SKILLMAN

Sector Skills Alliance
for Advanced Manufacturing
in the Transport Sector

YEARLY OUTLOOK OF THE OBSERVATORY ON ADVANCED MANUFACTURING FOR THE TRANSPORT SECTOR: COMPOSITES

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The European Community publications as the main reference of specific information about the joint policy, the technology roadmaps and about the main European projects on the transport technologies.

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Introduction

Introduction

This yearly observatory has been produced through the European Union funded SKILLMAN project. SKILLMAN is funded through the European Commission's Erasmus+ Lifelong Learning programme, which has been running since January 2015 and is due to end in December 2017. The project, whose full title is Sector Skills Alliance for Advanced Manufacturing in the Transport Sector, includes partners from the UK, Denmark and Italy. The partnership comprises industrial players, including Jaguar Land Rover, FIAT Research Centre and SAS, Scandinavian Airlines Systems, working in cooperation with research centres, further education colleges and awarding bodies.

I.I Setting the Scene: the New Skills Agenda for Europe

In June 2016, the European Commission adopted a new and comprehensive Skills Agenda for Europe. It includes a major package of proposals aiming to encourage the 28 Member States of the European Union (EU) to 'strengthen human capital, employability and competitiveness - the new Skills Agenda for Europe.[1]'

The new Skills Agenda sets out to address a number of important challenges and opportunities which include:

- Digital Skills Agenda: the digital transformation of the economy is re-shaping the way people work and do business; digital skills are needed for all jobs, from the simplest to the most complex. They are also needed for everyday life, and a lack of digital skills may lead to social exclusion
- Ageing Workforce: the EU workforce is ageing and shrinking, leading in some cases to skills shortages; yet labour markets do not draw on the skills and talents of all; for example, women's rate of employment remains below that of men.
- Quality & Relevance of Training Offer: the quality and relevance of the education and training available in Member States vary widely, which contributes to increasing disparities in countries' economic and social performance.

The Skills Agenda aims to address significant skills gaps and skills mismatches which exist; many people work in jobs that do not match their talents, although many employers say they have difficulty finding people with the skills they need to grow and innovate. These skills mismatches are noted as hindering productivity and growth. To address these challenges, three priority areas have been included:

- Improving the quality and relevance of skills formation
- Making Skills more visible and comparable
- Improving skills intelligence and information for better career choices

1 http://ec.europa.eu/social/main.jsp?catId=1223&langId=en

I.II How can SKILLMAN contribute?

A key objective of Skillman is to improve the quality and relevance of skills qualifications for the Advanced Manufacturing Sector, ensuring that skills frameworks are developed which are transparent and comparable, whilst meeting emerging and identified skills needs across key identified areas of the sector. The qualifications should thus contribute to improving skills by producing qualifications for the benefit of individuals, the labour market and the economy.

I.III Boosting skills intelligence and cooperation in economic sectors

Current and future skills needs vary across different sectors of the economy. New sectors emerge or change radically. The supply of the right skills at the right time is important for competitiveness and innovation. A major challenge for industry is to better anticipate and manage these changes. Skillman offers an opportunity to do this: One of the instruments in the instruments in Skillman is the Yearly Observatories which can support this process.

The main objective of SKILLMAN is to address, and understand in detail, the current skills challenges within the Advanced Manufacturing for Transport sector. Once this analysis is complete, a suite of EU collaborative qualifications will be developed to address key current and future skills challenges.

The three main priority areas targeted by the educational curricula and qualifications to be developed by SKILLMAN include:

- **Robotics and automated production lines**
- **ICT (Information and Communication Technologies)**
- **Composite and lightweight materials**

Skillman's Danish partners have chosen to focus on the area of Composites in order to understand and steer the development of skills solutions in this sector. This will enable the consortium to understand more fully the skills gaps that exist and to develop a qualification which addresses the challenges faced by manufacturing industries that operate across the European Union. According to one report, composites are increasingly regarded as a highly attractive option for manufacturers with their high strength-weight ratios and excellent resistance to fatigue and corrosion[2]. Aligned with this point are the benefits to energy performance and efficiency that arise out of using composites within the manufacturing process, in both transport and non-transport sectors. The purpose of using composites and the advantages in terms of energy saving and improved energy performance is another area which this Observatory will explore. The observation below highlights the perception from US Manufacturing but is relevant across the European Manufacturing space:

'Advanced fiber-reinforced polymer composites, which combine strong fibers with tough plastics, are lighter and stronger than steel. These materials could lower overall produc-

2 Skills and Training for Composites Manufacturing and Use in the UK: An Analysis, Paul Lewis, Department of Political Economy, King's College London, p.1

tion costs in U.S. manufacturing and ultimately drive the adoption of a new clean energy way of life.[3]'

Given the fact that manufacturers are increasingly turning to composites for, in particular, innovation and energy efficiency purposes, the question therefore arises: what are the skills required to operate in this sector and do those employed to work with composites possess them? Furthermore, what is required to ensure that skills needs continue to be addressed – if they are not already – and what is currently being done, and may need to be done to rise to this challenge? This e-book will also seek to examine how the SKILLMAN project itself may provide solutions for the questions presented.

The purpose of this Yearly Observatory is to support the delivery of the SKILLMAN project by drawing on published research and contributions by consortium partners in order to further understand the challenges faced by the application of Composites in modern-day manufacturing and the subsequent impact this has on skills. It is focused on making information available to relevant stakeholders to support them in these tasks.

3 'Advanced Manufacturing using Composites for Clean Energy' https://energy.gov/eere/amo/advanced-manufacturing-using-composites-clean-energy

Section 1: Summary of the Current State of Composite Skills within Industry

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In order to fully explore the current state of composites skills within industry, there needs to be a clear understanding and definition about what a composite actually is.

According to Paul Lewis in his report: *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*[1]: 'A composite is a mixture of two materials which, when appropriately combined, has new properties that neither of the individual materials taken alone possesses'. He explains that these properties are often highly attractive to manufacturers and include high strength-weight ratios and excellent resistance to fatigue and corrosion.

1.1 Background: the growing importance of the Composites industry

Paul Lewis also reports that 'the UK produces around £1.6 billion worth of composite materials, components and structures each year, adding around £1.1 billion to UK national output.[2]'

In more global terms, composites are increasingly deployed in several manufacturing sectors, including the automotive industry, which is now widely considered to be one of the '… most important growth and innovation drivers for the composites industry.'[3] The market for global automotive composite materials is forecast to reach €3.72 billion by 2017, representing a real opportunity for the European chemical and composites industry.

The automotive industry faces a new challenge aligning material properties, product design and production or assembly processes – especially in larger volume production series vehicles – but could take more advantage of the potential of composites for light-weighting vehicles. The demand for weight reduction is driven by the demand for better fuel efficiency and reduced emissions to comply with EU legislation. In 2007 over 500 million tons of CO2 emissions were estimated to be due to cars in the EU; it is estimated that savings due to composites light-weighting will result in a potential 1.4% improvement[4].

Until a few years ago, Carbon Fibre Reinforced Plastic (CRFP) was mainly used for low volume or sport applications due to its **high weight saving** benefits, but this was combined with a high cost. The main aspects to be considered for CRFP applicability in volume

1 *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis, Department of Political Economy, King's College London, p.9
2 As Above, p. 1
3 https://www.compositeseurope.com/composites_on_the_road_the_automotive_industry_as_the_growth_and_innovation_driver_of_the_composites_industry_54n154.html
4 http://baxcompany.com/how-can-europe-take-the-global-lead-in-automotive-composites-a-vision-by-suschems-stakeholders/

production include:

- Lightweight potential
- Costs
- Issues around recyclability
- Joining issues
- Process Rates

Indeed, weight reduction is increasingly one of the main drivers for the new models since CO2 reduction has become a regulatory condition for the transport sector[5], as set out in the Memorandum of Understanding form the Copenhagen Agreement of 2009; it set a target of 95g CO2/km for 2020 (a) from 120g C02/km as in 2015 and a higher target of 20g C02/km for 2050[6].

The automotive industry is not alone in employing composites. According to a report by COMPOSITES Europe[7], the weight reduction trend has driven the development of fibre-reinforced composites in automotive engineering, aerospace and construction. In 2016, the quantity of glass-fibre reinforced plastics produced in Europe was set to increase by 2.5 %, according to the industry association AVK, with the industry set to continue on this growth trajectory in future years, including in the transport and construction sectors, while hoping for additional gains from the use of composites in modern materials systems that go beyond individual groups of materials.

Moreover, approximately a third of the entire World Glass Fibre Reinforced Plastic (GFRP) market production volume is deployed in automotive applications, with the share of total worldwide GFRP processing demand standing at approximately 21%. The automotive sector is also seen as a key player among the users of thermoset materials. Applications in recent years have included mass-produced Bulk Moulding Compounds (BMC) headlight reflectors, Sheer Mould Compounds (SMC) tailgates, spoilers and trim components, oil pans, covers and micro-components.

The 2016 UK Composites Strategy further reinforces the importance of composites to the UK economy. It reveals that '… the global market for composite products in 2013, across all sectors, had a value of $68.1bn. The overall market is expected to grow at around 6.5% Compound Annual Growth Rate (CAGR) over the next 7 years to about $105.8bn in 2020.' Statements such as these underline the growing importance and benefits that composites bring and the major opportunity for the application of these materials across many industry sectors. Further, it predicts organic growth in the established composites-using sectors including Aerospace, Motorsport and Renewables, together with the emergence of substantial new markets for composites products in sectors which include Automotive and Rail[8].

5 2050 low-carbon economy perspective from the European Commission: https://ec.europa.eu/clima/policies/strategies/2050_en

6 Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles (23 April 2009).

7 https://www.compositeseurope.com/final_report_composites_europe_hybrid_lightweight_construction_on_the_up_and_up_54n167.html?sprache=englisch

8 The UK Composites Strategy: Composites Leadership Forum: Lightening the Load: Delivering UK growth through the multi-sector application of composites, p. 7

1.2 Overview of the Composite Skills Landscape

1.2.1 Case Study: the UK

A crucial aspect of preparing the industry for large scale composite uptake is preparing workers and companies to work effectively with composites. Workers and suppliers that are used to producing steel parts with old steel machinery need to get used to the special characteristics and production methods associated with Fibre Reinforced Plastics (FRPs). One of the main industry reflections is that the knowledge generated has not yet been disseminated sufficiently or effectively down the value chain[9].

An overview of composites skills in the UK is highlighted in the report entitled: *UK Composites 2013: A study into the Status, Opportunities and Direction for the UK Composites Industry*. The table below summarises the perception of industry need and a brief description of the provision on offer to match requirements[10]:

- The need for a wide range of materials and manufacturing technologies has led to a sector focused composites skills landscape with fragmented and reactive delivery by a limited number of training providers.
- The Composites Skills Alliance has developed a network of vocational providers and standard training products ranging from awareness to design theory.
- Composites Engineering Apprenticeships are now available.
- Taught content in Higher Education has been limited and variable, opportunities are now in hand to develop exemplar curriculum for wide take up of qualifications and CPD.
- Forecasting of skills demand must take into account technology changes some years in advance of industrial need to ensure that the industry has an appropriately skilled future workforce.

The UK report indicates that the skills challenges arise – as expected – from the increasing uptake and transition to the use of composites in engineering and manufacturing across a number of sectors, but that this has, in turn, exacerbated challenges to the forecasting of future resources and skills needs. The changing basis of the technology itself is likely to lead to changes and increases in demand which will in turn place different demands on skills and present new skills challenges.

