SSbD and Risk Assessment approaches in composites development

Putting in practice the Safe and Sustainable by Design framework for advanced materials: the REPOXYBLE experience on SSbD and risk assessment

Authors: Amaia Garcia-Bilbao[1], Isabel Rodríguez-Llopis[1], Leire Barruetabeña[1], Alberto Katsumiti[1], Christoph Olscher[2], Florian Part[2], Cyrille Durand[3], Elvira Villaro Abalos[4], Elena Destro[5], Olmo Guagnetti [5], Andrea Porcari[5]

(1) GAIKER Technology Centre, Basque Research and Technology Alliance (BRTA), ES
(2) University of Natural Resources and Life Sciences (BOKU)
(3) TEMAS Solution GmbH, CH
(4) Avanzare Innovación Tecnológica sl, ES
(5) Airi - Italian Association for Industrial Research, IT;

Dr. Amaia Garcia-Bilbao

Researcher at Gaiker Technology Centre

E-mail: garciaam@gaiker.es

repoxyble
BIO-BASED MULTIFUNCTIONAL RECYCLABLE COMPOSITES

Gaiker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

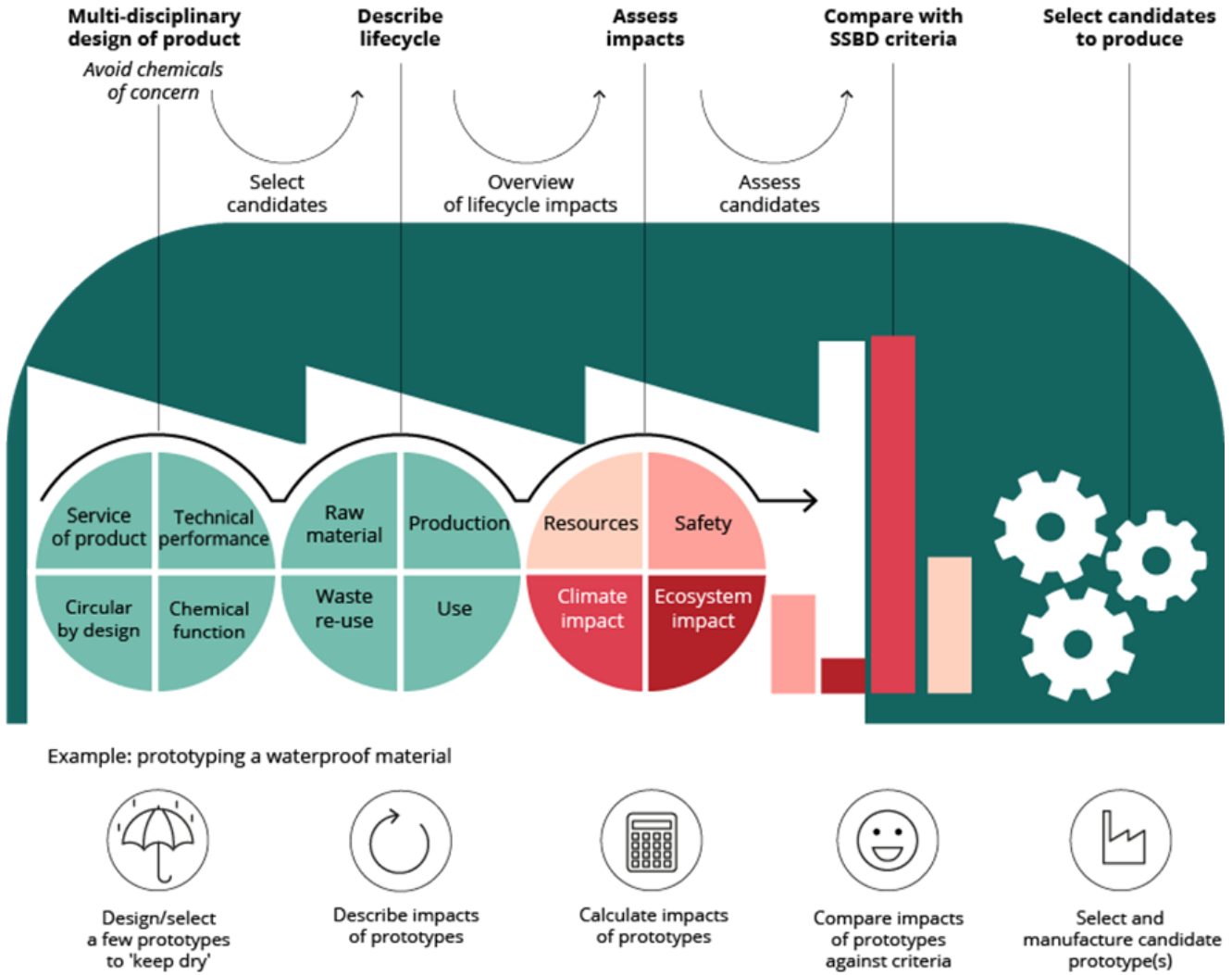
Funded by the European Union

List of contents

Funded by the European Union

Implementing Safe and sustainable by design approaches

Safety and sustainability becomes process and product requirements, to assess all along the product development



Origin: EEA (European Environment Agency)

Funded by the European Union

SSbD (Safe and Sustainable by Design)

Is a framework that incorporates safety, sustainability and circularity principles from the **earliest stages of the innovation**, aiming to minimize health and environmental risks while maximizing resource efficiency and socio-economic values.

