



SiToLub

*SIMULATION TOOLS FOR
THE DESIGN OF SAFE AND
SUSTAINABLE LUBRICANTS*

Feedback to the JRC on behalf of the SiToLub project

as of May 2026,
including feedback from the JRC

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Introduction to the Issue

In the application of the Safe and Sustainable by Design (SSbD) framework to benchmarking scenarios within the SSbD approach, several methodological inconsistencies arise. These relate primarily to the aggregation, clustering, and weighting of indicators across environmental, social, and economic dimensions. As a result, key principles such as transparency, reproducibility, and comparability are difficult to ensure particularly when Multi-Criteria Decision Analysis (MCDA) is applied across different assessment levels. A central ambiguity concerns the appropriate level of aggregation. Parts of the SSbD methodological guidance (e.g., scoring examples) suggest that evaluation should remain at the indicator level. However, other sections implicitly introduce clustering into thematic groups. This is common practice in most recent SSbD framework, for example:

Environmental (LCA) impact categories are often grouped into:

- Ecosystem quality and biodiversity
- Pollution
- Resources
- Climate change
- Toxicity

Safety and hazard indicators are structured into:

- Human health
- Environmental aspects
- Physical hazards

At the same time, the 2024 SSbD methodological guidance for chemicals and materials appears to favour (unweighted) aggregation, while more recent interpretations of the framework suggest that grouping of indicators may not be recommended at all. This creates uncertainty not only about whether clustering should be applied, but also at which stage of the assessment (e.g., indicator, midpoint, or endpoint level).

A related issue concerns the role of weighting. In principle, standards such as ISO 14044 discourage weighting due to its inherent subjectivity. The challenge becomes more pronounced when integrating multiple sustainability dimensions. The SSbD framework requires the combined consideration of Environmental Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). However, these domains differ significantly in how they handle aggregation and weighting. This is particularly evident in the case of social sustainability assessment. While recent SSbD guidance suggests indicator-level evaluation, practical implementations typically rely on:

- Grouping of social indicators
- Weighted aggregation into composite scores
- Compliance-oriented scoring approaches

Moreover, widely used S-LCA databases already apply pre-aggregated or semi-aggregated indicators, reinforcing the practical importance of clustering and weighting despite the lack of explicit methodological alignment within SSbD. As shown in the limited number of studies that applied benchmarking with the context of SSbD, it is not consistently applied:

Topic	Scope	Approach for Decision Making	Scoring	Source/DOI
Plasticizer for PVC	LCA	Grouped, non-weighted	'old' JRC scoring	Tosches et al., 2026, IEAM, vjag059
Graphene for Windmill	LCA	Grouped, non-weighted	used own scoring	Pitaro et al., 2025, Environ. Int. 197, 109345
Anti-Stick Coatings	S-LCA	Grouped, weighted	As in SHBD	Devecchi et al., 2026, J. Sustain. Res. 8, e260023
Flame Retardant	LCA	Grouped, non-weighted	used own scoring (Level 0 = -10%)	Maga et al., LCM 2025
None	LCA, LCC	Grouped, can be weighted	Unknown	SURPASS project, D5.3 SURPASS User Manual, p 23.
wastewater treatment	LCA	Grouped, unweighted	most likely old JRC	Fuentes et al., 2026, Green Chem. D5GC06437F
Coatings	LCA	Grouped, non-weighted	used own scoring	BIO-SUSHY LCA seminar, 2026

Hence, in practical benchmarking applications, some level of aggregation is unavoidable, particularly for communication and decision support. This raises a fundamental methodological question: **How to move consistently from detailed indicator-level results to aggregated scores suitable for comparison.** Currently, the SSbD framework does not provide clear guidance on:

- Whether grouping should be applied
- At which level aggregation should occur for benchmarking
- How (or whether) weighting should be implemented

The following sections outline the approaches considered for environmental weighting and discuss the associated challenges encountered in applying them within the SSDD benchmarking framework.

1. Environmental LCA

1.1. Approaches to Environmental Weighting

With regard to the environmental dimension, different methodological approaches can be applied to translate detailed impact assessment results into benchmarking outcomes within the SSbD context. In general, three main approaches can be distinguished, which will be presented in the following sections. First, an indicator-level benchmarking approach can be applied, where results are evaluated directly at the level of individual environmental indicators, followed by a subsequent aggregation step. Second, a cluster-based approach with equal weighting can be used, in which Environmental Footprint (EF) impact categories are grouped into thematic clusters and treated with equal importance across clusters. Third, a weighted EF grouping approach can be applied, where established EF weighting factors are used to aggregate impact categories and derive comparative results. These approaches differ fundamentally in terms of aggregation logic, treatment of weighting, and interpretability of results, and thus have direct implications for the robustness and comparability of environmental benchmarking within SSbD. Table 1 summarises the normalisation and weighting factors applied in the second and third approach described previously. Both approaches apply normalization factors for an average person-equivalent in the world and for the year 2010, as obtained from official JRC tables for EF 3.1. While the second approach applies an equal weighting approach on cluster level, followed by an equal weighting of contributing impact categories within those clusters, the third approach uses weighting factors based on an expert survey conducted by the JRC and published in the same tables. To obtain normalised and weighted values, the life cycle impact assessment results are divided by the normalisation factor before multiplication with the respective weighting factor. The normalised and weighted results obtained in the dimensionless unit of points (pt) are then grouped into the SSbD-conform clusters of Climate change, Toxicity, Pollution and Resources. These values and especially the weighting factors are not backed-up with scientific models and can be subjective. Nevertheless, they are useful to benchmark environmental performance of an SSbD benchmarking case.

Table 1: For SSbD conform impact assessment with clustering of impact categories an equal weight but also the EF weighing factors.

SSbD cluster	Impact category	Normalization [EF Unit/person]	EF Weighting [%]	Equal Weighting [%]
Climate change	Climate change	7.56E+03 [kg CO ₂ eq/person]	21.06	25.0
Toxicity	Human toxicity non-carcinogenic	1.29E-04 [CTUh/person]	1.84	8.33
Toxicity	Human toxicity carcinogenic	1.73E-05 [CTUh/person]	2.13	8.33
Toxicity	Freshwater ecotoxicity	5.67+04 [CTUe/person]	1.92	8.33
Pollution	Particulate matter	5.95E-04 [disease inc/person]	8.96	3.13
Pollution	Eutrophication marine	1.95E+01 [kg N eq/person]	2.96	3.13
Pollution	Ozone depletion	5.23E-04 [kg CFC-11 eq/person]	6.31	3.13
Pollution	Eutrophication freshwater	1.61E+00 [kg P eq/person]	2.80	3.13
Pollution	Eutrophication terrestrial	1.77E+02 [mol N eq/person]	3.71	3.13
Pollution	Acidification	5.56E+01 [mol H ⁺ eq/person]	6.20	3.13
Pollution	Photochemical ozone formation	4.09E+01 [kg NMVOC eq./person]	4.78	3.13
Pollution	Ionising radiation	4.22E+03 [kBq U235 eq/person]	5.01	3.13
Resources	Land use	8.19E+05 [Pt/person]	7.94	6.25
Resources	Metals and minerals	6.36E-2 [kg Sb eq./person]	7.55	6.25
Resources	Non-renewable energy	6.50E+4 [MJ/person]	8.32	6.25
Resources	Water use	1.15E+04 [m ³ /person]	8.51	6.25

To derive a single pass or fail score for the environmental dimension, indicator and cluster results then need to be aggregated further, which can be achieved through MCDA approaches.

