Are Existing Circular Economy Indicators Adequate to Capture the Role Biobased Products Can Play in the Circular Economy?

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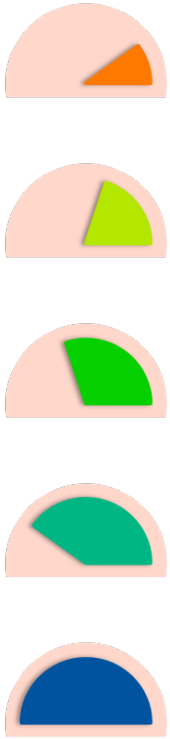
Outline



- Defining circular economy principles
- Review of existing CE indicators
- Identification of gaps
- Status of CE indicator development for biobased products
- Circularity assessment framework

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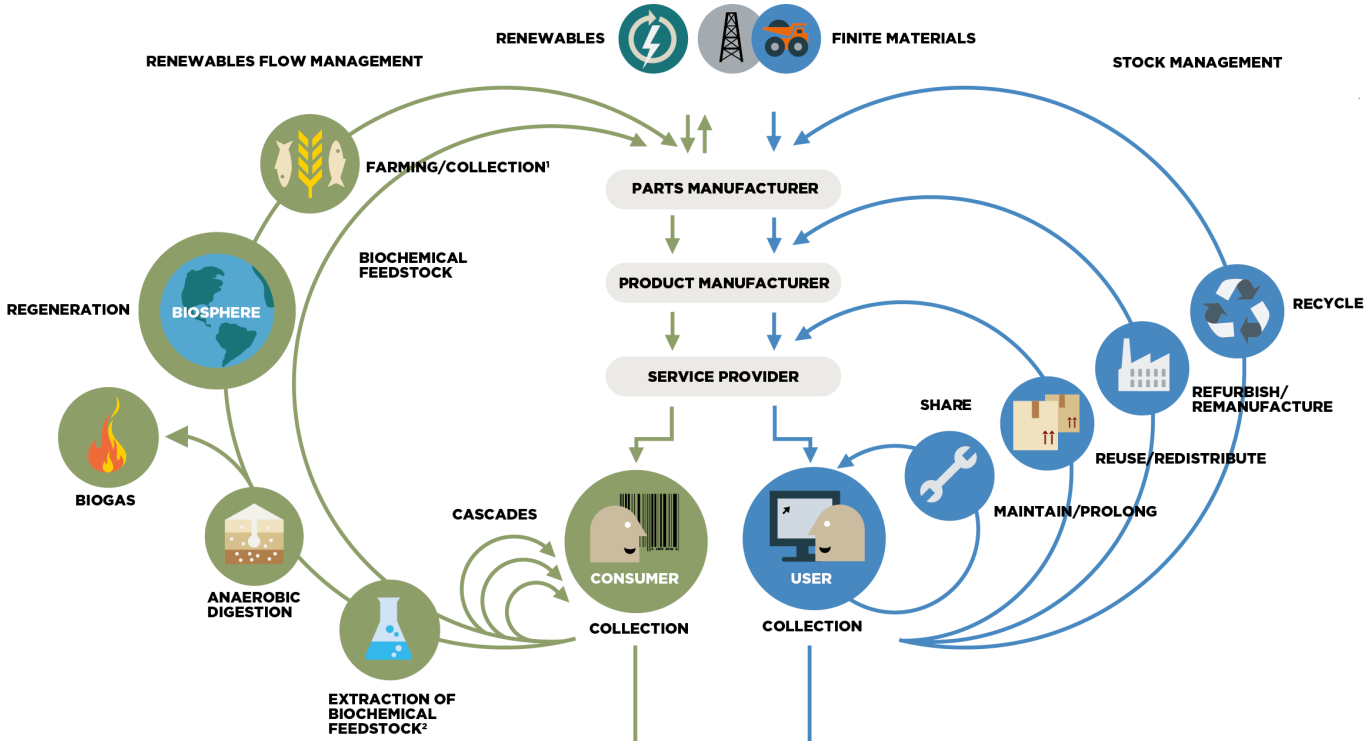
Defining circular economy principles



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough, Cradle to Cradle (C2C)

ELLEN MACARTHUR FOUNDATION

Defining circular economy principles

Natasha Sena - claspvisuals.com

Vural Gursel, I. et al. Sustainability 2022, 14, 12780. https://doi.org/10.3390/su141912780

For assessing intrinsic circularity, we need indicators on:

- Share of renewable resources
- Resource use efficiency (include use of residues)
- Degree of regeneration
- Degree of recirculation
- Utility (long & high quality)