In his report Paul Lewis expands on this and explains that there are 'shortages of both semi-skilled composites laminators and skilled technicians.'[11] In response, he states that employers are resorting to in-house training which includes:

- External upgrade training (in the case of semi-skilled laminator roles)
- Apprenticeship training as a means of developing new technicians who can work with composites
- Additional training to equip those technicians who are established employees but only skilled at working with metallic parts with the skills required to work with composites

9 *UK Composites 2013: A Study into the Status, Opportunities and Direction for the UK Composites Industry*, Composites Leadership Forum 2013, Department for Business, Innovation and Skills 2013 p. 103
10 *UK Composites 2013: A Study into the Status, Opportunities and Direction for the UK Composites Industry*, Composites Leadership Forum 2013, Department for Business, Innovation and Skills 2013 p. 103
11 Skills and Training for Composites Manufacturing and Use in the UK: An Analysis, Paul Lewis, Department of Political Economy, King's College London, p. 53

He explains that, generally speaking in the aircraft industry, the actual fabrication of composite parts tends to be carried out by semi-skilled laminators who account for a little over 20% of the workforce in such organisations. Lewis' report draws upon a survey (using five companies) to highlight the fact that all companies consulted experienced difficulties in recruiting high-quality, experienced workers. In the automotive and defence industries, he explains that it is semi-skilled laminators that fabricate composite parts and they therefore tended to make up around one third of the total workforce in the automotive firms included in the example and close to one half of the total workforce of the two defence companies. The share of technicians in the total workforce was correspondingly reduced, falling to an average of around one quarter in automotive and one third in the defence firms.

The report also defines the typical technician roles in firms that make and/or use composite materials. These are included in the table below:

Role	Predominantly found in their kinds of organisations	Skill Level (UK)
Composite laminators	Parts manufacturers, boat-builders	Level 2 (non-automated methods of production), level 3-4 (automated methods)
Fitters/trimmers	Parts Manufacturers	2-3
Machinists	Parts manufacturers, boat builders, space firms, specialist firms that machine/assemble composites, research and development organisations	3
Production/process engineers	Parts manufacturers, space firms, specialist firms that machine/ assemble composites	4, 5
Draughtsmen/junior design engineers	Parts manufacturers, space firms, specialist firms that machine/ assemble composites	3, 4
Quality engineers	Parts manufacturers, space firms, specialist firms that machine/ assemble composites, materials makers	4, 5
Non-destructive testing (NDT) technicians	Parts manufacturers, space firms, specialist firms that machine/ assemble composites, materials makers, MROs	3, 5
Mechanical testing technicians	Materials-makers, research and development organisations	3, 5
Aircraft fitters	Aerospace parts manufacturers, specialist firms that machine/ assemble composites	3
Aircraft mechanics and licensed aircraft engineers	MROs	3
Chemical process operators	Materials-makers	3
Maintenance technicians	Materials-makers	3

1.2.2 The wider European Market

In terms of the wider European market, research also identified a focus on skills and the recognition of a need for a knowledge of composites across a spectrum of roles. Germany is one case in point. The automated serial manufacturing of composites has been highlighted as a key technology for lightweight construction and, to this end, a key objective cited by the Composites Germany trade association is for Germany to become an industry-wide lead supplier of composite materials for lightweight construction[12]. It further emphasises that Germany can only become a lead supplier if sufficient attention is paid to initial and further training in using and manufacturing composites and highlights its key goal as being that of establishing lightweight mechanics as a skilled occupation, and its wish to obtain support from the German Federal Institute for Vocational Education and Training (BIBB) in creating a quality seal for CPD and further training activities, based on a point system.

This vision – a full and formal recognition for training programmes and qualifications in composites – is echoed across the European market. The European Composites Industry Association (ECIA) also proposes various solutions to increase/maximise the sector's competitiveness, based on what it sees as current market gaps. These include:

- Developing the necessary skills for successful integration of composites in new vehicles by automotive designers and engineers, as well as facilitating the transfer of composites' knowledge to such designers and engineers.
- Establishing training programmes that can instil the necessary skills into the workforce across the value chain of automotive design, production, assembly and end-of-life, e.g. modelling and simulation, safety, composites processing and assembly, Life Cycle Assessment (LCA) and materials recycling, etc.[13]

12 http://www.composites-germany.org/index.php/en/
13 http://www.eucia.eu/

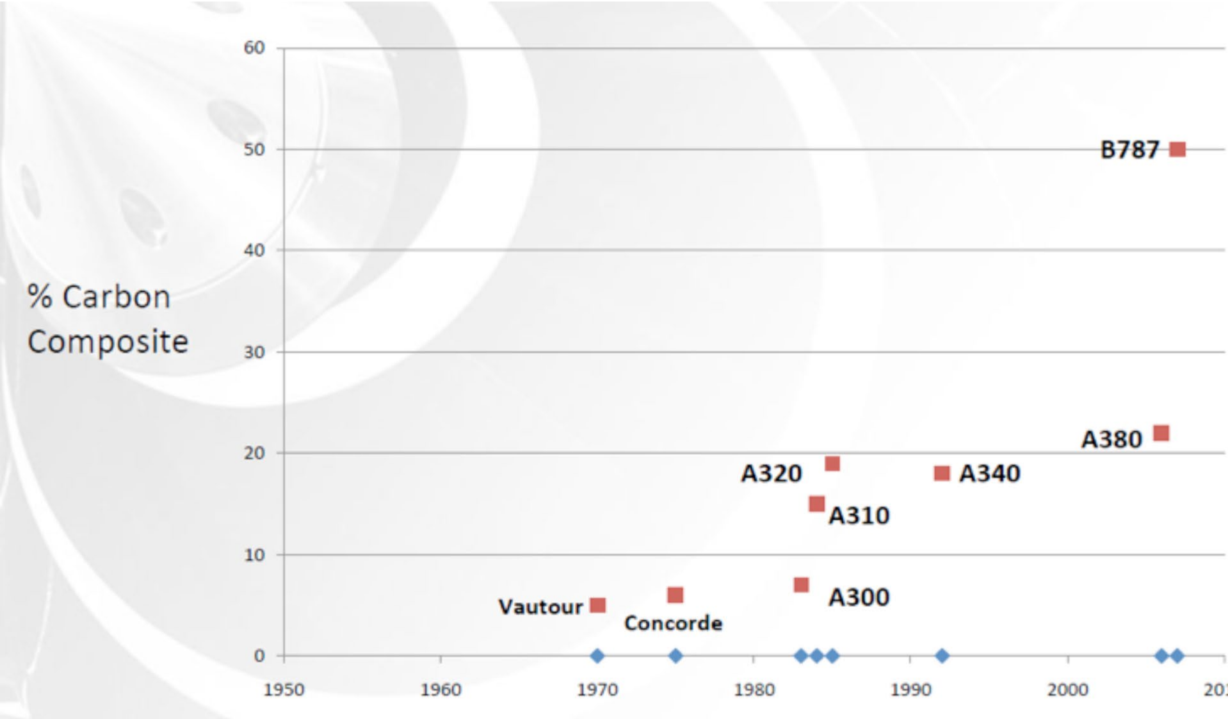
Section 2: Summary of the Composites Skills Challenges

Section 2: Summary of the Composites Skills Challenges

2.1 Introduction

The composites skills challenge currently facing Advanced Manufacturing is defined very clearly in the 2016 UK Composites Strategy[1]. It recommends that in order to develop, diversify and deliver success to meet growing market demand, there is an increasing need for new people with the right skills to be employed, and for those in work to be equipped with the right skills. It states: '*The current pool of people is small and as demand is increasing rapidly, this has already become a major inhibitor to growth*'.

The growth in the use of carbon composite materials is very evident in the North American aerospace industry. The chart below[2] reflects this:



As in the UK, the increasing use of composite materials in construction in the US has raised several issues about the skills required by those working in the industry, notably in terms of understanding how to effectively address safety and repair.

1 The 2016 UK Composites Strategy: Composites Leadership Forum – Lightening the Load – Delivering UK growth through the multi-sector application of composites, p.12
2 Northwest Aerospace Alliance: Current Challenges in the Aerospace Industry, Martin Wright

2.2 Case Study: Skills Challenges within the Aircraft Sector

In today's aviation industry, manufacturers have gradually making the transition from all aluminium aircraft to new generation aircraft that utilize composite materials for the majority of their primary structures.

Every year the aerospace industry uses a higher proportion of advanced composite materials in the construction of each new generation of aircraft.

But while airlines love how this lightweight concoction saves fuel, the recent fire on a 787 at Heathrow Airport in London provides the first test of how difficult and costly it will be to repair serious damage. It's happening at a pivotal moment for Boeing, which is eager to show that even significant damage to a carbon-composite plane like the 787 can be repaired as quickly and effectively as in the old aluminium models. Each day a jet remains grounded costs an airline tens of thousands of dollars.

New generation large aircraft, such as the Boeing 787 Dreamliner and Airbus A350 XWB, are designed with all composite fuselage and wing structures, and the repair of these advanced composite materials requires an in-depth knowledge of composite structures, materials, and tooling.

Following the certification of the Boeing 787 Dreamliner in 2011, a report produced by the US Government Accountability Office (GAO) highlighted the need for the study because '… although composites are lighter and stronger than most metals, their increasing use in commercial airplane structures such as the fuselage and wings has raised safety concerns.'[3] The report identifies four safety-related concerns with the repair and maintenance of composites:

- Limited information about the behaviour of aircraft composite structures:
- standardisation of repair materials and techniques
- training and awareness
- technical issues related to the unique properties of composite materials

The first concern highlighted relates to a lack of understanding about the behaviour of composite structures as they age or when they are damaged. The report claims this lack of awareness to be '… partly attributable to the limited in-service experience with composite materials used in the airframe structures of commercial airplanes.' The example is used of a repair technician potentially confusing materials or processes, which may result in improper repairs.

The study argues that mechanics and engineers frequently lack the skills to understand the differences between traditional metals and composites. An example cited is that of pilots lacking the competence to detect damages as threats when they conduct ramp checks raising the issue of challenges '.in detecting and characterising damage in composite structures, as well as making adequate composite repairs.'[4]

The study also notes that impact damage to composite structures is unique in that it may

3 Composite Repairs – the future – Aircraft Technology – Issue 119, p. 52
4 Composite Repairs – the future – Aircraft Technology – Issue 119, p. 56

not be visible or may be barely visible, making it more difficult for a repair technician to detect than damage to metallic structures. In short, it means a requirement to understand various techniques, e.g. nano-stitching which is used to reinforce carbon fibres' plies with nanotubes aligned perpendicular to the plies which start to become part of the norm. This is an example of one technique but it demonstrates the types of techniques that are being applied – and are required - and the expertise that is needed to implement them. This will impact on - and will mean that new skills will be required/demanded from - the maintenance personnel, whereas sheet metal repairs were previously regarded as common trades. 'Composite repair skills will be demanded with all the necessary background education like gluing, carbon and composite cloth handling. Know-how in vacuum and heat treatment techniques for curing of repairs and more Non-Destructive Testing (NDT) skills to verify repairs will be needed as well.'[5]

The issue of how to address major repairs is also raised by the report. It claims that this factors adds another layer of complexity to the challenge, arguing that it may only be possible for the aircraft manufacturers or very large organisations to afford to build up the requisite skills and invest in the tooling: 'Aircraft repairs will become more expensive…and the cost of labour will be under even more pressure – but the special skills will be more expensive.'[6]

Many of these points are reiterated in an article from *Reinforced Plastics*[7].

