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# 1 Introduction to the deliverable content

Working group 2 is expected to be a strong connection between industry and academia and its activities will focus on the identification of existing gaps in common industrial processes along with the main challenges that the industrial partners are currently facing towards technology advancements and the launch new smart products to the market.

The last activity required is a Technology report in which a Market Overview and Business Models were expected on breakthroughs realised within this Action.

The first step to be completed is to collect some information regarding the evolution and the forecast of the composite materials market.

The second part of the following report collects the main results obtained by the other WG and will discuss some exploitation strategies.

# 2 Evolution and forecast of the composite materials market

Composites are becoming more and more acknowledged as the ideal option across a variety of sectors as global companies concentrate increased emphasis on lightweight, high-performance materials to fulfill growing customer demands and regulatory needs. Moreover, two main industrial sectors, automotive and aerospace, are pushing this class of materials for lightweight automobiles in the automotive industry, increasing fuel economy and lowering pollutants and as manufacturers of aircraft strive to reduce operating costs and improve fuel economy in aerospace.

Furthermore, because of their strength and resistance to environmental deterioration, composites will be used more often in the construction industry for building materials, infrastructure projects, and environmentally friendly housing options. [1]

In order to understand the global composites market dynamics it is important to notice that in the next 5 years 11% of market increase is expected equally distributed between Asia, North America and Europe.

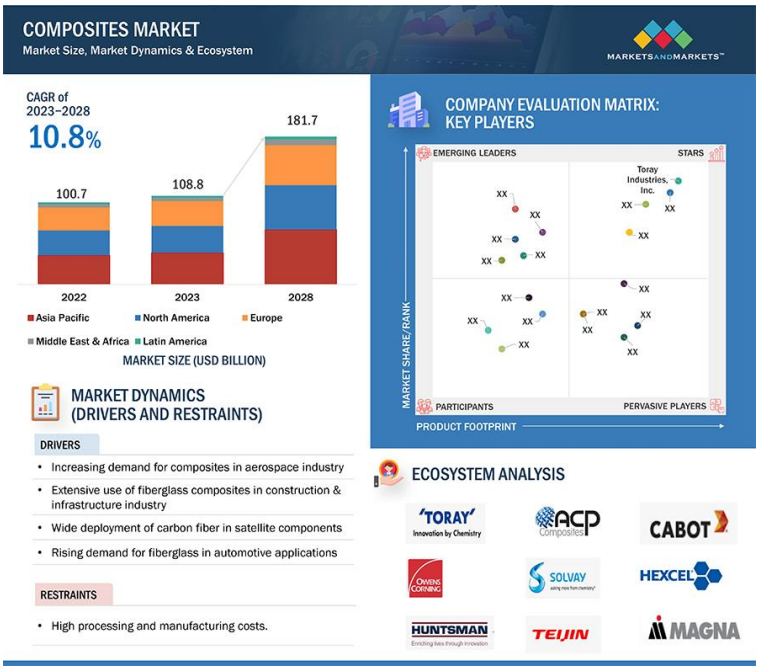

**Figure 1 Composites markets forecast [1]**

## 2.1 Drivers: Stringent eco-friendly regulations in automotive applications

One important factor in the production of automobiles is the better strength-to-weight ratio that composites offer. Automobiles with robust construction but low weight provide better mileage and fuel economy. When compared to traditional materials such as steel and aluminum, composites provide significant weight savings of 25% to 70% in the production of car bodies. A mere 10% reduction in the weight of the vehicle yields a 5% improvement in fuel efficiency. Compared to steel, carbon fiber can achieve a 30% gain in fuel efficiency. Strict laws, like the US government's required Corporate Average Fuel Efficiency (CAFE) criteria, are what propel the automobile industry. Because the transportation industry contributes significantly to greenhouse gas emissions, US automakers are required to meet these standards. As a result, there has been a noticeable shift in the manufacturing of lightweight cars to comply with CAFE standards, which call for 36.6 mpg by 2017 and 54.5 mpg by 2025. To reduce greenhouse gas emissions, this endeavor has sparked the development of electric and lightweight, fuel-efficient vehicles. Because carbon fiber composites can reduce diameter, eliminate joints, and sustain greater critical rotations, they are especially sought after for use in automobile engine propeller shafts. The key driver driving the growth of the composites industry is consumers' growing preference for lightweight and fuel-efficient automobiles. Doors, roof panels, windows, headrest back panels, seats, luggage bins, cooling ventilators, and braking materials for luxury and racing cars are a few notable automobile applications for composite materials.