For assessing the impact of the transition, we need indicators on:

- Risk of accumulation of hazardous substances
- Effect on environmental protection
- Effect on economic viability
- Effect on social equity

Identification of CE metrics

Criteria:

- Micro/product level
- Scientific + grey literature
- Quantitative metrics
- Linked to CE strategies

List of 25 Reviewed CE indicators	Abbreviation	Reference
Circular Economy Toolkit	CET	(Evans and Bocken, 2013)
Recycling indicator set	-	(Nelen et al., 2014)
Reuse Potential Indicator	RPI	(Park and Chertow, 2014)
Circular Economy Index	CEI	(Di Maio and Rem, 2015)
Material Circularity Indicator	MCI	(EMF, 2015)
Longevity Indicator	LI	(Franklin-Johnson et al., 2016)
Circularity calculator	-	(IDEAL&COExplore, 2016)
Eco-efficient Value Ratio	EVR	(Scheepens et al., 2016)
Recycling Indices	RI	(van Schaik and Reuter, 2016)
Global Resource Indicator	GRI	(Adibi et al., 2017)
Sustainable Circular Index	SCI	(Azevedo et al., 2017)
Circular Economy Indicator Prototype	CEIP	(Cayzer et al., 2017)
Circularity Index	CI	(Cullen, 2017)
Value-based Resource Efficiency	VRE	(Di Maio et al., 2017)
Circular Economy Performance Indicator	CPI	(Huysman et al., 2017)
Product-Level Circularity Metric	PLCM	(Linder et al., 2017)
Recycling Desirability Index	RDI	(Mohamed Sultan et al., 2017)
Circ(T)	-	(Pauliuk et al., 2017)
Combination Matrix	CM	(Figge et al., 2018)
Circularity Measurement Toolkit	CMT	(Garza-Reyes et al., 2019)
Circular economy benefit indicators	RBR, RCBR	(Huysveld et al., 2019)
Circularity of material quality	QC	(Steinmann et al., 2019)
Product Recovery Multi-Criteria Decision Tool	PR-MCDT	(Alamerew et al., 2020)
Product Circularity Indicator	PCI	(Bracquené et al., 2020)
In-use occupation indicator	-	(Moraga et al., 2020)

Analysis of CE metrics

Indicator	CE Requirements								
	1. Share of renewable resources	2. Resource use efficiency	3. Degree of regeneration	4. Degree of recirculation	5. Utility	6. Hazardous substances	7. Effect on environment	8. Effect on economy	9. Effect on society
Circular Economy Toolkit		*x*	*p*	*x*	*x*	*p*	*p*	*p*	
Recycling indicator set		*p*		*x*	*p*		*x*	*x*	
Reuse Potential Indicator				*x*				*p*	
Circular Economy Index				*x*	*p*			*x*	
Material Circularity Indicator		*x*		*x*	*x*				
Longevity Indicator				*x*	*x*				
Circularity calculator		*x*		*x*				*x*	
Eco-efficient Value Ratio							*x*	*x*	
Recycling Indices				*x*					
Global Resource Indicator		*x*							
Sustainable Circular Index		*p*		*x*	*x*		*x*	*x*	*x*
Circular Economy Indicator Prototype		*x*		*x*	*x*				
Circularity Index				*x*			*p*		
Value-based Resource Efficiency		*x*						*x*	
Circular Economy Performance Indicator				*x*	*x*		*x*		
Product-Level Circularity Metric		*p*		*x*				*x*	
Recycling Desirability Index		*p*		*x*			*p*		
Circ(T)		*x*		*x*	*x*				
Combination Matrix				*x*	*x*				
Circularity Measurement Toolkit	*p*	*x*		*x*	*x*		*p*	*p*	*p*
Circular economy benefit indicators				*x*	*p*		*x*		
Circularity of material quality				*x*	*x*		*p*		
Product Recovery Multi-Criteria Decision Tool							*x*	*x*	*x*
Product Circularity Indicator		*x*		*x*	*x*				
In-use occupation indicator		*x*		*x*	*x*				

