Eco-design, life cycle assessment and life cycle costing of PHA-based bioplastics

Enrique Moliner Santisteve

Sustainability Technologist

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[Applied Innovation Engineering]

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08/02/2024

COMPANY OVERVIEW

[INNOVA]

SUSTAINABLE solutions

- Engineering SME
- Founded in 2017
- Specialized in Environmental Engineering
- Offices in Valencia, Spain
- Awarded as Innovative SME

INNOVATIVE SME

Valid until Sep 16th 2025

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

LOMARTOV [Applied Innovation Engineering]

[INNOVA]

Professional counselling in innovation catalysis, technology transfer and investment opportunities

- Technological Coaching
- Financial counselling
- Certification & Standardization
- Scaling Up
- Value Map Proposition
- Business Planning
- Regulatory Compliance
- Communication & Dissemination
- Exploitation
- Data Management, IPR

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[Applied Innovation Engineering]

SUSTAINABLE solutions

Professional counselling in technology and innovation sustainability assessment.
From Design up to End of Life stages

ENVIRONMENTAL

- Environmental Impact Assessment
- Eco-design, Recyclability, Safe-by Design
- Life Cycle Assessment, Carbon & Water Footprint
- Material Flow Analysis
- Circular Economy Modelling

ECONOMIC

- Economic Impact Assessment
- Life cycle Costing
- Techno-economic Analysis
- Cost efficiency Evaluation

SOCIAL

- Social Life Cycle Assessment
- Societal acceptance and stakeholders' involvement
- Citizens engagement and communication
- Consumers behaviour and trends analysis
- Ethics, policy and legal assessment

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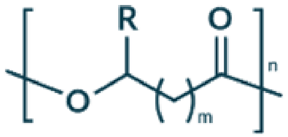
Introduction

Increase stakeholders and consumer awareness

Demonstrate the circular economy and sustainability of the nenu2PHAr value chain

Develop eco-designed PHA-biobased product for high volume consumer products

Develop new competitive bio-source of PHA polymer



Formulate and functionalise polymer masterbatchs and compoundings to provision plastic product manufacturers

Identify processes for PHA-material to reach defined functional properties better than fossil-fuel counterparts

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nenu2PHAr

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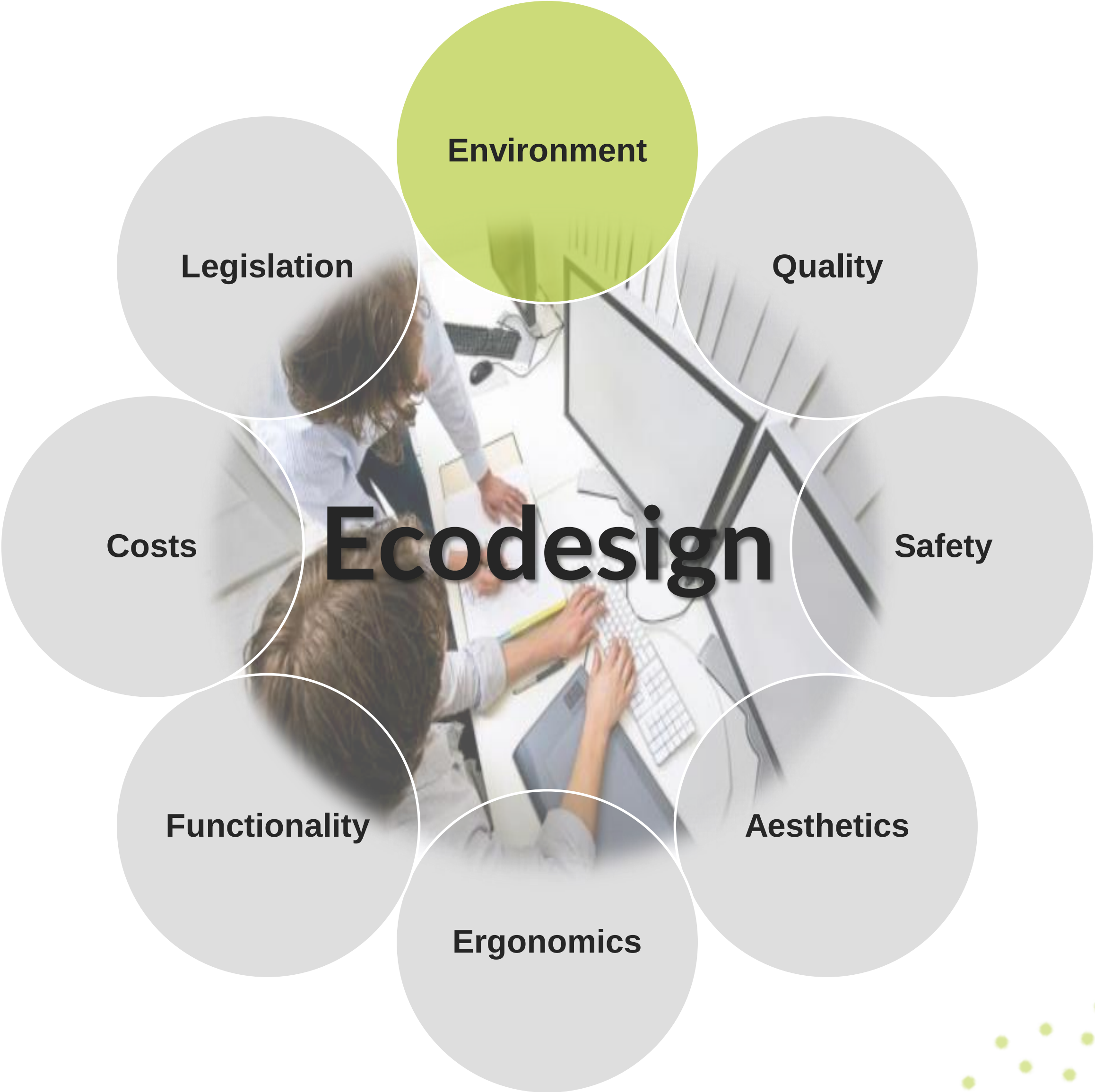
What is ecodesign?

