SUSCHEM
European Technology Platform
for Sustainable Chemistry

Polymer composites for automotive sustainability

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AUTHORS

CEFIC

Jacques KOMORNICKI
Innovation Manager and SusChem Secretary

Bax & Willems Consulting

Laszlo Bax
Founding partner

Harilaos Vasiliadis
Senior consultant

Ignacio Magallon
Consultant

Kelvin Ong
Consultant

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The SusChem Board has established light-weight materials and composites materials among its priorities, as reported in the SusChem Strategic Innovation and Research Agenda (SIRA) which can be consulted on-line http://www.suschem.org/publications.aspx

The SusChem Materials Working group has defined the main technical challenges spelled-out in the SusChem SIRA.

The SusChem Working Group on Composites Materials for Automotive pulled together experts from the chemical industry, the automotive industry, the automotive parts suppliers as well as academia and recommended the publication of this position paper as well as a wider consultation with the established competence centres in Europe.

In the course of the work leading to this publication we have contacted and interviewed the leaders of 10 European Clusters on Composites Materials who provided their views. 7 clusters also participated to a workshop organized by SusChem.

A number of experts from the chemical industry, the automotive industry and from academia have reviewed the paper before its publication.

List of reviewers

Thilo Bein	Professor, Head of Knowledge Management, Coordinator ENLIGHT project- Fraunhofer Institute for Structural Durability and System Reliability LBF
Peter Brookes	Business manager PU - Huntsman
Christoph Ebel	Group Leader Process Technology for Fibers - TUM (München)
Michel Glotin	Directeur Scientifique Matériaux - Arkema
Christoph Greb	Head of Composites Division - Institut fuer Textiltechnik of RWTH Aachen University and Textiles
Marc Huisman	Manager Advanced Thermoplastic Composites - DSM
Joseph J. Laux	Director of Business Development and Advanced Engineering (EU) - Light-weight Composites - Magna Management AG
Gérard Liraut	Expert Leader for Polymers “Characterization and Process” - RENAULT GROUP
Andrea Pipino	Research and Innovation Manager - Group Materials Labs - Centro Ricerche Fiat
Jens Rieger	Senior Vice President / Advanced Materials and Systems Research - Technology Incubation – BASF - Member of the SusChem Board
Eckart Ruban	Head of Automotive Industry Team - Evonik
Uwe Seemann	Innovation Manager Automotive - BASF
Kristian Seidel	Senior Manager Body Department - Institute for Automotive Engineering - RWTH Aachen University
Paruchuri Sreenivas	R&D Frames Engineering - Faurecia Autositze GmbH
Thomas Staffenberger	Head of Research, Automotive Division - BENTELER SGL Composite Technology GmbH
Ignaas Verpoest	Emeritus professor - ex-Chairman Materials Reserach Centre, Coordinator HIVOCOMP project - University of Leuven (KU Leuven)

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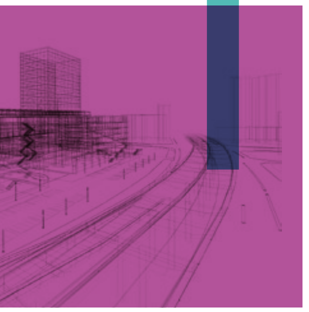

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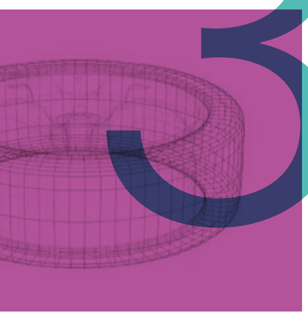

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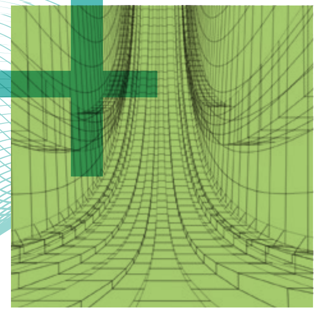

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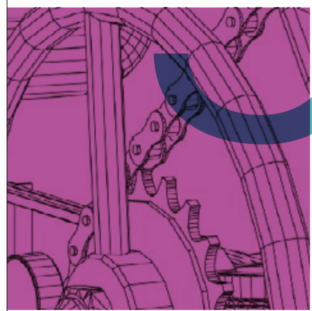

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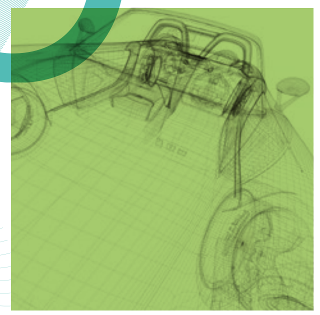

Executive summary

Automotive composites: a growing market driven by efficiency and emissions

The market for global automotive composite materials is forecast to reach €3.72 Bn (US$ 4.3 Bn) by 2017, up from €2.42 Bn (US$ 2.8 Bn) in 2011, and representing a compound annual growth rate (CAGR) of about 7%.[1] This represents a sizable growth opportunity for the European chemical and composites industry. However, the current composites share of the average automotive bill of materials stands at 3.6% with competing materials such as steel and aluminium. Perhaps surprisingly the automotive sector has the lowest composites penetration in comparison to other advanced product segments such as the maritime (ships) or consumer goods. The automotive industry faces a new challenge aligning material properties, product design and production or assembly processes - especially in larger volume production series vehicles. This industry could take more advantage of the potential of composites for light-weighting vehicles. High performance Fibre-reinforced Plastic (FRP) composites have the potential to outperform both steel and aluminium, but today both steel and aluminium producers are more successful in actively reducing weight in high volume production car bodies.

The demand for weight reduction is driven by the demand for better fuel efficiency and reduced emissions in order to comply with EU legislation (from <130g CO_2/km in 2015 down to <95g CO_2/km by 2021). Composites can offer lightweight benefits from 15-25% for glass-fibre reinforced composites (GFRP) to 25-40% for carbon-fibre reinforced composites (CFRP) in comparison to other structural metallic materials that are presently dominant, such as steel, iron and aluminium.[2] The benefits of light-weighting can be translated into potential savings of 8 million tons of CO_2 per year in the EU wide vehicle fleet[3], calculated using a theoretical 33% weight reduction on a 10% volume of the entire EU fleet. Considering that in 2007 over 500 million tons of CO_2 emissions were estimated to be due to cars in the EU, savings due to composites light-weighting would be translated into a potential 1.4% improvement on the present day situation in Europe.[4]

However the high cost of materials and the lack of suitable higher volume manufacturing methods and higher value recycling processes continue to be some of the major limiting factors for future growth. Improving the value at end-of-life of composites through high value recycling could help to improve the overall LCA score of composites, but remains challenging. This is especially important given the present EU end-of-life directive[5] for cars (valid since 1st of January 2015), which stipulates mandatory reuse and recycling of 85% of the vehicle (and does not consider 'energy recovery' of polymers to be recycling). Bio-based matrix materials and fibres can help in reducing the environmental footprint of composites. For these materials to be widely used, important barriers with regard to their cost effectiveness and their mechanical performance need to be addressed. To enable larger scale adoption of FRP, methods to determine damage to composite parts over the lifetime of the vehicle also need to be developed.

In order to overcome these (and other) challenges, various public-private partnership initiatives have already been launched in EU Member States, such as the establishment of composite and automotive lightweight materials innovation clusters (MAI Carbon Augsburg, CiC UK, AZL Aachen, Jules Verne IRT Nantes, IMAST). Fully private collaborations between automotive and the chemical industry (Toray – Daimler, SGL – BMW, SGL – VW, TohoTenax – GM) have also emerged. These have resulted in substantial resources being dedicated to this field, such as the investment of US$ 200 Mn by BMW-SGL to triple production capacity of its CFRP plant[6]. However, unlike other leading global regions such as the US or Japan, in the EU policy and R&D programmes to strengthen its expertise and capacities on automotive composites are coordinated at country level, making it difficult to consolidate and expand its leading global technology position without EU level coordination.

1 – http://www.lucintel.com/lucintel-globalcompositemarketanalysis-acma2012-educationalsession.pdf
2 – Automotive material mix (1975-2010), Lucintel
3 – This calculation is made assuming 8 gr/km less CO_2 / 100 kg of weight reduction in an ICE vehicle of 1200kg with an extended use of composites that allows a 33% weight reduction and runs 10,000 km / year, as well as a 10% penetration in an approximate EU fleet of 250M vehicles (2008).
4 – http://www.eea.europa.eu/data-and-maps/figures/variation-of-co2-emissions-from
5 – EU End of Life Directives 2000/53/EC
6 – http://ecomento.com/2014/05/12/bmw-drives-down-carbon-fiber-cost-for-electric-cars-with-mammoth-investment/

The Chemical industry's key role in the quest for more energy efficient, lower consumption vehicles: working closely together with the value chain

The European Commission's Horizon 2020 programme aims to enable relevant R&D&I investments that can bring real societal and business impacts. Horizon 2020 can and will definitely contribute to overcoming technological and market barriers towards lighter road vehicles offering best-in-class NCAP 5 star safety levels. While some OEMs focus on improving energy recovery, light-weighting has also been identified to be a potential enabler for electro-mobility uptake[7], contributing to the reduction of carbon emissions. Larger scale lighthouse R&D&I projects can inspire EU players in the automotive and chemical industries to accelerate their adoption of high performance FRP. The European chemical industry will continue as a key player in this transition in close collaboration with its value chain partners.

From its inception in 2004, SusChem identified advanced materials as an enabling technology critical to achieving its vision and mission. SusChem has set innovation priorities for advanced materials to be really adopted in key end user markets including automotive, as compiled in SusChem's Strategic Innovation & Research Agenda (SIRA), which is now in the process of being updated in the general framework of Horizon 2020[8].

Aligned with that purpose and connecting chemistry with its downstream allies in lightweighting road transport, SusChem and the automotive R&D association EARPA organised a joint workshop, "Exploring cross-innovation opportunities on automotive composites and bio-based materials", held in Frankfurt on 15 October 2013. The outcomes of this workshop, as well as the feedback collected by the stakeholder consultation held as a follow-up exercise, are summarised in several key conclusions and recommendations within this document.

7 – http://www.rolandberger.com/press_releases/lightweight_can_stipulate_electric_car_development.html
8 – http://www.suschem.org/publications.aspx

Key objective: Establishing a EU-wide programme and ensuring adequate support for automotive composites research and innovation for a competitive and energy efficient Europe

Taking into account SusChem's SIRA roadmap as well as the main automotive roadmaps (EGVI Multiannual Roadmap[9], EARPA roadmap[10]) this document integrates specific input from key stakeholders across the value chain, including those involved in production equipment. This document provides concrete recommendations to enable faster progress in advanced composites light weighting innovation uptake in the automotive industry, enhancing the competitiveness of the European economy.

A perceived uncertainty about continued, substantial EU funding dedicated to lightweight automotive materials and specifically (C-)FRP is seen by many players as a factor that makes it more difficult to launch and maintain a substantial, coordinated trans-disciplinary push to overcome innovation adoption barriers and really achieve breakthroughs.

In the context of the Horizon 2020 programme, SusChem's Working Group on Materials Technologies together with the above mentioned input of key industry stakeholders, understands the need to provide direct input to the Horizon 2020 agenda for 2016-17. A set of specific challenges is defined, with the purpose of presenting a credible package of R&D&I topics that can remove barriers through cooperation between materials and vehicle actors. Some of the identified examples of the most critical needs for research towards an accelerated implementation of advanced composite materials include:

- Novel and innovative polymer composite raw materials with enhanced recyclability properties.
- Low cost adaptive, flexible and efficient manufacturing and assembly processes specific to the high-volume automotive industry.
- Multi-attribute design optimization that works even in case of a multi-material architecture.
- Automated joining techniques for multi-materials and composites (foreseen in 2015 call).
- Invisible damage identification and repair techniques for composite parts.

However as a larger ambition level, beyond the identification of individual topics, we envision the creation of an EU-wide coordinated R&D&I programme with long term committed funding to allow for a well-structured, coordinated effort to bring real innovation uptake acceleration and leveraging the strong skills and expertise found in many regions in Europe.

As well as a coordinated R&D&I programme, we propose the establishment of a European Automotive Composites Competence Network. This network of R&D&I clusters (many of which launched and/or strengthened over the last five years in various Member States) can improve the coordination between local knowledge hubs in the following ways:

1. Facilitate the co-development of high volume production processes with suppliers throughout the value chain.
2. Developing the necessary skills for successful integration of composites in new vehicles by automotive designers and engineers, as well as facilitating the transfer of composites' knowledge to such designers and engineers.
3. Establish training programmes that can instil the necessary skills into the workforce across the value chain of automotive design, production, assembly and end-of-life, e.g. modelling and simulation, safety, composites processing and assembly, LCA and materials recycling, etc.
4. The unification and simplification of design tools, starting from material models and reaching simulation and vehicle design tools.

9 – http://www.egvi.eu/uploads/Modules/Publications/ppp-egvi-roadmap-oct2013.pdf
10 – http://www.earpa.eu/docs/2005/furore_road_map_final.pdf

Introduction

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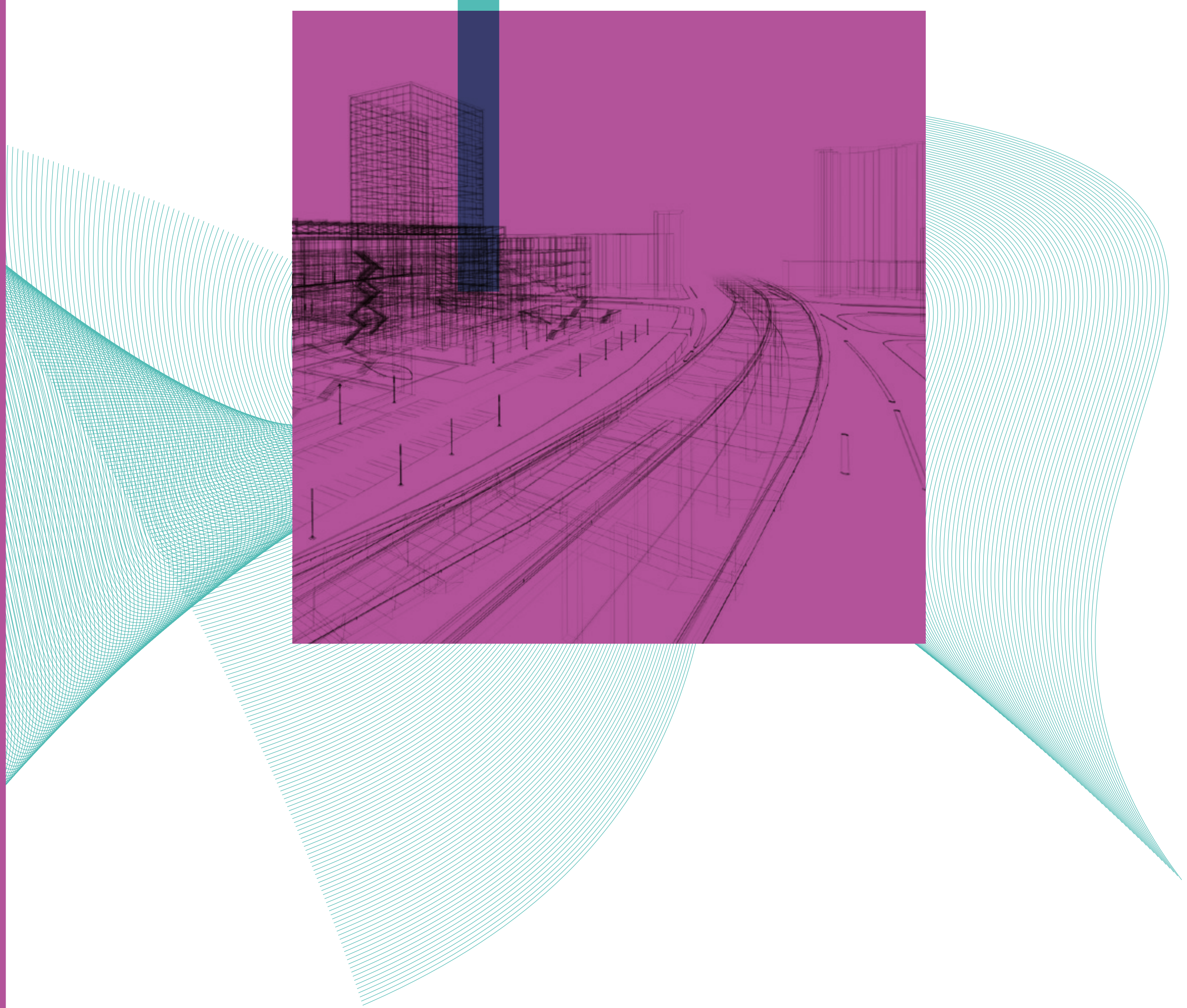
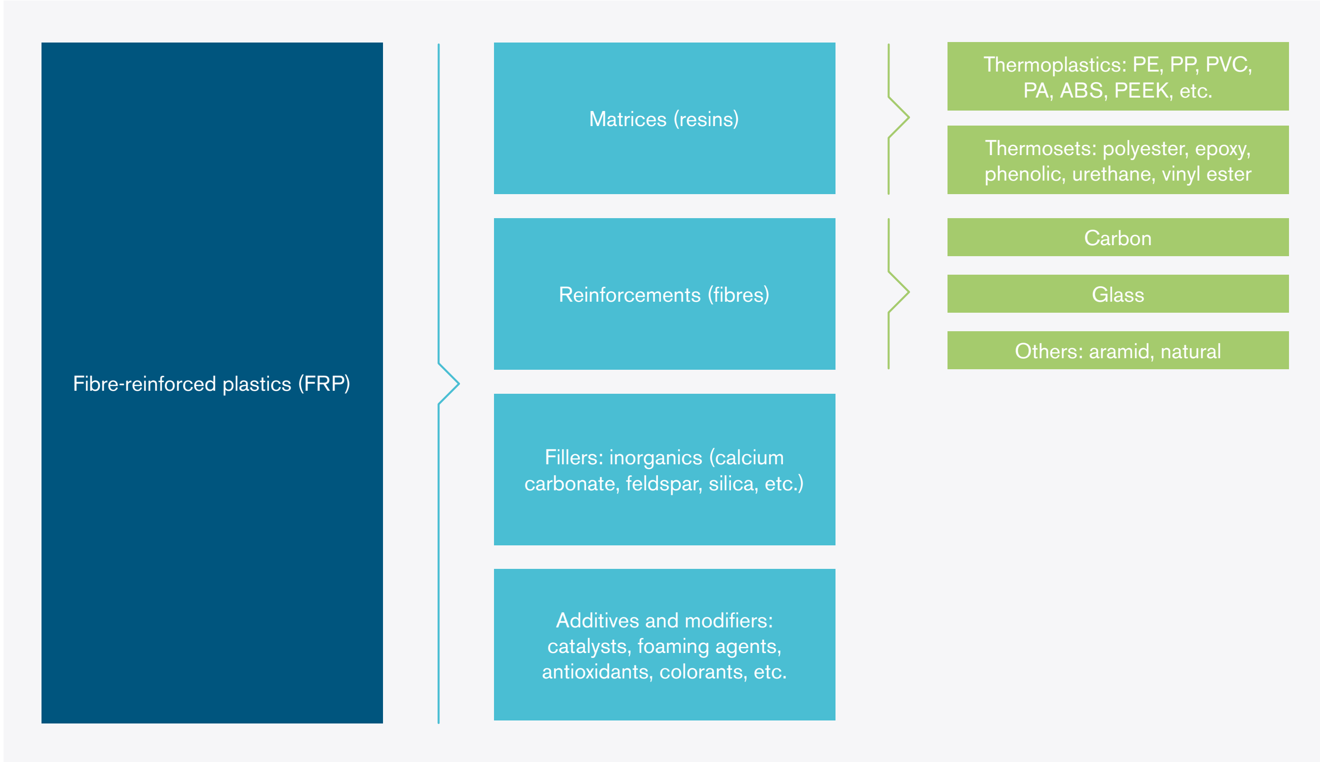