Risk Assessment

Is a systematic process that involves identifying hazards, characterizing their effects, assessing potential exposure, and estimating the probability and severity of adverse outcomes to human health or the environment.

Funded by the European Union

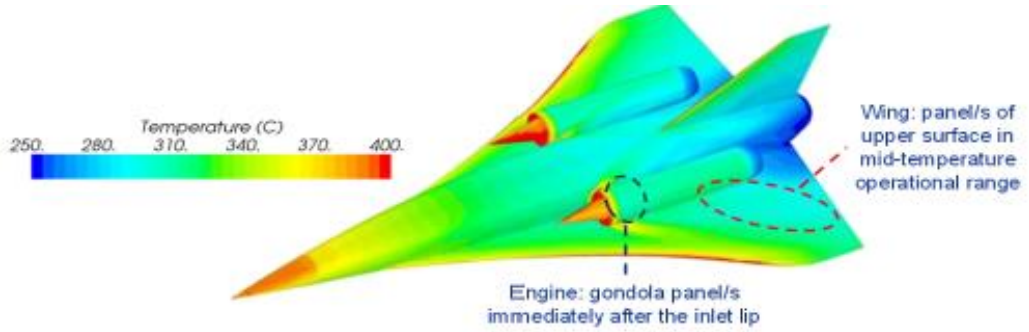
What are Epoxy resins and Composites?

Epoxy resins are a family of synthetic resins which contain at least one reactive side of either oxirane or epoxide and hydroxyl groups. For use they must be cross-linked with a **curing agent/hardener**

However the simple mixture of resin and curing agent rarely provides a material with the desired properties for a specific application therefore other materials are added, forming a **composite**

Funded by the European Union

Repoxyble Case Studies



- **Aerospace:**

High technical requirements (e.g. lightweight, high temperature resistence)

- **Automobile**

High sustainability (e.g. Recyclability, high bio-based content)

Funded by the European Union

AEROSPACE

AUTOMOTIVE

Sectorial trends:

- More efficient structures to **reduce use of resources and emissions**
- **New air mobility models** (capacity, speed, fuels, routes, inclusivity)

- Electric, hydrogen power, circular models, lightweighting to reduce use of **resources and emissions**
- **Smart & autonomous driving** (high electronics and wiring demand)

Advanced materials trends:

- **Lightweight materials, recyclable and circular models**
- Structural and functional **properties embedded** into materials for optimization, and weight and material savings

Challenges for epoxy :

- **Weakness** under specific and continuous mechanical and thermal conditions
- Release of toxic fumes and micro-particles when heated
- **Low possibility of recyclability/re-utilization**

Funded by the European Union

AEROSPACE

HYPLANE HIGH SPEED aircraft

AUTOMOTIVE

Fuel cell low-weight car powered by hydrogen, emitting water

- **Weight reduction**
- **High operative temperature**

Final product requirements

- **Manufacturing lead time**
- **Embedded electrical functions**
- **Durability**

Material and process requirements

- High proportion of biobased material
- Fast curing resins, embedded functionalities

Circularity and sustainability requirements

- Chemical recyclable via depolymerization of epoxy resins
- Recovery of functional monomers, fillers and additives (secondary raw materials)

Embedded functionalities:

1. Improved thermal management
2. Self sensing and structural (e.g. strain) health monitoring
3. Laser assisted circuits
4. Energy efficient manufacturing (integrated curing sensors).

Study cases: prototype of structural parts for transportation

Funded by the European Union

Approach to SSbD

Depolymerizable bio-based multifunctional closed loop recyclable epoxy systems for energy efficient structures

Aims to develop **bio-based epoxy composites** that are recyclable, sustainable, and cost- and energy-efficient, while keeping high performance during use. It follows a **holistic approach** across the entire life cycle—from raw materials and production to use and end-of-life.