x = considered, *p* = partially or implicitly considered

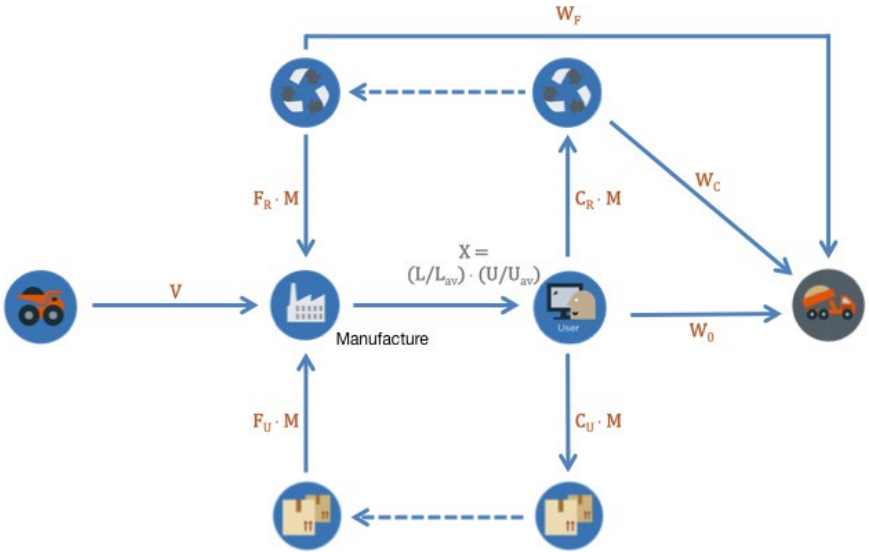
- ✓ Reviewed metrics cover well the prominent CE strategy of Recirculating materials (requirement #4). This concerns how much recycled input is used and/or to what extent a product gets recycled at the end of its life.
- ✓ Resource use efficiency (requirement #2) is also well covered and concerns reducing material losses and wastes, improving utilization of resources and accordingly reducing input of primary/virgin resources.
- X Yet, most of the indicators fail to integrate scarcity and criticality of the resources used. The ones that do use market prices as proxy.
- X All the CE metrics focus exclusively on the technical cycle. They fail in providing measure of the share of renewable resources (requirement #1) and degree of regeneration (requirement #3) and cascading use of biomass (within requirement #5).

- ✓ Regarding utility (requirement #5) – aspects of product lifetime and usage intensity are covered; this allows analyzing the contribution of circular practices to longevity or intensity or to both.
- X Yet, quality is another aspect of utility (requirement #5) that deserves further attention. This is captured in very few where quality of the recycled material and potential quality losses preventing closed loop recycling are considered.
- X The risk of accumulation of hazardous substances in closing the loops is not taken into consideration in the developed indicators (requirement #6).
- ✓ It is seen that several metrics considered the environmental or economic consequences, or a combination of both.
- X Yet, social dimension is much less covered due to difficulty in quantitative assessment.

Resource use efficiency

Biomass Utilization Efficiency (BUE)
Iffland et al. (2015) – molar mass ratio

Bioresource Utilization Index (Bu_{ind})
Vamza et al. (2021) – dry weight ratio



Material Circularity Indicator, MCI

EMF (2019)
Razza et al. (2020)

include biobased content as non-virgin input
account composting as contributing to recycling