Integrating environmental aspects during product design and development

Ecodesign is not just about environment



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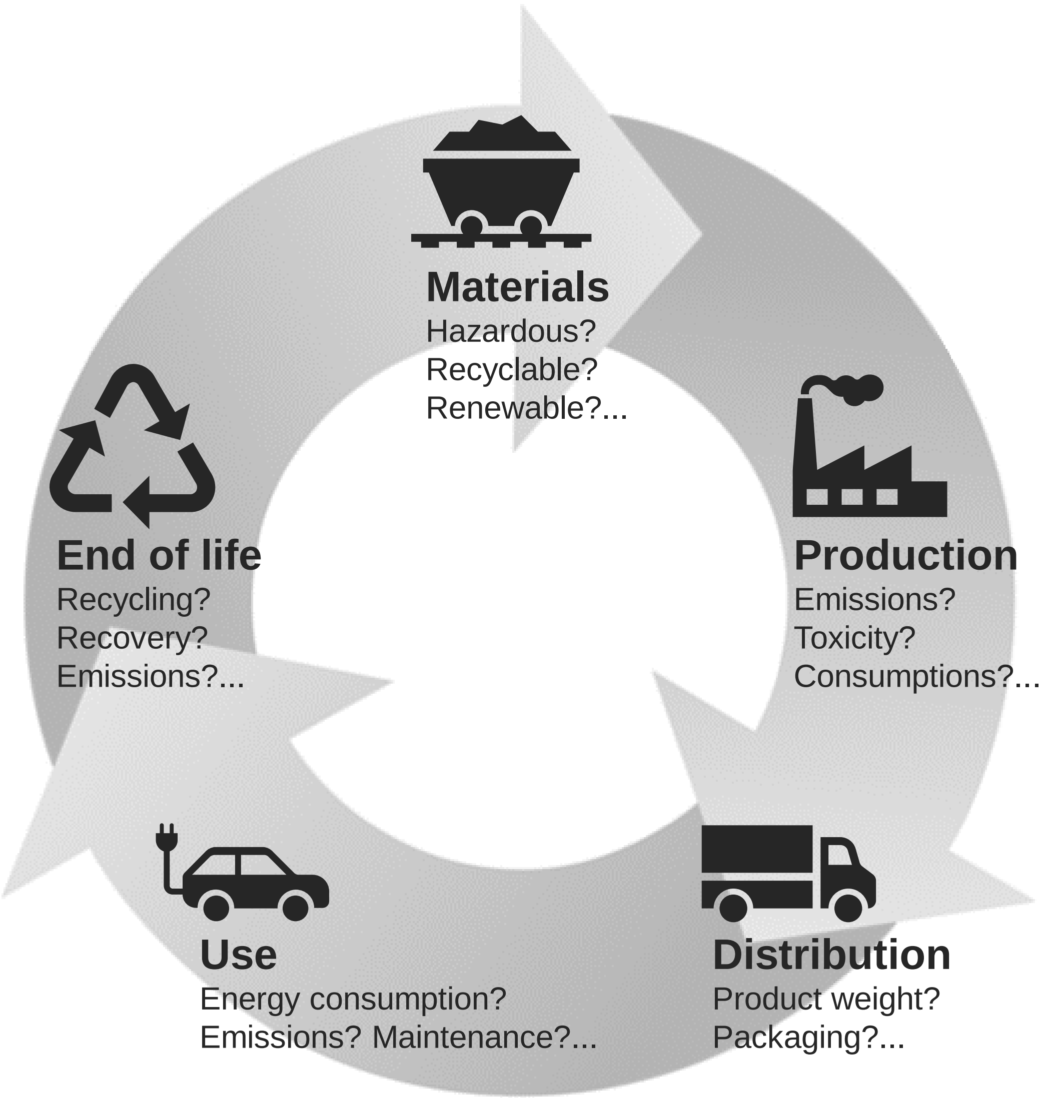
What is ecodesign?

The aim is to reduce the environmental impact of the products throughout their entire life cycle…

…from the cradle to the grave



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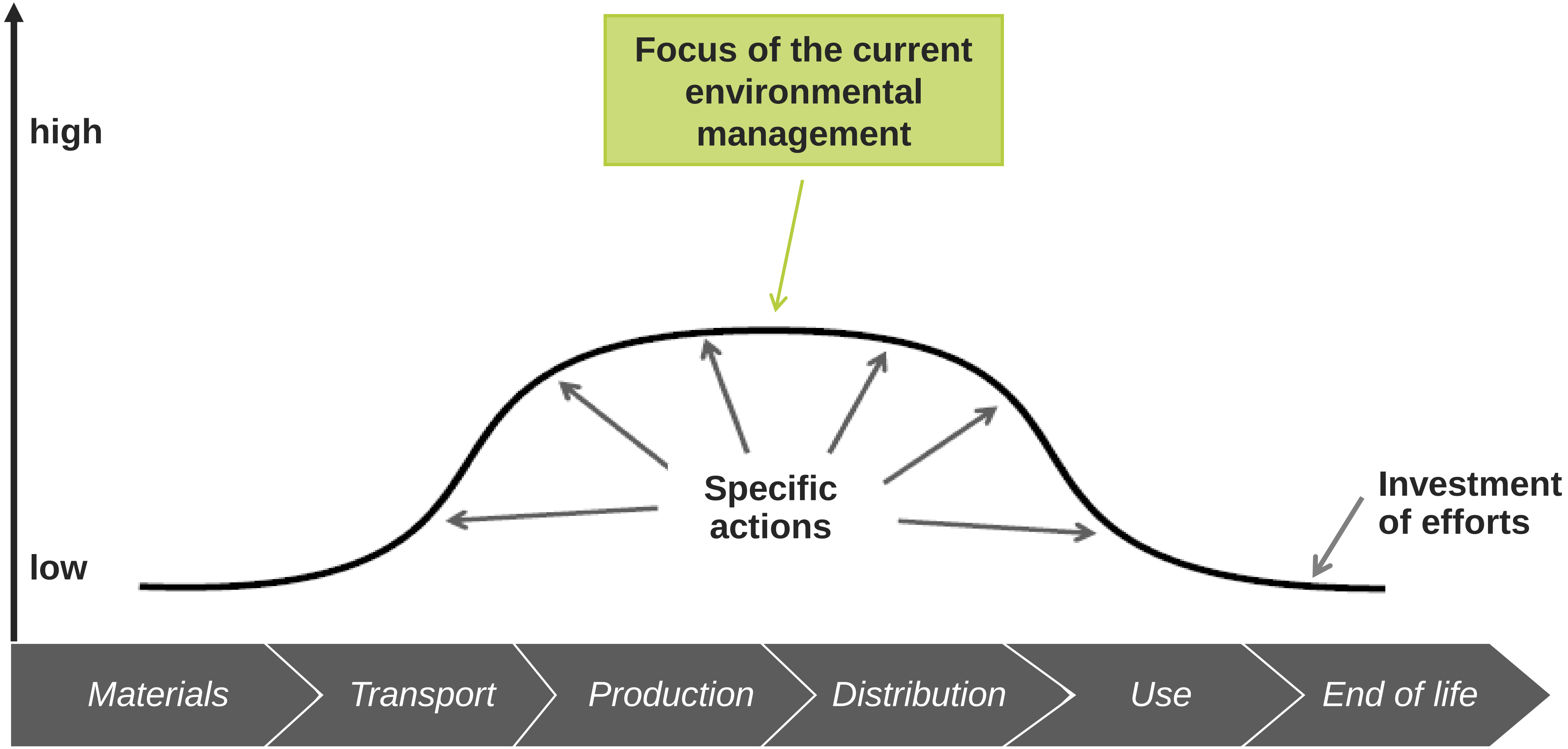
Why ecodesign?



