An overview of Circular Economy paradigm in the cosmetic sector

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Agenda

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- Research context
- Literature review
- Research Objective
- Circular Economy Performance Assessment methodology
- Application context
- Application example
- Conclusion and future research

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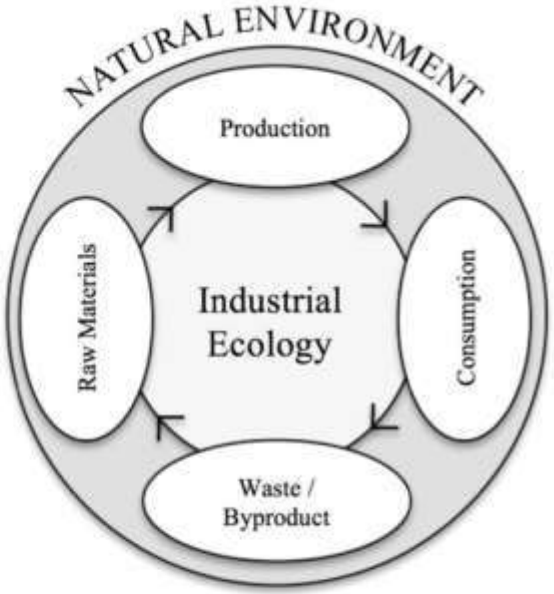
Research context: Industrial Ecology



Industrial Ecology represents the ***study of the flows of materials and energy within industrial activities****, the* ***effects*** *related to the use of these flows on the environment and the economic, political, regulatory and social influences on the flow, use and transformation of the resources themselves.*

Key Points:

- Biological analogy
- Systemic approach
- Key role of technological change
- Focus on industrial systems
- Dematerialization and eco-efficiency

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Research context: Circular Economy

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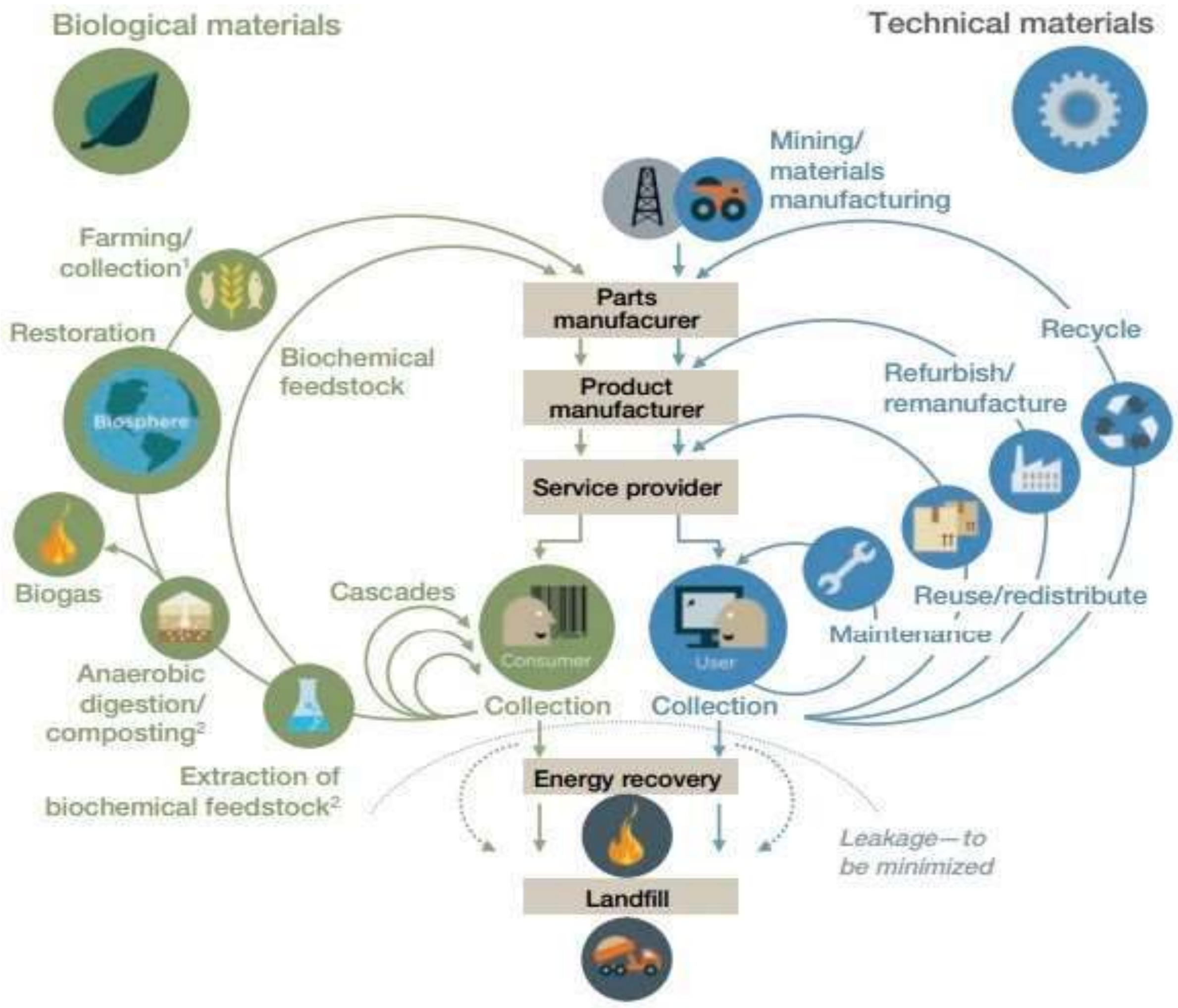