repoxyble
BIO-BASED MULTIFUNCTIONAL RECYCLABLE COMPOSITES

Funded by the European Union

Application of SSbD along the Project workflow: all steps

Lab scale
Raw materials selection & proof of concept

Scale-up
Process optimization

Case studies Automotive & Aerospace

TRLs

Simplified SSbD assessment

Design Requirements

Proof of concept composite recyclability

SSbD step 1
Raw material
Human & Environmental hazards

SSbD step 2-4
Life Cycle Thinking Questionnaire to identify hotspots

Intermediate SSbD assessment

SSbD step 2
Worker exposure in Manufacturing & Recycling processes

SSbD step 4
Early LCA
Manufacturing & Recycling processes

Circularity Assessment

Full SSbD assessment

SSbD step 4

Full LCA

Production model
Use phase model
Waste management model

Circularity Assessment

Funded by the European Union

Application of SSbD along the Project … all steps

Lab scale
Raw materials selection & proof of concept

Scale-up
Process o…

…lies Automotive & Aerospace

TRLs

Simplified SSbD assessment

Full SSbD assessment

Design Requirements

Pro…

Huma…

…exposure in …facturing & Recycling processes

SS… …p 2-4
Life Cycle Thinking Questionnaire to identify hotspots

SSbD step 4
Early LCA
Manufacturing & Recycling processes

Circularity Assessment

SSbD step 4

Full LCA

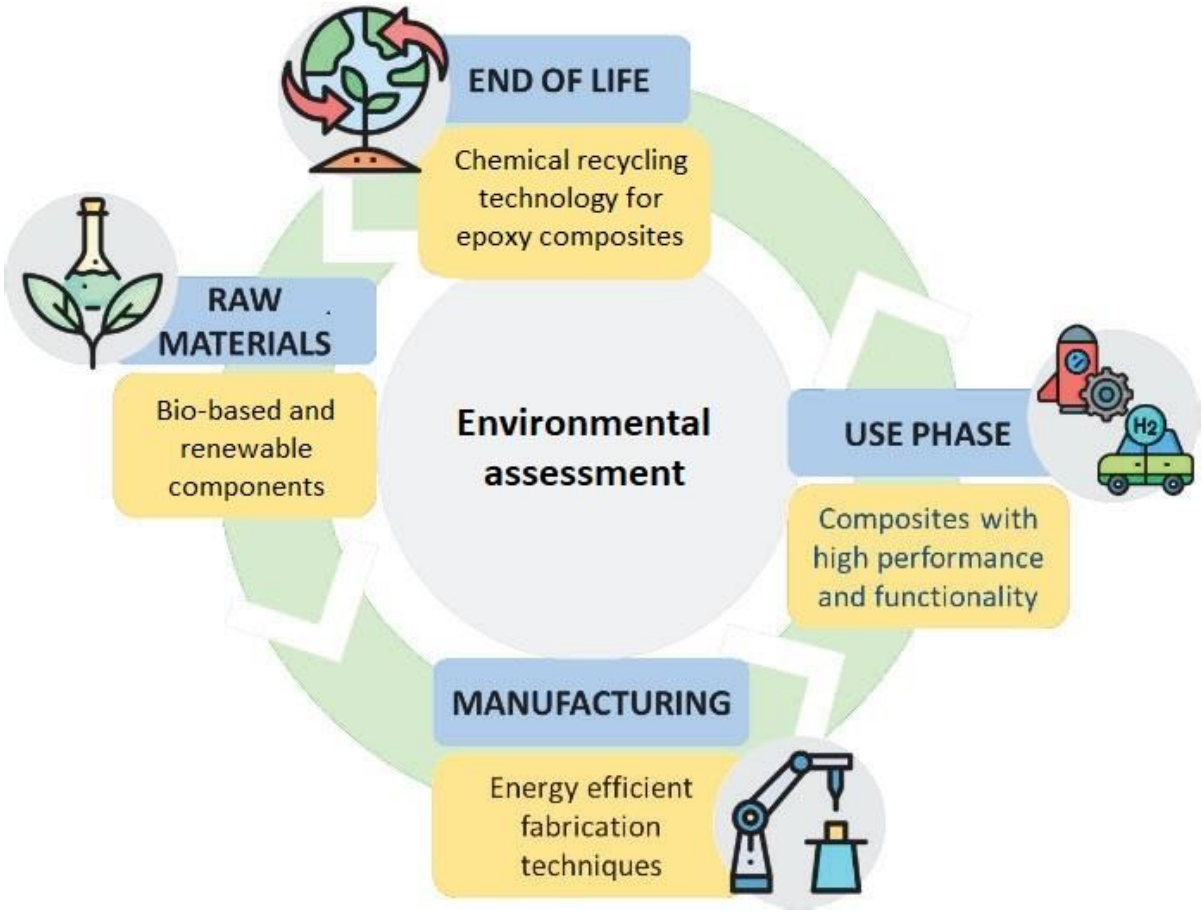
Production model
Use phase model
Waste management model

Circularity Assessment

The implementation of the SSbD approach brings **in-depth knowledge** on the **whole material life cycle.**