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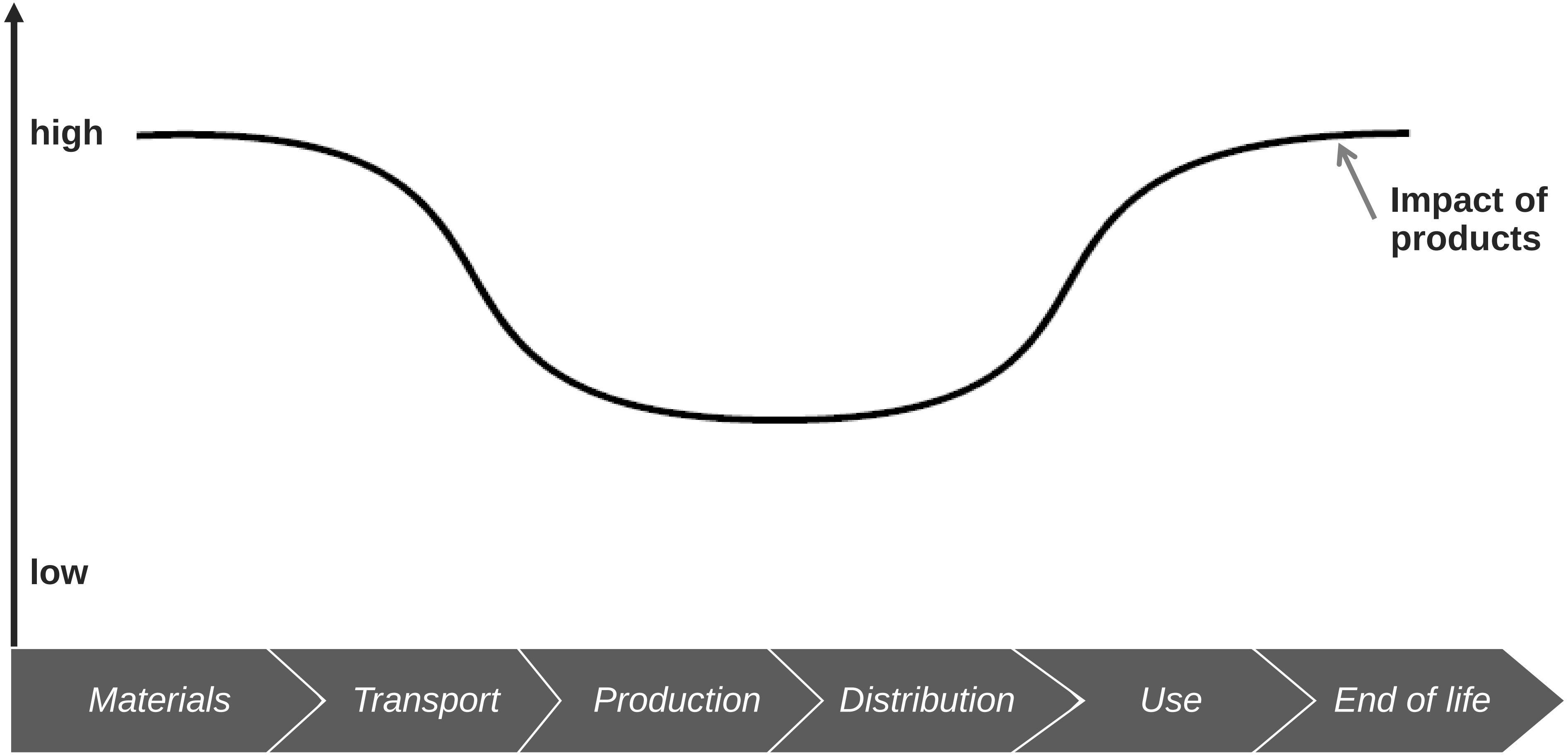

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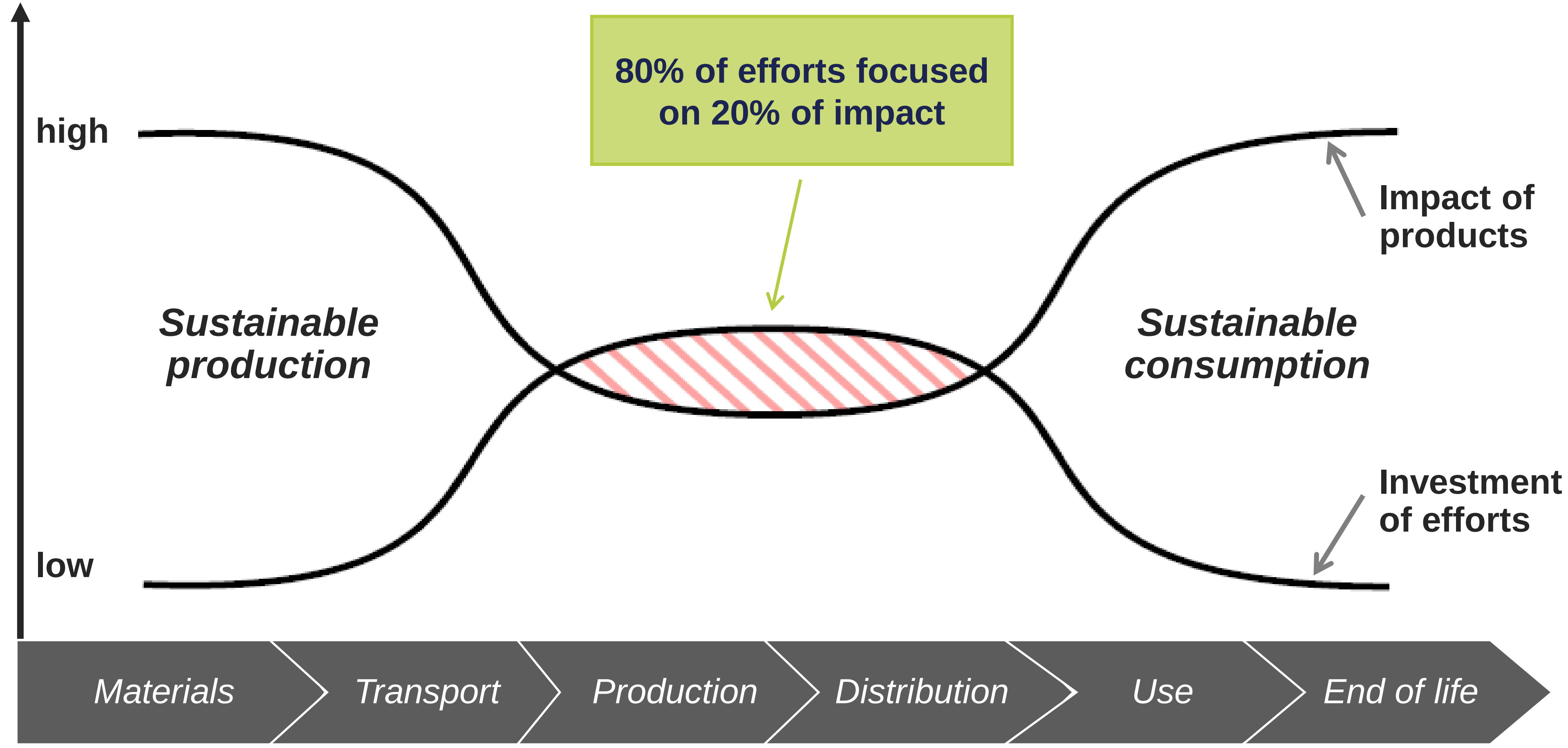

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How did we apply ecodesign?

Ecodesign of various target products (currently made of conventional plastics)

bio-mi SUSTAINABLE SOLUTIONS

elixance inspired by performance

bel for all for good

KAJ packaging solutions

DANONE ONE PLANET. ONE HEALTH

Medtronic

IFG Cresco

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How did we apply ecodesign?

