D6.6 Report on safe- and sustainable-by-design guidelines and best practice

Deliverable D6.6

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Keywords

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Abbreviations and acronyms

Acronym	Description
CFAE	Polysaccharides fatty acid esters
CeFAE	Cellulose fatty acid ester
CS	Coating System
D	Deliverable
EC	European Commission
ED	Endocrine Disruptor
FAIR	Findable, Accessible, Interoperable, Reusable
JRC	Joint Research Centre
LCA	Life cycle assessment
LCC	Life cycle costing
NA	Not Available
PBT	Persistent, Bioaccumulative, and Toxic
PFAS	Per- and polyfluoroalkyl substance
PROC	Process Category
QSAR	Quantitative Structure-Activity Relationships
RCR	Risk Characterisation Ratio
SoC	Substances of Concern
SSbD	Safe and Sustainable by Design
STOT-RE	Specific Target Organ Toxicity - Repeated Exposure
SVHC	Substance of very high concern
TRL	Technology readiness level
WP	Work Package

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1 Introduction

The ZeroF project has applied the Safe and Sustainable by Design (SSbD) framework of the European Commission (EC) to support the development of alternatives to the per- and polyfluoroalkyl (PFAS) substances for the packaging and textile coating applications and ensure their safety and sustainability. D6.1 (“Report on safe- and sustainable-by-design methodological framework”) included the description of the methodological framework, as interpreted by the consortium for the implementation of SSbD for the research innovations of the ZeroF project. In this deliverable we summarise the main results of the environmental sustainability, safety, and economic assessments, as described in D6.3 (“Report on Environmental sustainability evaluation”), D6.4 (“Report on chemical safety evaluation”) and D6.5 (“Report on techno-economic & social acceptance evaluation”) respectively. A preliminary integration of the results of the assessments for each of the application sectors is described in Section 2, followed by best practices and guidelines on how to effectively apply the SSbD framework (in its 2022 version [1], [2], without taking into consideration the updates under consultation during the summer 2025 and published in December 2025 [3]) in early stage innovation projects in Section 3.

The consortium has followed the methodological guidance of the Joint Research Centre (JRC) [4], [5] as closely as possible, given the nature of the innovative products and the well-established limitations on data availability and quality that innovations bring forward in the early stages of the process.

The cut-off criterion, as defined by JRC for step 1 regarding the hazard properties of the materials/chemicals has been applied, taking into consideration all the aspects of the technical development and the needs of the industrial partners in terms of technical performance and requirements. Hazard screening assessments and environmental sustainability screening assessments have been performed continuously and iteratively to support the design and development of the coating formulations, as the technological developments advanced. Scores have been attributed in Steps 1, 2, 3, 4 and 5 following the criteria defined within the project and the methodological guidance of the SSbD framework, to support decision making and possible future research.

In ZeroF, the targeted Technology Readiness Level (TRL) at the end of the project for the new developed materials has been TRL5. The intermediate and final SSbD evaluation presented in this deliverable (as well as in D6.3, D6.4 and D6.5) contain significant uncertainties, and more accurate data could be obtained at higher TRL. As described in D6.1, due to the expected low to medium data quality for the SSbD evaluation, the exclusion of design alternatives because they do not bring significant safety or sustainability benefits was not intended and was not prioritised. Options which are expected to generate significant trade-offs (after considering the range of possible data values) could be analysed further.

2 Application of SSbD methodology in ZeroF

The ZeroF project focused on two application sectors for the development of alternatives to PFAS:

- Polysaccharides fatty acid esters (CFAE), for single-use, paper-based food packaging applications.
- Silicone-based organic–inorganic hybrid coatings, trademarked as ORMOCER®, developed for high-performance upholstery textiles.

Section 2 presents a short overview of the alternatives developed and tested in pilot scale for each of the application sector. An introduction to the scoring system for safety, sustainability and economic results is provided below (section 2.1), followed by a summary of the safety, Life-Cycle Assessment (LCA) and Life-Cycle Costing (LCC) assessment results of the two ZeroF case studies (sections 2.2 and 2.3 for packaging and textiles respectively). The summary is followed by the integration of SSbD results, where possible, per application sector. Overall, a detailed, evidence-based analysis of how the SSbD framework was practically applied to the two target value chains within the ZeroF project is provided. The target was to utilise the multi-faceted SSbD assessment to actively steer material design and innovation away from harmful chemicals, and towards demonstrably safer and more sustainable alternatives with similar or superior technical performance.

2.1 SSbD Scoring for safety and sustainability aspects

The scoring system described below and applied to the ZeroF innovations is aligned with the proposed scoring system of the SSbD framework [4] and its methodological guidance[5].

Generation of a score for SSbD - Safety step 1

The generated hazard classes under step 1 can be transformed into SSbD scores based on [1], as shown below in Table 1. H1 classes fail the SSbD criteria evaluation and should be substituted, whereas every other hazard class passes the evaluation. H2 classes, however, pass with reservations as these are substances of concern and the aim is to minimize the use as far as possible.

Table 1. Scores to be applied to the generated hazard classes under step 1 of the SSbD assessment, based on [1].

Hazard class	**SSbD step 1 score**	**Colour code**	**Criteria evaluation**
H1	0	🟥	Fail
H2	1	🟧	Pass, with reservations
H3	2	🟨	Pass
H4	3	🟩	Pass

Generation of a score for SSbD - Safety step 2

The results of the risk assessments of workers under step 2 of the SSbD assessment were transformed into SSbD scores based on the generated Risk Characterisation Ratio (RCR) according to [1]. In addition to the scores presented in Table 2, many data gaps have been

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identified as well, which were indicated as 'Not Available – NA'. How data gaps need to be considered in the SSbD assessment needs to be further considered in future work.

Table 2. Scores applied to the outcomes of the step 2 assessment. Table is adapted from [1].

RCR	**SSbD Score**	**Colour code**	**Criteria evaluation**
>1,5	0	🟥	Fail the criteria
1 – 1,5	1	🟧	
0,75 – 1	2	🟨	Pass the criteria
0,5 – 0,75	3	🟩	
<0,5	4	🟦	

Generation of a score for SSbD - Safety step 3

The scoring system for Step 3 is the same as for Step 2 in the SSbD framework guidance. Though, the safety assessment for consumers and the environment (Step 3) within ZeroF did not allow for the direct derivation of a quantitative SSbD score, as the results generated within the project are predominantly qualitative. This is due to the generation of thousands of structures, for which the representativeness and the extent of exposure of consumers and the environment have yet to be demonstrated. Once the representativeness of the structures is confirmed, a strategy needs to be developed to combine the different outcomes per endpoint for all the (relevant) structures into a single output, before an SSbD score for step 3 can be derived. In addition, data gaps and data uncertainty should be incorporated, as well as the integration of quantitative and qualitative information. Addressing these aspects, however, goes beyond the scope of this deliverable.