Funded by the European Union

Repoxyble holistic approach

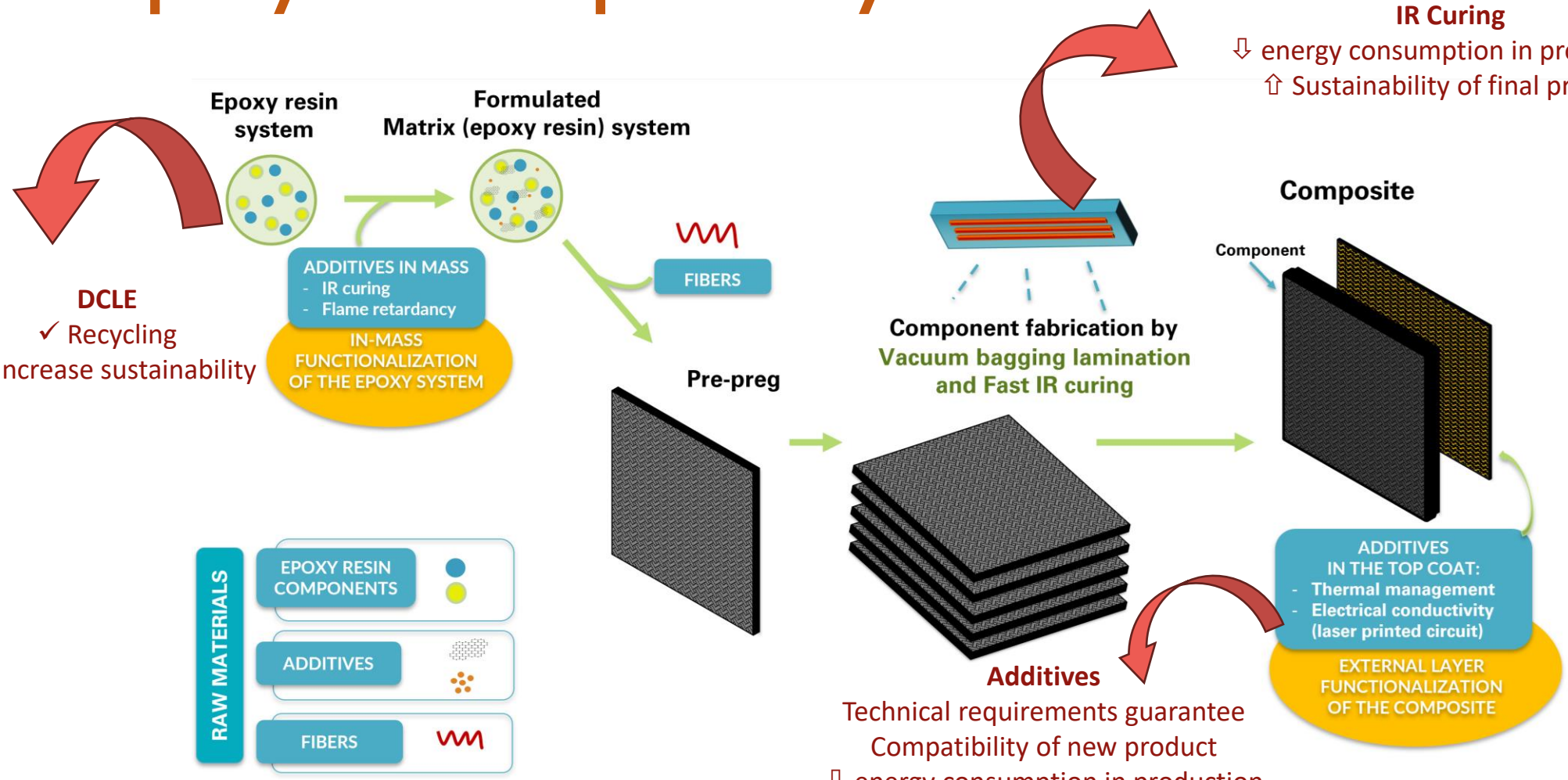


Multidisciplinary innovative development at **every stage of the composites life-cycle**:

from raw materials, manufacturing and use phase to end of life; for a **new generation of multifunctional, safe and sustainable-by-design plastics.**