According to the JRC (JRC. EC., 2025), the final score can be derived from relative improvements:

Table 2: Scores for the LCA results of the chemical being assessed in each impact category, based on the JRC.

Range of values	Score	Class of performance	Benchmark	Representative system
LCA result > maximum value	0	CP5	No improvement / Worsening	Fail the criteria
LCA result > Q3	1	CP4	Improvement + 5%	
Q2 < LCA result ≤ Q3	2	CP3	Improvement + 5% to 20%	
Q1 < LCA result ≤ Q2	3	CP2	Improvement + 20% to 40%	Pass the criteria
LCA result ≤ Q1	4	CP1	Improvement > 40%	

In the following section, results for an exemplary lubricant benchmark will apply both options to evaluate advantages and shortcomings of each.

1.2. Evaluation of the approaches

As described in the previous section, the current state of SSbD operationalisation allows for separate approaches in benchmarking. First, single indicator benchmarking followed by MCDA to derive an environmental dimension score, or second, alternatively deriving an environmental dimension score from grouped, normalised and optionally weighted LCIA results. In this section, either option will be discussed, including two separate weighting approaches that could be applied after grouping and normalisation. For this comparison, two exemplary lubricant formulations using PTFE additives will be used.

Figure 1 displays the relative LCIA results according to the EF 3.1 method published by the JRC. The benchmark reference uses a synthetic base oil blended with ester and other additives beside PTFE, while the alternative formulation is composed of a lower fraction of synthetic base oil, which is replaced by an increased ester fraction.

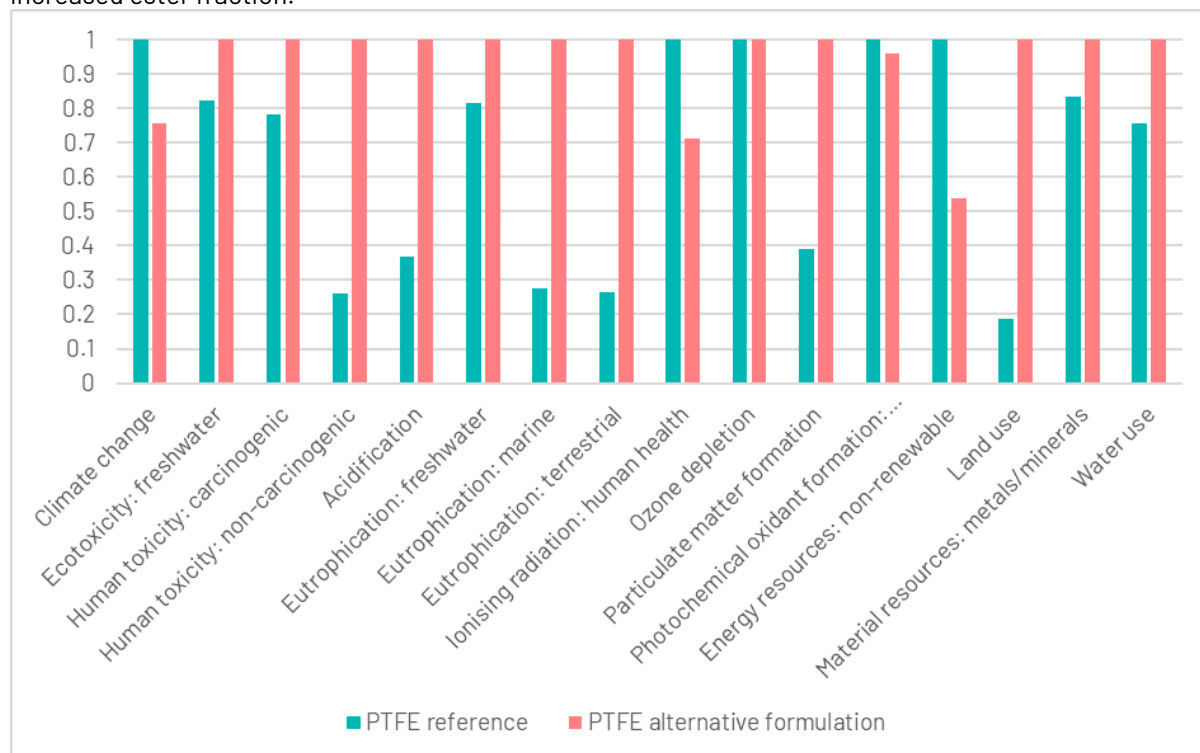


Figure 1: Life cycle impact assessment results for exemplary PTFE use case and alternative formulation using a high biobased ester mass fraction.

As the figure displays, using the alternative led to lower potential impacts in the impact categories climate change, ionising radiation, photochemical oxidant formation and non-renewable energy resources. Minor

increases in calculated impacts were observed for freshwater ecotoxicity, carcinogenic human toxicity, freshwater eutrophication, material resource consumption and water use. Major increases in non-carcinogenic human toxicity, acidification, marine eutrophication, terrestrial eutrophication, particulate matter formation and land use would result from pivoting to the alternative formulation. These changes would result directly from the replacement of the fossil supply chain of the synthetic base oil with agricultural processes used in the production of the vegetable oil processed in biogenic ester production, indicating significant trade-offs between the alternatives despite an increase in biobased material fraction.

In Table 3, the LCIA results of the benchmarking reference and the alternative formulation are displayed by impact category. For each category, the alternative case is assigned a score based on the improvement criteria displayed in Table 2. As described above, the majority of impact categories exhibit reduced environmental performance according to the SiToLub model, which leads to the lowest score of 0. Out of 16 total impact categories, only five see any improvement between -0.1% and -46.3% reduction in potential environmental impact. The highest score was assigned to the alternative in non-renewable energy resource consumption at 4, followed by a score of 3 for both climate change and effects on human health from ionising radiation and a score of 1 assigned to ozone depletion and photochemical oxidant formation.

Table 3: SSbD-scoring on impact category level of the exemplary PTFE lubricant benchmark.

LCIA category	PTFE base case	PTFE ester case	Unit	Difference	Score
Climate change	10.8	8.16	kg CO ₂ -Eq	-24.3%	3
Ecotoxicity: freshwater	31.7	38.5	CTUe	21.4%	0
Human toxicity: carcinogenic	2.10E-08	2.68E-08	CTUh	27.8%	0
Human toxicity: non-carcinogenic	4.08E-07	1.57E-06	CTUh	283.9%	0
Acidification	0.0384	0.104	mol H ⁺ -Eq	170.6%	0
Eutrophication: freshwater	0.00132	0.00162	kg P-Eq	22.7%	0
Eutrophication: marine	0.0102	0.0374	kg N-Eq	265.2%	0
Eutrophication: terrestrial	0.107	0.408	mol N-Eq	280.3%	0
Ionising radiation: human health	0.431	0.306	kBq U235-Eq	-29.0%	3
Ozone depletion	2.63E-04	2.62E-04	kg CFC-11-Eq	-0.1%	1
Particulate matter formation	2.74E-07	7.02E-07	disease incidence	156.0%	0
Photochemical oxidant formation: human health	0.0341	0.0326	kg NMVOC-Eq	-4.2%	1
Energy resources: non-renewable	193	104	MJ, net calorific value	-46.3%	4
Land use	89.5	476	dimensionless	431.3%	0
Material resources: metals/minerals	5.21E-05	6.24E-05	kg Sb-Eq	19.9%	0
Water use	1.63	2.16	m ³ world Eq deprived	32.2%	0

While these results are highly granular, the further aggregation of results into SSbD-compliant clusters and the final application of an MCDA is subject to significant value choices. In previous research, impact categories were grouped and a passing score in each category was assigned only to those exhibiting improvements across all contained LCIA categories. In the case of this example, that would only be the case for climate change. These results preserve high transparency and impact-specific detail, allowing for identification of specific hotspots before MCDA application. However, such results are hard to communicate and leave space for unharmonized MCDA processes.

