

Weighting in the context of the EF

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Content

- Normalisation updates
- Overview on weighting approaches and evaluation thereof
- Steps for developing a weighting for the EF
- Selection of the option
- Status update on implementation of the selected option
- Questions to the audience

Normalisation

- **EU27- 2010** – issues and uncertainty
- **Global 2010** – first release provided to pilots

Next steps:

- **updated set of global factors** available soon
- Work on **planetary boundary adaptation to LCA** available soon

Int J Life Cycle Assess (2015) 20:1568–1585 1575

Table 3 Normalisation factor for EU 27 in 2010 for domestic emission and resource extraction, the scoring is given from I—highest to III—lowest

Impact category	Unit	NFs for EU 27	NFs per person	Coverage completeness ^a	Robustness inventory ^b	Robustness impact assessment ^c	Overall robustness
Climate change	kg CO ₂ eq	4.60E+12	9.22E+03	I/II	I	I	High
Ozone depletion	kg CFC-11 eq	1.08E+07	2.16E+02	II	III	I	Medium
Particulate matter	kg PM _{2.5} eq	1.90E+09	3.80E+00	I	III	I	High
Photochemical ozone formation	kg NMVOC eq	1.58E+10	3.17E+01	I	II	II	Medium
Acidification	mol H ⁺ eq	2.36E+10	4.7E+01	I	II	II	Medium
Terrrestrial eutrophication	mol N eq	8.76E+10	1.76E+02	I/II	I	II	Medium
Freshwater eutrophication	kg P eq	7.41E+08	1.48E+00	I/II	II/III	II	Medium to low
Marine eutrophication	kg N eq	8.44E+09	1.69E+01	II	II	II	Medium to low
Land use	kg C deficit	3.78E+13	7.58E+04	II/III	II	III	Low
Resource depletion water	m ³ water eq	4.06E+10	8.14E+01	III	II	III	Low
Mineral, fossil and renewable resource depletion	kg Sb eq	5.03E+07	1.01E+01	II	II	II	Medium
Human toxicity cancer	CTUh	1.88E+04	3.77E+05	III	III	II/III	Low
Human toxicity non-cancer	CTUh	2.69E+05	5.39E+04	II	III	II/III	Low
Freshwater ecotoxicity	CTLe	4.46E+12	8.94E+03	III	III	II/III	Low
Ionising radiation	kBq U ₂₃₅ eq	5.64E+11	1.13E+03	I	II	II	Medium

^aCompleteness of the dataset used for the inventory. Coverage estimate based on the extent to which the inventory data are available compared to available flows in ILCD for the specific impact category. A detailed table is reported in SI. Double values reflect the fact that the coverage is depending on completeness for different compartments

Weighting – background

- **Weighting is not mainly natural science but inherently involves value choices** that will depend on policy, cultural and other references and value systems
- no absolute “consensus” on weighting seems could be easily reached and this is relatively inevitable in all multicriteria approaches to provide better and better implementable decision support
- the objective of JRC work is to find **a convention suitable for the EF**



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Weighting – intermediate steps

- **Global Normalization factors**
ILCD compliant;
- **Expert workshop on Weighting** together with DG ENV, Nov. 2015;
- Development of a distance to target **weighting method based on EU 2020 targets and EU27 Normalization factors**;
- **Review and evaluation of LCA weighting methods** and involvement in UNEP/SETAC LC Initiative cross-cutting issues (Pizzol et al 2016);
- Development of **Normalization and Weighting spreadsheet** for testing within the pilots (excluding monetization);

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POLICIES AND SUPPORT IN RELATION TO LCA

A distance-to-target weighting method for Europe 2020

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Abstract

Purpose Distance-to-target (DTT) methods are weighting methods aimed at assessing the distance of an existing situation from a desired state (the target). Weighting factors in DTT methods could be based on indicators which are performed as normalization factors (NFs) developed for life cycle assessment (LCA). At present, some DTT weighting sets have been developed. However, there is no DTT weighting set assessing the distance of EU domestic impacts from the desired state set by EU binding or non-binding policy targets (e.g., those related to the “Climate and Energy Package” and the “Roadmap to a Resource Efficient Europe”).