This chapter is intended as a primer for those who are not experts in the field of materials technology. It provides a basis for the discussion in the following chapters about the prospects and challenges of composites in the automotive industry. As such, those working in the industry who are already familiar with the content presented here, can skip to the next chapter.

1.1 Overview of polymer composites

Polymer composites are materials defined by the combination of a **polymer matrix** (**resin**, either thermoset or thermoplastic) and a **reinforcing** agent, mainly **fibres** (usually carbon, glass or natural fibres). As a result, they are often referred as **Fibre-Reinforced Plastics** (**FRP**). In addition, FRP composites may contain fillers, modifiers and additives that modify the properties and improve the performance of the composite material, contributing to cost reduction.

Fig.1 – Overview of polymer composites.



FRP composites are **anisotropic** instead of isotropic like steel and aluminium. Whereas isotropic materials present uniform and identical properties in all directions, FRP composites are directionally dependent, meaning that the best mechanical properties are in the direction of the fibre placement. In many structures and components, stresses and loads are different for different directions. As a result, FRP composites allow a **more efficient** structural **design**. Other benefits include a low weight, high strength-to-weight ratio, corrosion and weather resistance, long-term durability, low maintenance and dimensional stability.

The exact composition of FRP composites depends on each intended use according to many criteria. Both the type and quantity of the constituent materials as well as the manufacturing process used will affect the properties of the final composite. Overall, the most relevant **factors** to consider for the **design** of **composites** include the fibre (type, volume and orientation), type of resin, service conditions, the cost of the product, the manufacturing process and the volume of production.

1.2 Resins: Thermosets, thermoplastics and bio-based resins

The primary functions of the resins are to transfer the stress and load between the fibres, to act as adhesives that bond structural fibres firmly in place, and to protect the fibres from environmental and mechanical damage. Bio-based resins refer to thermoset or thermoplastic resins that are obtained from natural sources. **Thermoset** based composites account for about **60%** of the total composites market. Bio-based resins do not bring specific properties, but can possibly influence the emissions balance/ environmental impact of the materials.

1.2.1 ■ Thermoset resins

Thermoset resins are usually liquids or low melting point solids in their initial form before curing. That allows for the convenient impregnation of reinforcing fibres and ease of manufacturing. Thermoset resins also present other desirable **properties**, including excellent resistance to solvents and corrosives, tailored elasticity, excellent finishing and adhesion, resistance to heat and high temperature. However, they cannot be reshaped or remoulded. Through a catalytic chemical reaction, the thermoset resin cures from liquid to solid, creating extremely strong bonds that cannot be easily reversed or reformed. Because of this, the performance of this matrix material is superior to other matrices; nevertheless **recycling** of thermoset resins remains challenging.

The **most common** thermoset resin used today is unsaturated polyester, followed by vinyl ester and epoxy. Unsaturated polyester resin matrices reinforced by glass fibres make up 80% (by weight) of the thermoset based composites market. Vinyl esters present superior physical properties (strength, durability) than polyesters, but are more expensive. Epoxies present distinct advantages, including good electrical properties, long shelf life and excellent moisture and chemical resistance and provide high thermo-mechanical properties.

To produce bio-based polyester resins, combinations of diols and diacids are used to form the polyester resin base, which is then further processed into polyester resins. To produce bio-based epoxy resins, vegetable oils can be epoxidised to form a reactive component, which is further processed to become epoxy resins. A number of chemical companies already offer diverse bio-based products on the market.

1.2.2 ■ Thermoplastic resins

Thermoplastic resins are **solids** at room temperature. As a result, they are processed through a **melt-freeze** route: thermoplastic resins become soft when heated, may be moulded or shaped in the heated viscous state and will become rigid when cooled down. Typical melting temperatures range from 100°C (PE) to 400°C (PEEK – Polyether ether ketone). Therefore, they are potentially easier to **recycle**. Besides this reforming ability, it is important to highlight that many thermoplastic resins have an increased **impact resistance** to comparable thermoset resins. In addition, thermoplastic resins allow for faster moulding cycle times because there is no chemical reaction in the curing process. Examples of thermoplastic resins common in automotive composite applications are polypropylene (PP), thermoplastic polyurethane (TPU), polyethylene (PE), polyamide (PA) and polyvinyl chlorides (PVC).[11]

Thermoplastic resins can also be obtained from **bio-based** sources. It should be noted that the (bio)-sourcing of a thermoplastic material is independent of its end-of-life options: not all bio-based thermoplastics are biodegradable, while conventionally sourced materials could be biodegradable.

11 – Plastics Europe, 2013, "The world moves with plastic"

Thermoplastics: the next big composite development?

Thermoplastics are currently facing **barriers** that thermoset composites have largely overcome, including a lack of familiarity, established design codes, properties database, and proven production technologies, etc. **Investment** has favoured reinforced thermosets instead of thermoplastics because the latter are considered as higher risk. However, the advantages of using thermoplastics include shorter and more consistent cycle times as well as the potential to more easily achieve post-life recycling.

Recent developments confirm that reinforced thermoplastics could indeed be the next wave[1]. **BMW's i3** is the first mass-produced car to have a **thermoplastic exterior skin**. Thermoplastic wheel rims have also entered the market. **BASF** introduced thermoplastic wheel rims reinforced with long glass fibres in 2011, while **Sabic, Kringlan Composites** and other industrial partners are developing the world's first **CF reinforced thermoplastic** (polyetherimide) **composite wheel** for a German automotive company[2].

Back in 2012, BASF announced two partnerships to develop automotive thermoplastic composites: one with SGL[3], based on caprolactam formulations which will permit shorter processing cycles than conventional thermosetting RTM process, and another with TenCate and Owens Corning[4], focused on UD-tapes, prepregs and laminates. DSM has also started to offer a range of thermoplastic composites based on polyamide resins for weight reduction of automobile body, chassis parts and semi-structural components[5]. Also Teijin announced the launch of Sereebo-brand CFR thermoplastic for use in manufacturing recyclable composite components at enhanced production speeds[6]. Lanxess also acquired Bond Laminates, a producer of fully consolidated composite sheets with thermoplastic matrices[7].

1 – http://www.reinforcedplastics.com/view/39477/reinforced-thermoplastics-the-next-wave/
2 – http://www.plasticstoday.com/articles/worlds-first-thermoplastic-composite-wheel-polyetherimidecarbon-fiber-combination-140616a
3 – http://www.reinforcedplastics.com/view/28629/basf-and-sgl-to-develop-carbon-fibre-thermoplastics-for-automotive-applications/
4 – http://www.reinforcedplastics.com/view/31270/owens-corning-joins-tencate-basf-alliance-for-thermoplastic-automotive-composites/
5 – http://www.dsm.com/products/ecopaxx/en_US/press-releases/2013/09/2013-09-10-dsm-launches-solutions-in-advanced-thermoplastic-composites-for-lighter-and-more-sustainable-automotive-applications.html
6 – http://www.compositesworld.com/news/teijin-introduces-sereebo-brand-for-coming-cfrtp-products
7 – http://lanxess.com/en/corporate/media/press-releases/lanxess-leading-supplier-of-lightweight-technology-to-automotive-industry/?tx_editfiltersystem_pi1%5Bname%5D=&tx_editfiltersystem_pi1%5Bnews_date_start%5D=01.08.2012&tx_editfiltersystem_pi1%5Bnews_date_end%5D=30.09.2012&tx_editfiltersystem_pi1%5Bmatrix_segment%5D=0&tx_editfiltersystem_pi1%5Bmatrix_business_unit%5D=0

1.3 Fibres: Carbon, glass and natural fibres

The main function of fibres is to carry load along its length (not across its width) providing strength and stiffness in one particular direction. Fibres can be placed with a specific orientation (typically 0°, +/- 45° or 90°) to provide tailored properties in the direction of the loads applied. As a result, the mechanical properties of most FRP composites are considerably higher than those of un-reinforced resins.

Depending on the reinforcing fibre, FRP composites can be divided into three groups: GRP or GFRP (Glass-reinforced plastics, or Fiberglass), CRP or CFRP (Carbon-reinforced plastics) and NRP or NFRP (Natural fibre reinforced plastics). Fibres can also be classified according to length, which ranges from 3mm to 75mm or can be continuous. As a result, three main groups are identified: short fibres (3mm-10mm), long fibres (10-75mm) and continuous (endless). This paper mainly features the use of continuous fibres in composite materials.

GFRP (as a short fibre) is by far the largest group of materials in the composites industry, used in over 95% of the total volume of composites. As indicative data for the reader, Europe is expected to manufacture 2.2Mn tonnes of GFRP in 2014, while global demand of CFRP is estimated at 79 000 tonnes in 2014 *(AVK – CceV, 2014)*.

1.3.1 ■ Carbon fibres (CF)

Carbon fibres, also known as graphite fibres, can be based on three chemical sources: polyacrylonitrile (PAN method that is led by Japanese manufacturers), rayon (such as from the Indian manufacturer Grasim) or petroleum pitch. About 90% of the carbon fibres produced are made from **PAN**. The exact composition of each precursor varies according to the recipe of the manufacturers. Whereas PAN-based fibres offer excellent mechanical properties for structural applications, pitch fibres present higher modulus values and favourable thermal expansion coefficients. Carbon fibres are usually grouped according to the modulus band in which their properties fall and are supplied in different forms, from continuous filament tows to chopped fibres and mats. The main benefits of carbon fibres include their low density and hence high strength-to-weight ratio and stiffness; however its main downsides, compared to other fibres, are its cost and brittleness.

At 46 500 tonnes, **global annual demand** for CF in 2013 has seen a growth of 15.1% CAGR since 2009 (26 500 t). Global demand of CF is estimated to continue to grow reaching 71 000 t in 2018 and 89 000 t by 2020. Regarding **production capacities**, the most important regions are North America (30%), Europe (24%) and Japan (20%). The top five CF manufacturers according to production volumes in 2013 were Toray, Zoltek, Toho, MRC, SGL, in that order.

1.3.2 ■ Glass fibres (GF)

Glass fibre is based on an alumina-lime-borosilicate **composition**. The recipe can be varied resulting in different commercial compositions: E-glass (electrical), C-glass (chemical), R-glass, S-glass, and T-glass. **E-glass** accounts for 90% of the GF market and is often used in a polyester matrix offering high electrical insulation properties, low susceptibility to moisture and high mechanical properties. C-glass GF presents the best resistance to chemical attack, while S-glass has higher strength, heat resistance and modulus. Overall, GFRP exhibit very good thermal insulation and electrical properties and are also transparent; however, they are heavier than CF and due to the lower modulus, they require special design treatment in applications where stiffness is critical.

When referring to **GFRP** applied to the **automotive sector**, it is important to define two typical processes: Sheet Moulding Compound (**SMC**) and Bulk Moulding Compound (**BMC**). Together this is by far the largest area of the total composites market: European production in this area alone (estimated in 264 000 t for 2014) is significantly larger than the global CFRP market (estimated in 79 000 t for 2014). Whereas **SMC** is manufactured by compression moulding of long chopped fibres in thermoset resins, **BMC** uses chopped fibres and injection or compression moulding. As a result, the longer fibres in SMC result in better strength properties than standard BMC components.

1.3.3 ■ Natural fibres (NFs)

Natural fibres can also reinforce composites**.** Natural fibres are fibres extracted from the fruits, stems and leaves of specific plants. Dominant natural fibres include **flax**, hemp, kenaf and jute. These are combined mostly with **polypropylene** (also polyethylene) by **compression** or injection **moulding**.

The automotive industry has been using more and more natural fibre reinforcements in the interior parts of vehicles as an alternative to glass fibres as a light-weighting solution. NFs come from natural and renewable sources and thus have a smaller environmental footprint than carbon or glass fibres, which can help automotive OEMs meet stringent end-of-life directives. In 2012, more than 124 000 tonnes[12] of natural fibre composites were shipped for automotive purposes globally.

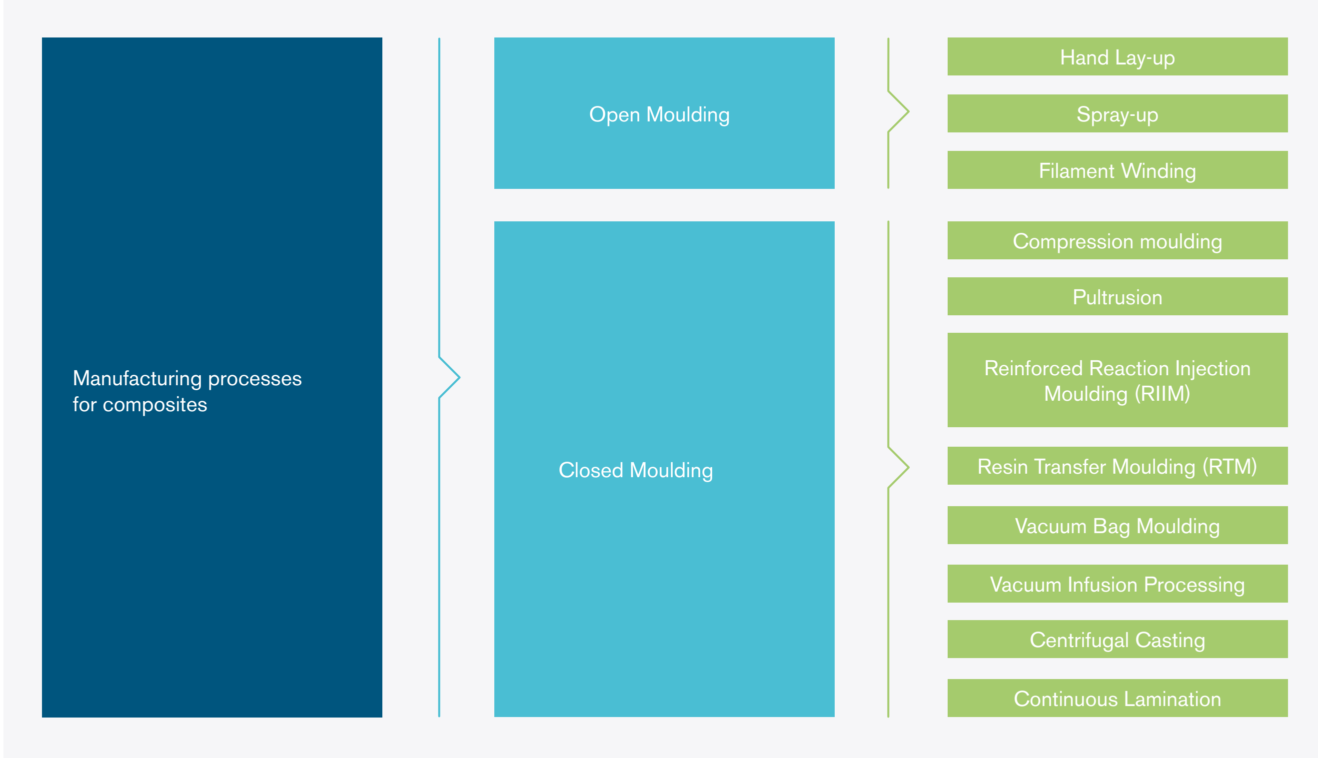
However, the low impact resistance of NFs and the moisture degradation that they face have been a limiting factor in their uptake by the automotive industry, as usage in structural applications is mostly targeted by the OEMs. R&D efforts are focused on improving these two aspects in NFs.

