



Composites Market Report 2015

Market developments,
trends, outlook and
challenges

The **GRP**-Market Europe – Dr. Elmar Witten (AVK)

The global **CRP**-Market – Thomas Kraus, Michael Kühnel (CCeV)

September 2015

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The European GRP-market 2015

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Its services include organisation of task forces, seminars and conferences as well as providing market relevant information (www.avk-tv.de).

The AVK is one of the four national pillars of the GKV – Gesamtverband Kunststoffverarbeitende Industrie and an international member of the European composites confederation EuCIA – the European Composites Industry Association.

The AVK is a foundation member of Composites Germany.

The GRP market in Europe 2015

Steady growth in production volume is continuing

Europe's production volume in glass fibre reinforced plastics (GRP) is continuing its steady growth in 2015 at a rate of 2.5%. Having reached 1.069 megatonnes, the production volume is now at its highest level in eight years.

On aggregate, the development of the previous year is continuing in all the European countries. This development is largely following the general economic trend in Europe as a whole and particularly in two areas of application which are the most important for the use of GRP: transport and construction. However, the situation differs from one country to another: Germany and the Eastern European countries under review recorded above-average growth. In Southern Europe, on the other hand, the GRP volume is growing only slightly or even stagnating. In Scandinavia we can even observe a downturn.

The development is similarly heterogeneous for the various processing methods that are used in the production of GRP components. Production has been high above average where it involves the use of RTM and particularly thermoplastic fibre reinforced plastics and composite materials.

The European GRP volume is growing more slowly than the global composites industry and also short fibre reinforced thermoplastics. Although the latter are composites, they are not explicitly included here. The European composite share – currently 25% of the world's total production – is set to drop even further. However, this does not necessarily apply to value creation, which differs according to the product, method and material (mix). Above-average growth potential can also be observed in European high-wage countries where it is in fact a specific feature. This is due, in particular, to specialisation, automation and adherence to a marked culture of innovation.

The market under review

As in previous years, this 2015 GRP Market Report is based on a survey and covers all the European countries whose production volumes could be recorded with valid figures. The volume in Turkey has also been considered, but continues to be listed separately as it lacks long-term comparability.

GRP refers to all glass fibre reinforced plastics with duroplastic matrices as well as glass mat reinforced thermoplastics (GMT) and long fibre reinforced thermoplastics (LFT). Another type that belongs into this group is that of continuous fibre reinforced thermoplastics, which are not covered separately here. The European production volume of short fibre reinforced thermoplastics is only available as a total volume and is therefore listed separately.

Carbon fibre reinforced plastics (CRP) will be considered separately in part two of this market report.

GRP production in 2015: overall development

The development of the GRP production volume in the second half of last year, 2014, was somewhat weaker than during the first half. The first half of 2015 met the expectations of most market players, and forecasts for the second half appear to be equally positive, so that we can expect continuous growth for the entire European GRP production volume. It is estimated that the overall European market has increased by 2.5%, to 1.069 megatonnes (see Fig. 1).

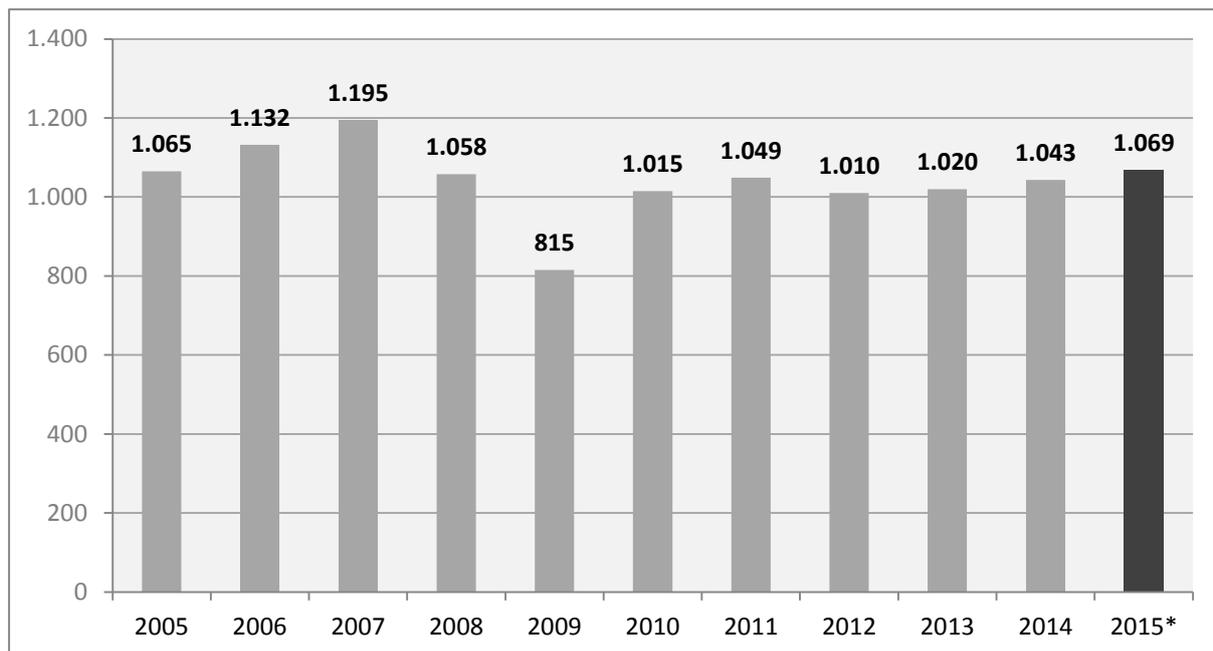


Fig. 1: GRP production volume in Europe since 2005 (in kilotonnes)
(2015* = estimated figure)

The main customer industries for GRP components are transport and construction, i.e. two sectors with relevance to the wider national economy. This is one reason why, under a long-term view, the production of GRP tends to follow general economic developments. Europe's decreasing share in the global gross domestic product (GDP) is paralleled by its steadily decreasing share in the global production volume of GRP, even though its volume is actually rising in absolute terms.

In particular, there has been a clear shift towards Asia and America in the production of commodities (i.e. standard products) over the last few years, especially in the BRIC countries (Brazil, Russia, India and China) with their above-average positive growth. However, in view of the current economic downturn, decreasing economic forecasts and the presence of environmental issues, particularly in industry, it is difficult to forecast forthcoming developments on those markets. Yet despite all insecurities, it is still true to say that the GRP volume in Europe is heading for growth, although its volumes will probably lag behind global developments.

Thanks to sustained growth, the 2015 production level will have been the highest since 2008.

Although a glance at a cumulative value for the European production volume provides an initial idea about the development of the market, it may sometimes give a false impression of what is actually happening. To obtain a genuinely meaningful picture of individual submarkets in the composites industry – an industry which is extremely heterogeneous – we need to break down market developments according to the processing methods used in GRP manufacturing and also according to requirements in each of the application industries and indeed separately for each European country. The following breakdown is therefore extremely necessary for us to derive any meaningful statement on developments in Europe.

Development tendencies of processes/parts

	2012 kt	2013 kt	2014 kt	2015* kt
SMC	188	184	190	191
BMC	70	71	74	74
∑ SMC/BMC	258	255	264	265
Hand lay-up	145	142	138	139
Spray-up	90	90	94	96
∑ Open mould	235	232	232	235
RTM	120	126	132	137
Sheets	78	84	84	86
Pultrusion	47	47	48	49
∑ Continuous processing	125	131	132	135
Filament winding	80	78	79	80
Centrifugal casting	67	66	66	68
∑ Pipes and tanks	147	144	145	148
GMT/LFT	108	114	121	132
Others	17	18	17	17
Total:	1,010	1,020	1,043	1,069

Fig. 2: GRP production volumes in Europe by processes/parts
(kt = kilotonnes, 2015* = estimated figure)

Duroplastic materials

SMC/BMC:

The production of SMC (sheet moulding compound) and BMC (bulk moulding compound) parts makes for a quarter of the overall European volume, so that it is still the biggest segment in GRP production, although its growth has been the weakest (below 1%). SMC is turned into components in a press-moulding process, and BMC in an injection-moulding process. Both methods have been used successfully for many years now, even in large series, showing that composites are perfectly capable of meeting the specific requirements that characterise large quantities. At nearly 45%, the electrical and electronics industries are the biggest area of application for both SMC and BMC. They allow for a broad spectrum of applications, due to their many positive qualities, such as dimensional stability, high thermal resistance, excellent insulation properties and good climate resistance. Applications range from cable distribution cabinets, through housings and panels, to covers, switches and parts of switches as well as control cabinets and connection boxes in buildings.

Alongside the electronics and electrical industries, the automotive industry is the second biggest area, with just over 40% for SMC and just under 40% for BMC. In BMC the best-known end products are probably headlamp reflectors made in large series. SMC components can be found in cars, commercial vehicles and public transport. Typical components are, for instance, boot lids, spoilers, panelling and cabinet parts, as well as oil tanks, covers and micro-components.

But SMC components are also used in construction. Typical applications include cable ducts, manhole covers, light shafts and formwork.

The biggest market in the automotive industry, both for SMC and BMC, is France – even before Germany, followed by Italy.

In the electronics industry Germany comes before France for SMC, followed by Italy, whereas for BMC Germany is just ahead of Italy, followed by France.

It is worth noting that the market for the relatively few European SMC/BMC manufacturers is currently showing various shifts and displacements, there are growing endeavours to focus on specialities.

SMC and BMC are partly competing with thermoplastic materials which are being used more and more widely, especially in the automotive industry. Moreover, it is not possible to develop new markets with new applications within a short period of time. This is a major future challenge for all manufacturers of such products.

Open Mould / Open Processing:

The manufactured volume with its so-called Open Processing – i.e. hand lay-up and fibre spray-up – is the second biggest on the GRP market. Following a downturn in 2012 and 2013 and then stagnation last year, we can expect to see some small growth in 2015, just above 1%.

The overall picture of a highly heterogeneous GRP market can also be observed in the Open Processing segment. In this segment both the company size and the manufactured parts can differ greatly in relation to the sizes of production batches and of the components and also the level of complexity.

Open Processing is mostly used where the manufactured components are very large and/or complex or indeed where only a small number of components is to be manufactured. In addition, Open Processing is often suitable in cases where complex layer structures are required.