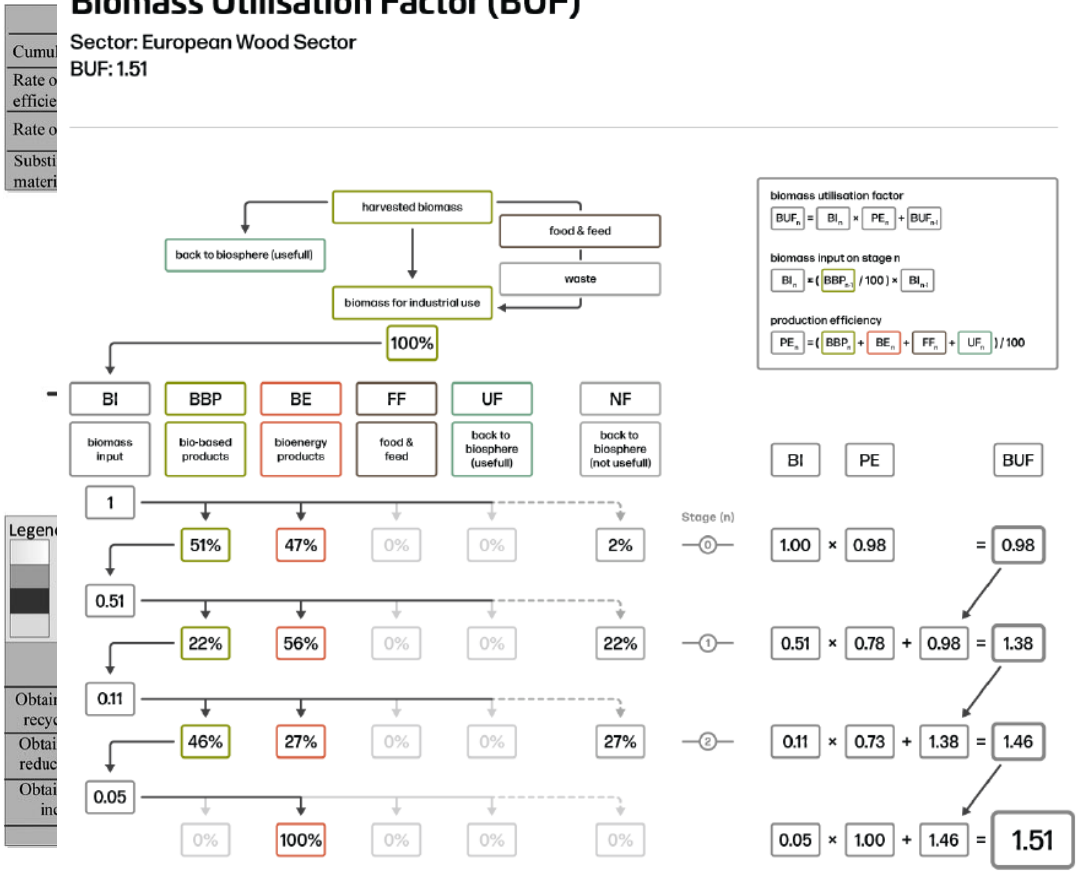
$$V = M(1 - F_R - F_U - F_S)$$

$$W_0 = M(1 - C_R - C_U - C_O - C_E)$$

Cascading use

Cascade use indicators
Hildebrandt et al. (2017)

Biomass Utilization Factor (BUF)
vom Berg et al. (2022)



Set of indicators

Hybridised sustainability indicators
Lokesh et al. (2020)

Circularity indicators
Ladu and Morone (2021)

Razza et al. (2020)

Circularity indicator	Unit
Presence of hazardous chemicals	-
Min. renewable content	%
Material circularity index	Adimentional
Waste intensity	Kg waste/useful products
Disposal instructions	Yes / no
Energy intensity	MJ/ useful products
Renewable energy	%

Hybridised indicators

Presence of hazardous chemicals
Feedstock intensity
Waste factor
Process material circularity
Renewability
Energy intensity

$$FI = \frac{M_{raw.mat}}{M_{main.prod} + M_{co.prod}}$$

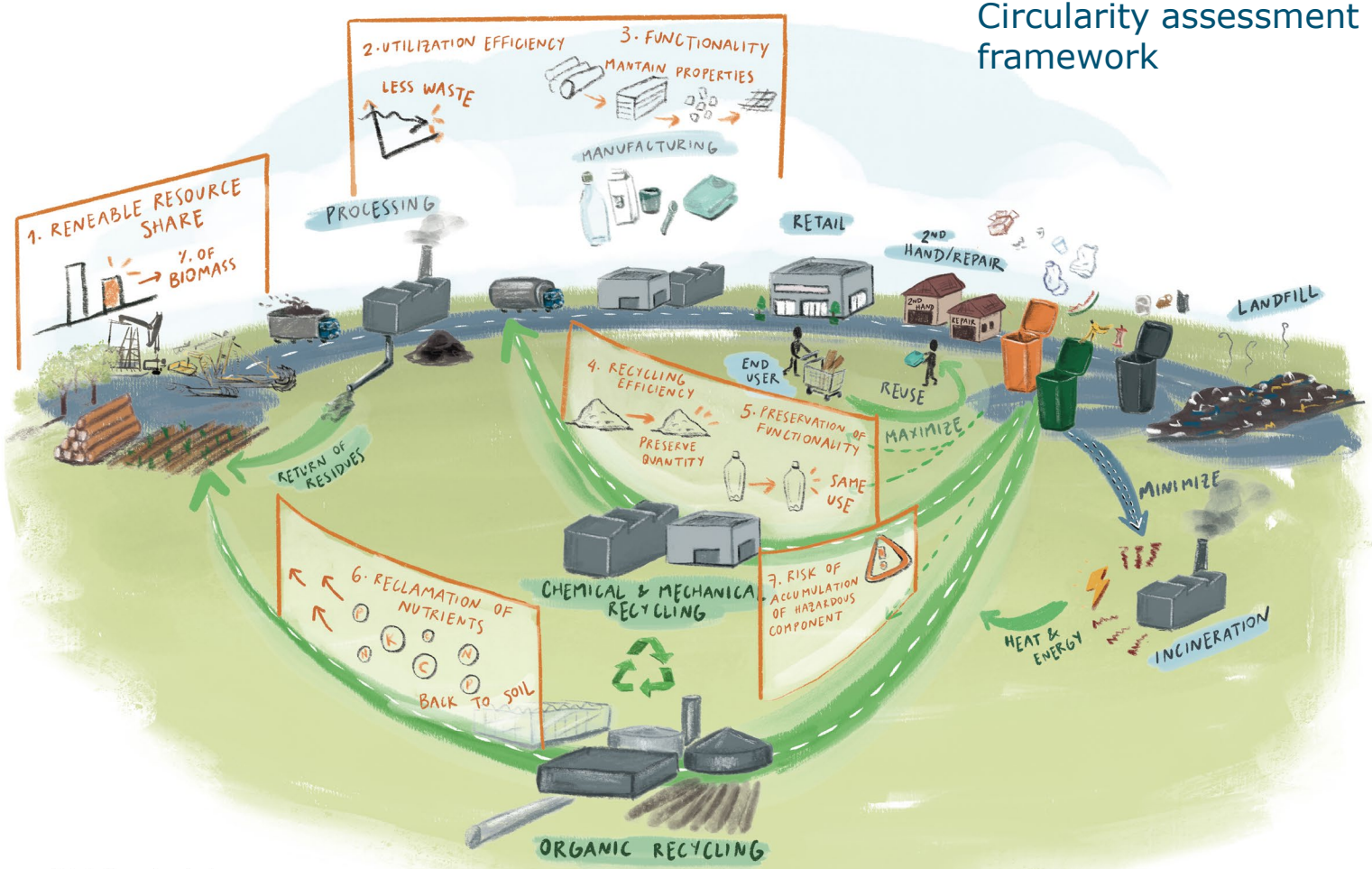
$$WF = \frac{M_{TotW}}{M_{Prod} + M_{co.prod}}$$