Ecodesign procedure step-by-step

Creation of the ecodesign team
- Multidisciplinary / Small: 5-6 members / Technical coordinator

Description of product specifications
- Technical specifications / Functional specifications / Regulatory specifications / Market demands
- Environmental specifications: corporate policy & environmental goals of the company

Environmental assessment of current product
- LCA of fossil-based counterparts → Identification of environmental hotspots

Ecobriefing and ecodesign strategies
- Proposal of ecodesign strategies
- Evaluation of strategies according to their feasibility
- Selection of the most feasible strategies

Conceptual development of ecodesign
- Design of product concepts including the selected ecodesign strategies

Environmental assessment of the ecodesigned product
- LCA of ecodesigned product → Comparison vs current product

Manufacturing of product prototype
- Prototype production

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Conceptual development of ecodesign
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Environmental assessment of the ecodesigned product (2 – Life Cycle Assessment (LCA))
- LCA of ecodesigned product (T8.1) → Comparison vs current product

Manufacturing of product prototype
- Prototype production

Life Cycle Assessment (LCA)

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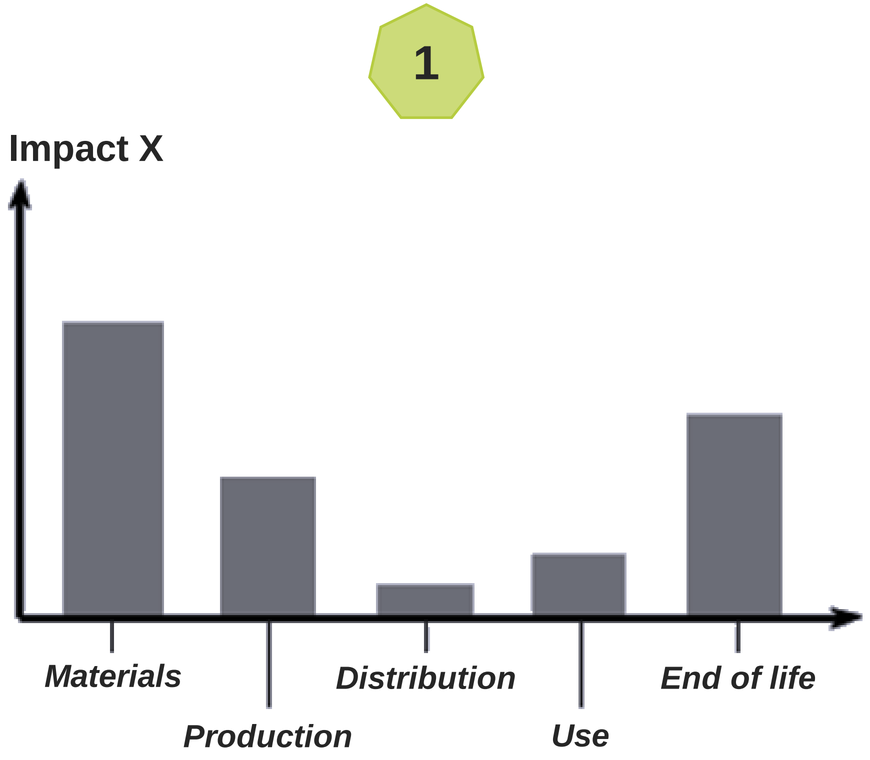
How did we apply ecodesign?

Life Cycle Assessment (LCA)



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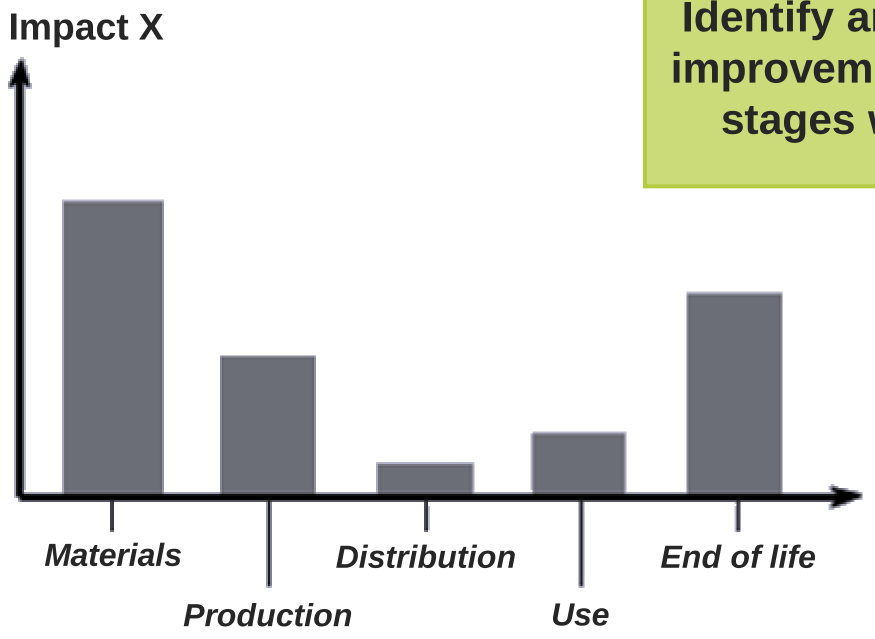
How did we apply ecodesign?

Life Cycle Assessment (LCA)

1



Identify and prioritise environmental improvement actions on the life cycle stages with the greatest impacts

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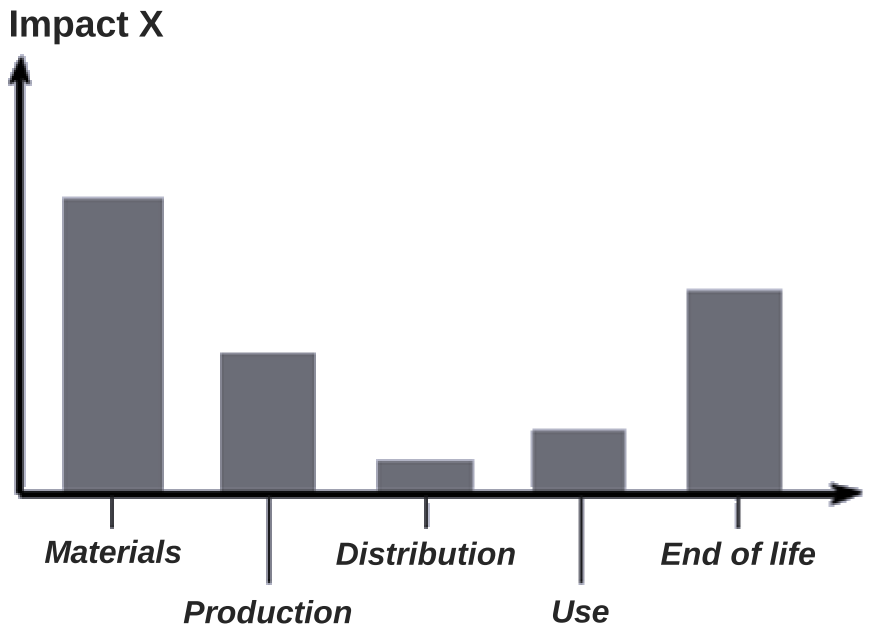
How did we apply ecodesign?

