Composites Market Report 2016

Market developments, trends, outlook and challenges

The **GRP**-Market Europe – Dr. Elmar Witten (AVK)
The global **CRP**-Market – Thomas Kraus, Michael Kühnel (CCeV)

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Content

The European GRP-market 2015

Author

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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.

1. The European GRP Market in 2016

Continuous production volume growth in virtually all market segments

The volume of glass fibre reinforced plastics (GRP) manufactured in the European countries considered in this report will grow by over 2.5% in 2016. Growth will thus continue at the same rate as in 2015. Total production is forecast to reach 1.096 million tonnes.

Glass fibres are still by far the most commonly used reinforcing material in fibre reinforced plastics and composites. Glass fibres are the material of choice for approx. 95 % of all composites. However, the European GRP market – this report will subsequently examine its various segments in more detail – is not growing as rapidly as the composites industry in other regions of the world. Europe's overall share of the global market is therefore generally continuing to decline. This is due not least to globalisation and the relocation of production facilities for "commodity products" to countries with different wage structures and production technologies.

The most rapidly growing European GRP market segments are currently SMC/BMC semi-finished products and the thermoplastic materials (LFT and GMT) also considered in this report. These segments primarily serve the transport sector but are also relevant in the electro/electronic industry and some areas of infrastructure applications. In general, the area of thermoplastics – including short fibre reinforced thermoplastics which are not studied here in detail – is growing more strongly than that of thermosetting materials.

Germany is the largest manufacturer of GRP in the region and – like the Eastern European countries included in this report – is also experiencing the most rapid growth. However, production in Scandinavia and Southern Europe also grew in 2016. Last year, these were less dynamic markets.

2. Markets considered in this report

As in previous years, the European GRP Market Report 2016 is based on a survey of those European countries, for which production figures can be recorded and validated. Turkish production is also considered but still stated separately due to the lack of data for long-term comparison.

The report aims to provide a view of the market which is consistent over the medium to long term. In the following, the term GRP refers to all glass fibre reinforced plastics with a thermoset matrix as well as glass mat reinforced thermoplastics (GMT) and long fibre reinforced thermoplastics (LFT). This group includes the area of continuous fibre reinforced thermoplastics which are not considered separately. Data on European production of short fibre reinforced thermoplastics are only available as an overall quantity and therefore stated separately.

Carbon fibre reinforced plastics (CRP) are dealt with separately in the second section of this market report.

3. GRP production in 2016: Overall development

The growth in GRP production volume observed last year has continued in 2016. As in 2015, the first six months of the year correlated closely with the forecasts and expectations of most market participants. The second half of the year is slightly below expectations. As in 2015, the European GRP market is expected to grow by 2.5% to an estimated total of 1.096 million tonnes (see Fig. 1). The overall percentage growth rate of the GRP market thus continues to outpace that of the European economy as a whole. However, the market trends vary widely depending on the specific European country in question as will be shown in this report.

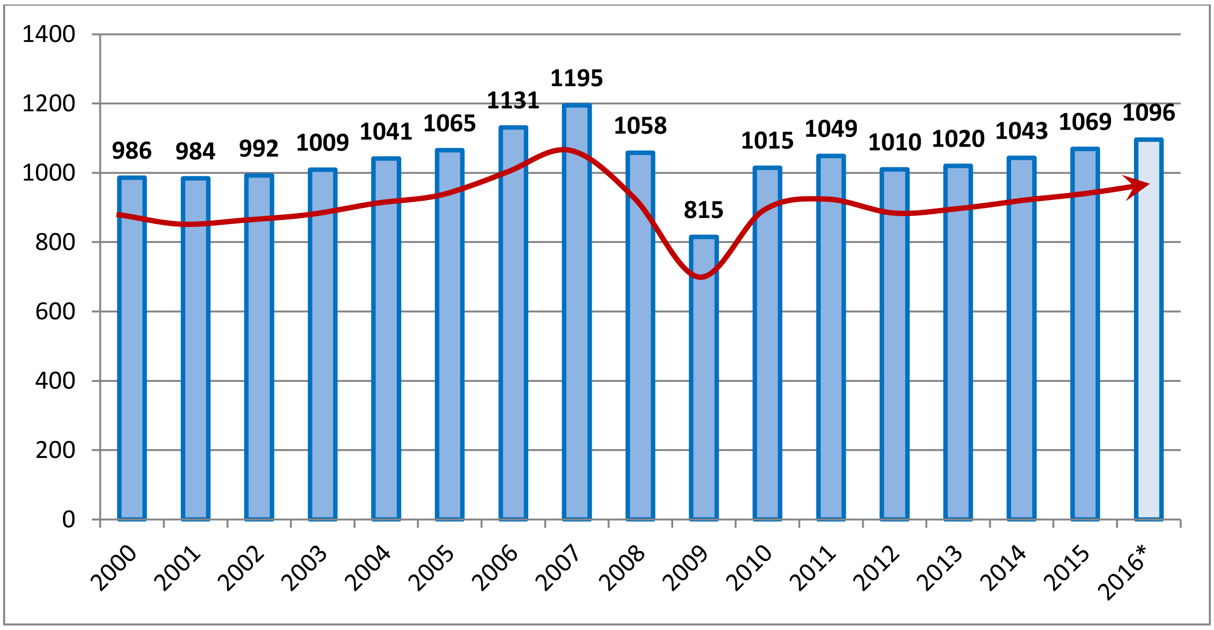

Figure 1: GRP production by volume in Europe since 2000 (in '000 tonnes)

(2016* = estimate)

The largest buyers of GRP components are to be found in the transport and construction sectors which each consume around one-third of total production and play a major role in national economies. This is one reason why the long-term trend for GRP production tends to follow the growth of the economy as a whole.

Significant changes in vehicle production in individual countries or a booming construction sector have an immediate knock-on effect for suppliers and thus for the GRP industry. Nevertheless, no rapid expansion of production (similar to that seen in the CRP segment) is to be expected in the near future. Firstly, this is due to the well-established and very considerable level of existing production. Even strong growth in individual segments has a relatively small impact on total production. Secondly, composite components are very diverse. They are used in an extremely wide range of applications. Fluctuations in one industry are usually “smoothed out” by other applications.

Europe’s share of global composites production continues to decline – despite its absolute growth in total production over recent years. Processing of commodities (standard products), in particular, has clearly shifted towards Asia and America over this period. In short, GRP production in Europe continues to grow but will probably lag behind the global trend.

This overview of the cumulative value of European production is useful in providing an initial indicator of the market trend as a whole. However, it does not reflect the widely differing trends in the continent’s various countries/regions, applications and manufacturing sectors. A truly meaningful assessment of the individual markets that make up the composites industry requires a more detailed study of the specific markets/segments.

4. Trends in the development of processes/components

	2013 Kt	2014 Kt	2015 Kt	2016* Kt
SMC	184	190	191	198
BMC	71	74	74	76
∑ SMC/BMC	**255**	**264**	**265**	**274**
Hand lay-up	142	138	139	140
Spray-up	90	94	96	97
∑ Open mould	**232**	**232**	**235**	**237**
RTM	**126**	**132**	**137**	**141**
Sheets	84	84	86	89
Pultrusion	47	48	49	50
∑ Continuous processing	**131**	**132**	**135**	**139**
Filament winding	78	79	80	80
Centrifugal casting	66	66	68	68
∑ Pipes and Tanks	**144**	**145**	**148**	**148**
GMT/LFT	**114**	**121**	**132**	**140**
Others	**18**	**17**	**17**	**17**
Sum:	**1,020**	**1,043**	**1,069**	**1,096**

Figure 2: GRP production volumes in Europe according to processes/components

(Kt = kilotonnes, 2016* = estimate)

4.1 Thermosetting materials

Most GRP components are made from a thermoset matrix based on a polyester, vinylester or epoxy resin. Unsaturated polyester resins are still by far the most commonly used. Glass fibre used for reinforcement generally contributes between 15 % and 70 % of the material used in these composites depending on the manufacturing process and application. The average proportion of glass used over all segments is around 25-35 %.

SMC/BMC:

Large scale series manufacturing processes for composites are currently a hot topic in the media. Yet these have been a reality for SMC (sheet moulding compound) and BMC (bulk moulding compound) components for many years – with production of some components even exceeding 100,000 pieces per year.

SMC and BMC semi-finished products are turned into components using pressing (SMC) and injection moulding (BMC) processes. They are primarily used in the electro/electronic sectors and the automotive industry. While the SMC/BMC segment had the weakest GRP production growth last year, in 2016 it has outperformed all other thermosetting materials with growth of over 3 %. Over one quarter of all GRP produced in Europe is manufactured from SMC or BMC – a total of 274,000 tonnes. The sector is dominated by SMC production (198,000 tonnes) which not only accounts for the lion's share of volume but is also growing somewhat faster than the smaller BMC sector compared to last year.

Mass-produced car headlamp reflectors are typical components made from BMC. SMC is used in the automotive sector, e.g. for tailgates, interior panelling and cabin components, oil sumps or covers. In the construction industry it is used, e.g. for light shafts, cable ducts and shaft covers, in the electro/electronic sector for switches, control cabinets and home junction boxes.