Methods In the present work, a methodology to derive target reference from policy-based targets in 2020 (EU2020), both binding (A) and non-binding (B), is presented. Resulting target factors and DTT weighting factors are then compared to the current normalization factors (based on 2010 normalization reference). The resulting weighting factor (WF) sets are presented and discussed in light of their use for decision sup-

ports and allocation. The three reference sets (NFs2010, NFs2020A, and NFs2020B) show, in some impact categories, a relatively small difference. With reference to set A and set B, the result is quite similar, with the only exception of water depletion impact category, for which a very relevant change in distance when considering the effect of the non-binding target of limiting the abstraction of water resource to 28 % of the available renewable water resources. This is mainly due to the higher difficulty in deriving quantitative targets from non-binding strategies and policies rather than from binding ones.

Conclusions The resulting weighting sets present strengths and limitations. The translation of policy targets into quantitative modifications to the baseline inventories appeared to be not a straightforward task, due to several reasons discussed in the paper (e.g., not all the policy targets are expressed in quantitative terms or can be translated into quantitative reductions and modifications of the elementary flows in the existing baseline inventories).

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CRITICAL REVIEW

Normalisation and weighting in life cycle assessment: *quo vadis?*

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Abstract

Purpose Building on the historic question “*quo vadis?*” (literally “Where are you going?”), this article critically investigates the state of the art of normalization and weighting approaches under life cycle assessment. It aims at identifying progress, current practices, pros and cons, as well as research gaps in normalization and weighting. Based on this information, the article aims to provide guidance to developers and practitioners. The underlying work was conducted under the umbrella of the UNEP/SETAC Life Cycle Initiative, Task Force on Green-Casting issues in life cycle impact assessment (LCIA-Method). The original work consisted in (i) an online survey to investigate the perception of the LCIA community regarding the scientific quality and current practice concerning

normalization and weighting; (ii) a classification followed by systematic expert-based assessment of existing methods for normalization and weighting according to a set of five criteria: scientific robustness, documentation, coverage, uncertainty and complexity. **Results and discussion** The survey results showed that normalized results and weighting scores are perceived as relevant for decision-making, but further development is needed to improve uncertainty and robustness. The classification and systematic assessment of methods allowed for the identification of specific advantages and limitations. **Conclusions** Based on the results, recommendations are provided to practitioners that desire to apply normalization and weighting as well as to developers of the underlying methods.

Keywords Life cycle impact assessment · Indicators · Multi-criteria decision analysis · Survey · Review

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1 Normalization and weighting, what is the problem?

According to the ISO 14044 standard on life cycle assessment (LCA), normalization is defined as “calculating the magnitude of category indicator results relative to a reference performance” and weighting as “converting and possibly aggregating indicator results across impact categories using normalized factors based on value choices” (ISO 2006a, boldface). Such definitions are also discussed in