### GROWTH OF THE CONSTRUCTION INDUSTRY

Bridges, waterfronts, and other structures require rehabilitation and replacement as a result of aging infrastructure. Composites provide corrosion resistance and durability, which contribute to low maintenance and long service life for structures, resulting in life cycle cost savings and a long-term economic advantage over traditional materials such as steel and concrete. Many promoters in the composites industry, from material suppliers to fabricators, are working to raise awareness about the advantages advanced materials offer for updating infrastructure around the world. The main applications of composites in architecture include cladding, domes, roofing, structures, bridge decks, full-bridge structures, bridge enclosures, masts and towers, pipes, modular structures, tanks, access covers, water control structures, housings, and refurbishment.

The growing construction industry in developed nations, with increasing investments in residential construction and infrastructure development. This market growth can be attributed to the increase in residential construction with the growing need for single-family dwellings. Moreover, with the European construction companies focusing on vertical integration to gain a competitive edge and expand their presence in other regions, the construction industry is expected to grow significantly during the review period. The construction market is expected to grow by USD 6.4 trillion in 2020 and reach USD 14.4 trillion by 2030. Sub-Saharan Africa is expected to have the fastest growth in regional construction, followed by emerging Asia. China, India, the United States, and Indonesia account for 58.3% of construction growth. Thus, growth of construction industry is likely to drive the growth of the Composites market revenue. [2]

This clear widening of the possible application of advanced composites opens to several considerations regarding the type of fiber and resin that are expected for a larger increase

## 2.2 Composites Type Insights

The Composites market segmentation, based on type, includes Glass Fiber, Carbon Fiber, and Others. The Glass Fiber segment held the majority share in 2021 contributing to around ~60.35% with respect to the Composites market revenue. Glass-fiber composite is a type of fiber-reinforced polymer composites, which are commonly known as fiberglass. The glass fibers are lightweight and exhibit low density, high tensile strength, tenacity, compression strength, thermal expansion, and easy processing. They have wide application in aerospace &defense, automotive & transportation, and building & construction resulting in the growth of the glass fibers segment during the forecast period.

### 2.2.1 Glass fiber composites segment to dominate the market in terms of value and volume.

Because of its remarkable qualities such as strength, flexibility, stability, durability, and resistance to heat, temperature fluctuations, and moisture—the glass fiber composites market segment commands the largest share in terms of volume and value. This is explained by its affordability, mass-production viability, and significant demand in a variety of industries, including infrastructure, sporting goods, wind energy, and construction. Glass fiber composites are used in underbody systems, deck lids, front-end modules, bumper beams, engine covers, instrument panels, and air ducts, among other components in the transportation sector.

## 2.3 Composites Resin Type Insights

The Composites market segmentation, based on resin type, Thermoplastic Composites, and Thermosetting Composites. The Thermosetting Composites segment held the majority share in 2021 contributing to around ~73.24% with respect to the Composites market revenue. The segment is expected to maintain its dominance over the forecast period. The properties of thermoset composites include excellent strength, lightweight, low specific gravity, excellent modulus of elasticity, and high corrosion resistance, among others. The superior properties of thermoset composites have contributed to their increasing applicability across various end-use industries, such as wind energy, automotive, and construction & infrastructure, among others. The growing demand for durable & lightweight substitute materials from the automotive and aerospace industries is one of the key factors propelling the growth of the thermoset composites market.