Lightweight design requirements are often a priority when developing components for vehicle production. However, the special properties of SMC and BMC – e.g. insulation properties, weather and temperature resistance – also allow them to be used in a wide range of applications in markets which are driven by specific material requirements.

Although there have been declines in some areas of the electrical and construction sectors, the number of applications in the transport sector – both for cars and commercial vehicles – is increasing. There is a growing demand for solutions in Class A applications as well as potential for carbon fibre reinforced SMC components.

Over the medium term, new applications in the aerospace industry also offer opportunities and therefore potential for a future niche market. Whether these will actually be implemented, especially on a large scale, is still an open question due to the long term nature of these projects.

One major challenge currently facing the industry is that the business in some customer segments is becoming ever more uncertain – because application industries/customers are ordering at ever shorter notice – including e.g. the electrical market despite the continuing construction boom.

Many market players are looking to open up new applications – e.g. for "high performance SMC" – but this is not always in response to an existing demand or "market pull".

<u>Open mould / Open processes:</u>

"Open processes" – hand lay-up and spray-up – are a segment which places greater emphasis on manual skills and craftsmanship. It is the second largest segment in the European GRP market with total production of 237,000 tonnes. The segment's trend of comparatively weak growth over recent years continued and is under one percent in 2016.

The business is characterised by a large number of small companies with few employees and often individual orders. It has a relatively low level of automation.

In all of the major European countries there are several hundred companies which supply various application industries with large and/or complex components or in fairly low numbers. Typical products include, e.g. housings for wind turbines, swimming pools, boat hulls or attachments and add-on components for special vehicles.

Despite the relatively weak growth in this segment of the GRP industry, the special requirements of products which can only be manufactured using hand lay-up or spray-up ensure that there will always be a place for these processes in the market.

<u>RTM:</u>

RTM (resin transfer moulding) components have continued their trend of slightly stronger than average growth (nearly 3%) which was also observed last year. European production in the segment totals 141,000 tonnes.

As in previous years, this category includes all components manufactured using a closed mould. Flagship projects, such as the use of these materials in manufacturing the structural components of the BMWi3, have been instrumental in persuading not only many companies but also research institutions to focus on developing new applications and refinements for the process. RTM components can also be manufactured in larger series but it is difficult to reduce cycle times compared to other processes. For example, it is possible to achieve an annual production of 10,000 pieces or more. However, it is probably impossible to increase this to the hundreds of thousands.

Applications include vehicle construction, housings for wind turbines, boat and ship building as well as the sport and leisure sector.

The quantities stated here are limited to “traditional” RTM processes and do not include GRP manufactured using the “infusion process”. It is not yet possible to obtain accurate European production figures for this segment but it can be assumed to be in the range of approx. 300,000 to 400,000 tonnes. Around half of this quite large amount is used in the construction of wind turbines. The marine sector is also very important to the industry.

Continuous Processing:

The consistently strong trend of recent years continues in the continuous processing segment. In 2016, European production has risen by 3% to 139,000 tonnes.

Panels have primarily been used in vehicles for many years, e.g. truck side panels, caravan superstructures or the conversion of commercial vehicles. These are supplemented by applications in the facade industry. However, innovations are also an important driver in the segment. These include antiseptic laminates for panelling in operating theatres and sports equipment such as skis, wakeboards or longboards.

The most significant applications for GRP pultrusion profiles are in the construction sector, e.g. in the production of bridge elements, such as supports, railing and ladder systems, and in plant construction. They are also used in the consumer/private sector in ladders, device sticks or fishing rods. In addition, pultrusion elements can be found in antenna systems, window frames and fences.

For a number of years, companies have been increasing their investment in developing techniques to optimise pultrusion processes for a number of years.

Official approval procedures and a lack of standardisation have hindered the adoption of series produced GRP composites in bridge construction in particular. The continuous processing segments are characterised by a relatively high level of automation. However, the processes used by the relatively few manufacturers operating in this sector are adapted very specifically to the requirements of the individual companies and are overwhelmingly in-house developments.

Pipes and tanks:

GRP pipes and tanks are manufactured either using the centrifugal casting or filament winding process. The market is dominated by a few large manufacturers not least because of the relatively high quantities of material involved per order – at least in terms of the GRP industry. This segment processed a total of 148,000 tonnes of GRP in Europe in 2016. However, it is the only segment included in this report to have stagnated since last year with zero growth – albeit at a relatively high level of production.

GRP pipes and tanks are principally used in plant construction and public/private pipelines but also by customers in the oil/gas and chemicals industries. The chemicals industry, in particular, has launched a large number of reinvestment projects although any potential demand here will only be felt in years to come.

Although standardisation and approvals from regulatory authorities offer opportunities to open up new markets there is also the risk that regulatory changes could close existing markets. There is currently a very strong trend towards greater regulation and standardisation for applications in the segment. This will also create challenges for companies operating in the international sector.

The European market for pipes and tanks is relatively small compared with those of some Central European and Middle Eastern countries (Turkey, Saudi Arabia) where the majority of GRP production is used for these products.

4.2 Thermoplastic materials

GMT/LFT:

As in previous years, glass mat reinforced thermoplastics (GMT) and long fibre reinforced thermoplastics (LFT) continue to be by far the fastest growing segment of the GRP market with growth of over 6 % in 2016. The total production of 140,000 tonnes in the segment is split between LFT and GMT in a ratio of around 2:1 with the proportion of LFT rising due to its higher growth rate. Production using so-called D-LFT processes is barely growing compared to traditional LFT processes due to the excessively high processing costs involved. The main drivers of growth for all these thermoplastic materials are projects in the automotive industry. Thermoplastic materials have a number of special properties. They are easy to process and combine well with other materials. This often makes them the material of choice for applications in vehicle production. The pressing and injection moulding techniques for manufacturing/processing components are well-understood in the industry and also used for other materials. In principle they can even be used for large series production of components in the range 100,000+. Typically these include products for underbody protection, bumpers, instrument panels or seat structures.

The figures for this segment also include “organosheets”. These are pre-consolidated semi-finished products in sheet form which can be heated and formed. Like the corresponding tapes, these continuous fibre-reinforced materials allow manufacturers to exploit all the mechanical properties of continuous fibres while keeping cycle times relatively short. Many OEMs and major producers of these materials are currently developing methods for integrating them in the automotive sector. They also offer excellent lightweight design potential especially in combination with injection moulding processes.

Short fibre reinforced thermoplastics:

GMT and LFT are the only thermoplastic materials included in this GRP market report. Their material properties, applications and, in some cases, processing methods are similar to those of thermosetting materials so it continues to make sense to consider both these areas together.
However, in addition to GMT/LFT there is another large market group of products which could be described as composites – short fibre reinforced thermoplastics. At approx. 1.3 million tonnes, the European market for thermoplastic, glass fibre reinforced compounds in 2015 was somewhat larger than the observed market for thermosetting materials plus GMT/LFT during the same period *(Source: AMAX)*. However, when GRP components manufactured using the infusion process – not previously included in the GRP figures – are added to the total, the markets for thermosetting and thermoplastic composites are roughly equal in size.

In 2015, the market for glass fibre reinforced compounds grew slightly more slowly than in 2014. Nevertheless, it was still above average at 4.5 % (*Source: AMAC*). The majority of applications are to be found in the transport sector as well as the electro/electronic and sport/leisure segments.

5. Application industries at a glance

Despite the different trends observed in the markets for the various manufacturing processes, the proportions of GRP used by the major application industries in Europe remain the same as last year. The transport and construction sectors each consume one third of total production. Other application industries include the electro/electronics sector and the sport and leisure segment (see Fig. 3).

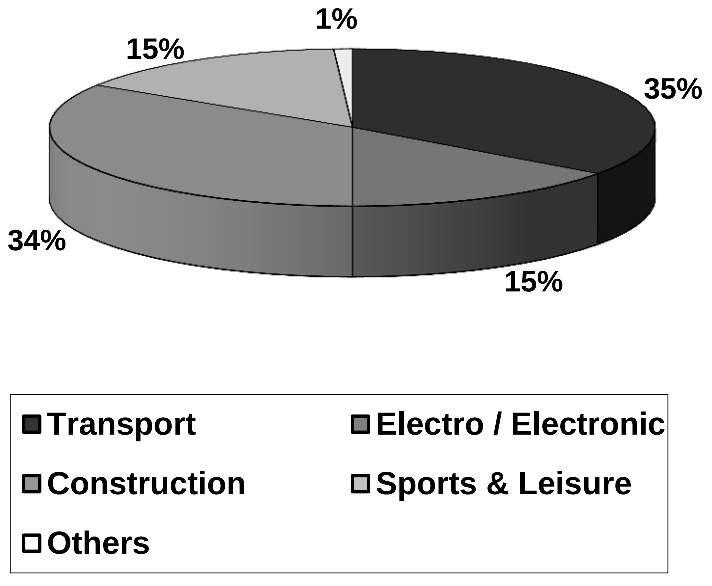

Figure 3: GRP production in Europe for different application industries (year: 2016)

6. GRP production in 2016 by country

The strongly divergent trends observed in European countries and groups of countries over recent years have moderated to some extent. Growth of between one and nearly four percent is being recorded for every country/region apart from Austria/Switzerland.