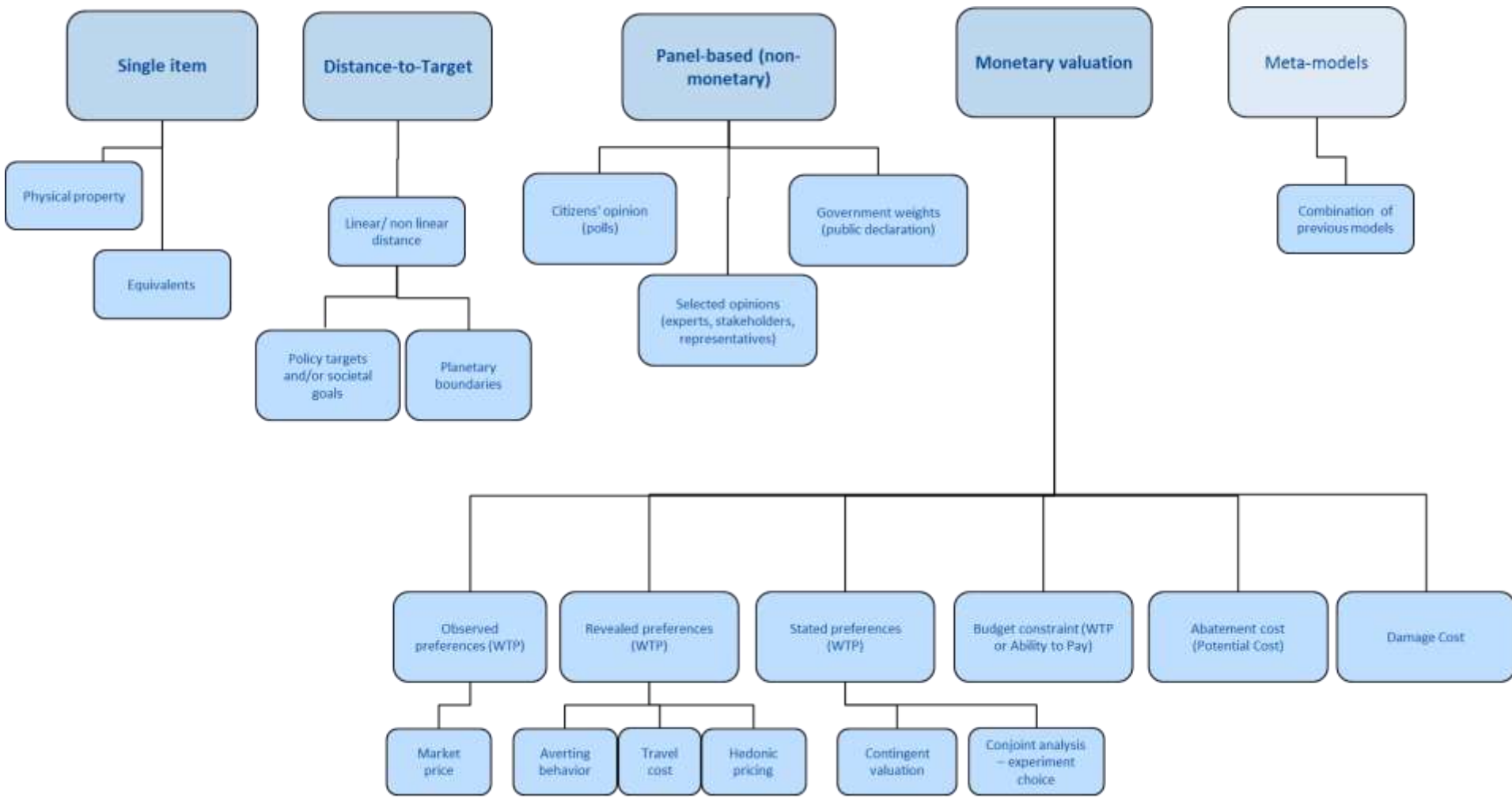
I	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	WEIGHTING APPROACHES TYPE AND METHODS									
																	SINGLE SCORE METHODS ¹						MULTIPLE INDICATORS METHODS – NO NORMALIZATION			
																	Distance to target			Damage oriented			Point based		Damage oriented	
Policy targets	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries	Iterative boundaries											
	Castellani et al. 2015 (MFA)	Castellani et al. 2015 (MFA)	EU2020	Incerti et al. 2015	Hoffler et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015	Pizzol et al. 2015										
	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet										
1	ILCD Impact Category	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD	ILCD										
2	Climate change	kgCO ₂ eq	7.00	8.42	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00										
3	Climate depletion	kgCO ₂ eq	8.42	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00										
4	Human toxicity, cancer effects	CTUh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
5	Human toxicity, non-cancer effects	CTUh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
6	Particulate matter respiratory inorganic	kgPM10 eq	7.40	8.42	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00										
7	Acidifying equivalent, human health	kgSO ₂ eq (air)	0.75	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00										
8	Particulate matter, coarse fraction, human health	kgPM10 eq (air)	7.40	8.42	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00										
9	Acidification	kgSO ₂ eq	2.10	2.40	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00										
10	Acidification terrestrial	kgSO ₂ eq	2.10	2.40	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00										
11	Acidification freshwater	kgSO ₂ eq	2.10	2.40	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00										
12	Acidification marine	kgSO ₂ eq	2.10	2.40	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00										
13	Land use	kgCO ₂ eq	4.40	5.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00										
14	Ecotoxicity freshwater	kgC ₆₀ eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
15	Resource depletion	kgC ₆₀ eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
16	Resource depletion mineral	kgC ₆₀ eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
17	Resource depletion fossil and renewable	kgC ₆₀ eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

¹ Note
² The colors in the table are indicative: light pink, meaning that the higher the weighting factor the redder and the lower the greener.
³ Not available according to the original method