Typical applications are, for instance, swimming pools, boat hulls, wind turbine shells, mould construction, shafts, bodyworks for camper vans and trailers, special designs in motor sports, etc.

With Open Processing it is often possible to work very flexibly, to keep mechanical work to a minimum and to use a large variety of different materials. This high level of flexibility means that such processing – which has many of the qualities of craftsmanship – will always have its place in the composites industry.

RTM:

Growth in previous years is also being repeated in the production of RTM (resin transfer moulding) components, with a robust above-average increase of nearly 4%. This volume covers all (infusion and injection-moulding) processes where an enclosed form is applied – processes which can be highly diverse. It follows that this segment covers a very wide range in terms of different processes. In the automotive industry, in particular, a substantial amount of work is currently taking place on the further development of processes – not just on the processes themselves but also the material. The resulting output ranges from small production runs to serial production. Compared with other processes, the benefits are, for instance, differentiated variation options for the process parameters and the possibility of using a variety of raw materials, sandwich materials and indeed (dry) semifinished products and preforms. Moreover, it is possible to apply correspondingly coloured gelcoat surfaces. Also, different processes make it possible to achieve levels of automation which can often be very high while at the same time keeping the cycle time low and complying with tight manufacturing tolerances.

Products can be found in nearly all the relevant areas of application. This includes vehicle construction, wind turbines, boat and shipbuilding, mechanical engineering as well as sanitary engineering, aerospace, sports and leisure.

Continuous Processing:

This year is seeing further growth in so-called Continuous Processing.

For many years panels have been made above all for vehicles, e.g. for truck side panels, for caravan bodies and in the conversion of commercial vehicles. Here, too, there is a major move to be innovative. This includes, for instance, the panelling of operating theatres, using suitable antiseptic laminates, and the production of skis, wakeboards and longboards.

The most important applications for GRP pultrusion profiles can be found in the construction sector, e.g. in the production of bridge elements, railing and ladder systems and in plant construction.

In bridge construction, in particular, “serial application” is prevented by the need for official permits and the lack of standardisation.

The market segments for Continuous Processing have relatively high levels of automation. Yet the processes used by the manufacturers – of whom there are relatively few – differ substantially, as they are adapted, from case to case, to the specific needs of companies, while also being marked by proprietary developments.

Pipes and tanks:

GRP pipes and tanks made under centrifugal casting and filament winding processes are primarily used in the oil/gas and chemical industries as well as in plant construction. The European market has been growing slightly this year, by 2%. It is dominated by a small number of large manufacturers, partly due to relatively large volumes per order and also the enormous administrative and licensing work that often accompanies each order. Nevertheless, the potential continues to be very high as nearly always large volumes are involved, especially in pipeline construction. Suitable GRP systems are almost consistently competing on a major scale with other groups of materials. In the water supply and wastewater disposal sectors, in particular, they are still rather a niche product. If markets can be further penetrated through licences and standardisation activities over the next few years, it will be possible to achieve a large amount of growth.

Thermoplastic materials

GMT/LFT:

Like in previous years, glass mat reinforced thermoplastics (GMT) and long fibre reinforced thermoplastics (LFT) have experienced above-average growth in 2015, reaching more than 9%. Of the total European volume (132 kt), nearly two thirds was LFT and one third GMT. Two-digit growth stimuli are coming from LFT products and from the automotive industry, in particular.

According to a market survey conducted by AVK this year, the future use of LFT in the transport sector will be influenced, above all, by cost requirements.

Moreover, this is a segment where companies are expecting to see a price drop in the currently used process technologies. Other important market drivers are the requirement to reduce weight and the need for specific material properties.

Applications in the automotive industry are generally very diverse. The relatively broad product spectrum is expected to generate considerable growth over the next few years, e.g. in seat structures, underbody protection and shock absorbers. It is also believed that more natural and carbon fibres will be used as materials by 2020.

Research is focusing not only on the development of new products, such as so-called organo sheets, but also – within thermoplastic systems – on so-called multimaterial systems. This includes combinations of different plastics – reinforced and unreinforced – and combinations of metal and plastic systems. Another research focus is the potential application of composite systems in structural components.

Whereas for many years projects largely concentrated on reducing cycles in component manufacturing, a range of other issues are currently becoming central. These include material developments and, above all, measures to ensure continuous quality assurance and optimisation as well as measures to develop integrated manufacturing solutions. Especially in the automotive industry challenges can be also found during the utilisation phase.

Short fibre reinforced thermoplastics:

In addition to the GMT/LFT volumes, which are included in the GRP figures of this market report, there is the large segment of short fibre reinforced thermoplastics. The European market for glass fibre reinforced thermoplastic compounds amounted to about 1,250 kilotonnes in 2014 and was thus somewhat bigger than the GRP market (duroplastic materials plus GMT/LFT) which was reviewed during the same period. With a volume increase of approx. 7% per year, this segment – which is marked by a high level of automation (injection-moulding processes) – delivers far stronger growth stimuli (*source: AMAC*). The largest number of applications can be found in transport, followed by the electrics, electronics, sports and leisure segments.

Application industries at a glance

Despite the different developments on the various markets shown here for each manufacturing process, the share of the big GRP application industries has remained constant in Europe. A third of the entire production volume is manufactured for transport, and another third for the construction industry. Other areas of application are electrics, electronics, sports and leisure (see Fig. 3).

Transport covers the vehicle industry (cars and commercial vehicles) and also locomotives and rolling stock, boats and aircraft. The production of components for wind turbines forms part of the construction industry.

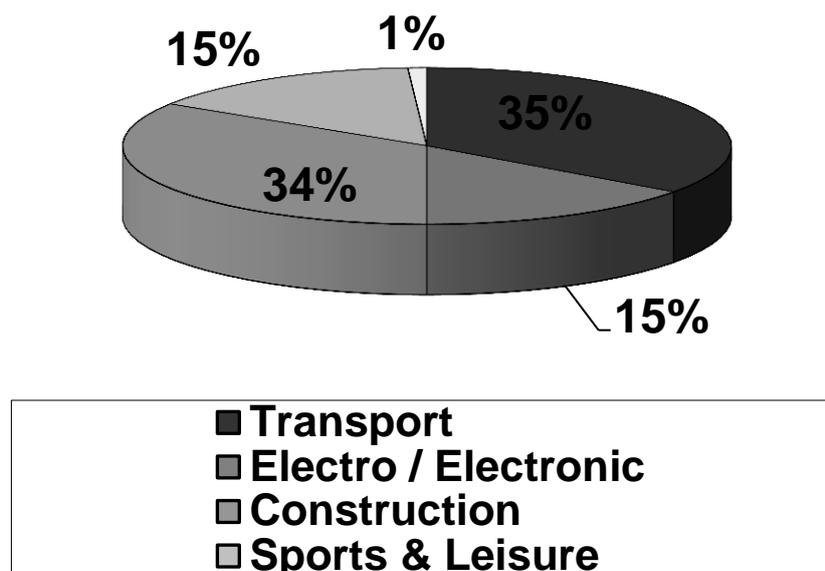


Fig. 3: Breakdown of GRP production in Europe by application industries (year: 2015)

GRP production in 2015: By countries

As well as taking a differentiated look at the overall European GRP volume by different processes/parts, we need to consider developments in different countries, as this is another area where potential differences become apparent.

The countries / groups of countries with the highest growth rates continue to be Germany, the UK / Ireland, and the Eastern European countries. Germany – the biggest European GRP/composites country has had the highest growth rate (6%) in 2015 compared with the previous year and a total volume of 212 kilotonnes. The Eastern European countries under review are developing at a rate of over 4%, and the UK / Ireland at nearly 3%.

The only countries with decreasing volumes are currently Scandinavia, while other groups – albeit at low absolute levels – are remaining stable (Austria / Switzerland) or are growing slightly (Benelux states).

Southern Europe is continuing the development of the previous year: Spain/Portugal and Italy display a small amount of growth, while the production volume is still stagnating in France. These shifts within markets are due to Developments in the various core industries in these countries, such as the automotive and boatbuilding sectors and also construction and infrastructure. The small beginnings of economic growth will impact the GRP industry as well.

For the last few years suitable surveys have also been available for the Turkish composites market. Compared with the European countries covered in this report, this is the biggest GRP market. For the first time, however, its growth has been slightly weaker in 2015 compared with previous years. This market, has been included in the (separate) survey since 2011. According to the Turkish Composites Manufacturers' Association (TCMA), it has grown by about 2%. (*Source: TCMA*).

The biggest growth potential – with a volume share of nearly 50% – continues to be seen in GRP pipes and tanks for infrastructure projects, which is still far the biggest application industry. This is an area where the potential continues to be high, especially for new equipment. Alongside CRP applications, another major growth driver in this area is the automotive and transport sector with a (relatively small) 20% share of the total GRP market.

	2012 kt	2013 kt	2014 kt	2015* kt
UK / Ireland ⁷	134	140	146	150
Belgium / Netherlands / Luxembourg	43	42	43	44
Finland / Norway / Sweden / Denmark	44	44	42	39
Spain / Portugal	160	152	154	156
Italy	152	146	148	150
France	117	112	108	108
Germany	182	192	200	212
Austria / Switzerland	17	17	18	18
Eastern Europe ^{**}	161	175	184	192
Total:	1,010	1,020	1,043	1,069
Turkey ^{***}	195	214	245	250

Fig. 4: GRP production volumes in Europe and Turkey by countries / groups of countries

(kt = kilotonnes / 2015* = estimated figure / Eastern Europe^{**} = Poland, Czech Republic, Hungary, Romania, Serbia, Croatia, Macedonia, Latvia, Lithuania, Slovakia and Slovenia / Turkey^{***} = source: TCMA)

Other composite materials

Although a different impression may be gained from current media reporting and from many conventions and trade shows, GRP continues to be by far the biggest material group in the composites industry. Glass fibres are used for reinforcement in over 95% of all composites (short and long fibres, rovings, mats, etc.).

Of the 8.8 megatonnes of composites produced globally in 2014 (*source: JEC Composites*), 2.3 megatonnes of glass fibre reinforced plastics was produced in Europe.

Of this volume, 1.04 megatonnes accounted for the market which has been shown here in detail for 2014, while short fibre reinforced thermoplastics were 1.25 megatonnes.