The strongest growth continues to be found in Germany (3.8 %) and Eastern Europe (3.6 %). Germany is the largest European producer of GRP and composites with production of 220,000 tonnes. Total output in the Eastern European countries considered in this report is 199,000 tonnes.

The GRP market in Austria/Switzerland remains stable at 18,000 tonnes. Output in the Benelux countries (45,000 tonnes) grew slightly despite falling in Belgium by approx. 5 %. Scandinavian production rose marginally to 40,000 tonnes with Norway and Denmark each producing 12,000 tonnes and Sweden and Finland 8,000 tonnes respectively. Two thirds of the applications, e.g. in Norway, are in the industrial sector, 20 % in the construction industry and 15 % in the marine sector.

The return to economic growth in Southern European countries has also contributed to improved growth rates in the GRP industry compared to recent years: In Italy the sector is growing at around 3 % with output at 154,000 tonnes. Growth in other countries in the region is slightly slower with production at 158,000 tonnes in Spain/Portugal and 100,000 tonnes in France. The UK/Ireland remains one of the largest groups. It will produce a total of 152,000 tonnes this year despite weaker growth than in the previous 12 months.

Market data has been available for Turkey since 2011 and is stated separately. This enables us to continue showing the long term trend for the GRP market (see Fig. 1). After relatively weak growth last year compared to recent years, the sector is expected to grow by 5% to a total of 257,000 tonnes in 2016 according to the Turkish composites Association TCMA. Turkish GRP production is therefore higher than in any other European country.

In contrast to the markets in the other countries considered in this report, pipes and tanks for infrastructure projects account for around 50% of GRP production. With around 110,000 tonnes being used in these applications, Turkey is by far the largest manufacturing country in this segment. The construction and automotive sectors are the other two major markets for GRP in Turkey with each accounting for around 20% of production.

When short fibre reinforced thermoplastics are included in the data, it becomes clear that Germany is a significantly larger composites producer than any of the other countries considered here. Italy, the Benelux countries and Eastern Europe are other countries/regions where components made from short fibre thermoplastics comprise a large proportion of production.

	2013 Kt	2014 Kt	2015 Kt	2016* Kt
UK / Ireland	140	146	150	152
Belgium / Netherlands / Luxembourg	42	43	44	45
Finland / Norway / Sweden / Denmark	44	42	39	40
Spain / Portugal	152	154	156	158
Italy	146	148	150	154
France	112	108	108	110
Germany	192	200	212	220
Austria / Switzerland	17	18	18	18
Eastern Europe**	175	184	192	199
Sum:	**1,020**	**1,043**	**1,043**	**1,096**
Turkey***	214	245	245	257

Figure 4: GRP production volumes in Europe – and Turkey – itemised by country/group of countries

(Kt = kilotonnes / 2016* = estimated / Eastern Europe** = Poland, Czech Republic, Hungary, Romania, Serbia, Croatia, Macedonia, Latvia, Lithuania, Slovakia and Slovenia / Turkey*** = Source: TCMA)

7. Other composite materials

Although current media reports and presentations at many conventions and trade fairs may create a different impression, GRP continues to be the largest material group in the composites industry by far. Glass fibres are used for reinforcement in over 95% of the total volume of composites (short and long fibres, rovings, mats …).

Of the 8.8 million tonnes of composites manufactured globally in 2014 *(Source: JEC Composites),* 2.3 million tonnes were glass fibre reinforced plastics produced in Europe. Of these, the GRP products studied in detail in this report accounted for 1.04 million tonnes and short fibre reinforced thermoplastics for the remaining 1.25 million tonnes.

Worldwide demand for carbon fibre reinforced plastics (CRP) is estimated at 100,000 tonnes in 2016 (see the second section of this market report).

No further updates to market data have become available for components made from natural fibre reinforced plastics since last year. 92,000 t of components made from NRP, mostly used in the automotive sector, were produced in the EU in 2012. Germany is by far the largest market for these products (*Source: nova-Institut GmbH*).

8. Outlook

Often classified as futuristic lightweight materials used primarily in the automotive and aerospace industries, existing applications for GRP are frequently overlooked. Yet these "materials of the future" serve real, existing markets and many of them have been used in a broad range of established applications for decades.

Naturally, current research projects into further series applications – especially for high performance materials – are very welcome indeed. However, it is important not to overlook the potential and opportunities emerging and expanding in other new and existing markets.

This is especially true for thermoplastic material systems which are currently enjoying a period of well above average growth – principally due to the gradual adoption of new processing methods and significant improvements in materials. Combinations of formed continuous fibre-reinforced semi-finished products with over- or back moulding are still a focus of interest. Organosheets are a source of particular excitement in this segment at the moment.

But "established" processes are also continuously being refined and adapted, e.g. there have been significant advances in the area of thermoplastic pultrusion and creating new versions of familiar processes. These include the development of radius pultrusion and combinations of pultrusion and pressing.

The SMC segment is also a hive of activity. The most notable applications here are the use of carbon fibre SMC # and SMC semi-finished products enhanced by continuous fibre-reinforced structures. In addition, researchers are working to create materials for components which are subject to high loads.

The ongoing optimisation of RTM processes, meeting the future challenges of integrated production technologies and adapting corresponding periphery systems to core processes continue to be important themes. Automation thus continues to be one of the most important issues.

The trend towards creating and refining multi-material systems and the use of hybrid components will remain one of the key challenges. The development of technologies for joining and connecting different materials is vital and a task that should also be addressed by companies/institutions outside the composites industry.

From today's standpoint, hybrid and multi-material systems would appear to be the future of lightweight design. "The right material in the right spot" remains one of the fundamental principles in this area.

Other factors will determine whether or how composites will be adopted by or become established in further sectors. For example, standards and regulations are often the keys to opening or closing doors of opportunity in the construction/infrastructure sector. These can differ widely depending on the country in question. The first applications in which composites have succeeded in replacing other materials in the construction sector give cause for hope that materials specialists and designers will give greater consideration to composites in future.

Composites are not only a reliable partner but a hope for the future in the area of materials. In combination with other materials, they often open up completely new horizons.

The global CRP-Market 2016

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.

9. The global CRP-Market 2016 – General

Now in its seventh 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 281 members (Status October 2016) CCeV represents a significant number of companies, research institutes and other sundry organisations in the Carbon Fiber (CF) and Carbon Composite (CC) markets in Germany, Austria and Switzerland.

As part of our contribution our members prepared information and data, also with the help of current market data from among others, Lucintel [1], [2] and Acmite [3], [4] who were also 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.

10. 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):

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

- **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.

11. The global Carbon fiber market

The global requirement for Carbon fiber of roughly 58,000 tonnes in 2015, complies with the expected figures from last years report. This represents a growth of 9.4% over the previous year (53,000 tonnes) and when the years after the financial crisis 2009 (26,500 tonnes) are compared, then requirement has more than doubled. The annual growth rate, (CAGR) taken from 2010 is roughly 12 %.

Total turnover achieved worldwide with CF makes up around 2.15 billion US$ for 2015. When one compares the figure of 1.98 US$ billion (2014), we see a growth rate of 8.6 %.

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 9.4 % for 2015 we see growth rates levelling out to a stable level. With a view to the coming years, it can be assumed that further annual growth rates (AGR) of double figures will be seen, which should swing between 10 and 13%, so that we could break through the 100,000 tonnes of carbon fibers demand mark already in 2020.

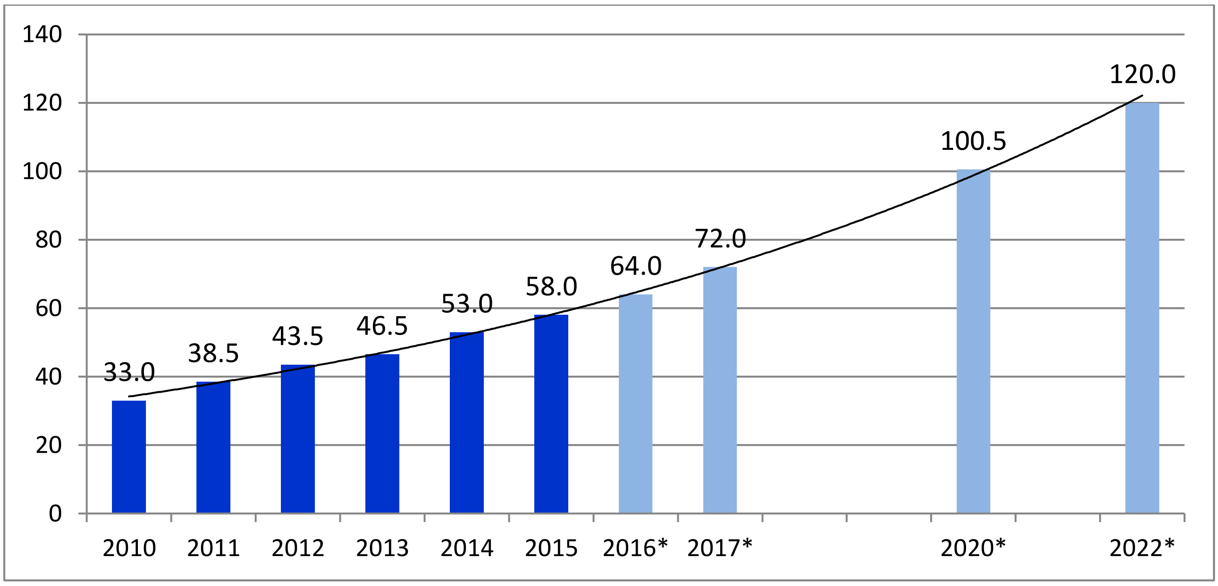

Figure 5: Global demand for Carbon fiber in 1,000 tonnes 2010 to 2022 (* Estimates).

