

Market Application of MXenes and Graphene Produced through a Safe and Sustainable-by-Design Framework

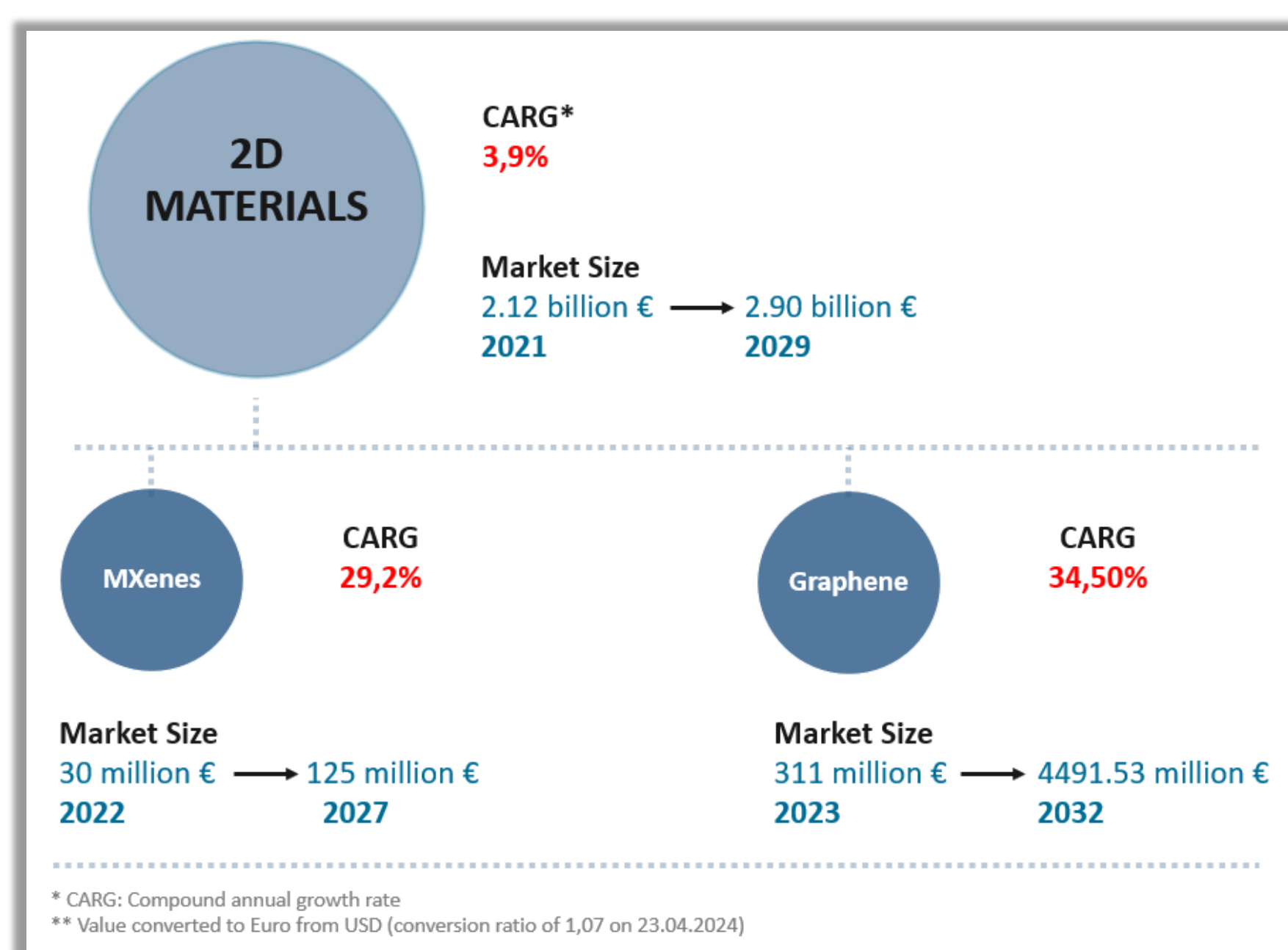
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THIS STUDY AND METHODOLOGY

In this study, we:

- ✓ Analyze the market for 2D materials, focusing on MXenes and Graphene.
- ✓ Identify innovation opportunities across three application fields: Conductive inks, Biosensors, Electromagnetic interference (EMI) shielding.
- ✓ Present the context of the **SAFARI project**, which aims to a) Hybridize MXenes and Graphene and b) Test the materials in the three end-user applications.
- ✓ Focus on more efficient and environmentally friendly production methods based on the Safe and Sustainable-by-Design (SSbD) framework.
- ✓ Evaluate the market potential through a) Market size assessments, and b) SWOT and PESTLE analysis to identify strategic opportunities and challenges.