Weighting methods



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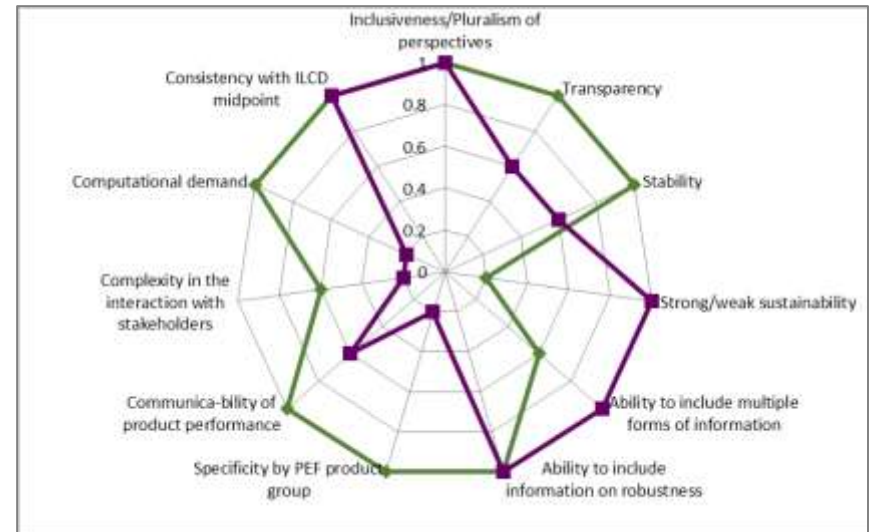
Weighting- results of evaluation

- All **weighting methods have technical pros and cons**, some are more complete than others in terms of coverage of ILCD impact categories;
- they adopt **inherently incompatible (or complementary) perspectives**;
- **Monetization is apart from a few methods limited in coverage and/or based in parts on inherent value choices**;
- **both Global normalization factors and sensitivity analysis on weighting methods are recommended within the UNEP/SETAC recommendations**;
- need for exploring combination of available perspectives as well as robustness levels

Options for weighting

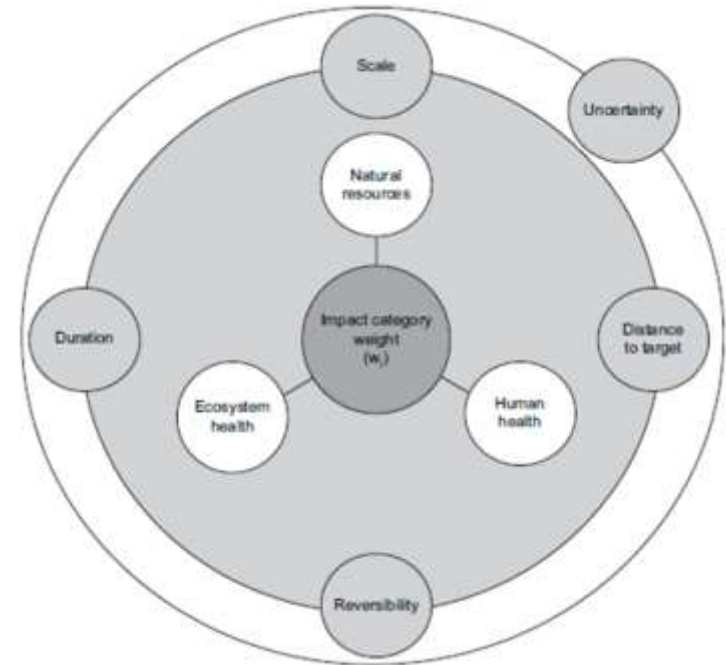
From the evaluation of the options it emerged that a promising approach could be inspired by the **metamodel of Soares et al. (2006)**

- **Four options have been developed** and presented in the report for the TAB.
- They were evaluated based on **criteria emerged from the workshop with DG ENV** in november 2015 such as: feasibility, stakeholder involvement, computational demand, consistency with ILCD midpoint indicators etc.



Building on Soares et al 2006

- The metamodel account for aspects related to
 - environmental relevance**, such as: **reversibility, scale, duration;**
 - socio-political relevance**, such as: **distance to target;**
 - scientific robustness**, such as: **uncertainty**
- Based mainly on expert judgment
- Several criteria may be considered for building a final weighting set



Assessment levels for the seven criteria

Criteria i							Evaluation ($e'_{i,j}$)			Certainty ($e_{i,j}$)		
Environmental consequences			Level of environmental consequences									
C1	C2	C3	C4	C5	C6	C7				High	Medium	Low
Very high repercussion			Global	Very long term	Irreversible	Far greater	100–80	100	90	81		
Rather high repercussion			Continental	Long term	Solely artificial (partial)	Greater	80–60	80	70	61		
Mild repercussion			National	Medium term	Solely artificial (complete)	Of the same order	60–40	60	50	41		
Low repercussion			Regional	Short term	Natural (partial)	Smaller	40–20	40	30	21		
Almost imperceptible			Local	Very short term	Natural (complete)	Far smaller	20–1	20	10	1		
Non-existent			Punctual	Momentary	Natural instantaneous	Infinitely smaller	0–1	0	1	1		