However, when results were normalised, weighted and grouped into the four environmental groups climate change, toxicity, pollution and resources as described in Table 1, the interpretation changes substantially. Figure 3 displays the normalised and EF-weighted results of the same benchmarking example used previously. The methodological change results in a relative change compared to the indicator-specific assessment since reductions in impact are calculated for both the climate change

cluster and the resource cluster, while pollution and toxicity performance of the alternative are significantly lower than that of the benchmark reference. This indicates that the aggregation procedure moderates the influence of isolated underperforming categories and places greater emphasis on the overall balance of environmental impacts. Results in this case are more facile to communicate.

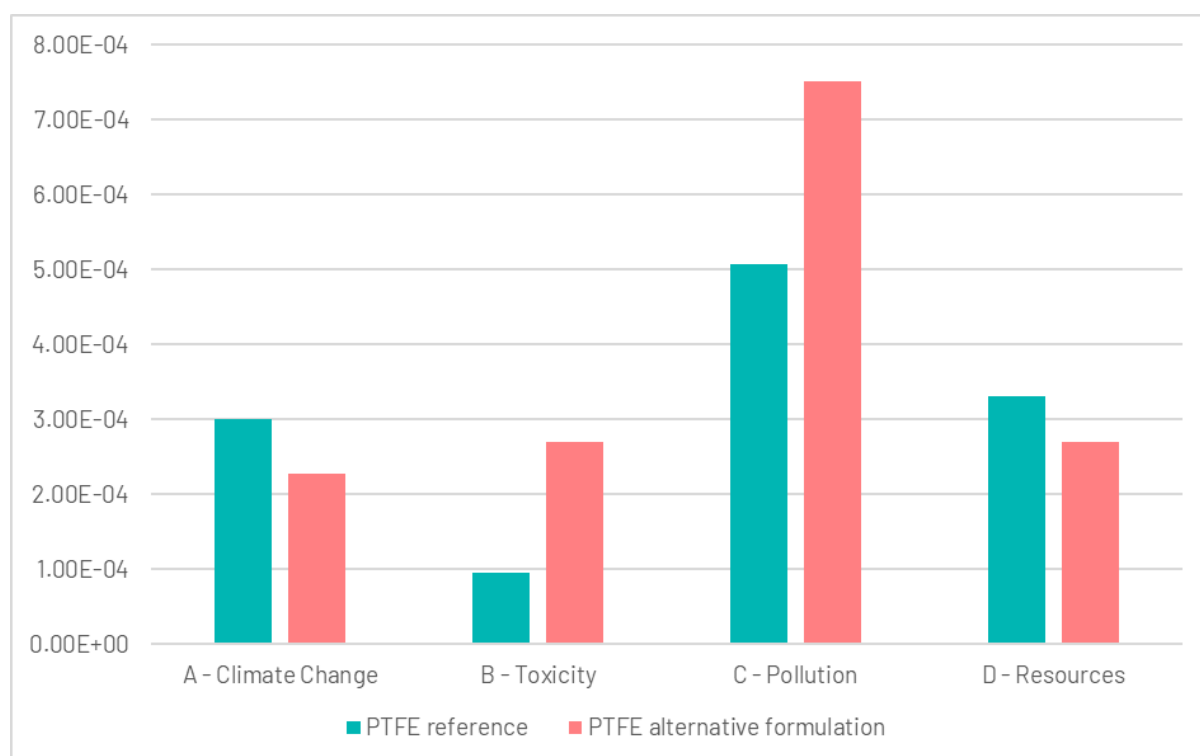


Figure 2: Normalised and EF-weighted life cycle impact assessment results for PTFE base case and alternative.

Another advantage of benchmarking after grouping and normalisation is the possibility of accounting for relative magnitude of environmental impacts in reference to the normalisation factor. This is most pronounced in the environmental cluster of resources, where a substantially lower performance of the alternative in three out of the four included impact categories of material resource consumption, water use and land use, is mitigated by a considerable impact reduction in energy resource consumption. Here, normalisation factors as displayed in Table 1 help to put the relative significance of environmental impact into perspective, leading to higher overall scoring, as displayed in Table 4. After normalisation, the difference in normalised impact in energy resource consumption is -0.00138 points, while the difference in land use, material resource consumption and water use accounts for a cumulative difference of 0.00109 points. After weighting, the total difference in resource consumption impacts accounts for a 18% decrease in environmental impact, a significant difference to the increase upwards of 400% for land use in the single category benchmark. Compared to the individual indicator comparison, this approach also allows for the calculation of results and relative performance in each SSbD-category for products without a benchmark.

Table 4: SSbD-scoring of EF-weighted and normalised results the exemplary PTFE lubricant benchmark.

Name	PTFE base case	PTFE ester case	Unit	Difference	Score
A - Climate Change	3.00E-04	2.27E-04	dimensionless	-24%	3
B - Toxicity	9.49E-05	2.70E-04	dimensionless	184%	0
C - Pollution	5.07E-04	7.51E-04	dimensionless	48%	0
D - Resources	3.30E-04	2.69E-04	dimensionless	-18%	2

While Figure 2 displays normalised, grouped and weighted results following the **EF-weighting approach**, Figure 3 displays results using the **equal weighting** approach as displayed in Table 1. Compared to the EF-weighting approach, the most significant differences lie in the weighting of toxicity impact categories, which are assigned weighting factors of 8.33% compared to the EF-weighting's factors ranging by 0.3% around 2% and in the weighting factors of impact categories assigned to the pollution cluster that range

widely from 2.8% to 8.96% compared to 3.13% equally distributed in this weighting approach. The effect of the weighting factors can be seen directly in the total results calculated for each cluster, which lend considerably higher relative importance to the toxicity cluster.