Life Cycle Assessment (LCA)

1



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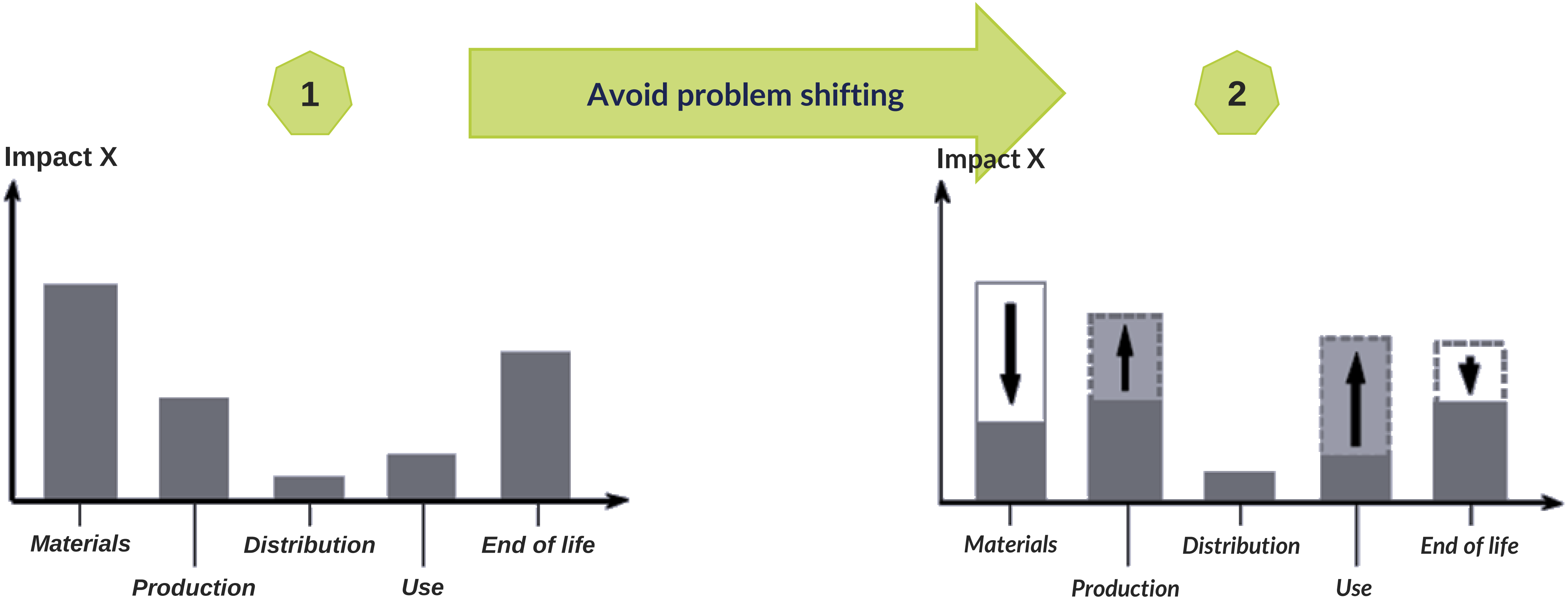

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Ecodesign of the roll-on bottle for cosmetics

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Ecodesign of the roll-on bottle for cosmetics

Creation of the ecodesign team

Person	Position in the company	Ecodesign roles covered
M.K.	R&D Manager	Production, laboratory and R&D, environment & quality
K.G.	Product Designer	Design, purchasing, marketing
A.J.	General Manager	Senior management
L.P.	Key Account Manager	Team coordinator, purchasing, marketing

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Ecodesign of the roll-on bottle for cosmetics

Discussion on the ecodesign driving factors (SWOT analysis)

1) Market demand

2) Improvement of the company image

3) Anticipate regulatory changes

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1) Market demand

2) Improvement of the company image

3) Anticipate regulatory changes

Description of product specifications:

Technical / Regulatory / Economic / Commercial / Environmental

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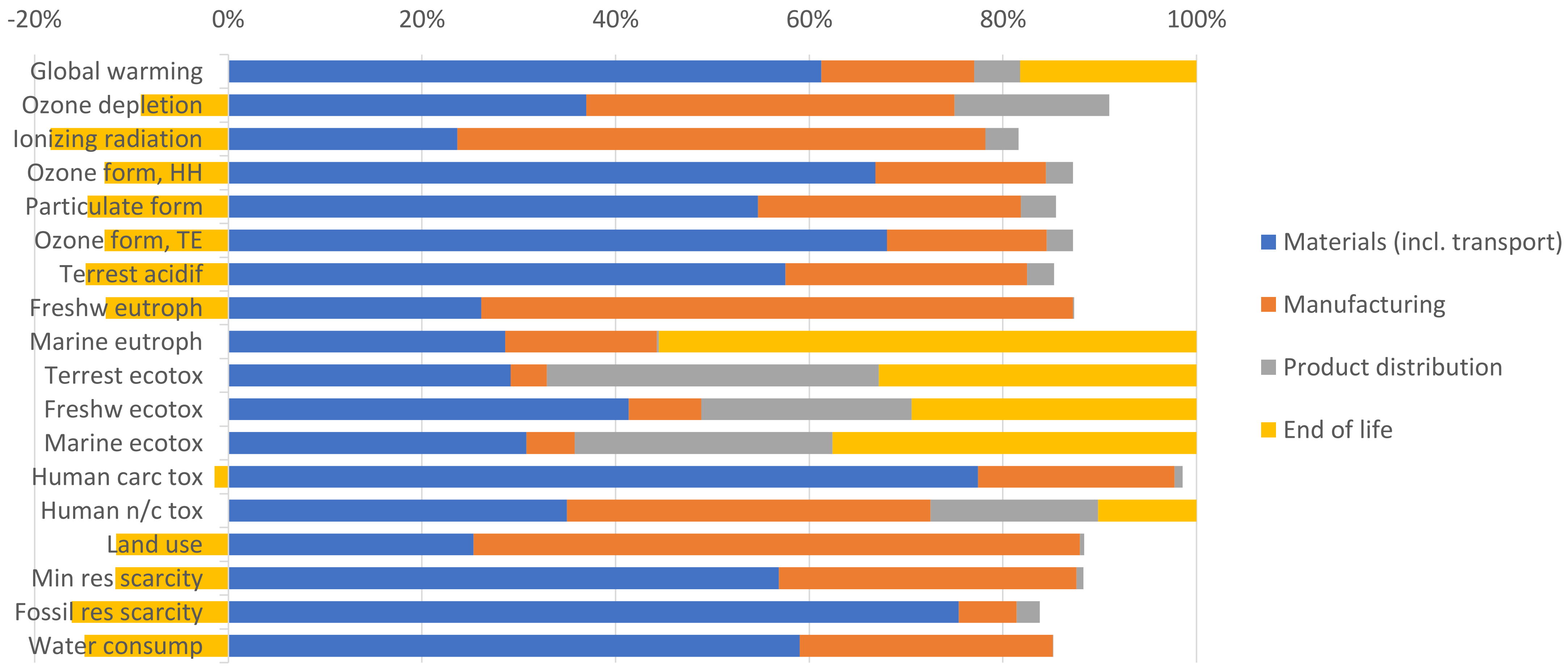
Ecodesign of the roll-on bottle for cosmetics

LCA of current product: identification of environmental hotspots



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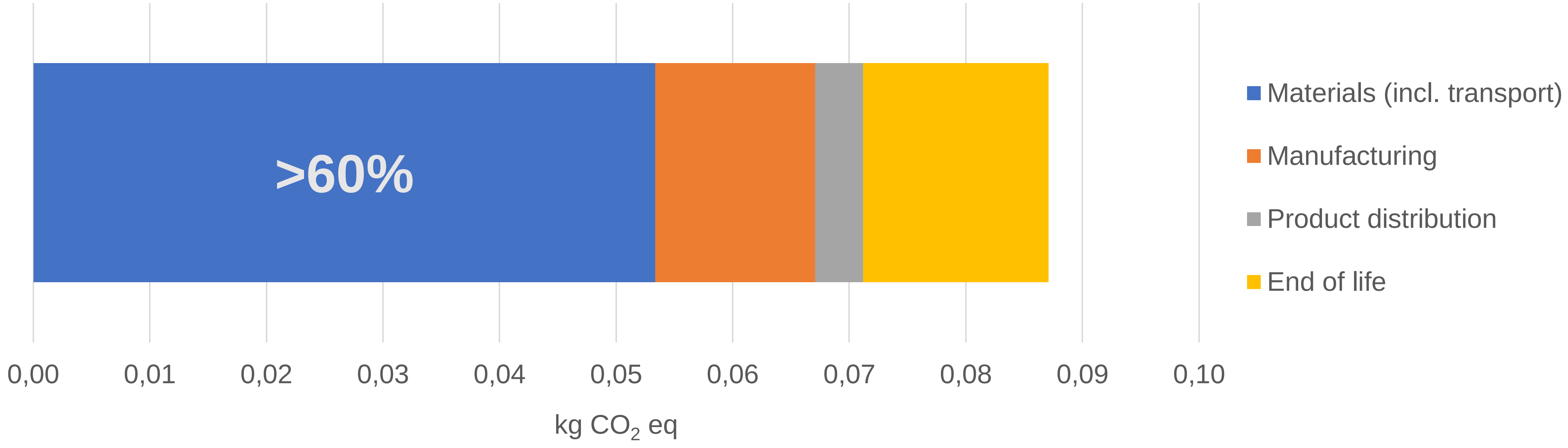
Ecodesign of the roll-on bottle for cosmetics