The global requirement for carbon fibre reinforced plastics (CRP) has been estimated as 91.000 tonnes in 2015 (see also part two of this market report).

No current market figures are available for components made from natural fibre reinforced plastics (NRP), compared with last year's market report. Used primarily in the automotive sector, 92,000 tonnes of NRP was produced in the EU in 2012, with Germany being by far the biggest market (*source: nova-Institut GmbH*).

Outlook

Composites and GRP are construction materials of the future. This is often emphasised in the (trade) media and many different events.

From the perspective of companies in the composites value chain, it can be seen as totally positive that there should currently be such great interest in future markets, both among the media and in the industry. There are, however, numerous challenges which need to be handled within the composites industry and also by working together outside the industry.

Hybrid and multimaterial systems vs. single material mindset

Quite often we can find rather an insular mindset within the composites industry. A major distinction is made between the individual material groups, e.g. duroplastics, thermoplastics, GRP, CRP, NRP, long fibres, short fibres, etc., though also in relation to different manufacturing processes. The relevant players and interest groups often emphasise the application options of the material or complex of materials on which they focus their attention. When we look at the underlying idea, then this is perfectly understandable. However, in view of competing systems and/or certain specified material properties, this can become a problem.

Take the automotive industry, for instance, it is easy enough to see that composites generally have enormous potential in lightweight construction. Any one-sided focus on a single material solution (e.g. LFT, SMC, CRP or other options) while neglecting other alternatives can ultimately mean that a manufacturing company is not using the best solution for its purpose. In the long term, this will lead to loss in credibility, lack of trust in the material group in general and ultimately losses in market shares.

Instead, it would be good to work together on an expansion of the market, across material boundaries. This also means that if there are any doubts, it is good to abandon one's "own" solutions and, where necessary, to pursue different options.

In fact, it is the only way to obtain long-term market shares and to continue establishing composites as construction materials.

Enforced standardisation and market access

Companies are often rather reluctant to face the idea of standardisation. It is often seen as unnecessary red tape and is therefore avoided wherever possible, only applying the necessary standards where they are expressly required by a customer.

Such companies, however, tend to forget that standardisation does not just cost money and resources, but it can also decide on access and/or barriers to a given market. For many years Germany and Europe have had a leading role in matters of standardisation and have therefore been also able to establish their standards in the international arena. The world and, above all, trade are becoming more and more international. Particularly in Asia the response to this development has not been simply to set up trade barriers – which are often rather difficult to enforce anyway – but to step up their standardisation work.

By enforcing one's own standards, Asian countries can streamline access to its market or at least have some control over it. European industry is currently losing a good deal of influence on international standardisation and is therefore becoming a “recipient” of the corresponding requirements.

Unfortunately, however, this link is hardly ever perceived by the industry as a challenge or as anything that can be impacted. A company can only specify and insist on its own standards if it makes an active contribution to the formulation of standards on a wider platform.

Practical suitability and feasibility

In recent years there has been quite an increase in composite research activities, particularly in the lightweight construction segment. Both in government-sponsored and industrial projects an enormous amount of new knowledge is being generated, covering the complete value chain and also potential options of application.

Like the media interest mentioned earlier, this must be seen as highly positive, as the insights generated in this way benefit both the parties who are involved and the entire industry. Suitable lighthouse projects with a focus on gaining fundamental insights are of major importance to the industry.

Yet it would be desirable if technical considerations could also concentrate more clearly on economic aspects. It would also be good if publications could put more emphasis on business plans, financing models and the actual implementation in industry.

If this aspect is lost or if it recedes too much into the background, then potential customers, who may not know the various materials in detail, will distance themselves even further from those materials. A wrong image is sometimes presented, and it is often falsely believed that enormous costs are involved in terms of raw material, procurement and production. As a result, the materials are sometimes avoided, even though a given solution may actually be rather attractive from an economic perspective.

Daily business vs. future

Composites only unfold their full “power” when products are designed with a view to the loads they need to bear. Yet this factor is only one among many specific features of composites and is communicated within the industry quite naturally. What may not be quite so natural – though it happens frequently – is that the specific knowledge which is needed in order to use composites for design purposes is not yet “generally” available. After all, composites are still being treated as marginal at universities, colleges and vocational schools, while other groups of materials are given far more attention. Yet it is today’s junior talent pool that will eventually make decisions on the use of materials one day. The students of today – with their questions and concerns – are often the potential customers or clients of tomorrow.

Ambition vs. reality

At the beginning of this report we mentioned SMC/BMC materials. These have been used in large-scale automotive manufacturing for many years now. Pultrusion and filament winding are Continuous Processing methods which sometimes involve high-tech equipment. Yet even today we often come across articles and presentations encouraging us to work on solutions to “manufacture composites in large quantities/series”.

Seen against the background described above, such work should actually be superfluous, as serial manufacturing is already in existence and indeed well established. Although there are many endeavours with regard to the serial production of high-performance composites, in particular, it is worth pointing out that they concern specific subsectors of the composites industry. Other materials can be serialised without any problem. To remain competitive, this should be communicated very clearly.

Forecasts vs. development

It is impossible to predict the future, and for centuries now it has been a well-known fact that nothing is as permanent as change. This is also very true indeed for composites. The composites market has been growing steadily over the past few years, even though its growth has not been the same in all segments and regions. It is impossible to predict any detailed growth figures for the next few years. The fact is that composites offer a wide range of options and that their potential often has not been fully developed or is still waiting to be used more fully. Nevertheless, together with all our partners along the entire value chain, we can look forward to a large number of options which, hopefully, will be used in the future. Ultimately, the prevailing material will be the one that offers the best long-term prospects for a given application. This may not necessarily be a composite, but it may well be.

The global CRP-Market 2015

CCeV and the Authors

Thomas Kraus and Michael Kühnel are project architects at Carbon Composites e.V. (CCeV) and have created the CCeV Market report since 2014.

Carbon Composites e.V. (CCeV) is a network of Companies and Research institutes, which cover the entire value chain of high performance fiber composite materials. CCeV links research and business in Germany, Austria and Switzerland.

CCeV sees itself as a competence network to promote the application of fiber composite materials. The activities of the CCeV are directed towards the marketable high performance fiber composite structures product group. The focus points lie on fiber composite structures with plastic matrixes as familiar to the general public from a range of applications, as well as on fiber composite structures with ceramic matrixes with their high resistance to temperature and wear and on high performance fiber composite materials for the construction industry.

The global CRP-Market 2015 General

General

Now in its sixth issue, the composites market report from CCeV and AVK has been published yearly since 2010 and in the meantime has been attracting more and more attention and recognition, also outside the German language spectrum. With a total of 272 members (Status September 2015) CCeV represents a significant number of companies, research institutes and other sundry organisations in the Carbon Fiber and Carbon Composite markets in Germany, Austria and Switzerland.

Almost 63% (a figure of 79,200 tonnes) of the worldwide production in 2014 of Carbon Fibers came from the CCeV members SGL, Toray, TohoTenax, Cytec and Hexcel which underlines the international relevance of the globally active CCeV membership. As part of our contribution our members prepared information and data and also with the help of current market data from among others, Lucintel [1], [2] and Acmite [3] were able to check and complement said information. With regards to structure, the current market report follows that of last year in order to bring you the familiar format and allow for easy comparisons.

Explanation of terms

Because some reports make no mention of how the reported growth rates are calculated, or indeed that these are sometimes mixed up, both of the most prevalent growth rates as well as their calculation, are listed below:

- **Averaged Annual Growth Rate (AAGR)** = Arithmetic Mean Return (AMR) = Arithmetic Mean from n annual growth rates (AGR):

$$AAGR(t_1, t_n) = \frac{AGR(t_1) + AGR(t_2) + \dots + AGR(t_n)}{n} = \frac{1}{n} \sum_{i=1}^n AGR(t_i)$$

- **Compound Annual Growth Rate (CAGR)** = annual growth rate between n years assuming a constant growth in percentage terms: $CAGR(t_1, t_n) =$

$$\left(\frac{A(t_n)}{A(t_1)}\right)^{\frac{1}{n}} - 1 \quad \leftrightarrow \quad A(t_n) = A(t_1)(1 + CAGR)^n$$

This market report calculates growth rates exclusively on the basis of the CAGR as this better represents exponential growth rate relationships when we have constant market growth rates. The represented trend lines in the following diagrams are based on exponential curves also for this reason.

The global Carbon fiber market

The global requirement for Carbon fiber of roughly 53,000 tonnes in 2014, slightly exceeds the expected figures from last year's report. This represents a growth of 14% over the previous year (46,500 tonnes) and when the years after the financial crisis 2009 (26,500 tonnes) are compared, then requirement has doubled. The annual growth rate, taking 2008 as a starting point (31,500 tonnes) is 9.1%, and when 2009 is taken (26,500 tonnes), it is 14.9%.

Total turnover achieved worldwide with CF makes up around 1.98 billion US\$ for 2014. When one compares the figure of 1.77 billion US\$ (2013), we see a growth rate of 11.9 %.

On a whole the demand for carbon fiber has shown steady growth since the general economic recession of 2009 (see Figure 1). The initial strong annual growth rates of over 20% seen after 2009 have reduced over the following years to a normal growth rate of 6.9% for 2013. From 2013 to 2014 we are again seeing a marked increase in the annual growth rate of 14%. With a view to the coming years, it can be assumed that a further slight increase in the annual growth rates will be seen, levelled off at around 12% so that we could break through the 100,000 tonnes of carbon fibers demand mark already in 2020.