Funded by the European Union

Repoxyble Composite system



DCLE
✓ Recycling
⇧ Increase sustainability

IR Curing
⇩ energy consumption in production
⇧ Sustainability of final product

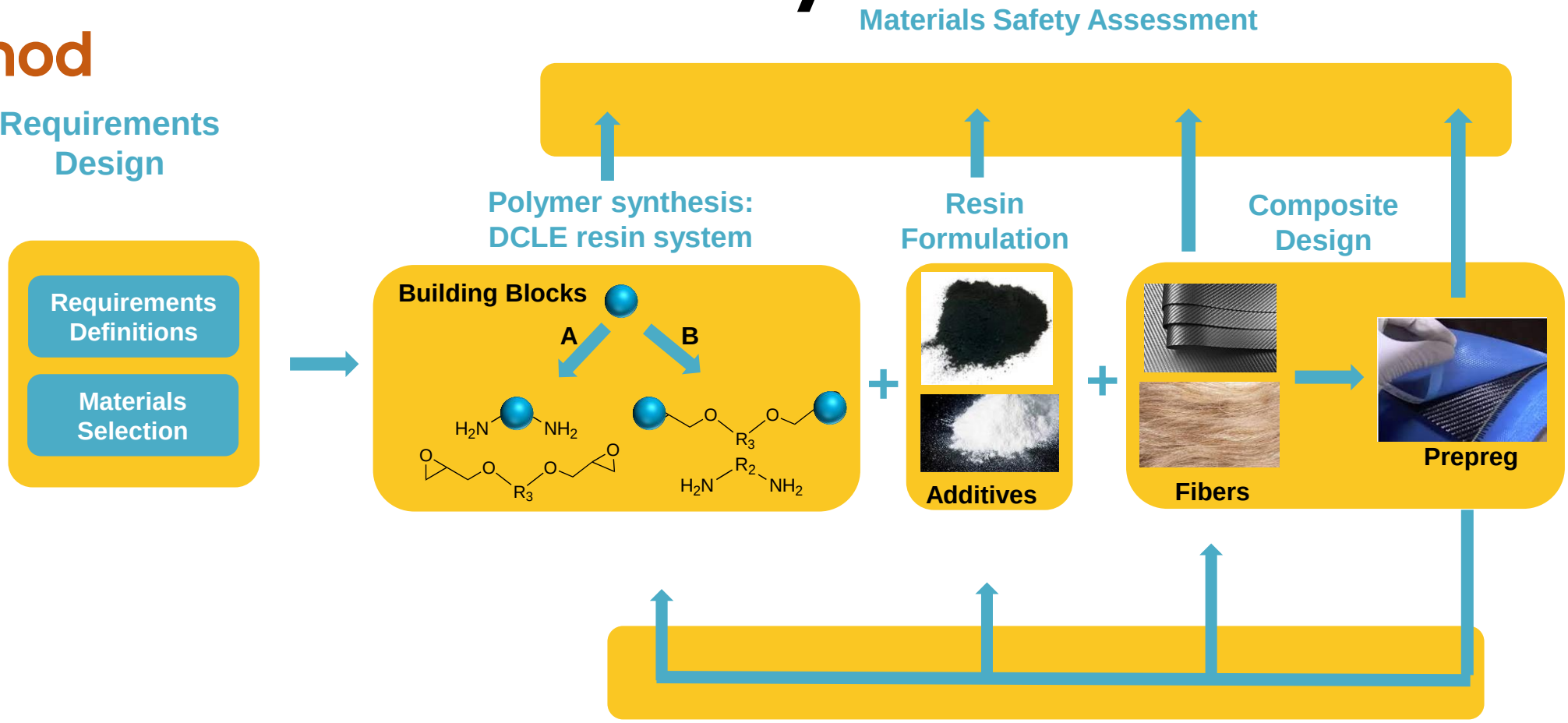
Additives
Technical requirements guarantee
Compatibility of new product
⇩ energy consumption in production
⇧ Sustainability of final product