RESULTS AND ANALYSIS



GRAPHENE

- Unique properties of the materials create expectation in terms of scientific discoveries, technological application opportunity and potential economic value.
- Time span is needed to generate economic impact.
- **Key Players:** Carbon Rivers, Alfa Chemistry, Matexcel, Reade Advanced Materials, Goodfellow, Nonotech Energy, MilliporeSigma, Nippon Shokubai Co., LTD. Graphene Flagship, NanoIntegris Technologies, Inc., Cleap Tubes.
- **Key innovations under development by sectors:**

Applications of Graphene	MXenes
Biomedical	Structure health monitoring, human motion detection
Energy Storage	Super capacitor, capacity energy storage, lithium-ion battery
Sensor	CO ₂ Gas Detection, NO ₂ Gas Sensors

2D Materials Predictions:

- Graphene-related technologies and innovations are expected to generate the highest market revenue from 2023 to 2030.
- Market interest is driven by its high electrical conductivity, high mechanical durability and excellent thermal stability.
- The quality and availability of the graphene supply stream is expected to steadily improve over time.
- The positive perception of the capabilities of 2D materials is growing as their applications in various fields become more established.
- 2D materials market is segmented to electronics, energy storage devices, composites & coatings, and biomedical application.
- Key players in the 2D materials sector include PPGIndustries, Axalta Coating Systems, NanoXplore, and 2D Materials Pte Ltd.

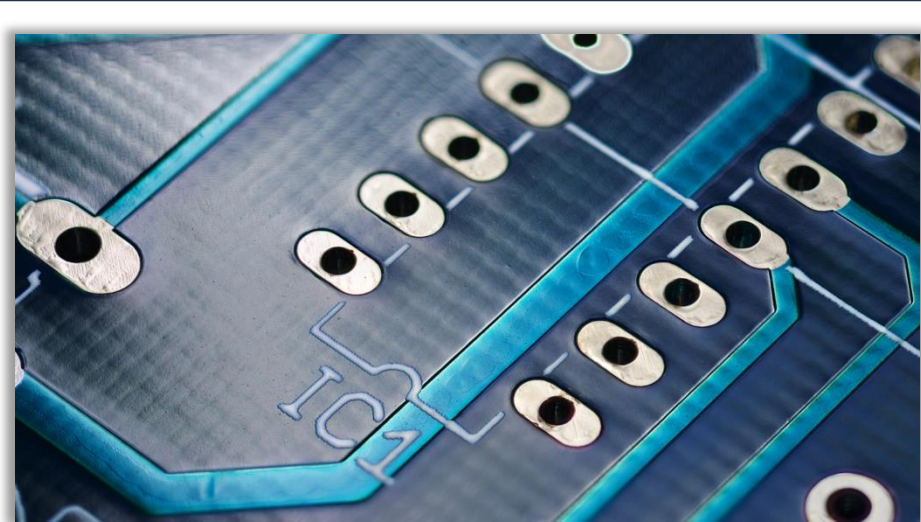
MXenes

- Research on the applications of MXenes has significantly grown in the past five years.
- The focus area of research is on the synthesis, processing, electronics, biomedical applications and optics.
- **Key Players:** American Elements, Sigma Aldrich, Drexel Nanomaterials, Institute, Murata Manufacturing Co., Ltd., Carbon-Ukraine Ltd, Japan, Material Technologies Corporation
- **Key applications under development by sector:**

Applications of MXenes	Innovative functionalities
Biomedical	Cancer treatment, anti-cancer modality
Energy Storage	Lithium-ion batteries, superconductor
Sensor	Superconductor, volatile organic compound sensor, pressure sensor, gas sensor