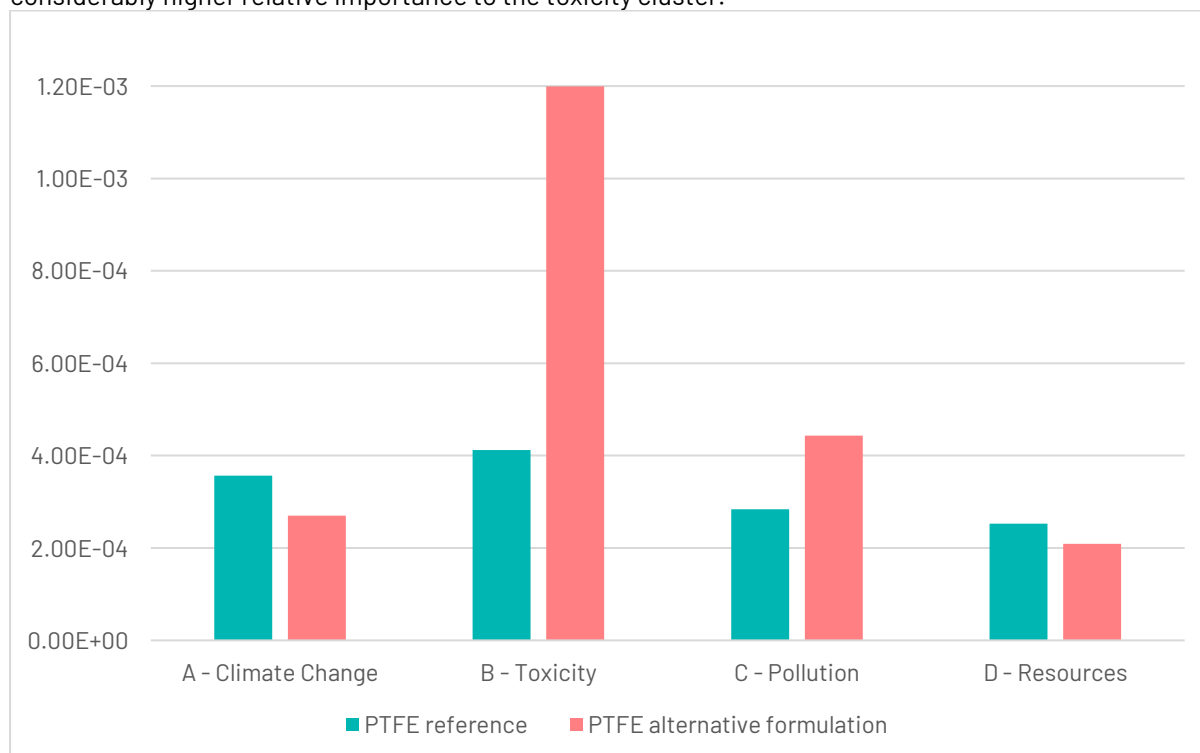


Figure 3: Normalised and equally weighted life cycle impact assessment results for PTFE base case and PTFE ester alternative.

While the advantage of using normalised and grouped results is maintained, lower certainty impact assessment categories are assigned higher weight using this approach. Relative differences remain largely the same, as do the scores assigned to each category. While this approach results in the same benchmarking scores by SSbD-category as only normalisation and grouping would, it does have the disadvantage of lower relative weights for clusters that contain a large number of indicators. Therefore, dimensionless results computed for pollution decrease considerably compared to those using the EF weighting approach. For non-benchmarked models, a true equal weighting approach without cluster-based weighting may be more appropriate.

Table 5: SSbD-scoring of equally weighted and normalised results of the exemplary PTFE lubricant benchmark

Name	PTFE base case	PTFE ester case	Unit	Difference	Score
A - Climate Change	3.57E-04	2.70E-04	dimensionless	-24%	3
B - Toxicity	4.12E-04	0.00120	dimensionless	191%	0
C - Pollution	2.84E-04	4.44E-04	dimensionless	56%	0
D - Resources	2.53E-04	2.09E-04	dimensionless	-17%	2

In conclusion, the single indicator benchmarking approach favours transparency and preservation of the significance of hotspot differences between the methods, while leaving more room for interpretation to the subsequent MCDA approach. However, a normalised and grouped benchmarking approach allows for the reflection of relative relevance of environmental hotspots to the reference normalisation value and allows for clear communication of results for non-benchmarked products as well. Clear guidance is needed regarding SSbD-operationalisation and preferred level of benchmarking application.

2. Social LCA

Within the SiToLub project, S-LCA was conducted as part of a full LCSA covering four lubricant additive use cases. The assessment followed a dual-layer approach: background supply chain risk was modelled using soca v4 (linked to ecoinvent) drawing on PSILCA social indicators, while the Social Hotspot Database (SHDB) supported the upstream hotspot analysis. Results are structured around the two SSbD socioeconomic pillars, Social Fairness and Competitiveness, and reported per socioeconomic aspect.

The functional unit, system boundary, and background database were kept consistent across the environmental LCA and S-LCA pillars to ensure methodological coherence.

2.1. Indicator selection and mapping

Indicator selection followed a two-stage process. First, the SSbD framework's recommended socioeconomic aspects and suggested indicators for the Social Fairness and Competitiveness pillars were reviewed as a normative starting point. Second, a hotspot analysis was conducted using SHDB and PSILCA to empirically identify which social topics carry the highest risk signal across the chemical supply chains as there were no sector specific representation. However, the chemical industry sector was selected in all cases.

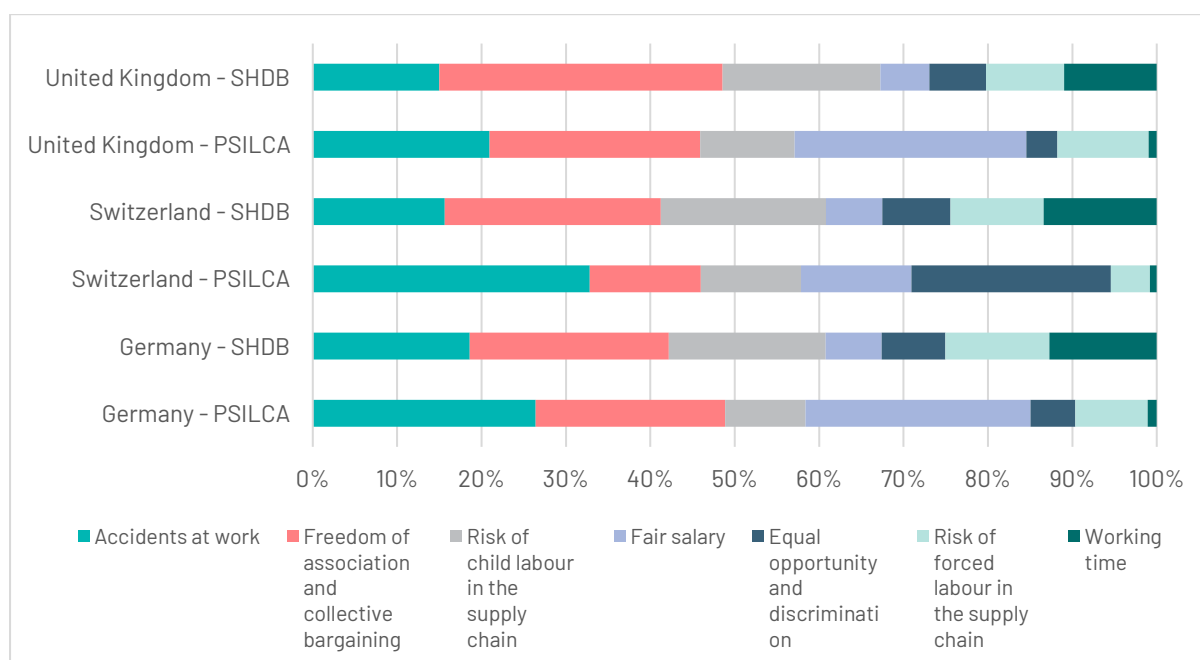


Figure 4 Social hotspot analysis using SHDB and PSILCA.

Indicators were retained where both criteria converged, i.e., where SSbD inclusion aligned with elevated hotspot risk in the background supply chain data. This dual basis strengthens the relevance of the final indicator set beyond framework compliance alone. The resulting alignment across SSbD, PSILCA, and SHDB is presented in the following table.