It underlines the point that repairs must be qualitatively beyond reproach (in airplanes), offering the highest levels of assurance. It highlights some of the complexities arising from using composites; it argues that because composites are – by definition - a mix of different materials drawn from an ever expanding palette of possibilities, precisely matching the original lay-up in the repair might not be practical. Maintenance organisations are rarely equipped to manage the diverse order lead times, storage requirements, processing regimes etc. to do this. At the same time, repair technicians vary widely in their backgrounds, experience, training and aptitude for the work.

It also emphasises the need to manage paint finishes, claiming that removing paint from large composite surfaces is tricky because the chemical strippers routinely used on metal aerostructures are apt to attack not only the paint, but also the underlying composite

Other issues discussed include the difficulty of establishing - after an impact - whether the laminate has suffered damage without there being any sign of it at the surface. Unlike metals that show they are 'hurt' by exhibiting dents, composites can spring back from low-energy impact such that damage several plies down within the laminate can be hidden behind an apparently unharmed surface.'

Clearly, these challenges require a need to minimise the risks associated with fuselage repairs which – according to *Reinforced Plastics* - are likely - over the next several years - to be one of the most significant challenges for composites. In terms of what this means for skill requirements, 'effective training' and 'hands-on practice' are highlighted as core. It goes on to say that' technicians will need considerable training and practice before they have the skill and finesse required to prepare and carry out scarfed repairs that are both strong and leave an aesthetically pleasing flush surface finish.'[8]

5 As above, p. 57
6 As above, p. 57
7 The Challenge of Composite Fuselage Repair: Reinforced Plastics, May/June 2012, p.30
8 As above, p. 32

2.3 Case Study: Skills Challenges within the Automotive Industry

The use of lighter materials – and thereby composites – is becoming increasingly important for the automotive industry. In the case of electric cars for example, it is considered that these will offset the weight of heavy power systems such as electric batteries and motors without increasing the overall weight of the vehicle. Other benefits include using lighter materials to reduce fuel consumption since it takes less energy to move a light object rather than a heavy one.

A report produced by the *European Sector Skills Council's Automotive Industry*[9] highlights the importance for maintenance technicians of knowing the strengths and weaknesses of the materials they are working with and, further, for them to ensure they use appropriate materials. The report emphasises that maintenance technicians will need to know about the manufacturing processes and machinery.

Changes to materials are also expected to have significant consequences for tool design and performance and, by extension, for the work of CNC operators/tools and die makers, as they will have to improve their knowledge and skills to provide high performance tools which correspond to industry norms and standards.

Paint technicians/motor vehicle painters are another cohort which are singled out as requiring a greater understanding of the properties of these materials. The expectation is that they will have to learn how to deal with complex parts in modern designs used for local structure optimisation, for example, in front and rear safety zones, side impact zone and for external panels. Materials portfolios are also increasingly more specific and complex, requiring material planning analysts to have a more sophisticated knowledge of the material that they are dealing with.

The UK Composites Strategy 2016 argues that the maturity of UK composite products and their associated sectors and markets give rise to three classes of action required for Manufacturing Clusters. These include:

- **Deliver** and accelerate organic growth in already established sectors using composites
- **Develop** technologies and supply chains to capture immediate market opportunities
- **Diversify** and enable UK industry to make a paradigm shift, taking advantage of composites in advancing user sectors

The report states that the uptake in composite manufacturing will require a plan of action to 'develop the UK supply chain for mid volume manufacturing and the need to diversify its capability to enable capture of longer term opportunities.'[10] A further challenge for the supply chain is to diversify so that it can take advantage of future opportunities in the low volume, structural manufacturing[11].

9 Report – European Sector Skills Council 'Automotive Industry', p. 7
10 The 2016 UK Composites Strategy: Composites Leadership Forum – Lightening the Load – Delivering UK growth through the multi-sector application of composites, p.9
11 The 2016 UK Composites Strategy, Composites Leadership Forum – Delivering UK growth through the multi-sector application of composites p. 9

2.4 Impact of Energy Performance & Efficiency Targets on Skills Challenges

Simply put, energy efficiency or performance means …'using less energy to provide the same level of energy.' Energy efficient use is achieved primarily by means of a more efficient technology or process with the expectation that energy efficient manufacturing processes and transportation could help reduce the world's energy needs in 2050 by one third, and helps controlling global emissions of greenhouse gases[12].

2.4.1 Overview of EU Energy policy and targets

The European Union has been instrumental in placing energy policy firmly at the heart of its policy agenda. To this end, it has set targets designed to increase energy performance and efficiency and reduce harmful environmental impacts. Energy efficiency is one of the key elements of the EU's energy policy; this is reflected in existing legislation and in targets to be reached by 2020 and 2030 respectively. For example, it is one of the priorities of the Europe 2020 strategy for smart, sustainable and inclusive growth and for the transition to a resource efficient economy. Better efficiency helps ensure security of energy supply, and reduce emissions of greenhouse gases and other pollutants. By 2020, the EU wants to reduce primary energy consumption by 20% as set out in its Energy Efficiency directive and the target is now projected to reach 17.6% instead by 2020. In more recent developments, in October 2014, EU leaders supported a 27% 2030 energy efficiency target[13].

2.4.2 Link to Skills and Composites

In practical terms, improved energy performance may be achieved through the use of composites and lightweight materials because they have good mechanical and chemical properties. For example, in the case of means of transport including cars, trains and airplanes, weight is reduced – and strength added – when high pressure hydrogen and natural gas tanks are overwrapped with liners of fibre-reinforced polymers. With lighter metal casings, transporting these tanks is much more fuel-efficient. Indeed, composite materials have the potential to substantially improve the efficiency of the transport sector, enable efficient power generation, improve the storage and transportation of reduced-carbon fuels and increase renewable power production. In their turn, lightweight composites can enable energy savings in applications where large amounts of energy use and carbon emissions occur in the use phase, such as fuel savings in lighter-weight vehicles.

In short, the more equipped the workforce is in producing and applying composite materials in the manufacturing process, the greater the benefits for energy saving and performance in Advanced Manufacturing. An understanding of the wider targets may provide some context to the daily tasks.

12 https://ec.europa.eu/energy/en/topics/energy-efficiency
13 https://ec.europa.eu/energy/en/topics/energy-efficiency

2.5 What about Research & Development (R&D)?

Whilst market developments are making a robust case for the need to up-skill technicians and other job roles across the Advanced Manufacturing sector, actions are required to produce an industry that is 'sustainable into the future'[14] according to the 2016 UK Composites Strategy.

It makes the point that by increasing the market penetration of composites, the need to incorporate circular principles alongside the rapid development of composites becomes more urgent. It argues that research is needed to develop cost-effective bio-based raw materials to further reduce environmental impact and de-couple prices from oil, and that there is an ongoing need to develop new markets for recyclite from end-of-life and process waste.

The Strategy proposes that this will naturally require R&D to integrate industrial biotechnology into the supply chain and optimise the value of natural fibres. This quite clearly supposes that Researchers with a background in and/or aptitude for this sector will be essential going forwards so that the industrial and technical developments are captured and the future framework is set.

14 As Above p. 13

Section 3: Impact of the Skills Gap on the deployment of Composites within Advanced Manufacturing for the Transport Sector

Section 3: Impact of the Skills Gap on the deployment of Composites within Advanced Manufacturing for the Transport Sector

3.1 Introduction

Of the opportunities arising within manufacturing from the increasing use of composites, the 2013 report '*Technology and Skills in the Aerospace and Automotive Industries*', produced by UKCES (the UK Commission for Employment and Skills) states: 'Addressing these skills challenges will help the sector better respond to performance challenges and opportunities.'[1]

One of the objectives of this chapter is to determine what this means in practice; what exactly it means for performance and production in the Advanced Manufacturing for Transport sector if the people it employs are not equipped with the skills to positively address challenges in the Composites sector.

3.2 Background - Part of a Bigger Problem?

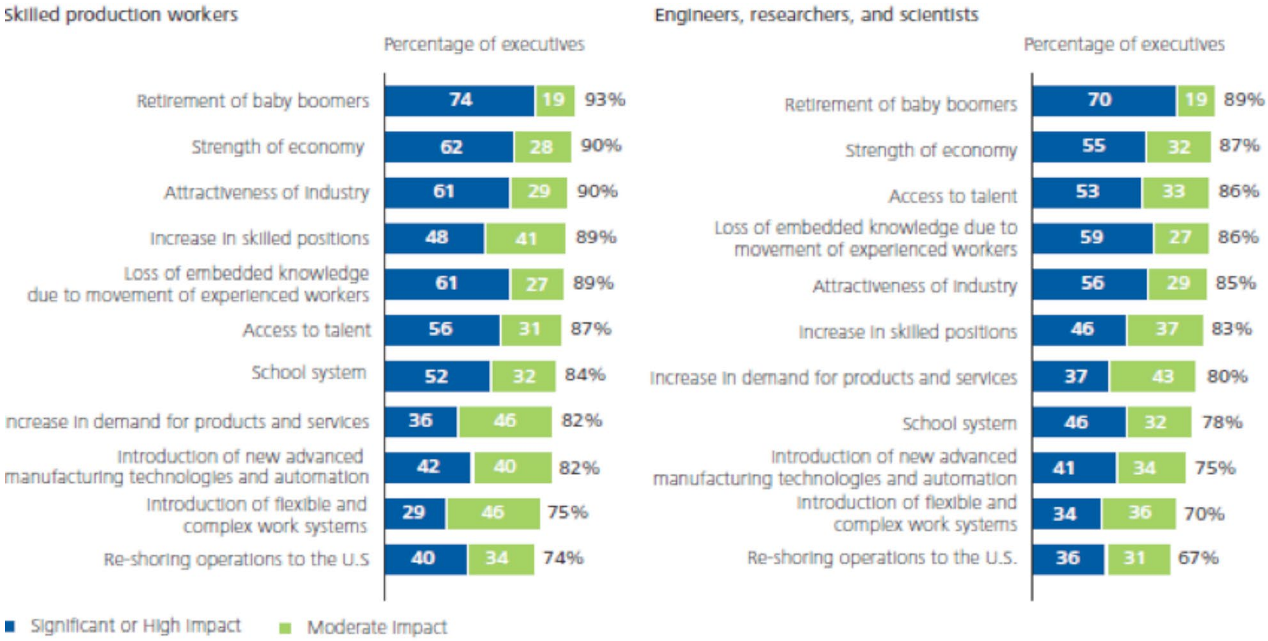
Perhaps what we need to understand is that, in addition to the reported skills gap in Composites, the manufacturing sector as a whole is facing several skills challenges. As a result of which: '*The misalignment between applicants' skills and the requisite skills for work in today's technologically advanced manufacturing industry are expected to leave these millions of jobs in the skills gap.*'[2]

What is behind this trend?

