EWG POR PRACTICE OF OR

OR in Collaboration
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Weighting life cycle environmental impacts

Luis C. Dias
University of Coimbra

FACULDADE DE ECONOMIA
UNIVERSIDADE D COIMBRA

CeBER

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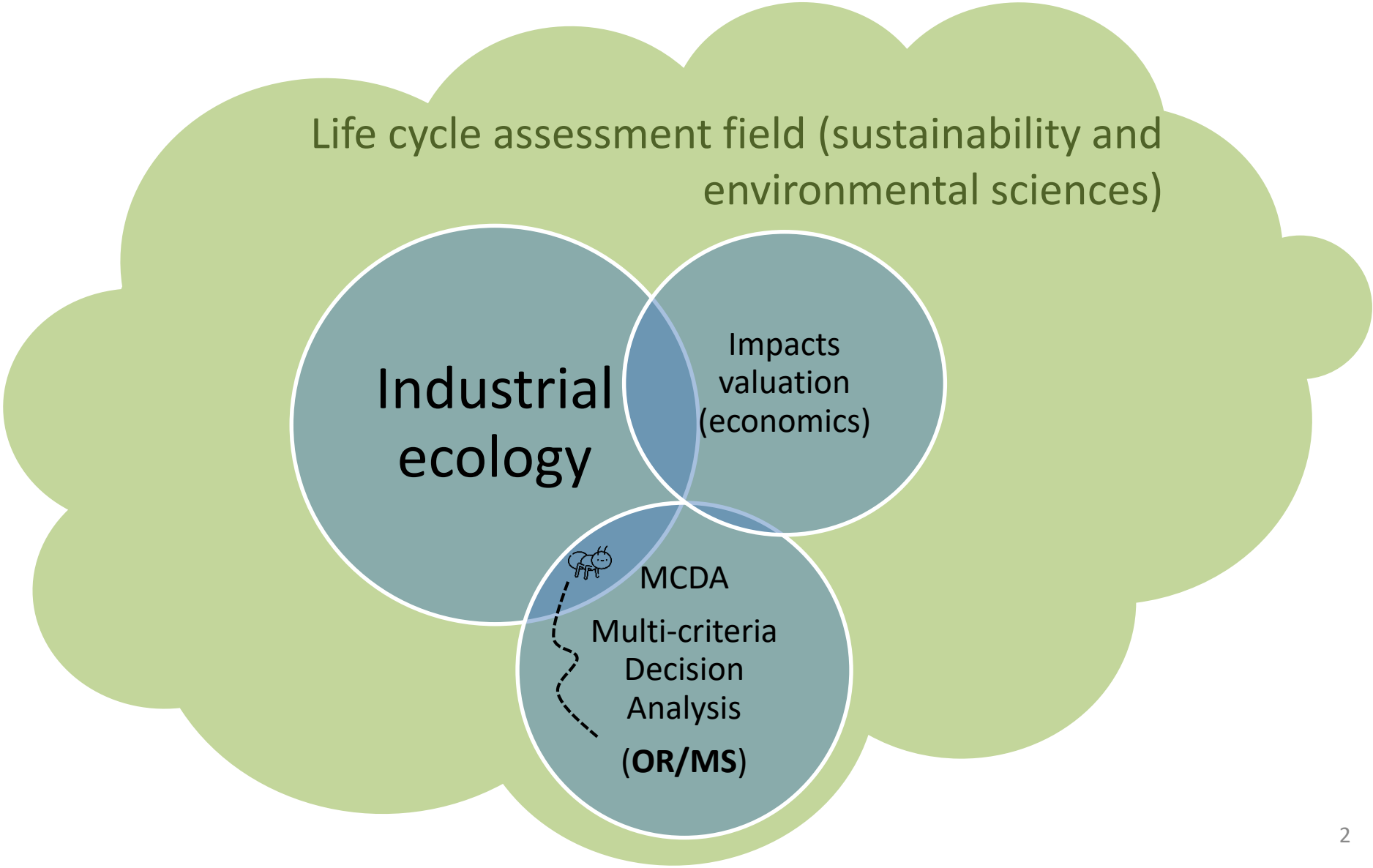
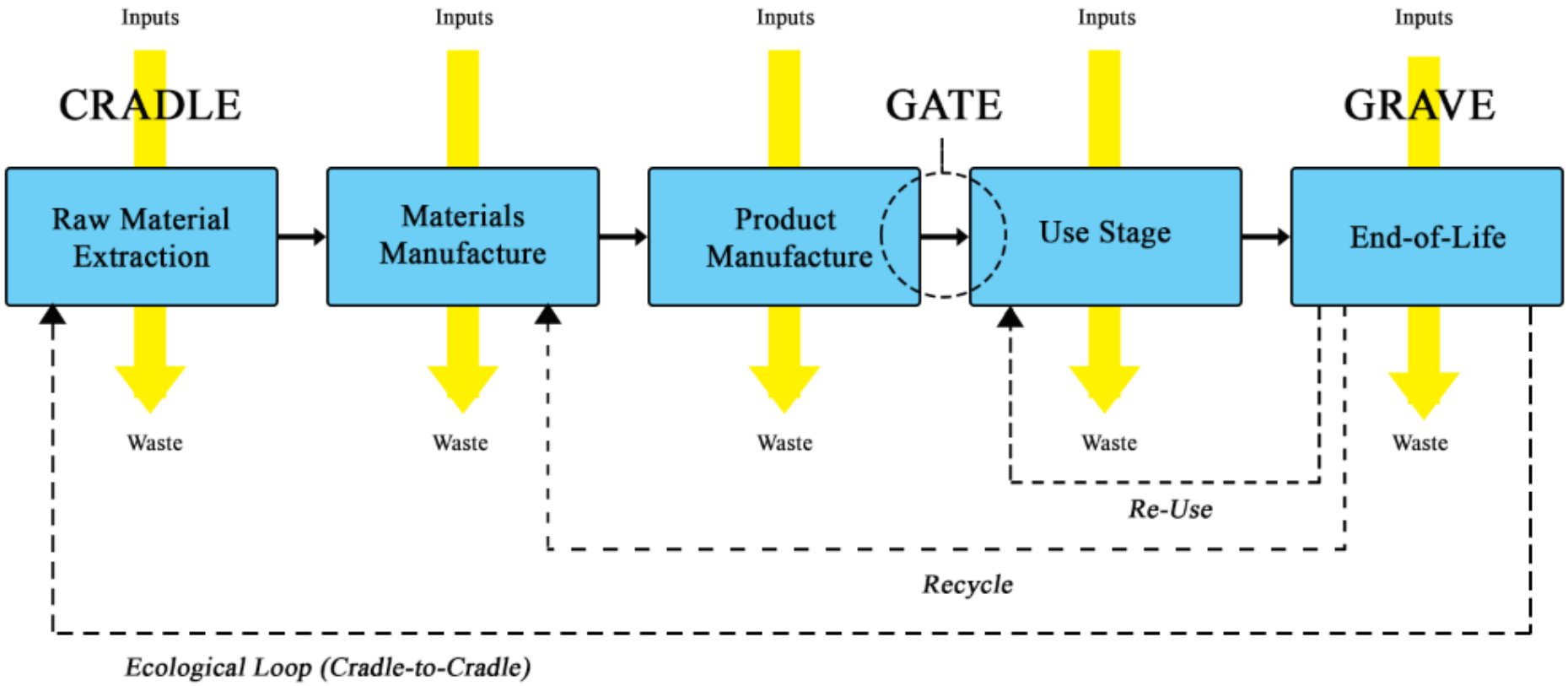