11.1 By manufacturer

Figure 6: Theoretical, annual CF capacities in 1,000 Tonnes acc. to manufacturer (09/2016). shows the theoretical, annual CF production capacities of the eleven leading carbon fiber manufacturers. The acquisition of Zoltek by Toray 2014 resulted in their having the largest CF capacity by some distance with 42,600 t in 2015. Compared to 2014, according to announcements from Toray, Zoltek's capacity has been reduced by 1,900 t or resp. rated lower. [5] With an estimated total global capacity of 130,900 tonnes of carbon fiber on the basis of Polyacrylnitrile (PAN) and Pitch, the Toray/Zoltek share encompasses around one third of the global CF market.

SGL and BMW, as part of their Joint Venture SGL-ACF, and as mentioned in last years report, have installed two further production lines in Moses Lake with a capacity of 3,000 tonnes. [6] As a result SGL (15,000 t) have pushed themselves to number two in the CF manufacturer rankings.

At the end of 2015 Solvay completed their takeover of Cytec. The expansion of CF production capacity already announced in 2014 by Cytec in their Piedmont plant (South Carolina, USA) [7] was completed in August 2016. This new CF production line means Solvay has almost doubled its annual CF capacity to 7,000 t. [8]

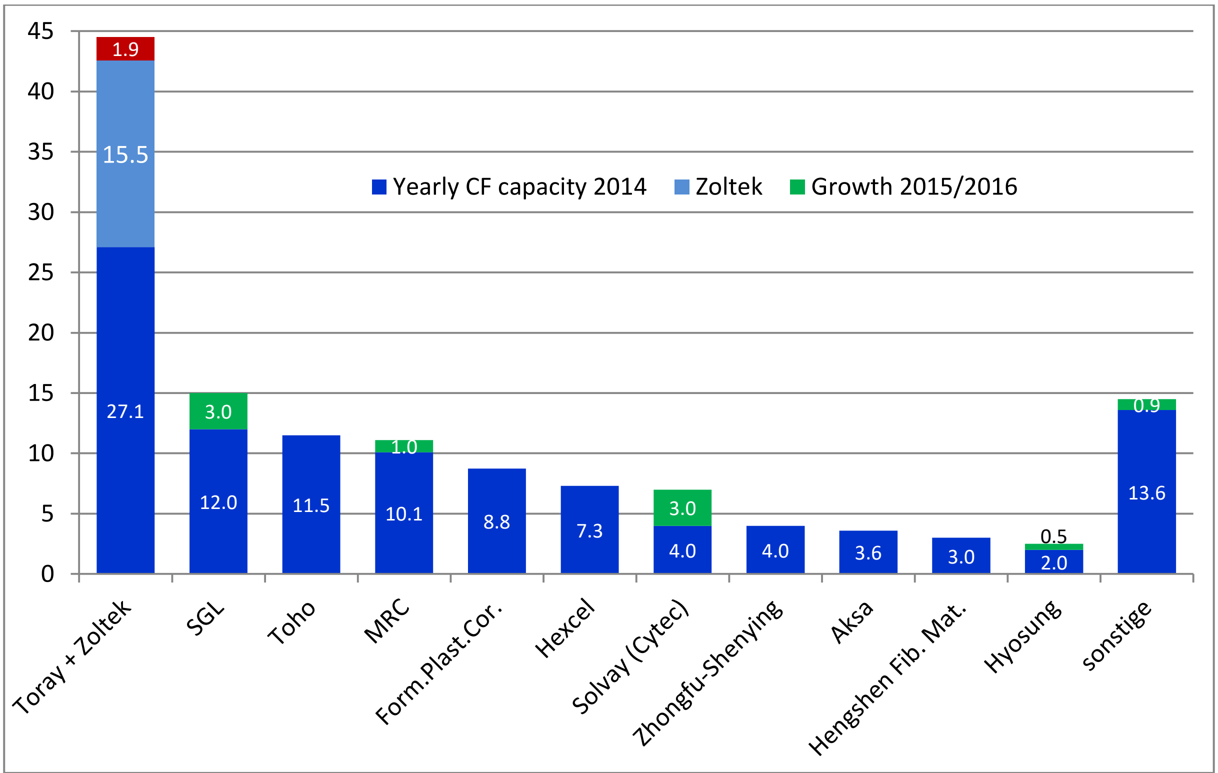

Figure 6: Theoretical, annual CF capacities in 1,000 Tonnes acc. to manufacturer (09/2016).

Mitsubishi Rayon (MRC) will complete their production capacity expansion in their plant in Sacramento (USA) this year and hence increase its CF capacity to 11,100 t. MRC are further investing in the Otake plant (Japan), in order to increase the annual large-tow CF capacity until September 2017 from an annual 2,700 to 3,900 t and therefore to achieve a total CF capacity of 13,300 t. [9]

The South Korean manufacturer Hyosung was ranked eleven in the overview after its expansion of 500 t to 2,500 t. According to their own statements, Hyosung wish to expand their CF capacity by 2020 to 14,000 t which would mean (depending on expansions at their competitors), they would probably find themselves among the Top 5 largest carbon fiber producers worldwide (acc. to amount). [10] The figure given in the source for 2015 of a CF capacity of 6,500 t has however not yet been confirmed. Other sources give the target for 2020 as 8,000 t. [11] Current aerial photographs (e.g. Google Maps) of Jeonju, (similar to those from Moses Lake), seem to show construction areas which would at least not rule out expansion of capacities when it comes to space available.

A slight growth has been recorded among the "sundries" comprised of smaller producers, above all from China (Dalian Xingke Carbon Fiber or Yingyou Group Corp.), Russia (Composite Holding Co., Alabuga-Fibre LLC) and India (Kemrock Industries and Exports Ltd.) with production capacities under 2,500 t.

In total the ten leading fiber manufacturers make up almost 87% of the global Carbon fiber capacity and are still the dominant forces. When one considers the predicted CF demand for 2016, then over capacity is still very high. CF production would only be utilised to a figure of 49 % if one takes the theoretical production capacity. However this value has two limitations: on the one hand, real utilisation should be higher than what is recorded from quotable sources. On the other hand, the theoretical production capacities are often not achieved in reality due to reduced total system efficiency (reduced availability of systems, reduced production performance, increased waste levels, etc.)

11.2 By region

The yearly production capacity of 130,900 tonnes divided up among the various regions resp. countries can be seen in Figure 3. The CF capacity in the USA has seen a marked increase of 7,000 t (whereby not all of the previously mentioned capacity expansions are included here) Otherwise, only a small growth in capacities from diverse producers in China and the Rest of the World has been registered.

As in previous years the most important regions are in Asia incl. the Pacific area with about 46%, and North American with 35 % followed by Europe with around 18% 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 with an amount of 25,000 tonnes, which remains unchanged from the previous year. Alongside this, China, with many small producers achieved a slight growth to around 13.3 thousand tonnes.