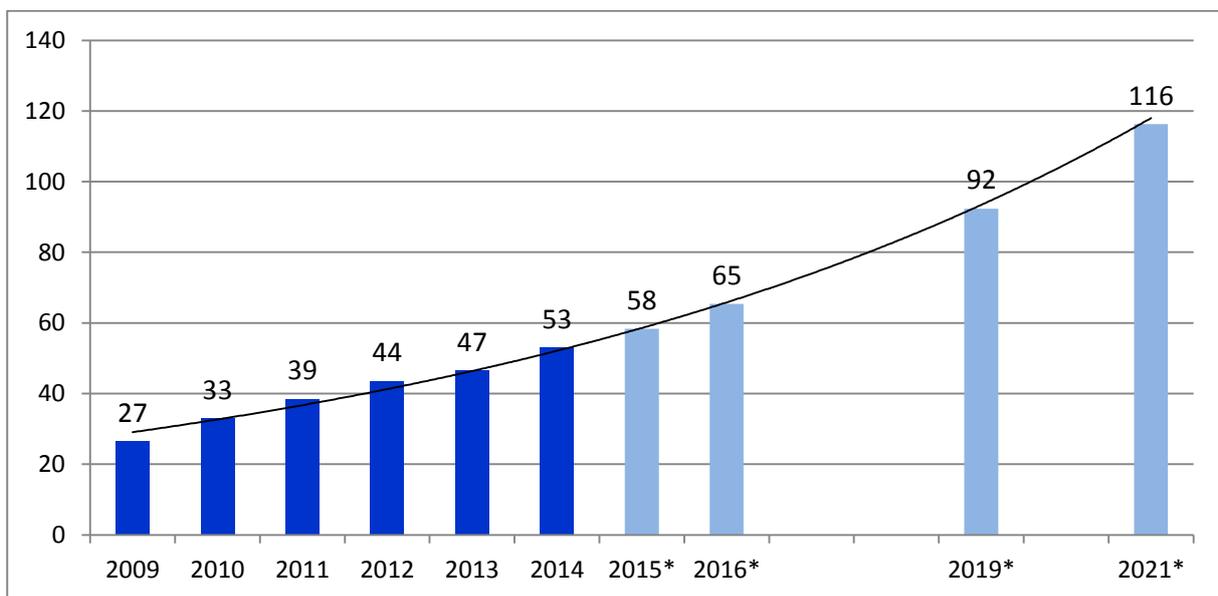


Figure 1: Global demand for Carbon fiber in 1,000 tonnes 2009 to 2021 (* Estimates).

By manufacturer

The takeover of Zoltek by Toray is certainly the most notable change in the overview of the ten leading carbon fiber producers (see Figure 2). The planned acquisition was already public at the end of 2013 and was executed last year. In 2014, the two firms together had a yearly production capacity of 44,500 tonnes of carbon fiber. Toray increased its capacity by 6,000 tonnes to 27,100 tonnes in 2014. [4] [5] With an estimated total global capacity of 125,000 tonnes of carbon fiber on the basis of Polyacrylnitrile (PAN) and Pitch, this encompasses around one third of the global CF market.

Other fiber manufacturers have also increased their CF production capacities, or have an increase planned. Mitsubishi Chemical Holdings Corporation announced that their two subsidiaries Mitsubishi Rayon (MRC) and Mitsubishi Plastics (MPI) will in the future operate together in the carbon fiber business. MRC produces PAN based Carbon fibers, MRC Pitch based fibers. [6] The CF capacity of MRC has been newly evaluated at 11,100 tonnes and a further expansion of the production capacity in Sacramento (USA) has been announced. [7] SGL and BMW have installed two further production lines in Moses Lake with a capacity of 3,000 tonnes in a cooperation already mentioned in last year's report. [8]

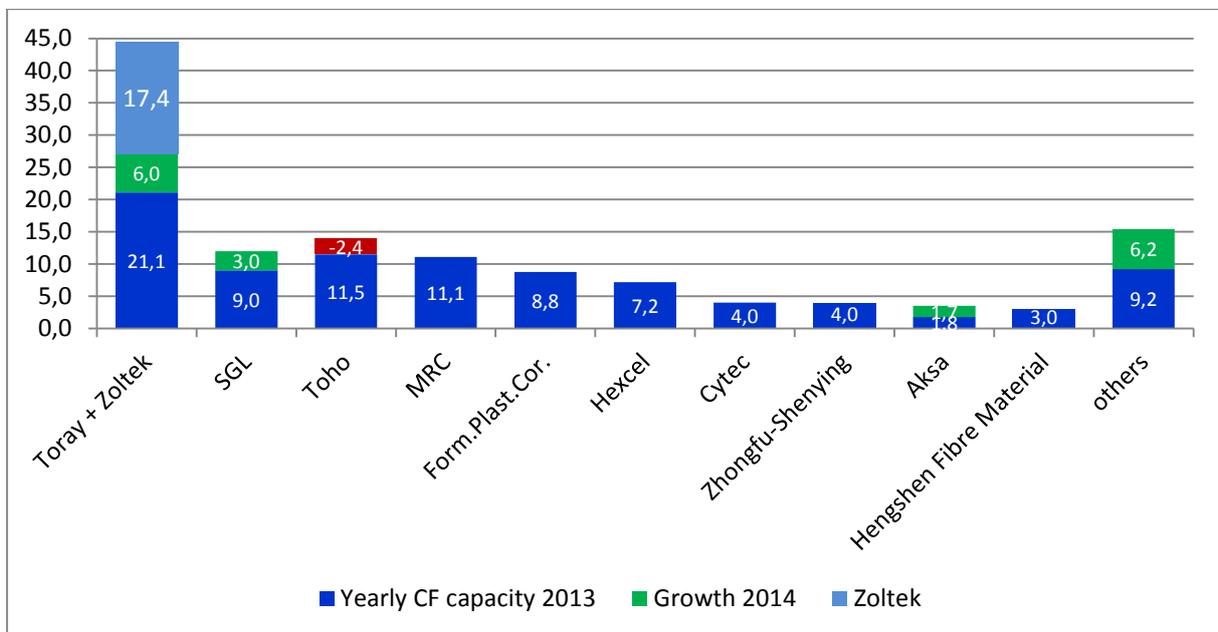


Figure 2: CF capacity by manufacturer in 1,000 tonnes. (2014)

AKSA has doubled its capacity with a second production line and a small expansion of its existing line. [9] Toho Tenax ended its CF production in the USA in 2014; the annual CF capacity therefore was reduced by the 2,400 tonnes lost in the USA, to 11,500 tonnes in total. New entries to the top ten are the Chinese firms Zhongfu-Shenyang and Hengshen Fibre Material with 4 resp. 3 thousand tonnes production capacity.

A relatively large growth can also be observed among the smaller producers summarised under the "others" tag, above all in China (Dalian Xingke Carbon Fiber or Yingyou Group Corp.), South Korea (Hyosung), Russia (Composite Holding Co., Alabuga-Fibre LLC) and India (Kemrock Industries and Exports Ltd.) with production capacities under 3 thousand tonnes. Saudi Arabia is also attempting to gain a foothold in the Carbon fiber market with Saudi Basic Industries Corp. (SABIC). A factory complex with a planned yearly capacity of 2 to 3 thousand tonnes CF should come into operation in 2015.

In total the ten leading fiber manufacturers make up almost 88% of the global Carbon fiber capacity and are still the dominant forces. When one considers the CF demand from 2014, then over capacity is still lying at around 42%.

By region

The yearly production capacity of 125 thousand tonnes divided up among the various regions resp. countries can be seen in Figure 3. As in previous years the most important regions are in Asia incl. the Pacific area with 47%, North American with 31% and Europe with around 20% of the global capacity in tonnage. In particular the Japanese based market leading fiber producers Toray, MRC and Toho account for the high percentage of capacity in the Asian sector. China is also building up its production capacity and has achieved a total of roughly 13 thousand tonnes for 2014 or resp. 10% of global CF capacity. Germany, France and Great Britain remain mostly unchanged and therefore make up a share of 5%, 4% and 3%.

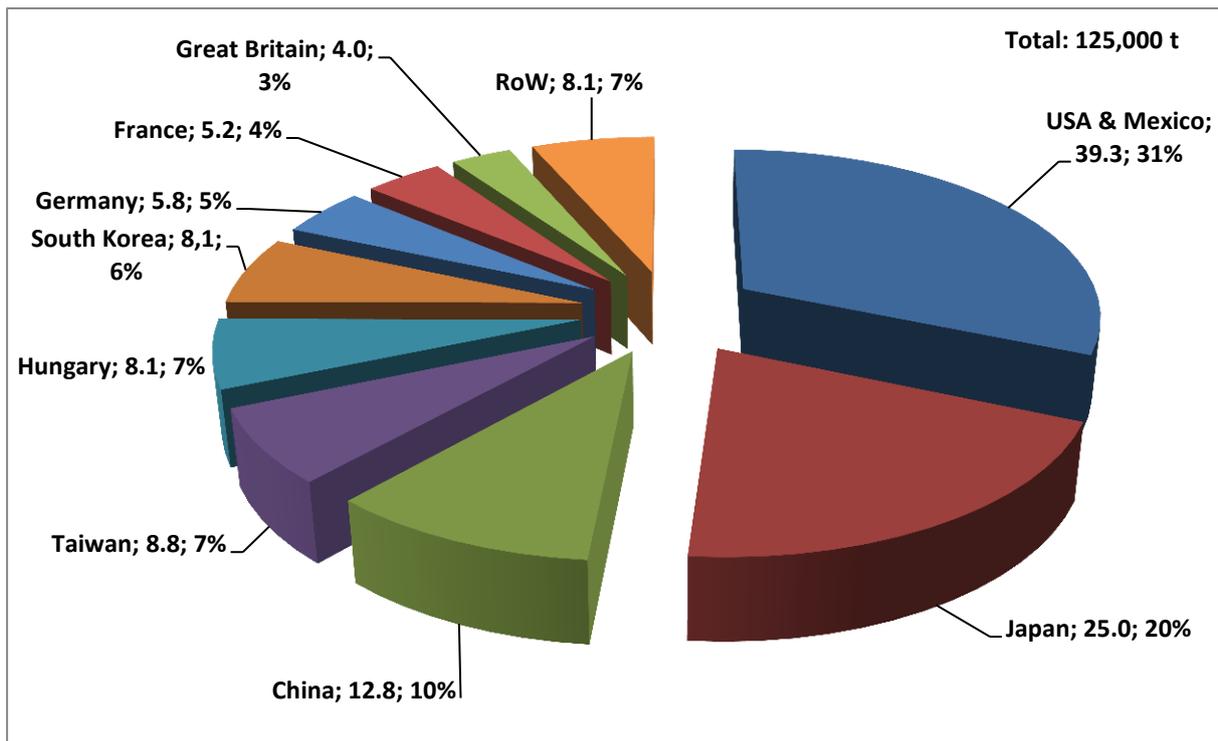


Figure 3: Yearly CF capacity 2014 by regions/countries in 1,000 tonnes.