Life cycle of a product or system



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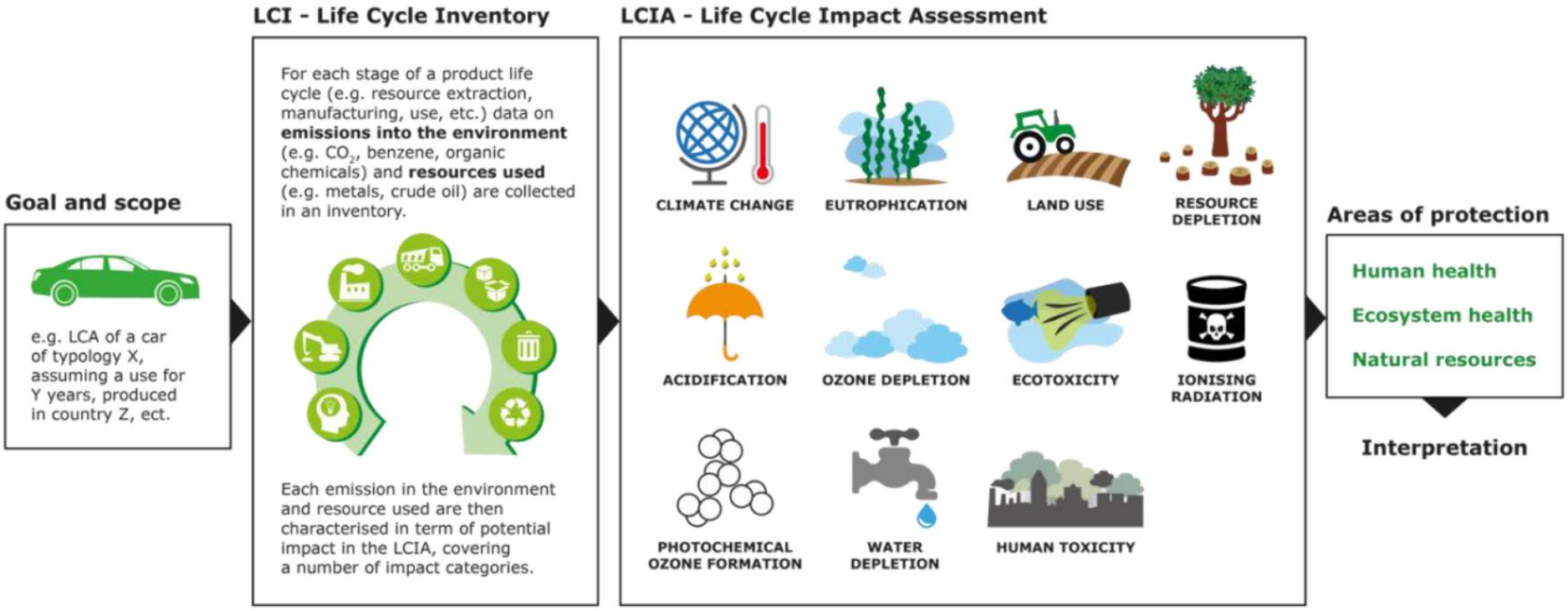
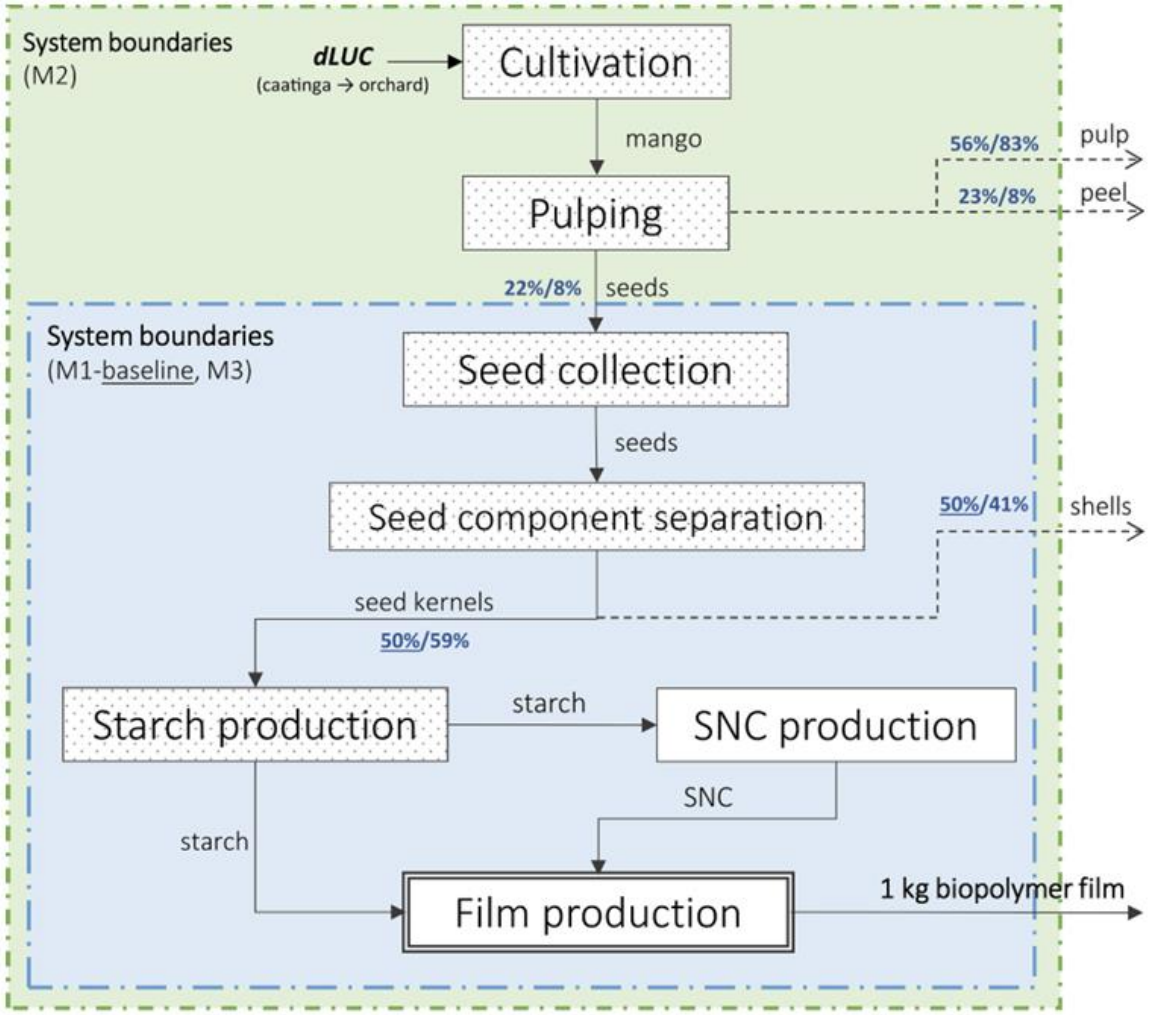
Life cycle assessment (LCA) stages