The Circular Economy, according to the definition given by ***Ellen MacArthur Foundation****, "is a generic term for defining an economy that is restorative and regenerative by design, and which aims to keep* ***products, components and material*** *at their highest utility and value at all times, distinguishing between* ***technical and biological cycles****"*

Pillars:

- Design out waste
- Building resilience through diversity
- Rely on energy from renewable sources
- Think in system
- Waste is food

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Literature review

- Databases: Google Scholar, Scopus, Science Direct
- Time horizon: none
- 45 articles selected

Available circularity performance assessment methods can be classified in 8 groups, basing on their focus:

1. DEA/Input-Output methods
2. DfX guidelines
3. LCA/LCI/LCIA
4. Multicriteria approaches/Fuzzy methods
5. Energy/emergy/exergy measurement approaches
6. Simulation/DES
7. MFA/MFCA
8. Others

Sassanelli, C., Rosa, P., ***Rocca, R.****, & Terzi, S. (2019).* ***Circular economy performance assessment methods: A systematic literature review. Journal of Cleaner Production****, 229, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019*

Literature review

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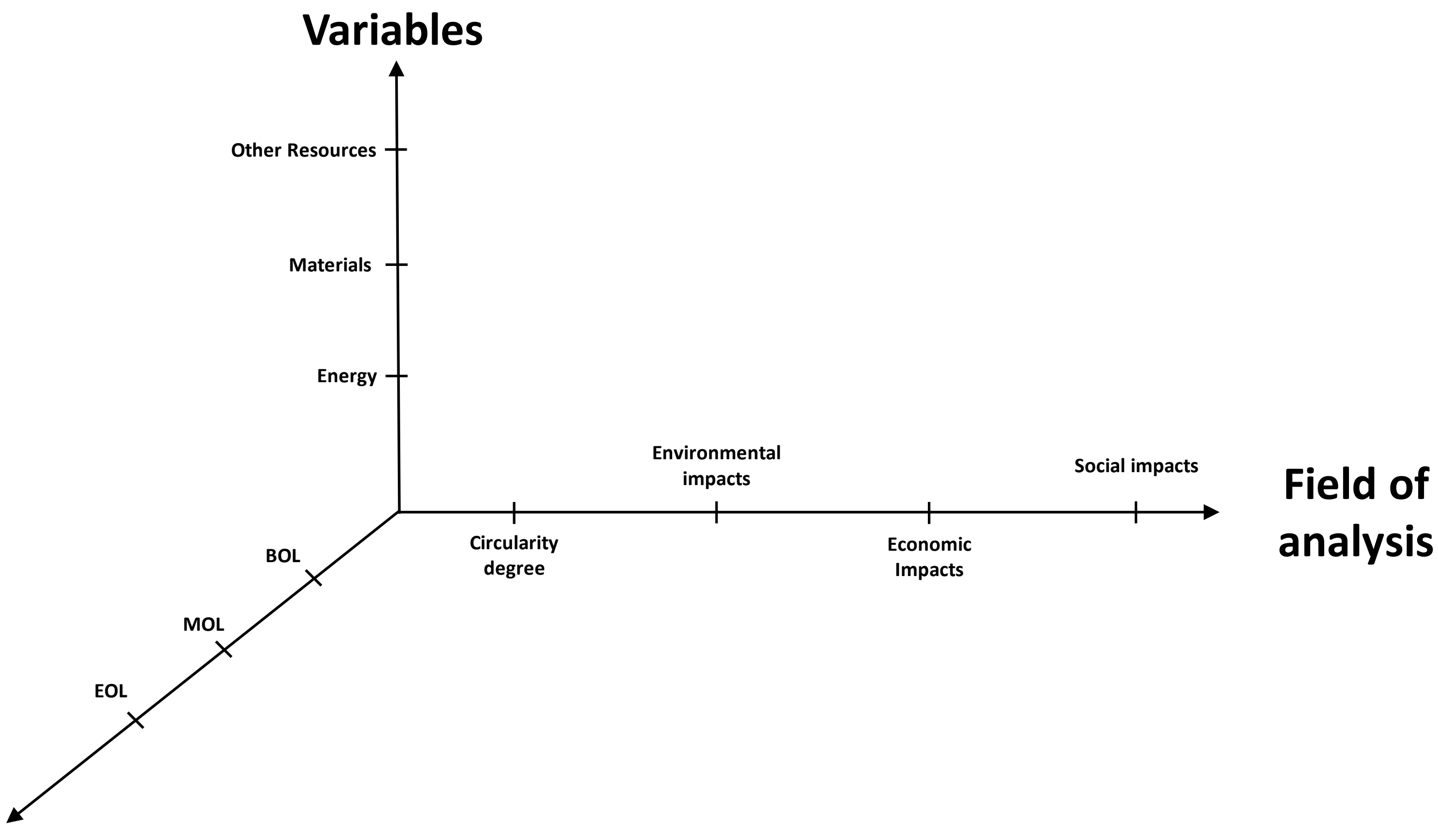
- A positioning framework to map existing circularity performance assessment methods has been identified.
- The positioning framework allowed to better understand what are the main gaps present in literature.