By application

When the Carbon fiber requirements for various applications are observed (Figure 4) it can be seen that the aerospace industry including defence makes up the most important area of application with a requirement of around 15,400 tonnes of Carbon fibers, roughly 29% of total global requirements, a figure of 53 thousand tonnes. A noticeable increase of 3,500 tonnes is to be observed in the automotive industry which now makes up almost 16% of global CF demand. An important part of that growth comes from the now up and running production of the BMW i3 which has seen 16,052 sold units worldwide in the past year. [10]

The sectors of wind turbines (14 %), sport and leisure (12 %) as well as molding & compound (11 %), make up a comparable share of CF demand to that of 2013, as do the other applications pressure tanks, construction industry and marine.

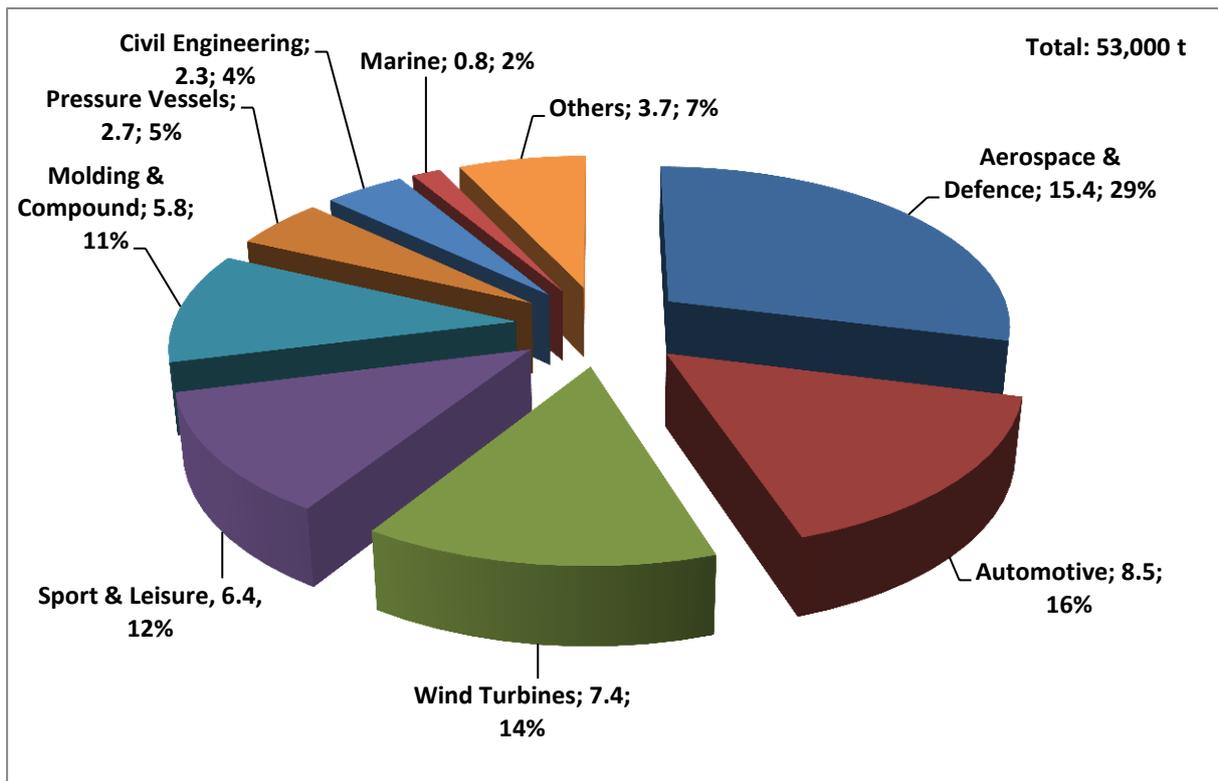


Figure 4: Global CF demand in 1,000 tonnes by application (2014).

When analysing carbon fiber revenues by application for 2014 (Figure 5) it must be taken into account that there are differences between the sectors in terms of the standard manufacturing processes and quality requirements.

In the segment "Aerospace & Defence" for example a figure of 29% of CF manufactured generates 48% of worldwide revenues. Especially in the aerospace industry, in addition to high quality demands, come high costs due to approval processes and material controls. In all the other application segments, the percentage share is lower than the produced amount; apart from sport and leisure the order is comparable to that in Figure 4.

As seen already from the CF demand, the segment of automobile construction has witnessed a notable increase when it comes to revenues, and has pushed itself slightly ahead of the segments sport and leisure, wind turbines and molding & compound. Otherwise there are no major changes in comparison with the turnover from 2013, at least with regards to the percentage share.

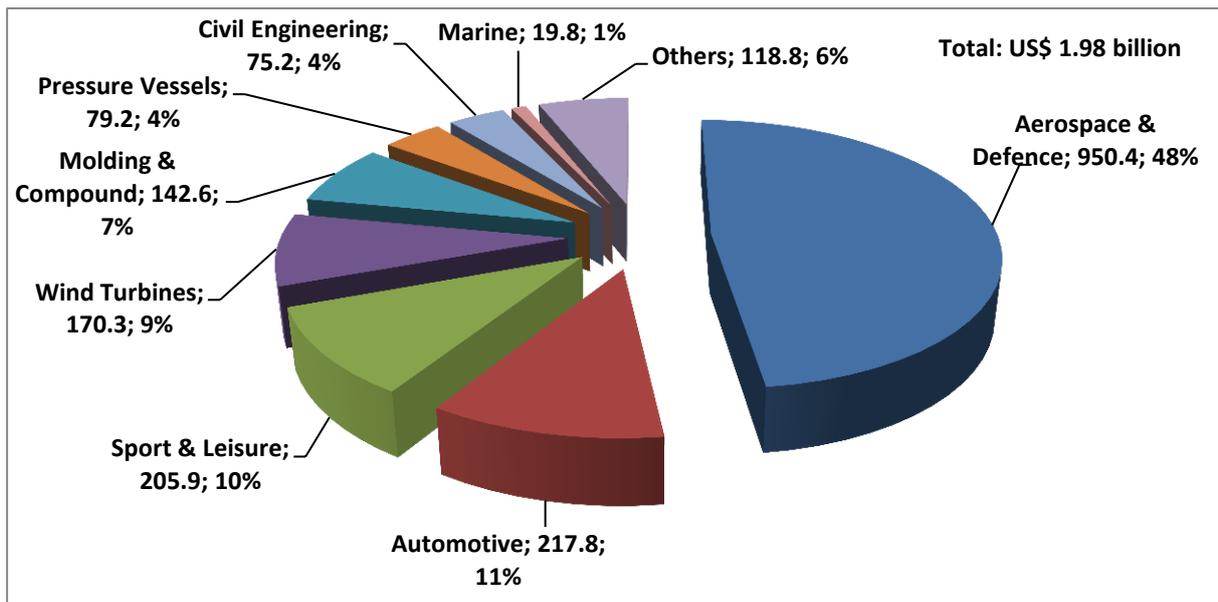


Figure 5: Global CF turnover in US\$ million by application (2014).

The global Carbon Composites market

The majority of manufactured carbon fiber is further processed to carbon composites, which is carbon fiber embedded in a matrix. The CC market is developing more or less analogue to the CF market, however because of the matrix component, the amounts mentioned below will be significantly higher.

Figure 6 shows the development of global CRP demand referring to the produced amount in tonnes. From 2013 to 2014 we can see growth of around 15 % from 72,000 to 83,000 tonnes. An annual growth rate of 11% is assumed for further development so in 2021 we see a CRP demand of 175,000 tonnes as being possible to achieve. The European regulations for the reduction of CO₂ emissions, together with the efforts in the USA to achieve more efficient fuel consumption with lightweight construction are the keys to an increasing share of CRP in the aerospace industry and especially in automobile construction. Both applications are seen as the driving forces behind growth over the next years.

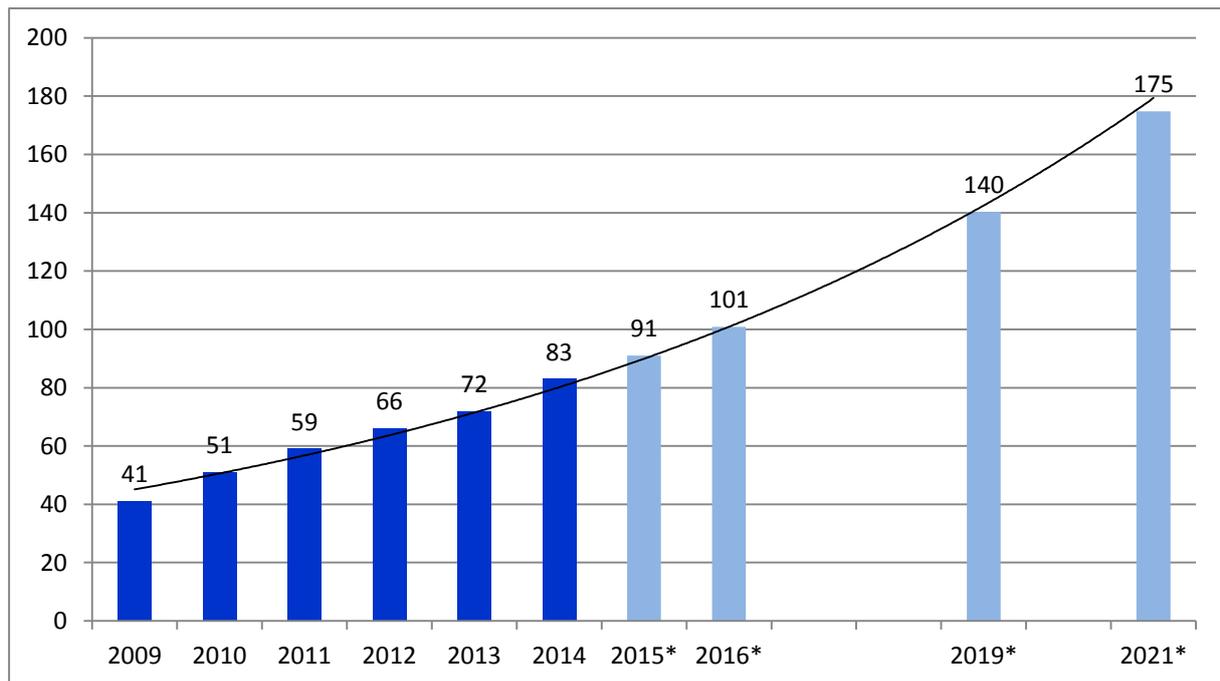


Figure 6: Global CRP demand in 1,000 tonnes 2009–2021 (*estimates).

