

SAFE AND SUSTAINABLE BY DESIGN GRAPHENE/MXENES HYBRIDS



e-NEWSLETTER *Magazine*

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1. SAFARI Enters Its Final Project Phase

TRANSLATING RESEARCH INTO FINAL APPLICATIONS

SAFARI has entered its final project phase, bringing together progress in advanced 2D-material development, safety assessment, sustainability and end-use applications. During the second reporting period, the project, advanced its Safe and Sustainable by Design (SSbD) approach from a methodological framework towards a practical, cross-cutting process that now supports decisions across the entire SAFARI value chain.

Safety and sustainability considerations are increasingly connected with material production and selection, functionalisation and hybridisation, advanced toxicological assessment, life-cycle analysis and the development of final applications.

As the project progresses towards its conclusion in May 2027, activities are focused on translating the knowledge generated so far into final applications and completing their safety, sustainability and exploitation assessment.

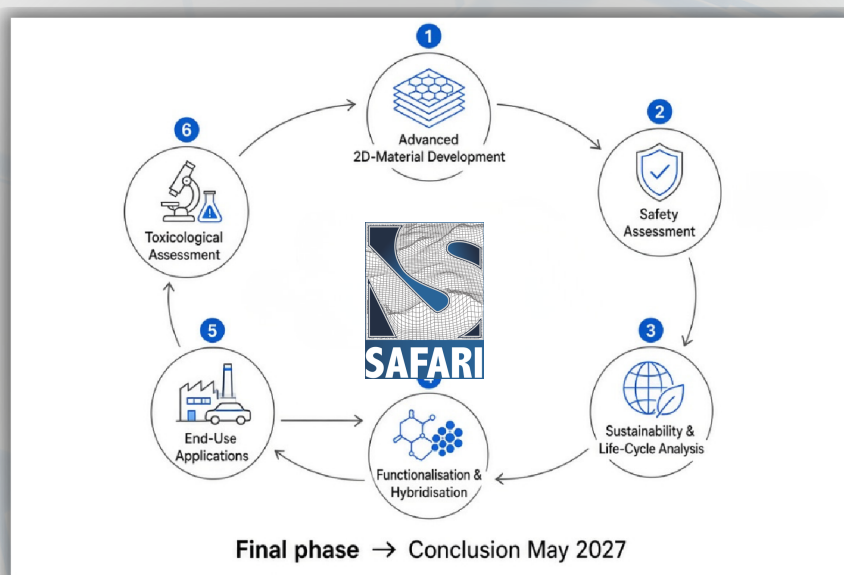


Figure 1: SAFARI Final Phase Overview

The SAFARI's
Newsletters:

Throughout the 42-month project, we'll be releasing multiple e-newsletters, each showcasing the milestones achieved by our partners in development of 2D materials using safe and sustainable practices.

1. SAFARI Enters Its Final Project Phase

Work will continue on the integration and assessment of MXene/graphene materials in real-world use cases, complemented by safety and release studies, life-cycle sustainability assessment, and further integration of project data into the SAFARI Decision Support System.

The final period will also prioritise the dissemination of project results, stronger engagement with scientific, industrial and wider stakeholder communities, and the consolidation of pathways for the future uptake of SAFARI's Key Exploitable Results.

The objective remains clear: to demonstrate how performance, safety and sustainability can be considered together when developing the next generation of 2D materials.