- The positioning framework is composed by three dimensions of analysis:

1. Product Lifecycle Stages (i.e lifecycle phases considered for Circular Economy evaluation)
2. Variables (i.e. types of variables considered and measured)
3. Field of analysis (i.e. adopted perspective of analysis of variables)



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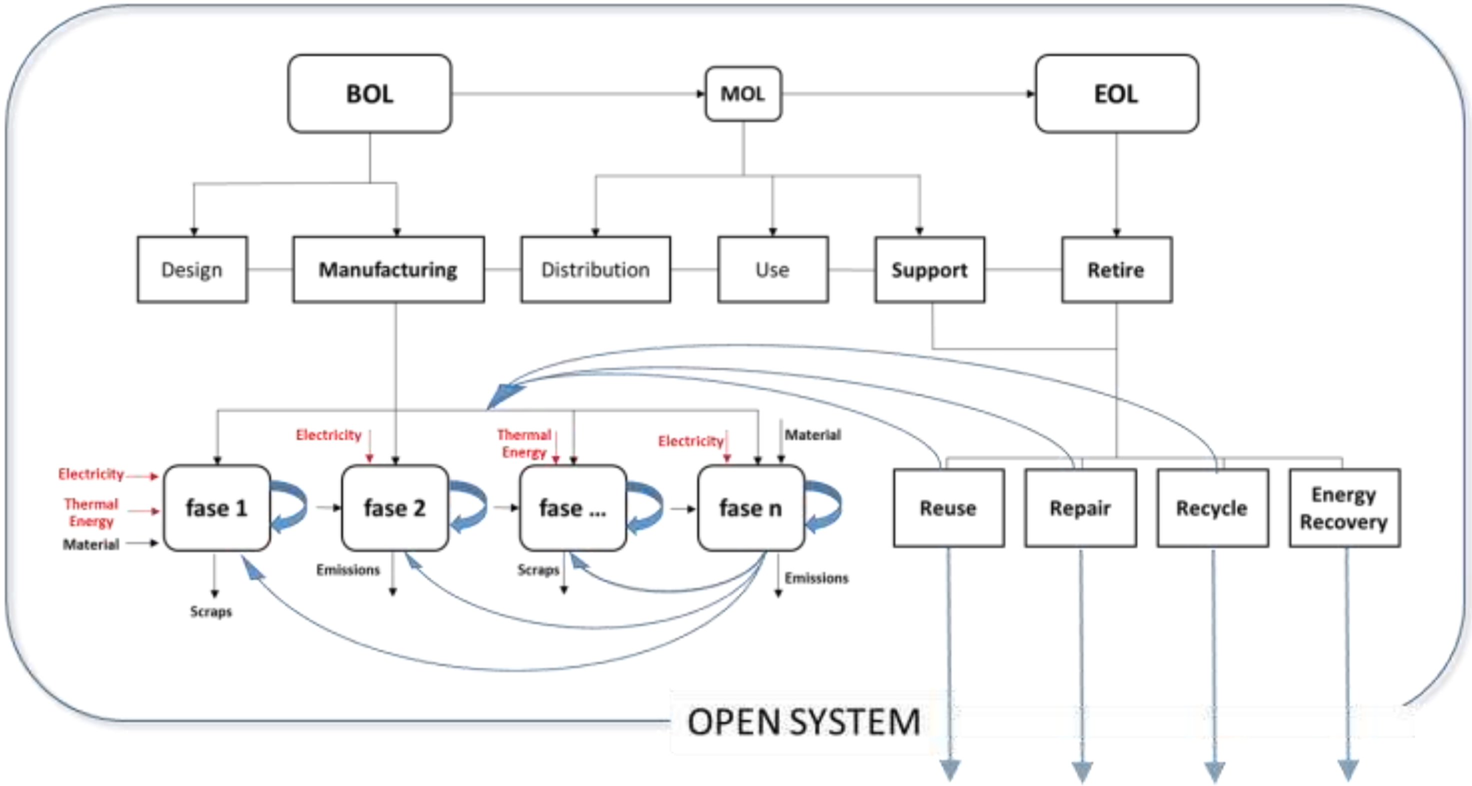
Research Objective



Further researches are needed to **develop methodologies**, based on the proposed framework, also providing a set of **Key Performance Indicators (KPI)** suitable to the assessment of the circularity performance. These KPIs can deal with the **circularity degree** of the resources presents within the product life cycle and can also support the quantification of those that are the **economic and environmental benefits** of the CE. Indeed, the possible application fields are:

1. Regulations and reporting perspective
2. Companies' portfolio circular innovation perspective

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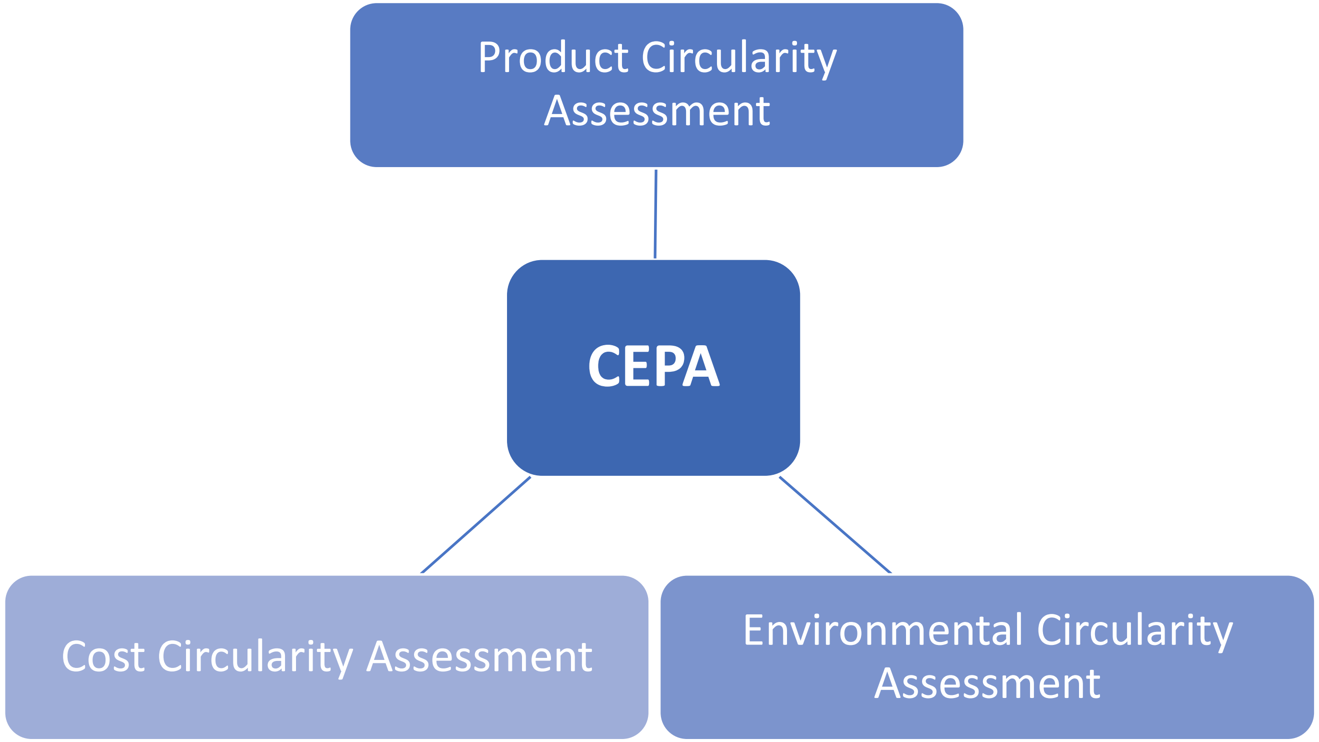
Circular Economy Performance Assessment methodology

The CEPA methodology proposed is composed by three sub-methodologies that are related to three different fields of analysis:

(i) the **Product Circularity Assessment** (PCA), that allows to calculate the circular share of resource flows used during the product life cycle, in order to obtain a set of CE indicators;
(ii) the **Cost Circularity Assessment** (CCA), through which it is possible to analyze and quantify the economic benefits related to CE adoption;
(iii) the **Environmental Circularity Assessment** (ECA). Finally, with this metrics it is possible to evaluate the environmental benefits resulting from CE adoption, quantifying different forms of pollution avoided by triggering resources circularities.



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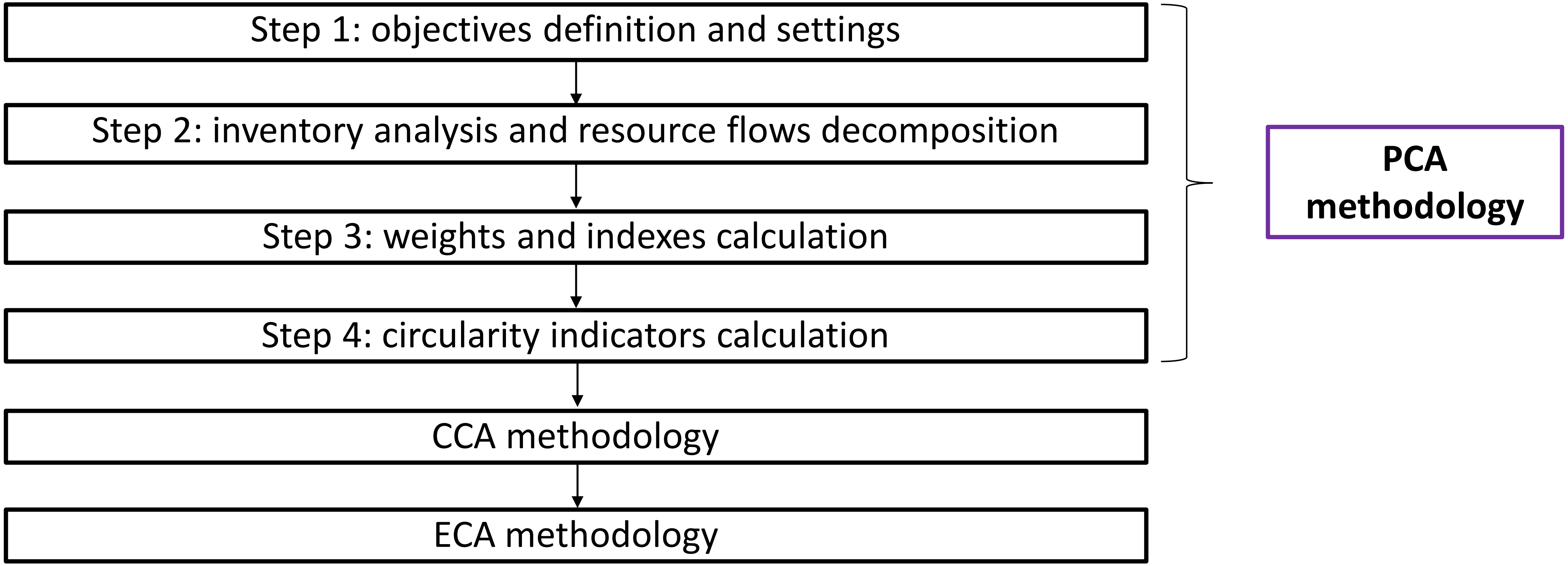
Circular Economy Performance Assessment methodology



- The objective of PCA sub-methodology is to quantify the circularity of each type of resource used within the product life cycle, calculating how much the economic-productive process is circular.
- This quantification has to be done for all the resources and the phases of the system. The term "circularity" refers to those resource flows (i.e. materials, energies and other resources) that fall retroactively in the system (the same or other systems) to be reused.

