

Integrating SSbD and Life Cycle Costing enables a more informed selection of safer fire retardants



- Safety must be assessed across the entire life cycle
- Environmental and economic trade-offs emerge clearly
- Early-stage design decisions are critical

Background

- SSbD supports safe and sustainable material design
- Multi-step life cycle evaluation framework
- Fire retardants raise safety and environmental concerns
- Lack of integration with economic assessment

Methodology

The evaluation is articulated into five sequential stages:

Step 1 – Hazard assessment: analysis of the intrinsic properties of the chemical/material to identify potential hazards independently of its use.

Step 2 – Production safety: assessment of human health and safety risks during the production and processing phases, considering exposure levels and existing risk management measures.

Step 3 – Application phase impacts: evaluation of human health and environmental risks associated with the use of the material in its final application.

These three steps jointly define the **safety dimension** of the framework.

Step 4 – Environmental sustainability assessment: analysis of environmental impacts along the life cycle using a Life Cycle Assessment (LCA) approach.

Step 5 – Social and economic sustainability: evaluation of broader socio-economic aspects, including costs, compliance, and societal implications, integrating a Life Cycle Costing (LCC) perspective.

Case study

- Fire retardant chemicals in wood products
- The analysis covers the Cradle-To-Gate:
 - Raw Material Extraction →
 - Transport to Production facility →
 - Manufacturing →
 - Packaging.

Results

Operating Costs(OPEX)

Step	Macrocategory	Microcategory	Unit
A1 Raw Materials	Raw Materials	Dimethyl Ammonium Phosphate	kg
	Raw Materials	Urea formaldehyde resin / Urea	kg
	Raw Materials	PolyDimethyl Siloxane	kg
	Raw Materials	Potassium Citrate	kg
	Raw Materials	Pentaerythritol	kg
	Raw Materials	Aluminium Hydroxide	kg
A2 Transport to pilot site	Transport	Transport to pilot site	t-km
	Manufacturing	Mixing electricity	kWh
A3 Manufacturing & Packaging Consumables	Manufacturing	Cleaning water / consumables	batch
	Packaging	PP bottle / container	pcs
	Packaging	Cap / sealing lid	pcs
	Packaging	Printed label	pcs
	Packaging	Stretch film / carton	pcs

Investments (CAPEX) - Pilot Scale with Batch Scenarios

Step	Microcategory	Quantity
Manufacturing	OSL-20L Stirrer / Mixer	1
Manufacturing	Mixing vessel / tank	1
Manufacturing	Precision scale	1
QC / Safety	pH or viscosity meter	1
Packaging	Semi-manual filling tool	1
Packaging	Sealing device	1
Packaging	Label printer	1
Safety	Chemical storage cabinet / spill tray	1

Externalities (environmental LCC)

Impact category	Unit of measure
Global warming	€/kg CO2 eq
Stratospheric ozone depletion	€/kg CFC11 eq
Ionizing radiation	€/kBq Co-60 eq
Ozone formation, Human health	€/kg NOx eq
Fine particulate matter formation	€/kg PM2.5 eq
Ozone formation, Terrestrial ecosystems	€/kg NOx eq
Terrestrial acidification	€/kg SO2 eq
Freshwater eutrophication	€/kg P eq
Marine eutrophication	€/kg N eq

Impact category	Unit of measure
Terrestrial ecotoxicity	€/kg 1,4-DCB
Freshwater ecotoxicity	€/kg 1,4-DCB
Marine ecotoxicity	€/kg 1,4-DCB
Human carcinogenic toxicity	€/kg 1,4-DCB
Human non-carcinogenic toxicity	€/kg 1,4-DCB
Land use	€/m2a crop eq
Mineral resource scarcity	€/kg Cu eq
Fossil resource scarcity	€/kg oil eq
Water consumption	€/m3