Safe and Sustainable by Design Strategies for the H2020 SUNSHINE case studies

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1. Introduction

The European Chemicals Strategy for Sustainability and the Zero Pollution Action Plan identify the need to transition towards Safe and Sustainable by Design (SSbD) chemicals and materials. In this context, the H2020 SUNSHINE project has developed an approach to operationalize SSbD, specifically addressing advanced multi-component nanomaterials (MCNMs). The main goal of SUNSHINE is to develop and validate SSbD strategies for products enabled by MCNMs and to facilitate their implementation at an industrial scale. These strategies can be considered as action plans to identify, mitigate, and ultimately resolve hotspots identified through the application of sustainability assessment methodologies. This contribution presents the SUNSHINE SSbD tiered approach and its application to four industrial case studies.

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2. Materials and methods

The SUNSHINE SSbD tiered approach is composed of two tiers. Tier 1 uses a scoring system to calculate indices for the different impacts and plot those on a chart that clearly visualizes safety and sustainability-related 'hotspots of concern' along the lifecycles of the materials/products which can be further assessed in Tier 2. Therefore, Tier 2 consists of LCA (Life Cycle Assessment), LCC (Life Cycle Costing), and S-LCA (Social Life Cycle Assessment) of the MCNMs and the products incorporating them in comparison with selected benchmark materials (Pizzol et al., 2023). The developed tiered approach has been tested on four advanced MCNMs . Since the approach is comparative, the assessed SSbD-modified material is always compared to a benchmark. Such a benchmark could be an alternative design option or a conventional material/product that has the same or a similar function.

The first material consists of a novel PFAS-free anti-sticking coating used in the bakery industry (i.e., coating of baking trays and pans), produced by the company Laurentia Technology SLL, which is compared to a conventional anti-stick coating (Teflon). The second, produced by the company Encapsulae S.L., consists of nano-drops of essential oil anchored at the surface of nano-clays and encapsulated in a polymeric film which keeps the packaged food free of insect pests. It is compared to conventional food packaging (LDPE). The third, produced by the company Avanzare Innovacion Tecnologica SL, consists of a nanocomposite of graphene oxide functionalized with chitosan which provides flame retardant properties and is compared to graphene oxide functionalized with casein, an alternative design option. Finally, the fourth, produced by the foundation CIAC (Centro de Innovación Andaluz para la Construcción Sostenible), is an additive for construction materials (i.e., mortar) based on zinc oxide and silica dioxide with photocatalytic decontamination properties (NOx gas removal), compared to a titanium oxide-based benchmark.

3. Results

Tier 1 is applied at the screening level in the early stages of innovation. Figure 1 shows the results that can be obtained, in terms of percentage of positive impacts to safety, functionality, and sustainability scores, for the innovative material and the benchmark. As a life cycle thinking approach is adopted, the safety, sustainability and functionality assessment is carried out by considering all life cycle stages: from raw materials acquisition up to the end of life (e.g., recycling, incineration). The blue columns report the results for the innovative material while the grey ones those for the benchmark. The light blue and light grey parts of the column show the relative uncertainty for both the innovative material and the benchmark. More specifically, results can be shown by life cycle stages (raw materials and resources needed to produce the material/product, production of the MCNM, production of the product incorporating the MCNM, use of the product, and end of life treatment) or by aspect (safety/environmental, social, economic sustainability/functionality).