LCA of current product: identification of environmental hotspots

Carbon footprint: **87.10 g CO_2 eq/unit**



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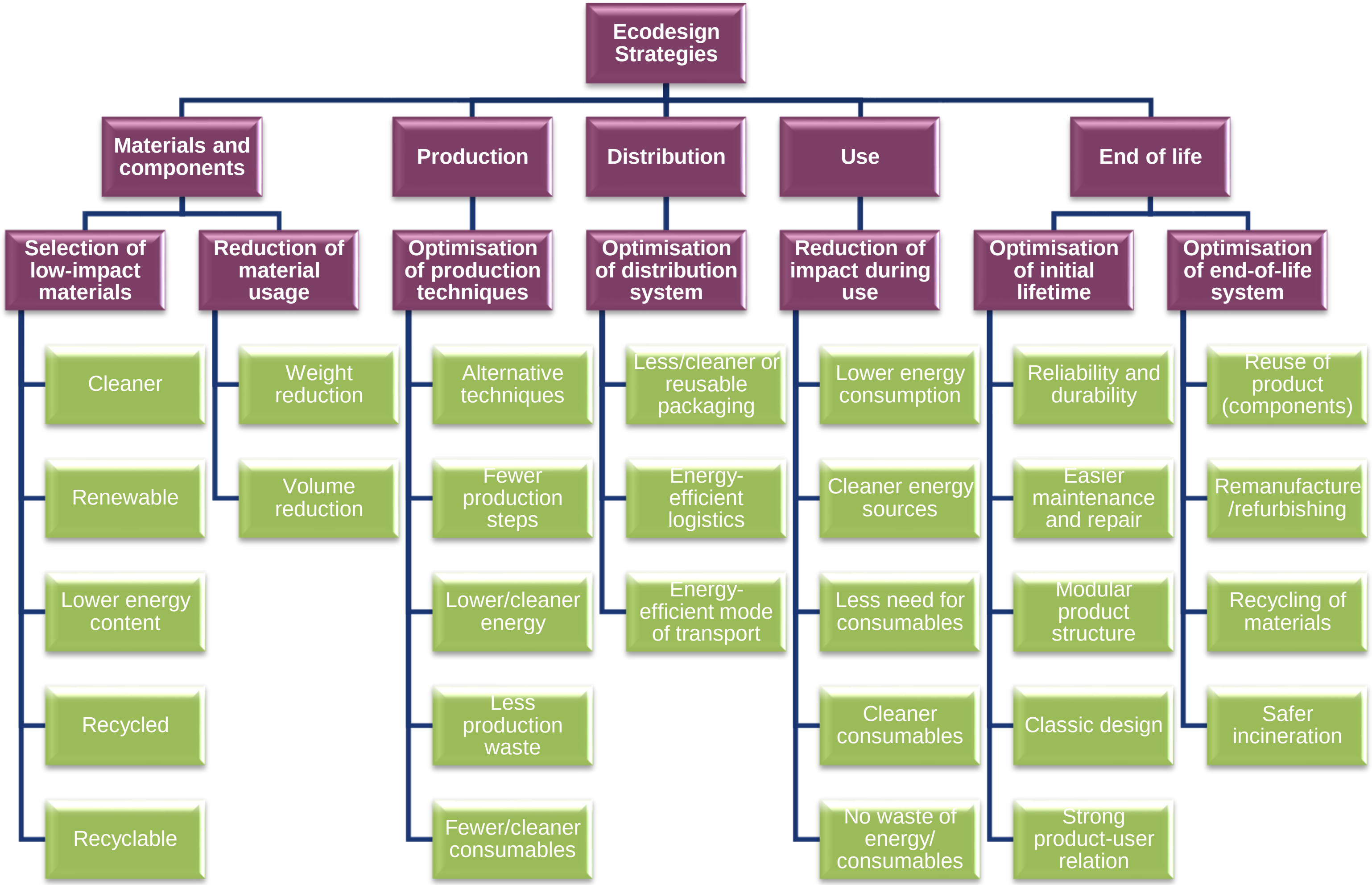
Ecodesign of the roll-on bottle for cosmetics

Proposal of ecodesign strategies and actions (brainstorming)



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Ecodesign of the roll-on bottle for cosmetics

Analysis of the different implications of the proposed ecodesign actions

Use of bio-based polymers to replace fossil-based (e.g., PHAs)		
Technical implications	(+) Market in process of expansion. (+) Wide variety of bio-based plastics, incl. some chemically identical to conventional commodity plastics. (+) Same manufacturing processes/equipment as for fossil-based plastics.	(-) Technical limitations (thermal resistance, chemical compatibility with packaged products, food safety, barrier properties, etc.). (-) Production capacity still limited (supply difficulties).
Regulatory implications	(+) Alignment with the EU Bioeconomy Strategy (future incentives?)	(-) No clear regulatory framework (uncertainty): the EC fails to suggest concrete legislative measures to capitalise on the bioplastics' benefits. (-) SUP Directive impacts the bioplastics in a similar way as the whole plastics industry.
Economic implications	(+) No high investments required since the same manufacturing process/ equipment can be used as for current plastic counterparts. (+) Improvement in production technologies and increase in production capacities expected in the coming years (more competitive prices).	(-) Production costs probably increased with bio-based plastics because of their higher market prices at present.
Commercial implications	(+) Growing consumer demand. (+) Higher added value to finished products (e.g., home compostability). (+) Opportunities for environmental communication and green marketing, e.g., ecolabels and certificates (OK biobased, OK compost, etc.). (+) Avoidance of social controversy about the ethics of using food crops (1^{st} generation biomass) by using 2^{nd}/3^{rd} generation biomass (e.g., µalgae).	
Environmental implications	(+) Reducing the dependency on fossil resources. (+) Support the rural economy in Europe. (+) Reduce GHG emissions or even be carbon neutral (if 100% bio-based). (+) Alternative EoL opportunities (biodegradation in different environments).	(-) Potential higher impacts related to agricultural practices (fertilisers and pesticides). (-) No adequate logistics and infrastructures for the collection and recovery of bioplastics waste (confusion in final consumers).