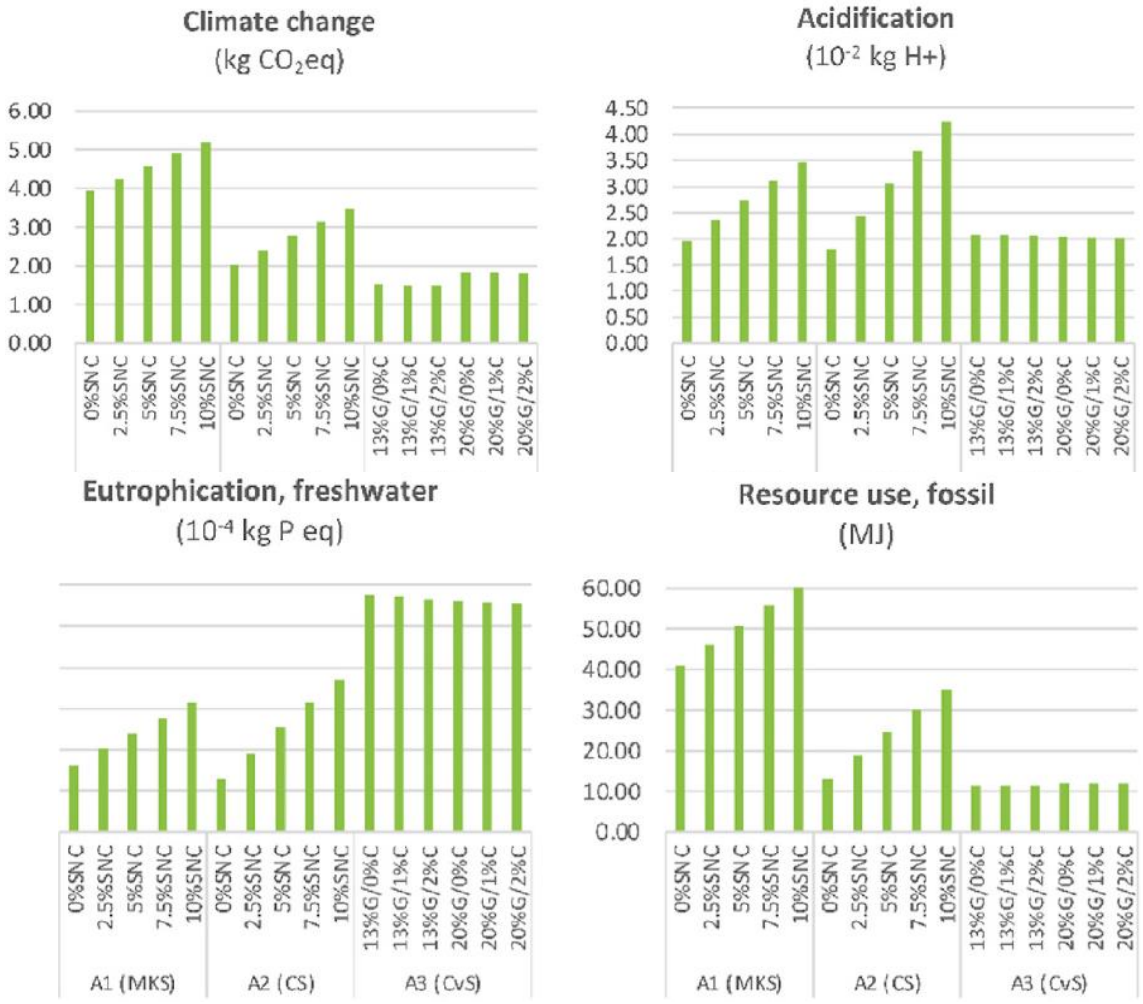
Source:
European Commission: Joint Research Centre, Cristobal-Garcia, J., Pant, R., Reale, F. and Sala, S., Life cycle assessment for the impact assessment of policies, Publications Office, 2016, https://data.europa.eu/doi/10.2788/318544