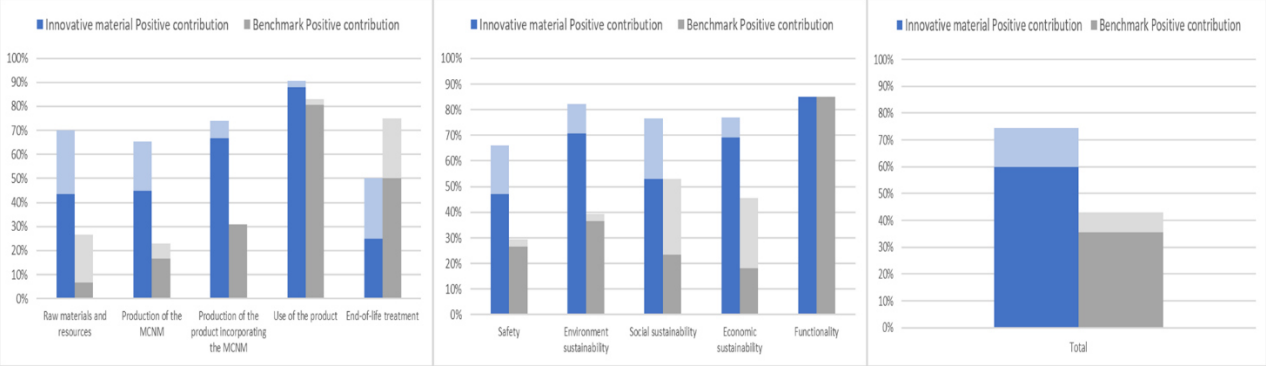

Figure 1 Percentage of positive contributions by life cycle stages, by aspect, and total.

Tier 2 instead, is applied at a more advanced level when the products are already developed and are ready to be released on the market as well as part of post-market evaluations. Example of Tier 2 results are reported in Figure 2.

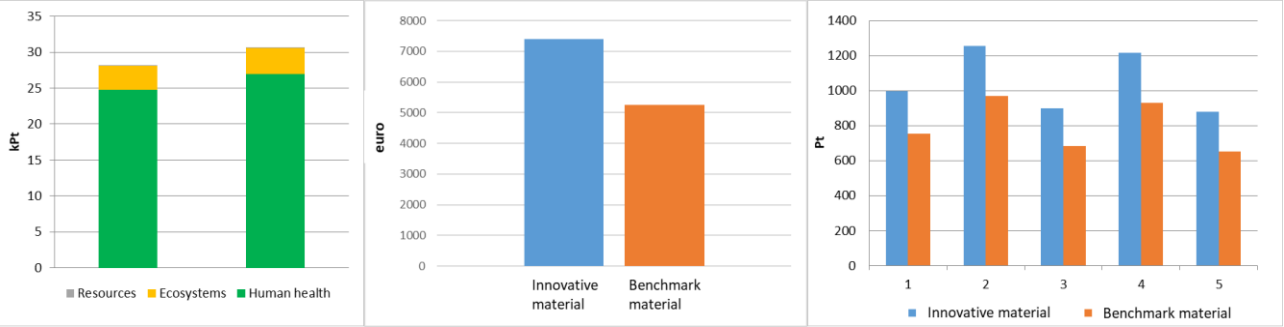

Figure 2 Life Cycle Sustainability Assessment (LCSA) results: LCA single score endpoint results, LCC aggregated results (total cost in euros), and S-LCA weighting categories results.

The application of the tiered approach to the case studies allows to identify safety, sustainability, and functionality hotspots to support the development of materials-specific strategies aimed at mitigating the identified hotspots and at supporting the identification of products' optimisation measures. As far as the case studies results, for each innovative material and product incorporating it, it has been developed a strategy that guided the development during the design phase and pointed out the advantages of such material development.

4. Conclusions

Following the adoption of the EC's SSbD Framework, the SUNSHINE experts have developed a tiered approach to operationalize it. The reason for adopting different tiers for the assessment stems from considerations that the information available for newly developed chemicals or materials could be limited in the early stages of development (e.g., R&D stage), while the availability of data and expertise increases in the later product development and optimization stages, which also demand more thorough assessment of safety and sustainability. The operationalization of the tiered approach proved that the obtained results and information can support decision-making processes, by discriminating between alternatives in a comparative analysis (i.e., an innovative product compared to a traditional benchmark product). In this context, it significantly improves the development of new products, positively affecting the impact of the R&D phase.

Moreover, the results prove the added value of the SUNSHINE SSbD approach in guiding early stages of innovation, along with the opportunity it provides in enabling companies to assess their sustainability performance easily and affordably, which can make them more competitive in the market while leading the design of more environmentally friendly nanotechnologies of high social and economic benefit.

5. References

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