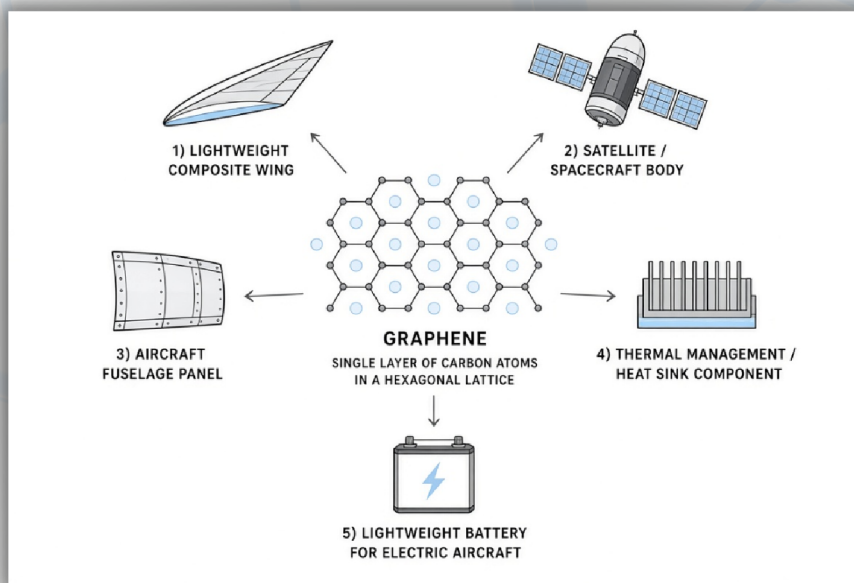


Figure 2: Connecting 2D-Material Innovation with Industry

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2. From Advanced Materials to Real Applications

One of the major priorities of SAFARI's final phase is moving from material development towards application-oriented validation. Work is progressing on the integration of MXene and MXene/graphene materials into three main application areas: electrochemical biosensors, conductive formulations and electromagnetic interference (EMI) shielding solutions.

This work connects the materials developed and characterised within SAFARI with functional applications and enables the consortium to investigate how material composition and properties influence performance. In electrochemical sensing, SAFARI is investigating MXene/graphene-based materials for glucose and lactate detection, contributing to the assessment of their potential for future sensing technologies.

In parallel, MXene-based materials are being incorporated into specialised formulations for electromagnetic shielding, exploring how the electrical properties of 2D materials can be translated into lightweight functional coatings.

These application activities will also provide important inputs for SAFARI's final safety and sustainability assessment.

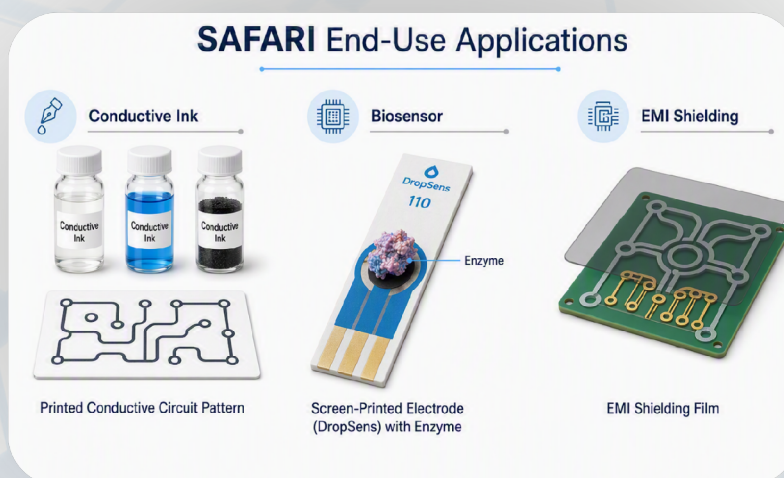


Figure 3: From Material Innovation to Functional Solutions

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3. Safety Assessment of MXenes

Developing high-performance materials is only one part of SAFARI's mission. Understanding how emerging 2D materials may interact with humans and the environment is equally important. During the second reporting period, SAFARI expanded its safety-assessment methodology to investigate functionalised and hybrid MXene systems using a combination of conventional cell cultures, advanced 3D human-cell models, ecotoxicological testing, occupational-exposure assessment and computational modelling.

The work showed why the choice of testing model matters. Material composition, functionalisation and the complexity of the biological model can influence the observed response, reinforcing the importance of combining different testing approaches when assessing emerging nanomaterials. This integrated approach is helping SAFARI build a more comprehensive picture of potential hazards and supports the project's broader Safe and Sustainable by Design (SSbD) strategy.