Generation of a score for SSbD – Sustainability step 4

The SSbD scoring system for the LCA is shown in Table 3. The score for each impact category reflects the degree of improvement relatively to the reference product.

Table 3. Step 4 scoring mechanism [1]

Improvement (%)	**Score for impact categories**
<= -10%	0
-10% - +5%	1
+5% - +20%	2
>20%	3

Generation of a score for SSbD – Economic assessment step 5

While a specific scoring system is not proposed for the economic assessment in literature, a mechanism similar to the one used for LCA is explored, for comparison purposes. The SSbD scoring system for the LCC is shown in Table 4. The score for each alternative reflects the improvement in terms of costs increase/decrease relatively to the reference product.

Table 4. Step 5 scoring mechanism

Cost increase (%)	Score for alternatives
<= -10%	3
-10% - +5%	2
+5% - +20%	1
>20%	0

Aggregation of safety and environmental sustainability dimensions

Following the recommendation from [1], a two-way aggregation is suggested and performed for the Safety and Environmental Sustainability dimensions. The aggregation formulas used are the following:

- Safety aggregation: $L_{Safe} = min\{L_{Haz}, L_{Pro}, L_{Use}\}$
- Environmental aggregation: $L_{EF} = \begin{cases} \frac{1}{4}(L_{Tox} + L_{CC} + L_{Pol} + L_{Res}), & if\ all\ L \geq 0.6 \\ min\left\{\frac{1}{4}(L_{Tox} + L_{CC} + L_{Pol} + L_{Res}), 2\right\}, & otherwise \end{cases}$

The suggested two-way aggregation scale is shown at Table 5.

Table 5. Two-way aggregation [1]

		Environmental score			
		0	1	2	3
Safety score	4	L1	L2	L3	L4
	3	L1	L2	L3	L3
	2	L1	L2	L2	L2
	1	L1	L1	L1	L1
	0	L0	L0	L0	L0

2.2 Packaging

2.2.1 Alternatives

The PFAS-free alternatives developed for packaging were based on Carbohydrates fatty acids esters (CFAE), specifically Cellulose fatty acid esters (CeFAE) derived from either starch or enzymatically treated cellulose pulp. Following initial development, multiple iterations of SSbD screening assessments, re-design and redevelopment (as described in the relevant deliverables of WPs 2-3-4) two final powder coating formulations were selected for the pilot scale and comprehensive SSbD assessments:

- Powder 1
- Powder 2

The final powder formulations (Powder 1 vs Powder 2) differed in composition, mainly in agents and solvents used during synthesis, as well as in the presence (or absence) of additives in the final coating.

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The reference product against which these alternatives were compared was the commercial PFAS product UNIDYNE TG-8111. All materials have been modelled and analysed for the production of 1 m^2 of coated paper.

2.2.2Safety assessment results

Detailed information on the safety assessment of the packaging coating formulations is included in D6.4 "Report on chemical safety evaluation" and specifically Sections 2.1, 3 and 4.1. Section 2.1 includes the materials and processes for the synthesis of the CeFAEs coatings formulations, their upscaling and their applications. Section 3 includes the methodological information for the application of the safety assessments within ZeroF, while Section 4.1 describes all the results of the safety assessment for the packaging value chain.

Hazard screening has been an integral part of the safety assessment together with screening of environmental impacts of the individual components of the coatings. Nevertheless, the focus in terms of scoring and integration of SSbD results is on the final coating formulations. An extract of the scoring for Step 1 of the SSbD framework for the final coating formulations of the packaging value chain is presented in Table 6.

Table 6. SSbD step 1 classification for the C(e)FAEs and their remaining data gaps (that would result in H1 classification) that could not be clarified *via* QSAR models and *in vitro* assays.

Name	**Physical form**	**SSbD hazard class**	**SSbD score**	**Unresolved data gaps for H1 classification**
Powder 1	Powder	4	3	Carcinogen, Mutagen, Reproductive toxicity, Respiratory sensitiser, ED, STOT RE, PBT
Powder 2	Powder	4	3	Carcinogen, Mutagen, Reproductive toxicity, Respiratory sensitiser, ED, STOT RE, PBT

An extract of the scoring for Step 2 of the SSbD framework for the packaging value chain is presented in Table 7. Detailed results of the scoring for Step 2 are presented in Annex I (Packaging) – Section 6.1.

Table 7. SSbD step 2 score for the production and processing phase.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Powder 1	3	4	NA	NA	NA
	4	4	NA	NA	NA

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	8b	4	NA	NA	NA
Powder 2	3	4	NA	NA	NA
	4	4	NA	NA	NA
	8b	4	NA	NA	NA

Table 8. Interpretation of scoring for Step 2 for powders 1-2.

Prototype	Step 2 SSbD score
Powder 1	4
Powder 2	4

While important data gaps and data uncertainty remain to be analysed and incorporated, the integration of quantitative and qualitative information for Step 3 did not allow the estimation of a quantitative score, as explained in Section 2.1.

2.2.3 Sustainability assessment results

The results of the % of improvement calculation for Powder 1 coating formulation and for the Powder 2 formulation are presented in Table 9 and Table 10 respectively, with the corresponding score as per the SSbD framework.

According to the evaluated product systems, the production of 1 m^2 of paper coated with CFAE powders shows significant environmental performance improvement in all impacts categories compared to the evaluated reference scenario. The only significant difference in impacts between the two CFAE formulations is in the freshwater ecotoxicity results, with Powder 1showing more than double the impacts of Powder 2. This is due to the solvent having a higher contribution to ecotoxicity impacts than the alternative used.

