# Safe and Sustainable by Design, Scoping, and Simplified Assessment of Alternative Flame Retardants for Use in Insulation Foams

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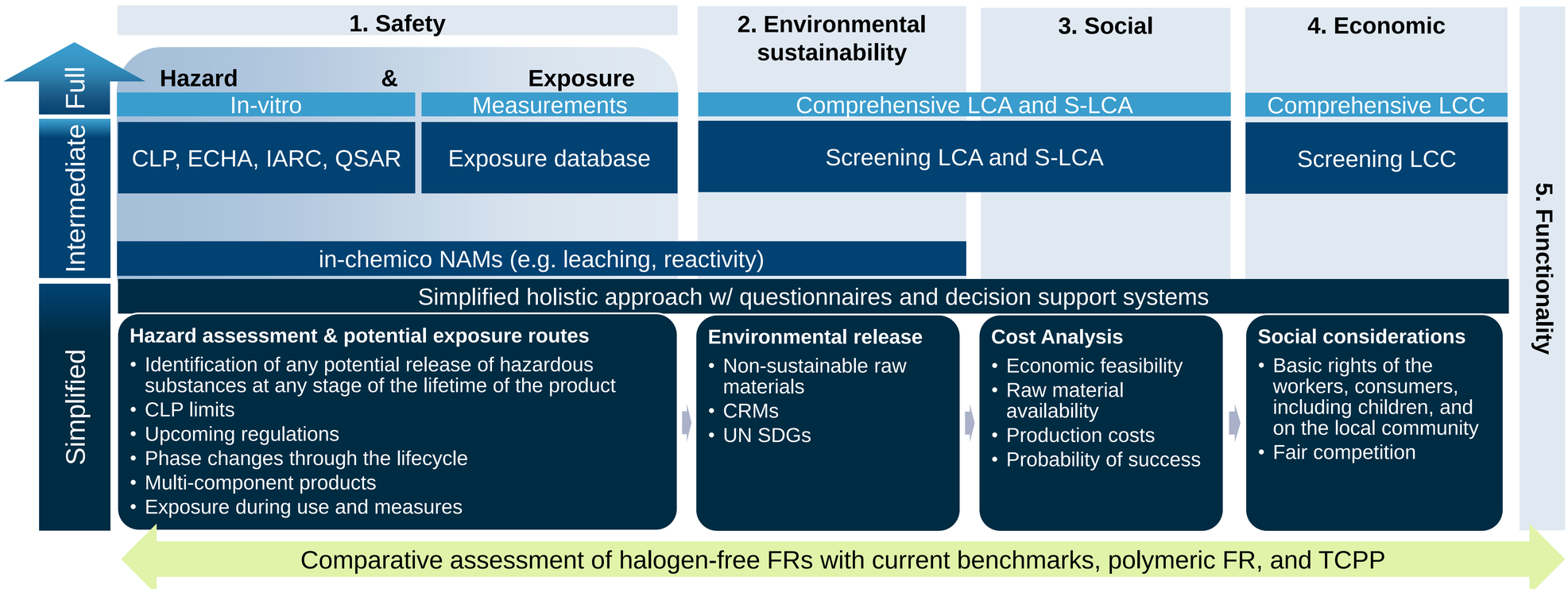
## Introduction

There have been **limited successful implementations of SSbD in R&D projects from the molecular formulation level**. PLANETS project seeks to address this issue by **encouraging the development** and **application of simple**, **effective**, and **cost-efficient SSbD strategies** for materials and products **through a tiered framework**. An evaluation of five dimensions, functionality, safety (hazard and exposure), environmental effects, and considerations of economic and social factors:

(i) preliminary scoping and simplified evaluations in Simplified assessment (Tier 1)
(ii) risk screenings supported by in-chemico NAMs, coupled with LCA using existing data in Intermediate assessment (Tier 2)
(iii) experimental methods alongside detailed LCAs in Full assessment (Tier 3)
In this research, we utilized Simplified assessment to find alternatives to flame retardants that may face restrictions under upcoming regulations.

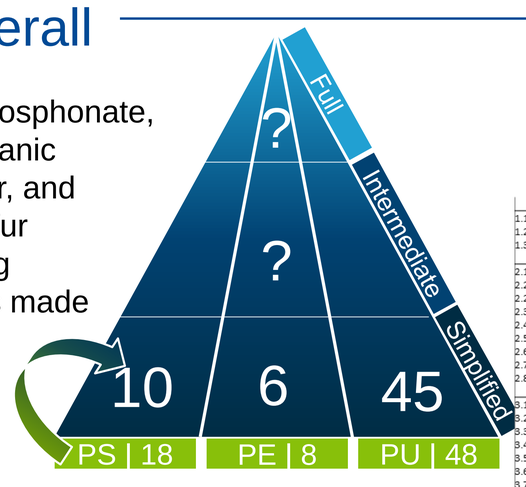



Five dimensions of SSbD Assessment with tiered approach and overview of the questionnaire

## Design Space: Overall

**Key alternatives:** s-triazine phosphonate, ammonium polyphosphate, organic phosphate, DOPO-P-S polymer, and styrene organophosphorus-sulfur copolymer, specifically targeting applications in insulation foams made from EPS, XPE, and PU.