SAFARI research has also resulted in a new peer-reviewed publication: "Multi-scale in-silico toxicological assessment of Ti_3C_2 and Cr_2C MXene nanoparticles at human biological interfaces".

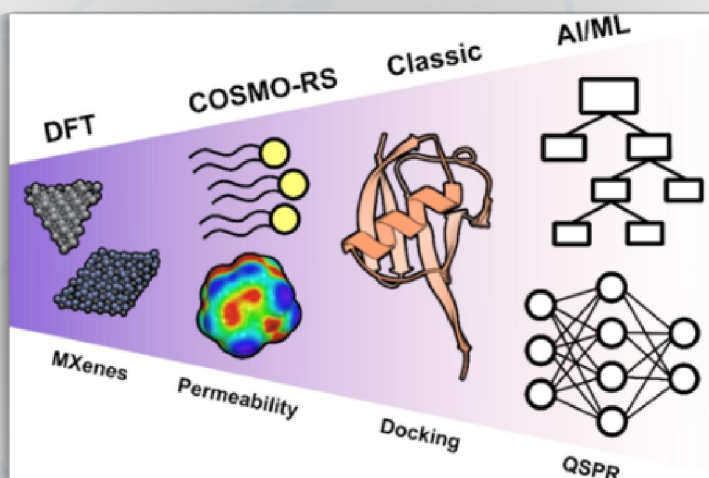


Figure 4: In-Silico MXene Safety Study

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3. Safety Assessment of MXenes

SELECTION OF MXENES MOST PROMISING FOR THE END USER APPLICATION:

Published in NanoImpact, the study develops a multi-scale computational methodology combining Density Functional Theory, membrane-interaction modelling, protein docking and machine-learning approaches to investigate how MXene nanoparticles may interact with human biological systems.

The study found very low predicted membrane permeability for the investigated Ti_3C_2 nanoparticles and generally weak surface-level interactions with the investigated human proteins.

Two machine-learning models were also developed to support the prediction of docking energies and more efficient early-stage hazard screening. The research contributes to SAFARI's SSbD activities by demonstrating how computational approaches can complement experimental testing, support early hazard identification and help prioritise subsequent safety studies.

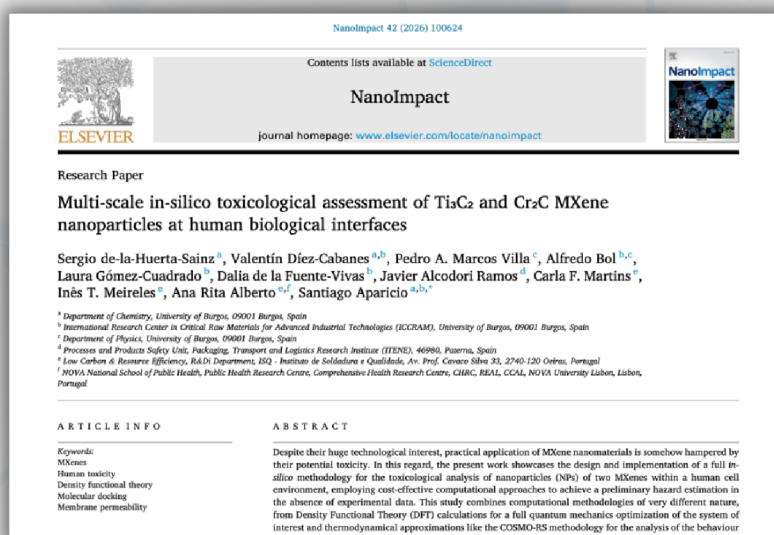


Figure 5: Preview of the Safari Publication

[See all our Publications on Zenodo here](#)

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4. Sustainability and Digital Decision Support

SAFARI is also examining what happens beyond material performance.

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) activities are being used to investigate the environmental and economic dimensions of MAX-phase synthesis, MXene manufacturing, functionalisation and MXene/graphene hybrid production.