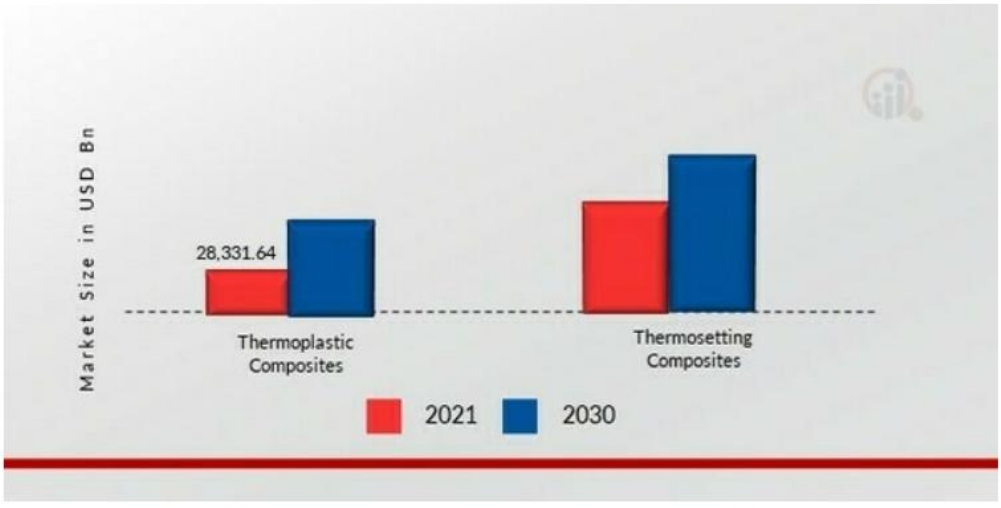

**Figure 2 Composites Market By resin Type 2021-2030 (USD Billions) [2]**

### 2.3.1 Thermoset resin is expected to hold the largest share in composites market.

Thermoset resins have been the industry leader in the resin type category of composites. Composites are manufactured using a variety of thermoset polymer matrices, such as vinyl esters, polyester, and epoxy. Thermoset composites with high toughness, impact strength, and moisture resistance are produced by fibers inserted in a matrix of thermoset resins. These composites are widely used in many different industries, including infrastructure, electronics, pipes and tanks, transportation, and construction. They are also extensively used in wind energy, marine, construction and infrastructure, transportation, sporting products, and a number of other end-use industries. Specifically, thermoset composites don't expand much in hot, humid settings, which makes them appropriate for applications where corrosive environments and high temperatures are present.

## 2.4 Composites Process Insights

The Composites market segmentation, based on Process, Layup Process, Injection Molding Process, Filament Winding Process, Pultrusion Process, Compression Molding Process, and Others. The Layup Process segment dominated the market in 2021 and Injection Molding Process segment is projected to be the faster-growing segment during the forecast period, 2022-2030. This is due to the Lay-up is an open molding process that can be used to create a wide range of composites products, from small to large. The manufacturing capacity per mold is small; though, it is possible to produce large production quantities by using multiple molds. Hand lay-up is the simplest composites molding technique, offering low-cost equipment, simple processing, and a wide range of part sizes. Furthermore, Good production rates and consistent quality can be achieved with trained operators.

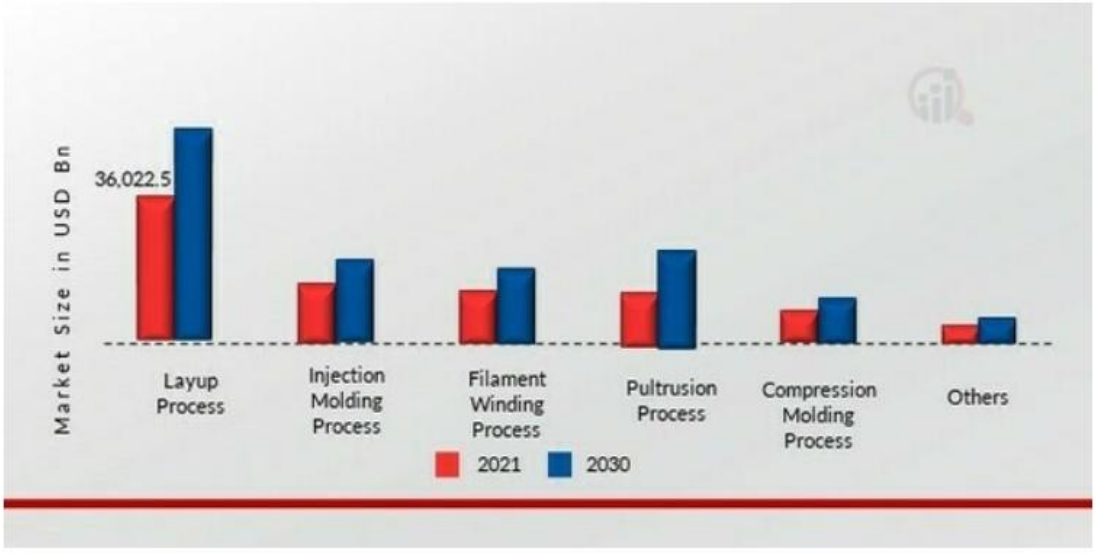


**Figure 3 Composite markets per process (USD Billions)**

Source [2]