Table 6 Mapping SSbD economic aspects to PSILCA and SHDB

Pillar	Socioeconomic Aspect (as in SSbD)	SSbD suggested indicator	PSILCA Social Impact Category	SHDB Social Impact Category
Social Fairness	Accidents at work	Rate of fatal accidents at workplace (cases per 100,000 employees per year)	Rate of fatal accidents at workplace	2B Injuries & Fatalities

Pillar	Socioeconomic Aspect (as in SSbD)	SSbD suggested indicator	PSILCA Social Impact Category	SHDB Social Impact Category
Social Fairness	Accidents at work	Rate of non-fatal accidents at workplace (cases per 100,000 employees per year)	Rate of non-fatal accidents at workplace	2B Injuries & Fatalities
Social Fairness	Presence of safety measures	Preventive measures and emergency protocols regarding accidents and injuries (cases of violation per 100,000 employees)	Presence of sufficient safety measures	Not specified
Social Fairness	Freedom of association and collective bargaining	Right of association, right of collective bargaining, right to strike (ordinal scales), and trade union density (% of employees organized in trade unions)	Freedom of association and collective bargaining	1G Freedom of Assoc
Social Fairness	Risk of child labour in the supply chain	% of children in employment (age 7-14)	Children in employment, total	1D Child Labour
Social Fairness	Fair salary	Living wage per month and sector average wage per month (used to calculate the ratio of salary to living wage)	Sector average wage, per month	1A Wage assessment
Social Fairness	Equal opportunity and discrimination	Gender wage gap (%)	Gender wage gap	3B Gender Equity
Social Fairness	Risk of forced labour in the supply chain	Risk of forced labour in the country (cases per 1,000 inhabitants)	Frequency of forced labour	1E Forced Labour
Social Fairness	Working time	Hours of work per employee per week	Weekly hours of work per employee, female	1F Excessive WkTime
Social Fairness	Working time	Hours of work per employee per week	Weekly hours of work per employee, male	1F Excessive WkTime
Competitiveness	Technology potential	Patent growth rate (%) of this technology over a defined period (e.g., 5 years)	R&D expenditures (not in the supply chain)	Not found
Competitiveness	Creation of knowledge-intensive employment	Knowledge-intensive jobs (% high-skilled employees (ISCO level 3-4) / total employees required for a unit of production)	Rate of researchers (not in the supply chain)	Not found
Competitiveness	Contribution to GDP	Contribution of the product/service/organisation to economic progress (e.g., annual growth rate of real GDP per employed person; sector level: % of GDP)	Contribution to economic development	Not found

For the Competitiveness pillar, technology potential, knowledge-intensive employment, and GDP contribution had no direct SHDB equivalent. These were carried forward on the basis of SSbD relevance alone, using PSILCA proxies, and should be interpreted with lower empirical confidence than the Social Fairness indicators.

2.2. Approaches to Social Weighting & Aggregation

Results are aggregated across two levels: indicators are equally weighted within each socioeconomic aspect, and aspects are equally weighted within each pillar.

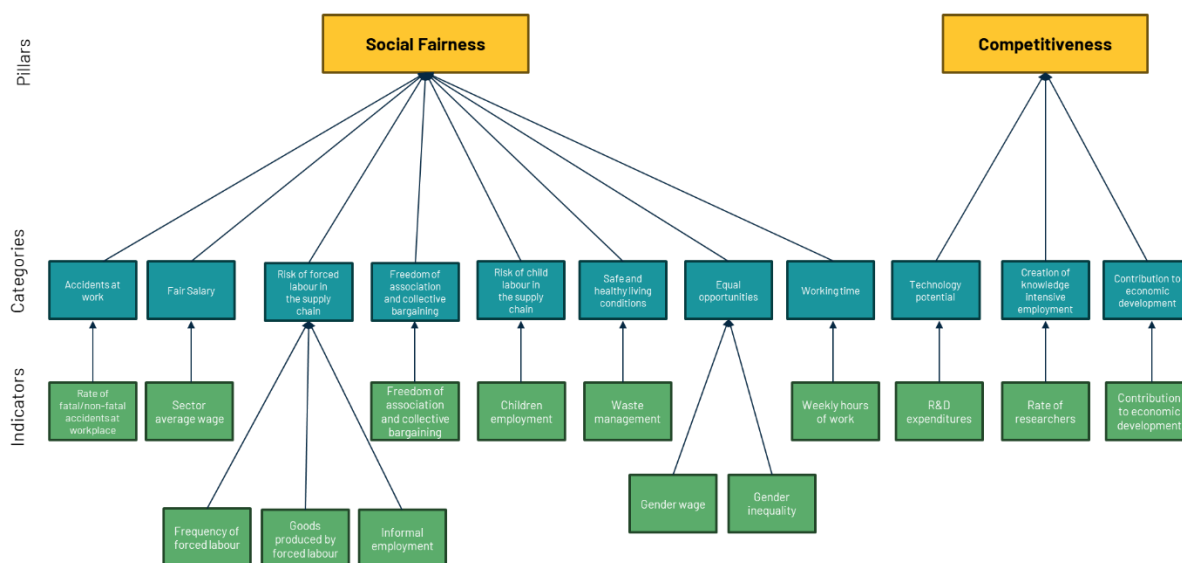


Figure 5: Own elaboration of combining indicators into categories into pillars.

Equal weighting is applied as an interim approach pending the outcome of an ongoing stakeholder weighting exercise. It is acknowledged that equal weighting implies equivalent socioeconomic severity across indicators, an assumption that is methodologically contested and for which no consensus scheme currently exists in the S-LCA field. The SSbD framework does not provide weighting guidance beyond noting that weighted scoring of aspects is an option (SSbD 2025, Section 13).

2.3. Results: PTFE Reference Case & Alternative formulation

Figure 6 presents S-LCA results for the PTFE reference formulation and its alternate variant – in which 12-HSA concentration is increased and base oil share is reduced – expressed in medium risk hours (mrh) per socioeconomic aspect.

The alternate formulation yields lower risk values across most aspects. The largest absolute reductions appear in Accidents at work (~35 mrh), Safe and healthy living conditions (~55 mrh), and Fair Salary (~35 mrh), which are predominantly driven by upstream raw material extraction and chemical manufacturing processes associated with base oil production. Risk of child labour in the supply chain is the sole aspect where the alternate formulation marginally exceeds the reference, attributable to the 12-HSA supply chain and its association with palm oil farming.

The Competitiveness aspects – Contribution to GDP, Creation of knowledge-intensive employment, and Technological potential – show smaller absolute differences, consistent with their lower overall risk magnitude and their reliance on PSILCA proxies rather than direct SHDB coverage.