By matrix

Carbon fiber is used almost exclusively to strengthen various matrices. Alongside carbon, ceramic and metal for materials used in special applications, the following shall focus mainly on carbon fiber reinforced plastics (CRP). Total revenues for carbon composites in 2014 were 16.6 billion US\$, of which CRP accounted for 10.6 billion US\$ (Figure 7). Composites based on a polymer matrix accounted for 64% of the total revenue achieved with CC in 2014, which is on a par with 2013. [3]

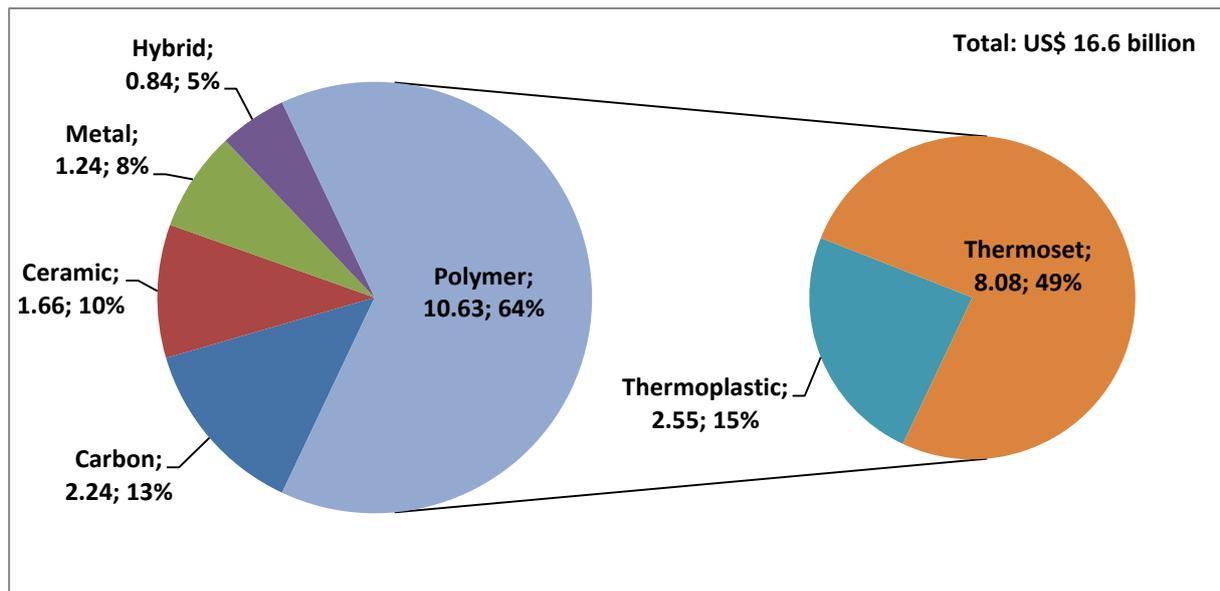


Figure 7 7: CC revenues in US\$ billion by matrix material (2014).

The matrix polymers used in CRP production can be further divided into thermoplastics and thermosetting plastics (see pie chart right Figure 7). Thermosetting plastics continue to be the most commonly used polymer matrix for carbon fiber. This is also reflected in the revenue shares of these two polymer types in the total CRP revenues. The reasons behind the establishment of the use of thermosetting plastics are for example:

- good mechanical properties
- temperature resistance
- low moisture absorption
- lower material costs for the user (less added value for the material manufacturer)
- large choice of matrix systems, material producers and production processes

Thermoplastics on the other hand have advantages which will probably see them being more widely used in the future, like:

- short processing times (no chemical reaction required as with thermosetting plastics)
- impact resistance, high damage tolerance

- easily formed and welded
- problem free storage
- easily recyclable

Elastomer matrices are not in common use at the moment, however they may have more acceptance in the future for e.g. elastic hingeless shaft connections in mechanical engineering applications.

The authors would like to address the often-put question about the sustained high prices for "ready-to-use" CRP components in connection with growth in the sector:

If one divides the revenues achieved with CRP of 10.6 billion US\$ by the worldwide demand in 2014 of 83,000 tonnes, one can infer an "imaginary" (averaged over all branches and applications) price per kilo of **128 US\$**. Even if this figure has not a high significance in reality, it does demonstrate that despite on-going calls for ever cheaper kilo prices particularly from the automotive industry for finished consolidated and bordered CRP components (partly 25US\$/kg and less) that the sizeable average of the branch lies over this figure and that the market is still showing constant two digit growth rates. The branch-wide cheapest achievable kilo price is only the edge of the Gaussian distribution. Even when reduced process costs continue to fall, the branch average for finished components will continue to lie well above this figure in the future. But this has not caused any problems to the notable developments of the past 5 years (demand doubled).

By manufacturing process

A variety of different production processes are used in the manufacture of CRP materials/components (see Figure 8). When compared to last year's market report, Layup processes using prepregs have seen a notable increase from 37% to 45% in market share. At the same time pultrusion and winding processes have dwindled from 40% to 26%. These changes can partly be attributed to the increased application of thermoset prepreg material in fiber placement as well as tape laying processes especially in civil aviation construction (above all A350 and B787).

Additionally one should be careful when comparing the figures with last year's report as then the figures were referring to **CRP revenues in US\$**, whereas this year on account of changed databases in production processes, they refer to **CRP demand**

in 1,000 tonnes. A correlation between various production processes regarding amounts produced and the turnover created, is not familiar to these authors.

This effect is overlain by the various groupings of manufacturing processes through differing sources (Acmite und Lucintel amongst others). There are several winding processes e.g. for pressure tanks in the aerospace sector or mechanical engineering, which use thermoset preregs. The winding bodies will be compacted in a subsequent heating process (not autoclave) through a vacuum build up as well as thermic expansion of the winding spindle. This sample process should demonstrate the difficulty and uniqueness of categorising some of the many production processes and their modifications.

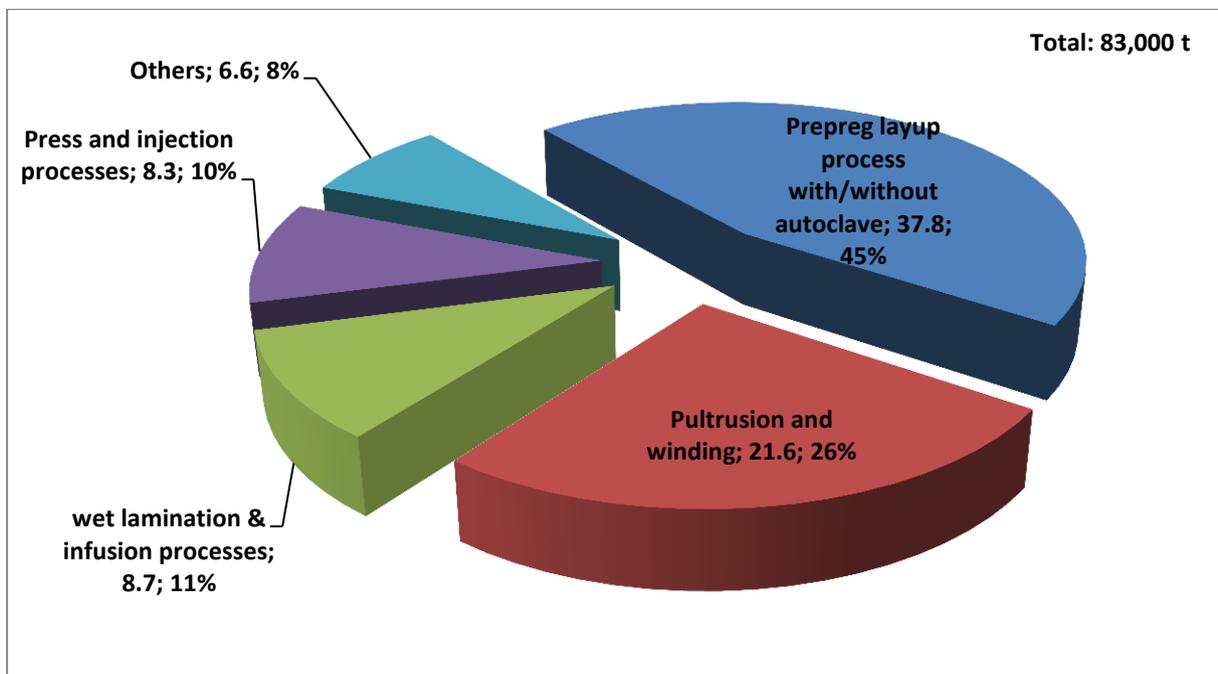


Figure 8: Deployment of production processes CRP in 1,000 tonnes (2014).

Wet lamination and infusion processes have maintained their figure of 11% and are playing a continued important role in small and minimum series production for small and medium sized companies. Pressing and injection processes have gained in importance with a figure of 10% which has justified the expectations of market analysts, like RTM, through the increase in production of the BMW i3.

By region

Figure 9 shows the demand in tonnes for Carbon Composites by region. The lion's share of global CC demand lies once more in North America and in the USA in particular with 38% or 40,000 tonnes resp. Driven by the aerospace and defence sectors, North America represents the most important economic zone. Next comes Europe with 35 %, where in addition to aerospace, the wind turbine, automotive and mechanical engineering sectors dominate the market. Alongside the Japanese fiber producers Toray, MRC and Toho, the Asian region including the Pacific region is carried by the emergent wind turbine sector. In India they are continuing with the initiation of a home produced airplane and China is also forcing its way onto the market through the Commercial Aircraft Corporation of China (Comac) and is attempting to compete with the A320 and B737 with their C919. In total, Asia and the Pacific region account for 23% of global demand.