Four options

Option	Name	Description
1	Flat weighting at the midpoints	Use of the characterization table for ICs based on (Soares et al. 2006) and comparison on 15 ICs in one round. Only experts in LCA can be involved. It uses weighted average as aggregation method.
2	Weighting at the endpoints	Use of mid-to-endpoint factors which lead to the calculation of 3 endpoint indicators, for each area of protection (human health, ecosystem quality, resources). Weights are elicited only for the endpoints and experts in LCA, EF stakeholders and public can be involved. It uses weighted average as aggregation method.
3	Hierarchical weighting at midpoint and endpoint	Two step procedure, establishing one set of weighting factors on the midpoint ICs clustered per endpoint and one set of weighting factors on the 3 endpoints. The two sets of weighting factors are combined in an overall scheme. For the weighting at midpoint level, several options exist, amongst others inspired by Soares et al 2006. Experts in LCA, EF stakeholders and public can be involved. It uses weighted average as aggregation method.
4	Outranking matrix	Use of the characterization table for ICs based on (Soares et al. 2006) and comparison on ICs clustered per endpoint. Experts in LCA, EF stakeholders and public can be involved. It uses a partially-compensatory method.

Selected option (3) : **Hierarchical weighting** **at midpoint and endpoint**

- This option tackles the drawbacks of the other options and combines the options to reduce the preference elicitation burden on the experts as well as to include the general public and non LCA-experts from EF stakeholders.
- Two-step procedure, establishing one set of weighting factors on the midpoint ICs clustered per endpoint and one set of weighting factors on the 3 endpoints.

Key features of the selected option

Two sets of weighting factors are combined in an overall scheme.

For the weighting at midpoint level, several options exist, amongst others inspired by Soares et al 2006.

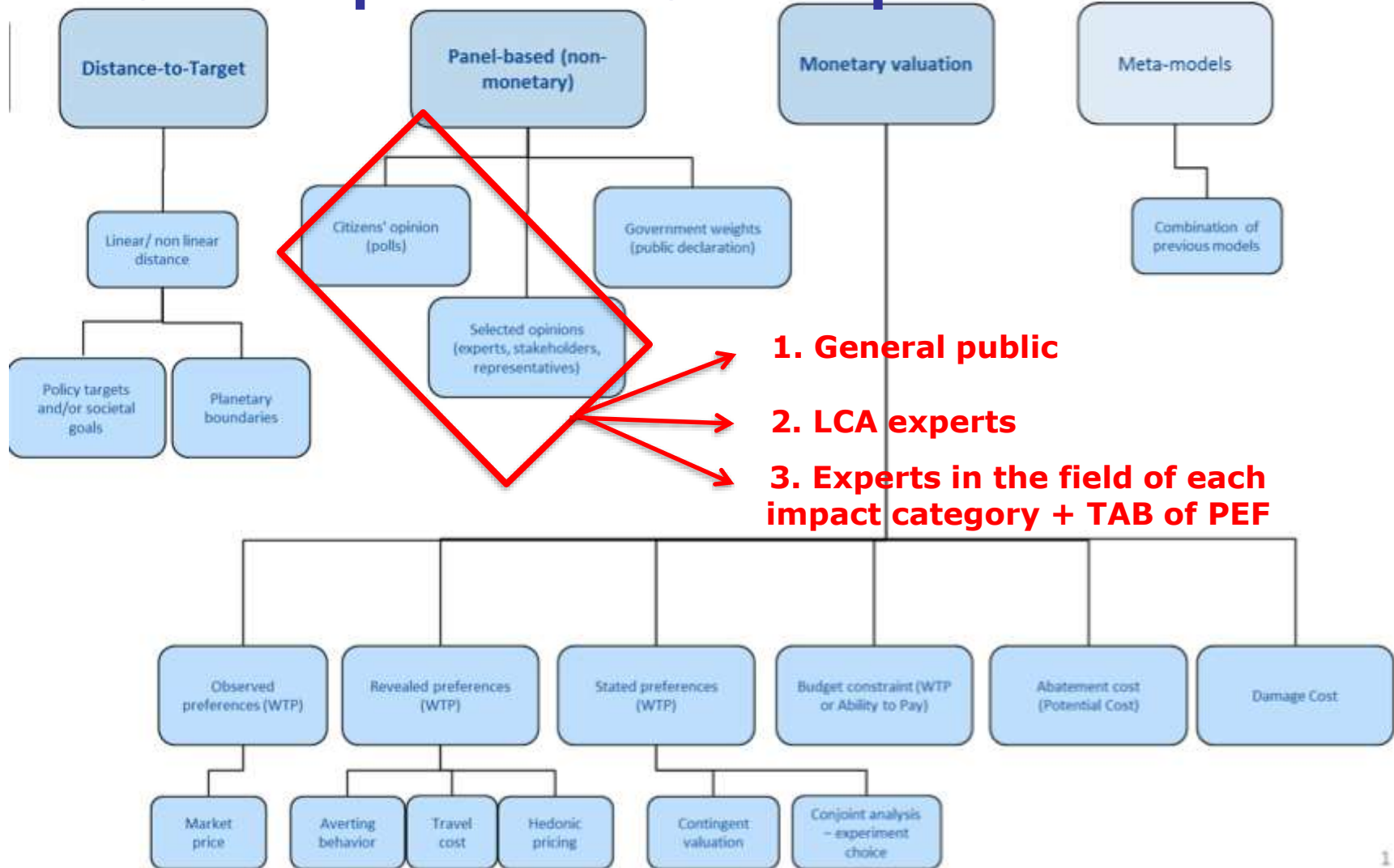
Experts in LCA, EF stakeholders and public can be involved.