Example: starch films for food packaging



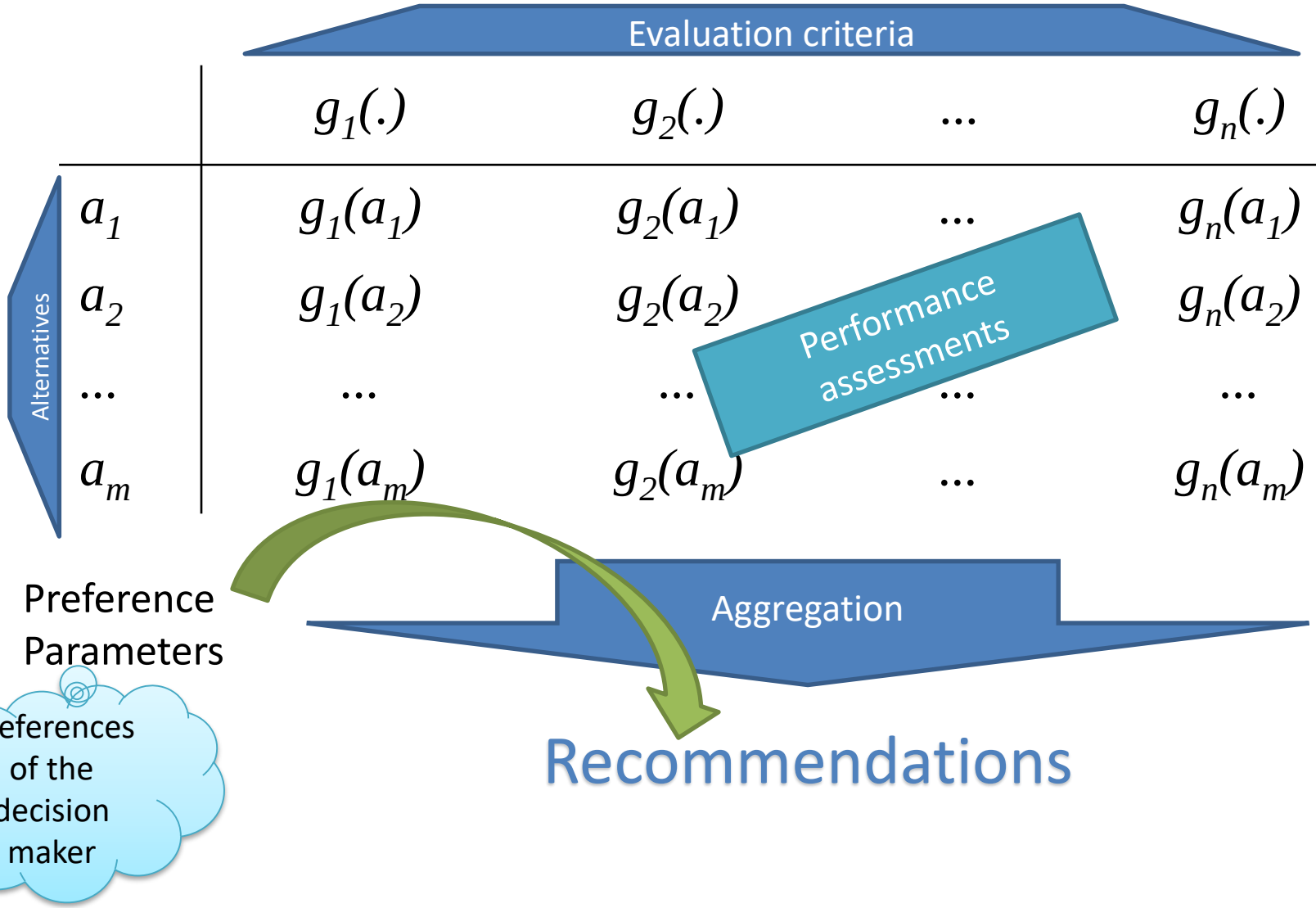
Müller-Carneiro, J., de Figueirêdo, M. C. B., Rodrigues, C., de Azeredo, H. M. C., & Freire, F. (2023). Ex-ante life cycle assessment framework and application to a nano-reinforced biopolymer film based on mango kernel. *Resources, Conservation and Recycling*, *188*, 106637.

Example: comparison of films for food packaging



Müller-Carneiro, J., Rodrigues, C., Dias, L. C., Antunes, C. H., Mattos, A. L., & Freire, F. (2023). A multi-criteria framework for the ecodesign of bio-based materials at early development stages. *Journal of Cleaner Production*, *427*, 139268.

A good client for MCDA application?

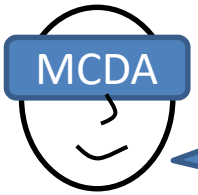


A good client for MCDA application?

Yes, but…

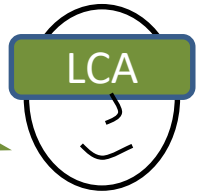
MCDA typically requires	but LCA practitioners often wish
Several alternatives being assessed (to select, to rank)	To assess a single system
Decision-maker(s) who state their preferences	To reach conclusions without a decision maker
Criteria weights elicited from decision makers	To perform a weighting of impacts "backed by science"
Discussing the type of MCDA aggregation: compensatory (additive value, AHP, …) vs. other methods (ELECTRE, PROMETHEE, TOPSIS, …)	To multiply impacts by weights (what else?)

