



OPPORTUNITY

45

SCOPE **VISIONARY**

UNCERTAINTIES

Technology, Collaboration

MEGATRENDS

Living with Autonomous Robots and Automation

TRENDS

Advanced computing
Artificial intelligence
Automation
Cross-sectoral partnerships
New Materials

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Energy, Oil, Gas & Renewables
Health & Healthcare
Infrastructure & Construction
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Real Estate
Utilities

What if machines could self-repair?

FOREVER MACHINES

Self-repairing machines, integrating preventive maintenance, smart materials, and advanced sensors enable downtime-free manufacturing and sustainable, long-lasting consumer products and robotics.





WHY IT MATTERS TODAY

Many machines and structures, such as telescopes, deep-sea cables, satellites, and drilling equipment in certain sites, are hard to reach in case of malfunction. Some take significant amounts of money and months, even years, to repair.⁹¹⁴ In some cases, repairs can also be dangerous, leading to workplace injuries.⁹¹⁵

The economic and environmental impact of a lack of repairability is a growing issue.⁹¹⁶ The premature disposal of repairable consumer goods generates 261 million tons of greenhouse gas emissions, uses 30 million tons of resources, and results in 35 million tons of waste in the European Union (EU) every year.⁹¹⁷ Some 77% of EU consumers prefer to repair goods⁹¹⁸ instead of discarding them, and the upcoming 'right to repair' directive in the EU is expected to generate \$5.3 billion⁹ in growth⁹¹⁹. More than 40 states in the United States have initiated efforts to develop distinct legislative proposals regarding the right to repair.⁹²⁰

Driven by artificial intelligence, 3D printing, and materials informatics, the field of materials science has been rapidly evolving and its impact is significant. In the chemicals industry, the use of materials that are more sustainable can help to reduce emissions, increase recycled inputs, and create safer chemicals.⁹²¹ Advanced materials, such as carbon-fibre composites, could enhance the efficiency and durability of wind turbine blades, with a 5%–13% lower energy and carbon payback period than current models.⁹²² The global self-healing materials market size was valued at \$1.68 billion in 2022 and is estimated to grow at a compound annual growth rate of 24.8% from 2023 to 2030.⁹²³

The global self-healing materials market size was valued at

\$1.68 billion

in 2022 and is estimated to grow at a CAGR of

24.8%

from 2023 to 2030

⁹Based on EURUSD exchange rate on 30 December 2023.



OPPORTUNITY

Self-repairing machines combine preventive maintenance, design for repairability, stretchable electronics,⁹²⁴ novel smart materials (such as metals,⁹²⁵ elastomers, and polymers⁹²⁶), and alternative next-generation batteries⁹²⁷ into one system.

Powered by advanced machine intelligence and advanced sensor technologies,⁹²⁸ self-repairing machines operate in an optimum way to avoid damage by combining sensory functions, opening up new frontiers for discovery and development in remote environments, such as extraterrestrial exploration and mining.

Manufacturing is downtime free as preventive and routine maintenance are no longer needed. The risk of defects due to machine failure is reduced to zero. Domestic appliances that repair themselves allow consumers to invest in new (or upcycled) products without infringing intellectual property (IP) rights. Even electronic devices can recover from almost any damage, prompting a market pivot towards device component upgrades instead of new device purchases. From vehicles and ships, to aeroplanes and rockets, self-repairing machines usher in a sustainable supply chain, with near-perfect circularity.

BENEFITS

Enhanced safety, reduced downtime, and extended machine and robot lifespans, reducing maintenance costs and improving the quality of products and service automation. Opens up opportunities for remote exploration and a near-perfect supply chain. IP-protected aspects of machines remain intact.

RISKS

Malfunctioning self-repair mechanisms could inadvertently harm users and the surrounding environment. Autonomous machines are susceptible to cyber threats, and their complex design and autonomous decision-making processes can result in increased costs, effort, and diminished benefits.