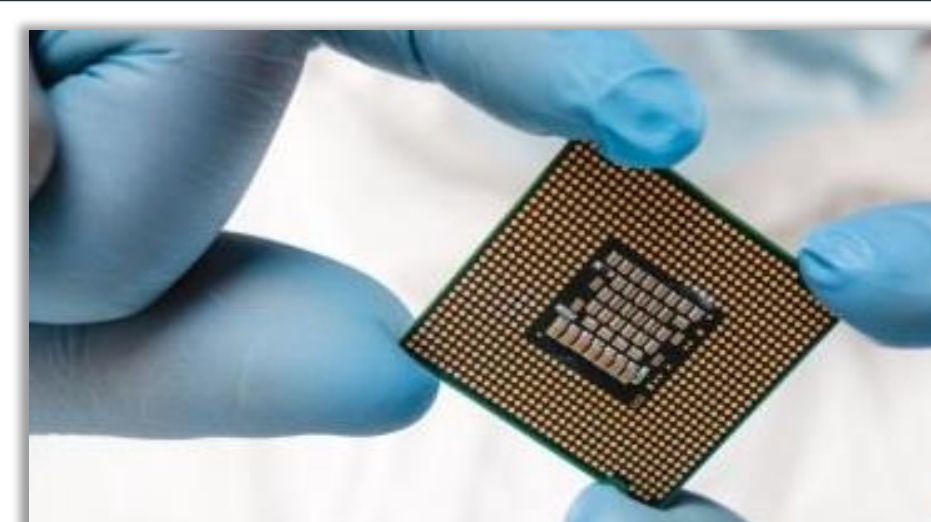
END USER APPLICATIONS

Developments of Graphene and MXenes composites of the SAFARI project are being tested for following applications:



Conductive inks in electronic sector

- Conductive Inks market of € 2.5 billion of in 2021.
- The Market is expected to have a CARG increase of 6% from 2022 to 2030.
- The growth is linked to the high demand in functional properties.
- The marked demand is directed towards high conductivities achieved.
- SAFARI is validating hybrid formulation of Graphene and MXenes assessing the conductivity of the composites.



Biosensors in healthcare sector

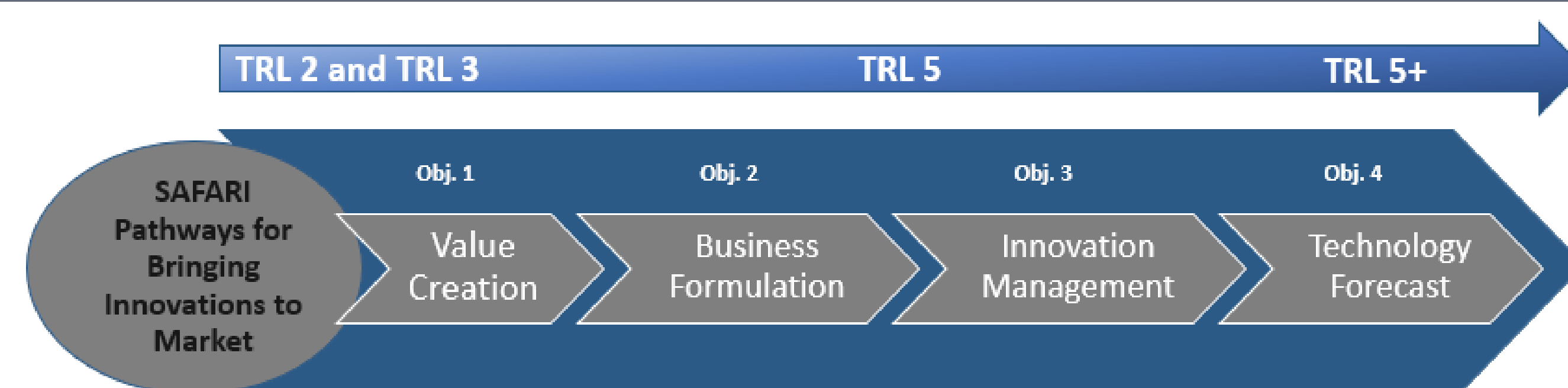
- Biosensors market of € 22.8 billion in 2023.
- The Market is projected to have a growth of 9.3% from 2024 to 2032.
- SAFARI is developing electrochemical sensors for glucose/lactate detection using MXenes/Graphene hybrids as sensing material.
- MXenes-Graphene hybrids into biosensors significantly enhances sensor performance, boosting sensitivity and enabling rapid detection of biomarker levels.



