About Lucintel

Vision
• To provide accurate data, insights, strategy and innovation which empowers companies to make better informed decisions

History
• Founded in 1998.
• Team of over 120 full time analysts / consultants including engineers, PhDs, and MBAs

Industry Leadership
• Over 1000 clients from 70 countries – Fortune 500 companies
• 20 years of proven management consulting & market research experience
• Panelists and key note speakers at leading conferences

Published Market Reports
• Over 500 published market reports - ~ 80 reports covering ‘Composites & Advanced Materials’

Consulting Services
• Market entry strategy, Opportunity screening, Competitive assessment, Strategic consulting, M & A services, Due diligence, Growth finance, Winning strategy formulation
1000+ Clients in 70 Countries Value Our Service
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- Global Market Insights
- UK Market Insights
- Innovation Areas for Composites Growth
- Business Case for Composites
- Future Market Disruptions in Composites
- Conclusions
Composite Materials Usage Expected to Grow Globally to 2023

- Increasing demand for lightweight materials in aerospace, wind energy, transportation (including automotive) and other end use industries will continue to drive future composites growth.
- Expanding urbanization in China, India and Brazil will also drive growth in use of composites.

# NB: Composite materials market data calculated as the value of key raw materials including: thermoset and thermoplastic resins, carbon fibers, glass fibers, fillers, additives and core materials, but excluding ‘intermediate’ materials such as: compounds, textiles and prepregs.
Strongest Global Growth Forecast in Aerospace & Transportation Markets to 2023

Key Insights

➢ High use of composites in newer aircraft such as B787, A350XWB, and C Series
  • The aerospace market likely to benefit from highest growth due to substantial back orders for Boeing 787 and Airbus 380 aircraft.

➢ Government regulations on automotive fuel efficiency continue to put pressure on OEMs to make vehicles lighter

➢ Automakers such as BMW, Mercedes, Ford, and GM are now looking for cost effective ways of incorporating carbon composites in ‘mass volume’ cars
  • Automobile manufacturers investing in R&D to develop new hybrid models which emit fewer pollutants into the environment and new plug-in all electric vehicles (EV).

NB: Bubble size represents value of global composites end products market in 2023.
## Composite Applications and Competing Materials in Major End Market Segments

<table>
<thead>
<tr>
<th>Aerospace</th>
<th>Transportation</th>
<th>Wind Energy</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuselage</td>
<td>Monocoques/Chassis</td>
<td>Wind blades</td>
<td>Bathtub</td>
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<tr>
<td>Wings</td>
<td>Body closures</td>
<td>Nacelles</td>
<td>Doors &amp; Windows</td>
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<tr>
<td>Control surfaces</td>
<td>Under the body</td>
<td>Spinners</td>
<td>Pultruded profiles</td>
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<tr>
<td>Fan blades</td>
<td>Interiors</td>
<td></td>
<td>Swimming pools</td>
</tr>
<tr>
<td>Tail cones</td>
<td>Front cabin (train)</td>
<td></td>
<td>Pole</td>
</tr>
<tr>
<td>Interiors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
</tr>
<tr>
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<td>Steel</td>
<td>Steel</td>
<td>Concrete</td>
</tr>
<tr>
<td>Composites</td>
<td>Iron</td>
<td>Iron</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel</td>
<td>Aluminum</td>
<td>Plastic</td>
<td>Iron</td>
</tr>
<tr>
<td>Plastics</td>
<td></td>
<td>Composites</td>
<td>Plastic</td>
</tr>
</tbody>
</table>

- Aluminum
- Composites
- Steel
- Plastics
Composite Applications and Competing Materials in Major End Market Segments

**Pipe and Tank**
- Oil & Gas
- Chemical
- Septic
- Waste water, etc.

**Electrical & Electronics**
- Printed circuit board
- Electrical enclosures
- Fuses
- Cabinets, etc.

**Consumer Goods**
- Golf shafts
- Bicycles
- Tennis rackets, Fishing rods
- Hockey sticks
- Surfboards
- Toys

**Marine**
- Hull
- Deck
- Mast

- Steel
- Plastics
- Concrete
- Composites

- Plastics
- Metals
- Composites

- Plastics
- Aluminum
- Steel
- Composites

- Composites
- Aluminum
- Steel
- Wood
- Plastics
Thermosets Still Dominate the Global Composites Materials Market but a Significant Shift to Thermoplastics since 2013