Table 9. SSbD scoring for the production of 1 m^2 of Powder 1 coated paper

LCA Assessment level	Impact category	Unit	Impact Powder 1	Impact PFAS	% change	Score	Level
Toxicity	Human toxicity, cancer effects	CTUh	2.11807E-09	9.25795E-09	77%	3	Pass
	Human toxicity, non-cancer effects	CTUh	5.13851E-09	2.24004E-08	77%	3	
	Ecotoxicity freshwater	CTUe	6.3741647	15.62224	59%	3	
Climate change	Climate change	Kg CO2eq	0.46353244	2.6346035	82%	3	Pass
Pollution	Ozone depletion	Kg CFC11eq	7.79575E-09	4.53E-08	83%	3	Pass
	Particulate matter	Disease inc.	2.28E-08	2.78E-07	92%	3	
	Ionising radiation	kBq U-235 eq	0.094423513	0.714546201	87%	3	

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	Photochemical ozone formation	kg NMVOC eq	0.001730269	0.013924972	88%	3	
	Acidification	mol H+ eq	0.003	0.017	84%	3	
	Eutrophication, terrestrial	mol N eq	0.006283328	0.043547845	86%	3	
	Eutrophication, freshwater	kg P eq	0.000288276	0.001173384	75%	3	
	Eutrophication, marine	kg N eq	0.000999141	0.00421456	76%	3	
Resources	Land use	Pt	25.386353	899.2141065	97%	3	Pass
	Water use	m3 depriv.	0.41040855	0.987637505	58%	3	
	Resource use, minerals and metals	kg Sb eq	2.37801E-06	0.000259807	99%	3	
	Resource use, energy carriers	MJ	7.1040675	42.94294783	83%	3	

Table 10. SSbD scoring for the production of 1 m^2 of Powder 2 coated paper

LCA Assessment level	Impact category	Unit	Impact Powder 2	Impact PFAS	% change	Score	Level
Toxicity	Human toxicity, cancer effects	CTUh	2.0846E-09	9.25795E-09	77%	3	Pass
	Human toxicity, non-cancer effects	CTUh	4.87198E-09	2.24004E-08	78%	3	
	Ecotoxicity freshwater	CTUe	0.000248014	15.62224	99%	3	
Climate change	Climate change	Kg CO2eq	0.54229098	2.6346035	79%	3	Pass
Pollution	Ozone depletion	Kg CFC11eq	7.47076E-09	4.53E-08	84%	3	Pass
	Particulate matter	Disease inc.	2.9454E-08	2.78E-07	89%	3	
	Ionising radiation	kBq U-235 eq	0.063059525	0.714546201	91%	3	
	Photochemical ozone formation	kg NMVOC eq	0.001764935	0.013924972	87%	3	
	Acidification	mol H+ eq	0.003163306	0.017	81%	3	
	Eutrophication, terrestrial	mol N eq	0.005506303	0.043547845	87%	3	

	Eutrophication, freshwater	kg P eq	0.000248014	0.001173384	79%	3	
	Eutrophication, marine	kg N eq	0.001202895	0.00421456	71%	3	
Resources	Land use	Pt	25.5547	899.2141065	97%	3	Pass
	Water use	m3 depriv.	0.19492554	0.987637505	80%	3	
	Resource use, minerals and metals	kg Sb eq	2.81687E-06	0.000259807	99%	3	
	Resource use, energy carriers	MJ	6.0111405	42.94294783	86%	3	

Although the modelling of the three scenarios (i.e. reference product and two ZeroF products) for the assessment of the packaging case study was based on similar maturity level for their production processes (i.e. small scale production for the reference product and theoretical calculation for the CFAEs coated products), the modelling of the reference product in this assessment represents the main limitation of the study since it is an approximation of the reference production process and may be overestimating material and energy inputs. The assessment is furthermore limited by the absence of the modelling of the end-of-life phase which would allow a more comprehensive evaluation of the impacts deriving from the release in the environment of PFAS from the different types of disposal mechanisms.

Based on the information above, it is possible to assign an overall score for Step 4 for the final formulations (Table 11).

Table 11. Step 4 score for the final formulations of the packaging value chain.

Name	Toxicity (average/ level)	Climate change (level)	Pollution (average/ level)	Resources (average/ level)	Average	SSbD sustainability score
Powder 1	3	3	3	3	3	3
Powder 2	3	3	3	3	3	3

2.2.4Socio-economic assessment results

The socio-economic assessment of the PFAS-free packaging solutions developed in ZeroF was carried out through a LCC approach, as detailed in D6.5. The objective was to evaluate the economic feasibility of the CFAE-based coating formulations at pilot to early industrial scale, and to benchmark them against a conventional PFAS-based reference used in food packaging applications.

In parallel, social acceptance was assessed through a combination of consumer surveys and stakeholder interviews, aiming to understand adoption drivers, perceived benefits, and potential barriers to market uptake of PFAS-free packaging solutions; these results are used in this report primarily to contextualise the economic findings.

The LCC analysis covers the main cost components relevant at this stage of technology development, namely material and energy costs, capital and maintenance costs, and labour costs, expressed per functional unit (€/m² of coated paper). The assessment reflects a baseline industrial scenario representative of Spain in 2025, consistent with the assumptions defined in D6.5.

The table below presents the total cost per square metre for the two CFAE-coated packaging prototypes, compared with a PFAS-based reference material

Table 12: Total cost per m² of the two CeFAE-coated packaging prototypes

	Powder 1	**Powder 2**	**PFAS**
Material and energy cost	€ 0.374	€ 0.430	-
Ownership cost (capital + maintenance)	€ 0.0026	€ 0.0026	-
Labour cost	€ 0.0017	€ 0.0017	-
Total cost (per m²)	**€ 0.379**	**€ 0.434**	**€ 0.305**
Increase %	**24%**	**42%**	
SSbD score	**0**	**0**	

Comparison with PFAS-free prototypes

When benchmarked against the PFAS-coated paper used as reference (€0.305/m²), both CFAE-based prototypes remain within a realistic industrial cost range, but are currently more expensive than the incumbent PFAS solution at this stage of development.

The Powder 1 prototype shows a total cost of €0.379/m², corresponding to an increase of approximately €0.074/m², or about +24%, compared to the PFAS baseline. The Powder 2 prototype reaches €0.434/m², i.e. €0.129/m² higher, corresponding to an increase of approximately +42% under the same baseline industrial assumptions.

The cost difference with the PFAS reference is mainly driven by higher material and energy costs, which reflect both the novelty of the CFAE-based chemistries and the limited scale of production considered in the assessment. In contrast, capital, maintenance and labour costs remain low and comparable across scenarios, indicating that the coating application process itself does not constitute a major economic barrier.

Interpretation in the SSbD context

Within the SSbD framework, the results of the LCC assessment are interpreted as decision-support information, rather than as a compliance or scoring criterion. Unlike chemical safety and environmental sustainability—which rely on screening approaches, regulatory thresholds and relative performance targets—the economic dimension of SSbD does not define pass/fail conditions or aggregated scores, particularly at low to mid Technology Readiness Levels.