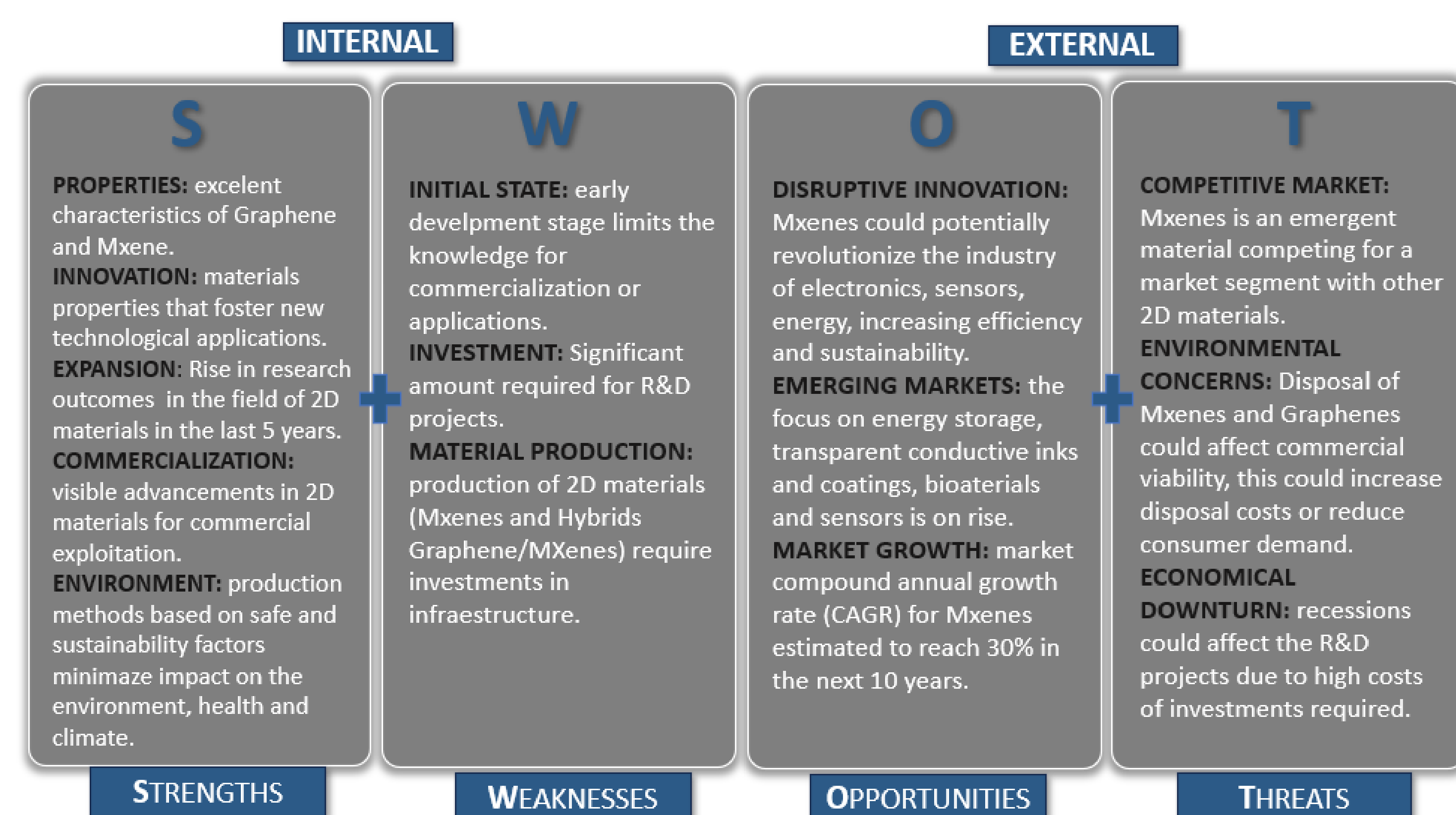
EMI in telecommunications sector

- EMI global shielding market of € 6.35 billion in 2023.
- Market size projected to have a CARG of 5.9% by 2028.
- SAFARI is developing EMI shielding painting. EMI shield has excellent material properties such as conductivity, magnetic permeability and thickness.
- EMI shielding based on MXenes and Graphene have excellent reflection, porosity and layered structure that facilitates penetration of waves.
- Growth of the market related to government regulations and standards and proliferation of wireless devices.