Endpoint	Midpoint
Human Health	<ul style="list-style-type: none"> Climate change Ozone depletion Human toxicity, cancer effects Human toxicity, non-cancer effects Ionizing radiation, human health Particulate matter/Respiratory inorganics Photochemical ozone formation, human health
Natural Environment	<ul style="list-style-type: none"> Acidification Climate change Ecotoxicity freshwater Eutrophication terrestrial Eutrophication freshwater Eutrophication marine Land use Resource use: water
Natural Resources	<ul style="list-style-type: none"> Climate change Land use Resource use: water Resource use: metals and minerals Resource use: fossil fuels



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Use of multiple stakeholders' preferences



Implementation strategy of the option 3

- Questionnaire for the public on midpoint and endpoint indicators → **Weighting set at mid and endpoint**
- Questionnaire for the LCA experts on midpoint and endpoint indicators → **Weighting set at mid and endpoint**
- Webinar with impact assessment experts providing input on the criteria based on Soares for each of the midpoint categories → **Weighting set related to Soares's criteria**

Questionnaires

Two different target groups have been approached using questionnaires:

- the **general population** online panel of a representative sample

During the life cycle of products resources and energy are used and emissions into air, water and soil are created leading to negative impacts on our health, our environment and the future availability of resources. We would like you to order these three impacts in terms of seriousness or concern to you.

Please give the one which is of most concern to you a rank of 1. Then give a rank of 2 to the impact that is of the next highest concern and a rank of three to the final impact.

- ... damages your health
- ... damages your environment
- ... uses resources

- and **LCA experts** (through JRC's mailing list, public LCA mailing lists, social networks)

Supported by open evidence and London school of economics (LSE)

Process for the web-based questionnaire

- Step 1 respondents swing the weightings of the three end points:
 - Most relevant end-point is set to 100 points
 - participants then have to rate the other 2 endpoints relative to the most relevant one
- Step 2 comprises the ranking of the mid points:
 - Participants are asked to select the most relevant mid-point of the top endpoint they selected in step 1.
 - Following the same logic applied in Step 1, the most relevant mid-point gets 100 points and the others are rated relative to number 1.

Status update: General public survey

- random sample of ~400 individuals from 6 countries: Germany, Italy, Spain, UK, Poland, France
- Total of ~2400 responses achieved
- Gathering the data across countries made it possible to ensure the validity and possibility to generalise about awareness and understanding of the impact categories as well as about the broader environmental awareness
- Survey is closed (Jan 18), results are in and are about to be evaluated

Status update: LCA experts survey

- 5820 experts were invited (mainly via existing LCA related email lists)
- 1053 opened the questionnaire
- 518 completed the questionnaire
- Survey is closed (Feb 13), results are in and are about to be evaluated

Status update: Soares inspired survey of impact assessment related experts

- ~ 600 people invited (on Feb 17) to participate
- People involved in LCIA related research activities, LCIA method developers, experts in the impact categories, EF TAB members
- 2 different dates for webinar are on offer (Feb 28, March 1)
- Questionnaire to be filled in during the webinar or latest by March 3
- Input requested on science based aspects for each of the impact categories as well as on the weighting of the different aspects