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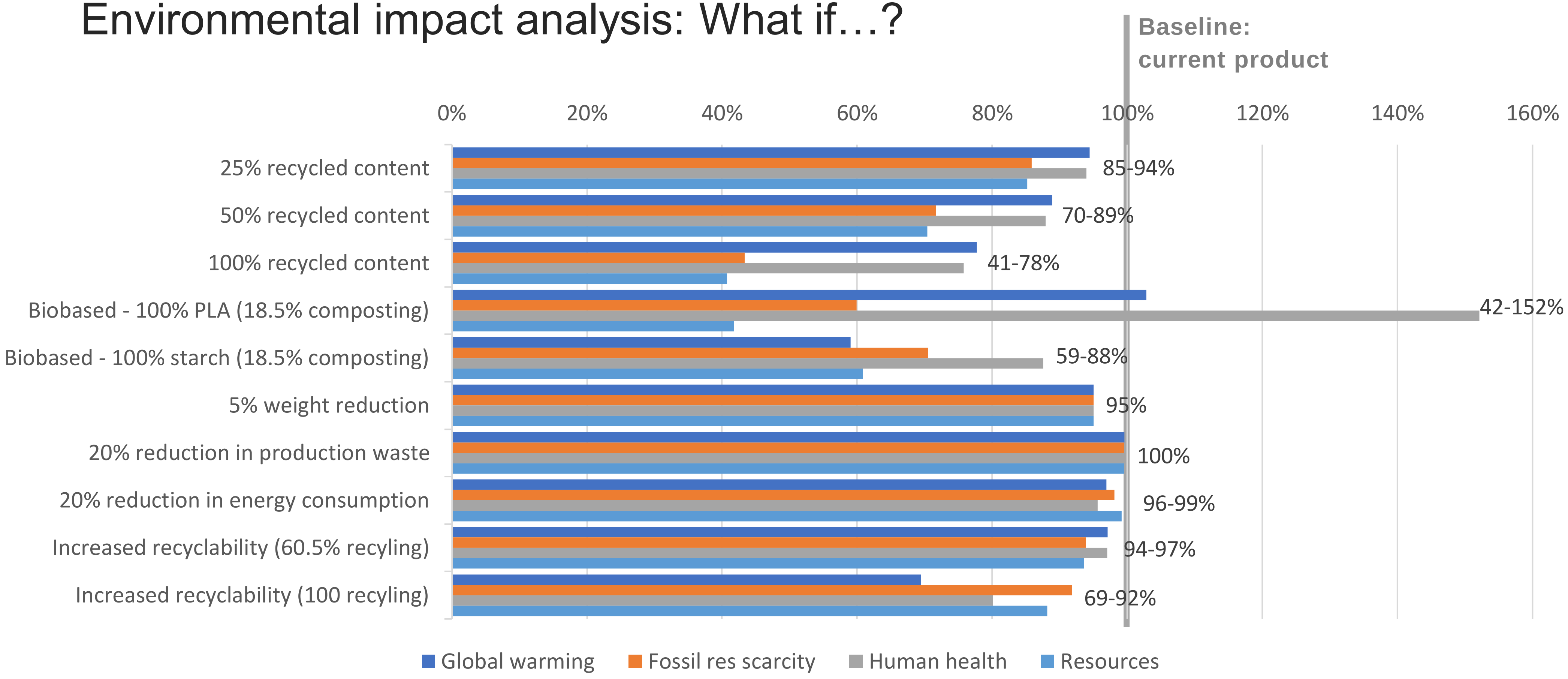
Ecodesign of the roll-on bottle for cosmetics

Analysis of the different implications of the proposed ecodesign actions

Environmental impact analysis: What if…?



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Ecodesign of the roll-on bottle for cosmetics

Selection of ecodesign actions (MCDA matrix)

Ecodesign action	Evaluation criteria						Total score	Time for implementation	N2P prototype implementation
	TV (20%)	RV (10%)	EcV (15%)	CV (20%)	EnV (20%)	DF (15%)			
1.2) Avoid or minimise the use of additives	2	1	2	1	2	1	1.55	Short term	Yes
1.3) Use of PHAs and/or other bio-based polymers to replace fossil-based PE and PP	1	2	-1	1	2	2	1.15	Medium term	Yes
1.4) Replace virgin polymers with recycled plastics (food-grade R-PET for bottle)	1	1	1	1	2	1	1.20	Short term	No
1.5) Making mono-material items (increased recyclability)	0	2	2	2	2	2	1.60	Short term	Yes
2.1) Implementing lighter counterparts of existing packaging	0	2	2	1	2	2	1.40	Medium term	No
2.3) Bottles without roller fitment, with integral neck	2	2	2	0	1	1	1.25	Short term	Yes
3.1) Use of bigger and efficient moulds	2	2	2	1	1	1	1.45	Long term	No
3.2) Automatization of production, using robots and assembling machines	1	2	1	1	1	0	0.95	Medium term	No
3.4) Use of highly-efficient machines and equipment with lower energy consumption	1	2	2	0	2	1	1.25	Medium term	No
7.2) Promoting mono-colour packaging (especially white/natural colours)	2	2	2	2	1	1	1.65	Short term	Yes

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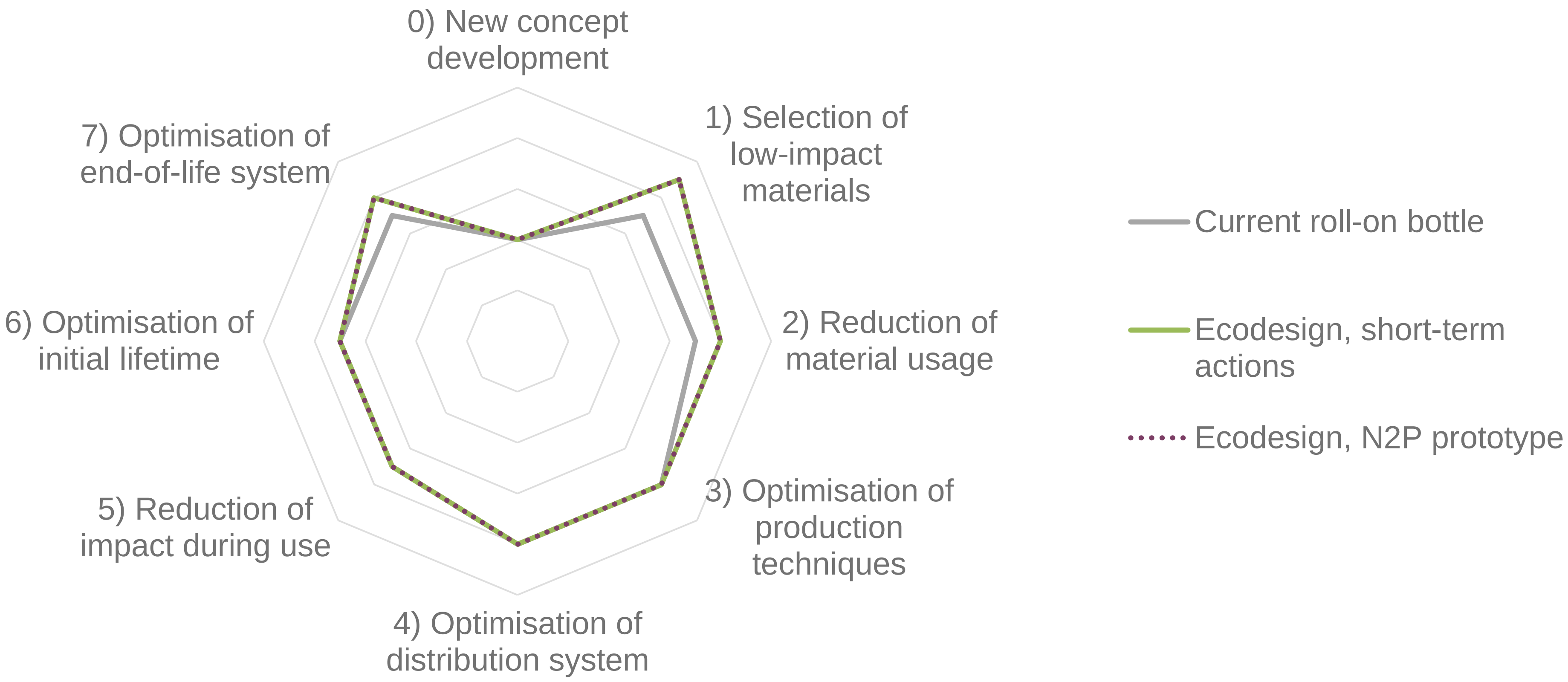
Ecodesign of the roll-on bottle for cosmetics

