A Vision and Roadmap for the use of FRP Composites in Construction

An activity undertaken on behalf of the Composites Leadership Forum Construction Sector Group

September 2019

Acknowledgements

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1. Executive Summary

The standard definition of a composite material is at least two materials, which combine to give properties superior to those of the individual constituents. In this body of work, the term composite predominantly refers to a significant subset of this standard definition, namely fibre reinforced polymer (FRP) composites, usually with carbon, glass, aramid, polymer or natural fibres embedded in a polymer matrix. Other matrix materials can be used and composites may also contain fillers or nano-materials, such as graphene. Fibre reinforced composites typically result in lighter, stronger, more durable solutions.

Key drivers for the construction sector

The key drivers for the construction industry and resulting challenge highlighted through this exercise are:

Cost – procurement is nearly always done on a first-cost basis.

- Until through-life costs are considered then composites will struggle to compete.

Performance in service – in particular fire, smoke and toxicity, and durability.

- There is a requirement for independent data to support these issues in order to give asset owners confidence in the use of composite materials

Programme risk – the construction sector is a risk adverse industry and carries huge insurance premiums.

- Thus, introduction of new materials and design procedures is difficult. Procurement of projects is also complex so all levels of the supply chain need to be educated in the use and specification of composite materials. Development of appropriate standards will aid with end-user confidence.

Sustainability – reduction in CO2 emissions

- There is a clear requirement for recycling routes through manufacture and end-of-life. Design for deconstruction has to be considered.
- Construction offers an opportunity to use recyclate but standards are required to enable this.

A vision for composites in construction industry

A construction sector that understands the benefits and synergies of the multitude of materials available.

At present most architects and design engineers do not routinely treat composites as part of their toolkit. There is a need for better promotion of composites, training courses for engineers and architects. Composites should be introduced at all levels of education.

Wider uptake to exploit the benefits of FRP Composites would naturally grow the supply chain; currently the supply chain is a mix of domestic and imported product. Clustering of the UK supply chain to enable scale-up and security of supply is highly desirable but does require encouragement, brokering and trust. Better marketing and PR will give a stronger message for the UK - a two-way flow of information between the composites and construction sectors.

It is increasingly apparent that the UK construction industry is lagging behind the ROW (rest of the world) in adoption of FRP Composites; infrastructure in North America, bridges in Holland, rebar in China, buildings in the Middle East for example.

Roadmapping

Three focused workshops and an online survey gathered input from 43 industry professionals across three key parts of the construction sector:

- Infrastructure
- Buildings – commercial and domestic
- Industrial and utilities

From this, key application areas were identified as offering solutions to current construction challenges and also potential high value to the UK, but each require key actions to enable delivery. Cross-application issues are common. Strategic demonstrators could be utilised to provide solutions to many of these issues and enable the wider uptake of FRP composites across the construction sector. The CLF (Composites Leadership Forum) construction group should thus look to develop consortia to bid into the Transforming Construction and other funding calls.

Key cross-application recommendations

Consistent supportive Government policy/strategy - to encourage and enable the long-term use of new technologies across the construction sector.

Consistent evidence/data on the value of using composites - to increase confidence within end-users in the use of composite materials. The construction sector as a whole has limited understanding of FRP composites and so education of the benefits and limitations of the materials is required at all levels of the procurement chain.

Durability - Independent data is required to prove the long-term design lives required of construction components and structures.

Standards – Standards were deemed to be important for the future of the sector but are currently not appropriate for use. A gap analysis of standards should be conducted to highlight where standards exist, need revising to include use of FRP composites, or don't exist at all so need developing.

Supply chain - It is essential to have an educated, skilled, well-trained and enthusiastic workforce. Cleaner and higher technology processes should help in attracting the right workforce and improving the cost effectiveness of production. Government funding needs to be allocated to training programmes.

Joining of materials - Construction involves the use of multiple materials in any project. We need to fully understand how these multi-material joints work, how they perform in service and how to dismantle at the end of life.