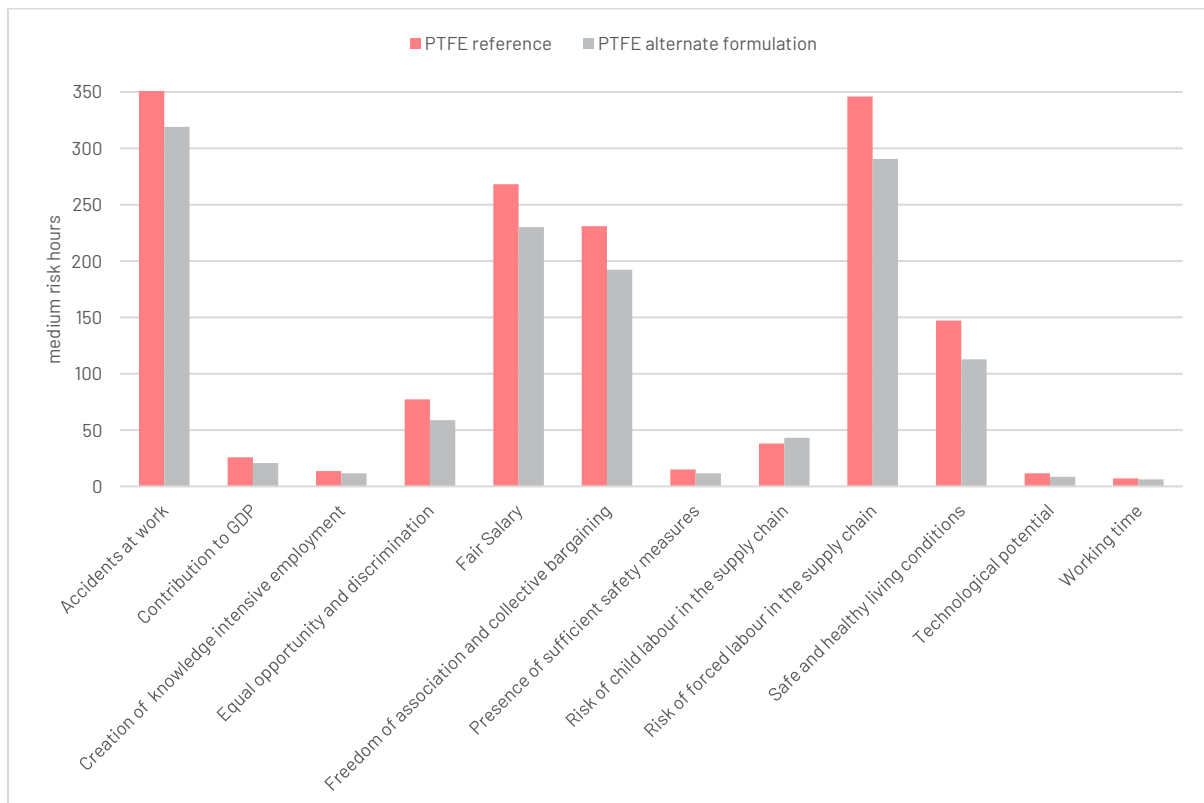


Figure 6: Social impact across socioeconomic aspect for the production of 1 kg for the PTFE formulation and the alternate formulation.

Figure 7 aggregates results to pillar level. Social Fairness dominates in both formulations (~165 vs ~140 mrh), consistent with the labour-intensive and geographically dispersed nature of the upstream supply chains captured by the background database. The alternate formulation reduces Social Fairness risk by approximately 15%. Competitiveness risk is lower for both (~17 vs ~13 mrh).

This pillar-level view illustrates two limitations of equal weighting. First, the Competitiveness pillar is structurally underrepresented in the aggregate due to fewer indicators and lower-magnitude proxy values. Second, and more critically, aggregation can obscure trade-offs that are material to the redesign decision. The elevated child labour risk of the alternate formulation – visible at aspect level – is absorbed within the overall Social Fairness improvement and disappears at pillar level. A decision based solely on the aggregate would miss it entirely. This reinforces the need for stakeholder-derived weights and for aspect-level disaggregated results to remain the primary reporting layer.

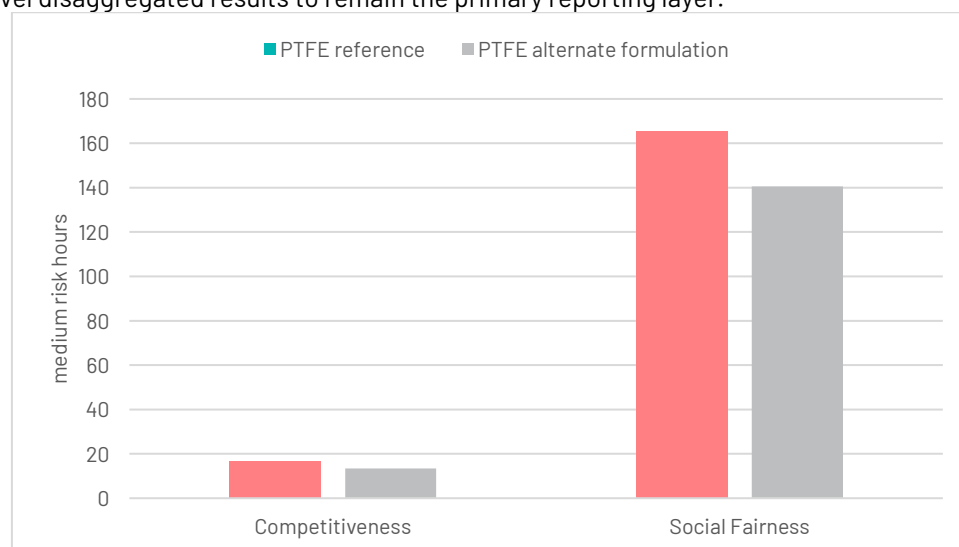


Figure 7: Competitiveness and social fairness mrh for the PTFE formulation.

This breaks down the comparison of two product systems down to two indicators. In similar fashion as the LCC should be benchmarked in the most recent SSbD framework, a relative change of those indicators could be quantifiable leading to a score.

Figure 8 presents the RSA risk distribution for the PTFE reference formulation, showing raw indicator values from SOCA v4 across life cycle stages and supply chain nodes, colour-coded by risk level – green (very low to low), amber (medium), and red (high to very high).

Indicator	VLR	LR	MR	HR	VHR	Raw Value
Rate of fatal accidents at workplace	2%	15%	28%	10%	26%	3.27204 [cases per 100,000 employees]
Rate of non-fatal accidents at workplace	8%	25%	4%	27%	18%	1247.42372 [cases per 100,000 employees]
Presence of sufficient safety measures	2%	5%	15%	0%	2%	0.00428 [OSHA cases per 100,000 employees and year]
Freedom of association and collective bargaining	7%	29%	14%	22%	28%	3.40137 [scale from 1 to 10]
Children in employment, total	12%	39%	38%	1%	4%	1.25039 [% of male children ages 5-17]
Sector average wage, per month	0%	0%	0%	5%	35%	0.22260 [USD/month]
Gender wage gap	14%	0%	1%	13%	2%	4.07413 [% difference male and female wages in reference year]
Gender inequalities	35%	50%	6%	2%	6%	0.17906 [scores]
Frequency of forced labour	36%	25%	1%	7%	30%	5.76664 [Cases per 1,000 inhabitants]
Goods produced by forced labour	0%	0%	0%	0%	11%	0.11355 [scores]
Informal employment, total	12%	31%	4%	9%	2%	10.50031 [% informal employment (total)]
Waste Management	34%	25%	16%	6%	19%	40.59899 [scores]
Weekly hours of work per employee, female	0%	45%	49%	0%	0%	38.85401 [Working time]
Weekly hours of work per employee, male	0%	69%	25%	0%	0%	39.87486 [Working time]
R&D Expenditures	58%	20%	20%	0%	1%	1.78460 [GERD as a percentage of GDP]
Rate of researchers	40%	31%	16%	13%	0%	2915.01756 [Researchers per million inhabitants]
Indicator	NOP		HO	MO	LO	Raw Value
Contribution to economic development	0%		30%	40%	25%	20.77848 [% of GDP]

Figure 8: RSA risk distribution along supply chain of soca for the PTFE reference.

This visualisation is only possible because soca v4, via its PSILCA foundation, provides access to underlying raw indicator values rather than pre-aggregated scores. This is the necessary condition for the scoring step described in the next section – without raw values, the SSbD 0–4 scale cannot be applied.

The full chain from background database raw values to SSbD-compatible scoring is implemented here within openLCA using SOCA v4, without requiring manual recalculation outside the model.

2.4. Scoring of S-LCA and the Primary-Secondary Data Gap

The SSbD 2025 framework defines a 0–4 ordinal scoring scale for S-LCA results, where 0 = very high risk and 4 = very low risk, anchored to reference scales per indicator. However, in similar fashion to the scoring in environmental LCA, the most recent SSbD framework recommends to benchmark as following:

Table 7. Scores for the S-LCA results for the social indicator “% of children in employment” based on the JRC and pass/fail according to own interpretation.