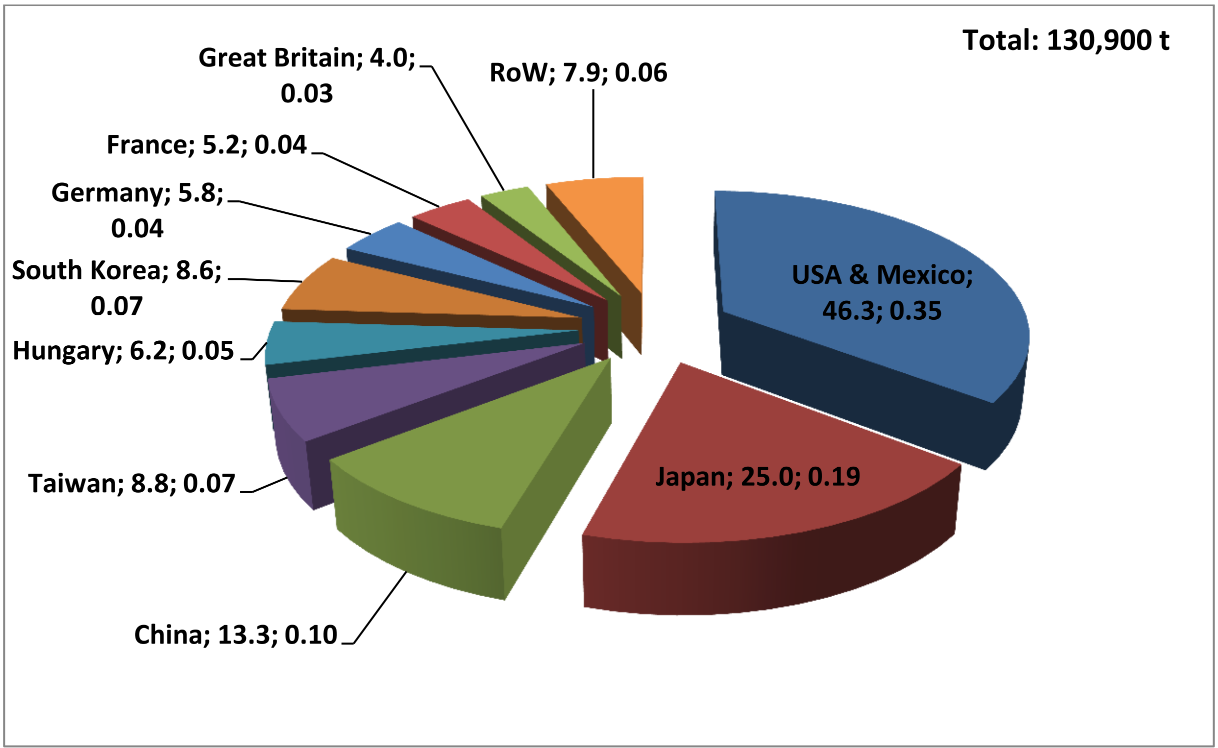

Figure 7: Yearly CF capacity by Regions/Countries in 1,000 tonnes.(2016)

12. 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 4 shows the development of global CRP demand referring to the produced amount in tonnes. From 2014 to 2015 we can see growth of around 10 % from 83,000 to 91,000 tonnes. This gives us an annual growth (CAGR) of 12.3% from 2010 to 2015. An annual growth rate (AGR) of 10 to 13% is assumed for further development, so in 2022 we see a CRP demand of 191,000 tonnes as being possible to achieve. Lightweight construction and the application of CC are seen as the key to efficient use of fuel. This is not only seen in the USA and Europe as an important path to the future, but also now in Asia, in particular in South Korea and China. The increasing share of CRP in the aerospace industry and in automobile construction is seen as the driving force behind growth over the next years.

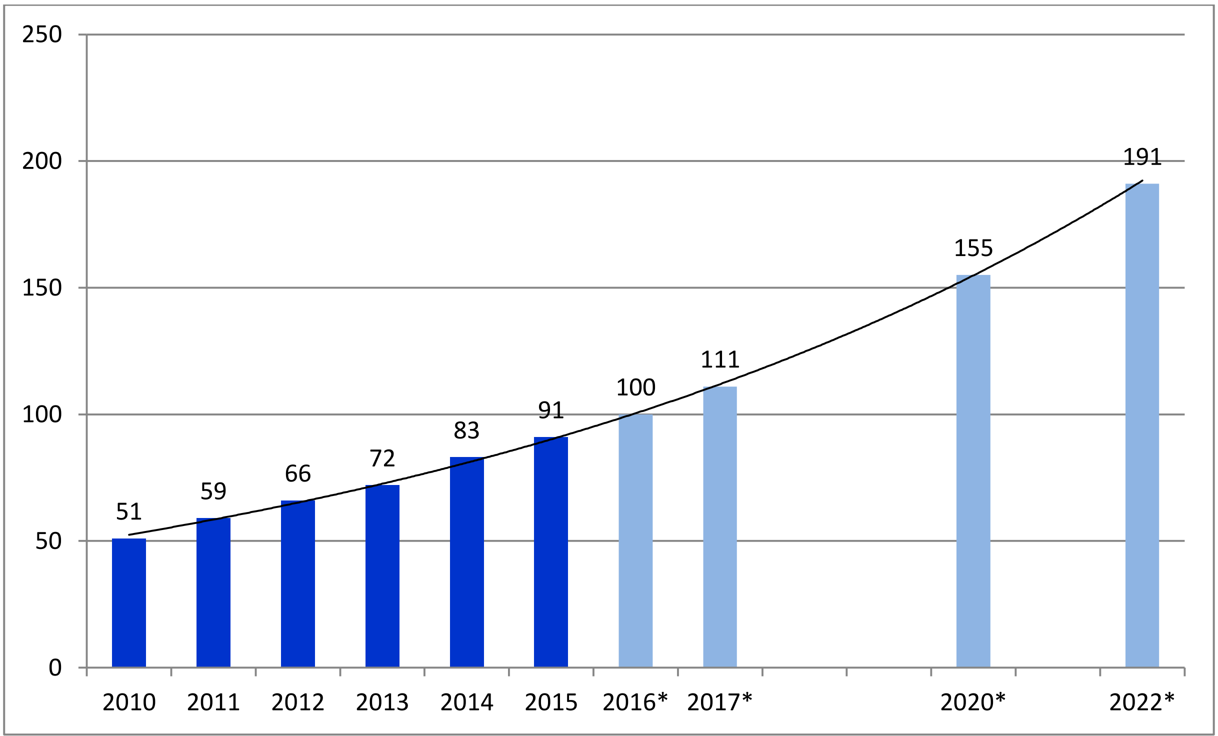

Figure 8: Global CRP demand in 1,000 tonnes 2010–2022 (*estimates).

12.1 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 2015 were 17.9 billion US$, of which CRP accounted for 11.6 billion US$ (Figure 5). Composites based on a polymer matrix accounted for 65% of the total revenue achieved with CC [3] [4]

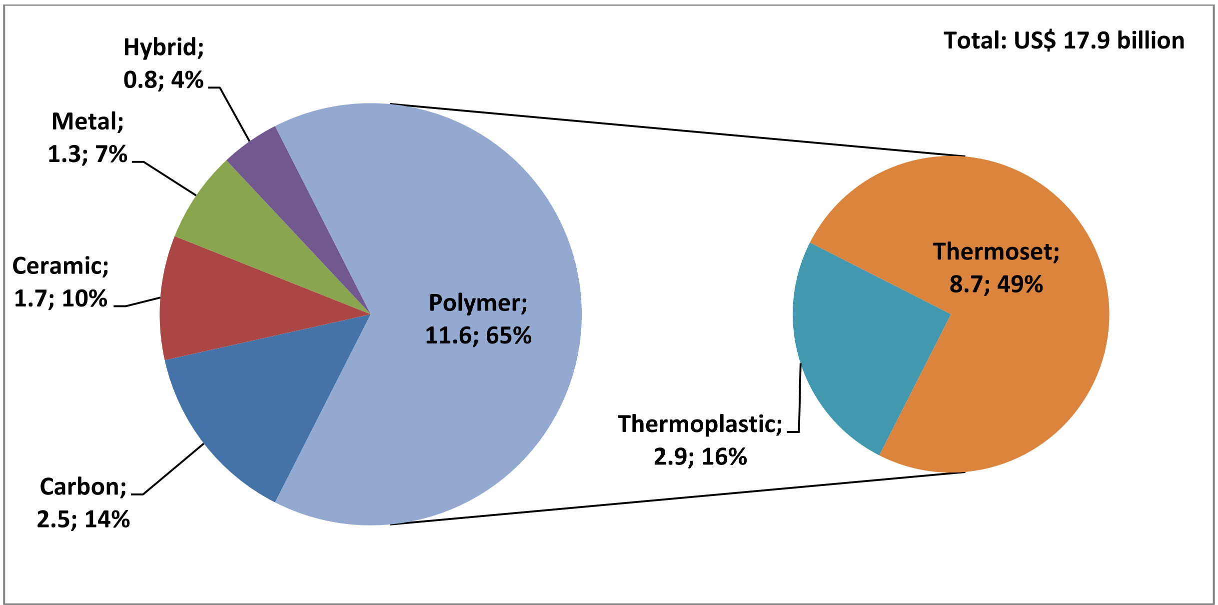

Figure 9: CC revenues in billion US$ by matrix material (2015).

The matrix polymers used in CRP production can be further divided into thermoplastics and thermosetting plastics (see pie chart right Figure 5). 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 acceptances in the future for e.g. elastic hinge less shaft connections in mechanical engineering applications or form variable structures in the aerospace industry (adaptive satellite antennae, aeroplane wings, etc.).

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 11.6 billion US$ by the worldwide demand in 2015 of 91,000 tonnes, one can infer an "imaginary" (averaged over all branches and applications) price per kilo of **127 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 tip of the (Gauss-like) frequency scale. 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).

12.2 By manufacturing process

A variety of different production processes are used in the manufacture of CRP materials/components (see Figure 6). When compared to last year’s market report, no major differences have been noted. Layup processes using prepregs with 45% in market share make up the lion's share still. Pultrusion and winding processes with 27% follow. Wet lamination and infusion processes have maintained their share of 11% and still have a very important role in small and minimum size lot productions for SMEs. Pressing and injection processes with 9% are lying around the mark from last year and are being sustained by the continuing BMW i3 and new beginning 7 series Production (a.o. RTM).