These analyses help identify potential hotspots and provide evidence that can support process optimisation and material-selection decisions within the SSbD framework. The next phase extends this work towards more complete life-cycle modelling, covering raw-material production, manufacturing, application, use and end-of-life scenarios.

Social Life Cycle Assessment activities will complement this work by considering relevant social and socioeconomic dimensions. This means SAFARI's final SSbD assessment will bring together multiple dimensions rather than considering safety, environmental performance and technical functionality independently.

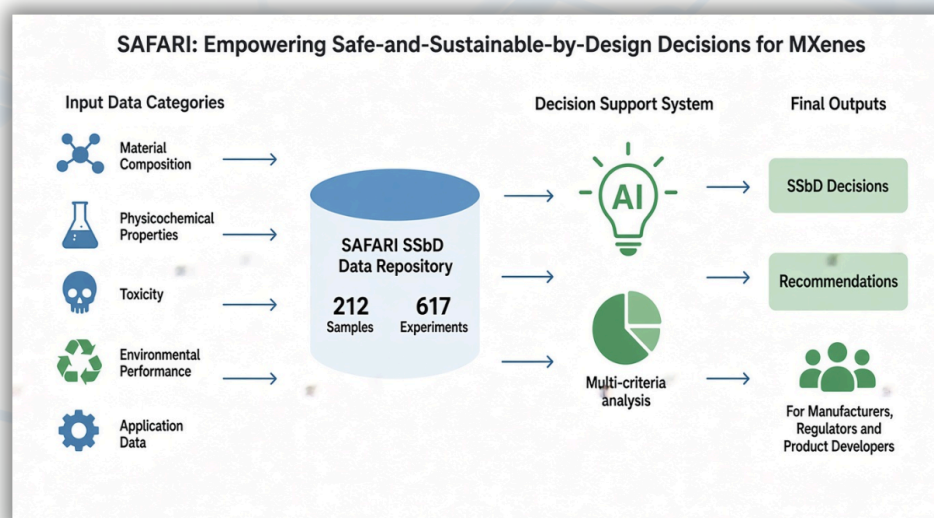


Figure 6: Empowering SSbD Decisions for MXenes

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4. Sustainability and Digital Decision Support

DIGITAL FOUNDATION FOR SSbD DECISION-MAKING

Making SSbD decisions requires information from many different disciplines from material composition and physicochemical properties to toxicity, environmental performance and application data. SAFARI is addressing this challenge through its dedicated data repository and Decision Support System activities.

By the end of RP2, the SAFARI repository contained information covering 212 material samples and 617 experiments. The system has been progressively expanded to accommodate MXene- and MXene/graphene-specific information and different types of experimental results. During the final phase, additional hybridisation and application-related data will be integrated, with increasing attention to SAFARI's final use cases.

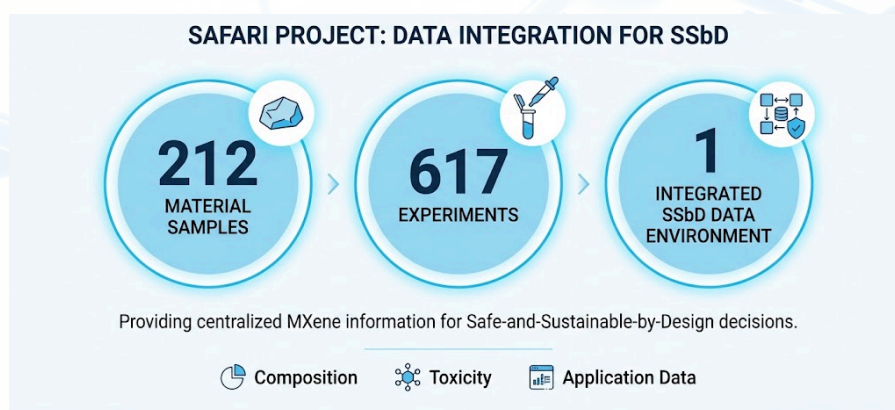


Figure 7: Data integration for SSbD

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5. Protecting Innovation: Patent Progress

WHERE YOU WILL FIND US:

SAFARI has also progressed in protecting and preparing project results for future exploitation. A significant development concerns PIT's MXene-production technology.