Perspectives on weighting



Weights reflect the preferences of the decision makers, so that the recommendation suits them as well as possible.
Weighs are derived from a dialogue between them and the MCDA analyst

Weighting is optional and should not be used if the analysis intends to inform the public



Weighting can inform decision makers to find hotspots and make comparisons. Weights can be derived from:

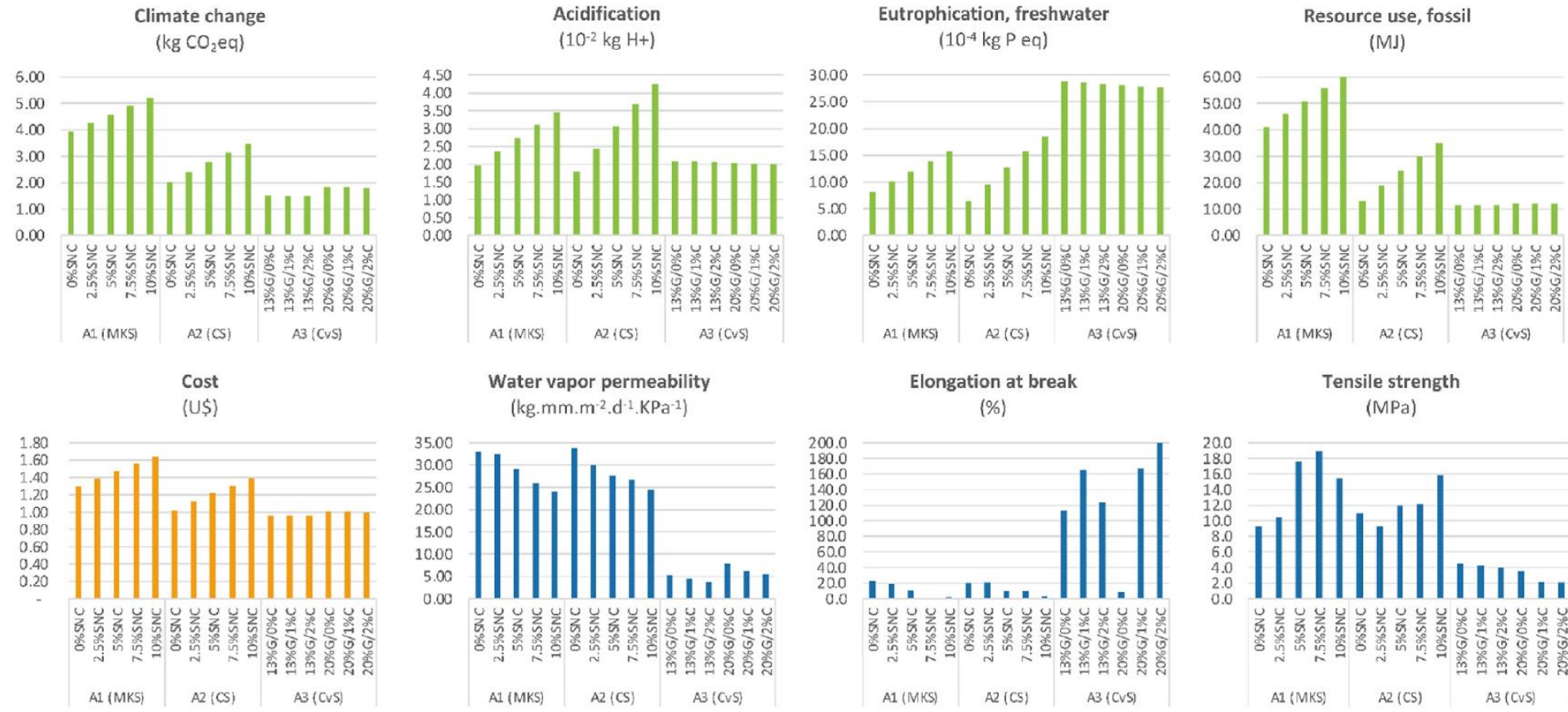
- The data (e.g. data entropy)
- Physical considerations (e.g. considering planetary boundaries)
- Economic considerations (e.g., abatement cost)
- Society's preferences (e.g., conjoint analysis)
- Decision makers, stakeholders, experts (MCDA)

OR in collaboration (1): MCDA-LCA in the MCDA spirit

Müller-Carneiro, J., Rodrigues, C., Dias, L. C., Antunes, C. H., Mattos, A. L., & Freire, F. (2023). A multi-criteria framework for the ecodesign of bio-based materials at early development stages. *Journal of Cleaner Production*, *427*, 139268.

- Comparison of films for food packaging (polyethylene vs biofilms)
- 16 alternatives/variants, some experimental (low TRL)
- LCA indicators + technical criteria + costs
- Additive aggregation model
- 3 decision-makers (DMs) of an R&D institute
- Weights were elicited from the DMs