### 2.4.1 Filament winding process is expected to register the highest CAGR during the forecast period.

There is a notable increase in demand for the filament winding process in the composites manufacturing industry, as seen by its outstanding Compound Annual Growth Rate (CAGR). This method, which is well known for its efficiency and versatility, involves applying continuous fibers, like carbon or glass, in a predefined pattern, onto a revolving mandrel. The resulting composite structures exhibit exceptional strength-to-weight ratios, corrosion resistance, and long-lasting durability, making them highly suitable for a wide range of applications in different industries. One of the main reasons filament winding is growing at a significant rate is that it is being used widely in industries including aerospace, automotive, marine, and energy. Due to their lightweight design and structural integrity, filament wound components are used in rocket motor casings, aircraft fuselages, and wings in the aerospace industry. Similar to this, filament-wound tanks and pressure vessels are becoming more and more popular in the automotive industry for uses such as fuel storage and hydrogen fuel cell technology, which improves fuel economy and environmental sustainability. Furthermore, filament-wound composite pipes and tanks are essential components of solar panel structures and wind turbine blades in the field of renewable energy, helping to efficiently generate and store clean energy. The filament winding industry's growth trajectory is further supported by ongoing advancements in automation, robotics, and material innovations, which provide producers with increased efficiency, precision, and scalability.

## 2.5 Composites Key Market Players & Competitive Insights

The Composites market is characterized by the presence of , regional, and local players. The market is highly consolidated, with all the players competing to gain significant market share. The key market players of Composites compete based on cost, product quality, availability of raw materials, and durability of the product. There has been substantial revenue growth for selected composite companies, particularly those located in Asia or those with major operations in Asia. This is the result of an increased domestic demand within Asian countries, as well as an overall rise in composite demand across the globe. However, some major companies produce more than one of the composites. A clear example is Teijin, which produces carbon fiber as well as aramid fiber.

PPG Industries, Inc. (US), Hexion (US), Jushi Group Co., Ltd (China), Toray Industries Inc. (Japan), Owens Corning (US), Teijin Limited (Japan), Hexcel Corporation (US), SGL Carbon (Germany), Mitsubishi Chemicals Corporation (Japan), Solvay (Belgium), and Huntsman International LLC (US) are the key players operating in the Composites market. The Composites market remains highly fragmented with the majority of tier-1 players, with leaders, including PPG INDUSTRIES INC, Teijin Limited, Mitsubishi Chemical Corporation, Solvay, and Toray Industries Inc., accounting for the largest market share. Players in this market adopted various strategies to expand their footprint and augment their market share.

PPG Industries, Inc. (PPG), a leader in transportation and industrial coatings, is engaged in the production and distribution of a broad range of paints, coatings, and specialty materials. It caters to customers operating in a wide array of end-use industries, including automotive, aerospace, marine, and construction. PPG operates through two business segments, namely, performance and industrial coating. PPG manufactures an extensive portfolio of coatings systems through 156 manufacturing facilities and has a presence in over 39 countries across the globe and sales in more than 70 countries. The company offers flooring coating products under the protective coating solutions offered by its performance coatings business segment.

Also, Hexion is engaged in the manufacturing of advanced specialty chemicals and performance materials. It is a leading manufacturer of adhesives and epoxy resins, and coatings. It operates through business segments, namely epoxy, phenolic and coating resins, and forest products resins. The epoxy, phenolic, and coating resins segment accounted for around USD 2,052 million by the end of 2017. The company serves diverse markets, such as architectural and industrial paints, packaging, consumer goods, automotive coatings, aviation, energy, oil & gas, and electrical composites. Hexion has a worldwide network with production facilities in more than 90 countries severing to over 3,000 customers. Its customers include Akzo Nobel N.V., 3M, BASF, Bayer, Dow, Monsanto, PPG Industries, Owens Corning, Valspar, and Weyerhaeuser.

This list is not exhaustive but gives an important feedback on the potentiality of the market and of the topic. [2]

### 2.5.1 Asia Pacific to be the largest and fastest growing regional market in the global composites market.

With significant producers of glass fiber and carbon fiber in China and Japan, as well as emerging economies in India and China, the Asia Pacific region has the lion's share of the worldwide composites market. Notably, the region is seeing tremendous expansion in the wind energy sector, which is a major user of composites. Additionally, the Asia Pacific area is seeing a noticeable growth in the transportation end-use industry, which is another significant consumer of composites. This growth is being driven by OEMs placing a greater emphasis on the manufacture of electric vehicles. All of these elements work together to fuel the region's growing need for composites.