Key Insights

➢ Shift to thermoplastics expected to continue, driven by easier recyclability and faster production cycle times.
➢ Thermoset composites will still predominantly be used in Construction, Pipe & Tank, Wind blades, Marine, E & E.
➢ Aerospace, Automotive & Transportation and Consumer goods expected to grow more thermoplastic applications.
➢ New applications being developed in all key forms (polymer resins, sheet and prepreg) of thermoplastic materials - LFT, SFT, GMT, and CFRT.
➢ Lower cost automated ‘net shape’ processing techniques (e.g. AFP/ ATL, thermoforming, compression moulding, injection moulding, welding) being developed.
➢ Aerospace & Defence OEMs, R & D bodies, and supply chain working on next generation thermoplastic composite designs for airframe, interior and other applications.
➢ Key thermoplastic resins include: PP, PA, PPS, PEI, PEEK, PEKK, PAEK and others.
# Key Composites Issues to Deliver Better Solutions

## Issues

- High materials costs
- Lack of high volume process for making structural parts
- Fiber print through
- Machining and joining
- Repair and recyclability

## Industry Expectations

- Carbon fiber price reduction by 50%-60% (~$5/lb)
- Glass fiber price reduction by 10%-30%
- Resin price reduction by 10%-40%
- More than 30,000 parts annually using continuous fiber composites
- Part manufacturing cycle time 1-2 minutes
- Materials layup rate up to 150 kg/hr
- Class A surface finish for exterior applications
- Improved machining and joining technologies for composites
- Improved technologies for composite part repair and recycling
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**Key Insights**

- **UK composite materials market** expected to grow at a CAGR of ~1% during the next five years to reach ~0.32 million metric tonnes at a value of US$ 1.2 B by 2023.

- Aerospace and Automotive are the key markets in the UK composite materials market
  - Light weighting requirements for increasing range and fuel efficiency is driving increasing usage of composites in these key markets.

- **UK wind industry** has faced sudden fall, as new onshore wind farms effectively banned since 2015 and UK Government put emphasis on offshore installations
  - Offshore wind energy market will lead to the growth of UK wind industry, as it has huge potentials in the region.

**The UK Composite Materials Market in US$ B: 2017 - 2023**

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2023</th>
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<tbody>
<tr>
<td>Value</td>
<td>1.0</td>
<td>1.0</td>
<td>1.2</td>
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</tbody>
</table>

**The UK Composite Materials Market in Million MT: 2017 - 2023**

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.28</td>
<td>0.28</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Source: Lucintel
Aerospace & Defence, Wind Energy and Transportation Markets
Accounted for ~57% of UK Composite Materials Market in 2017

UK Composite Raw Materials Market in 2017: ~ £1.0 Billion

Key Insights

➢ Aerospace & Defense, Transportation and Wind energy markets are the main consumers of composite materials in the UK
  • Airbus UK is the highest aerospace composites parts consumer in the UK
  • Others includes key Marine and B & C markets using composites

➢ UK new wind installations increased by more than 400% in 2017 as the main larger projects Renewable Obligation Certificates (ROCs) financial support scheme was coming to an end and developers rushed to ensure applicability for onshore installations in UK
  • Wind energy market expected to recover in coming years due to offshore wind potential

➢ Automotive expected to be one of the biggest potential growth markets in the next 5-10 years
  • Automotive OEMs investing heavily in CFRP to meet CO₂ emission reduction targets.
Aerospace and Automotive Industries Offer Huge Growth Potential for the UK Composites Industry

- High aerospace demand for composites
- Key part fabricators, such as GKN, Airbus UK, Bombardier, and BAE Systems are all utilising composites in their products
- Rolls Royce is also looking to adopt composites in its engine fan blades & cases

- Strong position in composites in F1, motorsports and super cars
- Increasing demand for light weight materials offers huge potential for composites in higher volume cars and new EV models

- Government ban of onshore wind farms led to sudden installations fall off in 2015/2016
- 2017 registered largest ‘spike’ growth of major installation as ROC financial support came to an end and developers rushed to get project included.
- UK wind energy installations, particularly offshore, expected to undergo resurgence, with Siemens and MHI Vestas having made key investments in the region.
- Industry gaining pace in the UK and expected to grow in the foreseeable future.
## Key Success Factors (KSF) for UK Composites Industries