The various groupings of manufacturing processes through differing sources (Acmite und Lucintel amongst others) result in differing estimates of the described production processes. There are several winding processes e.g. for pressure tanks in the aerospace sector or mechanical engineering, which use thermoset prepregs. 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.

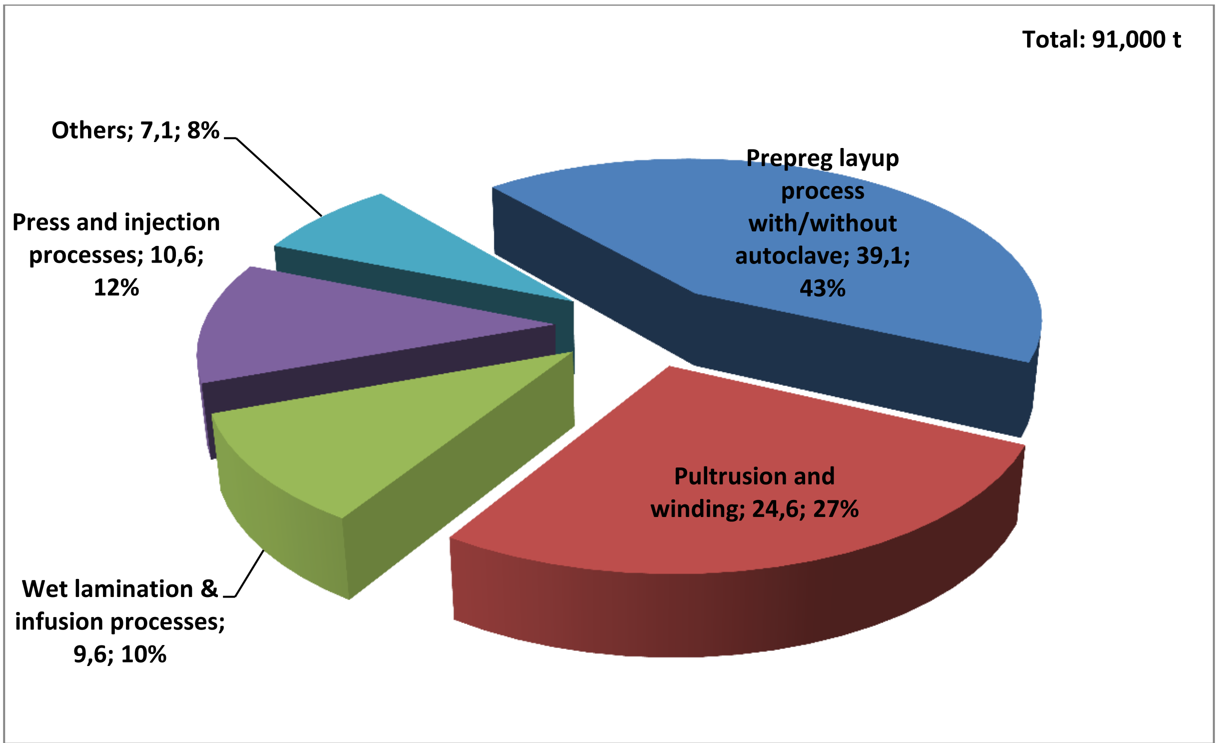

Figure 10: Deployment of production processes CRP in 1,000 tonnes (2015).

12.3 By region

Figure 7 shows the demand in tonnes for Carbon Composites by region. CC demand in the observed regions has risen to a total of 116,500 tonnes. The lion's share of global CC demand lies once more in North America and in the USA in particular with 38% or 44,000 t 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 being driven by several state sponsored funding programs. Alongside the investments described in the CF section by Hyosung in Jeonju, more state sponsored funds are being used to build up the Province of Jeollabuk-do to be the so-called "economic hub of Northeast Asia“. Further examples are the national program to come up with a home produced air-plane in India and also the Commercial Aircraft Corporation of China (Comac) is at-tempting to compete with the A320 and B737 with their C919. In total, Asia and the Pacific region account for 23% of global demand.

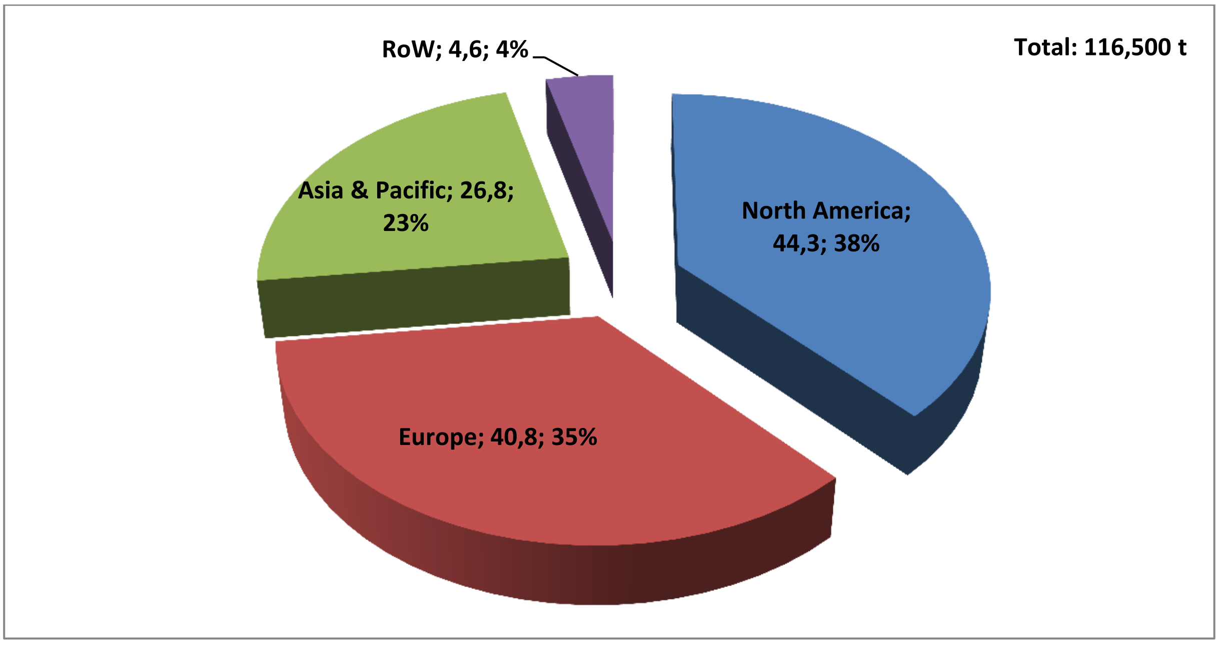

Figure 11: CC demand in 1,000 t acc. to Regions (2015).

12.4 By application

Similar to the CF market, the most important market segment in the CC market is aerospace including defence, with about 30% of the global CC demand of 116,500 tonnes (Figure 8). Commercial aviation above all showed a steady growth rate of 7% over the past years in supplied units. Boeing is delivering 12 B787s monthly, at the moment with around 700 open orders. [12] After 27 delivered A380s in 2015, the production level to 2018 should be reduced to 12 machines per year. [13]. About 120 orders are still open. Composite structures account for about 28% of the A380 and around 50% of the 787, meaning they are a major component of both models.

The A350XWB is Airbus' development in the long haul passenger aircraft sector and boasts the highest current proportion of CC in the fuselage and wing sections (about 53 %). The production figure for 2015 was 14 delivered machines and is currently at 21 aircraft for 2016 (status 2016-08-31).

The automotive construction sector makes up the second largest share with 22% or around 26,000 t CC. The Joint Venture with SGL to expand the production capacity of CF in Moses Lake makes it clear that the Bavarian car manufacturer sees a high potential in lightweight construction with Carbon Composites and is sounding out the market for Electric resp. Hybrid Sports cars with its i-Projects, and is also gathering experience in dealing with Carbon Fiber Composite materials. In 2015 about 24,000 i3s and 5,500 i8s were sold. Regarding the new 7 Series with Carbon Core Technology, sales figures of about 64,000 are expected for 2016. [14] This is followed by Wind turbines (13%), Sport & Leisure (12%), Construction industry(civil engineering) with 5% and Ship building with 1%.

Figure 9 shows the same industry sectors but represented by turnover in billion US$. When analysing revenues by application 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 industry including defence" for example a figure of 30% of CC manufactured generates 61% of worldwide revenues. Especially in the aerospace industry, in addition to high quality demands come high costs due to approval processes and material controls. The revenues are respectively smaller for the other applications, and the order is comparable to that seen in the ranking according to CC demand.

If one calculates an imaginary branch specific CC Kilo price from CC turnover and CC demand, one sees a result as follows acc. to branch:

Aerospace & Defence:	310 US$/kg	Wind turbines:	97 US$/kg
Automobile construction:	86 US$/kg	Sport & Leisure:	94 US$/kg

While Aerospace and Defence occupy the highest price segment as expected, it is a little surprising that the average value in Automotive construction still occupies a value which lies far above the minimum demanded by the branch. Of course this can be partly explained by the Sport and Premium applications inherent in Automobile construction. The suspicion remains however that, as already mentioned in Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**, the expected minimum price will only be the lower limit of a broad spectrum in the future. Even though these figures need to be observed with care, they do impart a good impression of which price segment on average is relevant to the respective branches.