- Adam Robinson's article states that this situation is partly due to the fact that approximately 60% of today's unfilled manufacturing jobs are due to a shortage of applicants with sufficient proficiency in science, technology, engineering and math (STEM) skills[3].
- A report by *Deloitte* argues that issues occur when we talk about skills gaps in terms of the increasingly technical nature of manufacturing work[4]. The Report states that many manufacturers have redesigned and streamlined production lines while increasing automating processes. It says that while some remaining job roles will require less technically

1 UKCES: *Technology and Skills in the Aerospace and Automotive Industries*, Evidence Report 76, October 2013, page 41
2 Two Million Vacant Manufacturing Jobs by 2025... How can we tackle the Skills Gap? Adam Robinson, 2015
3 As above
4 Deloitte: The Skills Gap in U.S. Manufacturing 2015 and beyond, page 6

skilled workers, these trends and innovations demand more skilled workers. It goes on to state that when it comes to highly specialised and innovative employees, such as researchers specialising in composites, their shortage could affect new manufacturing processes and new product development[5]. The diagram below provides an indication of the importance of the impact of new skills and new technologies on the US manufacturing job market.[6]



Note: "Significant impact" and "High impact" responses have been summed together.

The research indicates that the sophistication of today's (and tomorrow's) factories places a greater onus on new and existing workers to increase their skillset, and to come to the table with the STEM skills necessary to operate in an advanced manufacturing facility.

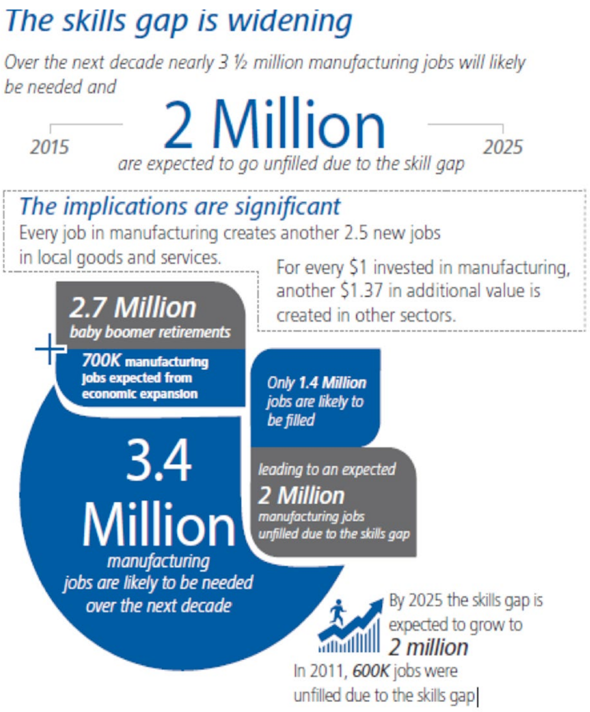
However, in general terms, in the U.S, the skills gap is widening and over the next decade, 3.4 million manufacturing jobs will likely be needed[7] and estimates state that 60 per cent of these roles are likely to be unfilled due to the talent shortage. As a result, only 1.4 million out of 3.4 million positions are expected to be filled, implying that the U.S. manufacturing sector is likely to suffer a shortfall of 2 million workers over the next decade.[8]

3.3 Impact of the Skills Gap

In her article entitled: '*Why the Manufacturing Skills Gap is Serious*', Anna Wells, IMPO Executive Editor writes: 'In an industry that has yet to recover the jobs lost in the recession, we're dealing with vacancies in the skilled trades that threaten to derail production growth and sector expansion.'[9] One interpretation of this issue must surely be that, if skills gaps are prevalent across Advanced Manufacturing, they may be even more apparent in

5 As above, page 7
6 Deloitte: The Skills Gap in U.S. Manufacturing 2015 and beyond, page 7
7 As above page 8
8 Deloitte Analysis based on data from U.S. Bureau of Labour Statistics and Gallup Survey, taken from Deloitte: The Skills Gap in U.S. Manufacturing, 2015 and beyond, page 5
9 Why the Manufacturing Skills Gap is Serious, Anna Wells, 2014

a growth area such as composites due to the specialised, advanced skills requirements. The diagram below illustrates the extent to which the skills gap is increasing across the manufacturing industry:[10]



3.4 What do Composites offer?

3.4.1 Case of the Automotive Industry

The automotive industry is one of the main driving forces for the European economy accounting for almost 7% of the EU's Gross Domestic Product (GDP) representing 8% of total value added, the sector provides employment to 12 million workers.

At the same time, the sector is facing many structural changes, including ever stricter emission standards and decarbonisation as part of new mobility concepts, connectivity and an ever-growing share of digital technologies in the added value of cars, changes in consumer preferences, relocation to low-cost countries and development of global manufacturing systems, and last but not least, dealing with the implications of an ageing workforce.

A strong and thriving automotive sector capable of tackling these challenges is therefore of strategic importance for the future of Europe's industry and should be a cornerstone in any strategy supporting the re-industrialisation of Europe. The importance of education, skills and training can hardly be underestimated: knowledge has become the dominant production factor and innovation, R&D and competence development are now more important than ever for all industrial policies, whether it be at national or European level. The automotive sector is developing ever faster and its future jobs are likely to have a different mix of skills and will require permanent upgrading of skills levels and competences.

10 Deloitte: The Skills Gap in U.S. Manufacturing 2015 and beyond, page 5

In order to understand the impact of a shortage resulting from a lack of employees with the appropriate knowledge of and skills in composites, we first need to fully understand the opportunities created by such a change in technology. In terms of the UK, the UKCES report argues that composites offer '*an opportunity to create tomorrow's vehicles, increase market share and create new supply chain companies*.'[11] In the same way, it also suggests that 'skills gaps have constrained recent growth (2013) within the automotive sector with above levels of hard-to-fill vacancies, difficulty retaining staff and technical skills gaps.'[12]

In terms of vehicles, the report highlights what exactly composites can do. This includes:[13] using carbon fibre composite components for cosmetic parts e.g. spoilers, trim accents and wheels. Other composite applications include under-trays using stamp or flow moulded thermo plastic composites. Carbon composites are widely used in alternative vehicles e.g. electric/hybrid and fuel cell vehicles. Advantages include:

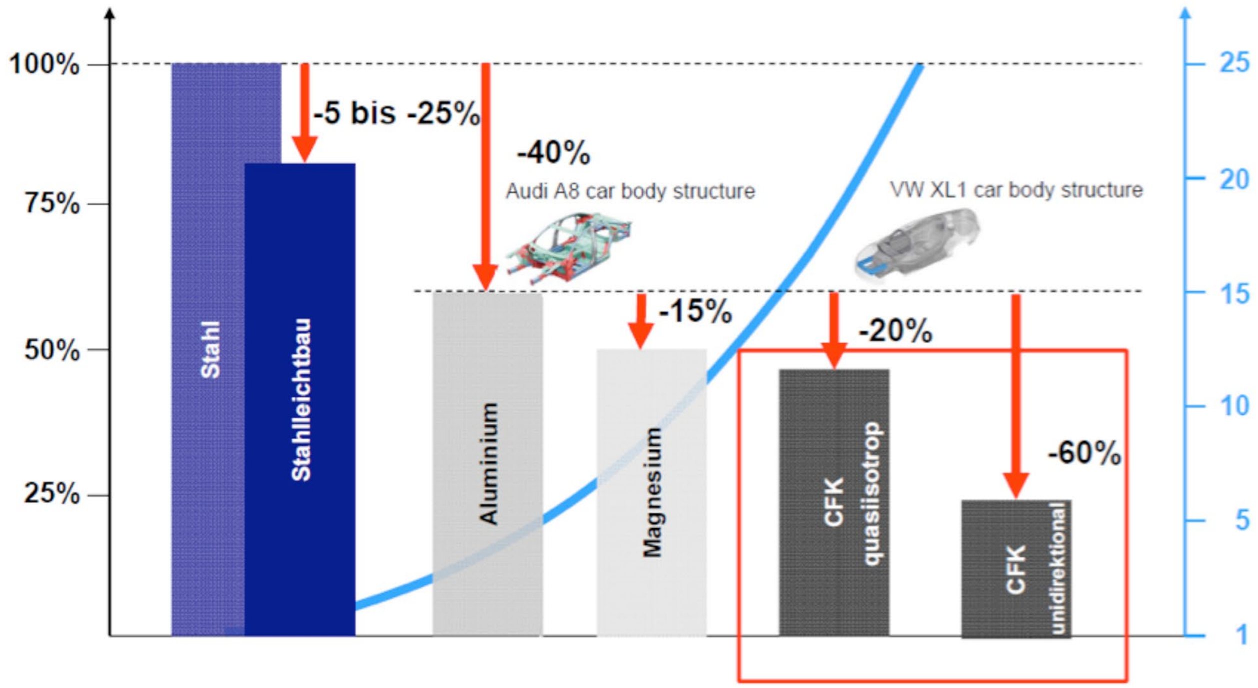
- Cost reduction
- Weight reduction: weight advantages over traditional steel and injection moulded automotive parts
- Recyclability- reduced material scrap, improved work safety conditions, elimination of painting steps, elimination of tedious production steps via automation and greatly improved recyclability

The UK Composites Supply Chain Scoping Study (Ernst and Young 2010) identified an expected annual growth rate of 10% in relation to carbon fibre composite demand within the UK automotive sector over the period 2010 – 2020, although from a relatively small base. In the automotive sector, composites have traditionally been used in high-end small-volume car production e.g. Formula 1, Aston Martin, Ferrari and Porsche. In the current market, composites are being used by Formula 1 car manufacturers and other high-end low-volume performance car makers.

This said, several major automotive car makers appear to have investigated the potential advantages of using composites.

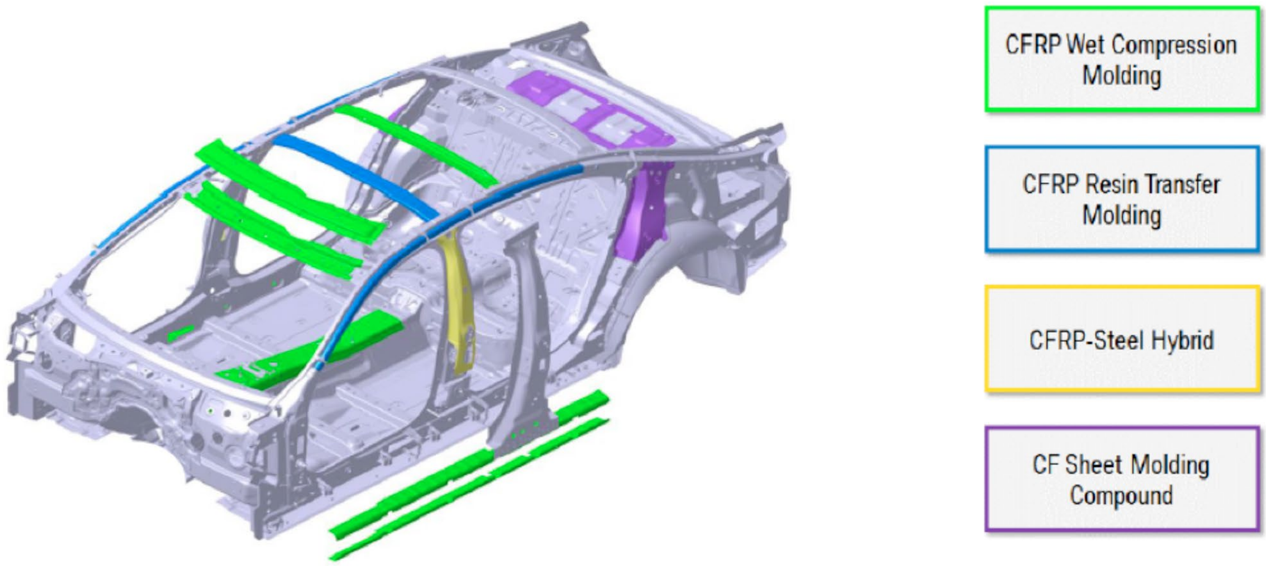
In a recent investigation by VW group (c), is it possible to see how great the volume of weight reduction will be when standard materials are replaced by composites[14].