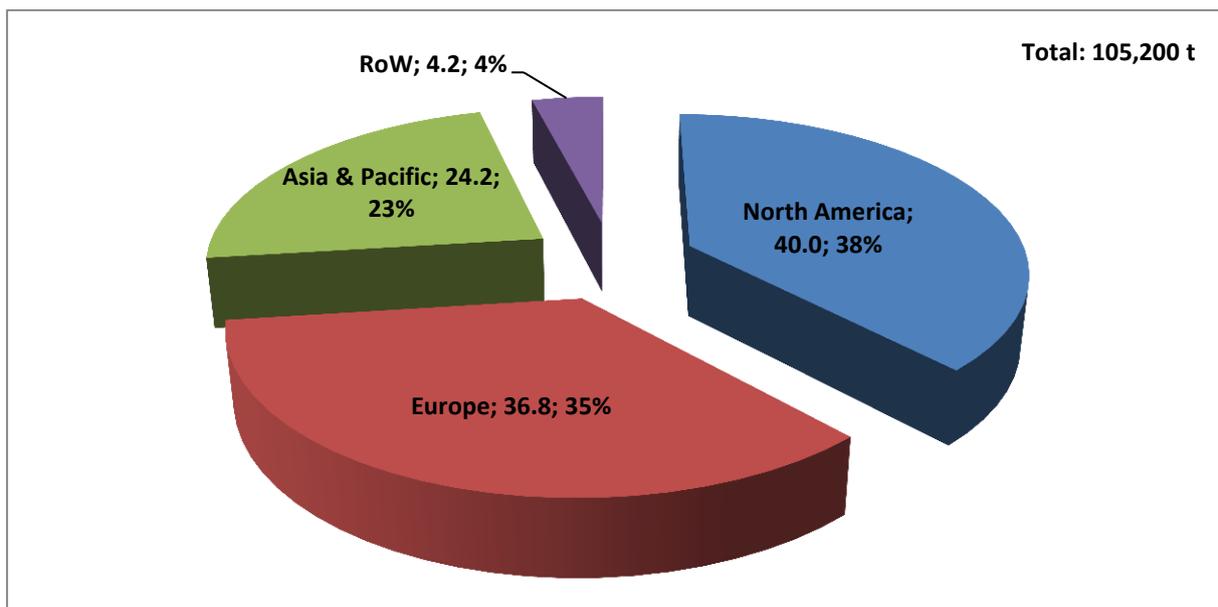


Figure 9: CC demand in 1,000 tonnes by region (2014).

By application

Similar to the CF market, the most important market segment in the CC market is aerospace including defence with about 31% of global CC demand at 105,200 tonnes. (Figure 10) Commercial aviation above all showed a steady growth rate of 7% over the past year in supplied units. Boeing delivered 114 B787s in 2014, almost double the figure of the previous year.

Airbus are completing 25 to 30 units of their A380 yearly and have 150 orders still open. A major component of both models are composite structures, accounting for 28% in the A380 and around 50% in the 787.

The automotive sector has the second largest percentage with 21% or almost 22,000 tonnes CC. As announced, BMW has increased production of the i3 over the course of 2014 to about 100 units per day; the sports car i8 is also on the increase with 10 cars per day being produced and an upward trend reported. [11] The cooperation with SGL to expand the production capacity of CF in Moses Lake emphasises that the Bavarian car manufacturer sees a high potential in lightweight construction with Carbon Composites and is sounding out the market for electric or hybrid sports cars with its i-projects as well as striving to gain experience in their dealings with carbon fiber composite materials. Next in importance are wind turbines and sport and leisure with 12% each, civil engineering with 5% and marine with 1%.

Figure 11 shows the same breakdown, however by revenues in billion US\$. It should be considered that for the subdivision of turnover by application, the various areas of application are differentiated with regards to standard production processes or quality requirements. 62% of worldwide revenues with 31% of total CC tonnage came from the sectors of aerospace including defence, but on account of the high quality demands amongst other factors, costs are incurred for approvals and material testing. In all other application areas the revenue share is reduced, the order however remains the same as that of CC demand.

If one is to calculate an "imaginary" branch specific kilo price from CC revenues and CC demand, then the results would be as follows:

Aerospace & Defence:	317 US\$/kg	Wind turbines:	98 US\$/kg
Automotive:	87 US\$/kg	Sport & Leisure:	91 US\$/kg

While it was to be expected that aerospace and defence would have the highest price it is somewhat surprising that the average value for automotive lies in a region which is far removed from the minimum demanded in the branch. Of course this can be partly explained by sports and premium applications in automotive construction.

However the suspicion remains that, as mentioned in Chapter 4.1, the expected minimum values represent only the lowest limit of what will be a broad spectrum, also in the future. These figures should also be treated with caution, even if they provide for optimism, about the price segment prevalent within the industry.

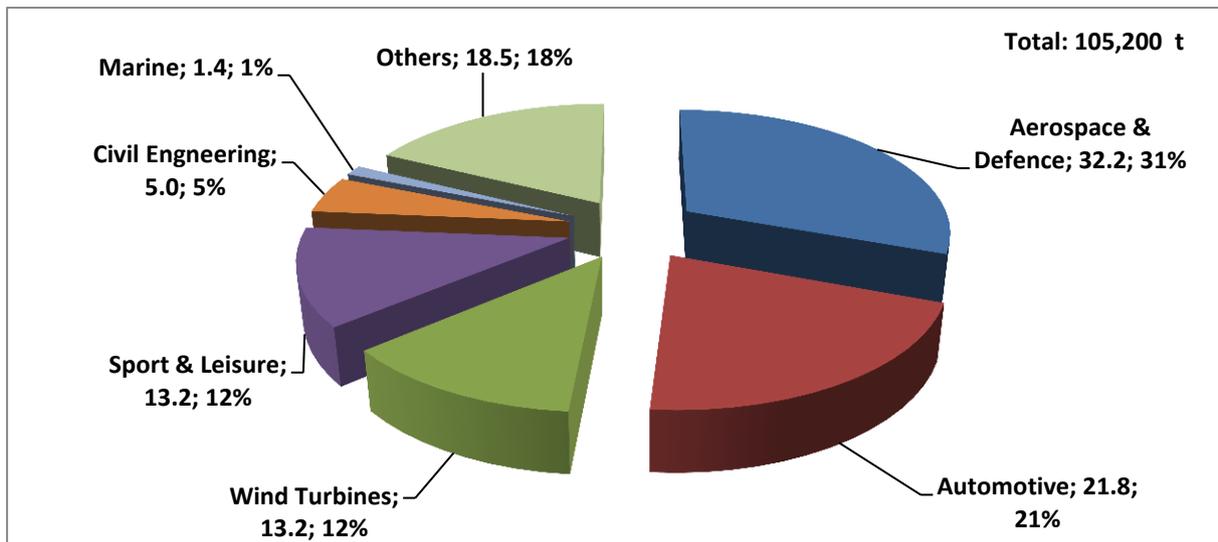


Figure 10: CC demand in 1,000 tonnes by application (2014).

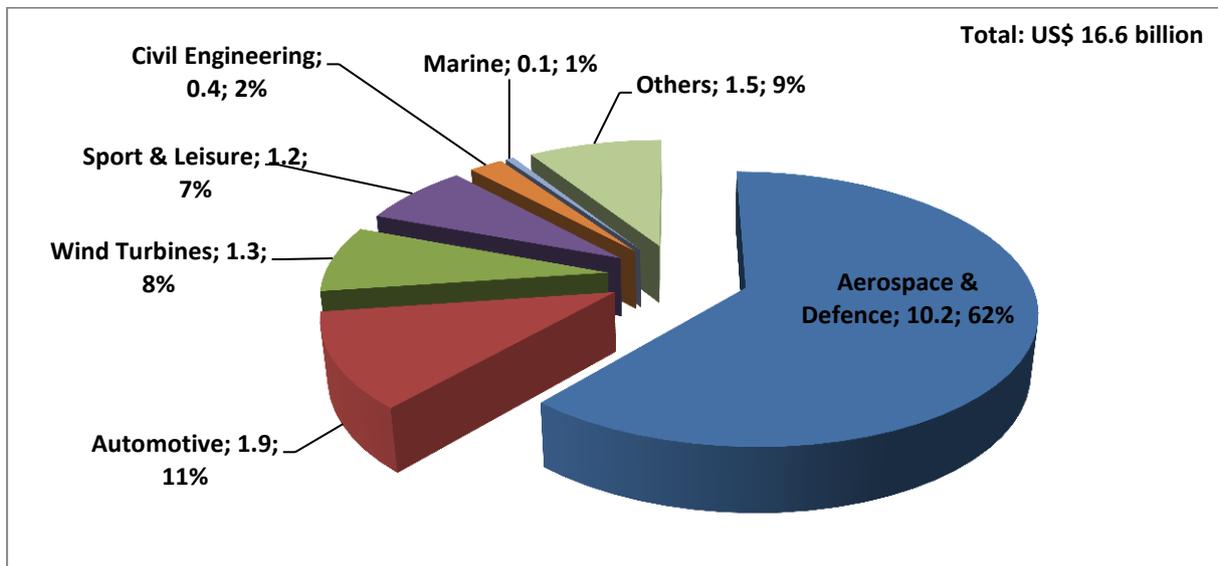


Figure 11: CC demand in US\$ billion by application (2014).

Trends and outlook

The global **Carbon fiber market** has been showing an excellent, stable growth rate since 2009 and indeed the development over the past year has been better than

expected (Figure 1). For this reason the average annual growth rate of 12% has been assumed for the next few years. In 2020 we can break through the 100,000 tonne mark for CF demand. Revenues from CF came to almost 2 billion US\$ in 2014 and we are also assuming a growth rate of 11% here, which means that in 2021 a global figure of 4.3 billion US\$ can be achieved

By region (CF)

These positive developments are being supported by the investment plans and cooperation's of many fiber producers:

- SGL and BMW have already increased the annual production capacity in the plant in **Moses Lake** from 3,000 to 6,000 tonnes. In the medium term a third expansion step will raise the capacity to 9,000 tonnes. [8]
- Mitsubishi Rayon will increase its production capacity in its CF **Sacramento, California plant** by the middle of 2016 by 2,000 tonnes, thereby doubling its total capacity. [12]
- Zoltek is planning to double its global production capacity by 2020. In April 2016 its plant in **Guadalajara, Mexico** will double its capacity to 5,000 tonnes. [13]
- Ford and DowAKSA have agreed a cooperation to drive the cost effective production of CC components through joint research and development. This should occur under the framework of the "Institute for Advanced Composites Manufacturing Innovation" (IACMI) which is based in welches in **Knoxville, Tennessee**. [14]
- Hexcel is investing 250 million US\$ in the construction of a new factory for CF production in **Roussillon, France**. The construction will begin in September 2015 and should be completed in 2018. They are also investing 22 million in their nearby plants for weaving and production of prepregs between now and 2018. [15]

Unfortunately the authors have no comprehensive figures available to enable them to create a graphic representation of the global situation. It is however clear that the CF and CC "hot-spots" in the USA and Europe would be well advised to equip

themselves for competition from their growing rivals from Asia in the future, particularly as major state subsidies have been recently announced or are expected for the CC and CF sectors.