When one compares the CC per kg prices, which were published in the previous year, then we see a slight reduction, apart from in the Sport and Leisure sector.

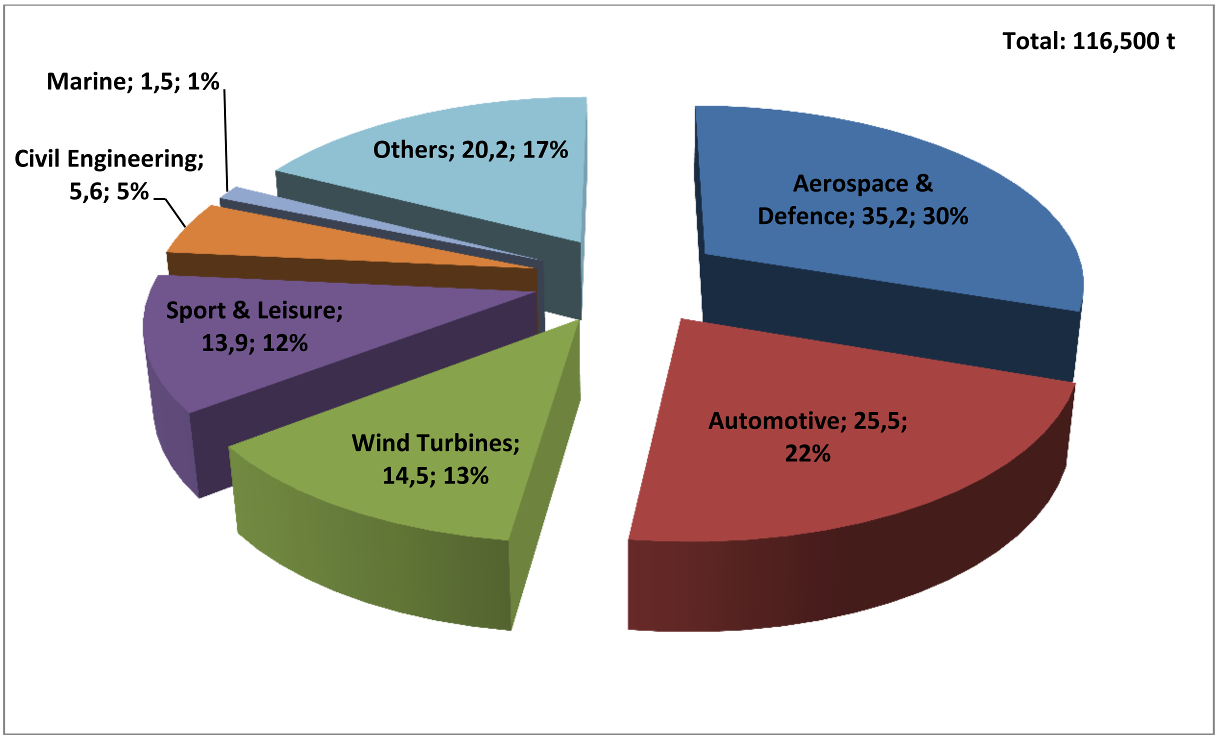

Figure 12: CC demand in 1,000 t acc. to application (2015).

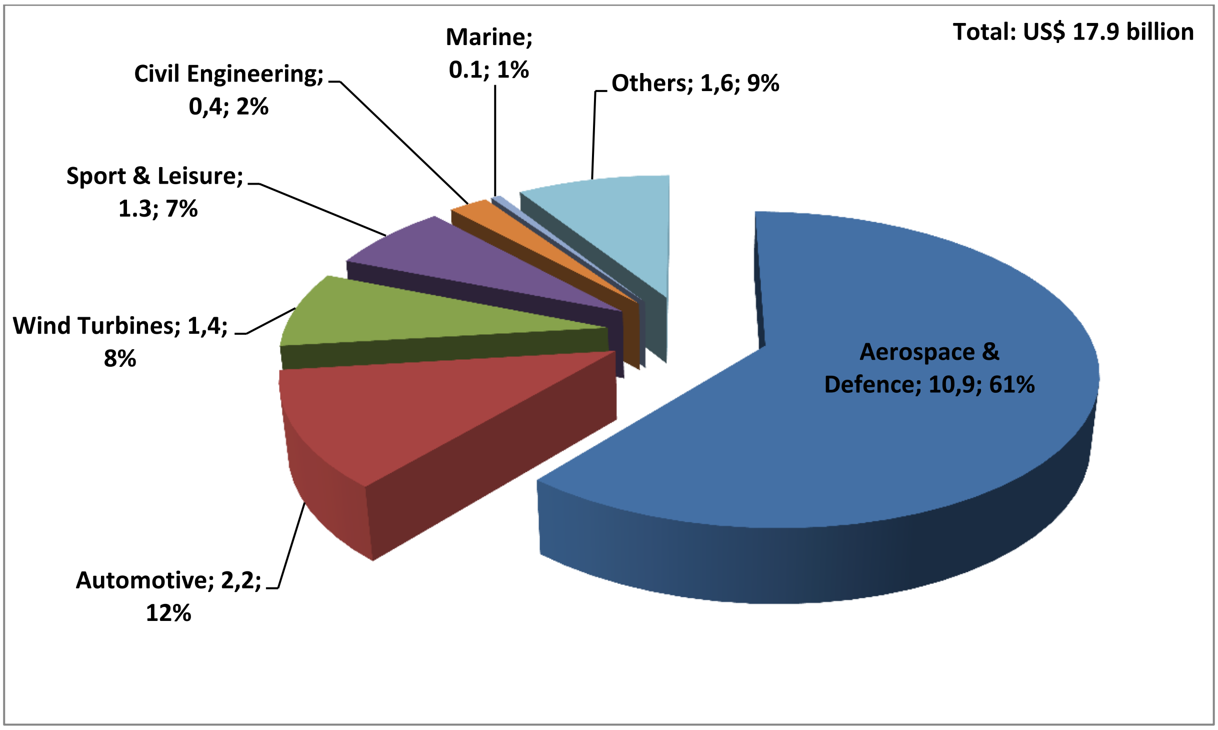

Figure 13: CC demand in billion US$ acc. to application (2015).

13. Trends and Outlook

The global **Carbon fiber market** has been showing an excellent, stable growth rate since 2009, which has continued throughout 2015 (Figure 1). An average annual growth rate of between 10 and 12% has been assumed for the next few years. This is a slightly lower growth rate than was assumed last year, however we can still break through the 100,000 tonne mark for CF demand in 2020. Revenues from CF came to almost 2.15 billion US$ in 2015 and we are also assuming a growth rate of 10 to 11% here, which means that in 2022 a global figure of 4.2 billion US$ in CF turnover can be achieved

13.1 By Region (CF)

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

- **SGL and BMW** have increased their production capacity to 9,000 tonnes per annum in their joint venture in **Moses Lake (USA)**. [6]
- **Mitsubishi Rayon** has already increased its CF production capacity in **Sacramento (USA)** to achieve a total capacity of 11,100 t. MRC is investing further in the plant in **Otake (Japan)**, in order to increase their annual capacity for large-tow CF from 2,700 to 3,900 t by September 2017 and therefore to achieve a total CF capacity of.13,300 t. [9]
- According to its own statements **Hyosung** plan to increase their CF capacity to 14,000 t in their plant in **Jeonju (Korea)** by 2020. [10] The figure given in the source for 2015 of a CF capacity of 6,500 t has however not yet been confirmed. Other sources give the target for 2020 as 8,000 t. [11]
- Zoltek is planning to double its global production capacity by 2020. By April 2016 the plant in **Guadalajara, Mexiko** should have doubled its production capacity to 5,000 Tonnes. [15]
- The **"Institute for Advanced Composites Manufacturing Innovation" (IACMI)** was launched on its path at the start of 2015 by President Obama and should become a national development centre for Composites in the USA with

its Headquarters in **Knoxville, Tennessee.** Initially, 250 Mi. US$ in funding will be made available and the IACMI can already boast 156 members. Alongside Tennessee, the focus lies on the states of **Michigan, Indiana, Ohio, Kentucky** and **Colorado**, where a lot of users and research centres for Composites are already to be found. The lion's share of production and R&D for the US Automobile industry, for Wind power stations and pressure tanks are found in the above-mentioned states and also the National Renewable Energy Laboratory (NREL), the Purdue University, Michigan State University, University of Dayton Research Institute (UDRI), Oak Ridge National Laboratory (ORNL), University of Tennessee and University of Kentucky are among the most important Research institutes and Universities when it comes to Composites. [16]

- 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 **Knoxville, Tennessee**. [17]
- Hexcel is investing 250 million US$ in the construction of a new factory for CF production in **Roussillon, France**. The construction began 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. [18]

On the whole it is clear that both in the USA, as well as in Asia, (and in particular Korea and China) intensive efforts are being undertaken to drive the CC and CF sectors. This process is also being supported by state sponsored funding programs with the aim of creating and developing "Hot Spots".