End of life - This needs to be considered for all applications. A clear recycling route should be identified. Design for deconstruction must be considered.

Product Approval- Fast-track reduced time/cost approval system to enable bridgehead deployment of new products on highly regulated sub-sectors such as rail that are intrinsically biased towards more traditional materials.

General recommendations

- There was some discrepancy between the findings of the workshops and the online survey results. These should be investigated further to better understand whether applications determined as not needing significant further development in the workshops are indeed at that position of development.

- It is essential to work with the CLF working groups to enable sustainability, standards, skills and technology challenges to be addressed.

- Work more closely with the wider construction sector to facilitate education, increase confidence and thus the uptake of FRP composites.

- Engage with the Construction Innovation Hub to explore where it might be possible to get involvement in the Transforming Construction programme of work. The Hub consists of a consortium including Manufacturing Technology Centre (MTC), the Buildings Research Establishment (BRE) and the Centre for Digital Built Britain (CDBB) at the University of Cambridge.

- Link closely with the I3P and key stakeholders to understand emergent challenges and how FRP Composites can be utilised to address them.

2. Introduction

In 2006, the National Composites Network (NCN) commissioned a 'Technology Roadmap for Composites in the Construction Industry'. In the 12 years that have followed, there have been clear changes to both the composites and construction industries.

The 2006 industry roadmap led to recommendations focused on vision, skills, technologies and branding. Whilst it is evident that some actions were taken, it is clear that it is time for a review and so the Composite Leadership Forum (CLF) Construction Group tasked Composites UK and Fluency Marketing with providing an in-depth and up-to-date roadmap for composites in the construction industry.

The roadmap has brought together people and companies from across the supply chain to include construction companies and specifiers, especially some of those with no experience in the use of composite materials. For the purpose of the project, this will focus on 3 separate stakeholder groups; buildings, infrastructure and industrial.

The purpose of the roadmap is to identify major barriers, opportunities, policy measures for policy makers, and industry and financial partners to accelerate R&D efforts on a national level.

The roadmap will enable government and industry bodies, investors and composite and construction industry suppliers and buyers to identify the steps and measures needed to accelerate required technology development and uptake. It will include:

- technology requirements
- supply chain capacity (production, installation, maintenance skills etc.)
- evaluation/assessment criteria and indicators
- required policy and institutional measures
- existing and needed cooperation/collaboration
- a plan for branding and then marketing the industry

The goal is to accelerate and improve the market interest in composite materials, to reinforce CLF as thought leaders in the market and to lead to increased use and specification of composite materials in the construction sector.

The report outlines the key issues raised in the construction and composites industry strategies, details the findings of roadmapping activities and draws top-level conclusions and recommendations for the CLF construction group to review and implement.

The project is supported by Innovate UK and the National Composites Centre.

3. The UK Construction Industry Strategy

The construction sector is a big part of the UK economy – roughly 9% of it – and employs around 10% of the UK workforce. Its output – the built environment – enables the services that drive around 43% of the economy. From roads and rail to offices and factories. However, the way we build has not changed significantly in over 40 years.

The sector currently operates by mobilising a skilled workforce so costs are related to people and quality is related to how skilled they are, and the UK workforce is ageing. Construction projects are labour intensive and this is a major reason why productivity on the sector lags that of other parts of the economy. The sector currently has a mindset that each project is a prototype, reliant upon an itinerant site-based workforce with little utilisation of digital technologies, often working to a largely series programme with inevitable congestion of work and wastefulness. These factors and the reliance on craft skills lead to wastefulness and low-productivity compared to other parts of the economy.

The Construction sector deal builds on Construction 2025, a joint strategy from government and industry for the future of the UK construction industry published under the 2010 to 2015 Conservative and Liberal Democrat coalition government. It sets out an ambitious partnership between the industry and the government that aims to transform the sector's productivity through innovative technologies and a more highly skilled workforce. In June 2019, the UK Government became the first major economy in the world to pass laws to end its contribution to global warming by 2050. The target will require the UK to bring all greenhouse gas emissions to net zero by 2050, compared with the previous target of at least 80% reduction from 1990 levels.