11 UKCES: *Technology and Skills in the Aerospace and Automotive Industries*, Evidence Report 76, October 2013, page 42
12 UKCES: *Technology and Skills in the Aerospace and Automotive Industries*, Evidence Report 76, October 2013, page ix
13 As Above, page 45
14 Use of fibre reinforced composites in automotive lightweight design – Chances and challenges, Dr. Olaf Täger, Volkswagen AG, DE, MATERIALS IN CAR BODY ENGINEERING 2016 Conference, 9 MAY 2016



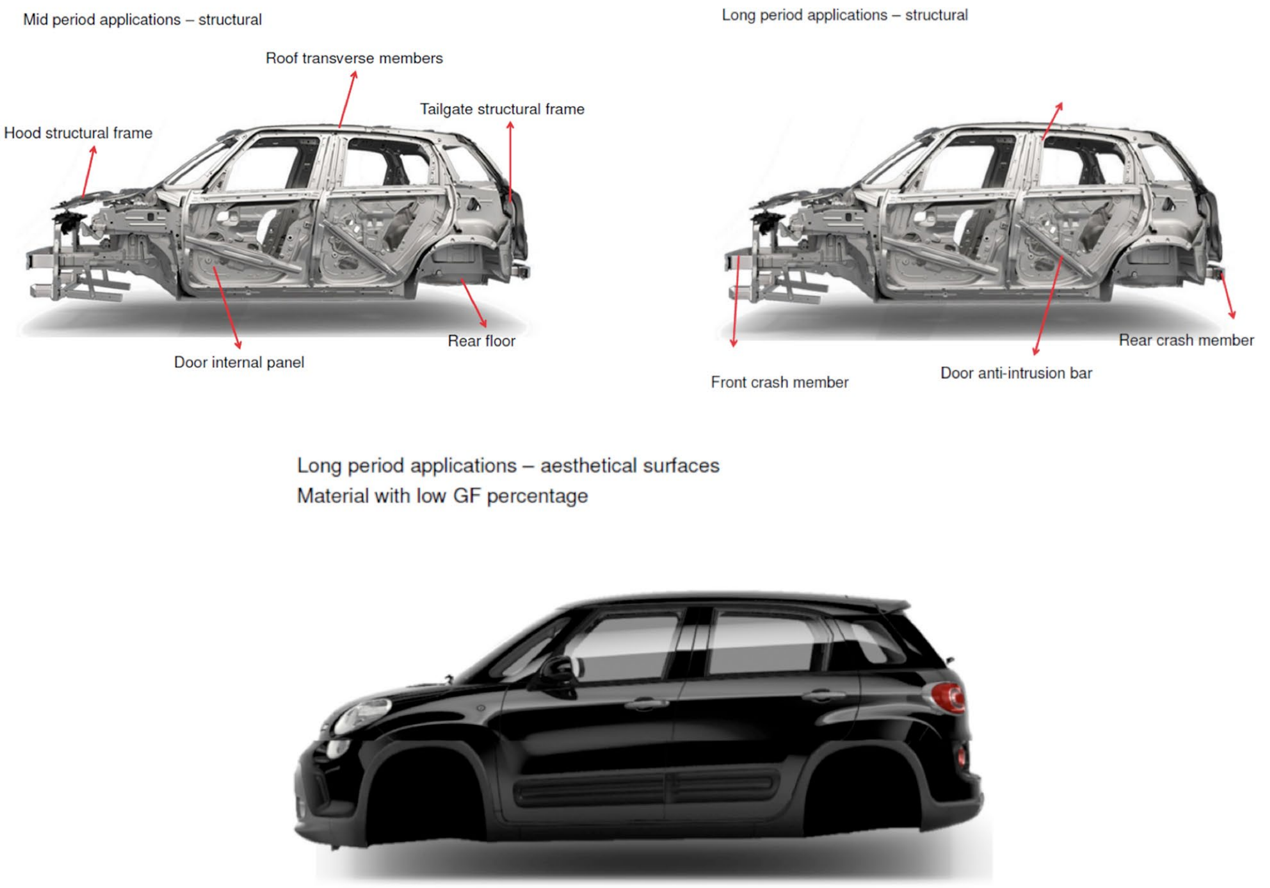
The high cost incurred when employing composites is a major concern. For this reason, new Composites materials originating from thermoplastics matrix are going to be developed by major material suppliers.

Composites may be suitable for large parts like floors or bonnets, where the weight saving potential could be really high, or for hybrid parts where metals are co-moulded or co-formed with the composite. An example of this last application is the B-pillar, where a steel B-pillar may be integrated with composites reinforcement. A similar hybrid solution has been implemented by BMW for the new BMW 7 series[15]:



15 An example for the manufacturing implementation of an innovative steel-CFRP lightweight design concept: the hybrid B-pillar in the new BMW 7 Series Peter Frei, BMW Group, DE. MATERIALS IN CAR BODY ENGINEERING 2016 Conference, 9 MAY 2016

The diagram below is used to demonstrate how a wider application of composites may be foreseen in the next years, as soon as production technology will guarantee higher productivity for these materials, together with a cost reduction. The following diagrams show how composites may be included in future vehicles from a mid-period to a long period timescale:



BMW has been using composites as part of its medium volume production and has established an in-house manufacturing process over the entire composites process chain. Body in White (BiW) is around 230 k; considering the BiW without hand-on and fenders, half of the weight is due to composite parts.

Thermoplastic body skins are used to confer a proper aesthetical aspect for exterior parts. For this reason, it is evident that Composites will increasingly be a material that will increase its applicability in the automotive sector, bringing with it an improved and efficient solution, but with new skills required for the automotive sector – from the manufacturing and assembly aspects through to repair and recycling.

In 2010, it was reported[16] that BMW had undertaken a programme of investment in the development and production of a composite hybrid car all in-house. They were due to invest $100m in a carbon fibre manufacturing facility in partnership with producer SGL at Moses Lake in the US. The site was chosen because of its location – near to the availabil-

16 UKCES: *Technology and Skills in the Aerospace and Automotive Industries*, Evidence Report 76, October 2013, page 46

ity of hydro-electric power to carbon offset the energy intensive carbon fibre production process with the aim of yielding lower cost, lower carbon footprint raw materials.

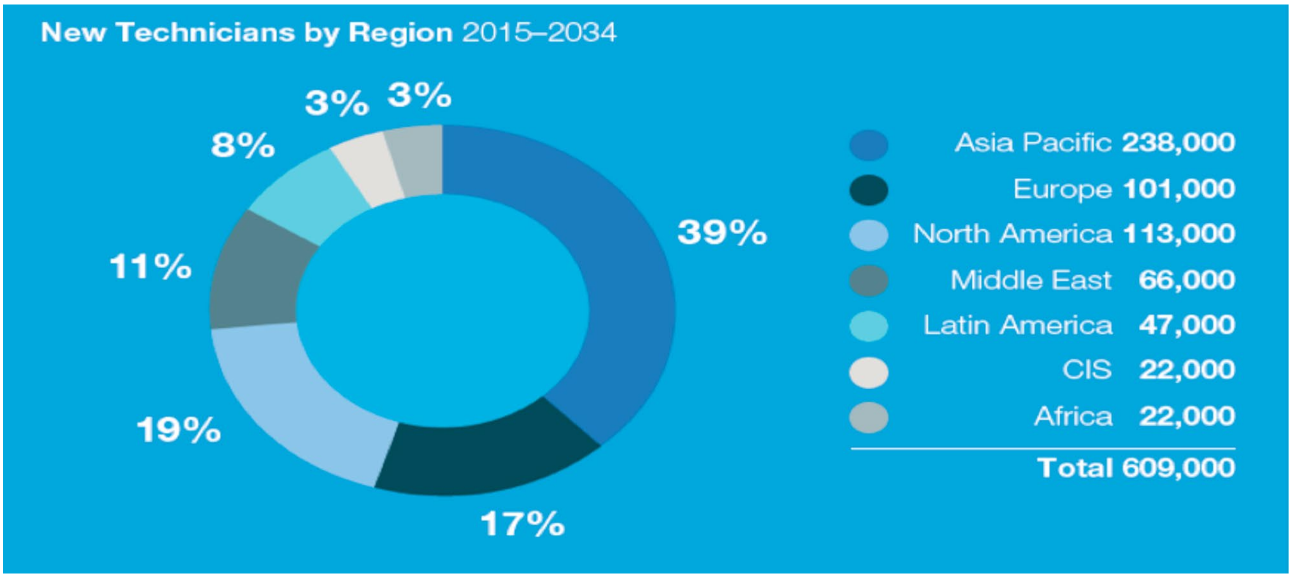
Given these developments and the considered need to include composites within the automotive industry, what does this mean in practice, in terms of skills and workforce?

In terms of the supply chain, there are several factors that influence the profile of the composites workforce. The UKCES report[17] gives a good overview of the workforce skill requirements and, usefully, a summary of the factors that influence the profile of the composites workforce within the supply chain. These include:

- Market focus: Organisations specialising in the 'high end' automotive sector are likely to have a somewhat different workforce profile than those serving the aerospace OEMS.
- Position in the Supply Chain: The workforce profile of companies developing and supplying composites materials (pre-preg material, resins etc.) will differ from those producing composite components for example; and
- Size of the organisation

3.4.2 Case of the Aerospace Sector

The Air Transport industry is offering a wide range of skilled job vacancies, especially in high specialized engineering disciplines as well as for technical support staff. According to Boeing's 2015 Pilot and Technician Outlook projects that between 2015 and 2034, the world will require 558,000 new commercial airline pilots and 609,000 new commercial airline maintenance technicians (101,000 technician in Europe).



Future needs for skilled technicians and workers in Europe in the Aerospace Sector

In terms of the aerospace sector, the same report notes that 'there is a strong demand for highly skilled people within the UK composites sector'[18]. The article cites some job

17 As above, page 47
18 UKCES: *Technology and Skills in the Aerospace and Automotive Industries*, Evidence Report 76, October 2013, p.42

adverts posted in 2012 which showed that there were nearly 800 jobs posted within the UK which had the word 'composites' in the job specification. Of these jobs, over half were in higher-level occupations such as technicians, professionals and managers. Increasingly – over recent years – composites have been increasingly perceived as a *critical technology in driving change with the aerospace industry*. In order to pursue this appropriately, the report advises that large-scale research investment will be necessary to achieve this and in order to achieve this, high level research skills/aptitude/knowledge is a requisite.[19]

In terms of skill requirements for the aerospace industry, there has been considerable growth in the aerospace composite workforce in the first ten years of this century. In Aircelle in Burnley, there were 130 shop floor workers employed in composites-related roles in 2012, an increase from about 55 in 2008.[20]

In the example of Aircelle in Burnley, the composites workforce was reported as making up about a fifth of the total 1,000 employees – its composites workforce included: engineers involved in control, stress and quality assurance and manufacturing/process engineers.