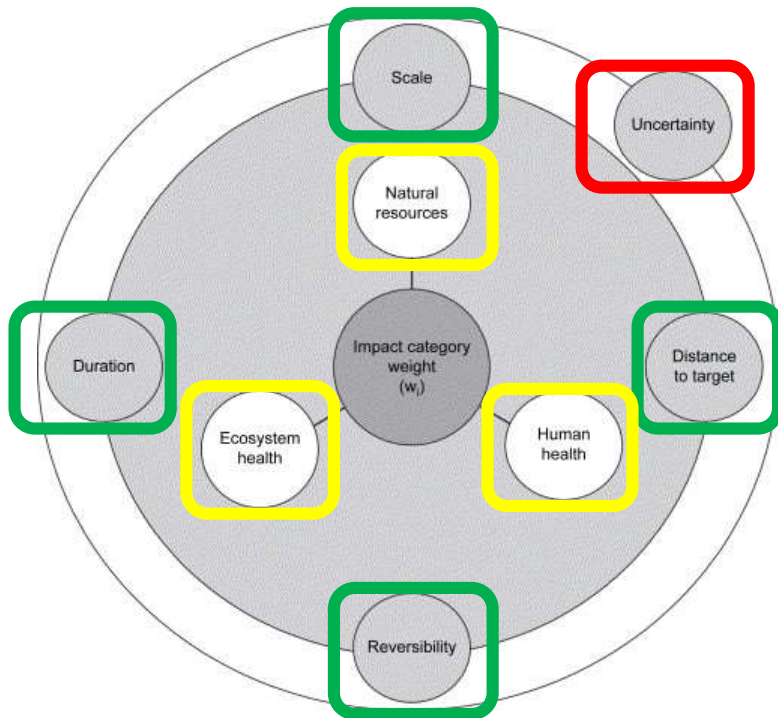
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Table for experts inspired by Soares approach

Used in webinar with impact assessment experts

Impact category	Scale of impacts	Spread of pressure	Duration of impact	Reversibility	Planetary boundary	Effect on human health	Effect on ecosystem quality	Effect on resources availability
Climate change	Global	Globally present	Very long term	Natural (partial)	Greater	High	Low	Medium
Ozone depletion	Global	Highly diffused	Medium term	Natural (complete)	Far smaller	Very high	High	Not-existing
Human toxicity, cancer effects	Global	Widespread	Very long term	Irreversible	Greater	Very high	Not-existing	Not-existing
Human toxicity, non-cancer effects	Global	Widespread	Long term	Solely artificial (partial)	Of the same order	Very high	Not-existing	Not-existing
Particulate matter/Respiratory inorganics	Local	Widespread	Long term	Solely artificial (partial)	Greater	High	Not-existing	Not-existing
Ionizing radiation, human health	Global	Little diffused	Very long term	Irreversible	Of the same order	Very high	Low	Not-existing
Photochemical ozone formation, human health	Local	Medium diffused	Long term	Solely artificial (partial)	Of the same order	High	Low	Not-existing
Acidification	Regional	Highly diffused	Medium term	Natural (partial)	Far smaller	Not-existing	High	Medium
Eutrophication terrestrial	Regional	Highly diffused	Medium term	Natural (partial)	Far greater	Not-existing	High	Medium
Eutrophication freshwater	Regional	Highly diffused	Medium term	Natural (partial)	Far greater	Not-existing	High	Medium
Eutrophication marine	Regional	Medium diffused	Medium term	Natural (partial)	Far greater	Not-existing	High	Medium
Land use	Local	Little diffused	Long term	Natural (partial)	Of the same order	Not-existing	Very high	High
Ecotoxicity freshwater	Global	Little diffused	Long term	Solely artificial (partial)	Far greater	Not-existing	Very high	High
Resource depletion water	National	Little diffused	Medium term	Solely artificial (partial)	Far smaller	Very high	Very high	Very High
Resource depletion, mineral	Global	Little diffused	Very long term	Irreversible	n.a.	Low	High	Very High
Resource depletion, fossils	Global	Little diffused	Very long term	Solely artificial (partial)	n.a.	Low	High	Very High