The market however is not completely ready for composites materials wide introduction. In the following some restraints will be described.

# 3 Restraints: Lack of standardization in manufacturing technologies

The growth of composites in a number of industries, including consumer products, marine, and recreational goods, is still hampered by non-recurring development and manufacturing expenses. The three key issues are maintenance technology, process standardization, and design consistency. In the automobile and aerospace industries, mass production and economic viability are hampered by manufacturers' preference for conservative designs due to the lack of standardized materials and procedures. Furthermore, the absence of standards pushes producers to stick with traditional goods rather than investigating composites for a range of uses. Additionally, a barrier to the wider adoption of composites is the lack of human resources with the necessary training and experience.

# 4 Opportunities: High demand for carbon fiber composites in CNG and hydrogen storage

Carbon fiber composites are experiencing heightened demand for the storage of compressed natural gas (CNG) and hydrogen due to their exceptional strength-to-weight ratios, rendering them particularly well-suited for pressure vessels necessitating reduced weight and heightened safety standards. Applications for carbon fiber pressure vessels include the storage of hydrogen gas for hydrogen storage tanks, breathing air for firefighting in SCBA/SCUBA systems, and compressed natural gas for CNG storage tanks. Carbon fiber composites are also widely used in industries like marine and aerospace

transportation that need to store gases under high pressure. Interestingly, carbon fiber composites have the lightest CNG volume, which increases vehicle range, fuel efficiency, and payload capacity. As a result, it is anticipated that these materials will grow in the years to come.

# 5 Challenges: Recycling of composites to be a major challenge for market growth

Composites are being used in a variety of end-use sectors to reduce weight, which improves performance and fuel efficiency and simultaneously lowers CO2 emissions and increases accident safety. However, recycling composites has certain difficulties. Automotive composites are particularly difficult to recycle due to their complex constituent compositions and thermoset resins' cross-linked nature. The recycling process is exacerbated by thermoset polymers' resistance to remolding. End-of-life aircraft structures made of carbon fiber composites primed with hexavalent chromium present a relevant problem. Because hexavalent chromium can seep into the earth, these composites cannot be disposed of on land because they are classified as hazardous waste.

# 6 Challenges: CNMs composite market

As reported in D3.2 [3], the market for nanomaterials has been experiencing steady growth, driven by increasing research activities and technological advancements. It is considered highly competitive with the presence of large-scale key players operating in it, including Strem Chemicals, Inc., Sigma Aldrich, Inc., Nanoshell LCC, Nanocyl, Graphenea, and so many others. The global nanomaterials market was estimated at USD 12,42 billion in 2023 and project to grow at a compound annual growth rate (CAGR) of 15% from 2024 to 2030. This significant growth is promoted by emerging technologies.

The diversity of particles and interesting properties, described in the previous section, allows the utilization of CNMs in several sectors, as it can be seen in Figure 4, for a wide variety of applications, which will be exploited in more detail in the following sub-sections