Preliminary evaluation of the ecodesign concepts proposed



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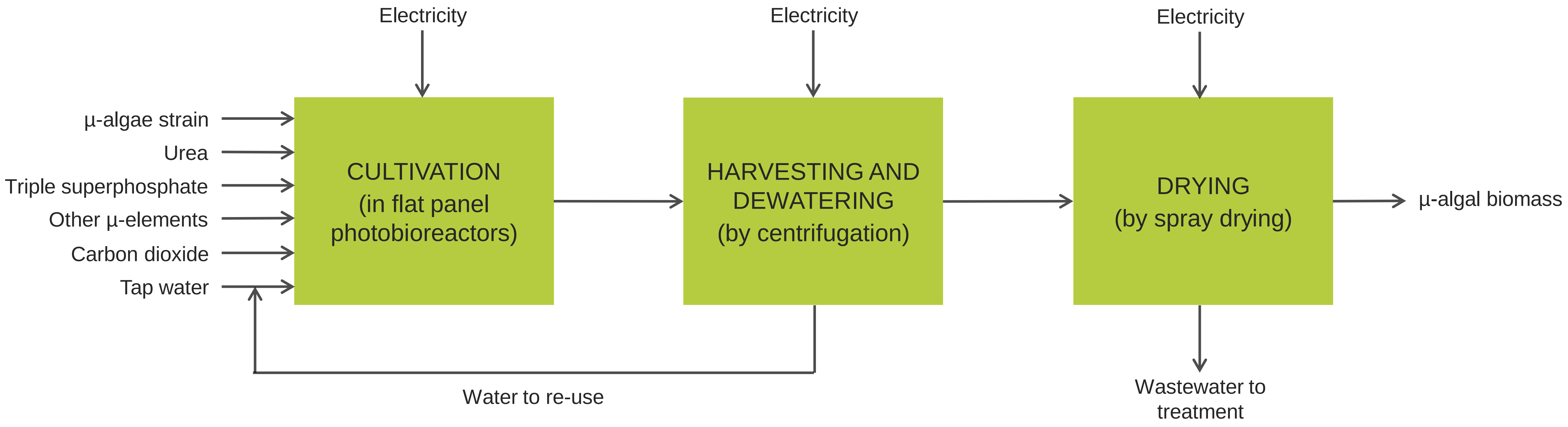
LCA and LCC of PHA production chain

Example: µ-algal biomass cultivation process



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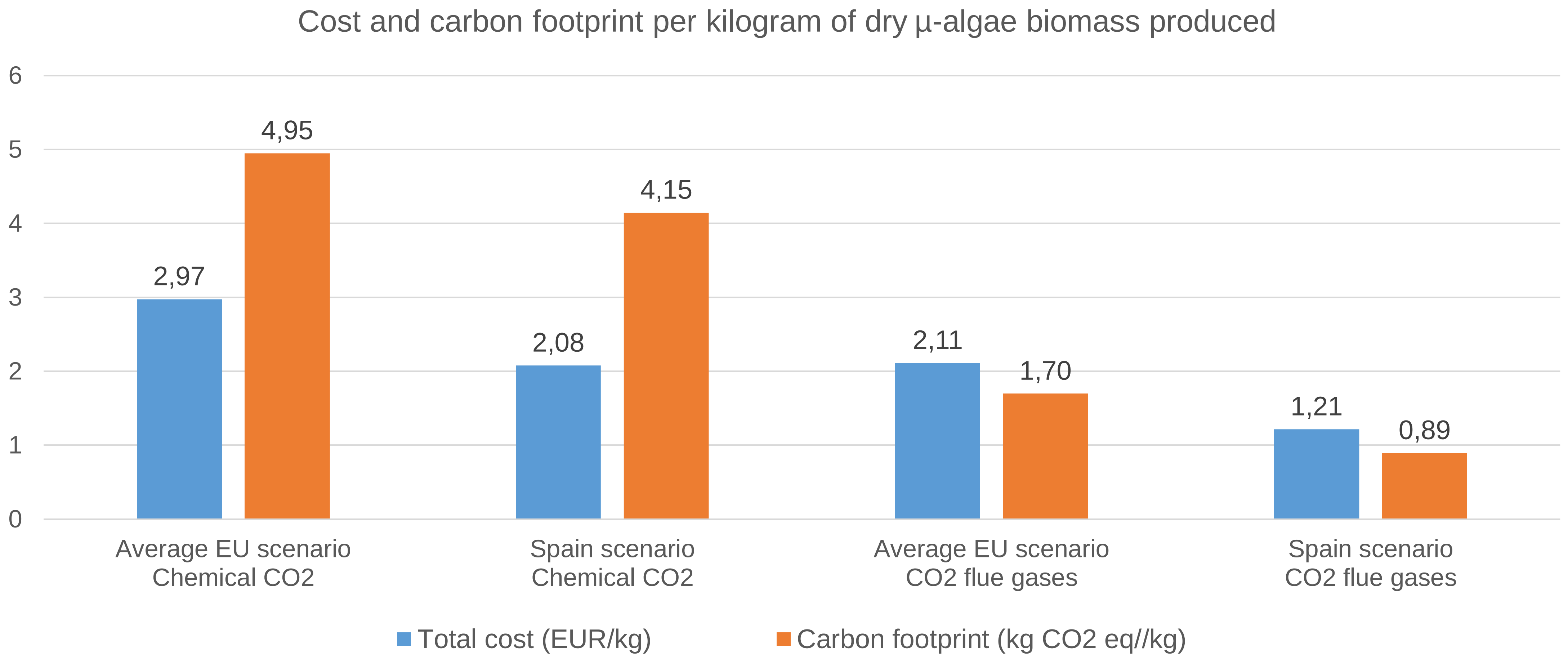

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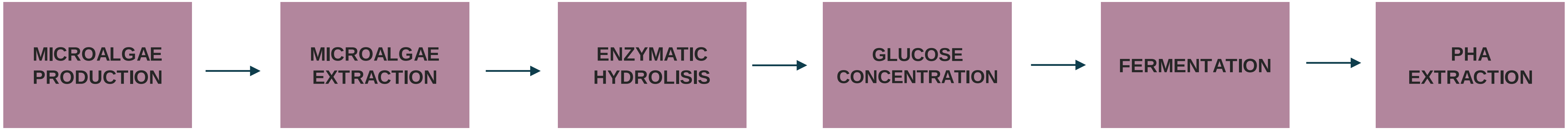
LCA and LCC of PHA production chain

Next steps

- To complete LCA/LCC for the whole production chain (industrial-scale level)
- To perform social LCA



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