12 – http://www.lucintel.com/LucintelBrief/Lucintel-brief-Opportunity-and-Challenges-in-Automotive-Composites-Industry.pdf

1.4 Processes: a comparative overview

A thorough understanding of the available composite manufacturing processes and their advantages, downsides and limitations will allow the selection of the most efficient. Some of the key factors include production volume and rate, geometry and size of the product, economic targets, surface complexity, materials and performance requirements.

Fig. 2 – Overview of manufacturing processes.



There are two main **categories** of manufacturing processes: **open moulding** and **closed moulding**. Whereas in open moulding the gel coat and laminate are exposed to the atmosphere during the process due to the use of a one-sided mould, in closed moulding the composite is processed either in a two-sided mould set or within a vacuum bag. Open moulding and hand lay-up are the most common and widely used methods to manufacture FRP. With open moulding, products are manufactured from the exterior to the interior of the part. Open moulding can create very large parts, with the only restriction to size being the ability to handle the part. They are labour intensive, low volume but low cost processes, where emissions can become an issue. On the other hand, closed moulding can offer new strategies to meet emission standards. Additional benefits include: ability to make superior parts in a consistent manner and higher volumes, reduction of labour costs and finishing work, lower scrap rate, and automation of parts with fewer moulds.

The table below presents an overview of the most typical manufacturing processes and the production volumes that they are suitable for.

Table 1 – Comparison between manufacturing processes according to production volumes enabled.

Process	Production Volume		
	Low (<5k parts)	Medium (5k-15k parts)	High (15k-100k> parts)
Compression Moulding			
Bulk Moulding Compound (BMC)/ Sheet Moulding Compound (SMC)			X
Liquid Composite Moulding (LCM)		X	
Injection Moulding			
Reinforced Reaction Injection Moulding (RRIM)			X
Structural Reaction Injection Moulding (SRIM)			X
Vacuum Infusion Processing (VIP)	X	X	
Resin Transfer Moulding (RTM)	X	X	
Filament winding		X	
Pultrusion			X
Prepregs + autoclave	X		

1.5 Milestones and recent examples of composites applied to the automotive sector

Fig. 3. – "Composites in automotive applications" timeline.

Composites in automotive applications

1940s Composites have a **long track record** in the automotive industry, dating back to the **1940**s, when they were first used as a material for car parts. The Stout 46 developed by Owens Corning and William Stout in **1945** is acknowledged as the world's first composite prototype car, with a **fiberglass** body shell and air suspension.

1950s In **1953**, MGF launched the **first production** model with fiberglass body panels: Chevrolet Corvette. Regarding **CF**, it wasn't until the late 1950s that high tensile strengths CF were discovered, with rayon being the first precursor.

1960s The 1960s saw the discovery of the **SMC** process.

1981 The **McLaren MP4/1** (1981) was the **first F1 car** to use a CF composite monocoque.

1984 But it was not until **1984** that it was applied to a high-volume car: the Pontiac Fiero, with body panels made from SMC.

1980s Some supercars have incorporated CFRP extensively (monocoque chassis and other components).

1990s However, only recently the material began to be used, albeit in limited quantities, in mass-produced cars.

2013 The **i3 model** by **BMW (2013)** represents the automotive **world's first** attempt at **mass-producing** CF.

In recent years, more and more parts are being manufactured from composite materials, replacing traditional materials in the process. The table below presents an overview of some examples of composites applied to automotive components in the market of the past five years.

Table 2 – Examples of composite components applied to automotive. (Sources: Lucintel, Alfa Romeo, Adler Plastics, Amber Composites).

OEM-Model	Application	Material	Year
BMW i3	Passenger cell	CFRP	2013
BMW i8	Passenger cell	CFRP	2014
Alfa Romeo 4C	Chassis	Prepreg (CF, epoxy)	2013
Alfa Romeo 4C	Outer body	SMC	2013
Alfa Romeo 4C	Bumpers and mudguards	CF + PUR-RIM	2013
McLaren MP4-12C Spider	Car roof, chassis, bodywork	CF monocell, lightweight CF body panels	2013
BMW M6 convertible	Roof compartment cover, trunk lid	GFRP	2013
BMW M6 Coupe	Car Roof	CFRP	2012
Daimler Smart 3rd generation electric	Wheel rims	GFRP	2012
Callaway Corvette	Body aerodynamics Kit	CFRP	2012
Lexus LFA	Cabin, floor, roof, pillars, hood	CFRP	2012
Lamborghini Aventador LP700-4	Front and rear bumpers, body aerodynamics kit	CFRP	2012
Land Rover – Evoque	Instrument panel, inner door modules	GFRP	2011-12
Faurecia Jeep Liberty SUV	Door module	GFRP	2010
Daimler AGT-Mercedes	Fluid filter module	GFRP	2009-10

Furthermore, carmakers are specifically targeting some car parts with **more potential** for development with composites: chassis, exterior and interior. This includes the following **parts and components**, as examples:

GFRP: interior headliner, underbody system, air intake manifold, instrument panel, bumper beam, air cleaner housing, load floor, deck lid, air duct, airbag housing, front end module, engine cover.

CFRP: chassis / monocoque, roof, tailgate, hood, floor panel, side panels, trunk lid, hood frame, fender, rear spoiler, bumper.

The market and opportunities

2

2.1 Supply: the European automotive composites value chain

The automotive composites value chain is currently undergoing a major redesign. Composites in the automotive sector have in the past enjoyed considerable success in Formula 1 motorsport and in the supercars segment. This has created a fragmented support industry, consisting of numerous and diverse small high-tech players with specialised knowledge. In recent years, CFRP usage is cascading from these high-end luxury segments down to higher volume vehicles. Composites suppliers need to upgrade their capabilities and translate their expertise into higher volume segments. This lack of experience and industrialisation in producing mainstream composites will drive OEMs to look for reliable suppliers who can provide an increasing proportion of the composites value chain.

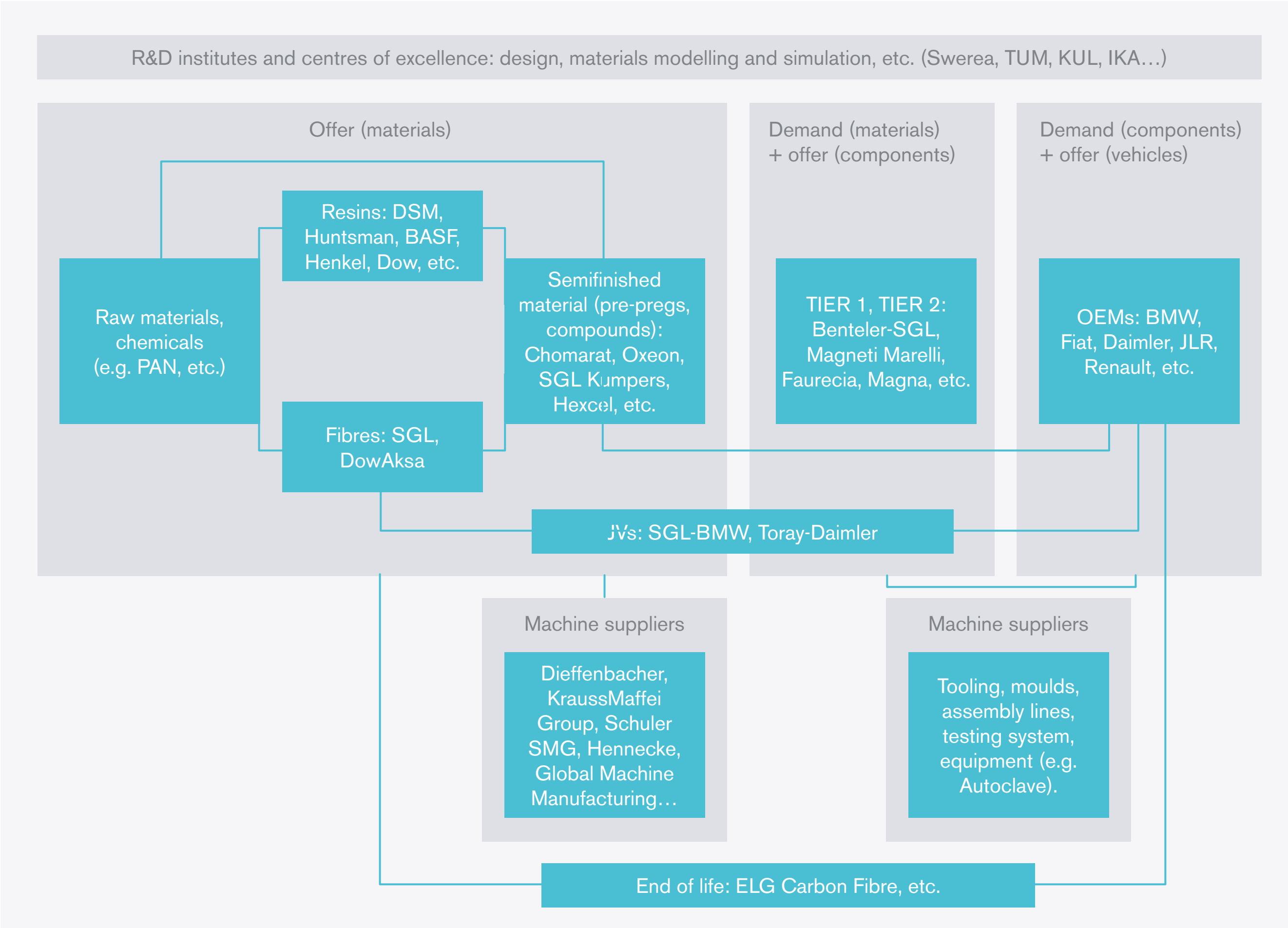
From 2009 onwards, the industry has seen numerous automotive manufacturers **partner** with composite suppliers. To meet the high volume requirements, currently hampered by high material costs, long production cycles and lack of automation, as well as industrialising manufacturing to meet emissions regulations, Tier 1 suppliers and OEMs have adopted different strategies to allow **vertical integration** of the value chain. This includes: partnerships, joint ventures and acquisitions. Examples of these strategies are provided below.

Table 3 *– Strategies from OEMs and Tier1 suppliers to allow vertical integration in high volume automotive composites. (Sources: Lucintel, Ricardo).*

Strategy	Companies involved	Goal
Partnership	BASF + SGL Carbon	Accelerate industrialisation of CRP, develop processing times suitable for mass production.
	Toray + Nissan, Honda	Develop a new CF material for mass production market.
	GM + Teijin	Develop technology to improve fuel economy.
	JRL + Cytec	Develop cost-effective composites automotive structures for high-volume production.
	Ford + Dow Automotive	Use CFR in high-volume vehicles to improve fuel efficiency.
JVs	BMW + SGL Carbon	Supply semi-finished CF products exclusively to BMW.
	Daimler + Toray	Manufacture automotive CFRP parts.
	SGL Group + Benteler Automotive	Cost-efficient solutions of fibre-composites components, from the initial design to series production.
	SGL Group + Kümpers GmbH	Production of high-performance materials from carbon, glass and aramid fibres for the composites industry.
Acquisition	Faurecia acquired Sora Composites	Sora Composites had an automotive business unit, with expertise in glass and carbon fibre for automotive applications.
	Lanxess acquired Bond laminates	Mass production of fully consolidated thermoplastic composite sheets for Consumer Electronic, Sports and Automotive business.

The graph below summarizes the value chain for automotive composites, indicating some of the diverse players previously described.

Fig. 4 – Overview of the polymer composites value chain for automotive.

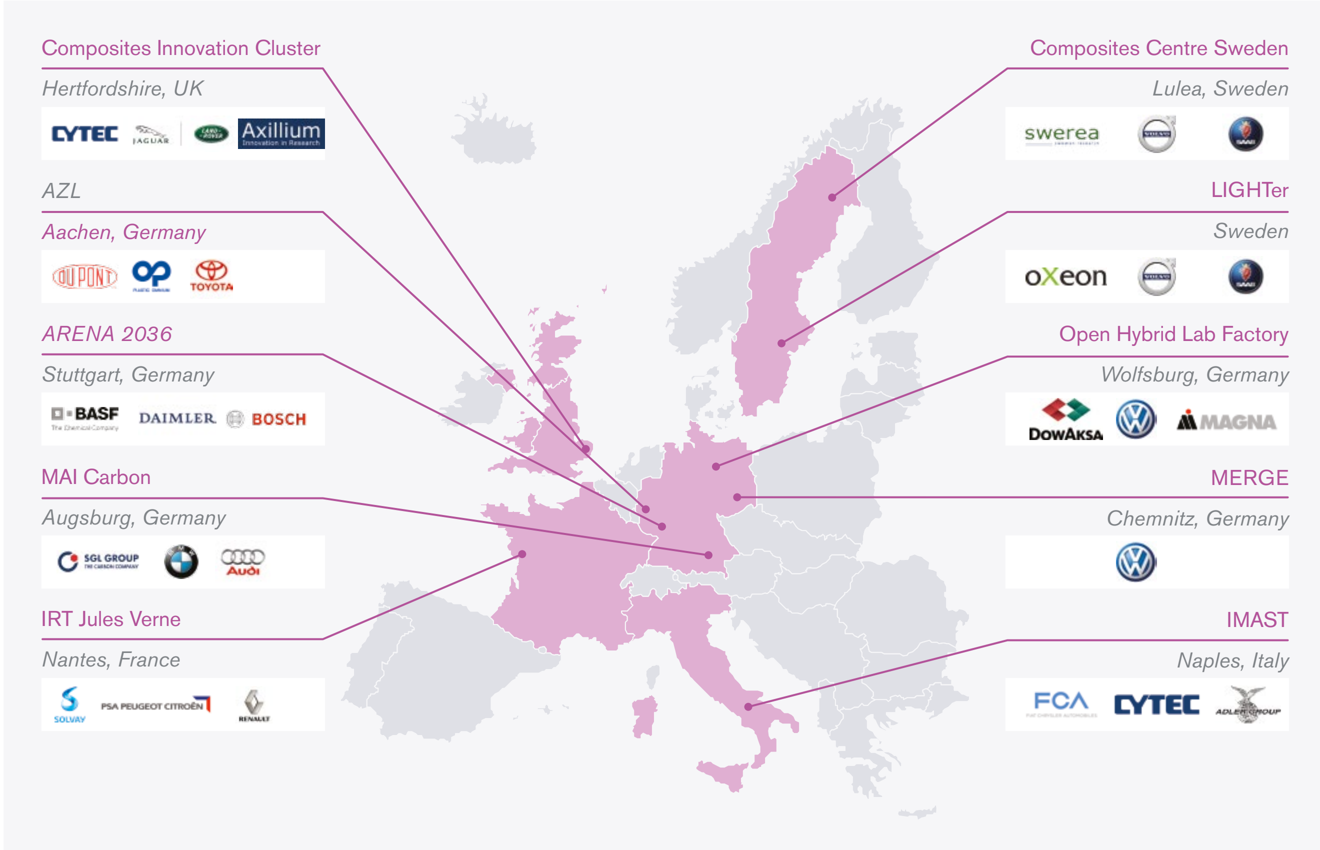


2.1.1 ▪ European scientific and technical excellence

In recent years, governments across Europe have begun recognising the opportunities in automotive composites. Large investments have been made to set up research centres, often in collaboration with universities and industry partners.

With the advances in the US and Japan, Europe needs to maintain its industrial leadership. Germany, recognised as one of the leading countries, already operates several centres that involve collaborations between the plastics, composites and automotive industries, academia and government. Munich-Augsburg-Ingolstadt (MAI) Carbon was set up in 2007 at the suggestion of Carbon Composites eingetragener Verein (CCeV). This was followed by other centres such as Aachen Centre for Integrated Lightweight Production (AZL Aachen) (2013), Hybrid Open Labfactory (2013) and Arena 2036 (2013).