OR in collaboration (1): MCDA-LCA in the MCDA spirit



OR in collaboration (1): MCDA-LCA in the MCDA spirit

Additive value function model

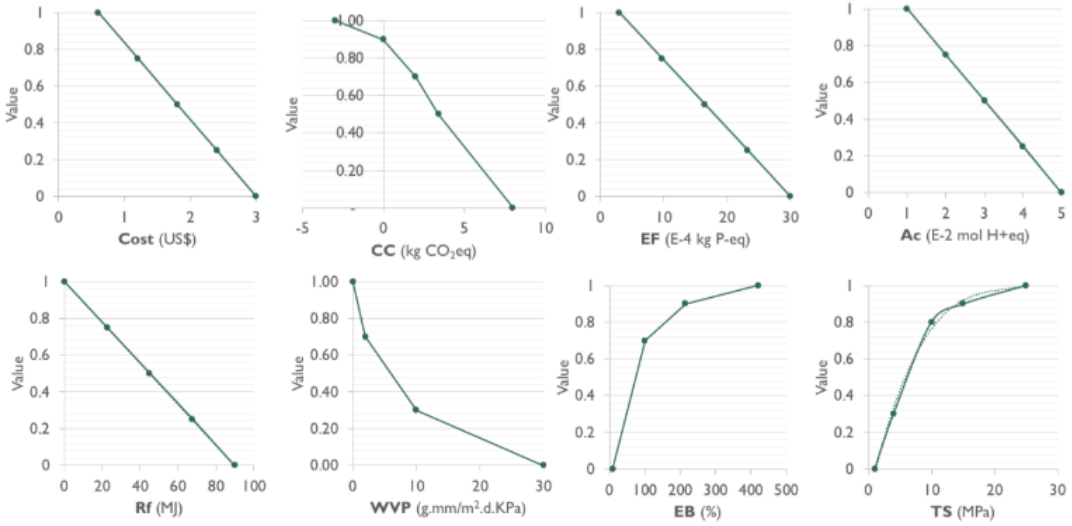
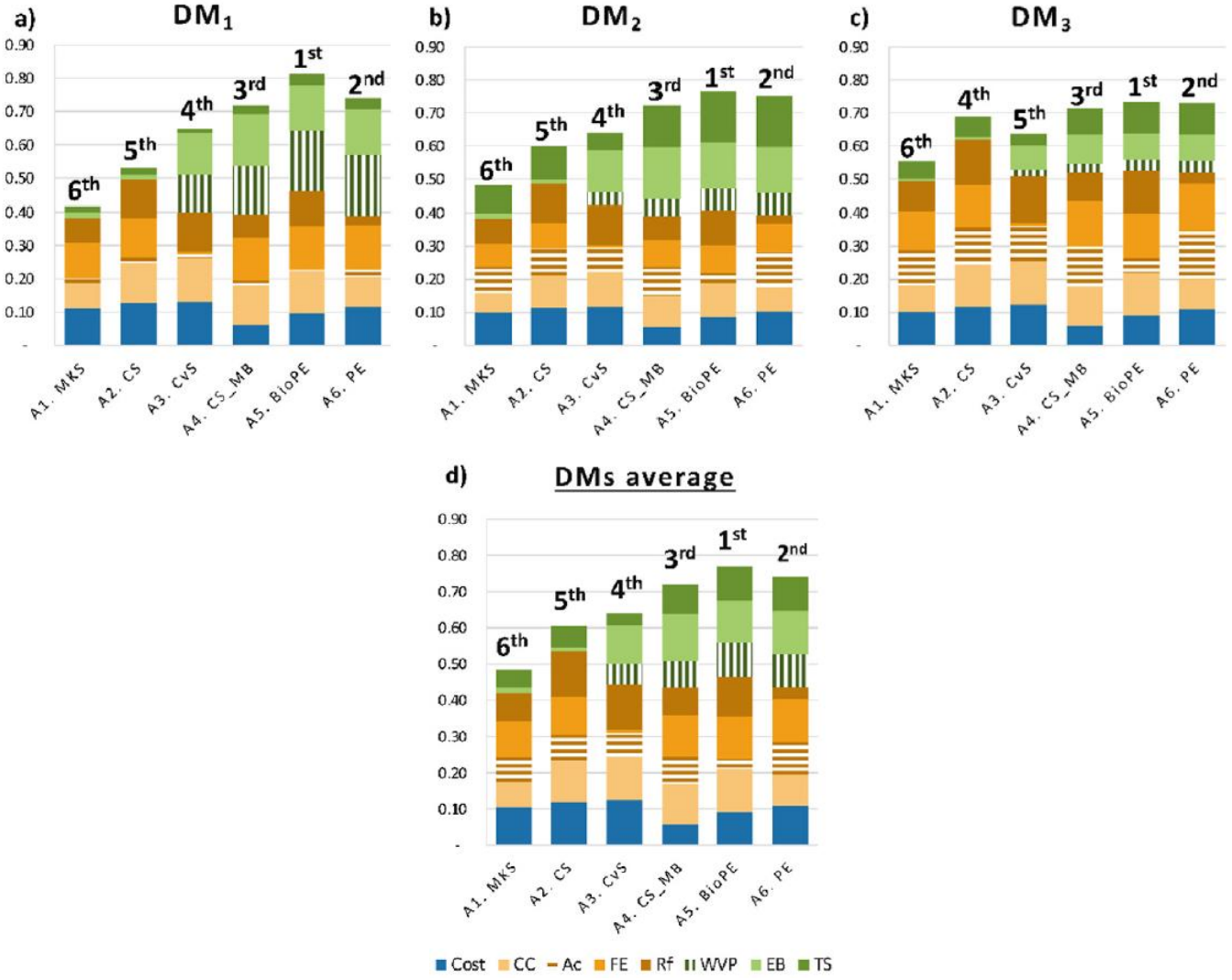


Fig. C.1. Value functions

Table C.1. Scaling coefficients (k) for each decision maker (DM) and average

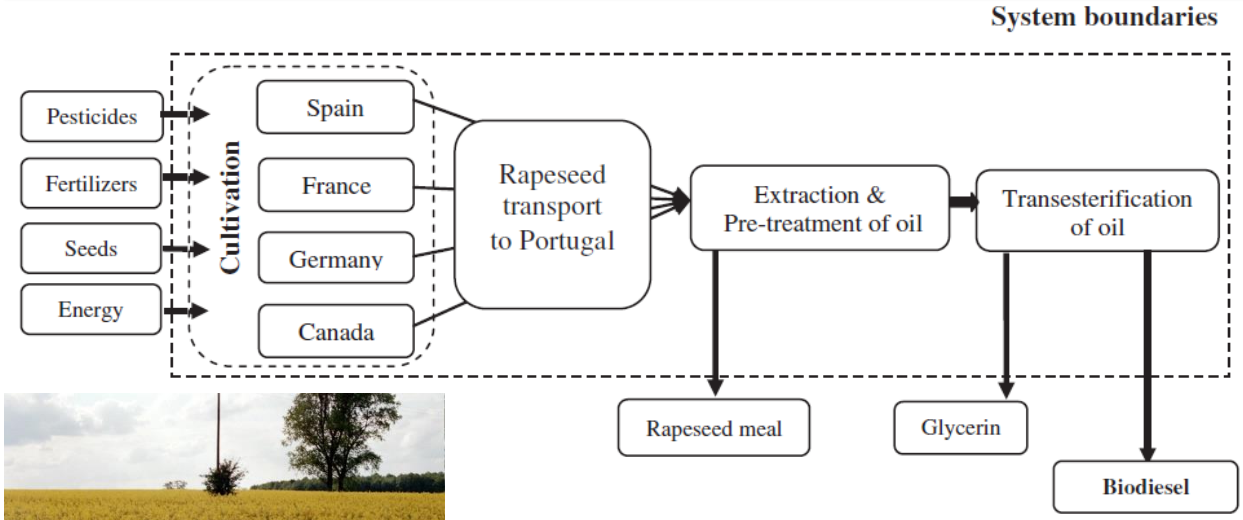
Criterion	Indicator	Unit	v=0	v=1	k			
					DM_1	DM_2	DM_3	Average
j1	Cost	US$	3	0.6	0.15	0.14	0.14	**0.14**
j2	Climate change (CC)	kg CO_2 eq	8	-3	0.17	0.14	0.18	**0.16**
j3	Acidification (Ac)	E-2 mol H+ eq	5	1	0.02	0.10	0.14	**0.09**
j4	Eutrophication, freshwater (EF)	E-4 kg P-eq	30	3	0.13	0.09	0.14	**0.12**
j5	Resource use, fossil (Rf)	MJ	90	0	0.13	0.14	0.16	**0.14**
j6	Water vapor permeability (WVP)	$g.mm.m^{-2}.d^{-1}.KPa^{-1}$	30	0.08	0.19	0.07	0.04	**0.10**
j7	Elongation at break (EB)	%	9	420	0.15	0.16	0.09	**0.13**
j8	Tensile strength (TS)	MPa	1	25	0.04	0.17	0.11	**0.11**
Total points					**1.00**	**1.00**	**1.00**	**1.00**