In the ZeroF project, the economic assessment was nevertheless conducted against an internal cost-performance target, defined in the project objectives, whereby PFAS-free alternatives should aim to remain within a maximum 20% increase in production cost compared to conventional PFAS-based solutions. This target serves as a design and prioritisation benchmark, rather than as an exclusion criterion within the SSbD framework.

The LCC results for the packaging applications show that the Powder 1 formulation slightly exceeds this target, while remaining close to it, whereas the Powder 2 formulation currently exceeds it more significantly under the baseline industrial scenario considered. These deviations are mainly driven by material and energy costs, reflecting the early development stage of the CFAE chemistries and the absence of full industrial scale and supply-chain optimisation.

It is important to note that the cost increases identified in the LCC assessment relate specifically to the coated paper substrate at production level, and not to the final end-user packaging product. In practice, the coating represents only one component of the overall cost structure of food packaging, which also includes forming, converting, logistics, branding and distribution, as well as commercial margins applied along the value chain. As a result, a higher unit cost at coating level does not translate linearly into an equivalent cost increase for the final packaged product. Depending on the application and the position in the value chain, cost absorption mechanisms, optimisation at downstream processing steps, and margin allocation can significantly dilute the relative cost increase at end-product level. Consequently, the economic impact perceived by food manufacturers, retailers or end consumers is expected to be substantially lower than the relative cost increase observed at coating level, particularly in applications where packaging represents a limited share of the total product cost.

From an SSbD perspective, this distinction is essential to avoid overestimating market barriers at early development stages. Rather than disqualifying solutions, the economic assessment provides actionable guidance for iterative improvement, enabling the identification of cost hotspots and supporting informed trade-offs between performance, safety, environmental benefits and economic feasibility. The LCC outcomes were therefore used within the project as an iterative feedback mechanism, supporting formulation prioritisation and scale-up decisions alongside safety and environmental performance.

Overall, the economic assessment confirms that the CFAE-based PFAS-free packaging solutions developed in ZeroF remain economically plausible within an SSbD pathway, provided that continued optimisation, learning effects and scale-related cost reductions are achieved. The 20% cost-increase target thus functions as a pragmatic internal reference point, complementing the SSbD framework by supporting balanced, transparent and value-chain–aware decision-making.

2.2.5 Integration of results

Based on the availability of data for performing the SSbD assessments and the various assumptions that have been undertaken in relation to the scale up of the ZeroF innovations, some of the proposed scores for SSbD, especially in relation to Step 3 of the Safety assessment, could not be calculated. Therefore, an interpretation of how the scoring system may be used for early-stage innovations is provided below.

Following the methodology described in Section 2.1, we estimate the safety aggregation scores for the two coating formulations for packaging (Table 13), followed by the environmental sustainability aggregation scores (Table 14). The two-way aggregation of safety and sustainability is estimated and complemented with the score of the economic impacts for further analysis and decision making (Table 15).

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Table 13. Safety aggregation scores for packaging

Name	**L_{Haz}**	**L_{Pro}**	**L_{Safe}**
Powder 1	3	4	3
Powder 2	3	4	3

Table 14. Environmental aggregation scores for packaging

Name	**L_{EF}**
Powder 1	3
Powder 2	3

Table 15. SSbD scoring for packaging and economic aspects

Name	**Level**	**Economic score**
Powder 1	L3	0
Powder 2	L3	0

In this particular example, there is no differentiation of the scores between the two powder coating formulations, therefore further investigation is needed for future research or decision-making in terms of SSbD and the various aspects that can be taken into consideration. As noted above, there is a significant number of uncertainties, missing data and interpretations, which may be updated once more data become available or once the technologies become more mature and are possibly scaled up. Nevertheless, based on the available information both coating formulations may be tested and developed further for industrial applications, as their safety/sustainability profiles are high ranked and the economic impacts may improve significantly in higher TRL levels.

2.3 Textiles

2.3.1 Alternatives

The PFAS-free alternatives developed for textiles are hybrid ORMOCER® coatings, with variations in composition. The pilot scale developments focused primarily on variants of Coating System 1 (CS1). Following initial development, multiple iterations of SSbD screening assessments, re-design and redevelopment (as described in the relevant deliverables of WPs 2-3-4) four distinct hybrid coating prototypes were developed and evaluated, each with key compositional differences in terms of precursors, dispersants, catalysts and additives:

- Prototype 1 (P1)
- Prototype 2 (P2)
- Prototype 3 (P3)

- Prototype 4 (P4)

The reference scenario for comparison was a standard textile treated with a conventional C6 PFAS-based coating.

2.3.2Safety assessment results

Detailed information on the safety assessment of the textile coating formulations is included in D6.4 "Report on chemical safety evaluation" and specifically Sections 2.2, 3 and 4.2. Section 2.2 includes the materials and processes for the synthesis of the textile coating systems, their upscaling and their applications. Section 3 includes the methodological information for the application of the safety assessments within ZeroF, while Section 4.2 describes all the results of the safety assessment for the textile value chain.

Hazard screening has been an integral part of the safety assessment together with screening of environmental impacts of the individual components of the coatings. Nevertheless, the focus in terms of scoring and integration of SSbD results is on the final coating formulations. An extract of the scoring for Step 1 of the SSbD framework for the final coating formulations of the textile value chain is presented in Table 16, based on mixture assessment and classification.

Various drawbacks and considerations have been identified for Step 1 assessment and described in detail in D6.4 (e.g., limited availability of information under REACH for polymers and polymeric networks, data gaps, limited literature, limited applicability of QSARs for predictions and more). Therefore, an interpretation of the scoring system is presented, for further exploration in future studies.

Table 16. Mixture classification of ORMOCER® and polymer additive, based on individual components during processing conditions, as a proxy for hazards to workers. Hazards reported in bold drive the hazard score according to step 1 of the SSbD assessment.