The Construction Sector Deal sets out how the construction industry will contribute to this, with a £420 million joint investment from the sector and the government in new technology and techniques. This will build on existing initiatives such as the Centre for Digital Built Britain; the technology roadmap developed by the Infrastructure Industry Innovation Platform (i3P) consortium; and work with construction clients to drive demand for innovative construction materials, technologies and techniques.

Two key initiatives under this strategy offer opportunities to the composites sector to help drive a step-change in the construction industry:

- Infrastructure Innovation Platform (I3P)
- Transforming construction programme

The sector deal provides a framework for the sector to deliver:

- a 33% reduction in the cost of construction and the whole life cost of assets
- a 50% reduction in the time taken from inception to completion of new build
- a 50% reduction in greenhouse gas emissions in the built environment –supporting the Industrial Strategy's Clean Growth Grand Challenge
- a 50% reduction in the trade gap between total exports and total imports of construction products and materials

These goals will be met by focusing on 3 strategic areas:

- Digital techniques deployed at all phases of design will deliver better, more certain results during the construction and operation of buildings. Clients, design teams, construction teams and the

supply chain working more closely together will improve safety, quality and productivity during construction, optimise performance during the life of the building and better our ability to upgrade and ultimately dismantle and recycle buildings.

- Offsite manufacturing technologies will help to maximise quality whilst minimising the wastage, inefficiencies and delays that affect onsite construction, and enable production to happen in parallel with site preparation – speeding up construction and reducing disruption.

- Whole life asset performance will shift focus from the costs of construction to the costs of an asset across its life cycle, particularly the use of energy for buildings. The government will ensure that our modern Industrial Strategy and our significant investments in housing and infrastructure support this change and innovation. Performance may also be improved through the use of more durable material which will limit disruption of an asset during future maintenance cycles.

As part of the Clean Growth Grand Challenge, the Prime Minister has announced a mission to at least halve the energy use of new buildings by 2030 through developing innovative energy and low carbon technologies driving lower cost, and high-quality construction techniques. This presents a significant opportunity for new materials such as FRP composites.

3.1 Infrastructure Innovation Platform

The Infrastructure Industry Innovation Platform (i3P) is an innovation community that shares ideas and opportunities across the UK infrastructure industry, promoting a culture of collaboration to positively impact both current and future major project and programme delivery. The launch of the i3P in October 2016 with 22 major construction and infrastructure client and supply chain organisations extended Crossrail's Innovate18 programme-wide model to ensure an industry wide approach to innovation.

In 2017 a Technology Roadmap was developed around the critical challenges which need to be addressed in order to meet the targets set in the Government's Construction 2025 Strategy. It is aligned around the three strategic themes of the Construction Leadership Council (CLC) Sector Deal:

- Digital Transformation
- Manufacturing Construction
- Lifecycle Performance

Results from the roadmapping for composites in construction should be fed into the I3P in order to establish pathways and dependencies between Technology, Industry and Manufacturing Readiness Levels (TRL / MRL's) for each application considered to enable the industry to form coherent programmes of work which will transform how Construction and Infrastructure is delivered.

3.2 Transforming construction programme

The sector deal for construction aims to do just this and address sector issues such as improving procurement practices, skills, exports and innovation. The £170 million Transforming Construction programme (with £250 million committed match from industry) in the Industrial Strategy Challenge Fund is at the heart of the Construction Sector Deal, driving the innovation part and feeding into all the other strands. It will help industry overcome the innovation barriers in moving to a greater use of digital, manufacturing and integrated energy technology approaches when delivering new buildings and infrastructure.