Range of values	Score	Class of performance	Risk Level	Representative system
$20 \leq y$	0	CP5	Very high risk	Fail the criteria?
$10 \leq y < 20$	1	CP4	High risk	
$5 \leq y < 10$	2	CP3	Medium risk	Pass the criteria?
$2.5 \leq y < 5$	3	CP2	Low risk	
$0 \leq y < 2.5$	4	CP1	Very low risk	

Table 8 Secondary data of PTFE reference formulation based on soca v4 background data only with scoring from SSbD. Risk levels were abbreviated.

Indicator	Base Case	Altern. Case	Rel. Change	Risk Base	Risk Alt.	Risk Changed
Rate of fatal accidents at workplace	3.27 cases/100,000	3.40 cases/100,000	+4%	1	1	No
Rate of non-fatal accidents at workplace	1247.42 cases/100,000	1232.47 cases/100,000	-1%	1	1	No
Presence of sufficient safety measures	0.00428 OSHA cases/100,000	0.00419 OSHA cases/100,000	-2%	1	1	No
Freedom of association and collective bargaining	3.40 (scale 1–10)	3.29 (scale 1–10)	-3%	1	1	No
Children in employment, total	1.25%	1.29%	+3%	2	2	No
Sector average wage, per month	0.22 (ratio to living wage)	0.216 (ratio to living wage)	-2%	0	0	No
Gender wage gap	4.07 %	4.37 %	+7%	4	4	No
Gender inequalities	0.18 GII score	0.178 GII score	-1%	3	3	No
Frequency of forced labour	5.77 cases/1,000	5.68 cases/1,000	-1%	2	2	No
Goods produced by forced labour	0.11 (score)	0.100 (score)	-9%	0	0	No
Informal employment, total	10.50%	11.64%	+11%	3	3	No
Waste management	40.60 (score)	41.77 (score)	+3%	3	3	No
Weekly hours of work, female	38.85 hrs/week	39.17 hrs/week	+1%	2	2	No
Weekly hours of work, male	39.87 hrs/week	40.31 hrs/week	+1%	2	2	No
R&D expenditures	1.78% GDP	1.84% GDP	+3%	4	4	No
Rate of researchers	2915.02 per million	2967.94 per million	+2%	3	3	No
Contribution to economic development	20.78 % GDP	20.29 % GDP	-2%	2	2	No

As displayed, the relative changes were not sufficient to alter the assigned SSbD risk levels, since all indicators remained within the same scoring intervals. Although some indicators showed moderate percentage differences, no transition between performance classes (CP1–CP5) occurred. Therefore, the alternative PTFE formulation demonstrates a social risk profile comparable to the base case according to the SSbD benchmark methodology.

2.5. Primary–Secondary Data Gap

The following section demonstrates how this scoring works across three layers: background secondary data from soca on the PTFE formulation, hypothetical primary data collected directly from the PTFE formulation company, and a weighted combination of both. The underlying challenge, how to combine these two types of data in a meaningful way, is one that the SSbD framework does not yet resolve, and which the ORIENTING project (D2.5) has only partially addressed.

Table 9 presents the raw values returned by SOCA v4 for the PTFE reference formulation as shown previously in figure, scored against the PSILCA evaluation schema and translated into SSbD scores.

Table 9 Secondary data of PTFE reference formulation based on soca v4 background data only with scoring from SSbD

Indicator	Raw Value	Risk Level	Score
Rate of fatal accidents at workplace	3.27 cases/100,000	High Risk	1
Rate of non-fatal accidents at workplace	1247.42 cases/100,000	High Risk	1
Presence of sufficient safety measures	0.00428 OSHA cases/100,000	High Risk	1
Freedom of association and collective bargaining	3.40 (scale 1–10)	High Risk	1
Children in employment, total	1.25 %	Medium Risk	2
Sector average wage, per month	0.22 (ratio to living wage)	Very High Risk	0
Gender wage gap	4.07 %	Very Low Risk	4
Gender inequalities	0.18 GII score	Low Risk	3
Frequency of forced labour	5.77 cases/1,000	Medium Risk	2
Goods produced by forced labour	0.11 (score)	Very high risk	0
Informal employment, total	10.50 %	Low Risk	3
Waste management	40.60 (score)	Low Risk	3
Weekly hours of work, female	38.85 hrs/week	Medium Risk	2
Weekly hours of work, male	39.87 hrs/week	Medium Risk	2
R&D expenditures	1.78 % GDP	Very Low Risk	4
Rate of researchers	2915.02 per million	Low Risk	3
Contribution to economic development	20.78 % GDP	Medium Opportunity	2

The supply chain profile shows consistent stress in labour conditions, sector average wage returns the lowest score (0), while safety, freedom of association, and fatal accident rates all score 1. Gender wage gap and R&D expenditures are relative strengths at score 4.

Table 10 presents hypothetical primary data collected directly from the PTFE formulation company, scored on the same 0–4 scale. Foreground worker hours are 1.2 hrs per kg of formulated lubricant.

Table 10 Hypothetical primary data of PTFE manufacturer

Indicator	Raw Value	Risk Level	Score
Rate of fatal accidents at workplace	0.9 cases/100,000	Low Risk	3
Rate of non-fatal accidents at workplace	420 cases/100,000	Low Risk	3
Presence of sufficient safety measures	0.025 OSHA cases/100,000	Very Low Risk	4
Freedom of association and collective bargaining	1.8 (scale 1–10)	Medium Risk	2
Children in employment, total	0.0 %	No Risk	4
Sector average wage, per month	3.2 (ratio to living wage)	Very Low Risk	4
Gender wage gap	14.5 %	Low Risk	3
Gender inequalities	0.07 GII score	Very Low Risk	4
Frequency of forced labour	1.8 cases/1,000	Very Low Risk	4
Goods produced by forced labour	0 (score)	No Risk	4
Informal employment, total	6.5 %	Low Risk	3
Waste management	62.4 (score)	Very Low Risk	4
Weekly hours of work, female	38.5 hrs/week	Medium Risk	2
Weekly hours of work, male	41.0 hrs/week	Low Risk	3
R&D expenditures	3.1 % GDP	Very Low Risk	4
Rate of researchers	5210 per million	Very Low Risk	4
Contribution to economic development	22.0 % GDP	Medium Opportunity	2

The company profile is markedly stronger than the background supply chain across most indicators, particularly for sector average wage, child labour, forced labour, and safety measures. Freedom of association (score 2) and weekly working hours for female employees (score 2) remain areas where the company does not fully outperform its supply chain context.

Combining primary and secondary scores

Figure 9 illustrates why combining primary and secondary data requires careful handling. Primary data collection realistically covers the focal company and, where feasible, tier-1 suppliers. The background database, in this case soca v4, covers the full supply chain depth, from tier-1 through to raw material extraction. As the ORIENTING project (D2.5) notes, the share of the supply chain assessed through primary data is typically small and increasing that share is a practical challenge even in well-resourced studies.

