess the different CE actions through scenario analysis;

Accounting for CE beyond dedicated indicators

Defining the functional unit and/or reference flow:

- the lifetime of the product needs to be properly addressed;
- two different situations:
  - Strategies that involve maintaining the same functions = FU; longer lifetime;
  - Strategies that involve changes in the product/material functions = system expansion or another allocation approach.

Conclusions

Most circularity measurements are at company level (i.e. not at product level).

Adapting the **functional unit and/or proper definition of the reference flow.**

Distinguishing **life cycle stages** according to relevant steps from a CE point of view (such that LCIA indicators could largely be sufficient to show the impact of different CE measures):

- mining/resource extraction stage,
- product development/design stage,
- manufacturing;
- transportation/distribution processes;
- use phase;
- maintenance, repair and refurbishment;
- and, End-of-Life;

CE indicators that measure the improvements in absolute terms (i.e., changes in terms of sustainability impacts) and not in relative terms (e.g. share of recycled material);
Note that CE is a means while sustainability indicators immediately relate to ends

If CE indicators are presented alongside with the sustainability indicators, trade-offs with sustainability indicators (i.e., environmental, social, economic) might occur.

The integration of indicators into the ORIENTING framework will be the subject of WP2.

Next steps

1. Publication of the related report and others in ORIENTING-WP1;

2. Further investigation of the CE indicators identified here and its application in LCSA; + of the methods identified through experts interview (e.g. WBSCD);

3. Further investigation of scenario analysis and functional unit/reference flow/system expansion adaptation in the context of the ORIENTING project;

4. Provide guidance on the integration of CE metrics into the LCSA framework.

THANK YOU FOR YOUR ATTENTION!

How circular economy strategies could be considered in Life Cycle Sustainability Assessment of products - conclusions from a literature review

Isadora Hackenhaar
PhD candidate - UGhent

E isadora.correahackenhaar@ugent.be
Isadora Hackenhaar
RG Isadora-Hackenhaar

ORIENTING

W https://orienting.eu/
OrientingEU
OrientingEU

Subscribe to the newsletter!

Horizon 2020 European Union Funding for Research & Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 958231

References

1. Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring innovation in the product chain - Policy report. *PBL Netherlands Environmental Assessment Agency*, *2544*, 42.
2. Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., de Meester, S., & Dewulf, J. (2019). Circular economy indicators: What do they measure? *Resources, Conservation and Recycling*, *146*, 452–461. https://doi.org/https://doi.org/10.1016/j.resconrec.2019.03.045
3. Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A taxonomy of circular economy indicators. *Journal of Cleaner Production*, *207*, 542–559. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.10.014
4. Linder, M., Boyer, R. H. W., Dahllöf, L., Vanacore, E., & Hunka, A. (2020). Product-level inherent circularity and its relationship to environmental impact. *Journal of Cleaner Production*, *260*, 121096. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121096
5. Linder, M., Sarasini, S., & van Loon, P. (2017). A Metric for Quantifying Product-Level Circularity. *Journal of Industrial Ecology*, *21*(3), 545–558. https://doi.org/https://doi.org/10.1111/jiec.12552
6. EMF, & Granta. (2019). *Circularity Indicators - An approach to measuring circularity - Methodology*. https://www.ellenmacarthurfoundation.org/resources/apply/material-circularity-indicator.
7. Franklin-Johnson, E., Figge, F., & Canning, L. (2016). Resource duration as a managerial indicator for Circular Economy performance. *Journal of Cleaner Production*, *133*, 589–598. https://doi.org/10.1016/j.jclepro.2016.05.023

References

8. Zampori, L., & Pant, R. (2019). *Suggestions for updating the Product Environmental Footprint (PEF) method* (Issue EUR 29682 EN, JRC115959). Publications Office of the European Union. https://doi.org/doi:10.2760/424613
9. Bracquené, E., Dewulf, W., & Duflou, J. R. (2020). Measuring the performance of more circular complex product supply chains. *Resources, Conservation and Recycling*, *154*. https://doi.org/10.1016/j.resconrec.2019.104608
10. Pauliuk, S., Kondo, Y., Nakamura, S., & Nakajima, K. (2017). Regional distribution and losses of end-of-life steel throughout multiple product life cycles—Insights from the global multiregional MaTrace model. *Resources, Conservation and Recycling*, *116*, 84–93. https://doi.org/10.1016/j.resconrec.2016.09.029
11. Di Maio, F., Rem, P. C., Baldé, K., & Polder, M. (2017). Measuring resource efficiency and circular economy: A market value approach. *Resources, Conservation and Recycling*, *122*, 163–171. https://doi.org/10.1016/j.resconrec.2017.02.009
12. Azevedo, S. G., Godina, R., & de Oliveira, J. C. M. (2017). Proposal of a Sustainable Circular Index for Manufacturing Companies. *Resources*, *6*(4), 63. https://www.mdpi.com/2079-9276/6/4/63
13. Moraga, G., Huysveld, S., De Meester, S., & Dewulf, J. (2021). Development of circularity indicators based on the in-use occupation of materials. *Journal of Cleaner Production*, *279*. https://doi.org/10.1016/j.jclepro.2020.123889

References

14. EC-JRC. (2010). ILCD Handbook: Framework and requirements for LCIA models and indicators First edition. In *Publications Office of the European Union* (First edit). https://doi.org/10.2788/38719
15. UNEP. (2019a). *Global Guidance on Environmental Life Cycle Impact Assessment Indicators – Volume 2*.