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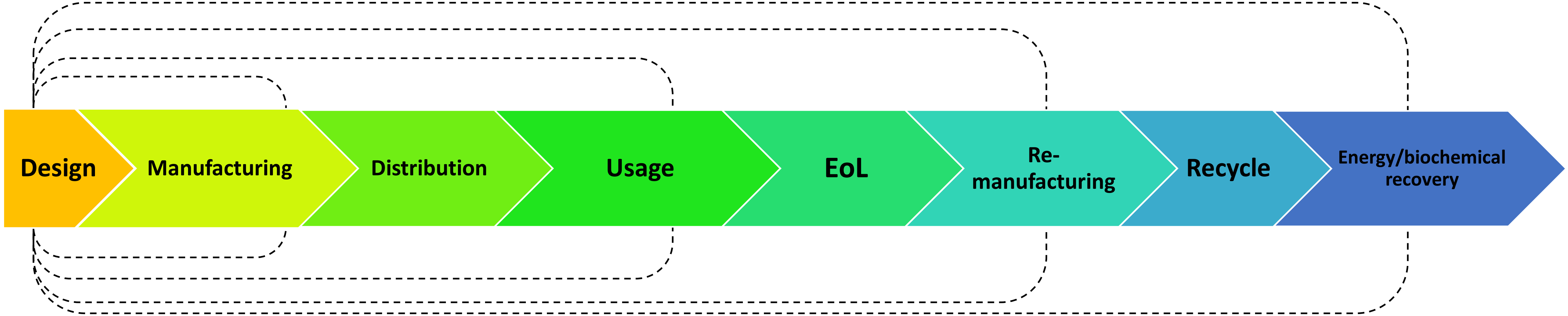
Product Circularity Assessment – step 1

LCA docet

➢ **Objectives definition and settings**

1. System boundaries
2. Functional unit and reference flow
3. Allocation and multi-process cases resolution
4. Data requirements and characteristics
5. Hypothesis
6. Limitations



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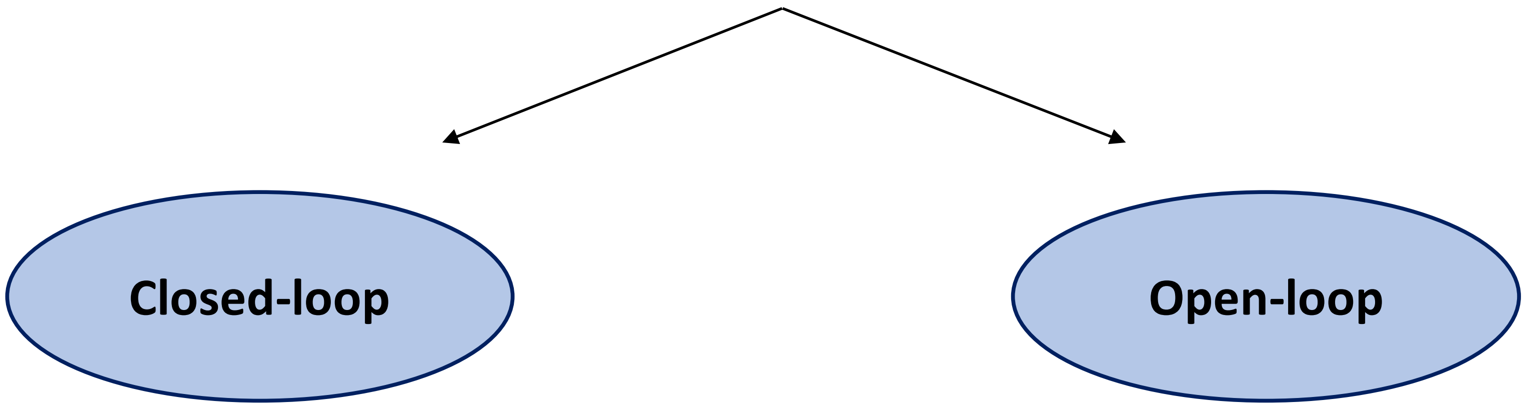
Product Circularity Assessment – step 1

- Given the methodology objective, **it is necessary to allocate the material circularities of a system correctly**. With the term "secondary material", we refer to materials produced by recycling phases, while the term "primary material" refers to materials produced from virgin resources.

- Therefore, secondary materials can be used to replace primary materials. This way, it is important to consider that **every recycling activity influences the environment through the consumption of resources**, the release of emissions and waste. Hence, the procedure for the allocation of flows are a key factor for the analysis of benefits related to circularity and material recycling.

- Referring to (The International Standards Organisation, 2006), it is possible to distinguish between the **"closed-loop "** allocation procedure and the **"open-loop"** allocation procedure.