$$PMC = \frac{\sum_{i=1}^{n} \left(\frac{M_{rec.Pro.aux}}{M_{Pro.aux}} \right)}{n} \times 100$$

$$EI = \frac{E_{FosD} + E_{RenD} - E_{IntD}}{M_{Prod} + M_{Co.prod}}$$

- With set of indicators rather than composite aggregated indices.
- Each aspect of circular economy can be expressed independently to facilitate a clearer understanding of their complementarities, and possible trade-offs.
- Using a set of indicators is promoted in the CE monitoring systems on macro scale such as the one proposed by the EC.
- Results in an indicator framework which is defined to entail a collection of indicators that provide measurement for each of the circularity aspects and provides altogether a comprehensive picture of circular economy

Circularity assessment framework



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Complement these circularity indicators with existing life cycle sustainability assessment methods to avoid burden shifting

Ability to assess the circularity of biobased products will be crucial to support industry and policy makers in setting suitable circular economy targets

Challenges

* *Cascading mechanisms are currently not accommodated*
* *Desired recycling infrastructure is not in place*
* *Quality needs to be stimulated rather than quantity alone*

Thank you for your attention! Questions?

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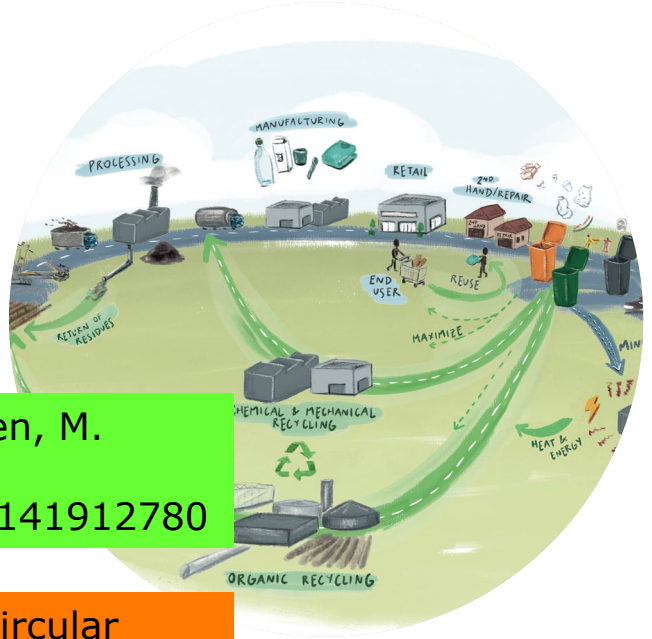

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Vural Gursel, I.; Elbersen, B.; Meesters, K.P.H. Monitoring circular biobased economy – Systematic review of circularity indicators at the micro level. Resources, Conservation and Recycling 2023, forthcoming.

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