OR in collaboration (1): MCDA-LCA in the MCDA spirit



OR in collaboration (2): MCDA-LCA in the LCA spirit

Dias, L. C., Passeira, C., Malça, J., & Freire, F. (2022). Integrating life-cycle assessment and multi-criteria decision analysis to compare alternative biodiesel chains. *Annals of Operations Research*, 312, 1359–1374.



"Well-to-Tank"

Comparison of imported rapeseed supply chains

Only LCA indicators as criteria
Additive aggregation model
No decision maker
Stochastic weights and robustness analysis

OR in collaboration (2): MCDA-LCA in the LCA spirit

LCA (CML 2001)

AD Abiotic depletion
Ac Acidification
Eu Eutrophication
GW Global warming
OLD Ozone layer depletion
PO Photochemical oxidation

	GW ($kg\ CO_{2,eq}$)	AD ($kg\ Sb_{eq}$)	Ac ($kg\ SO_{2,eq}$)	Eu ($kg\ PO_4^-{}_{eq}$)	OLD ($kg\ CFC_{11}^-{}_{eq}$)	PO ($kg\ C_2H_4\ eq$)
CE1	4,84E-02	2,54E-04	4,52E-04	3,14E-04	4,48E-09	4,75E-06
NA	4,67E-02	2,67E-04	6,16E-04	4,03E-04	6,59E-09	8,04E-06
SE	5,26E-02	2,77E-04	5,86E-04	4,37E-04	6,02E-09	4,87E-06
CE2	4,81E-02	2,18E-04	4,91E-04	4,14E-04	4,31E-09	3,64E-06

$$u_{ij} = \frac{x_{ref,j} - x_{ij}}{x_{ref,j}}$$

	GWP	AD	Ac	Eu	OLD	PO
CE1	-0.037	0.050	0.267	0.221	0.321	0.409
NA	0.000	0.000	0.000	0.000	0.000	0.000
SE	-0.126	-0.037	0.050	-0.085	0.087	0.394
CE2	-0.031	0.185	0.204	-0.028	0.346	0.548

OR in collaboration (2): MCDA-LCA in the LCA spirit

Additive value model:

$$V(a) = \sum_{j=1}^{n} w_j v_j(a_j)$$

No specific weights vector was set, but the following restrictions were considered:

$$w_j / w_k \leq r, \qquad \forall j, k$$

$$w_1, \ldots, w_n \geq 0$$

i.e., the criteria have similar roles (all are treated in the same way), but not necessarily the same weights

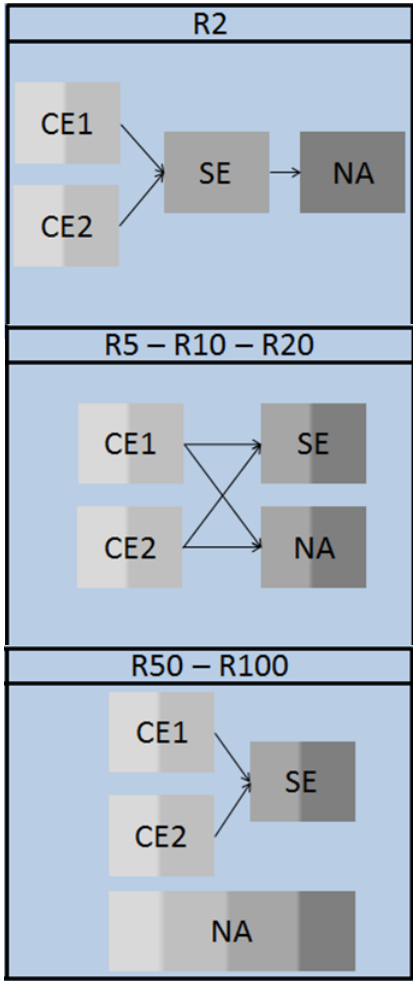
Analyses:

- Extreme ranges and value differences (robustness analysis)
- Weights Monte-Carlo simulation (stochastic analysis)

OR in collaboration (2): MCDA-LCA in the LCA spirit

Winning probability, maximum advantage, and robust rankings

		CE1	NA	SE	CE2
R2	CE1		100% | 0.247	100% |0.189	52.22% | 0.040
	NA	0% | -0.155		0% | -0.004	0% | -0.146
	SE	0% | -0.127	100% | 0.097		0% | -0.137
	CE2	47.78% | 0.033	100% | 0.265	100% | 0.178	
		CE1	NA	SE	CE2
R20	CE1		100% | 0.360	100% | 0.271	47.55% | 0.190
	NA	0% | -0.021		20.15% | 0.085	0% | -0.002
	SE	0% | -0.049	79.85% | 0.311		0% | -0.081
	CE2	52.45% | 0.118	100% | 0.465	100% | 0.235	
		CE1	NA	SE	CE2
R100	CE1		99.9995% |0.397	100% |0.298	46.96% | 0.235
	NA	0.0005% | 0.023		23,74% | 0.116	0.0097% | 0.023
	SE	0% | -0.023	76.26% | 0.374		0% | -0.063
	CE2	53.04% | 0.131	99.9903% | 0.528	100% | 0.253	