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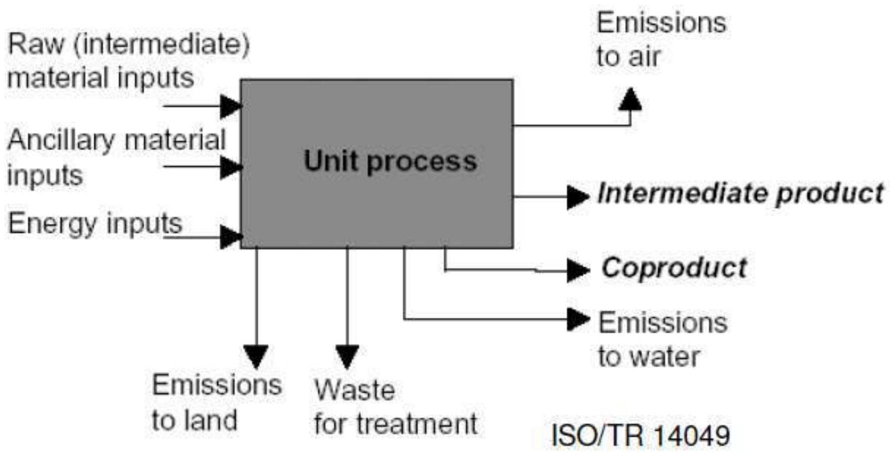
Product Circularity Assessment – step 2

> ➢ **Inventory analysis and resource flows decomposition**: the main objective is the identification and quantification of inputs and outputs of each product life cycle stage included in the system boundaries. The resources flows are then categorized according to their circularity characteristics.

1. Energy flows (electricity and thermal energy).

2. Material flows. They concern the different materials that make up the product.

3. Other resources flows used for product manufacturing. They concern the resources that do not constitute the materials that make up the product, but which are still necessary for the formation of the product.



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Product Circularity Assessment – step 2

- At this point, all the resource flows used within the product life cycle are analyzed in order to calculate the different types of circularity. **“Circularities quantification”** means determining the share of the resource flows that can be considered circular with respect to the total resources used.
- This way, it is possible to obtain **a set of percentage circular indicators** that are representative of the circularity degree of each resource flow within the system boundaries. In this analysis, the possible interactions with other products life cycles have to be also considered.
- In particular, the following types of circularity have been considered:

(i) electric or thermal energy flows from renewable energy sources and from energy recovery of waste;
(ii) materials flows or other non-virgin resources in input from other systems or from the same system analysed (i.e. “**short-range**” circularities if they come from the same phase p, “**long-range**” circularities if they come from another phase p, or from the EoL);
(iii) material flows or other non-virgin output resources that are reused in the same system or in other systems;
(iv) resource flows saved as a result of de- or re-manufacturing activities.

Absorbed circularity ≠ Generated circularity

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Product Circularity Assessment – step 3

- **Weights and indexes calculation**: not all the resource streams affect the system in the same way. For this reason, different weights and indexes used in CEPA are calculated in this step of the methodology.

W^{E}_{p}

$$W^{E}_{p} = \frac{EE_p + TE_p}{E\_system}$$

W^{M}_{m}

$$W^{M}_{m} = \frac{MF\_in_m + (A * \sum^{F}_{f=1} MF\_maint\_in_{m,f})}{\sum^{M}_{m=1}(MF\_in_m) + (A * \sum^{F}_{f=1} \sum^{M}_{m=1} MF\_maint\_in_{m,f})}$$

$W^{M,P}_{m,p}$

$$W^{M,P}_{m,p} = \frac{MF\_in_{m,p}}{MF\_in_m + (A * \sum^{F}_{f=1} MF\_maint\_in_{m,f})}$$

W^{R}_{r}

$$W^{R}_{r} = \frac{RF\_in_r + (A * \sum^{F}_{f=1} RF\_maint\_in_{r,f})}{\sum^{R}_{r=1}(RF\_in_r) + (A * \sum^{F}_{f=1} \sum^{M}_{m=1} RF\_maint\_in_{r,f})}$$

$W^{R,P}_{r,p}$

$$W^{R,P}_{r,p} = \frac{RF\_in_{r,p}}{RF\_in_r + (A * \sum^{F}_{f=1} RF\_maint\_in_{r,f})}$$

CRI_{m}

$$IRC = \beta * Rs$$

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Product Circularity Assessment – step 4

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- **Circularity indicators calculation**: in the last methodology step, the circularity indicators for the different types of resources are calculated.

- In particular, the circular shares are weights for each flow present in each system phase grouped into a single final indicator, the Circularity Product Indicator (CPI). The main results of this phase are:

1. **CPI calculation**: quantification of circular flows entering a certain process phase of the system.

2. **Circularity yield vector calculation**: comparison of generated versus absorbed circular flows in a certain process phase of the system.

3. **Circularity function calculation**: quantification of circularity levels of the system both considering the CPI index and the yield vector.

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Product Circularity Assessment – step 4

Energy KPI

EEC p

$$EEC_p = \frac{EE\_R_p}{(EE_p + TE_p)}$$

TEC p

$$TEC_p = \frac{TE\_R_p}{(EE_p + TE_p)}$$

ECI p

$$ECI_p = W^E{}_p * \left(EEC_p + TEC_p\right) * 100$$

ECI

$$ECI = \sum_{p=1}^{P}(ECI_p) + A * \sum_{f=1}^{F}(EC\_maint_f * W^E{}_{f_f} * z_f)$$

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Product Circularity Assessment – step 4

Material KPI

MCI $_{m,p}$

$$MCI_{m,p} = \frac{(MFC\_in^{short}{}_{m,p} + MFC\_in^{long}{}_{m,p} + MFC\_in^{eol}{}_{m,p} + MFC\_in^{OS}{}_{m,p})}{MF\_in_{m,p}}$$

MCI m

$$MCI_m = \sum_{p=1}^{P} [MCI_{m,p} * W^{M,P}{}_{m,p}] + A * \sum_{f=1}^{F} [MC\_maint_{m,f} * W^{M,F}{}_{m,f_f} * z_f]$$

MCI

$$MCI = \sum_{m=1}^{M} [(MCI_m * W^{M}{}_m * IRC_m) * 100]$$

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Product Circularity Assessment – step 4