13.2 By application (CC)

The **Carbon Composites Market** is following the development in growth rates seen in the CF Market and shows a total revenues generated figure of about 17.9 billion US$ for 2015, whereby the major part comes from CRP with 11.6 billion US$ resp. 91,000 t annual production.

Alongside the continuing demand from the aerospace sector, stable growth is guaranteed above all by the growing usage of CC in automobile construction and in industrial applications. When 2010 is further taken as a basis, then a CAGR of almost 11% can be assumed for the next few years. This means that CC turnover could be doubled by the year 2022. Based on a similar proportional growth by matrix, the revenues from CRP will increase to 23.5 billion US$ resp. 191,000 tonnes annual production.

The application of CC in the aerospace and defence sector will also show strong yearly growth rates of up to 13%. Current projects like the A350 and the B787, where more than 50 % of the structure is comprised of CC [9] as well as new projects like the Boeing 777X with CC wings [10] or the planned successors to A320, B737 and 757, which will apparently have reduced Composite shares but markedly higher volumes than the long haul aircraft, demonstrate that both producers will have increased requirements over the lifetime of the A350 resp. the 787 and beyond.

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 leading edge 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. [19] 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, and has optimised a sensible material mix for their mid to large series cars with their efforts for the 7 series. However the other leading automotive manufacturers are somewhat reserved in their enthusiasm. This could change in the coming years with the increasing market pressure coming from technology trailblazers like for example Tesla or Hyundai.

The application segment construction (civil engineering) is showing a surprisingly low demand for CC at the moment, but harbours however a high potential for the future. Reinforcement by means of carbon reinforced concrete, so called carbon concrete, is becoming more and more common, for example in the repair of bridges or other constructions which are aging. The high price when compared to steel reinforced concrete is somewhat balanced by the cheaper and quicker assembly times, easier transportation and a sustainable stabilisation of constructions. If the costs of carbon concrete can be further reduced, then the application will make increasing economical sense. In addition a verification of the substantial quality has to be made public in order to create the necessary acceptance of carbon concrete.

Figure 10 shows a prediction of CC demand in thousand tonnes up to 2022, 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 245,000 tonnes by 2022, roughly 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 percentual shares as in 2014. (Figure 8)

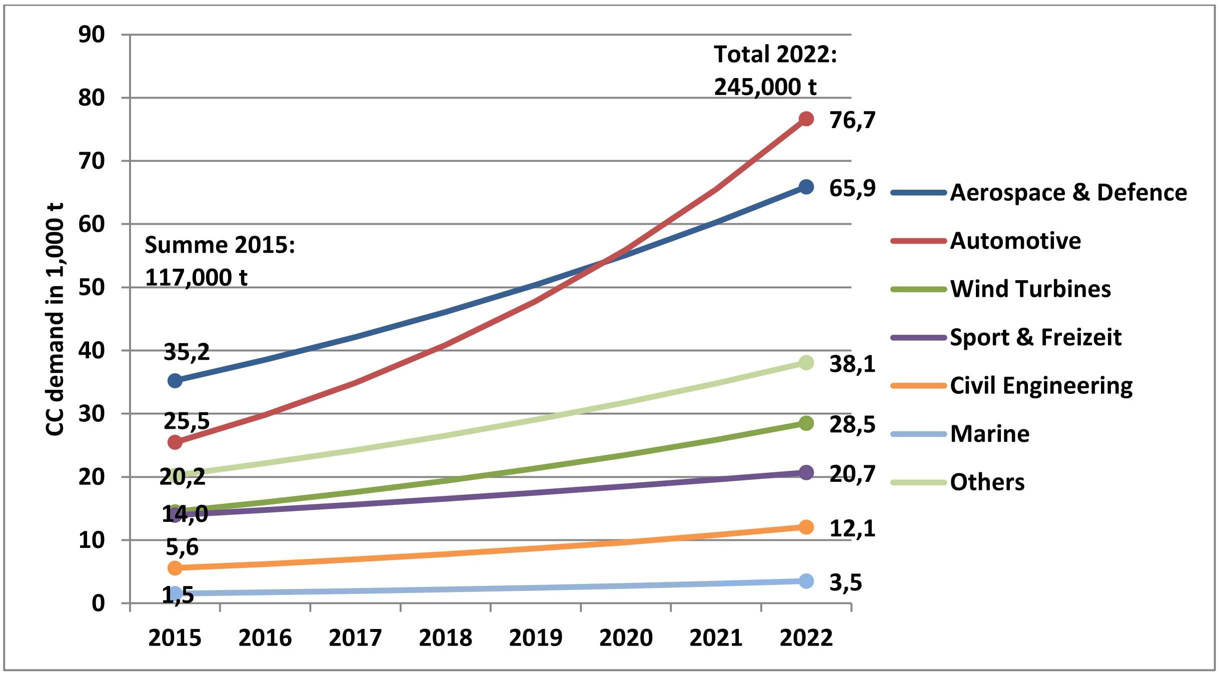

Figure 14: Predicted CC demand in 1,000 t acc. to application until 2022.

13.3 Comparison with Composites Germany market survey

A very positive market outlook can again 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 and 2015, the results for the first 6 months of 2016 show once again a positive evaluation of the business situation. 95% of those surveyed pronounced the world-wide business outlook as either improving or stable future development (this was 92% in the previous survey). For the Composites Market, automotive construction and aerospace are seen as the drivers of growth. However the members surveyed see their own business situation more critically. The share of positive and very positive reactions fell by 7% to 72%. [20] This trend fits very well into the picture of positive outlook found in this report, which does not purport to be CFK Hype, but does see a further stable growth of a consolidated market in which competitive pressure will also increase.

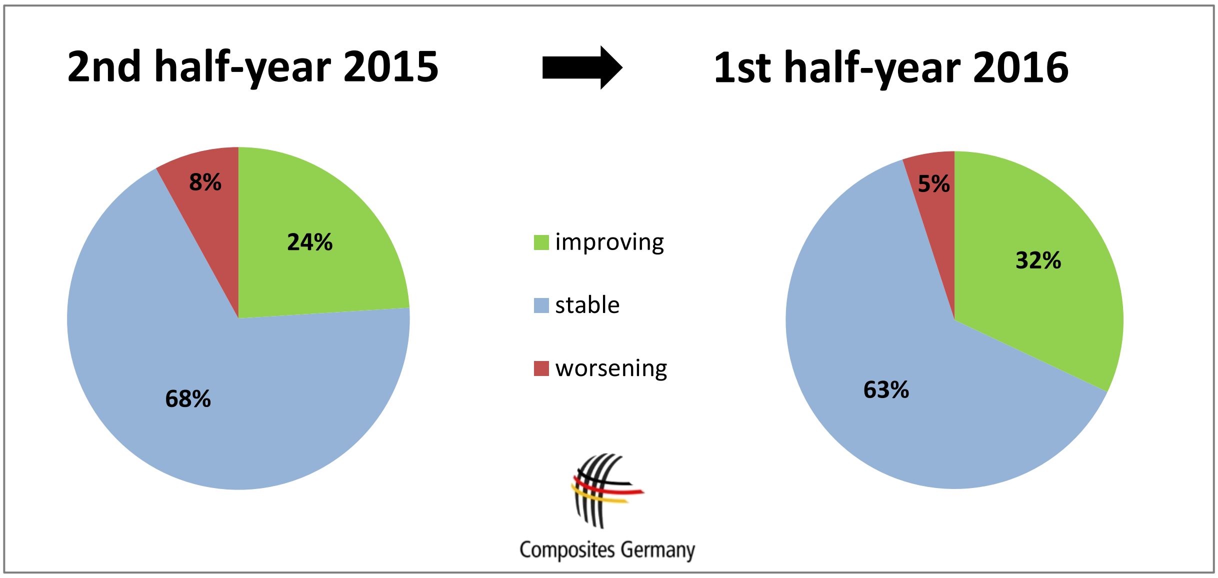

Figure 15: General business situation development (worldwide). [21]

14. Final observations

In summary, the CF and CC Markets can be further seen as promising, future ready business sectors. The **annual growth rates** are and have remained stably at a high level of between **9 and 12%**.

It is also evident that the pressure on CC from the growing competition offered by hybrid light weight constructions with suitable material combinations is increasing..At the same time, CC is setting itself up as an **established name in the Material mix**.

"**Neither Hype, nor Stagnation**" – that would be the description best suited to the behaviour of the CF and CC Markets for the current and the coming years. The potential for savings in material and production costs is the decisive factor for a growing share in future applications for CC. On the whole the market is demonstrating a lot more stability than what was expected a few years ago. Neither great positive nor negative bolts from the blue are to be expected in the short term which is typical behaviour for a market which has over the years evolved from a **rapidly expanding start-up technology market** to being an **established high-tech market** with constant high growth rates.

Through increased taxes and tighter regulations (e.g. higher taxes for and city centre bans on vehicles with combustion engines, accelerated expansion of wind power after clarification of political differences on power lines, stronger CO_2 emission requirements for buildings and vehicles....) an **extra Stimulation for requirements of lightweight construction material** may emerge. This could bring additional dynamics to the CF and CC markets, above all in the sectors of Automotive, Construction and Wind power.

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