Coating system	Mixture classification	SSbD hazard class	SSbD score (step 1)	Classification from SDS
P1-P2-P3 basis formulation	Acute Tox. 2: H300, H332; Skin Irrit. 2: H315 Eye Dam. 1: H318 **Skin Sens. 1: H317** STOT SE3: H335 Aquatic Chronic 3: H412	H2	1	Skin Irrit. 2.: H315 Eye Dam. 1.: H318 STOT SE3: H335 Aquatic Chronic 3: H412
P4 basis formulation	Acute Tox. 2: H300, H332; Skin Irrit. 2: H315 Eye Dam. 1: H318 **Skin Sens. 1: H317** STOT SE3: H335	H2	1	Skin Irrit. 2: H315 Eye Irrit. 2: H319
Additive polymer	Skin Irrit. 2: H315 **Skin Sens. 1: H317** Eye Irrit. 2: H319 STOT SE 3: H335	H2	1	Skin Irrit. 2: H315 Skin Sens. 1: H317 Eye Irrit. 2: H319 STOT SE 3: H335

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An extract of the scoring for Step 2 of the SSbD framework for the textile value chain is presented in Table 17. Detailed results of the scoring for Step 2 are presented in Annex II (Textile) – Section 6.2. While most of the RCRs are missing, the ones calculated through the predictions of ECETOC TRA are overestimated, leading to an uncertain and probably unrealistic result for conventional chemical handling during the production and processing phase. Therefore, SSbD scores cannot be estimated for the four prototypes, based on the available information. Nevertheless, following a semi-conservative approach and information provided by the technical partners, we assign a low score for Step 2 for P1 and P2 based on the use and handing of Curing Agent A, an intermediate score for P3 based on the use of Catalyst A and a higher score for P4 due to the absence of Curing Agent A and Catalyst A, as seen in Table 18.

Table 17. SSbD step 2 score for the production and processing phase.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Curing agent A	5	NA	0	NA	NA
	19	NA	0	NA	NA
Catalyst A	5	NA	4	NA	NA
	19	NA	1	NA	NA
Additive C	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
Additive D	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
Additive E	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
ORMOCER®	5	NA	NA	NA	NA
	19	NA	NA	NA	NA

Table 18. Interpretation of scoring for Step 2 for Prototypes P1-P4.

Prototype	**Step 2 SSbD score**
Prototype 1	1
Prototype 2	1
Prototype 3	2
Prototype 4	4

2.3.3 Sustainability assessment results

The impact assessment results for all ZeroF products alternative and the reference product are presented in Table 19. The results of the % of improvement calculation for the four prototypes used in the pilot testing are presented in Table 20, with the corresponding scores as per the SSbD framework.

Table 19. Impact assessment results of textile coated with the four ZeroF prototypes and the reference coating.

LCA Assessment level	Impact category	Unit	Impact PFAS	Impact P1	Impact P2	Impact P3	Impact P4
Toxicity	Human toxicity, cancer effects	CTUh	1.25E-08	1.39E-08	1.65E-08	1.73E-08	1.46E-08
	Human toxicity, non-cancer effects	CTUh	3.79E-08	4.07E-08	4.71E-08	4.87E-08	6.55E-08
	Ecotoxicity freshwater	CTUe	2.10E+01	2.14E+01	2.72E+01	3.11E+01	3.95E+01
Climate change	Climate change	Kg CO2eq	4.68E+00	4.95E+00	5.43E+00	5.65E+00	6.32E+00
Pollution	Ozone depletion	Kg CFC11eq	3.68E-06	6.35E-06	9.02E-06	9.03E-06	6.43E-06
	Particulate matter	Disease inc.	1.19E-07	1.25E-07	1.43E-07	1.63E-07	2.98E-07
	Ionising radiation	kBq U-235 eq	1.85E+00	1.89E+00	1.94E+00	1.94E+00	1.97E+00
	Photochemical ozone formation	kg NMVOC eq	1.60E-02	1.68E-02	1.86E-02	1.93E-02	2.32E-02
	Acidification	mol H+ eq	1.87E-02	1.95E-02	2.14E-02	2.31E-02	2.90E-02
	Eutrophication, terrestrial	mol N eq	3.65E-02	3.74E-02	4.09E-02	4.47E-02	5.69E-02
	Eutrophication, freshwater	kg P eq	1.97E-03	2.07E-03	2.23E-03	2.30E-03	2.22E-03
	Eutrophication, marine	kg N eq	4.45E-03	4.18E-03	4.52E-03	5.03E-03	6.05E-03
Resources	Land use	Pt	1.93E+01	1.58E+01	1.73E+01	2.23E+01	1.71E+01
	Water use	m3 depriv.	1.55E+00	1.57E+00	1.77E+00	1.98E+00	1.79E+00
	Resource use, minerals and metals	kg Sb eq	2.43E-05	2.52E-05	2.92E-05	3.20E-05	2.99E-05
	Resource use, fossils	MJ	9.75E+01	1.03E+02	1.12E+02	1.14E+02	1.27E+02

Following the SSbD framework methodology, the % of improvement with respect to the reference product was calculated for all ZeroF prototypes and a score assigned to each impact category (Table 20). Textile coated with prototype 1 shows better environmental results compared to all the other prototypes, but it does not show any improvement when compared to the reference product. The only improvement is obtained for eutrophication of freshwater with a decrease of impacts of 18%. For this reason, it does not pass any of the assessment levels.

Despite the hotspot analysis throughout the project duration and the iterative application of SSbD principles, the improvements in terms of environmental performance are minimal but still promising. It is important to note at this stage that the upscaling of laboratory or pilot scale ZeroF processes includes a significant number of assumptions and uncertainty, which require further refinement.

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Table 20. SSbD scoring for the production of 1 m^2 of ORMOCER® prototypes (P1-P4) coated papers

LCA Assessment level	Impact category	%change P1	Score	Level	%change P2	Score	Level	%change P3	Score	Level	%change P4	Score	Level
Toxicity	Human toxicity, cancer effects	-4%	1	Not passed	-14%	0	Not passed	-23%	0	Not passed	-55%	0	Not passed
	Human toxicity, non-cancer effects	-6%	1		-16%	0		-21%	0		-35%	0	
	Ecotoxicity freshwater	-2%	1		-29%	0		-48%	0		-88%	0	
Climate change	Climate change	-5%	1	Not passed	-20%	0	Not passed	-37%	0	Not passed	-152%	0	Not passed
Pollution	Ozone depletion	6%	1	Not passed	-2%	1	Not passed	-13%	0	Not passed	-36%	0	Not passed
	Particulate matter	-5%	1		-13%	0		-17%	0		-13%	0	
	Ionising radiation	-3%	1		-12%	0		-22%	0		-56%	0	
	Photochemical ozone formation	-11%	0		-32%	0		-38%	0		-17%	0	
	Acidification	-7%	1		-24%	0		-29%	0		-73%	0	
	Eutrophication, terrestrial	-2%	1		-5%	1		-5%	1		-7%	1	
	Eutrophication, freshwater	18%	2		10%	2		-15%	0		11%	2	
	Eutrophication, marine	-72%	0		-145%	0		-145%	0		-75%	0	
Resources	Land use	-5%	1	Not passed	-16%	0	Not passed	-20%	0	Not passed	-45%	0	Not passed
	Water use	-6%	1		-15%	0		-17%	0		-31%	0	
	Resource use, minerals and metals	-4%	1		-20%	0		-32%	0		-23%	0	
	Resource use, fossils	-1%	1		-14%	0		-28%	0		-16%	0	

Based on the information above, it is possible to assign an overall score for Step 4 for the final formulations (Table 21).