3.5 Conclusion

This section has described a clear shortage of sufficiently skilled workers that are needed to fulfil the 'corporate mission' – at a minimum, this requires the maximising development of the company's core competencies in current personnel as well as indirectly cultivating prospective applicants before they even enter the job market. What is clear, however, is that there is a likelihood of two million vacant manufacturing jobs by 2025 and the prospect of a very real skills gap. The following chapters will consider how up skilling in the Composites sector may start to be addressed.

19 As previously, page 43
20 As previously, page 43

Section 4: Impact of the Skills Gap on Advanced Manufacturing in Non-Transport Sectors

Section 4: Impact of the Skills Gap on Advanced Manufacturing in Non-Transport Sectors

The purpose of this Section is to examine industries outside of the transport sector which use composites to manufacture their products. The Chapter will explore how these industries use composites and examine the value and advantages they are bringing, before finally considering what the impact may be if the workforce is ill equipped with the appropriate skills.

4.1 Composites in the Sports Industry

Composites are widely used in the sports industry to produce innovative products and goods of the highest quality. Indeed, an article by Ellis Davies for *Materials World Magazine*[1] explains that the sports industry was one of the first to take up composite materials and is a significant consumer of carbon fibre, accounting for 14% of industry consumption. The article further includes case studies showcased at Composites in Sport, a 2017 event covering the technical aspects of recent developments in sports equipment. Examples highlighting innovative approaches include:

- Rockwood Composites UK and its spin-off hockey specialist ZEEK employ a manufacturing process using compression and bladder moulding. This process manufactures hockey sticks made mostly of carbon fibre, with the blade made up of multiple layers of composites wrapped around a foam core. ZEEK says its stick combines strength, lightness and flexibility for better performance and usability. Indeed, the conference pointed out that products are now manufactured to perform within the boundaries of safety and regulations following indications that rules of the sport have had to be altered to accommodate new equipment. Ice Hockey sticks allow for a more powerful shot and the ability to engineer specific properties.
- Stefan Mohr, Team Leader for R&D Predevelopment Racquet Sport at global sporting goods company Head, outlined its many branches in various sports, including diving, winter sports and tennis, and talked about the materials used to make high performance racquets. They contain 180g of complex carbon and glass fibre composite, 30g of steel, 40g of PU-parts in the handle and grip, 20g of lacquer, 30g of plastic in the form of grommets and 15g worth of strings made of a combinations of plastics and natural gut. The racquet head can withstand up to 30kN of implosion force, and up to 2kN in peak forces from ball impact. Mohr highlighted that the racquet must also be deal with external influences such as impact with the court and net.

4.1.1 Advantage Sports Equipment?

In terms of benefits over standard materials, Ellis Davies includes an example cited by the UK National Composites Centre (NCC) which recounted how, during the 2016 Olympics, it

1 Innovative Uses of Composites in Sport, Ellis Davies in Materials World Magazine, 4 January 2017

provided the Australian cycling team with four chain rings that were pre-formed in seven hours[2]. It explained that traditionally, these parts are manually laid up, stacking materials by hand to form the composite product. In this case, the NCC used automated fibre placement (AFP). Material is fed, laid and cut into narrow unidirectional strips, and is heated using laser homogeniser optics before being pressed onto the previous layer.

The NCC explained that using AFP over the manual process offers a 90% reduction in lay-up time. It offered what it termed a pyramid cycle design, which included a rapid inquiry response, manufacturing expertise with AFP, access to an advanced thermoplastic pre-forming facility and an improvement over existing manufacturing.

In short, what does using composites achieve in sport?

Composites have characteristics of the resin matrix and of the carbon fibres, and there are many different variations of each of these materials to consider. Then of course there is the interaction between the fibre surface and the matrix. This complexity is the source of the value that carbon fibre brings to sporting goods and its numerous other end-uses," explains Steven Carmichael, director of Sales and Marketing at Grafil, a subsidiary of the Japan based Mitsubishi Rayon, a major Carbon Fibre producer.[3]

Carbon fibre has made hockey sticks lighter, replaced breakable wooden bats and allowed the creation of 10m-long fishing poles. Golf shafts are often manufactured with two or three different types of carbon fibre materials. Different ply thickness, orientation and even selection of the fibre's tensile modulus properties are optimized for specific types of club, points out Carmichael in his article.

"With this capability, manufacturers can carefully dial in the dynamic performance, providing both strength and dynamic performance, performance that can be controlled - an achievement that simply is not possible with a homogenous material such as metal," he says.[4]

4.2 Composites in the Healthcare Sector

As has been demonstrated, carbon fiber reinforced materials are currently used primarily in materials science, for instance in aerospace, vehicle construction, for sports equipment or in construction. Composites are, in addition, increasingly being used in the Healthcare sector.

The expectation is that until 2020, demand for carbon fiber reinforced materials for medical technology will increase significantly all over the world.[5]

Composites in medicine range from the large scale components, such as those used for x-ray applications, to the almost invisible: composite bolts used internally to support bones. The uses for composites in medicine are far-reaching, including equipment components such as mammogram plates to state-of-the-art carbon fiber exoskeletons[6]. What's

2 Innovative Uses of Composites in Sport, Ellis Davies in Materials World Magazine, 4 January 2017
3 'Sports is a key market for carbon fiber', ICIS Chemical Business, 18 August 2009
4 As Above
5 The future of medical technology: Carbon Fibre Reinforced Materials, 03/02/15, COMPAMED Magazine
6 http://www.prfcomposites.com/industries/medical/

more, carbon is already built into medical devices such as angiographs and CT scanners for instance as well as being used in electromedicine, radiology and radiosurgery.

Composites also play an important role in the creation of artificial limbs spirally woven tapes and spiral braids which can be used in a number of applications, such as limb exoskeletons . Carbon is already being used in orthopedics, prosthetics and orthotics, meaning for artificial legs and arms, as explained previously. Surgical instruments and wheelchairs are also in part made from carbon fiber.

4.2.1 Advantages of using Composites in Healthcare

Carbon prepreg, with specific matrix, maintains the transparent properties of the material that are necessary for x-ray applications but retains all the mechanical benefits that carbon fiber has to offer. Carbon is lightweight and resistant to chemicals, corrosion and temperature. It is very moldable and still features high stability and rigidity. One big advantage is its X-ray transparency, which improves patient tolerance of X-rays. Carbon fibers are also suited for producing technical textiles, making the material ideal for use in medical technology.

To date, composites have not been used as widely in the healthcare sector as in other industries; compared to other materials sciences, carbon fiber technology is still quite new and as a result still offers many corresponding future growth areas. What's more, products made of carbon fiber reinforced materials are still relatively expensive. To utilize the described market and development potentials and further develop the already existing technologies and existing expertise of network partners, respectively, close collaboration along the entire value chain from production and development all the way to the market-ready product or process is needed.[7]

4.3 Composites in the Wind Energy Sector

In terms of non-transport sectors, wind energy is a sector that is increasingly using composites as part of its manufacturing process to be more innovative and energy efficient. This is particularly the case in turbine blade technology: in wind energy generation, high strength and stiffness, fatigue-resistant lightweight materials like carbon fibre composites are renowned for supporting the development of lighter, longer blades and increased power generation[8]. The very essence of clean energy is wind power. With wind turbines, the challenge has been to extract as much energy from the wind as possible. Turbine blades made of new advanced composites can be made longer, stiffer, lighter, and more responsive to sudden shifts in wind speeds than older blades.

Polymer Matrix Composite Materials are those that are typically used in wind turbine blades. They contain reinforcing fibres (to add strength and stiffness) and matrix (to hold and protect fibres and distribute the load). The advantages are that the materials are easier to process and have high toughness facilitating recyclability purposes; they both minimise mass for assigned stiffness and strength.[9]

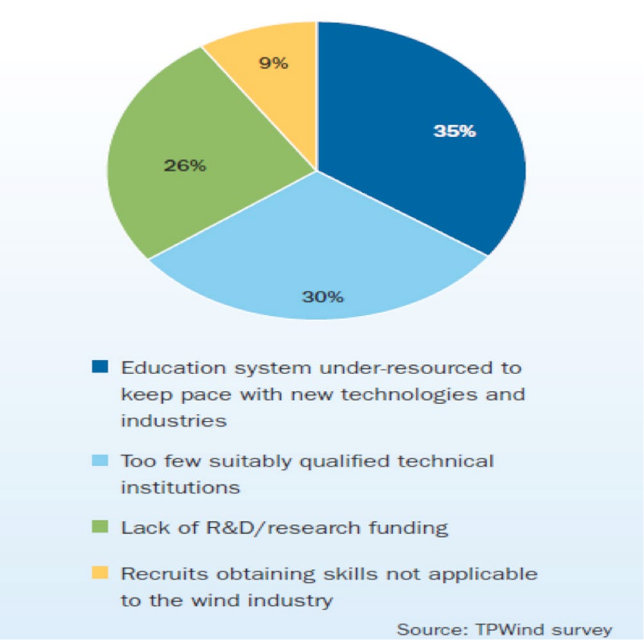
7 The future of medical technology: Carbon Fibre Reinforced Materials, 03/02/15, COMPAMED Magazine
8 'Longer, Stronger, Lighter, Cheaper', Composites Manufacturing Magazine, May 1, 2017 http://compositesmanufacturingmagazine.com/2017/05/improvements-in-composite-turbine-blades-power-the-wind-industry/5/
9 Composite Materials for Wind Turbines and Blades: Issues and Challenges: Francesco Aymerich, July 2012 University of Patras

In terms of skills challenges, increased technological complexity may simplify some of the job tasks but make others more intricate. 'Ongoing changes like these must be reflected in curriculum in order to meet the needs of industry where expectations for workers are evolving.'[10] highlights Barbara Hins-Turner, Executive Director for Washington State Centre of Excellence for Energy Technology.

4.3.1 Lack of Skills and Call for the standardisation of curricula

This point is reinforced in the European Wind Energy Technology Platform's report: 'Workers wanted: The EU wind energy sector skills gap'. It highlights the fact that there is currently a shortage of 7,000 qualified personnel required by the European wind energy sector, a figure that could increase to 15,000 by 2030 according to some reports[11]. Moreover, the education and training on offer lags behind technical developments in the wind energy sector: 'The current focus on academic rather than practical and problem solving skills means there is strong industry support for an EU wide standardisation of curricula.'[12] The skills shortage is highlighted as most likely to be in operations and maintenance roles in the wind energy sector, with the requirement expecting to double by 2030, exacerbating the skills gap[13]. In a survey carried out by the European Wind Energy Technology Platform amongst European Wind Energy companies, the most frequently cited reason for the constraint in supply was a mismatch between the education system and new technologies and industries, perhaps due to links with academia not being strong enough. The figure below gives an overview of the answers[14]:

FIGURE 8 OBSTACLES TO A SUITABLY SKILLED WORKFORCE



10 Skills Standards for Wind Turbine Technicians, Washington State Centre of Excellence for Energy Technology, p. 21
11 Workers wanted: The EU energy sector skills gap, August 2013, European Wind Energy Technology Platform, p. 6
12 As above p.14
13 As above p.6
14 As above p. 14

4.4 Conclusion

This chapter has demonstrated the range of benefits that using composites can have for the sport, healthcare and wind energy sectors.

Ellis Davies' article – and the example of Rockwood in particular – have demonstrated the power composites have to outperform other products on the way to producing optimal performance. Paul Sherratt of the Sports Technology Institute at Loughborough University explained that the rationale for including a high level of composites in sport is because of lower levels of regulation, quick concept-to-market turnaround, multiple niches and general enthusiasm from consumers[15].

