What if products built themselves?

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Self-Assembling Molecules

GenAI

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Materials Revolution

TRENDS

Automation
Future of Raw Materials
New Materials

TECHNOLOGIES

Agile & Smart Manufacturing
Nanotechnology

SECTORS IMPACTED

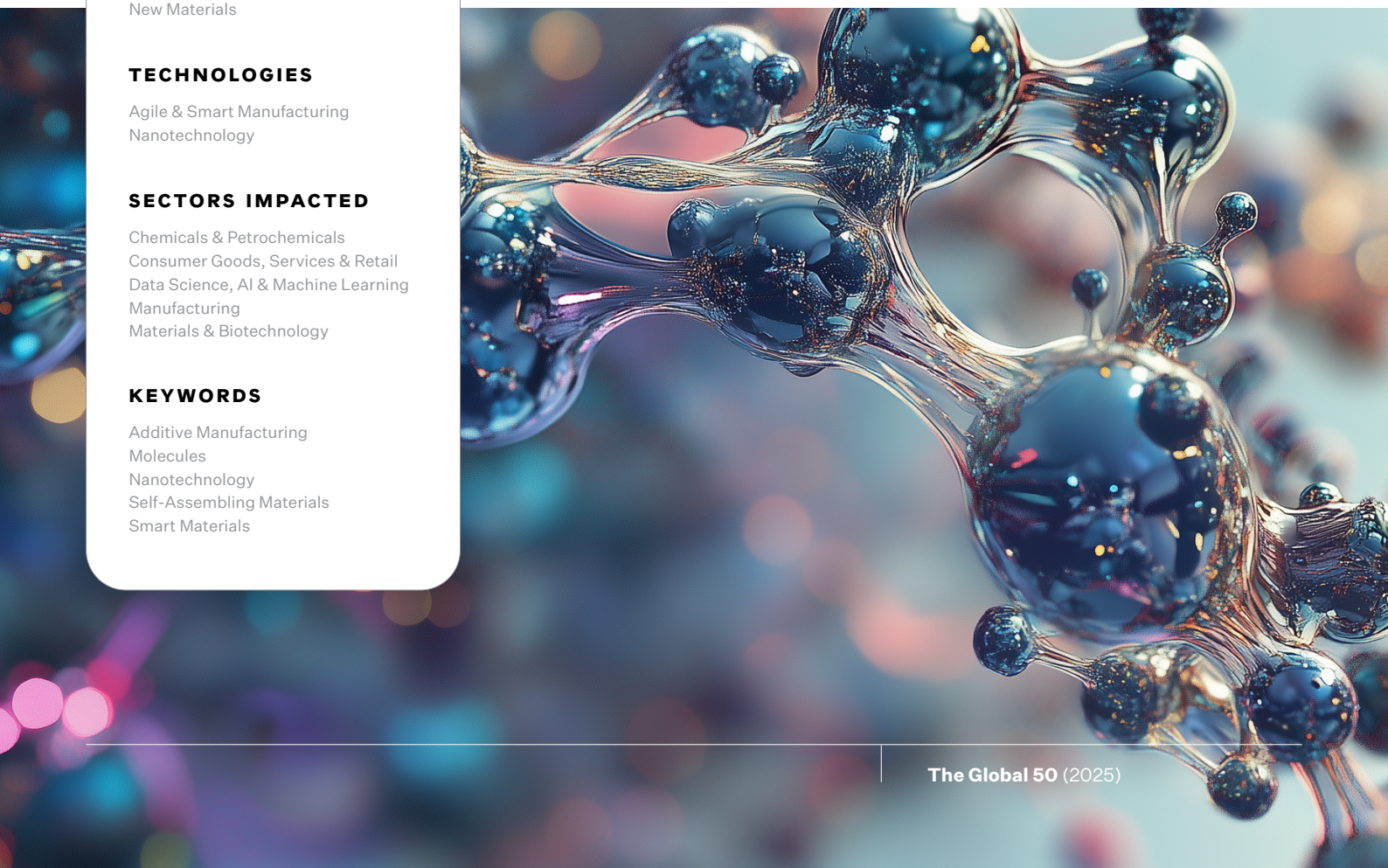
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Manufacturing
Materials & Biotechnology

KEYWORDS

Additive Manufacturing
Molecules
Nanotechnology
Self-Assembling Materials
Smart Materials

Within Reach | Transitional | **Visionary**

Engineered through nanotechnology and computational design, self-assembling molecules represent the next generation of manufacturing, autonomously forming and transforming when triggered by chemicals or light.



WHY IT MATTERS TODAY

Globally, around

$163 billion

worth of inventory is discarded each year due to oversupply or damage, resulting in a substantial environmental impact, including increased air pollution and water contamination.

The global supply chain model is undergoing a major transformation. Over the past few decades, supply chains have become optimised for mass production and low costs, but they lack resilience.[1260] They are focused on efficiency but ignore environmental impacts and sustainability.[1261] However, companies are now shifting to more flexible, segmented supply networks that prioritise security, the sustainable energy transition, and agility.[1262] Globally, around $163 billion worth of inventory is discarded each year due to oversupply or damage, resulting in a substantial environmental impact, including increased air pollution and water contamination.[1263]

Over the past two decades, local material consumption has surged by 65%.[1264] Currently, overall, materials handling and use is responsible for 70% of global greenhouse gas (GHG) emissions,[1265] while only 7.2% of materials are recirculated.[1266] Research indicates that adopting circular economy strategies for four key industrial materials – cement, steel, plastics, and aluminium – could reduce global GHG emissions by up to 40% by 2050 through more efficient and sustainable material use.[1267]

Interest is growing in self-assembling materials, following early successes. Recently, researchers at Northwestern University in the United States developed soft, sustainable electroactive materials made from nanosized strips that mimic biological systems and are biodegradable. The material self-assembles when water is added, achieving stable ferroelectric properties previously unattainable with traditional plastics. Potential uses include smart fabrics and sticker-like implants.[1268] In another case, food proteins were hydrolysed to release self-assembling peptides, which serve as key components of hydrogels that can self-assemble for use as carriers for nutrients, solutions for wound-healing, and biosensors.[1269]

Adopting **circular economy strategies for four key industrial materials** – cement, steel, plastics and aluminium – could reduce global GHG emissions by up to

40%

by 2050

THE OPPORTUNITY

Through nanotechnology and computational design, molecules are engineered with capabilities that allow them to autonomously recognise and connect with one another in a manufacturing-like process. Energy – from chemicals or light – triggers the assembly process by providing the power needed to initiate and control self-assembly.[1270] Once a product has been assembled, modifications or disassembly can be triggered as needed by sending further instructions to the materials. Products can be dynamically reconfigured, repaired or completely transformed without traditional mechanical interventions.

Inspired by biological systems such as protein folding and cellular organisation, self-assembling molecules have the potential to create everything from advanced electronics to medical devices.

BENEFITS

Sustainable manufacturing; reduced waste and environmental impact; support for the circular economy; adaptive production.

RISKS

Job displacement; cybersecurity vulnerabilities in molecular assembly networks.

Self-assembling molecules are engineered with capabilities that allow them to **autonomously recognise and connect with one another in a manufacturing-like process**