DCLE. Depolymerisable closed loop epoxy system

Funded by the European Union

SSbD and Reciclability

Method



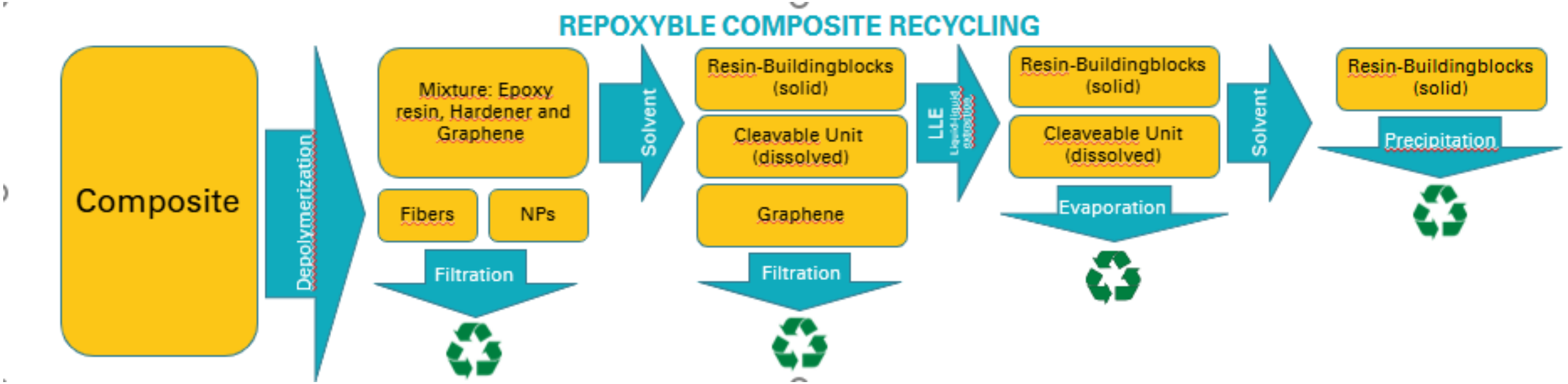
DCLE. Depolymerisable closed loop epoxy system

Recyclability of thermosets and components

Funded by
the European Union

SSbD and Reciclability

Composites components



Funded by the European Union

Requirements Design

Selection of Materials

1 **Requirements List: 6 Lines of Evidence**

- Performance (P)
- Technological (T)
- Safety (Saf) and Sustainability (Sus)
- Legal (LE)
- Economical (EC)

2 **Prioritization of the Requirements based on Product Solution**

Prioritization of Requirements based on the final application

3 **Inventory of Materials**

Materials Safety Assessment

SSbD

4 **Materials Selection**

List of materials with assessment

Funded by the European Union

Requirements Design

Inventory of Materials

- Identification of benchmark materials
- Identification of information needed for safety: JRC SSbD framework safety indicators for human and environmental hazards,
- Identification of sources of information: MSDS and ECHA databases information
- Development of EXCEL file that includes: materials for each application, performance requirements, safety and sustainability requirements, information about human and environmental hazards categorised according to CLP/GHS

Information included:

✓ Performance requirements
✓ Safety and sustainability aspects
✓ Human and environmental hazards

Performance Requirements (Aerospace)		Performance Requirements (Automotive)		Safety & Sustainability	
Temperature for 1hr sustained flying (300-320°C) (min-optimum)	Tensile-compression and shear stress	Manufacturing time (fast curing)	Low energy curing process	Substances of very high concern	Bio-based

- Benchmark materials for aerospace and automotive
- REPOXYBLE candidate materials for both applications
- Different combinations that will be made during the project after the materials selection
- Chemicals that could be potentially used in the recycling process.

Funded by the European Union

Requirements Design

Inventory of Materials

- **JRC SSbD framework safety indicators**
- **MSDS and ECHA databases information**
- **CLP/GHS safety categories**

HUMAN HEALTH HAZARDS	ENVIRONMENTAL HEALTH HAZARDS
Carcinogenicity	Persistent, bioaccumulative and toxic/ very persistent and very bioaccumulative (PBT/vPvB)
Mutagenicity	Persistent, mobile and toxic/very persistent and mobile (PMT/vPvM)
Reproductive toxicity	Endocrine disruption
Endocrine disruption	Hazardous for the ozone layer
Respiratory sensitisation	Chronic aquatic toxicity
Specific target organ toxicity-repeated exposure (STOT-RE)	Acute aquatic toxicity
Skin sensitisation	
Specific target organ toxicity-repeated exposure (STOT-SE)	
Acute toxicity	
Skin corrosion	
Skin irritation	
Serious eye damage/eye irritation	
Aspiration hazard	