With composites being increasingly regarded as a highly attractive option for manufacturers with their high strength-weight ratios, resistance to fatigue and corrosion and the mechanical benefits they bring, there is clearly a challenge to remain competitive and attractive to consumers in the sports sectors if there are not enough skilled people to design and manufacture highly desirable products for the sports sector. Similarly, it is likely that the healthcare sector will suffer from access to highly effective applications to treat patients if products cannot continue to be produced at the same level. Perhaps the challenge to the Wind Energy sector is even greater: will energy performance targets be missed and the environmental benefits decline if there are not enough skilled technicians equipped to produce lightweight wind turbines?

15 Innovative Uses of Composites in Sport: Ellie Davies in Materials World Magazine, 4 January 2017

Section 5: A Review of the Current Approaches to Address Skills Gaps in Composites

Section 5: A Review of the Current Approaches to Address Skills Gaps in Composites

The report has sought to demonstrate how extensively composites are being used across the Advanced Manufacturing for Transport sector.

For example, it is clear that the use of composites within the aerospace industry is both prevalent and long standing. At the same time, there is growing concern that the shortage of skilled workers and an inability to recruit experienced engineers could constrain the composites manufacturing industry's growth, both in Europe and worldwide.

This chapter will examine the initiatives in place across the sector, both in Europe and worldwide, to address the skills gaps.

5.1 Current and Future Skills Requirements

There is growing concern that the shortage of skilled workers and an inability to recruit experienced composites engineers could constrain the UK composites manufacturing industry's growth. There is a skill shortage for composites as recruitment into the industry has not kept pace with the explosion in demand for components, regardless of whether in F1 or aerospace, medical or defence. In an interview with the online magazine, CiM (*Composites in Manufacturing*), John Toner from Teledyne Composites underlined the challenges faced by manufacturing, notably in transport sectors including aerospace and automotive:

"In aerospace alone, worldwide demand for composites grew by 10.7% in 2014. When considering that in the 1990s only 5% of an aircraft was composite to 50% plus in new aircraft, such as the B787 and the A350 in 2014, simply not enough new engineers are being brought into the industry to support this rapidly rising demand.'[1]

In his report: *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis explains that in the UK aerospace and automotive industries with whom he consulted, and who fabricate composite parts, semi-skilled laminators account, on average, for anything between 20% and 50% of the workforce.[2] He further makes the point that in the automotive sector, technician roles – typically involved in the fabrication of composite components, tend to typically account for only 20-30% of the total workforce, but this share of technicians in the workforce in the aerospace sector is typically higher at around 45% in firms that manufacture composite parts for the aerospace industry. This is normally due to a requirement for skills at UK level 3 or above, but as composites become an increasing part of manufacturing processes in the automotive sector, the requirement

1 Mind the skills gap', CiM (Composites in Manufacturing), September 21, 2015
2 Skills and Training for Composites Manufacturing and Use in the UK: An Analysis, by Paul Lewis, published by Gatsby, 2013

for higher level skills will increase.[3]

It should also not be forgotten that employers dealing with composites also employ people who require skills at level 4/5 to fill associate professional/technical roles such as production/manufacturing engineer, quality engineer, and draughtsman/junior design engineer. Such workers tend to have qualifications such as an apprenticeship or a degree level qualification. This does not take into account the need – already highlighted in this report – for scientists and researchers, specialising in composites to be part of the wider skill set requirements.

5.2 Current Responses in Training Provision

5.2.1 In-House Training Provision

Given the difficulties of identifying training specifically related to the needs of composites, coupled with the shortages of people with the appropriate skills, e.g. semi-skilled laminators and technicians, a number of major employers and the composite supply chain have taken the approach of developing their own in-house training, whether that be external upgrade training or a combination of apprenticeships and internal upgrade training.

Some examples of varying approaches are set out below:

5.2.2 Creation of an in-house purpose built Training Centre:

The Bombardier Skills Centre: Bombardier in Northern Ireland opened a new Skills Centre in Belfast in January 2013 with a view to providing training at all levels of the workforce. The Centre includes state of the art training facilities and is committed to the development of people within the Composites Sector. It includes:

- *Up-skill training*: this includes taking semi-skilled people and up-skilling them. The Up-skill programme also includes an apprenticeship.
- *Training skilled* people from outside the company and the aerospace industry – these skilled workers follow a bespoke programme which is not academic but rather, purely about the application of existing skills and on-the-job training

5.2.3 Design & Development of accredited training provision purely on Composites

Companies developing their own composite training programmes have done so based on links with HE/FE (Higher Education/Further Education). To this end, they have therefore worked very closely - in the UK one example is with Rolls Royce, for example, to develop specific training requirements.

Aircelle was the first company in the UK to develop and implement a structure of accredited training purely on composites. Key features:

- Initiated a close collaborative partnership with Burnley College to develop a relevant composites qualifications framework.
- Developing robust relationship with Burnley College on composite apprenticeships, including those for fitters and CNC machinists (who are increasingly involved in the com-

3 Skills and Training for Composites Manufacturing and Use in the UK: An Analysis, by Paul Lewis, published by Gatsby, 2013, p. 53

posites area as the company moves towards automation).

Aircelle has also been working with local schools in Burnley and involving the 50 STEM ambassadors that have been recruited from within *Aircelle*.

Teledyne CML Composites is another example of one company that has decided to address skills shortages by investing heavily into the retaining of time served machinery and sheet metal fabrication engineers to make the move into composites manufacture. It has subsequently launched an apprenticeship scheme to guarantee the supply of composite engineers into the future.

In Paul Lewis' report, he explains the format of typical apprenticeship training in automotive and aerospace manufacturing:[4]

- Apprenticeship training: automotive - typically, a UK further education college holds the contract to deliver training. In the case studies provided by Paul Lewis, apprentices are studying for Advanced Apprenticeships in mechanical engineering, taking composite modules as part of that training programme. At 17% the intensity of apprentices at the two firms that supplied the necessary data is high, reflecting the fact these firms are expanding rapidly, and as a result, need to increase the size of their technician workforce.
- Apprenticeship training: aerospace – Once again, training is provided by a specialist training provider or an FE college, which takes formal responsibility for arranging and coordinating the various elements of the apprentices' training. Frequently, the number of well-qualified applicants outstripped the number of places with some firms mentioning ratios of applicants to places of over 20 to 1. Modules taken by apprentices involve various aspects of working with composite materials, which typically include: pre-preg laminating, vacuum-bagging and curing, de-moulding, trimming, assembling, machining, testing, repairing, and the electrical bonding of composite parts.

In the UK, there are many examples of Colleges coming together with major enterprises to launch their own training programmes linking industry back up with employees' needs and industry and college together.

Why? Because there has not been in place a structured composite industry apprenticeship framework (at least not until 2013 – see below) and so, subsequently, employers have had to put in place their own apprenticeship framework.

5.2.4 Composite Engineering Apprenticeship Framework (2013)

In the UK, the creation of the aforementioned framework apprenticeship in the UK was overseen by the employer-led Composite Sector Strategy Group from SEMTA (the Sector Skills Council for Science, Engineering and Manufacturing Technologies). The Framework consists of a level 2 pathway aimed at semi-skilled operator operations where UK manufacturing is identified as currently experiencing serious and persistent skill shortages with a Level 3 pathway for developing craft skilled and technician occupations, identified by SEMTA as critical if UK manufacturing is to maintain its competitive advantage in world markets and a crucial step in putting in place mechanisms to underpin the supply of composite skills.[5]

4 Skills and Training for Composites Manufacturing and Use in the UK: An Analysis, by Paul Lewis, published by Gatsby, 2013, p. 40 - 41

5 Technology and Skills in the Aerospace and Automotive Industries, UKCES – Evidence Report 76, October 2013, p. 62

Elsewhere in Europe, as well as globally, training in Composites is starting to take shape as composites becomes a major manufacturing sector.

- In **Canada,** for example, Advanced Composites Training – originating from an association established by Transport Canada in 1996 to develop and build aircraft and manage structural repair – is well known and respected. Focused predominantly on aircraft, it delivers innovative and accredited courses in the applied technologies of composites manufacturing, tooling, maintenance, structural repair and non-destructive inspection. The training in predominantly focused on the aerospace sector with training operations audited by the Canadian Council for Aviation and Aerospace (CCAA) and accepted by the Federal Aviation Administration (FAA). Training is frequently provided in a company's on-site facilities.
- In **France**, companies such as **Airbus**[6] provide their own programme of in-house training on composites, amongst other areas of focus. The growth in aerospace composites use, and France's share of Airbus programmes, has fostered a similar industry structure to that in the UK, with a number of composite structure and composite component manufacturers such as Composites Aquitaine, Duqueine, and several others having revenue exceeding £20million. France also houses a number of subsidiaries of internationally leading players, for both raw materials and semi-finished materials which export worldwide.
- The **German** aerospace industry is a big player in the area of wing manufacture, evidenced by parts of Airbus wing skins made in Germany. With established scale and significant experience, wind turbine blade production is becoming significant. As a leader in the apprenticeship programme, Germany already offers composites as a module but is also looking closely at more on-the-job training through its national sector group, Composites Germany.[7]
- In recent years, **Spain** has positioned itself as a manufacturing base specialising in composites, compared to UK manufacturers who are built around particular applications (e.g. wings).

5.2.5 Research & Development

As previously mentioned, there is an increasing need for research and development skills in composites to support the development of innovation in the sector.

The **Advanced Composites Manufacturing Centre (ACMC)** is a leading composites R&D facility at the **University of Plymouth in the UK**. Based in the School of Marine Science and Engineering (SMSE), ACMC is active in a wide range of projects, and aims to bridge the traditional gap between academic R&D and the needs of industry.

The Centre works closely with companies in all areas of polymer composites engineering, enabling them to benefit from research, contacts and experience. It also runs short courses and workshops in composites design and manufacture, and has worked with large and small companies in all sectors of the composites industry in implementing new technology, improving processes, testing materials and components and solving manufacturing and materials problems[8].

6 http://www.airbus.com/support-services/services/training/
7 http://www.composites-germany.org/index.php/en/activities/education-training
8 https://www.fose1.plymouth.ac.uk/sme/acmc/

Similar undertakings exist across the rest of Europe, notably in the form of a high-level partnership between German and Dutch research companies. The lightweight construction of aircraft with carbon fibre reinforced polymers (CFRP) is a dynamically developing field of research. On 17 June 2013 at the Paris Air Show, the **German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt; DLR**) and the **National Aerospace Laboratory of the Netherlands (NLR**) signed a Cooperation Agreement in the field of Fibre Reinforced Composites. Together, both partners are developing production techniques for lightweight components for use in the aviation and transport sectors, which will contribute to a reduction of fuel consumption and the associated carbon dioxide emissions[9].

5.3 Conclusion

Despite the approaches to training and up-skilling highlighted in this Chapter, training provision appears to remain fragmented. It does appear that those companies that have developed their own training programmes have the critical mass and resources to underpin the development of this provision and the influence to drive change with local training providers. This said, it appears that across Europe, some countries are more developed and advanced than others in terms of their composite training and focus although clearly the sector is developing and advancing and training needs to keep up.