Fig. 5 – Indicative mapping of EU (automotive) composites hubs.
Brief descriptions of the various clusters can be found in Annex A



The UK has also made moves that indicate its desire to step up to the composite challenge. The Composites Innovation Cluster in Hertfordshire, a consortium of 25 organisations includes the National Composites Centre (NCC), was founded in 2011. It entered Phase II in November 2014, with expanded facilities to better fulfil its function as a High Value Manufacturing Catapult for the UK. Together with partners such as GE, Rolls-Royce, TenCate and the University of Bristol, it coordinates a network of regional composite centres and supports the UK Composites Strategy that was launched in 2009. It aims to improve aspects of composite technology, manufacturing, and skills and training to ready the UK composites supply chain to be competitive in meeting future global demands for skilled personnel, technologies and processes.

Developments elsewhere in Europe, such as the Jules Verne Institut de Recherche Technologique (Jules Verne IRT) in France founded in 2012, the Ingegneria dei Materiali polimerici e compositi e STrutture (IMAST) centre in Italy and the Composites Centre in Sweden, show that European governments recognise the importance of developing new ways of manufacturing and using automotive composites for the future.

Furthermore, recent collaborative projects have already seen research efforts bearing fruit. As Annex B illustrates, many projects in the European Research Framework Programmes (and continuing in the new Horizon 2020 programme) have made significant advances in the fields of lightweighting vehicles using composite materials (TECABS, ENLIGHT), of developing composite components and methods for use in mass production (HIVOCOMP) and in lowering the cost of carbon fibres and precursor materials (CARBOPREC, NEWSPEC, FIBRALSPEC).

However, these centres and initiatives remain independent and uncoordinated, reducing the potential to create impact at an EU-wide level. Linking them together could provide the impetus for faster and bigger technological breakthroughs.

2.2 Global outlook

The investments of the past years have kept Europe at the cutting edge of composite automotive technologies. However, the established centres are often independent collaborations between private manufacturers, research institutions and government that remain unconnected from each other. Harnessing these various initiatives and spheres of expertise could propel the industry forward in the coming decades of increased competition from other parts of the world, such as the USA and Japan.

2.1.1 ▪ USA

The USA recognises the opportunities in the sector too. The Corporate Average Fuel Economy (CAFE) regulations released in 2012 aims to raise the average fuel efficiency of new cars and vehicles to 54.5 miles per gallon[13] by 2025 to reduce national dependence on oil. This regulatory pressure means that the American automotive industry has to use solutions such as light-weighting to meet fuel efficiency targets.

To that end, the American Chemistry Council published the "Plastics and Polymer Composites Technology Roadmap for Automotive Markets" in March 2014. It outlined nine priority actions to establish composites as the preferred automotive material by 2030, bringing together the automotive, plastics and composites industries in close collaboration. The challenges that it aims to solve include mass manufacturing processes, improving collaboration between different parts of the value chain and lowering the costs of composite parts.

Ultimately, implementing these priority actions would make the automotive composites players in the USA work closely together to improve the USA's position in the world market. Lobbying organisations such as the Automotive Composites Alliance, established in 1988 to promote the use of composites, have members such as Huntsman and Owen Cornings and represent industry interest and potential participation in such policies.

Fig. 6 – ACC Roadmap

Industry-Wide Demonstrations

1 Establish an independent, pre-competitive technology development center where OEMs and suppliers can conduct laboratory work and test concepts at small volumes while collecting standardized data

2 Develop generic cost models to demonstrate the cost and benefit of plastics and polymer composites compared to alternative materials as examples to provide mass reduction possibilities

Material Selection & Part Design

3 Define a standard package of material properties desired for automotive applications, and then test the data through simulation for a specific automotive system (e.g., engine mounts, instrument panel, cross-car beams)

4 Establish design guidelines (e.g., for wall thickness, radii) and tools for typical plastic and polymer composite structures that are intended to be used by design engineers

5 Develop models that can simulate the behavior of plastic and polymer composite materials and components during and after impact events

Manufacturing & Assembly

6 Develop a manufacturing center or consortium to advance high-speed polymer composites processing

7 Develop technically and economically viable techniques to join plastics and polymer composites to similar or dissimilar materials and study service, repair, and disassembly

Continued Materials Development

8 Support development of engineered plastics and polymer composites with improved properties (e.g., stiffness, strength, fatigue, environmental resistance, creep, energy management, temperature capability), and develop performance standards to characterize the properties for designers

Supporting Initiatives

9 Advocate for plastics and polymer composites training classes and degree programs at all major universities

13 – Environmental Protection Agency and Department of Transportation, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule, 77 Fed. Reg. 62623 (Oct. 15, 2012).

Recent federal initiatives are also encouraging for advanced composites, including for automotive applications. From January 2015, the US Department of Energy will be investing $70 million, with a consortium of 122 industry partners, universities and non-profit organisations who themselves will be investing more than $180 million to launch an advanced composites manufacturing institute. OEM members of this initiative include Volkswagen, Honda and Ford. The institute, headquartered in Knoxville, Tennessee, aims to lower the manufacturing costs of advanced composites for all applications, to reduce the energy needed to produce composites, and to improve their recyclability.

This federal initiative follows private initiatives. Aiming at driving a transition to fossil-fuel-free US transportation by 2050 via making cars lighter, the Rocky Mountain Institute (RMI) launched the Autocomposites Commercialization Launchpad (ACL)[14] in June 2013. The ACL has two key focus area: developing a commercialization project that unites the supply chain to incorporate a CFRP part on a mainstream vehicle at the highest production volume ever achieved; and setting an innovation hub focused on centralizing and coordinating R&D and collaborative progress in the FRP industry.

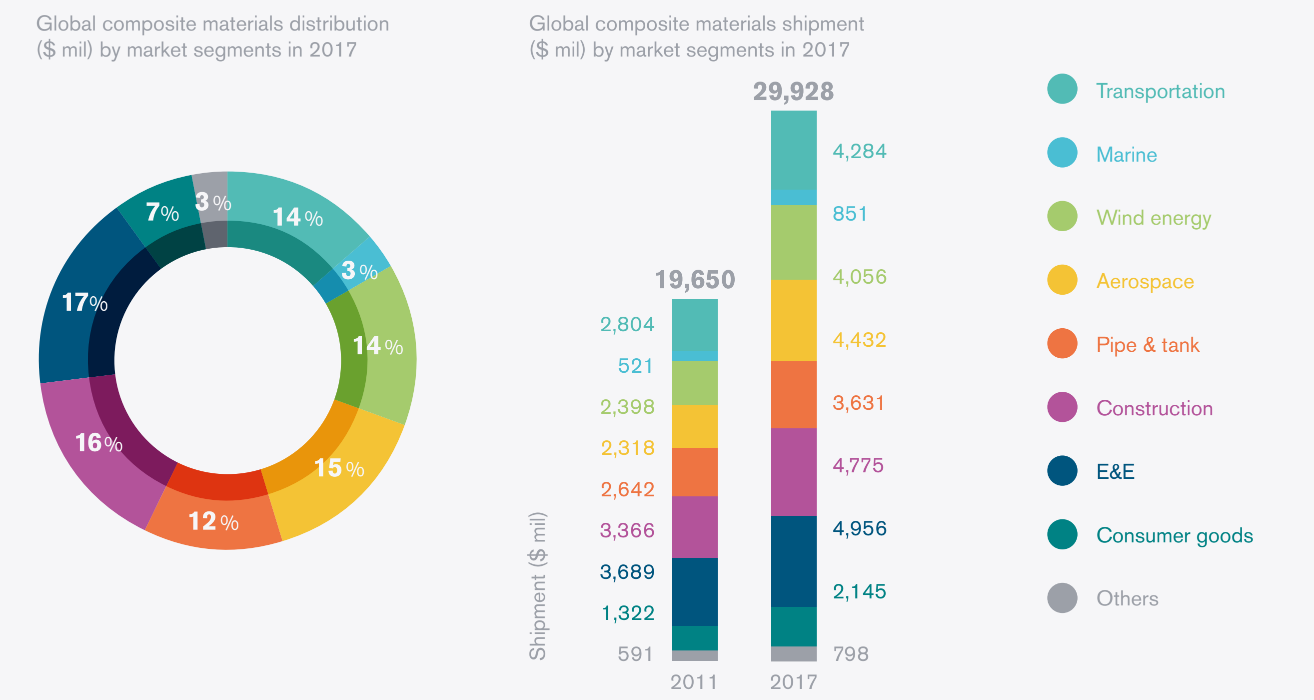
2.2.2 ▪ Japan

Japan is traditionally a strong automotive composite player. It is home to industry giants such as Toray, Teijin and Fuji Heavy Industries amongst others. As the need to develop new methods of mass production and lower costs became apparent, the National Composites Center was established at Nagoya University in 2013 as a triple helix research institute. It aims to develop and commercialise new processes of CFR thermoplastic components.

Japanese chemical companies have also been actively expanding domestically and abroad. The Toray group has invested about €300 million in its production facilities for diverse products including automotive parts, not only in its Japanese production facilities but also in its facilities in the US, France and South Korea. In fact, it is notable that Japanese manufacturers are turning increasingly to foreign collaborations, joint ventures and takeovers to bolster their own capacities. Besides the aforementioned investment, Toray took over Zoltek Inc for €468 million to be ready for the surge in demand for low-cost carbon fibre precursors. Teijin has also invested millions in Michigan to develop new carbon fibre technologies in partnership with GM.

2.3 Market demand: CRP/GRP trends

Fig. 7 – Global FRP shipments by market segments. (Source: Lucintel)



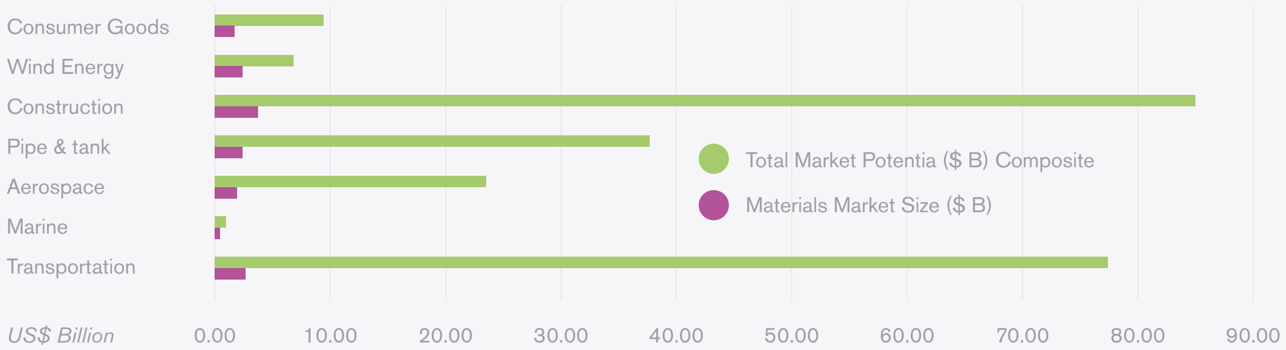
14 – http://www.rmi.org/autocomposites

The global automotive composite materials sector is expected to reach **US$4.3Bn (€3.7Bn) by 2017**, up from US$2.8Bn (€2.41Bn) in 2011, at a compound annual growth rate (**CAGR**) of about **7%**[15].

This is partly due to the fact that today, **transportation** and specifically **automotive** stand as one of the largest **market segments** with the **lowest composites penetration** (**3.6%**) in comparison to competing materials such as aluminium or steel (see Fig. 8). The above numbers state clearly the **great opportunity** that lies in the mass application of composites in the automotive sector.

Fig. 8 *– Composites penetration in different market segments, compared to competing materials (St, Al). (Source: Lucintel).*

Market Segment	Composite Materials Market	Structural Materials Market (Steel, Al & Composites)	Composites Penetration	Performance Gap	Price Gap
Transportation	$2.8 B	$77.8 B	3.6%		
Marine	$0.5 B	$0.8 B	68%		
Aerospace	$2.3 B	$23.2 B	10%		
Pipe & tank B	$2.6 B	$37.8 8	7%		
Construction	$3.4 B	$85.1 B	4%		
Wind Energy	$2.4 B	$6.4 B	38%		
Consumer Goods	$1.3 B	$9.4 B	14%		



This chapter analyses trends within the carbon and glass-fibre reinforced market.

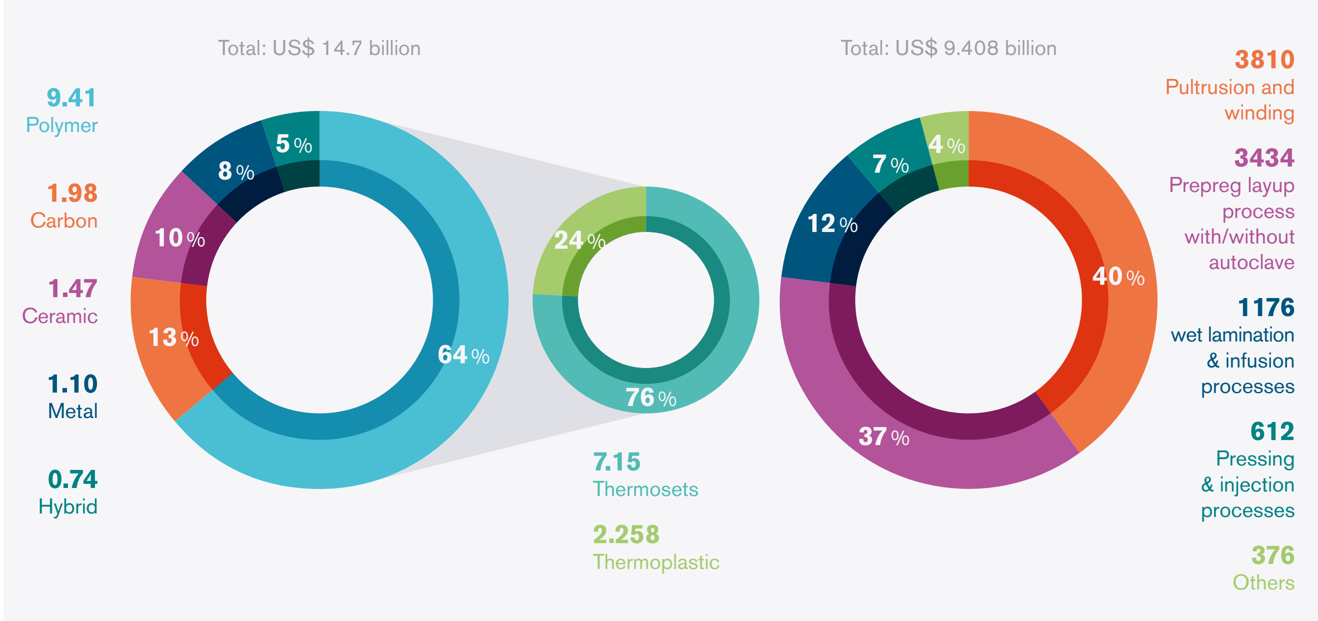
2.3.1 ■ Carbon composites and the CFRP market

In 2013, global demand for CFRP was around 72 000 tonnes, generating revenues of US$7.56Bn (€6.5Bn). CFRP represented 64% of the total carbon composites market, accounting for US$14.7Bn (€12.64Bn). Growth in CFRP consumption is forecast to continue at 10.6% until 2020 to reach a demand of 146 000t and revenue of US$16Bn (13.75Bn). Within CFRP, thermosetting plastics have a more established market position, accounting for 76% of the revenues (US$7.15Bn, 6.15B), with the remaining 24% accounting for thermoplastics (US$2.258B, €1.94Bn), with polypropylene, polyurethane and polyamide thermoplastics accounting for a large part of this.

Two manufacturing categories make up the majority of the CFRP market, with pultrusion and filament-winding accounting for 40% of the market and prepreg layup process with and without autoclave accounting for 37%. North America has a 34% share (US$5.07Bn, €4.36Bn) of the CFRP market, closely followed by Western Europe with a 32% share (US$4.7Bn, €4.04Bn) and Japan with a 15% share (US$2.21Bn, €1.9Bn).