Table 21. Step 4 score for the final formulations of the textile value chain.

LCA Assessment level	P1 Score	Average	Level	P2 Score	Average	Level	P3 Score	Average	Level	P4 Score	Average	Level
Toxicity	1	1	1	0	0	0	0	0	0	0	0	0
	1			0			0			0		
	1			0			0			0		
Climate change	1	1	1	0	0	0	0	0	0	0	0	0
Pollution	1	0.875	1	1	0.5	0	0	0.125	0	0	0.375	0
	1			0			0			0		
	1			0			0			0		
	0			0			0			0		
	1			0			0			0		
	1			1			1			1		
	2			2			0			2		
	0			0			0			0		
Resources	1	1	1	0	0	0	0	0	0	0	0	0
	1			0			0			0		
	1			0			0			0		
	1			0			0			0		

2.3.4Socio-economic assessment results

The socio-economic assessment of the PFAS-free textile coating solutions developed in ZeroF was carried out using a LCC approach, as detailed in D6.5. The objective was to assess the economic feasibility of ORMOCER®-based coating formulations for upholstery textile applications and to benchmark their cost performance against a PFAS-based coated fabric reference currently used at industrial scale.

In parallel, social acceptance was assessed through consumer surveys and interviews with textile industry stakeholders, with the aim of understanding adoption drivers, perceived value, and potential barriers to market uptake of PFAS-free textile solutions. Within the scope of this report, social assessment results are primarily used to contextualise the economic findings.

The LCC analysis considers the main cost components relevant at this stage of development, including material and energy costs, capital and maintenance costs, labour costs, and residual bath treatment costs, expressed per functional unit (€/kg of coated fabric). The assessment reflects baseline industrial scenarios representative of current European textile finishing operations, in line with the assumptions defined in D6.5.

The table below presents the total cost per kilogram for the four PFAS-free coated fabric prototypes, compared with a PFAS-based coated textile reference.

Table 22: Total cost per kilogram of coated fabric prototypes

Prototype	Total cost (€/kg)	Increase %	SSbD score
Prototype 1	€43.50/kg	-16%	3
Prototype 2	€63.47/kg	22%	0
Prototype 3	€63.57/kg	22%	0
Prototype 4	€58.90/kg	13%	1
Reference PFAS coated fabric	€52.00/kg		

Comparison with PFAS-free prototypes

When compared with the PFAS-based coated fabric reference (€52.00/kg), the costs of the four PFAS-free coated textile prototypes remain within a realistic industrial range, while showing differentiated cost performances depending on formulation complexity and material composition.

Prototype 1 appears slightly cheaper than the reference, with a total cost of €43.5/kg, corresponding to a reduction of approximately 16% relative to the PFAS-based coated fabric. This result highlights the potential for economically competitive PFAS-free solutions when formulation complexity and additive content are limited.

Prototypes 2 and 3, which contain higher ORMOCER® concentrations and additional additives, show higher costs of approximately €63.5/kg, corresponding to an increase of around 22% compared to the PFAS-based reference. Prototype 4 reaches €58.9/kg, representing an increase of approximately 13% relative to the reference.

These differences are mainly driven by raw material costs and formulation complexity, while the coating application process itself does not introduce major additional capital or labour cost penalties.

Interpretation in the SSbD context

Within the SSbD framework, the economic results for textile applications are interpreted as decision-support inputs, rather than as compliance criteria. As for packaging, the SSbD framework does not define economic pass/fail thresholds, particularly at low to mid TRL, but encourages the use of LCC to inform design choices and prioritisation.

In the ZeroF project, the textile LCC results were assessed against the internal project target of remaining within a 20% cost increase compared to PFAS-based references. From this perspective, Prototypes 1 and 4 already meet this target, while Prototypes 2 and 3 slightly exceed it under the baseline industrial assumptions considered.

Importantly, the costs reported here correspond to the coated textile material at production level, and not to the final upholstered product. In downstream applications, the coated fabric represents only one component of the total cost of upholstery products, which also includes cutting, assembly, logistics, branding and retail margins. Consequently, cost variations observed at coating level are not expected to translate directly into proportional price increases for end users, particularly in applications where textile finishing represents a limited share of the final product cost.

From an SSbD perspective, these results demonstrate the value of early-stage LCC in highlighting economically promising formulation routes, identifying cost hotspots, and guiding iterative optimisation. Rather than excluding higher-cost formulations, the economic assessment supports informed trade-offs between performance, safety, environmental sustainability and cost, in line with the holistic intent of the SSbD framework.

Overall, the LCC results confirm that several ORMOCER®-based PFAS-free textile coatings developed in ZeroF are economically plausible candidates for scale-up within an SSbD pathway, provided that formulation optimisation, supply-chain maturation and scale effects are achieved.

2.3.5Integration of results

Based on the availability of data for performing the SSbD assessments and the various assumptions that have been undertaken in relation to scale up of the ZeroF innovations, some of the proposed scores for SSbD, especially in relation to Step 3 of the Safety assessment, could not be calculated. Therefore, an interpretation of how the scoring system may be used for early-stage innovations is provided below.

Following the methodology described in Section 2.1, we estimate the safety aggregation scores for the two coating formulations for packaging (Table 23), followed by the environmental sustainability aggregation scores (Table 24). The two-way aggregation of safety and sustainability is estimated and complemented with the score of the economic impacts for further analysis and decision making (Table 25).

Table 23. Safety aggregation scores for textiles

Name	**L_{Haz}**	**L_{Pro}**	**L_{Safe}**
P1	1	1	1
P2	1	1	1
P3	1	2	1

P4	1	4	1

Table 24. Environmental aggregation scores for packaging

Name	**L_{EF}**
P1	0.97
P2	0.125
P3	0.03
P4	0.09

Table 25. SSbD scoring for packaging and economic aspects

Name	**Level**	**Economic score**
P1	L1	3
P2	L1	0
P3	L1	0
P4	L1	1

In the textile value chain, the wealth of information that may be extracted from the SSbD assessments is clearly demonstrated. The four prototypes have very diverse scoring summaries. While the two-way aggregation gives higher importance to the Safety dimension, it is clearly demonstrated that the Environmental dimension of P1 is better, therefore providing valuable information to the technical partners for future development. Taking into consideration the economic impacts, which also favour P1 as a more viable option for upscaling, a preference may be given to this prototype. Of course, all the results will have to be coupled with the technical performance of the coating formulations and be enriched once more data become available, in order to reduce the uncertainties that are tied to the SSbD assessments performed within ZeroF.