OR in collaboration (3): MCDA-Econometrics-LCA

Bayazıt Subaşı, A., Askham, C., Sandorf, E.D., Dias, L.C., Campbell, D., Taş, E.F., Itsubo, N., Nagawa, C.B., Kyarimpa, C.M., Djerma, M. & Bazie, B.S.R. (2024). Weighting factors for LCA—a new set from a global survey. *Int J of Life Cycle Assessment*, forthcoming

- To derive global weights for the three endpoint impact categories of the United Nations Environment Programme (UNEP) Life Cycle Initiative's "Global Guidance for Life Cycle Impact Assessment Indicators and Methods" (GLAM) project
- Discrete choice experiment with population samples from a subset of countries with different income level
- Econometric approach: multinomial logit model
- MCDA approach: inference of an additive value function for each individual (linear optimization)

Life Cycle Initiative

hosted by UN environment programme

OR in collaboration (3): MCDA-Econometrics-LCA

Example of a choice card

human health

ecosystem quality

natural resources and ecosystem services

OR in collaboration (3): MCDA-Econometrics-LCA

Experimental design

- three blocks of nine choice tasks each
- 3000+ respondents, randomly allocated to one of the blocks

		Reference scenario			Scenario 1			Scenario 2		
		HH	EQ	NRandES	HH	EQ	NRandES	HH	EQ	NRandES
Block 1	ct_2	0	0	0	1	−1	−0.75	−0.75	1	−0.75
	ct_10	0	0	0	−1	0.25	−0.75	0.75	−1	1
	ct_11	0	0	0	0.25	1	−0.25	−1	−1	1
	ct_12	0	0	0	0.5	0.75	−0.5	1	−1	−1
	ct_16	0	0	0	1	−0.75	−0.75	−1	1	−0.75
	ct_18	0	0	0	−0.25	−1	1	−1	1	1
	ct_20	0	0	0	1	−0.25	0.75	1	1	−1
	ct_26	0	0	0	0.75	0.75	−1	−1	−1	0.75
	ct_27	0	0	0	−1	1	0.75	1	0.75	−0.25
Block 2	ct_4	0	0	0	−0.75	−1	0.75	−1	1	1
	ct_5	0	0	0	−1	1	−1	1	−0.25	−1
	ct_8	0	0	0	−1	0.25	1	1	−1	0.75
	ct_9	0	0	0	0.75	1	−1	−1	1	1
	ct_14	0	0	0	1	0.75	−1	1	−0.5	1
	ct_15	0	0	0	0.25	−1	−1	−0.25	1	1
	ct_17	0	0	0	0.5	1	−0.75	−1	−1	1
	ct_19	0	0	0	−1	1	−0.75	1	0.75	−0.75
	ct_21	0	0	0	−1	−0.25	1	1	−1	−0.5
Block 3	ct_1	0	0	0	1	1	−1	1	−1	1
	ct_3	0	0	0	0.25	−1	−1	−0.75	−1	1
	ct_6	0	0	0	−1	1	1	0.25	−1	−1
	ct_7	0	0	0	1	−0.25	1	−0.75	1	−0.75
	ct_13	0	0	0	−0.75	1	−1	−0.25	0.75	1
	ct_22	0	0	0	−1	0.75	0.75	−1	1	−1
	ct_23	0	0	0	0.75	1	−1	1	−1	1
	ct_24	0	0	0	1	−1	−1	0.25	0.75	−1
	ct_25	0	0	0	0.75	−1	1	−0.75	1	−1

OR in collaboration (3): MCDA-Econometrics-LCA

Inferred econometric model (multinomial logit regression)	Human Health	Ecosystem Quality	Natural Resources & Ecosystem Services
All income groups	0.42 [0.41, 0.43]	0.31 [0.30, 0.32]	0.26 [0.25, 0.28]
High-income group	0.34 [0.32, 0.36]	0.41 [0.40, 0.43]	0.25 [0.23, 0.27]
Upper-middle-income group	0.36 [0.35, 0.38]	0.36 [0.35, 0.37]	0.28 [0.27, 0.29]
Lower-middle-income group	0.36 [0.35, 0.38]	0.32 [0.30, 0.33]	0.32 [0.31, 0.34]
Low-income group	0.54 [0.51, 0.56]	0.24 [0.23, 0.26]	0.22 [0.20, 0.24]

Inferred MCDA model (linear variant, using LP)	Human Health	Ecosystem Quality	Natural Resources & Ecosystem Services
All income groups	0.41 [0.40, 0.42]	0.32 [0.32, 0.33]	0.27 [0.26, 0.27]
High-income group	0.36 [0.34, 0.37]	0.39 [0.37, 0.4]	0.26 [0.24, 0.27]
Upper-middle-income group	0.39 [0.38, 0.40]	0.33 [0.32, 0.34]	0.28 [0.26, 0.29]
Lower-middle-income group	0.39 [0.38, 0.40]	0.31 [0.29, 0.32]	0.31 [0.29, 0.32]
Low-income group	0.48 [0.47, 0.49]	0.27 [0.26, 0.29]	0.25 [0.23, 0.26]

Population-adjusted	Human Health	Ecosystem Quality	Natural Resources & Ecosystem Services
Econometric	0.37	0.34	0.29
MCDA Linear	0.39	0.33	0.29

Some takeaways

- Challenging problems need OR in collaboration
- OR tools such as MCDA, simulation, robustness analysis and model inference
  - Were helpful in this context
  - Its essence was not hard to communicate
- But this type of intervention is prone to epistemological / philosophical divergence

- Keeping an open mind is essential
- For the best collaboration, OR experts need to assess their ignorance and learn about the other fields