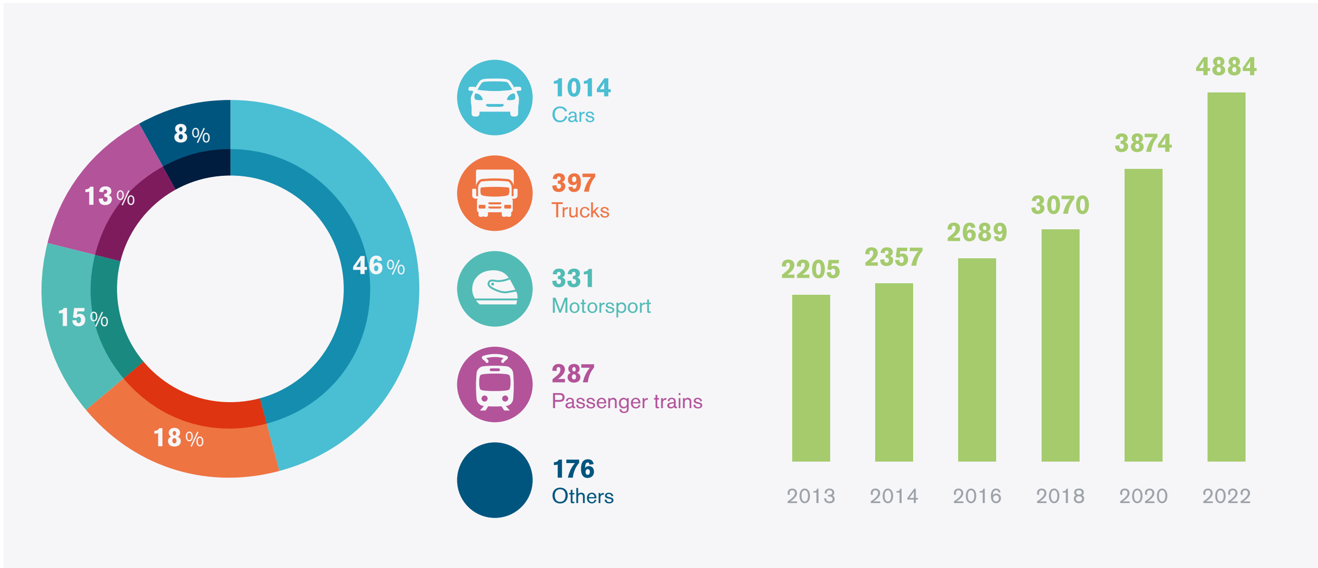
15 – http://www.lucintel.com/lucintel-globalcompositemarketanalysis-acma2012-educationalsession.pdf

Fig. 9 *– Left: Carbon composite revenues in US$ billion by matrix material (2013).*
Right: CFRP market share in US$ million by manufacturing process (2013).
(Source: AVK – CceV, 2014).



As far as automotive and transportation applications are concerned (excluding aerospace and defence), these are increasingly important to the carbon composites market with US$2.2Bn (€1.89Bn) in revenues in 2013. Cars are the main sub-segment (46%, US$1.014Bn, €0.87Bn), where their use is now restricted primarily to luxury cars due to the high cost of carbon composite components. The growing use of CFRP in automotive, construction and industry is a key factor driving the market. In the automotive sector, revenues are expected to grow by 7% annually until 2018. By 2022, annual global carbon composite revenues are forecast to reach US$4.9Bn (€4.21Bn) corresponding to 20 000 tonnes of carbon fibre. Automotive applications are set to rise to second place ahead of wind turbines in the table of market segments.

Fig. 10 *– Left: Carbon composite revenues in US$ million in the automotive sector according to sub-segment (2013).*
Right: Carbon composites revenues outlook in the automotive market segment (US$ million).
(Source: AVK – CceV, 2014).

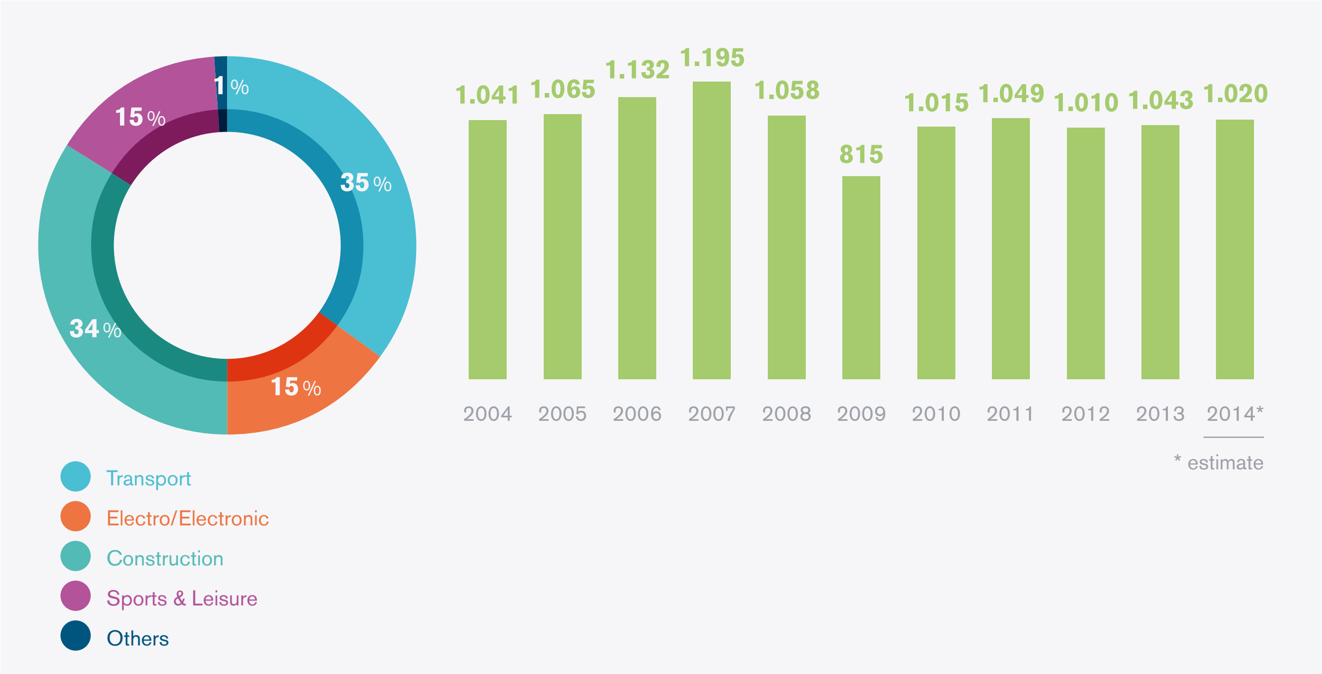


2.3.2 ▪ Glass fibre composites and the GRP market

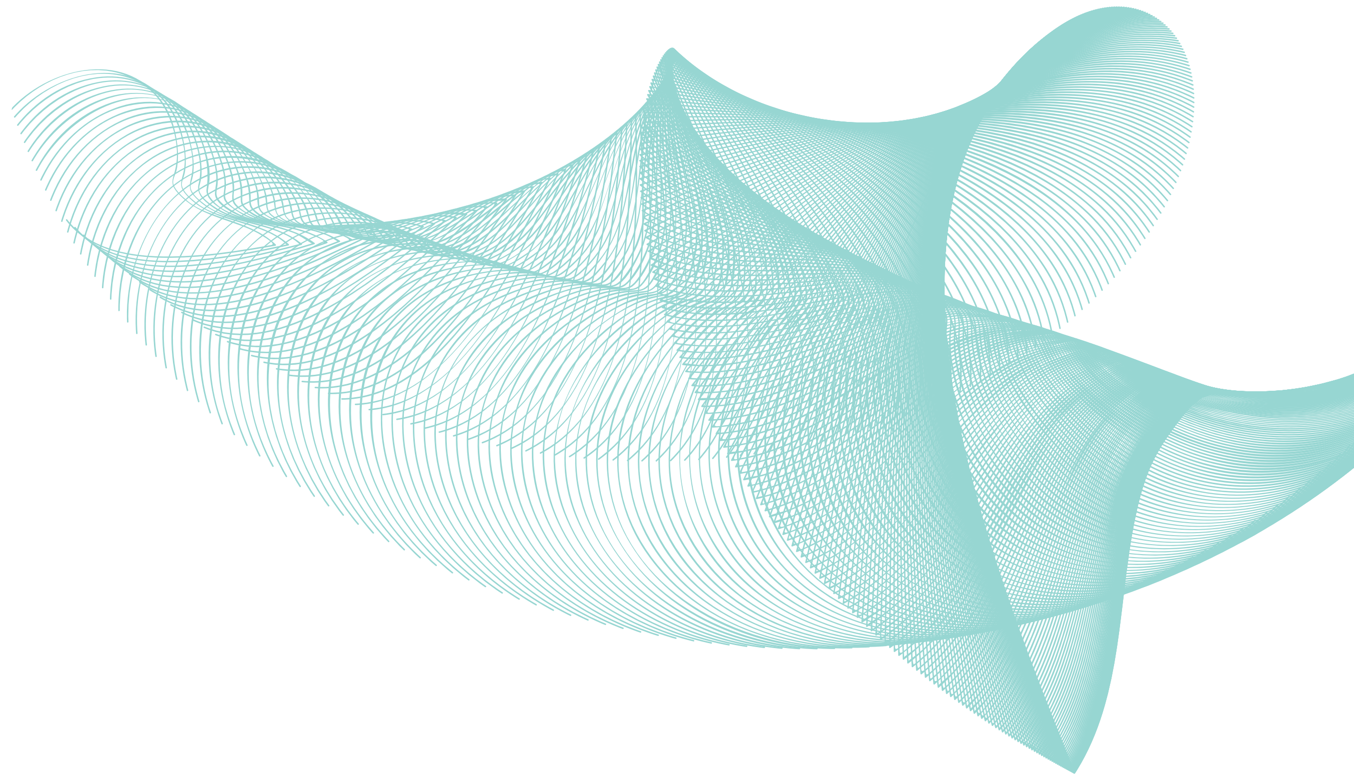
EU production of GFRP in 2014 is estimated at 2.2Mn tonnes (1.043Mn t if short fibre thermoplastics are disregarded)8, corresponding to a total value of US$5.093Bn (€4.4Bn)[16].This value matches the absolute level of 2004, illustrating that the level achieved before the economic crisis (1.195M t in 2007) has not yet been regained. Focusing on that 1.043M t, the vast majority (>85%) accounts for thermosetting materials, whereas a small share (11%) represents other thermoplastic materials such as glass-mat reinforced thermoplastics (GMTs) and long fibre reinforced thermoplastics (LFTs). Whereas relative growth is above average in some EU countries such as Germany (automotive industry) and UK (construction sector), production and consumption is also shifting to the BRIC countries.

Regarding GFRP distribution per application industry, the **transport sector** consumes one-third of total production (35%, about 357 000 t). The transport sector includes road vehicles, railway locomotives and rolling stock and boats and aircraft. **Lightweight constru**ction solutions, required to meet official CO2 emissions standards, continue to be the principal market driver in vehicle construction. For automotive, the worldwide suppliers of GFRP for the automotive market include Owens Corning, Millfield Group, Vetrotex, Lanxess and Ahlstrom.

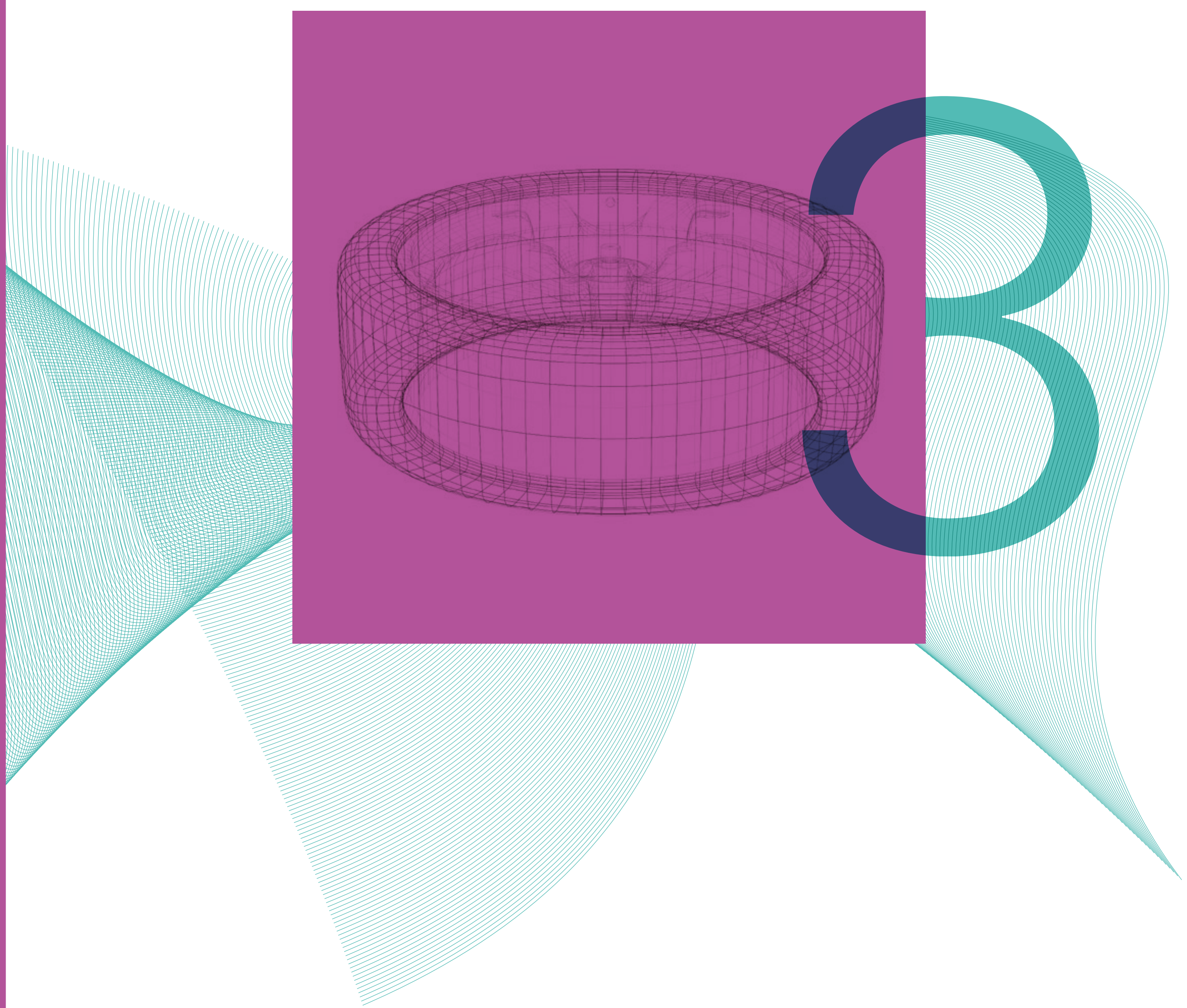
*Fig. 11 – Left: GFRP production by volume in EU since 2004 (in '000 tones, SFT disregarded).
Right: GFRP production in EU for different application industries (year 2013).
(Source: AVK – CceV, 2014).*



16 – Using the maximum price of €2/kg from Ignaas Verpoest for SusChem "Composites Materials Research Challenges"



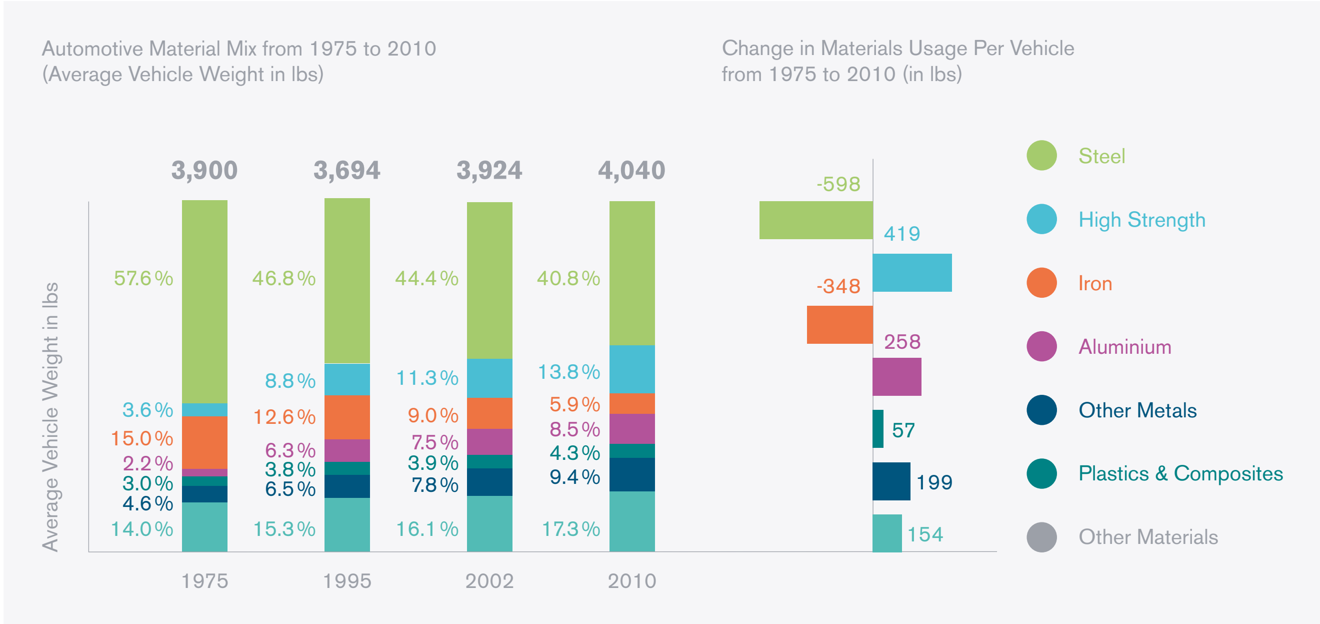
The motivation and drivers



Growth in the automotive composites market used to be driven by the need to reduce corrosion in metal parts. However, metallic parts started to be coated in zinc to prevent rusting. Automotive manufacturers then used composites for aesthetic reasons. Composite materials gave automotive manufacturers the possibility to build parts with distinct shapes, textures and visual appearances in their vehicles. One example is the BMW M3. Especially in small series production, composites have been a viable option due to the low cost tooling and machinery needed to produce the required composite parts. The premium price that these vehicles demand also allows manufacturers to incorporate more expensive composite parts.