Other resources KPI

RCI r,p

$$\mathbf{RCI_{r,p}} = \frac{(\mathbf{RFC\_in^{short}}_{r,p} + \mathbf{RFC\_in^{long}}_{r,p} + \mathbf{RFC\_in^{eol}}_{r,p} + \mathbf{RFC\_in^{OS}}_{r,p})}{\mathbf{RF\_in_{r,p}}}$$

RCI r

$$\mathbf{RCI_r} = \sum_{p=1}^{P} [\mathbf{RCI_{r,p}} * \mathbf{W^{R,P}}_{r,p}] + \mathbf{A} * \sum_{f=1}^{F} [\mathbf{RC\_maint_{r,f}} * \mathbf{W^{R,F}}_{r,f_f} * \mathbf{z_f}]$$

RCI

$$\mathbf{RCI} = \sum_{r=1}^{R} [(\mathbf{RCI_r} * \mathbf{W^R}_r) * 100]$$

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Product Circularity Assessment – step 4

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Final KPI

CPI

$$\mathbf{CPI} = \frac{\mathbf{K}}{\sqrt{\mathbf{3}}} = \frac{\sqrt{\mathbf{ECI}^2 + \mathbf{MCI}^2 + \mathbf{RCI}^2}}{\sqrt{\mathbf{3}}} * \mathbf{100}$$

The circularity yield vector is then calculated. It represents the quantification of the generated circularity compared to those absorbed. **In fact, CPI fails to take into account how much a system can make available reusable resource flows, compared resource input.** This is due to the difficulty in allocating circular flows, which in many cases involve different phases of the system or different systems.

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Product Circularity Assessment – step 4

Circularity yield vector

E_rec^{M}

$$E\_rec^{M} = \left\{\left[\sum_{p=1}^{P}\sum_{m=1}^{M}\left(MFC\_out^{en\_rec}{}_{m,p} * LHV_m * \eta^{en\_rec}{}_m\right)\right] + \left[\sum_{m=1}^{M}\left(MFC\_out^{en\_rec}{}_{m,eol} * LHV_m * \eta^{en\_rec}{}_m\right)\right]\right\}$$

$E\_rec\_max^{M}$

$$E\_rec\_max^{M} = \left\{\left[\sum_{p=1}^{P}\sum_{m=1}^{M}\left(MF\_out_{m,p} * LHV_m\right)\right] + \left[\sum_{m=1}^{M}\left(MF\_FP_{m,eol} * LHV_m\right)\right]\right\}$$

ECI_{out}

$$ECI_{out} = \frac{(E\_rec^{M} + E\_rec^{R})}{(E\_rec\_max^{M} + E\_rec\_max^{R})}$$

η_{EC}

$$\eta_{EC} = \frac{ECI\_out}{ECI}$$

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Product Circularity Assessment – step 4

Circularity yield vector

η_{MC}

$$\eta_{MC} = \frac{MCI\_out}{MCI}$$

η_{RC}

$$\eta_{RC} = \frac{RCI\_out}{RCI}$$

η_{C}

$$\eta_{C} = \sqrt{\eta_{EC}^2 + \eta_{MC}^2 + \eta_{RC}^2}$$

Φ

$$\Phi = \{[\pi * CPI^2] * (1 + \eta_{C})\}$$

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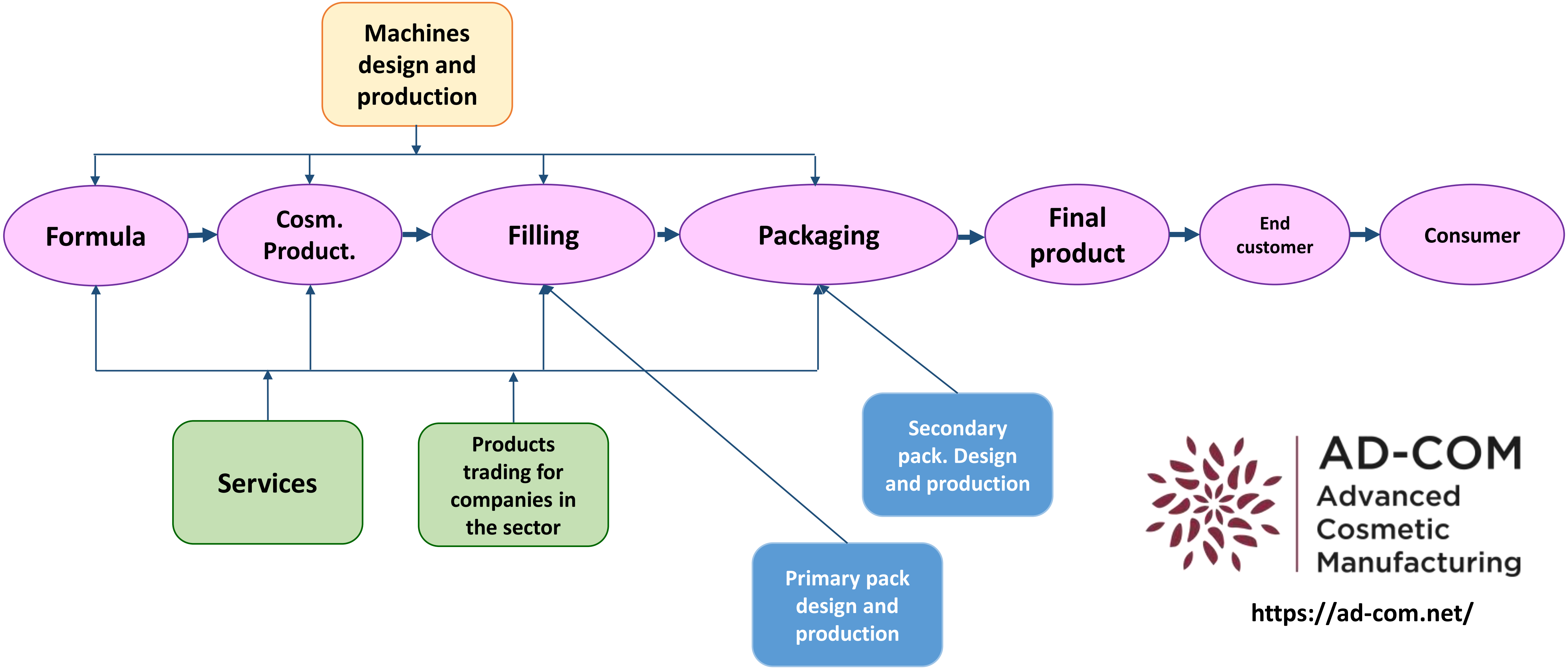
Application context