<table>
<thead>
<tr>
<th>KSF Description</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Capacity Expansion</strong></td>
</tr>
<tr>
<td>Investment by major players in the raw material &amp; component manufacturing capacity to meet future growth in all key sectors</td>
</tr>
<tr>
<td><strong>2. Composite Hubs, Gov. Bodies &amp; Associations</strong></td>
</tr>
<tr>
<td>Further development and expansion of composites hubs, government bodies and associations supporting UK composites companies in all node of the value chain covering both thermoset and thermoplastic composites</td>
</tr>
<tr>
<td><strong>3. Collaborative Research &amp; Development</strong></td>
</tr>
<tr>
<td>Encourage private investment in R &amp; D programs to participate in new composite development programs for key growth industries and sectors</td>
</tr>
<tr>
<td><strong>4. Encourage Indigenous Manufacturing</strong></td>
</tr>
<tr>
<td>Encourage new start ups and provide more growth support for UK composites companies through: additional government funding, exporting support, financial incentives, attractive loans and more grants</td>
</tr>
<tr>
<td>Table of Content</td>
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<tr>
<td>• Global Market Insights</td>
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<td>• Innovation Areas for Composites Growth</td>
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<td>• Business Case for Composites</td>
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<tr>
<td>• Conclusions</td>
</tr>
</tbody>
</table>
Innovation Areas to Drive Further Global Composites Growth

<table>
<thead>
<tr>
<th>A</th>
<th>Cost Reduction</th>
<th>Impact on Composites Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Cost reduction in composites, especially for carbon composites parts</td>
</tr>
<tr>
<td>B</td>
<td>Light Weighting</td>
<td>• Light weighting trends driven by government regulations and targets for new vehicle fuel efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• New transformative technologies with low cycle times (&lt; 2 mins) for mass production composite parts</td>
</tr>
<tr>
<td>C</td>
<td>Low Cycle Time</td>
<td>• Parts made with a mix of metals and composites which have enhanced properties and higher performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Development of more environmentally friendly bio resins, natural fiber and recycled composite systems with required mechanical properties</td>
</tr>
<tr>
<td>D</td>
<td>Hybrid Composites</td>
<td>• Development of better repair and ‘end of life’ recycling technologies for composite materials</td>
</tr>
<tr>
<td>E</td>
<td>Green Composites</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Cradle to Grave</td>
<td></td>
</tr>
</tbody>
</table>

- Huge growth opportunity in mass volume vehicles
- Increased usage of CFRP and CNRP in Automotive, Aerospace & Wind Energy
- HUGE growth opportunity in mass volume vehicles
- Increased penetration with new hybrid composites applications in Automotive, Aerospace & Construction
- Increased usage of sustainable materials to make greener composite parts, especially in Transportation & Construction
- Huge opportunity for recycled composites in Automotive, Aerospace & Construction
Composites Opportunities Across the Globe

- Growing wind energy installations
- Demand for greater % composite content aircraft (Bombardier C Series)

- Automotive: CO₂ emission EU standard for new cars 2020 target: < 95g/km (2015 target:130g/km)
- Aerospace - high order backlog of A350XWB
- Sustainable growth in wind energy
- Rail - orders for new lightweight high speed trains

- Automotive: CAFÉ standards - 54.5 MPG by 2025 and higher automotive production.
- High demand for high composite content aircraft (BOEING 787 - 50% by wt. usage of advanced composites).

- High demand of commercial aircrafts and helicopters
- High investment in infrastructure
- High wind energy installations
- Continuous shift in E&E and sporting goods

- Growing wind energy installations
- Increasing automotive production

- Offset Requirement (30%)
- High investment in infrastructure
- Increasing automotive production
- High metro and mono rail orders
- No indigenous advanced material production capability
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## Major Factors Driving the Usage of Carbon Composites in Boeing 787 and Benefits since ’80’s Boeing 767

### Benefits of B787 over B767 ++

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Efficiency</td>
<td>20%</td>
</tr>
<tr>
<td>Low Emission</td>
<td>20%</td>
</tr>
<tr>
<td>Reduction in No. of Parts</td>
<td>26%</td>
</tr>
<tr>
<td>Reduction in Maintenance Cost</td>
<td>30%</td>
</tr>
</tbody>
</table>