By application (CC)

A similarly notable growth has been seen in the **Carbon Composites market** with total revenues in 2014 of 16.6 billion US\$, wherein the lion's share comes from CRP with 10.6 billion US\$ or 84,000 tonnes. The main drivers of these markets are, alongside aerospace and wind turbines, the growing applications of CRP in the automotive sector and industry. Market analyses are predicting a yearly growth rate of around 10.6 %, resulting in CC revenues of 33.6 billion US\$ in 2021. Based on a similar proportional growth by matrix, the revenues from CRP will increase to 21.5 billion US\$ resp. 175,000 tonnes annual production by 2021. This corresponds to a CRP kilo price of **123 US\$/kg** when averaged over all branches and applications which underlines the authors assumptions in Chapter 4.1, as well as the strict differentiation between a "cheapest achievable" price and CRP price averaged from all the branches.

The application of CC in the aerospace and defence sector will also show strong yearly growth rates of up to 13%. The future projects like A350XWB, which will be constructed with a Composite share of 53 % [9] or the Boeing 777X with CC wings [10] show that both producers are planning for increased future demand after the lifetime of the A380 or the 787.

The establishment of high performance carbon composite materials in the automotive market sector depends in the main on whether an automated highly efficient production of CC components will result in prices cheap enough for the wider application in middle class cars and not as present only in the luxury and sport cars segment.

That is why the technical objective (among others) of the top cluster project "MAI Carbon" is the reduction of process costs by 90% in comparison with a state-of-the-art aerospace approved hand rest process from 2010, reducing the material costs by 50% as well as reducing the cycle times to under a minute. [16] As soon as these

very ambitious targets can be reached a comprehensive application of CC in the automotive, mechanical engineering and plant construction industries is to be expected. BMW has taken on a leading role with their i-project, however the other leading automotive manufacturers are somewhat reserved in their enthusiasm.

Figure 12 shows a prediction of CC demand in thousand tonnes up to 2021, by application. It is expected that in summary a markedly higher share of CC will be used in automotive construction and that by 2020 a higher percentage will be used in this industry than in aerospace and defence. With a predicted total demand of 220,000 tonnes by 2021, one third will be for automotive construction, one quarter for aerospace incl. defence, followed by the other applications wind turbines, sport and leisure, construction (civil engineering) and marine with similar percentage shares as in 2014. (Figure 10)

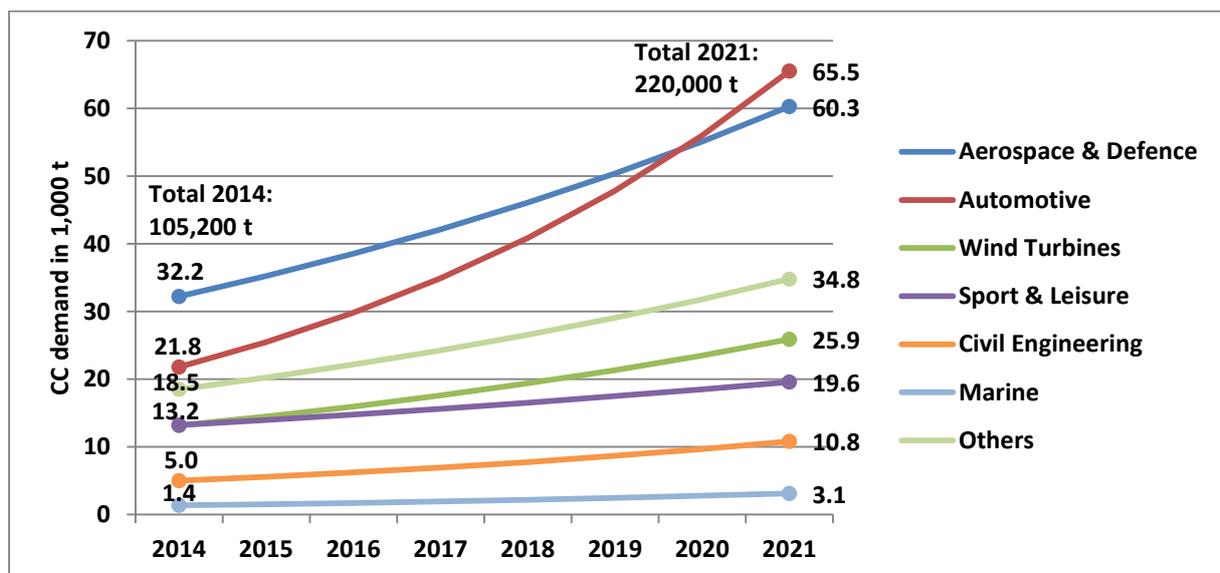


Figure 12: Predicted CC demand in 1,000 t by application up to 2021.

Comparison with Composites Germany market survey

A very positive market outlook can be inferred from the twice-yearly market survey carried out by the four largest organisations from the composites industry in Germany, AVK, CCeV, CFK Valley Stade and VDMA Forum Composite Technology under the umbrella of Composites Germany since 2013 among their members.

Following on from the positive trend determined in the survey from the second half of 2014, the results for the first 6 months of 2015 show once again a positive evaluation of the business situation. 90% of those surveyed pronounced the worldwide business outlook as either "mostly positive" or "very positive" (this was 2/3rds in the previous survey). Europe was positively evaluated as a business region by over 80% of those surveyed with CRP as the growth driver among the composite materials. [17]

This trend fits very well into the picture of positive outlook found in this report and provides hope that the two digit growth rates of 2014 can be sustained for the future and indeed even exceeded.

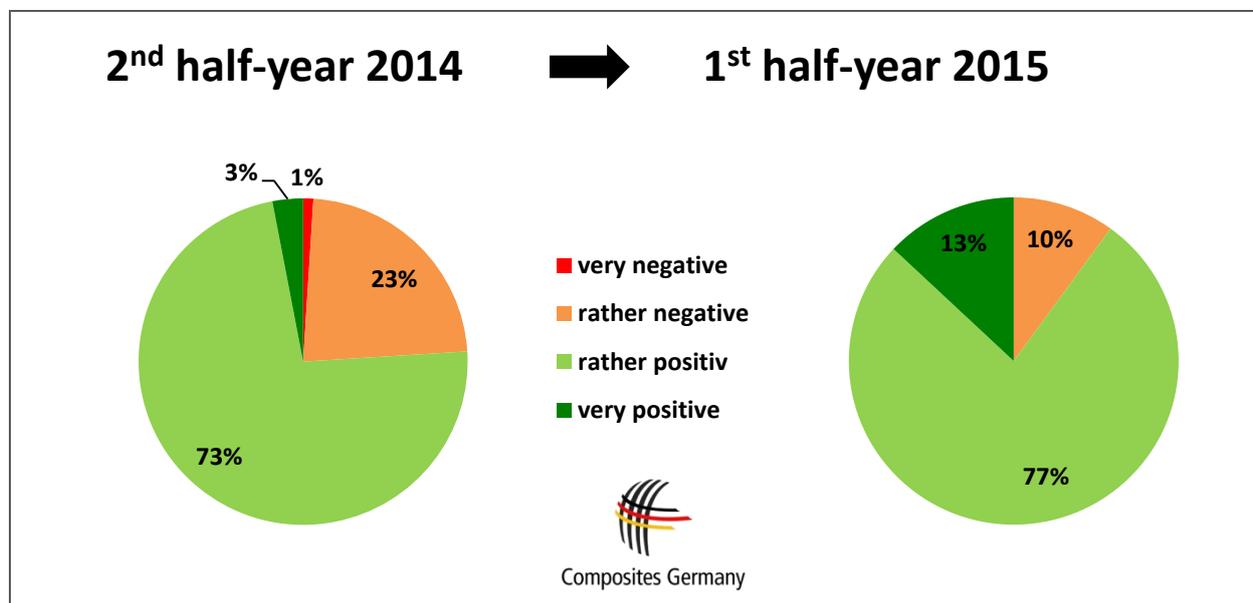


Figure 13: Evaluation of the current business outlook (worldwide). [17]

Final observations

After the years of recovery from the financial crisis were marked by an above average growth rate of 25% (CF demand 2009→2010) this went steadily downhill to 7% (CF demand 2012→2013), but 2014 bucked the trend: the global carbon fiber market showed growth of 14% in CF demand, which is a much higher rate than in recent years. Demand was 53,000 tonnes of carbon fiber and revenues of almost 2 billion US\$.

This strong growth is also evident in the CRP market with 83,000 tonnes produced and a turnover of 10.6 billion US\$ in 2014. When one takes the entire Carbon Composites Market, total revenues are 16.6 billion US\$. A stable growth rate of 11% per annum is expected over the next few years. The sectors of aerospace including defence, automotive, wind turbines and sport and leisure are the major driving forces behind this growth.

The automotive branch shows enormous growth potential, as long as the mass introduction and establishment of Carbon Composites actually occurs. The strong growth in demand expected could exceed that of the aerospace and defence sector by 2020. The most important criteria here are the price developments of CF and CC as well as the reduction of process cycle times. This uncertainty makes the forecast of future CF/CC demand as well as the revenues in the automotive sector a less than exact science.

Even conservative estimates predict an extremely vibrant future market. However the industry must also overcome a number of hurdles for example in automation, cost cutting and the development of manufacturing processes suitable for mass production. The price-performance ratio will then decide which materials or combinations of materials will be adopted in which application areas. Ecological aspects (if these are demanded by lawmakers or are not economically disadvantageous) are likely to assume greater importance than pure economic considerations in the future.

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