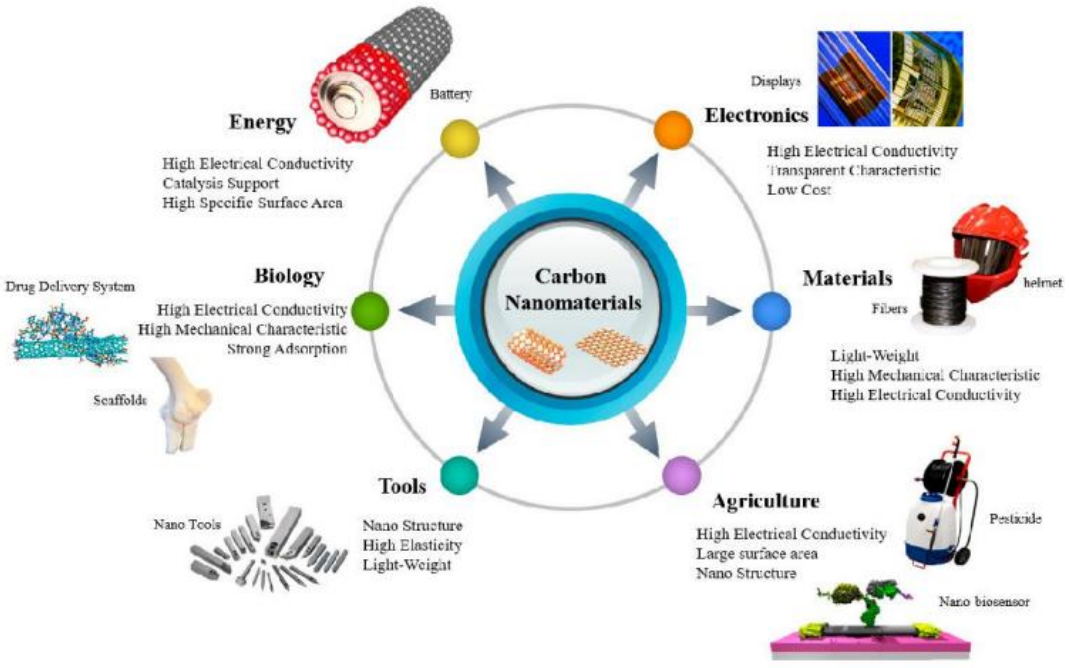


**Figure 4 An overview of the different applications of CNMs [3 and ref therein]**

# 7 CNMs feasibility market introduction

A very important aspect to consider is the feasibility study that identifies potential risks and challenges that limit the larger utilization of CNMs at this moment. Based on the information from previous chapters, the following challenges can be referred as the most important for the broader commercialization of products containing CNMs.

Later on the most important aspects will be reported and summarised from D3.2

**Production Costs and Scalability**

• High Costs: One of the primary challenges in the widespread adoption of CNMs is their high production cost. The processes for synthesizing high-quality CNTs and graphene, such as CVD, can be expensive

• Scalability Issues: Producing these materials on a large scale while maintaining consistent quality is a significant hurdle. [4]

**Quality and Consistency**

• Material Variability: Carbon nanomaterials often exhibit significant variability in terms of size, purity, and structure, which can affect their performance in applications. Ensuring uniformity and reproducibility in production is difficult, leading to inconsistencies in material properties.

• Characterization Challenges: The complexity of these nanomaterials makes it challenging to characterize them accurately and consistently. Advanced techniques are required to analyse their properties, adding to the complexity and cost.

**Dispersion and Integration into Matrices**

• Dispersion Issues: Incorporating carbon nanomaterials into other materials (such as polymers) often requires them to be well-dispersed to achieve the desired properties. However, CNTs and graphene have a tendency to agglomerate due to van der Waals forces, which can lead to weak points in the material.

• Integration Techniques: Developing effective methods to integrate these nanomaterials into existing manufacturing processes without degrading their properties is a challenge. This includes finding suitable binders and ensuring strong interfacial bonding with matrix materials.

**Health and Environmental Concerns**

• Toxicity and Safety: There are ongoing concerns about the potential health risks associated with the inhalation and exposure to carbon nanomaterials. Studies on the toxicity of CNTs and graphene are still emerging, and there is a need for comprehensive assessments to ensure safe handling and use.

• Environmental Impact: The environmental impact of producing and disposing of carbon nanomaterials is not fully understood. Ensuring sustainable practices and assessing the longterm ecological effects are crucial for broader adoption.

**Regulatory and Standardization Issues**

• Lack of Standards: There is a lack of standardized testing and quality control measures for carbon nanomaterials, making it difficult for industries to adopt these materials confidently. Developing global standards for their characterization, testing, and use is essential.

• Regulatory Challenges: Navigating the regulatory landscape for new materials can be complex. Manufacturers must comply with a range of regulations regarding safety, environmental impact, and consumer protection, which can vary significantly acro

**Market Acceptance and Awareness**

• Industry Reluctance: Industries may be hesitant to adopt new materials without proven longterm benefits and reliable supply chains. The novelty of carbon nanomaterials means that many industries lack the experience or confidence to integrate them into their products.

• Awareness and Education: There is a need for greater awareness and understanding of the potential benefits and challenges associated with carbon nanomaterials. Educating stakeholders about the capabilities and safe handling of these materials can facilitate broader adoption.

# 8 Conclusion

The potential for composite materials is enormous and they could completely change the products, not only in niche market, but also in the wider ones. Furthermore, CNMs in revolutionizing various industries is massive. In order to push their widespread application, several challenges must be addressed to facilitate greater utilization. A continuous research is thus necessary, pushed not only by academic institutions but also driven by the industrial playersin order to  development and optimize production methods, improve material consistency, and address safety concerns, which are critical steps toward integrating carbon nanomaterials more fully into industrial applications.

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