### Insights

- **50% composite content (B767 6%)** plus titanium and other super alloy lightweight materials in B787. Improved engine efficiency: GEnx-1B & Trent 1000 consume 15% less fuel.
- Quieter engines with 20% lower emissions.
- Better aerodynamics and more efficient electric-motor-driven hydraulic pumps.
- Use of composites enables redesigning with fewer parts in the BOM.
- Reduced assembly time and less need for adhesives and fastenings.
- 30% lower maintenance costs.

[** Boeing 767 entered service in 1982.**]

### Challenges in the adoption of CFRP

- Materials standardization
- Relatively immature and ill-equipped to meet the material and fabrication needs
Boeing 787 Sales >1,200 Aircrafts Since Inception in 2004. Airbus 350 XWB Sales Also Now Ramping Up

Global Commercial Aircraft in Unit Delivery (2015-2021)

CAGR (2015-21)

<table>
<thead>
<tr>
<th>Aircraft Model</th>
<th>CAGR (2015-21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A318, A319, A320</td>
<td>(-5%)</td>
</tr>
<tr>
<td>A350 XWB</td>
<td>19%</td>
</tr>
<tr>
<td>A380</td>
<td>2.1%</td>
</tr>
<tr>
<td>B737</td>
<td>(-2.0%)</td>
</tr>
<tr>
<td>B777</td>
<td>(-2.0%)</td>
</tr>
<tr>
<td>B787</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

Source: Lucintel
Major Factors Driving the Usage of Carbon Composites in BMW i Series Electric Vehicles

Factors Driving the Use of Carbon Composites by BMW

- **A** Weight Saving
- **B** Emission Reduction
- **C** Part Consolidation
- **D** Strength and Safety gains
- **E** Efficiency Improvement

Strategies Adopted by BMW to Ensure Effective Usage of CF Materials

Challenges to adopt Carbon Fiber

- High cost of carbon fiber parts restricting current usage in lower end mass volume vehicle models
- Continuous availability
- Profitability

Solutions

- BMW & SGL jointly invested to establish carbon fiber manufacturing plant at Moses Lake
- The facility supplies CF and preforms for BMW i3 & i8 series plug-in electric vehicles, and in BMW 7 series
- JV strategy helps BMW to have better control over CF prices
Since 2014 Carbon Fiber Composites in Automotive Industry Significantly Impacted by BMW i3 and i8 EV Model Sales

Global BMW i3 and i8 Sales: 2014-2017

<table>
<thead>
<tr>
<th>Units</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
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</thead>
<tbody>
<tr>
<td>BMW i3</td>
<td>15,000</td>
<td>20,000</td>
<td>25,000</td>
<td>30,000</td>
</tr>
<tr>
<td>BMW i8</td>
<td>1,000</td>
<td>2,000</td>
<td>2,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

Key Insights

➢ High cost of carbon fiber impact profitability of BMW i3 and i8, but achieves the light weight objective for electric vehicle (EV) models
➢ In last four years, carbon fiber composites in automotive industry driven by growth in sales of BMW i3 and i8 models
➢ BMW facing growing cost pressure from other EV suppliers, which is likely to impact future carbon fiber demand
➢ BMW is currently working on ways to reduce the cost of carbon components

Source: Lucintel
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# Major Disruption Technologies in the Composites Industry

## Major Disruptions

<table>
<thead>
<tr>
<th>Cost Reduction of Carbon fibers</th>
<th>Improvements in Productivity</th>
<th>3D Manufactured Mass Customization</th>
</tr>
</thead>
</table>
| Alternative precursors, such as lignin, olefin, textile PAN, etc.  
A low cost carbon fiber ($3-$6 per lbs.) expected to be developed in the foreseeable future. | Low temperature, rapid cure resins and faster processing technologies.  
Composite part manufacturing with 1 - 2 minutes cycle time for higher volume production. | Continuous fiber-reinforced 3D printed thermoplastic composite parts (glass, carbon and aramid fibers).  
Moldless ‘out of autoclave’ 3D printed composite parts manufactured using advanced robotics.  
Latest technology can 3D print thermoset materials - MVP ‘Thermobot 3D printer installed at ORNL, USA in April ’18 |