Our project coordinator PIT submitted patent application P.454018 to the Patent Office of the Republic of Poland for a method and associated system for producing MXene nanomaterials from MAX phases.

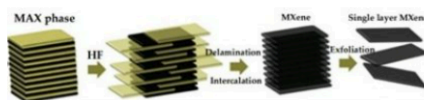
The approach combines microwave-assisted processing and high-frequency acoustic waves within an integrated MXene-production process.

This development complements SAFARI's wider exploitation activities, which include the assessment of Key Exploitable Results, market opportunities, intellectual-property landscapes and pathways for the future uptake of project technologies.

[Click here to Read more about MXene on our website](#)

MXenes

MXenes are a group of 2D materials that are similar to graphene. However, unlike graphene, which is produced through delamination of graphite, MXene is produced by etching the MAX phase (M – transition metal, A – usually Al, X – C/N) to remove the A element. This results in the delamination of the compound and the formation of a similar 2D structure. The process of MXene formation is presented in the figure below.



MXenes can be synthesized by many routes. The etching in F^- containing aqueous solution is the first and most widely used route. This is the simplest method and can be scaled up for mass production. However, this method generally takes a long time and MXene laminates prepared by HF etching often contain a certain number of defects (such as holes), which will adversely affect the application of MXenes.

Figure 8: Preview of our Website's MXene section

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UPCOMING EVENTS

6.Upcoming Events

WHERE TO MEET SAFARI NEXT:

SAFARI continues to engage with the European research and innovation community through a series of upcoming scientific events.

Over the coming months, project partners will present new results related to the Safe and Sustainable by Design production, functionalisation and assessment of MXenes and MXene/graphene hybrids, providing opportunities to exchange knowledge with researchers and stakeholders working across advanced materials, sustainability and life-cycle assessment.

Graphene Week 2026

|Porto, Portugal | 22-23 September 2026

SAFARI will participate in Graphene Week 2026 with a poster presentation by Valeria Acevedo García (AIMEN) entitled: "Safe and Sustainable by Design Production of Niobium MAX Phases and MXenes"

The contribution will showcase SAFARI's work towards integrating Safe and Sustainable by Design considerations into the development of advanced 2D materials.

[Graphene Week 2026](#)



Figure 10: Graphene Week 2026 in Porto

SAFARI CONNECTS
WITH THE EUROPEAN 2D
MATERIALS COMMUNITY

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6.Upcoming Events

WHERE TO MEET SAFARI NEXT:

SETAC Europe 27th LCA Symposium

| Bruges, Belgium | 19-21 October 2026

At the SETAC Europe 27th LCA Symposium, Valeria Acevedo García (AIMEN) will present the poster:

“Safe and Sustainable by Design Functionalised MXenes: Environmental Impact Comparison through LCA”

The presentation will highlight SAFARI's work on using Life Cycle Assessment (LCA) to investigate the environmental performance of functionalised MXenes and support SSbD-oriented material and process decisions

[SETAC Europe 27th LCA Symposium](#)



Figure 11: SETAC Europe 27th LCA Symposium

SAFARI CONNECTS
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6.Upcoming Events

WHERE TO MEET SAFARI NEXT:

SSbD26 Conference

| Stockholm, Sweden | 9-11 November 2026

SAFARI will also be represented at the SSbD26 Conference by Joa Laranjeira (ISQ) with the presentation:

“Safe and Sustainable by Design Assessment of 2D MXenes and MXenes/Graphene Hybrids: The SAFARI Project Approach”

The presentation will provide an opportunity to share SAFARI's integrated approach to SSbD assessment and exchange knowledge with the wider European Safe and Sustainable by Design community.

[SSbD26 Conference](#)



Figure 12: SSbD26 Conference in Stockholm

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