Option 3c: Inclusion of aspects from Soares

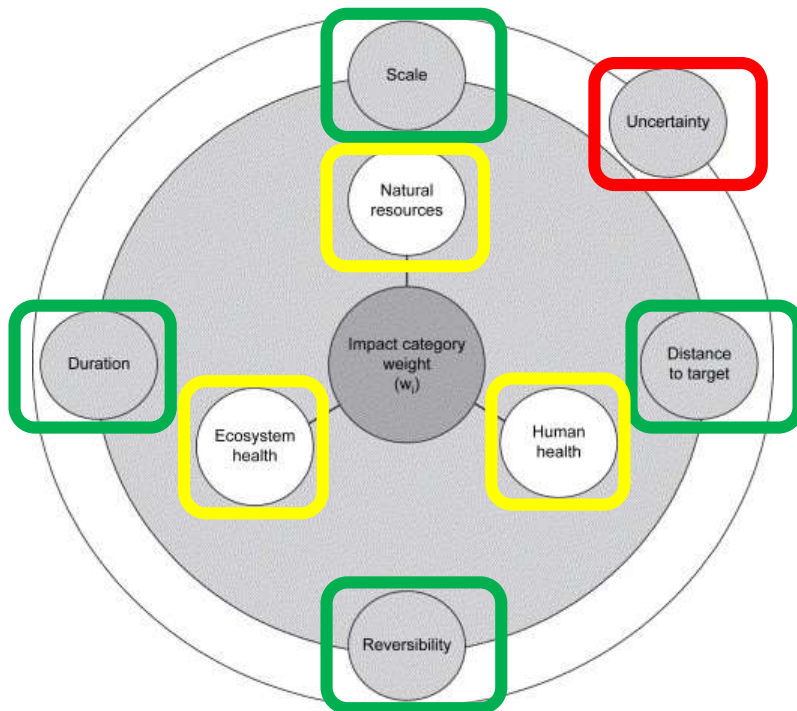


- **Expert weighting based on the scoring of the criteria (via webinars)**

- **Captured by weighting of endpoints (based on questionnaires)**

- **Captured by the robustness factors in interpretation or to be assessed by experts in webinar**

Option 3d: Inclusion of aspects from Soares



- Embedded in the planetary boundaries concept, used for normalisation

- Captured by the two levels weighting approach (midpoint/ endpoint) based on questionnaires (to public/experts)

- Captured by robustness factors in interpretation

Linking the bits and pieces I

Different combinations of the results from the Soares based approach with other aspects are possible...

Normalisation

Weighting

Global

Planetary
boundaries
as distance
to target

Public and
expert elicitation

Uncertainty
of LCIA
models

Linking the bits and pieces II

Different combinations of the results from the Soares based approach with other aspects are possible...

Normalisation

**Planetary
boundaries as
normalisation**

Weighting

**Public and
expert
elicitation**

Robustness factors (interpret.)

**LCIA models and
normalisation
robustness/ data
availability**

Building on a table assessing the uncertainties of LCIA/normalisation/ inventory

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Table 3 Normalisation factor for EU 27 in 2010 for domestic emission and resource extraction, the scoring is given from I—highest to III—lowest

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Acidification	mol H ⁺ eq	2.36E+10	4.3E+01	I	II	II	Medium
Terrestrial eutrophication	mol N eq	8.76E+10	1.76E+02	I/II	I	II	Medium
Freshwater eutrophication	kg P eq	7.41E+08	1.48E+00	I/II	II/III	II	Medium to low
Marine eutrophication	kg N eq	8.44E+09	1.69E+01	II	II	II	Medium to low
Land use	kg C deficit	3.78E+13	7.58E+04	II/III	II	III	Low
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^aCompleteness of the dataset used for the inventory. Coverage estimate based on the extent to which the inventory data are available compared to available flows in ILCD for the specific impact category. A detailed table is reported in SI. Double values reflect the fact that the coverage is depending on completeness for different compartments

Weighting – questions to the audience I

What is the most appropriate approach?

- Is the planetary boundaries concept 'fit for purpose' as normalisation or should it be – as distance to target – form a part of the weighting?
- Should uncertainty of LCIA models be a part of weighting step or should it be together with robustness of normalization factors and kept for the interpretation?
- In a comparative context: would you base your decision for or against a product rather on differences which are robust or on differences in impact categories with high uncertainty?

Weighting – questions to the audience II

- Does the relevance of the midpoint categories for the endpoints human health, ecosystem health, and natural resources sufficiently describe their severity?
- Or should severity be assessed as one of the weighting parameters independent from the 3 endpoints?

Weighting – questions to the audience III

What is the most appropriate approach?

- What is the best way (if any) to combine the resulting weighting sets from
 - **Public (midpoint and endpoint questionnaire)**
 - **LCA experts (midpoint and endpoint questionnaire)**
 - **Impact assessment experts (inspired by Soares approach)**
- Or should the 3 weighting sets remain separated and the decision which one to choose left to decision makers?

In any case what we will provide is an input to decision makers, the decision on a weighting approach will be taken by policy makers

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