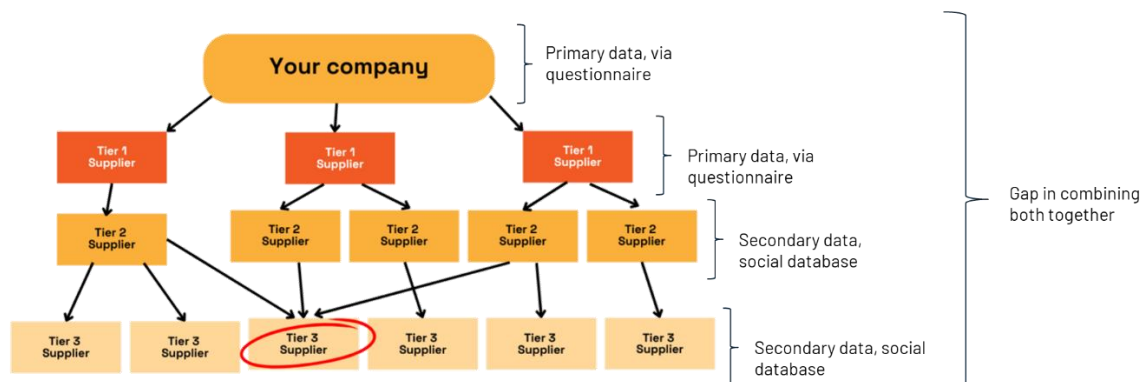


Figure 9 Gap in combining primary data via performance level and secondary data

This means the two scoring layers do not describe the same portion of the supply chain. More importantly, they do not describe the same type of information. Secondary scores reflect potential risk, the likelihood that a given condition exists in a sector-country context, estimated statistically across many companies. Primary scores reflect actual measured conditions at one specific company. Both use the same 0–4 scale, but treating them as equivalent would hide this difference.

The ORIENTING project identifies this gap explicitly. D2.5 (section 7.4) states that a fully quantitative combination of risk and performance results is currently not possible due to differences in social topic definitions, reference scales, and the fact that only performance assessment captures positive impacts. The narrative approach proposed in ORIENTING, where risk and performance results are interpreted side by side rather than merged, remains the most methodologically honest option available.

Building on this, we propose two complementary reporting approaches:

Parallel reporting presents both scores side by side for each indicator, and interprets the gap between them as a finding in its own right. Where the primary score is higher than the secondary score, as seen for sector average wage, child labour, and safety, the company performs better than its supply chain context would suggest. Where scores are similar or the primary score is lower, the background risk level stands without reassurance. This approach is recommended as the primary reporting mode, consistent with the ORIENTING guidance, because it keeps the two data types clearly distinct.

Weighted combination merges both scores into a single value, weighted by the share of total worker hours each layer represents. Table 11 presents the weighted average raw values and their resulting scores.

Table 11 Weighted average raw values

Indicator	Weighted Raw Value	Risk Level	Score
Rate of fatal accidents at workplace	4.35 cases/100,000	Very High Risk	0
Rate of non-fatal accidents at workplace	1993.90 cases/100,000	High Risk	1
Presence of sufficient safety measures	0.00603 OSHA cases/100,000	Medium Risk	2
Freedom of association and collective bargaining	2.10 (scale 1-10)	High Risk	1
Children in employment, total	1.10 %	Low Risk	3
Sector average wage, per month	0.51 (ratio to living wage)	Very High Risk	0
Gender wage gap	-1.82 %	Very Low Risk	4
Gender inequalities	0.14 GII score	Low Risk	3
Frequency of forced labour	4.85 cases/1,000	Medium Risk	2
Goods produced by forced labour	0.02 (score)	No Risk	4
Informal employment, total	7.51 %	Low Risk	3
Waste management	40.58 (score)	Low Risk	3
Weekly hours of work, female	39.19 hrs/week	Medium Risk	2
Weekly hours of work, male	40.29 hrs/week	Low Risk	3
R&D expenditures	2.04 % GDP	Very Low Risk	4
Rate of researchers	3393.32 per million	Low Risk	3
Contribution to economic development	16.52 % GDP	Low Opportunity	1

The weighted scores shift upward for several indicators, safety measures (1→2), children in employment (2→3), weekly hours for male employees (2→3), reflecting the company's stronger performance pulling the combined result in a positive direction. However, for two indicators the weighted score does not improve: sector average wage remains at 0, and fatal accidents worsens from 1 to 0. This is because upstream processes, particularly raw material extraction at tier-2 and tier-3 supplier level, carry very high accident rates and large worker hour contributions that the formulation company's performance alone cannot offset at system level.

This outcome demonstrates why parallel reporting and weighted combination serve different purposes and should be used together. The weighted score is useful for comparing design options on a single value. Parallel reporting shows where change is possible at the company level and where the risk is structural to the supply chain, which is the most actionable information for a design decision.

The gap in the SSbD 2025 framework: the framework presents a unified 0–4 scoring scale without specifying how to handle situations where primary and secondary data are both available for the same indicator. It does not distinguish between potential risk estimated from a background database and actual performance measured at a specific company, and it does not reference the combination approaches developed in the ORIENTING project (D2.5). Explicit guidance on this, covering both parallel reporting and weighted combination, and specifying when each is appropriate, is needed for the framework to support consistent application across SSbD studies.

Questions

1. How to predict supply chain for low TRL
2. The first tier should not have high risk
3. How to mitigate the social risk
4. Direct procurement selection
5. Comparison should be on the first and second tier
6. Combine foreground, first and second tier

3. Conclusion and Outlook

The application of the SSbD framework within the SiToLub project has demonstrated that, while the SSbD framework provides an important foundation for integrating environmental, social, and economic sustainability considerations, **substantial methodological ambiguities remain regarding benchmarking, aggregation, and weighting procedures**. Across both the environmental LCA and S-LCA dimensions, the performed case studies revealed that different methodological choices can significantly influence the interpretation of results and, consequently, decision making outcomes. Indicator level benchmarking preserves transparency and allows the identification of environmental and social hotspots, while grouped and weighted approaches improve interpretability and comparability for benchmarking purposes. However, aggregation procedures may also mask critical trade-offs, particularly in the case of social risks or isolated environmental burdens.

For S-LCA in particular, the benchmarking but also the coexistence of risk based secondary datasets and performance based primary company data creates a methodological gap that is currently unresolved within the SSbD framework. Furthermore, PSILCA provides underlying raw quantitative values in addition to the benchmarked risk levels applied in SSbD. These raw values can support a more nuanced interpretation of small changes that may not be reflected in the final ordinal scoring categories. Moreover, the approaches explored in this work, namely parallel reporting and weighted combination, provide practical interim solutions, but explicit methodological guidance is required to ensure consistency and comparability across studies.

Therefore, we strongly encourage the JRC to provide further clarification and harmonised methodological recommendations regarding:

- preferred benchmarking approaches across SSbD dimensions
- acceptable aggregation and weighting procedures
- integration of MCDA methodologies
- treatment of hotspot indicators within aggregated scoring
- integration of primary and secondary S-LCA data

For industrial stakeholders, especially within the chemical industry, harmonisation and methodological consistency are essential prerequisites for broader uptake and acceptance of the SSbD framework. Companies require assessment procedures that are sufficiently robust, transparent, and standardised to support decision making, communication, and potential future regulatory alignment. A framework that allows significantly different methodological choices for similar case studies may create uncertainty regarding compliance, interpretation of results, and fairness of comparisons.

4. Feedback from the JRC

The initial version of this report was sent on 11.05.2026 to the SSbD team of the JRC. However, no reply was received.

Following individual outreach, a meeting was held with the JRC on 19 June 2026 to discuss our approach to the S-LCA and address remaining uncertainties. The main conclusions of the meeting were as follows:

- The S-LCA approach of SiToLub was well received
- Foreground and background data should not be merged in the S-LCA
- Social indicators should not be clustered for decision-making purposes
- The JRC emphasised that the framework will remain flexible to encourage its uptake
- Respectively, the exact way of performing scoring for S-LCA will be vague