3.1 Lightweighting

Fig. 12 – Automotive material mix (1975-2010) (Source: Lucintel)



Today, lightweighting is a crucial factor leading to the rapid expansion of the global automotive composite market. Different lightweight materials have always been part of the automotive materials mix, but as shown in Fig 12, **high strength steel, aluminium and plastic composites** are increasingly used. Due to their **lightness and stiffness**, plastic composites are a feasible option to reduce vehicle weight. Reducing the weight of vehicles is gaining more and more prominence due to the factors explained below.

3.2 CO2 Regulations

Firstly, European carbon emissions regulations will be lowering the permitted amount of emissions per kilometre, from below 130g/km CO_2 in 2015 to 95g/km CO2 in 2021. A level of 68-75g/km CO2 is proposed beyond that, possibly by 2025 or 2030. This will be confirmed in 2015[17]. This encourages OEMs to improve the fuel economy of their car fleet. One possible method would be to reduce the vehicle's weight **using composite components**. However, certain OEMs have expressed their concerns at the planned regulations as they are more stringent compared to other regions in the world, potentially leading to added costs in product or technology development.

17 – http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

3.3 Customer demand for fuel economy

Compounding the effect of stricter regulations, consumers are demanding cars that are more fuel-efficient. With rising social awareness of climate change and the emphasis on environmental issues combined with high fuel prices, consumers are turning to cars that have an improved fuel economy. The fuel efficiency of cars factors increasingly into the purchasing decision of consumers as they take into account the total cost of ownership of the product. With the twin objectives being to meet regulations and to appeal to market demand, automotive OEMs are developing ways to make their vehicles more fuel-efficient, such as lightweighting.

3.4 Increased uptake of electric vehicles

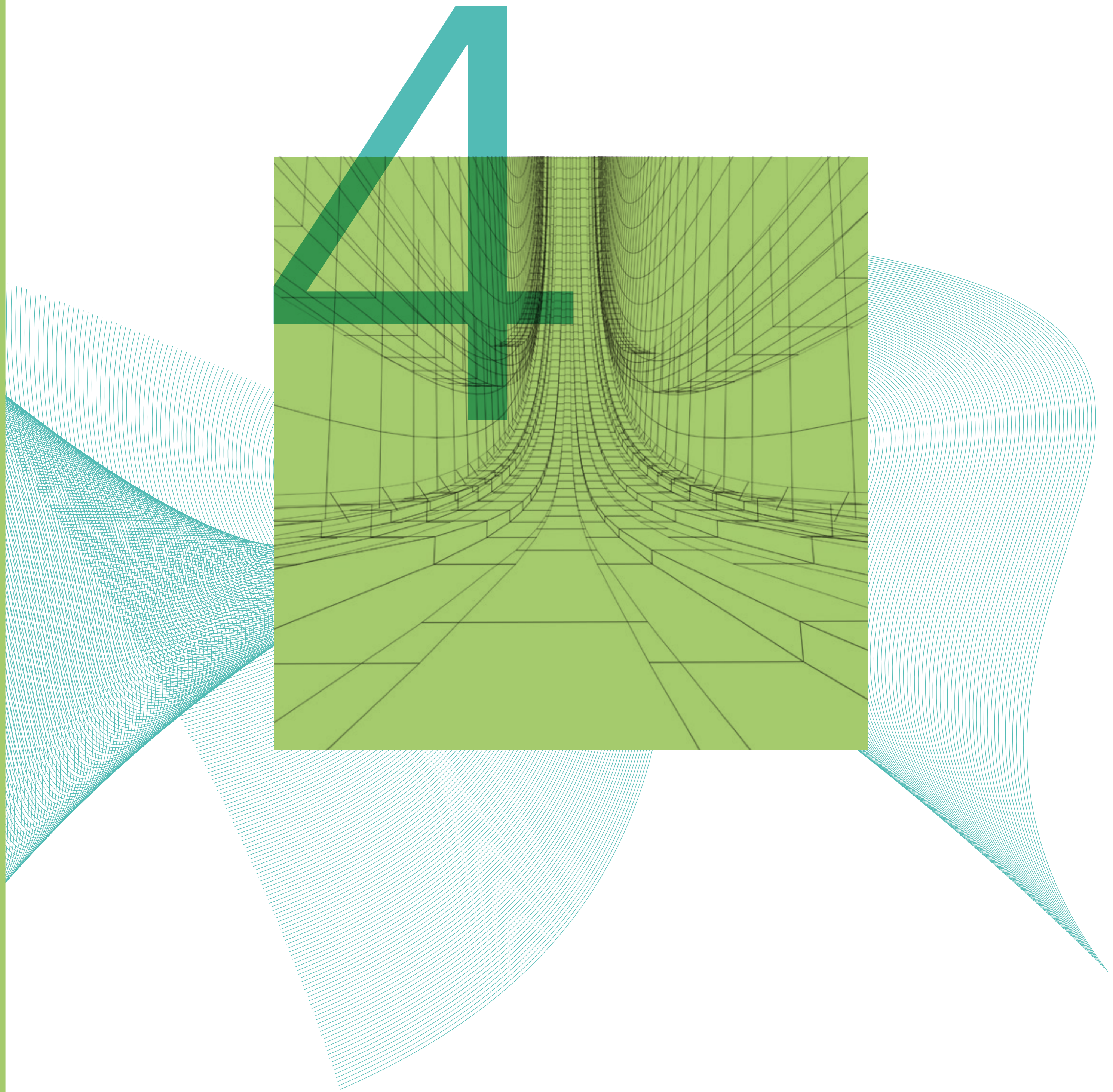
Many experts consider electric vehicles will allow for higher costs per kilo of weight saved in vehicle weight reduction strategies. While normal ICE-driven mass production cars can, in many cases, only afford to pay 2-3 per kilo of weight saved, several experts have put[18,19] the level of 'acceptable added cost per kilo of weight saved' at €7-8/kg saved for electric vehicles. It must be noted that advances in brake energy recovery (something very much pursued by e-vehicle developers as it increases the range for given battery capacities) partially cancel out the importance of lightweighting. In general, heavier vehicles, which consume more energy while accelerating in standard drive cycles, are also able to recover higher amounts of kinetic energy through brake energy recovery. Although braking energy recovery is not expected to reach 100% efficiency in the near future, a high percentage of brake energy recovery could reduce the energy efficiency impact of lightweighting in e-vehicles, compared to ICE driven vehicles, which cannot recover braking energy unless they are at least hybrid e-driven.

However, most carmakers are increasingly looking at composite materials as part of their multi-material lightweighting strategies both in ICE and E-drive vehicles. In e-vehicles, a lower weight vehicle body allows downsizing batteries while maintaining range. Reducing vehicle body and battery pack weight then leads to a compounding effect on weight reduction of the overall vehicle by enabling the downsizing of other parts such as brake systems and drivetrain parts. In ICE-driven vehicles, the lower weight reduces emissions and improves performance at equal drivetrain power and torque levels.

However, to become truly ubiquitous in the automotive industry, composite materials have to overcome a number of technical and transversal challenges, as detailed in the following chapter.

18 – http://www.rolandberger.com/media/pdf/Roland_Berger_E_Mobility_Index_Q1_2015_e_20150325.pdf
19 – http://www.rolandberger.com/press_releases/lightweight_can_stipulate_electric_car_development.html

Challenges



The automotive composites sector faces challenges that can be broadly classified into two categories: technical and transversal. Technical challenges relate to the readiness of technologies in the industry for the mass uptake of composite materials. Transversal challenges are challenges that affect more than one part of the value chain of the industry. Through interviews with industry players, the following challenges have been identified in these two categories, as summarised below.

4.1 Technical Challenges

The technical challenges that automotive composites face in their uptake stem mostly from the fact that composites are more commonly used in high-precision, low-volume applications, such as in the aeronautical sector. Technologies that are used in cost-intensive applications need to be developed, adapted and applied to the automotive industry, where volume and the length of production cycles are significant factors in making automotive composites more attractive for high volume commercial applications.

4.1.1 ▪ Recycling process

The recycling process for automotive composites is not as straightforward as the recycling process for metallic materials. There are three reasons behind this. Firstly, fibre reinforced parts are often joined to other parts such as metal fixings. The complexity of disassembly, de-bonding and separating the parts from the automobile to be recycled presents an obstacle.

Secondly, even if the parts can be separated from each other, it is difficult to extract individual materials from the composite. This stems from the fact that composites are a mix of different materials and cannot be melted down and recycled.

Lastly, the recycling of composites is hampered by the lack of suitable processes that allow the recycled composites to maintain their original characteristics. This leads to down-cycling (for example, continuous CF gets recycled to long fibre CF to short fibre CF). Since the recycled composite is no longer able to fulfil its original function, the recycled materials are used in lower-quality applications. The cost of recycling composites in the automotive industry makes it a cost ineffective option. The use of TP resins with appropriate recycling schemes could drastically improve this situation.

Existing recycling processes include melting thermoplastics to separate them, pyrolysis to extract high value carbon fibres from thermosets, and incineration to recover the energy contained in composite materials. Also, some composite materials can be shredded to be used as filling materials for other applications.

End-of-Life Directives (Directive 2000/53/EC Article 7)

The end of life directives stipulate that as of 1 January 2015, the percentage weight of an average vehicle that has to be 'reused and recycled' is 85%, up from 80%, while the weight that has to be 'reused and recovered' has to be to 95% instead of 85%. The difference between the 'recycling' and 'recovery' in these regulations is that recycling involves processing the material to be reused for the same or a similar purpose, while recovery can involve the incineration of the materials to recover energy. This means that an additional 5% of the average weight of a vehicle can be incinerated to recover energy, bringing it to a total of 10%.

This is a clear regulatory push towards recyclable materials. OEMs and suppliers have to embed recyclability in the design of the vehicle and associated components. This will force OEMs to take into account vehicle disposal and material usage in their vehicle designs even more than present.

4.1.2 ▪ Manufacturing process

Firstly, the cost of the raw materials in composite manufacturing process remains too high for manufacturers to offer a competitive price to OEMs and consumers. CFRP materials cost much more than its component base material due to the complex processes involved in manufacturing carbon fibre. Processes such as weaving, non-crimp fabrics and pre-impregnation of fibres drive the cost of CFRP above what is economically viable. GFRPs are cheaper to obtain and thus see more applications in a wider range of sectors. Obtaining lower cost carbon fibres is a prerequisite for greater uptake by automotive manufacturers.

To meet industry cost requirements, the manufacturing process needs to be further developed. At the moment, thermosets have a cure cycle that is too long. To be used commercially, the set time has to be reduced to below three minutes. Thermoplastics are an option as they have much shorter production cycles, although using thermoplastics requires different processes from thermosets, such as a combination of compression and injection moulding. Several chemical companies are already developing techniques that utilise such a combination. Automation could also be increased in the production process to reduce production time.

4.1.3 ▪ Methods determining damage to materials

As composite materials contain fibres, they are less ductile than metals and suffer damage differently. The damage is often beneath the surface, resulting in barely visible impact damage. At the same time, the non-destructive testing techniques that can be applied to smaller composite items cannot be applied to components that are integrated into vehicles. This is essential for structural parts where damage detection and assessment is crucial.

Once the damage is assessed, techniques to repair the damaged material are also limited. Replacing the entire part made of composites is often the most accessible method, which leads to increased costs and difficulty. Traditional mechanics and workshops lack the suitable equipment or infrastructure to repair the composite parts of such vehicles.

4.1.4 ▪ Joining techniques

The introduction of composite materials into vehicles reduces the total vehicular weight. These materials are used in conjunction with existing metal parts as metals have some structural characteristics that are more suitable to certain applications compared to composites. This combination results in multi-material car bodies where components and car bodies are composed of several types of materials. These materials need to be joined together by stable and reliable processes. The surface of composite materials also needs to be prepared for joining techniques. Joining techniques commonly used in joining metals such as welding are not a possibility when it comes to composite materials. Besides joining composites to metals, joining composite materials to other types of composite materials also presents a challenge. Although techniques such as adhesive bonding are used for multi-material car bodies, they could be made more cost effective. Increased automation and faster forming adhesive bonds could contribute to this.

At present, the industry has not standardised these processes or materials across suppliers. The evaluation of the structural strength, reparability and performance of these joining techniques is also not standardised and this detracts from the applicability of composite materials in multi-material car bodies.

4.2 Transversal Challenges

The transversal challenges of the automotive industry run throughout the industry and are not limited to one link in the value chain. This requires not just technical know-how and the resolution of technological challenges, but a concerted push to integrate the expertise that can be found laterally and vertically across the industry.

4.2.1 ▪ Cascade of knowledge and multi-material design process

Some parts of the automotive value chain do not possess composite knowledge although they play crucial roles in the vehicle production process. With composites having different properties and joining techniques, it is challenging to determine where and how they should be used in cars. Engineers from Tier 1/2 suppliers also need to adapt their component designs to satisfy new criteria. Depending on where composite materials are used in the vehicle, engineers have to take into account the revised characteristics that composite materials have, such as the strength and integrity of the entire structural chassis, its structural crash resistance and energy absorption during crash behaviour. Composite usage has to meet the minimum standards in these aspects. To take full advantage of the benefits of advanced materials, composite knowledge needs to be shared through education and training in the value chain, as the chemical industry experiences a similar learning curve as OEMs and tier suppliers, especially compared to the metal industry.

4.2.2 ▪ Intra-industry cooperation

Within the automotive sector, more intense collaboration is happening as the industry realises that there are common challenges that can be tackled more efficiently by pooling resources and sharing insight and knowledge. All automotive players need to meet increasingly stringent international regulations and adapt to global trends. To this end, many OEMs actively seek to create synergy with each other and prevent resources from being invested in competing against each other, when they could instead be invested to meet societal needs.

The chemical industry could follow the example of the automotive industry and increase its intra-industry value chain cooperation. As in the automotive industry, there are challenges that span the industry. Better coordination on how to face these challenges could save resources and create an impact for all industry players.

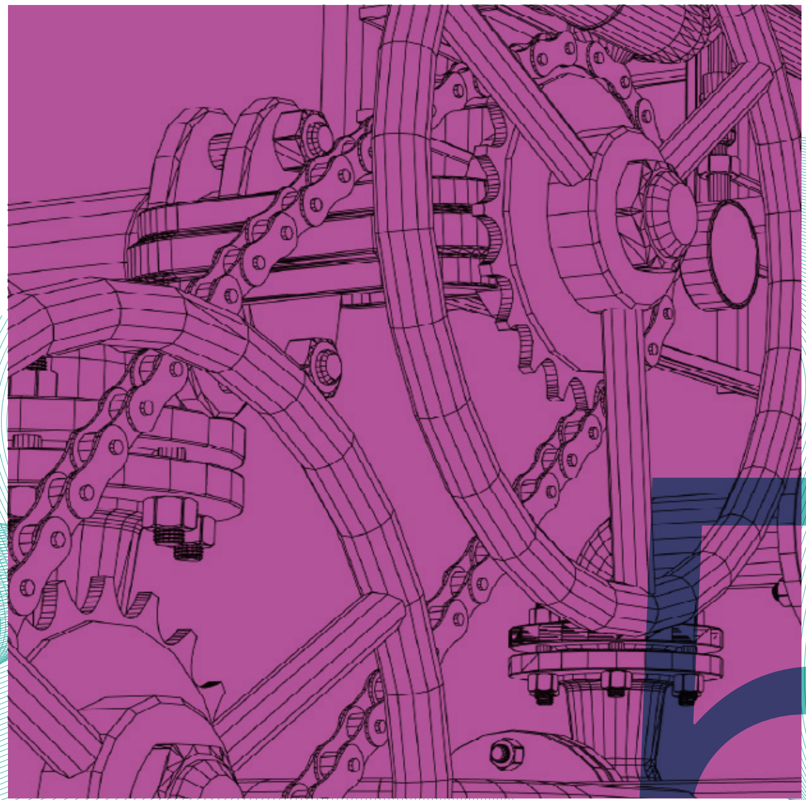
At the same time, the coordination between the chemical industry and the automotive industry could also be tightened to reflect the challenges that composites materials face in the automotive industry. While more individual partnerships between chemical companies and automotive companies have been formed in recent years, coordinated efforts to instigate cross-industry collaboration on an institution level could be further implemented. This is also reflected in industry cooperation with machine builders, tier suppliers and fibre and matrix producers. Working closer together could lead to faster and more tailored solutions to overcome the present and future challenges.