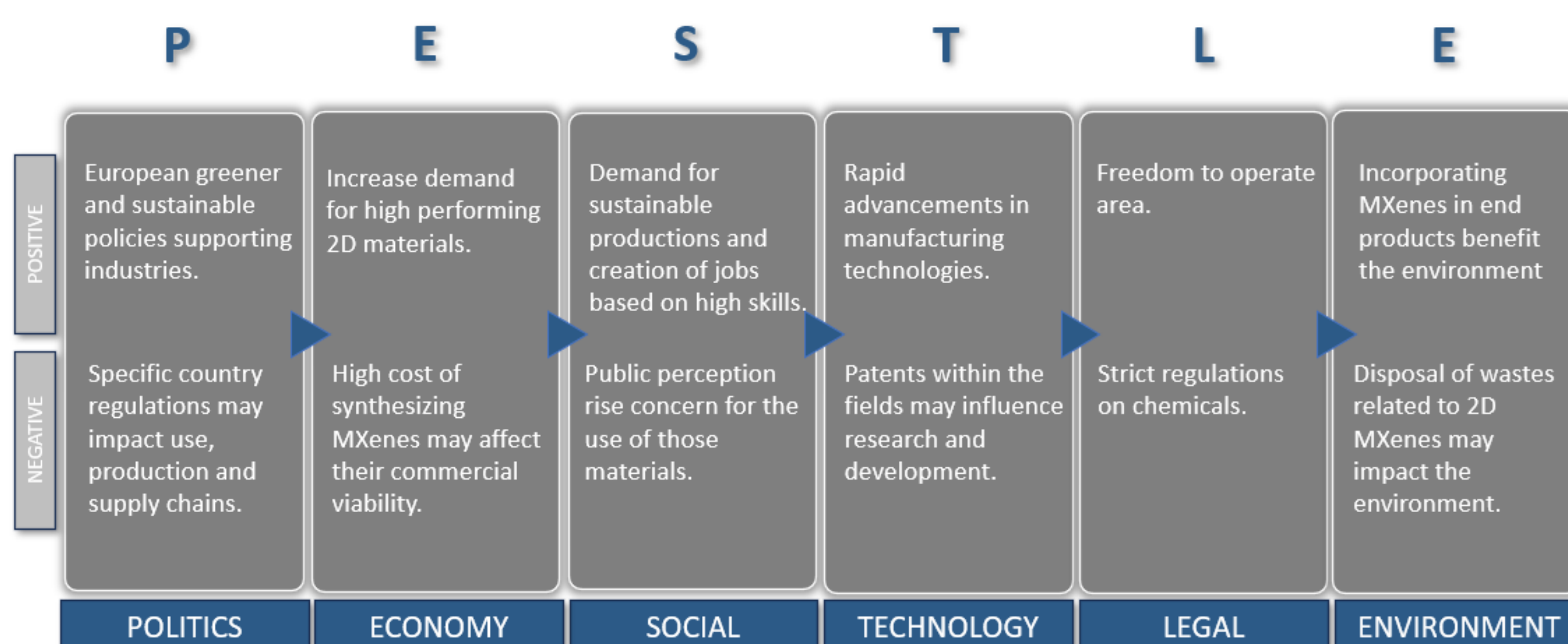
MARKET INNOVATIONS: SAFARI's route to scaling up the technology aims to transition from the research phase (TRL 2 and 3) to the development stage (TRL 5 to 5+) following the project timeline. The strategy focuses on four main objectives:



The SWOT analysis below highlights the key strengths, weaknesses, opportunities and threats associated with the developments from the SAFARI projects. The project is aiming to scale up the technology by producing, testing and applying the developed materials into three market applications.



SAFARI is validating hybrid formulation of Graphene and MXenes assessing the conductivity of the composites



CONCLUSIONS

Based on our study on the 2D market, specifically with a focus on the hybridization of Graphene and MXenes under development in SAFARI project, we can conclude that:

- ✓ The 2D materials field is going to a consolidation phase (mainly in the supply industry of Graphene) with positive economic impact and market growth.
- ✓ Producers seek for target markets (applications, consolidations, demand volume and price perspective) and customers perspective for business development and scaling up.
- ✓ Specific characteristics of Graphene and MXenes have already attracted many players in this industry.
- ✓ Applications of 2D materials on the sector of electronics, healthcare and telecommunications have a high CARG.
- ✓ SAFARI is expanding the development of hybrids of MXenes and Graphene for this three applications presented.
- ✓ SWOT and PESTLE analysis detailed characteristics of the market for Graphene/MXenes based on Safe and Sustainable by Design Approaches.

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SAFARI PROJECT



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