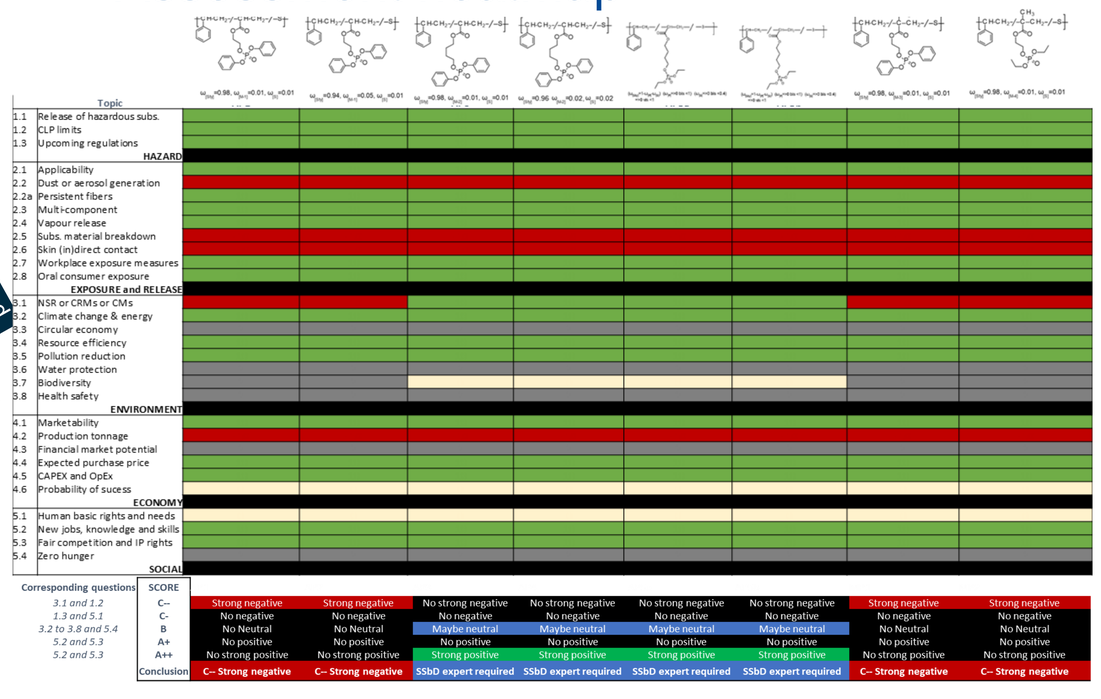
**Decision criteria: Score≥B**




Number of alternative FRs for respective insulation foams at each tier

- For some alternatives **low sustainability ratings due to critical raw materials.**
- **P is essential** for flame retardant functionality and substitutes Br.
- Cu is used as a reactive intermediate in the synthesis process.
- **A red flag** in simplified assessments does **not** mean **a definitive "stop."**
- Indicates the need for an intermediate assessment to **weigh trade-offs.**

## Design Space: Exemplary Simplified Assessment heatmap




## Conclusion

- **+74 alternative FR-insulation foam combination** were assessed using Simplified assessment questionnaire.
- The **discriminating power of using a holistic questionnaire** for alternative FRs relies on i) consideration of all stages of the product lifecycle (starting from raw materials to the end-of-life), ii) upcoming regulations, and iii) UN SDGs.
- **Identification of gaps** in available data, suggests plans for enhancements, and specifies methods for advanced assessments
- Demands **minimal data requirements** and basic understanding of SSbD principles.
- **Promotes the implementation of SSbD** by incorporating the perspectives and needs of industry participants.

Limitations:

- **Molecular variations** within a molecule class **cannot be compared** in Simplified assessment.
- **Limited information** is available **during the development of new molecules**/flame retardants.
- Some Simplified assessment questions must be answered as "unknown," excluding them from evaluation.

## Future work

- Apply **further selection criteria** in addition to Simplified assessment **to reduce the number of FR for Intermediate assessment** – cost-benefit analysis.
- **Intermediate SSbD** incl. risk screenings and in-chemico NAMs on the selected alternatives, using established benchmarks for comparison.
- **Full SSbD** incl. life-cycle releases, in-vitro NAMs, prospective life-cycle assessment .
- Guidance for future substitution **('lessons learned')**.

## References

M. Andruschko, M. Luksin, P. Frank, T. Paululat, U. Jonas, S. Fuchs, A set of intrinsically flame retardant, halogen-free styrenic copolymers: Synthesis, characterization, processing, and properties, Polymer Degradation and Stability, 2025

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