4.2.3 ▪ Synchronisation of policy and research agenda

On a higher level, the policies regarding composites in the automotive industry need to be coordinated in tandem with industry to promote the usage of composite materials in automotive applications. The policies, regulations and guidelines need to be material neutral. For example, the utility parameters in current CO_2 regulations are based on weight and are not favourable to the use of lightweight materials in automotive applications. These include the life cycle assessment, the end-of-life directives and recycling guidelines.

The research agendas of the various industry research centres can also be further aligned to prevent the duplication of effort and a common vision of where automotive composites are headed and what needs to be done to get there. At the moment, on-going research is fragmented and segregated by interests dictated by individual industry players.

Possible approaches to address industry-wide challenges



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The challenges that automotive composites are facing require a broad array of actions that inspire and convince the private sector to follow the public sector to invest effort and resources. With industry feedback and input, these actions can be bound together by a coordinated, virtual network of existing centres to coordinate the timely and appropriate implementation of the following actions.

5.1 Increase coordination between existing centres

A virtual network of centres could be set up in order to coordinate the activities of the various centres of expertise distributed across Europe working on automotive composites. At the moment, the centres do not have a coordinated strategy or a combined overview of the areas of research within the composites sector. In some centres, automotive composites represent only a department within the larger organisation that supports the strategy of the centre itself. While advancing the agenda of the individual centre, these departments could contribute more to the European strategy regarding automotive composites. In addition this virtual network could support active and innovative SMEs in the field of lightweighting to speed up their material, process and application development.

As confirmed by industry players through specific interviews, there are already a number of physical centres, which precludes the need to establish further physical facilities. Therefore, the network would remain virtual managed by a small project office or coordination team, possibly based in Brussels, to ensure a close working relationship with SusChem and policy makers to fulfil a set of roles and responsibilities that are detailed below.

5.1.1 ▪ Roles and responsibilities

Define a FRP roadmap and vision for Europe

The virtual network would act as the organisation that represents the interests of players within the European automotive composites field on the highest level. This places it in a unique position to consolidate the expert knowledge of the centres in the network, as well as to provide a well-informed, accurate and ambitious vision for European automotive composites.

Facilitate collaboration on common research goals

The network will facilitate existing research centres to create and work on common research themes to reach shared targets. As the various automotive composite departments follow the objectives set out by their respective centres, which might differ from each other, the network could align those targets so that they would complement or build on the work carried out by other departments.

At the same time, the network could also promote the sharing of knowledge generated in the network through intellectual property agreements to avoid the duplication of research efforts.

To advise the EC on cross-industry knowledge areas to be developed

The comprehensive industry overview that the network would possess would allow it to identify industry knowledge gaps. The network could serve an advisory function to the EC on how to bridge those gaps. This might come in the form of suggesting European funding calls to support and incentivise future research (see below) or through influencing policies and direct dialogue with relevant EC officers.

Discuss and provide input on EU regulations

Furthermore, the network could also advise the EC about regulations on material recyclability, life cycle assessment procedures and end-of-life directives. Advice from the virtual centre could highlight specific factors that need to be looked at in greater detail, such as more rigorous life cycle assessment procedures, or other factors that do not play a critical role in the reduction of carbon emissions, such as certain end-of-life directives. Optimising regulations by looking at alternative methods of valuing carbon emissions would help the industry allocate resources to achieve the required reduction in carbon emissions in line with European Commission objectives.

A look at current regulations

With the new end-of-life directives starting in January 2015, OEMs are suitably concerned that the directives might detract from the goals that they set out to achieve. The high quota of 85% reuse and recycle and 95% reuse and recovery mean that alternative methods have to be found to incorporate the use of composites in vehicle manufacturing. Simultaneously, composites are necessary to reduce vehicular weight and meet the lower carbon emission targets. The automotive industry would have to reduce its emphasis on meeting the carbon emission targets to meet recycling targets.

In consultation with industry and research institutes, a possibility to be considered is the usage of an alternative benchmark of carbon emissions or end-of-life efficiency measurements. A more holistic life cycle assessment could be introduced with less stringent recyclability regulations for vehicles that contain composite parts. This would allow significant carbon savings to be gained through the usage of composites without the penalisation of the same composites in the end of life phase of the vehicle.

5.2 Consider establishing large scale demonstration projects

The automotive composites industry could discuss if and how to set up pre-competitive demonstration project(s) that would mobilise the entire industry to work together towards a common ambition of establishing composites as an affordable lightweighting option. Such project(s) could showcase what advanced composites can do and how they can meet the requirements of automotive industry, and at the same time bringing together all the actors of the value chain, including designers, Tier 1/2 suppliers and OEMs. Similar demonstration projects have been carried out by the steel and aluminium industries in the past.

5.2.1 ▪ ULSAB: the steel industry demonstration project

The international steel industry developed several demonstration projects. The **Ultralight Steel Auto Body programme** brought together major industry names to build a demonstration vehicle that proved steel as a lightweight material with big potential for vehicles. Over 30 steel manufacturers from 18 countries banded together and invested €22 million confirming steel as a viable material for contributing to carbon reduction targets without compromising safety or functional aspects. Porsche Engineering Services (PES) was contracted by the consortium to leverage its expertise to define the project goals, and provide engineering and manufacturing insights.

By the end of the project, the demonstrator vehicle met all mandated crash requirements, had significant improvements in torsional rigidity, bending rigidity and first body mode, while having mass savings of 25% without increasing the costs of production. The knowledge generated in the project was released to its customers and to the public. Over a period of more than eight years, the consortium partners carried out the project in three phases, developing the concept, validating the concept and then testing the feasibility of such a vehicle created through assembling and evaluating a vehicle prototype.

5.2.2 ▪ Possible process

The European composites industry could use a similar process to demonstrate that composites represent a feasible and cost-effective method to construct such a vehicle of the future. Many polymer materials suppliers and composite part producers are already working on demonstrators with car makers, universities and technical centres. Bundling such initiatives together could allow the joint composites industry to showcase a complete vehicle build-up, without the need to start from scratch nor disclose sensitive data on a single component manufacturing or at a materials chemistry level.

INcar plus: ThyssenKrupp Steel car project

ThyssenKrupp Steel took the lead in developing weight saving components and solutions for the automotive industry. These innovations resulted in up to 50% weight savings and up to 20% cost savings, leading to emission reductions of up to 8 grams of CO2/km. The consortium that developed these innovations consisted of staff from the ThyssenKrupp Steel business areas of Steel Europe, a leading material partner to automotive OEMs, Components Technology, a leading component supplier, and Industrial Solutions, a leader for engine and transmission assembly and body-in-white lines. A hundred engineers from eight companies working in 15 locations created 40 innovations that were production-ready.

Although this project did not involve the entire industry, it can illustrate the new possibilities that may be generated when different agents of the value chain look to overcome predetermined challenges together.

5.3 Strengthen technical/academic skills

A crucial aspect of preparing the industry for large-scale composite uptake is preparing the workers and firms to work effectively with composites. Workers and suppliers that are used to producing steel parts with old steel machinery need to get used to the special characteristics and production methods associated with FRPs. One of the main industry reflections is that the knowledge generated has not been disseminated sufficiently or effectively down the value chain.

More support could be provided for suppliers or OEMs who decide to introduce or scale up the use of composites, for example in the form of a skills training programme. This would need an assessment of the needs that industry players have and existing knowledge.

Taking into account industry needs, a Knowledge and Innovation Community (KIC) could be a good instrument to leverage the overlapping areas in education, technology, research, business and entrepreneurship, providing the necessary support to the industry. For instance, a KIC on advanced materials could lay out an agenda to close the identified knowledge gaps on automotive composite material uptake.

At the same time, the Factories of the Future (FoF) programme under Horizon 2020 could also be used to develop novel technologies needed for competitive and commercial methods of automotive manufacturing. It covers the full spectrum of manufacturing and aims to research enabling technologies in several fields, including the novel industrial handling of advanced materials to facilitate optimum production with less resource use and waste. For example, the FOF-12 2015 call covers technologies for joining multi-materials, which is one of the challenges for composites materials.

Through the KIC and FoF programmes, the following areas can be looked at in consultation with key industry stakeholders.

5.3.1 ▪ Skills training for workers / Tier 1 suppliers

To create a skills training programme, the industry could be consulted to find out where knowledge shortcomings are, both in technical areas and in the manufacturing process. A corresponding syllabus could then be developed for the industry to use in workshops and training events.

5.3.2 ▪ Education programme

To attract and train more new talent, a dedicated European Master's or PhD programme on automotive composites could be coordinated between the top universities in the field including KU Leuven, TUM, Aachen, EPFL, Leeds and Warwick.

5.3.3 ▪ Knowledge dissemination

To disseminate the knowledge generated and gathered throughout the industry, workshops, webinars and Massive Open Online Courses (MOOCs) could be organised. The aim of these programmes would be to keep all industry players up to date with the latest relevant research that could encourage further use of composite materials.

5.4 Consolidate a roadmap: encourage further innovation

Coordinating the research agendas of the various research centres in Europe is equally important as the need to mobilise the industry to contribute to European knowledge in automotive composites. This can be achieved through predetermining certain research themes for SMEs and corporations to follow using the existing research programmes. As these programmes are already in place, supporting actions such as workshops, brokerage events and communication actions could be used to encourage SMEs and industry players to participate more in the programmes detailed below.

5.4.1 ▪ Supporting innovative SMEs

More companies could be encouraged to devote time and research efforts to the challenges that composites in the automotive industry are facing. An innovation cash prize could be set up to deal specifically with automotive composites challenges. Such a tailored programme does not exist on a European or international level and could be a driver for the industry to tackle specific problems.

Innovation prizes are instruments that can be used to drive innovation in conjunction with funding programmes. A sum of money is set aside as a prize to be awarded to one or multiple winners who are chosen by a panel of judges. This would stimulate SMEs/OEMs to develop the technologies and techniques identified in the challenges to be disseminated throughout the industry.

The European Commission launched five innovation prizes that offered a total of €6 million as reward for technological breakthroughs in health, the environment and ICT. These breakthroughs were specifically related to the challenges highlighted in the prizes including the 'reduction of the use in antibiotics prize', 'food-scanner prize' and so on.

SusChem and other stakeholders could sponsor a specific innovation prize in the field of composites materials for automotive.

JEC Innovation Program

JEC (Journées Européennes des Composites) is the biggest composites industry organisation in Europe and internationally. They provide networking and information services that seek to expand and develop composite markets in various sectors. Over the past 15 years, the worldwide **JEC Innovation Programme** has been running to recognise innovative composite solutions, to encourage companies and their partners to innovate and to increase the visibility of these advances to the composite industry. To do this, JEC awards prizes to companies that have submitted innovations in many categories ranging from automotive, railway, wind energy and aeronautics among others. This year, Porsche won in the automotive category for 'innovative material and manufacturing approach for a multi-part aerodynamic body' in the 918 Spyder. The Innovation Programme brings recognition in the industry and beyond, as it is highly regarded among companies active in the diverse chemical and composites applications industries.

LITECAR Challenge

More recently, a public-private partnership between Local Motors and the federal Advanced Research Projects Agency – Energy (ARPA-E) presented the LITECAR challenge (Lightweighting Technologies Enabling Comprehensive Automotive Redesign) with a total prize money of US$150 000 and a grand prize of US$60 000. The challenge aims to leverage the knowledge of designers, scientists, engineers, innovators and inventors to rethink vehicle design applying new technologies, materials, designs and manufacturing methods. Participants will submit designs to be evaluated by expert judges for several criteria such as curb weight reduction, vehicle safety, innovation and supporting evidence. This innovation prize increases the visibility of the challenge and encourages cross-disciplinary innovation.

Alternatively, a dedicated **Fast Track 2 Innovation** programme can be set up for automotive composites to accelerate market relevant developments. This is part of the Horizon 2020 programme and brings innovations from European businesses and organisations from research to the market. Consortia that consist of three to five organisations with a high degree of industry participation can apply with ideas in any technology or application. The flexibility of this programme provides chances to be selected for innovations from many different areas. This format could be adopted to have a specific focus on the automotive composites industry.

5.4.2 ▪ Inclusion of priority call topics for future H2020 calls

Over the years the **Horizon 2020 programme** has seen much success in advancing the state of the art in many areas. However, there are hardly any topics so far in the Horizon 2020 programme that focus on pushing the envelope on automotive composites. Horizon 2020 has a budget of €80 billion over seven years, with a budget in 2015 of €9.9 billion. As one of the foremost tools that the European Commission uses in galvanising industry support, it is important to ensure the inclusion of priority call topics on automotive composite materials for future Horizon 2020 calls (2018-2019). The technical challenges presented above, as well as other challenges that industry feedback has indicated, can be addressed in such topics. This is crucial to securing the dominant position in automotive composites that Europe currently enjoys and builds on the successful projects of the previous Research Framework Programmes (See Annex B).

Some suggested priority research call topics are:

- *Novel and innovative polymer composite raw materials with enhanced recyclability properties*
- *Low cost adaptive, flexible and efficient manufacturing and assembly processes specific to the high-volume automotive industry*
- *Integrated process modelling, simulation and energy optimisation*
- *Multi-attribute design optimization that works even in case of a multi-material architecture*
- *Automated joining techniques for multi-materials and composites (Already foreseen in a Horizon 2020 2015 call)*
- *Invisible damage identification and repair techniques for composite parts*
- *Strategies for new holistic approaches to enhance design, materials and process integration within the value chain of composites*
- *Coordination & Support Action to coordinate and create a network of research and innovation projects, programmes and policies*

5.4.3 ▪ Supporting the coordination of European composites clusters

Supporting the coordination of European composites clusters is one option that can move the automotive composite industry in the right direction. Its feasibility can be verified in workshops and through discussions with key stakeholders. Setting up a virtual network of existing European clusters requires more than time, political will and vision. Imperative to its realisation, existing financing tools have to be leveraged to support its various actions as well as the initial investment required and overhead costs.

Under the Horizon 2020 programme, the 'Coordination & Support Action' (CSA) provides funding for the coordination and networking of research and innovation projects, programmes and policies.

The **European Regional Development Fund (ERDF)** concentrates its investments on innovation and research, the digital agenda, SME support and the low-carbon economy. In developed regions, 80% of the funds or more must focus on at least two of these priorities. In the case of the virtual network, innovation and research and the low-carbon economy could be the two priorities.

Eureka is another potential source of funding. It is a network of national innovation funding agencies in Europe that has realised 5 440 research projects over twenty-eight years, aiming to use national funds for international cooperation by facilitating transnational coordination and allocation of research funding. Eureka has several clusters that are initiatives led by industry developing important technologies. These clusters promote the participation of industry, SMEs, research institutions and other public or private organisations. It is possible to apply to become a Eureka cluster. For example, Metallurgy Europe has done this for 2014-2020[20].

The European Institute of Innovation and Technology (EIT) combines higher education, research and business in its Knowledge and Innovation Communities (KICs). The KICs are spread across Europe, located in several hubs across the continent. The funding for the KICs is obtained from the EIT (25%), and non-EIT bodies (75%) including the resources of KIC partners, public funding at national, regional and EU level. The virtual network would include some academic partners as well as industry partners, thus being eligible to be designated an EIT KIC. The EIT has a €2.7billion budget available for the funding period 2014-2020, although the call for KICs proposal does not have a fixed amount of funding.

It is feasible to develop the project ideas to greater maturity before presenting them to the European Commission services to allow them to recommend relevant programmes. With an intimate knowledge of the European Commission funding programmes and aims, Commission officer would be able to advise SusChem on the most appropriate funding route to take.

However, due to the complexity of the possible actions and approaches, close cooperation and consultation is necessary between the relevant authorities, industry players and academia. The following table summarises how the possible approaches can tackle the challenges that the composite industry is facing.