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Cosmetic and sustainability

New trends in the cosmetic sector

Sustainability

Digitalization

E-commerce

- Today's consumers are increasingly sensitive and informed on sustainability issues
- In addition to consumer attention, there are the regulations, restrictions and transparency mechanisms in the transmission of information relating to the sustainability of products and production processes
- Retroactively, these aspects increasingly influence the needs of all stakeholders in the cosmetic supply chain
- Consequently, the supply chain itself needs to be able to absorb these needs through the redesign of products, production processes and business models in a more sustainable way

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Cosmetic and Circular Economy

In order to make the **circular model real and concrete**, a scientific approach is needed that considers the entire products life cycle and resources consumption. The assessment of environmental performance for the optimization of production processes and chemistry in the research and development phase **play a central role**.

To become a **factor of development and competitiveness** for the entire cosmetic economy, the circular model must be based on three fundamental pillars:

1. Ecodesign,
2. Industrial symbiosis
3. Supply chain cooperation

With reference to the world of cosmetics, there are three areas on which companies can focus more on developing the circular model:

(i) sustainable procurement
(ii) resource efficiency
(iii) packaging.

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Cosmetic Packaging and Circular Economy

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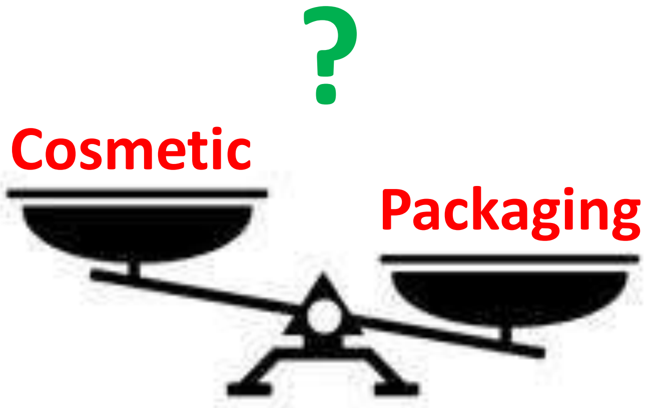
More Benefits



Sustainable packaging → ***Design approach and materials***

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Application example

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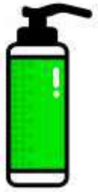
- The company involved is specialized in the cosmetic primary packaging sector and it supplies the market with standard and custom packaging lines.

- The analyzed product is composed by two assembled: a glass jar and a plastic cover, with a total weight of 111.4 g, while the system boundaries includes the following phases:

(i) plastic drying;
(ii) internal logistics of plastics;
(iii) injection molding of styrene-acrylonitrile (SAN) lens;
(iv) injection molding of polypropylene (PP) sub-lens;
(v) cover assembling;
(vi) colors preparation for glass screen printing;
(vii) glass screen printing;
(viii) glass drying;
(ix) final assembling;
(x) distribution and usage;
(xi) EoL.



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Application example: functional unit

Index	Resource
m=1	Styrene-acrylonitrile (SAN) lens
m=2	Polypropylene (PP) sub-lens
m=3	Tri-seal gasket
m=4	Glass jar
r=1	Screen printing colours
r=2	Raw material cardboard packaging
r=3	Raw material plastic packaging
r=4	Pallet
r=5	Raw material plastic packaging – type 2
-	Electrical energy from photovoltaic plant
-	Electrical energy from the grid

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Application example: results – Circularity Indicators

Indicator	Value
ECI	29.93%
MCI	0%
RCI	78.63%
CPI	**48.53%**
ECI_out	7.12%
η_{EC}	23.78%
MCI_out	40.34%
η_{MC}	0%
RCI_out	49.29%
η_{RC}	62.69%
$\boldsymbol{\Phi}$	**67.05%**

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Conclusion

- The paper presents an overview of the CE trends which are currently **pushing company business models**, focusing the attention on **cosmetic sector**, since sustainability plays a fundamental role in the cosmetic industry of today.
- A new Circular Economy Performance Assessment (CEPA) methodology and the metrics explanation for the **product circular degree** calculation has been presented, together with an exemplary its application to a cosmetic primary packaging.
- The methodology output consists in **a set of specific circular KPIs** regarding resources circularity degree and it can be used in different fields of application: (i) creation of a product certification system related to the circularity of resource flows; (ii) design for Circular Economy; (iii) comparison between different versions of a product based on their circularity degree and analysis of the benefits they can bring from economic and environmental side.

FUTURE RESEARCH

- Methodology testing on different products, processes and sectors to strengthen the metrics
- Study and analysis of digital technologies to support CE performance measurement

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An overview of Circular Economy paradigm in the cosmetic sector

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