3 SSbD guidelines and best practice

The application of the SSbD framework to the development of PFAS-free coatings for textile and packaging applications has proven to be an effective approach for addressing both environmental and health concerns while maintaining product performance. The iterative nature of the SSbD framework allowed for continuous refinement and optimization, ensuring that each stage of the development process integrates safety, sustainability, socio-economic and technical performance considerations, up to the highest possible level, depending on the availability and quality of data for the assessments.

Through the application of the (re)design principles and the multiple, incremental iterations of the safety, sustainability and economic assessments, a set of significant improvements and updates has been achieved within the project:

- 20+ substances and materials (e.g., raw materials, precursors, solvents, additives) have been substituted, prioritised for substitution or used in reduced amounts in case of necessary use due to technical requirements
- Employment of innovative laboratory techniques to minimise use of resources (e.g., materials, energy) and reduce process emissions in the air (e.g., reduction of environmental impacts).

It has to be noted that the improvements and updates were made possible based on the available data and were incremental in many cases, as full SSbD assessment (or even intermediate) has not been possible to be performed until very late in the project and the innovation process.

Several key factors contributed to identified improvements and successes:

- Foundation through Scoping: An interpretation of the "Scoping Analysis" has been highly appreciated, as it allowed establishing a common technical and terminological basis, across multidisciplinary research teams that had to collaborate outside the usual comfort zones. Even though the scoping analysis it has not been performed based on the formalised notion of the revised SSbD framework version (December 2025) [3], the approximate activity within ZeroF has allowed to mitigate the risk of fragmented objectives and was a natural consequence of the expected activities within WP6.
- Proactive Hazard Screening: The dual approach of manual and automated screening for Substances of Very High Concern (SVHC) and Substances of Concern (SoC) ensured a high level of safety integrity within the project. This process facilitated a multidisciplinary and fertile interaction among chemists, chemical engineers, data engineers and SSbD practitioners, shifting safety from a final check to a primary design driver.
- Iterative Hotspot identification and Design Evolution: The framework's strength lies in its iterative nature. By identifying "hotspots" in Steps 1, 4, and 5 (Safety and Sustainability assessments), technical partners could apply immediate changes to experimental processes.

Nevertheless, various considerations have emerged during the implementation of the SSbD framework in ZeroF and are shortly discussed below.

One of the primary challenges in replacing PFAS with safer alternatives is ensuring that the new coatings meet the performance standards required for textile and packaging applications in the relevant industrial sectors. Early trials have shown that certain non-fluorinated alternatives can achieve similar water and oil repellence properties to PFAS-based coatings, although some trade-offs may be necessary that may require further developments. Such developments may be time consuming or outside the boundaries of a research project, but have to be explored, emphasizing that SSbD is a multi-disciplinary and collaborative effort.

A commonly raised issue lies within the material/chemicals dynamics and the subjectivity that can be introduced within SSbD. The perception of "concern" is not always uniform. Chemists and chemical engineers may view substances (e.g., Ethanol) differently based on best practices, laboratory handling standards versus sole intrinsic properties. The introduction of exposure-based risk approach in the revised SSbD version is welcomed and in the right direction. Better consideration/integration of functionality and chemical reactivity (i.e. if a hazardous chemical reacts completely away during the process) could be incorporated within the safety criteria and assessments, to reduce uncertainties. Furthermore, discrepancies between harmonized classifications and notified classifications can lead to subjectivity in assessment, potentially undermining the framework's objective of

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standardization. In addition, while the duo of manual and automated hazard screening has clear advantages, it also introduces another level of possible discrepancies as high level expertise is required to analyse and treat the information that may be collected.

While various improvements have been introduced at the revised version of the SSbD framework, some points should be elaborated further. An important aspect is related to the introduction of commercial products that may contain SoC (or SVHC) during the innovation process (production or use), for which there is no standardised way to treat or incorporate in the assessment. While these products may be compliant with REACH or relevant sectoral regulations, the possible introduction of "non-SSbD compliant" substances (cut-off) cannot be excluded, while they may be considered as "black boxes" for the SSbD practitioners.

Despite the various benefits, several bottlenecks may hamper the seamless integration of SSbD into fast-paced industrial innovation. Low-tier innovation processes may suffer from important data gaps due to the various unknown parameters (e.g. toxicity, bioavailability and degradability potential) and the limited applicability of available *in silico* tools for innovative polymeric substances. In direct connection, the workload/expertise needed and possible speed mismatch, play an important role. The framework requires an "extremely high" level of expertise, man-hours and communication effectiveness, often exceeding the capacity of standard innovation departments, while innovation cycles may move faster than complex assessment (e.g., safety assessment and toxicity modelling-*in silico/in vitro*), leading to safety data arriving after design decisions are already made. The interpretation bias, as described above and extended to multiple topics, may bring additional uncertainty in results and lead to subjective decision-making due to the lack of standardised techniques and outcomes. In relation to the reduction of the data gaps, various methodologies can be employed (e.g., complex modelling, New Approach methodologies, *in vitro* testing). While these are time and resource consuming or may even be employed at a late stage of the innovation, whereas the actual data may be relevant early in the innovation process.

Strategic Recommendations for Framework Optimisation

The transition of the SSbD framework from a research-intensive exercise to a standard industrial practice, is a natural step that may be followed up in the near future. Some methodological refinements are suggested for SSbD practitioners:

- Establishment of tiered and hypothesis-driven SSbD (sub-)assessments, based on TRL and defined within the system boundaries.
  - Testing of specific hypotheses with direct practical implications in the molecular, process and/or product design.
  - Low TRL: Focus on specific hypotheses regarding molecular design and initial safety screening with "acceptable uncertainty". Proceed with risk and exposure-based safety assessments, based on pre-defined timelines.
  - High TRL: Conduct full-scale LCA and socio-economic impact studies when the product composition is stabilised, best design options identified.
- Data FAIRification and Tool Validation.
  - Standardised/harmonised, product specific, data collection templates for SSbD assessment would be highly useful. This would contribute to the "FAIRification" (Findable, Accessible, Interoperable, Reusable) of data, which is considered essential in the long term. The data collection templates would reduce the "workload" obstacle and would contribute highly to the

    improvement of the reliability and relevance of safety and sustainability assessments results (especially Environmental Sustainability-Step 4).
  - Furthermore, establishing a clear validation path for modelling tools would provide stakeholders with the confidence needed to speed up the safety assessment and enable high-stakes investment decisions early in the innovation process.