20 – http://www.eurekanetwork.org/metallurgy-europe/about

***Table 4** – Table of current challenges in the automotive composites industry and possible approaches. Own elaboration based on interviews with industry players.*

Specific challenge	Possible approach
Recycling process	
Manufacturing process	Use new and existing policies to encourage the private sector to innovate according to a pan-European research agenda.
Methods determining damage to materials	Provide a consolidated roadmap for the advancement of industry technology.
Joining techniques	
Cascade of knowledge and multi-material design process	Start a consultation process on a cross-industry initiatives that join forces within the value chain working together towards a common goal.
Intra-industry cooperation	Implement coordinated industry skills training and dissemination activities
Synchronisation of Policies and research agendas	Give input to the relevant authorities and help design future policies

Summary

A coordinated Vision for European automotive composites

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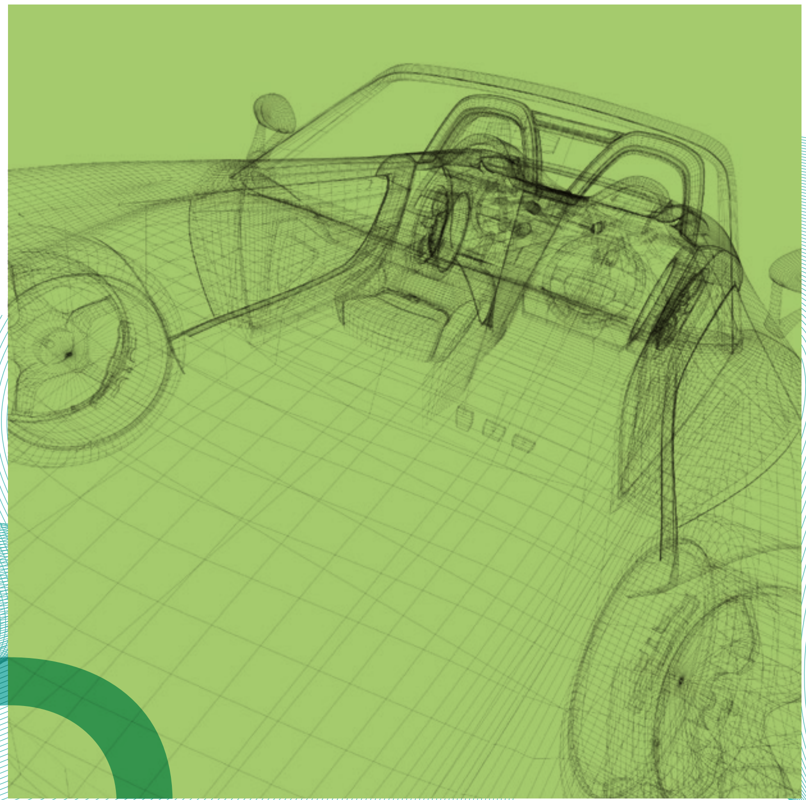
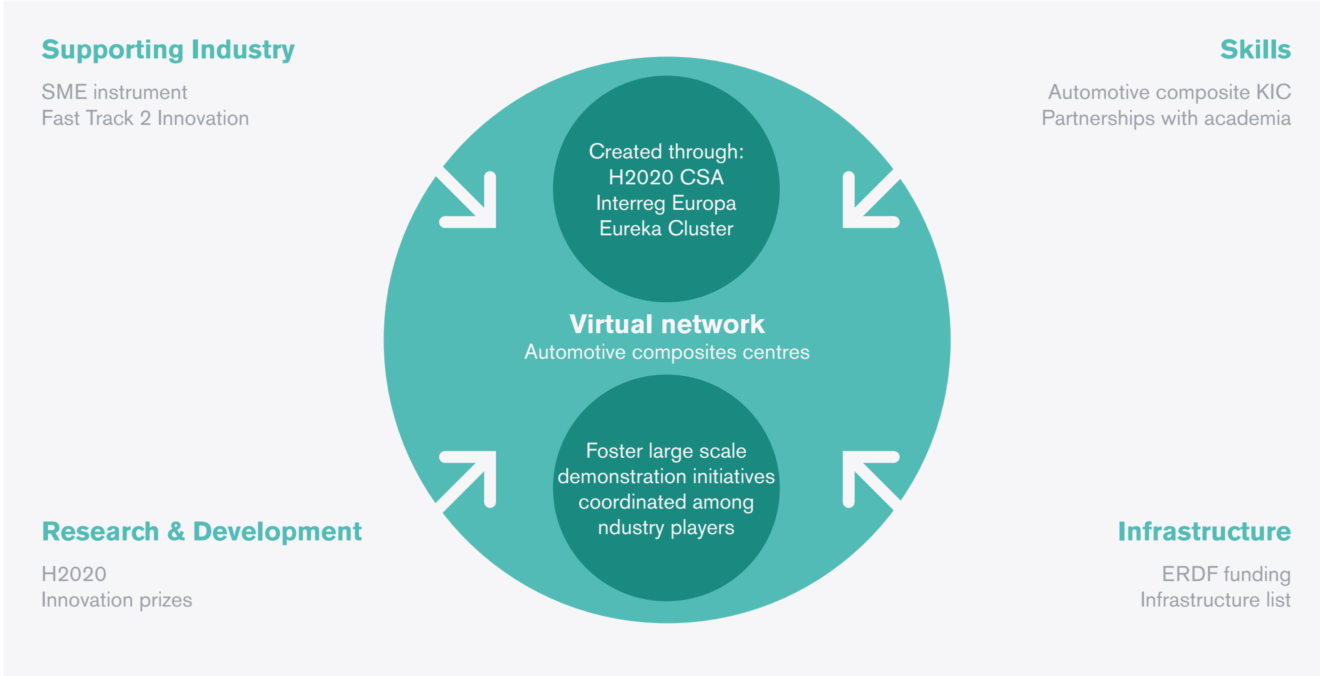


Fig. 13 – Vision for the European virtual network of automotive composites.



The automotive composites industry has an undeniably bright future. In terms of market demand, it is set for rapid growth due to the reasons outlined above. In terms of applications, with the forthcoming improvements in technology and manufacturing processes, composite materials can be used in more and more components and parts that were previously the domain of traditional lightweight materials such as steel and aluminium. The European automotive composites industry can capitalise on these trends.

Given the current state of the market, technology and industrial organisation, the actions proposed above can smooth the way for automotive composites to achieve its full potential. Ultimately, the virtual network of automotive composites centres would coordinate all the required actions, including supporting the industry and SMEs through providing guidance for SME instruments and Fast Track 2 Innovations, ensuring that more companies and SMEs are involved in the research and development of new and critical technologies that will enable the expansion of the industry, and build up the industry skills that are currently in short supply. At the same time, the virtual network, having a cross-section of industry personnel, would be positioned to initiate, coordinate and lead a flagship initiative that would bring all parts of the automotive composite value chain together to advance the industry and materials into mainstream acceptance and adoption.

This would lead to a scenario where the various industries involved (plastics, chemical, automotive) are working closely together with input from national and international organisations that coordinate and aid the growth of the industry. This close working relationship would manifest itself in the form of existing research institutions infused with triple helix participation that are producing talent, cutting edge research and new applied methodologies for the uptake of automotive composites throughout the entire industry value chain. Technological breakthroughs at SME-level would combine with the advances at the industry-level created through the flagship initiative, as skills and knowledge are widely shared and constantly updated to reflect the high pace of composite innovation. With such a comprehensive portfolio of actions, the automotive composite industry will eventually become an even greater European success, at a faster pace, than envisioned by industry commentators and experts.

Annex A

Overview of existing European automotive composite clusters that could form the possible basis of a virtual network

Open Hybrid LabFactory
Wolfsburg, Germany

The Hybrid Open LABfactory is a public-private partnership begun in 2012 between the TU Brainschweig and the Lower Saxony Automotive Research Centre. It is located close to the main plant of Volkswagen and the Mobile Life Campus in Wolfsburg. It has a representation of the entire value chain from conceptual component design skills through to recycling.

Composites Centre Sweden Lulea
Sweden

The Composites Centre Sweden is a collaboration between the Lulea University of Technology and Swerea SICOMP (Sweden's research institute for composites). It aims to establish an international centre for composites education and promote high technology spin-off companies in composites. It has a research group that studies how composite materials can be used in multi-functional, high-strength applications for the automotive industry.

LIGHTer arena Stockholm,
Sweden

LIGHTer is a cross-industry lightweighting forum which intends to create a structure for the efficiency of technology development involving personnel with unique, multi-disciplinary capability to create products with low weight. LIGHTer coordinates activities in research, development, technology and competence development, and is the Swedish hub of lightweight technology.

Institut de Recherche Technologique (IRT) Jules Verne
Nantes, France

The IRT Jules Verne comprises the Technocampus Composites, Technocampus Ocean and the Industrial Virtual Reality Centre with satellites located at Le Mans and Saint-Nazaire. It conducts research in emerging technologies with a TRL level of 3 or more in collaboration with institutions and research organisations in applied fields in partnership with companies with specific market needs.

Composites Innovation Cluster (CiC)
Hertfordshire, UK

An example of the organisations that the NCC is coordinating is the CiC, a consortium of 25 organisations. It aims to improve aspects of composite technology, manufacturing and skills and training. It aims to ready the UK composites supply chain to be competitive in meeting future global demands for skilled personnel, technologies and processes.

Arena 2036
Stuttgart, Germany

A campus that contains expertise in research and development, Arena (Active Research Environment for the Next Generation of Automobiles) 2036 concerns itself with diverse fields, including the lightweighting of vehicles. It operates as a public-private partnership testing and demonstrating cutting edge results. Its partners include Fraunhofer, BASF, Daimler and the University of Stuttgart.

Aachen Centre for Integrative Lightweight Production (AZL)
Aachen, Germany

AZL aims to transform lightweight design in mass production through promoting synergies between material science and production technologies. AZL focuses on the process of composite mass manufacturing and the development and production of load and cost optimised multi-material systems. The RWTH Aachen University contributes to this centre and it offers a diverse range of research opportunities for interns and students looking to write their thesis on lightweight applications of composites and manufacturing processes.

MAI (Munich Augsburg Ingolstadt) Carbon
Augsburg, Germany

MAI Carbon is a division of Carbon Composites e.V. (CCeV) and was nominated as a leading cluster of the German Federal Ministry of Education and Research. It is composed of companies and research facilities focused on the applications of composites in automobile manufacturing, aerospace, mechanical and plant engineering. They have many projects that are following research themes in those fields between local partners.

IMAST
Naples, Italy

IMAST links scientific research to companies, selecting organisations and promoting partnerships. Public and private research is carried out within IMAST and it also promotes higher education in the field. IMAST has many partners in Italy ranging from companies, universities to research centres.

MERGE Cluster Chemnitz, *Germany*

Merge Technologies for Multifunctional Lightweight structures aims to provide top-level research for international visibility and performance. The vision of the Cluster of Excellence is to tap into the joint resource potential of merged technologies and lightweight structures by adopting an integrated approach. The Chemnitz Cluster MERGE is pursuing a long-term strategy of bivalent resource efficiency (BRE strategy) which is a competitive factor for Germany as a production site and for the protection of jobs within the manufacturing sector.

Annex B

Current and recent European R&D&I projects and initiatives on automotive composites

Recently, the automotive industry has turned to composite materials to meet industry regulations and to improve vehicle performance. European industry players realised that the state of the art of certain technologies were insufficient to fully meet these industry needs. To advance the state of the art, many collaborative, cross-sector projects were initiated including:

Project	Description
MULTEXCOMP 1996-1999	The 4th Research Framework Programme (FP4) funded this project to produce lightweight structural parts out of composite materials to reduce the weight and the maintenance cost of vehicles. Daimler Benz, Eurocopter and Intermarine represent three transport OEMs in the automotive, aerospace and shipbuilding sectors that worked together with suppliers and universities to develop new textile technologies that can produce long fibre reinforcements at affordable prices.
TECABS 2000-2004	Under the 5th Framework Programme (FP5), the OEMs Volkswagen, Volvo and Renault joined forces with Engineering Systems International, KU Leuven and other knowledge and research institutes to develop low cost, carbon composite automotive structures. The aim was to reduce the weight of a Body in White by 50%, and of the entire vehicle by 40%. Several technologies were developed to reduce the number of parts required, to create high speed, low cost RTM processes and cost effective, fast preform and resin technologies amongst others, to reach a production rate of 50 units per day per line, an improvement over the state of the art at that time.
SuperLIGHT-Car 2005-2009	SuperLIGHT-Car (SLC) began under the 6th Framework Programme (FP6) to explore a multi-material approach to reduce the weight of high-volume production vehicles. A large and comprehensive consortium, consisting of research centres, OEMs and tier suppliers, led by Volkswagen demonstrated methods to process, join, and design multi-material parts on a part-by-part basis. Simulation tools were also used to predict how multi-material parts would affect car structures, price and sustainability.
HIVOCOMP 2010-2014	Under the 7th Framework Programme (FP7), the OEMs Volkswagen and Daimler teamed up with chemical companies Huntsman and Benteler-SGL and knowledge partners Fraunhofer, KU Leuven and others to develop two cost effective production systems for high performance CFRP parts. Using polyurethane thermoset matrix materials and thermoplastic polymer composites with continuous carbon fibre reinforcements, production cycle times were shortened without compromising parts performance.
EAM Cluster **2012-2016**	The SEAM cluster was established to coordinate four automotive projects funded by the European Commission. These projects include MATISSE, ALIVE, and ENLIGHT. Fraunhofer LBF and Bax & Willems Consulting Venturing hosted the SEAM cluster office to obtain synergies and carry out dissemination and communication activities for these automotive projects.
MATISSE 2012-2015	OEM Daimler and CRF Fiat were part of a consortium of knowledge institutes including the technical universities of Munich and Graz to research the crash behaviour of vehicle structures constructed from FRP composites. The partners recognised the importance of accurate modelling and prediction of crash behaviour as a prerequisite for the industry to adopt FRP composites. Numerical simulation methods were developed to advance the state-of-the-art in this field.
ALIVE 2012-2016	FP7 also funded ALIVE, bringing Volkswagen, Volvo, Porsche together with chemical partners such as KUL, Faurecia, Benteler and research institutes such as CRF and Fraunhofer to develop lightweighting techniques suitable for mass production of around 1 000 vehicles per day. These techniques should be affordable and reduce the weight of the Body in White by the 30% demonstrated in other EU-funded projects. The techniques included advances in vehicle design, material, forming and joining technologies, simulation and testing.
ENLIGHT 2012-2016	ENLIGHT is an ambitious project that aims to stimulate the development of various composite materials for electric vehicles. The partners, led by the Fraunhofer Institute with OEMs such as Volkswagen, universities such as KU Leuven, and chemical suppliers such as DSM, will test how several composite parts of an EV architecture will perform in structural functions. The objective is to show that composite parts are a viable option in the EV of the future.
Urban-EV 2013-2016	Urban-EV intends to develop prototypes of electric vehicles for the urban environment. Using a multi-material approach, the project will reduce the weight of the vehicle architecture while using manufacturing processes that can produce multi-functional components. The processes implemented are mature, being either commercially available or developed in previous research projects. The consortium is led by the Fraunhofer Institute, CIDAUT foundation, and other parts suppliers.
NEWSPEC 2013-2017	NEWSPEC aims to produce carbon fibres through low-cost polyethylene precursors. The project uses an available pilot scale facility where continuous carbon fibres processes are designed and optimised. This could be expanded later to an industrial scale. Throughout the project, carbon composites prototypes are manufactured and tested to ensure that the products of the carbon fibre processes are validated.
PMJOIN 2013-2016	PMJOIN is a project under FP7 with partners such as Citroen, Fraunhofer and Faurecia. It aims to develop a new technique for joining metals to plastics, since most modern vehicles are made of multiple components made of several types of materials. The new joining technique will involve a direct non-contact laser without filler, glue or mechanical joints, resulting in a robust joint while maintaining structural integrity.
CARBOPREC 2013-2017	Under FP7, CARBOPREC involves Renault, Arkema, Sigmatex and other composite manufacturers, knowledge institutes and research centres, with the aim of developing low cost composite precursors from renewable materials widely available in Europe, reinforced by carbon nanotubes to produce carbon fibres for a range of applications. This project studies two methods of continuous fibre production: a wet spinning approach for cellulose dissolved in phosphoric acid and melt spinning by extrusion for lignin.
FIBRALSPEC 2014-2017	FIBRALSPEC is a FP7 research project that will develop new processes to streamline and improve the control of current carbon fibre manufacturing. The University of Athens, University of Birmingham and Thales SA among other partners aim to develop carbon fibre precursors that are more cost efficient with improvements in their mechanical and chemical properties. Also new recycling techniques will be developed that use discarded carbon fibres to manufacture commercial products.

About SusChem

SusChem

SusChem is the European Technology Platform for Sustainable Chemistry.
It is a forum that brings together industry, academia, governmental policy groups and the wider society.

SusChem's **mission** is to initiate and inspire European chemical and biochemical innovation to respond effectively to society's challenges by providing sustainable solutions.

SusChem's **vision** is for a competitive and innovative Europe where sustainable chemistry and biotechnology together provide solutions for future generations.

SusChem's **priority** areas include: Catalysis, Information and Communication Technologies (ICT), Materials for Energy, Sustainable Bioeconomy and Water.

SusChem across Europe

SusChem has established a network of National Technology Platforms in 14 countries across Europe (Austria, Belgium, Czech Republic, France, Germany, Greece, Italy, Netherlands, Poland, Romania, Slovenia, Spain, Switzerland and United Kingdom) that work on sustainable chemistry initiatives within their own country, support national engagement in EU collaborative projects and programmes and contribute to transnational collaborations.

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SUSCHEM

SusChem Secretariat
Cefic - The European Chemical Industry Council
Avenue E. van Nieuwenhuyse, 4 box 1B
1160 Brussels
T +32 2 676 7461
F +32 2 676 7433
E suschem@suschem.org
W www.suschem.org

SusChem
European Technology Platform
for Sustainable Chemistry