## Enablers

- Automotive
- Industrial
- Construction

## Impacted Industries

- Automotive
- Industrial
- Aerospace
- Defense
- Automotive
- Healthcare

## Impact

- Cost Reduction of Carbon fibers
- Improvements in Productivity
- 3D Manufactured Mass Customization
Disruption 1: Development of Low Cost Carbon Fiber Using Alternative Precursors and Manufacturing Process

Current carbon fiber price still very high for mass volume. Auto Industry looking for price around US $3- $6/lbs

Major Areas of Carbon Fiber Cost Reduction

Alternative Precursors

- Commercial grade PAN
- Textile grade PAN
- Lignin based
- Polyolefin based

Cost Reduction Potential: 20%-30%

Manufacturing Process

- Advanced Oxidative Stabilization
- MAP Carbonization
- Advanced Surface Treatment & Sizing
- Tow Splitting

Cost Reduction Potential: 40%-60%

Zoltek (Toray Group) commercial grade carbon fiber = $9 / lb
Disruption 2: Major Players are Developing Faster Curing Epoxy Resins to Reduce Production Cycle Time

<table>
<thead>
<tr>
<th>Product</th>
<th>Resin</th>
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<tbody>
<tr>
<td>1</td>
<td>VORAFORCE 5300</td>
</tr>
<tr>
<td>2</td>
<td>VORAFORCE 5300</td>
</tr>
<tr>
<td>1</td>
<td>Araldite MY 0610</td>
</tr>
<tr>
<td>2</td>
<td>Araldite LY 3585</td>
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<td>3</td>
<td>Araldite LY 3031</td>
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<table>
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<tr>
<th>Product</th>
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<tbody>
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<tr>
<td>1</td>
<td>CYCOM 823 RTM</td>
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<td>2</td>
<td>XMTR50</td>
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<td>XMTR750</td>
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<table>
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<td>2</td>
<td>EPIKOTE 04695-1</td>
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<tr>
<td>3</td>
<td>EPIKOTE Resin 06465</td>
</tr>
<tr>
<td>4</td>
<td>EPIKOTE TRAC 06170</td>
</tr>
</tbody>
</table>

Aerospace and Defense
- Spars
- Fan blades
- Interior parts
- Drone rotor support arm
- Hollow composite parts
- Propellers, etc.
- Jigs & mold tooling

Automotive
- Car body
- Air intake
- Airfoil
- Roof parts, etc.

Healthcare
- Orthopedic implants
- Prosthetics
- Surgical guide tools
- Hearing aids, etc.

Impact on Industries
So far, 3D printing has emerged as a viable process for prototypes, tooling jigs, model making, demonstration units and small volume & custom part production.
- Improved customization
- No tooling costs or storage
- Parts on demand – no stock
- Little to no scrap
- Short lead time

Major Barriers to Overcome
High unit cost, skill requirements, redesign needs, testing, standards & certification, warranties, approved 3D Printing tier 1 & 2 part suppliers, availability of raw materials & 3D printing machines.

Source: Lucintel
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Conclusion – A Positive Global Outlook for Composites

➢ Composite materials market expected to globally grow at 4% CAGR to hit US$38 B in 2023 based on innovations in materials, processing and reducing costs, especially carbon fibers.

➢ To succeed, the composites industry globally and in the UK, needs to focus on:
  – Cost reduction in composite parts, still offering lightweighting and in-use performance
  – Development of production technologies with reduced cycle times for high volumes
  – Solve OEM challenges in repair and recycling with new technologies for composites

➢ Companies in the composites industry need clear strategies and objectives to compete globally (what materials, applications, segments, technologies, etc.)

➢ Lucintel can help your company to define and implement a strategy designed to grow your business by in–depth analysis to:
  – Identify and evaluate attractive opportunities: Develop dynamic understanding of the relevant market segments where you should compete, broken down by segment, application, technology, and region. What gaps exist to realize full potential?
  – Market entry strategies: organic growth by selling in new markets and geographic regions
  – Screen M & A options for growth: Help to identify a suitable strategic partner or finance.
Thank You for your kind attention.

If you would like a copy of the presentation sent to you, please leave me your business card.

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