4 Conclusion

The SSbD framework offers a promising approach for the development of safer, more sustainable alternatives to PFAS in coatings for textile and packaging applications. By integrating safety, sustainability, and performance considerations from the earliest stages of development, the framework enables the development of innovative coatings that meet not only functional but also safety and environmental sustainability requirements, while incorporating economic and social aspects in the innovation process. Thus, it supports the move beyond mere regulatory compliance toward a holistic "Safety + Sustainability + Performance" model. The iterative nature of SSbD ensures that hotspots and potential risks are identified and addressed early in the development process, leading to more informed decisions and ultimately safer, more sustainable products. In the case of PFAS-free coatings, it has successfully guided the elimination of hazardous substances and the reduction of environmental footprints. To increase the convergence of the complex relationships among technical requirements, safety, and sustainability, the applicability of the SSbD framework would benefit from certain timelines for decision-making (vs open-end, continuous decision spaces). Nevertheless, different paces between SSbD assessments and technological developments also limit the application of the SSbD Framework during the innovation process. Data gaps and limited applicability of *in silico* tools are a challenge for the safety and sustainability assessment of PFAS-alternatives. For widespread industrial adoption, the framework must address the subjectivity of results, the expertise barrier, and the data gap regarding innovative materials. As regulatory pressures to phase out PFAS continue to grow, the SSbD framework provides a valuable tool for industries seeking to innovate responsibly and sustainably.

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6 Annexes

6.1 Annex I: Packaging - Step 2 SSbD scoring

6.1.1 Powder 1 synthesis components for industrial scale applications

Table 26. Overview of Powder 1 synthesis components for industrial scale applications and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	PROC	*Score: Long-term inhalation*	*Score: Short-term inhalation*	*Score: Long-term dermal*	*Score: Short term dermal*
Enzymatically treated cellulose dry	3	4	NA	NA	NA
	8b	4	NA	NA	NA
Starch, potato	3	4	NA	NA	NA
	8b	4	NA	NA	NA
Solvent A	3	4	4	4	NA
	4	4	4	4	NA
	8b	4	4	4	NA
Solvent B	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Solvent C	3	4	4	0	NA
	4	4	4	0	NA
	8b	4	4	0	NA
Base and solvent A	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Acylation agent A	3	NA	2	NA	NA
	4	NA	0	NA	NA
	8b	NA	0	NA	NA
Alternative solvent)	3	NA	NA	NA	NA
	4	NA	NA	NA	NA
	8b	NA	NA	NA	NA
Co-products	3	NA	NA	NA	NA
	4	NA	NA	NA	NA
	8b	NA	NA	NA	NA

Powder 1	3	4	NA	NA	NA
	4	4	NA	NA	NA
	8b	4	NA	NA	NA

6.1.2Powder 2 synthesis components for industrial scale applications

Table 27. Overview of Powder 2 synthesis components for industrial scale applications and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Enzymatically treated cellulose dry	3	4	NA	NA	NA
	8b	4	NA	NA	NA
Starch, potato	3	4	NA	NA	NA
	8b	4	NA	NA	NA
Solvent D	3	4	4	NA	NA
	4	4	0	NA	NA
	8b	4	4	NA	NA
Solvent A	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Solvent B	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Solvent C	3	4	4	4	NA
	4	4	4	4	NA
	8b	4	4	4	NA
Base and solvent A	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Acylation agent B	3	NA	4	NA	NA
	4	NA	4	NA	NA
	8b	NA	4	NA	NA
Alternative solvent	3	NA	NA	NA	NA
	4	NA	NA	NA	NA
	8b	NA	NA	NA	NA
Powder 2	3	4	NA	NA	NA
	4	4	NA	NA	NA
	8b	4	NA	NA	NA

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6.1.3 Occupational safety for C(e)FAE synthesis

Table 28. Overview of CFAE and CeFAE starting materials following the industrial hypothetical settings described in D6.4 Annex I and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Enzymatically treated cellulose dry	3	4	NA	NA	NA
	8b	4	NA	NA	NA
Starch, potato	3	4	NA	NA	NA
	8b	4	NA	NA	NA

6.2 Annex II: Textile - Step 2 SSbD scoring

6.2.1 ORMOCER® CS1 without inorganic network component C

Table 29. Overview of ORMOCER® CS1 without inorganic network component C and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Inorganic network component A	3	4	0	NA	NA
Inorganic network component B	3	4	0	NA	NA
Catalyst A	3	4	4	NA	NA
	4	4	4	NA	NA
	8b	4	4	NA	NA
Additive A	3	4	4	NA	NA
Additive B	3	NA	4	NA	NA
Dispersing agent A	3	NA	1	NA	NA

6.2.2 ORMOCER® CS1 with inorganic network component C

Table 30. Overview of ORMOCER® CS1 with inorganic network component C and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Inorganic network component A	3	4	0	NA	NA
Inorganic network component B	3	4	0	NA	NA
Catalyst A	3	4	4	NA	NA
	4	4	4	NA	NA
	8b	4	4	NA	NA
Additive A	3	4	4	NA	NA
Additive B	3	NA	4	NA	NA
Inorganic network component C	3	NA	NA	NA	NA
Dispersing agent A	3	NA	1	NA	NA

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6.2.3Performance additive formulation

Table 31. Generated SSbD score for workers for the formulation of the performance additive. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Component A	3	4	4	NA	NA
Component B	3	4	4	NA	NA
Component C	3	NA	4	NA	NA
Dispersing agent A	3	NA	0	NA	NA

6.2.4Formulation of ORMOCER® coating system

Table 32. Formulation of ORMOCER® coating system and the generated SSbD score for workers for different routes of exposure. NA = not available.

Name	**PROC**	***Score: Long-term inhalation***	***Score: Short-term inhalation***	***Score: Long-term dermal***	***Score: Short term dermal***
Curing agent A	5	NA	0	NA	NA
	19	NA	0	NA	NA
Catalyst A	5	NA	4	NA	NA
	19	NA	1	NA	NA
Additive C	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
Additive D	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
Additive E	5	NA	NA	NA	NA
	19	NA	NA	NA	NA
ORMOCER®	5	NA	NA	NA	NA
	19	NA	NA	NA	NA