9 http://www.dlr.de/dlr/presse/en/desktopdefault.aspx/tabid-10307/470_read-7358/year-2013/#/gallery/11298

Section 6: The Future Need for Composites Skills in the Advanced Manufacturing for Transport Sector

Section 6: The Future Need for Composites Skills in the Advanced Manufacturing for Transport Sector

6.1 Introduction

The purpose of this Chapter is to consider future trends in the Advanced Manufacturing for Transport Sector and, in particular, how these relate to Composites. This approach will help to determine the future state of play and consider which skills are therefore likely to be required to address future needs.

6.2 Findings and Recommendations from Official Reports

The US Government's Accountability Office published a report in September 2011 focusing on Aviation Safety and, notably, on the Federal Aviation Administration (FAA)'s recommendations to address the safety of composite airplanes[1]. It includes the table below[2] which highlights some of the EASA's (European Aviation Safety Agency) specific recommendations on safety and security. These include a recognition to increase awareness and understanding around the tolerance and strength of composite materials to minimise risk and damage.

1 Aviation Safety: Status of FAA's Actions to Oversee the Safety of Composite Airplanes, GAO: United States Government Accountability Office – Report to Congressional Requesters, September 2011
2 As above, page 26

Table 3: EASA Review Items That Differ from FAA Special Conditions and Equivalent Level of Safety Finding

EASA review item design feature or issue	EASA review item description
Fuel tank's flammability precautions and ignition prevention	EASA requested that Boeing comply with related proposed amendments to airworthiness standards (special condition; means of compliance).
Composite wing fuel tank's protection from lightning	EASA clarified its guidance material related to precautions, including lightning protection, for the composite wing fuel tank (means of compliance).
Performance of composite materials on fin deck	Because of the use of novel methods, EASA desired greater knowledge of the composite material's strength and fatigue and damage tolerance (means of compliance).
Composite structures' protection from tire and wheel debris	EASA desired greater knowledge of structural fatigue and damage tolerance of composite materials, specifically those in the trajectory of tire and wheel debris (means of compliance).
Fuel tank, composite wing, and composite fuselage's protection from engine debris	EASA desired greater knowledge of performance of composite structures, specifically those in the trajectory of engine debris (means of compliance).
Fuel tank access covers' protection from engine debris	EASA requested that Boeing comply with a related proposed amendment to specific airworthiness standards (special condition).

The report further highlights that the table captures the views inherent in relevant literature and interviews with experts which may essentially be categorised into key safety-related concerns touching upon four areas. These include:

- Limited information on the behaviour of composite airframe structures
- Technical concerns related to the unique properties of composite materials
- Limited standardisation of composite materials and repair techniques
- Level of training and awareness on composite materials

It is clear that, in the airline industry, these skills are essential and necessary for addressing safety concerns.

These points were confirmed by Larry Ilcewicz from the FAA in a presentation at Montana State University. Amongst other things, his speech highlighted that composite airframe applications are increasing and that design and manufacturing integration is essential during composite product development and certification. He added that as advanced composite manufacturing, maintenance and structures technologies continue to evolve, skills needs will also change and require attention and manufacturing technicians will require training to meet and fully address these needs[3].

In his report: *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis devotes a whole chapter to future technician needs within the composite sector, across the Manufacturing area as a whole. He indicates that the problem of skills gaps arises **at all skill levels**; he reports shortages of both semi-skilled composites laminators and skilled technicians.

3 *'Past Experiences and Future Trends for Composite Aircraft Structure'*, Larry Ilcewicz, FAA, Montana State University Seminar, 11/10/09

Amongst the companies he surveyed for his report, almost all stated that it was currently hard to find good, experienced composites laminators from the external labour market[4]. Similar problems, but perhaps less pronounced, were also recorded at the technician level. Some of the most acute difficulties in recruiting were highlighted as recruiting staff skilled in composites manufacturing.

A further point highlighted in the report was the difficulty in upgrading suitable workers, either in those cases where the firms do not have workers suitable for internal upgrading or in those (many) cases where the firms in question are expanding and so need additional staff. The evidence therefore indicates that companies dealing with composites materials face significant problems in recruiting semi-skilled laminators and technicians.[5]

In the case of these skills gaps, the response from the companies featured in the report has typically included:

- Apprenticeship training to acquire specialist technician skills and to support succession planning – due to an ageing workforce – with a view to creating – or maintaining – a workforce with a more balanced age distribution.
- In-house training, typically of between 8 – 12 weeks, to provide composites training for people who are already technicians. Such training is reported as being highly structured and covering such issues as:
    - The nature and properties of composite materials (knowledge of energy performance)
    - Manufacturing techniques required for drilling, reaming, fastening together, electrically bonding (earthing), and carrying out the non-destructive testing of composite parts and;
    - The appropriate behaviour to adopt around composites e.g. the need to be aware of how long carbon pre-preg material has been kept outside of the freezer

In order to ensure appropriate industry standards are met, Paul Lewis highlights the absolute necessity for employer and training provider engagement to ensure industry needs are met and accommodated. This will ensure training requirements are formalised for both employers and employees.

6.3 Conclusion

In conclusion, this Section has indicated that there are significant problems in recruiting both semi-skilled laminators and technicians. Indeed, there appears to be a shortage of people acquainted with best practice at working with composite materials at all skill levels in all the sectors. Moreover, we have seen some of the skills needs that are required, including knowledge of repair skills in composites; growth and innovation requires the right training for the sector, at all levels, including in research and development[6].

4 *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis, Gatsby, 2013, p. 33
5 *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis, Gatsby, 2013, p. 35
6 *Skills and Training for Composites Manufacturing and Use in the UK: An Analysis*, Paul Lewis, published by Gatsby, 2013, p. 53

Section 7: The Impact the SKILLMAN Project could have on this challenge

Section 7: The Impact the SKILLMAN Project could have on this challenge

7.1 Introduction

The Skillman project is a Sector Skills Alliance founded at the beginning of 2015 to address three challenges which are transversal and relevant for the advanced manufacturing in transport sector:

- Composites and Advanced Combined Materials
- Robotics and Robotic Programming
- Infotechment, Wireless Technologies and ICT for safety and user commodities

The above problem areas generate specific competencies and skills needs which are going to be tackled by the Alliance by establishing joint European curricula based on European transparency tools.

7.2 Summary of the Challenges

Still in time of crisis, in spite of what should be a surplus of workers, advanced manufacturing companies are now experiencing a shortage of the workforce competencies they need to grow. At the heart of the challenge is the changing nature of the skills needed by workers as the product has changed; composites have produced a more lightweight end-product, and manufacturing processes now require different skill sets.

This Observatory has highlighted some key observations included across the range of research drafted together across the Skillman Consortium, which demonstrate how manufacturers are adapting composites and the skills challenges that are arising from this development:

- Technology is continually advancing and opportunities exist for human beings to create the new versions – better, faster, more customer-centric. Companies need to create an environment that prepares the workforce to adapt to win in the ever changing Future of Work[1].
- 'The jobs that will be lost are more mundane and routine work – the jobs that will be gained will be those that require higher skills and thus higher pay. The actual challenge here is when the job is not lost - but transformed. In this case, we actually need a better skilled worker than we have hired for the older techniques in manufacturing. This is where all of our internal skills-based training and our partnerships with local community colleges really come into play'[2].

1 *The Workforce of the Future: Advanced Manufacturing's impact on the global economy*, GE, April 2016, p. 24
2 *The Workforce of the Future: Advanced Manufacturing's impact on the global economy*, GE, April 2016, p. 24

- Higher education levels are necessary to compete in the new digital world of advanced manufacturing[3].
- There is a need to drive through and increase the talent pool of STEM professionals, highlighted by the report produced by GE as the need for Advanced Manufacturing needs to make this a priority which it currently is not)[4].
- There is a need for curricula to address energy efficiency and performance and develop the skills required to produce advanced reinforced composites. Increasingly, cars and other vehicles include more parts made of composites, dramatically cutting weight and adding strength and improving fuel economy. For vehicles on the road, for high-pressure hydrogen and natural gas tanks, and for wind turbines, fibre reinforced composites offer a game-changing technology. And as manufacturing innovation accelerates the use of advanced composites, they are likely to be applied to an ever-broadening array of manufactured products and components – saving fuel, saving energy, reducing waste, and contributing to a cleaner, and greener, planet. Curricula is therefore necessary which addresses manufacturing innovation and the techniques which will be required to generate energy performance and efficiency. By improving the skills base in understanding the manufacturing processes in composites, it is likely that we will be on our way to improving awareness in energy efficiency. The thinking here is that at the core of this manufacturing revolution is a focus on vastly reducing energy consumption and carbon emissions. By putting these advanced materials into the manufacturing mainstream, manufacturers will be able to lower overall production costs and ultimately drive the adoption of a new clean energy way of life.

The report also indicates that it is the responsibility of governments, educators and the private sector to provide applicable training and education to those whose jobs are transitioned by technology. The worker is also responsible for making changes and adapting their skills to capitalise more fully on these opportunities. Both this chapter and chapters 5 and 6 highlight the increasing role of internal provision and the need for delivery, frequently in partnership with local colleges. This will assist with building a long-lasting loyal relationship with talent and create a pipeline of workers that will enable manufacturers to ensure that talent is steeped in the culture of an organisation.

7.3 Role of Skillman in meeting skills challenges

Skillman is focused on building robust links between industry and Vocational Education and Training (TEC) providers to build and develop training in composites to meet industry requirements. It is building and developing materials in this sector through its robust partnership between community and Further Education Colleges and Industry. This approach is designed to ensure that the joint European curricula are in line with labour market needs. This approach will also include:

- Promoting the quality of teachers, trainers and other VET professionals, by devising innovative train the trainers opportunities, including ICT in blended learning environments as well as job-shadowing for trainers in host companies in other countries
- Enabling flexible access to training and qualifications, by modular approach of joint EU curricula based on learning outcomes, structured around units of learning, compliant

3 As Above, p. 19
4 As above, p. 17

with European tools, with special reference to European Commission VET (ECVET) and the European Qualification Framework (EQF), in relation with the full adoption of learning outcome approach, declined in skills, knowledge and competencies, and their clustering in Units of Learning, and to European Quality Assurance in Vocational Education and Training (EQAVET), in terms of quality assurance in all phases from conception to delivery of training programmes, as well as by offering short-cycle qualifications to both learners and workers for both re-skilling and up-skilling processes

- Fostering the international dimension of VET by embedding transnational learning mobility in the curricula and by establishing an international Open Network of Associated Partners and stakeholders, both across Europe as well as in third countries

Industrial partners in the advanced manufacturing for transport sector aim to continue collaborating on matching and anticipating skills and jobs, and on organising the exchange of information and best practices. Skillman is enabling close cooperation between Industrial partners, training providers and qualification bodies, and more widely into its networks of public authorities, Skills Councils etc. will contribute to enhanced 'skills intelligence': the monitoring and forecasting of skills needs, understanding skills mismatches and improving dialogue between education and the labour market.

7.4 Conclusion

Delivering the right skills for the Manufacturing for Transport Sector and investing in the employability of its workers are at the heart of Skillman's concerns. It believes that the curricula should be used to become a permanent platform for setting skills agendas and developing the right skills policies in close cooperation with European policymakers.

Skillman provides an effective answer to the constantly and rapidly evolving scenario of new technologies affecting the advanced manufacturing in the transport sector by not only establishing innovative joint European curricula addressing current competencies and skills requirements, but also establishing a structured approach in detecting and sharing information one merging new needs via the Observatory on Advanced Manufacturing for the Transport Sector. The Observatory ensures the continuity of the labour market intelligence activities as well as the relevance of the joint European curricula in connection with emerging technologies.

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