Legend for safety assessment

no	No classification
miss	data missing
cat 1	category according to CLP
cat 2	category according to CLP
cat 3	category according to CLP
cat 4	category according to CLP
na	not applicable

Funded by the European Union

Safety assessment

Selected indicators and assays

Human hazard						Environmental hazard	
Mutagenicity	Endocrine disruption (human)	Skin sensitization	Skin corrosion/ irritation	Eye damage/ irritation	Inhalation toxicity	Chronic aquatic tox	Acute aquatic tox
GAIKER/UL	*GAIKER*	*GAIKER*	*GAIKER*	*GAIKER*	UL	UL	UL
OECD 471. Ames test	OECD 455. ERα-HeLa-9903 cell	OECD 442C. DPRA	OECD 439. 3D model	OECD 492. 3D model	Cytotoxicity asssays	OECD 211. Daphnia	OECD 202: Daphnia sp
Comet assay		OECD 442D. Keratinosens™			integrity of the barrier		OECD 236: Fish Embryo
							ISO/TS 4988:2022. *Tetrahymena* sp.

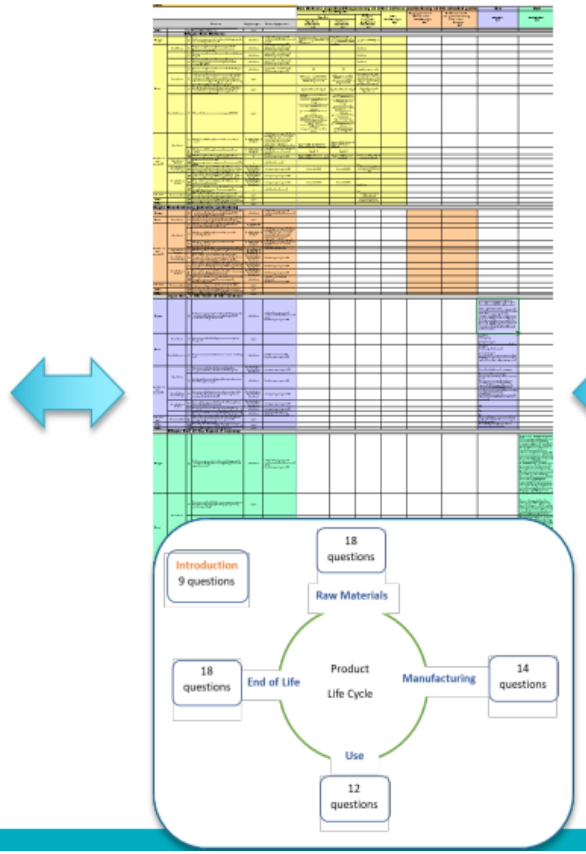
Funded by the European Union

Real world challenges in hazard assessment

Funded by the European Union

LIFE CYCLE THINKING

Raw materials acquisition/Preprocessing of other materials input	Epoxy resin	ONY, GURIT
	Formulated epoxy resin with additives	AVA, GURIT
	Fibers	UoS, AEROGEL
Manufacturing	Prepreg	UoS, AEROGEL
	Composites (cured)	AEROGEL
Use		RIVERS (Automotive)
		DAC (Aerospace)
EoL		BOKU / ONY
Safety & Sustainability assessors		GAIKER, TEMASOL, AIRI, UL



T1.6 Material Safety Assessment

T3.6 Safety and Sustainability of manufacturing

T4.6 Verification of Sustainability

T5.6 Development of Decision Support System

D5.5 Fulfillment of SSbD criteria

Consider the whole picture before deciding what is truly sustainable

Funded by the European Union

Safe and Sustainable by Design is not a single step – it’s a mindset

This holistic approach ensures that what we create today doesn’t become a problema tomorrow

As researchers, designers and decision-makers we have the opportunity to integrate safety, sustainability and circularity from the very beginning

THANK YOU FOR YOUR ATTENTION!

Funded by the European Union