The aim is to transform the construction sector – enabling it to produce safe, healthy, efficient building using the latest digital manufacturing techniques. This will enable us to meet the UK's national infrastructure programme target of £650 billion worth of projects by 2025. The challenge will support industry in adopting technologies and help buildings to be constructed 50% faster, 33% cheaper and with half the lifetime carbon emissions.

The challenge programme will start with some of the most important buildings in society – schools. The UK builds 2000 primary schools a year to replace aging stock. Improving the efficiency of this would mean more schools, faster at a lower cost to the taxpayer. By incorporating new technology into the buildings, it would be possible to optimise the learning environment, and potentially generate energy for use in the local community.

The Sector Deal and the Transforming Construction challenge programme are enabled by a government commitment to procure buildings and infrastructure differently; placing a value on the whole life cost and performance. With consistent aggregated demand from government the sector will be able to invest in the shift to a model that mobilises supply chains rather than people and improve the efficiency of all projects. Through a Construction Innovation Hub, the programme knowledge will be transferred to other buildings such as houses and into major infrastructure projects.

The programme has established an Active Buildings Centre to bring down the cost of energy generation and storage technology that is integrated into the building fabric, and demonstrate its use at scale on real developments.

The second round of the UKRI Transforming Construction CR&D (collaborative research and development) programme launched in August 2019 will invest up to £36 million across two separate competitions. The competitions will fund collaborative R&D projects and demonstrators that go beyond the state-of-the-art in improving productivity, quality and performance of the UK construction sector investing in Modern Methods of Construction (MMC), digital and whole-life performance. This funding call provides an excellent means to build collaborations for some of the applications identified as 'low hanging fruit' and of immediate opportunity to the UK.

4. The UK Composites Industry Strategy

The initial development of composites, and the advanced materials required to produce them were achieved in the UK (e.g. carbon fibre and epoxy resin) in the 1950s & 60s. Publication of the first UK Composites Strategy in 2009 provided a shared platform and determined a cross-sector plan to ensure strategic growth of the UK composites industry.

The 2009 Strategy led directly to the creation of the National Composites Centre (NCC) and the Composites supply chain R&D programme.

Since 2009, strategic Government support of the composites industry has made a substantial impact. Rate of growth and range of deployment of composites in UK aerospace applications has significantly exceeded industry forecasts of only ten years ago as a result of successful programmes of technology and supply chain development.

The 2016 strategy focuses on delivery, development and diversification across the main end user sectors. Construction was identified as a sector for diversification meaning that the UK currently supplies relatively small amounts of composites into the sector and UK based OEMs (original equipment manufacturers) and the supply chain may not yet recognise the market opportunity afforded by composite solutions. It was recommended that promotion of the potential benefits of composites and development of the supply chain should help deliver the longer-term potential of the composites in construction sector to the UK. Likely investment of over £370bn on UK infrastructure and the challenge to deliver affordable housing were seen as opportunities to increase the application of composites. Should major infrastructure providers (Rail, Highways, Utilities) and pre-fabricated houses widely adopt composites, the size of the market would quickly exceed the forecast figures. However, it was noted that the sector is conservative with a focus on initial cost rather than through-life costs and lack of suitable codes, standards and design know-how are significant barriers to take-up. The results of this roadmapping exercise confirm these issues.

A major driving force behind the development of composites has been the fact that they are a designer's dream - the combination of the reinforcement, the matrix and additives within the matrix, as well as where each is positioned within a component, can all be changed to meet the required final properties of a component. This ability to design a complex material structure within a part is very different from the homogeneity of other materials, such as metals. This tailorability means that composites can, for example, be used to design a part that saves weight while maintaining the stiffness and strength that would be provided by other materials. For example, carbon-fibre reinforced composite can be five times stronger than 1020 grade steel while having only one fifth of the weight.

Composites are not new materials by any means, people have been using wood, nature's natural composite, for many millennia. However, our understanding of, and ability to work with, these designer materials is now at a level where they can be designed to solve a variety of engineering challenges across a wide range of industry sectors at acceptable cost, resulting in the predicted growth figures for the composites sector shown below.

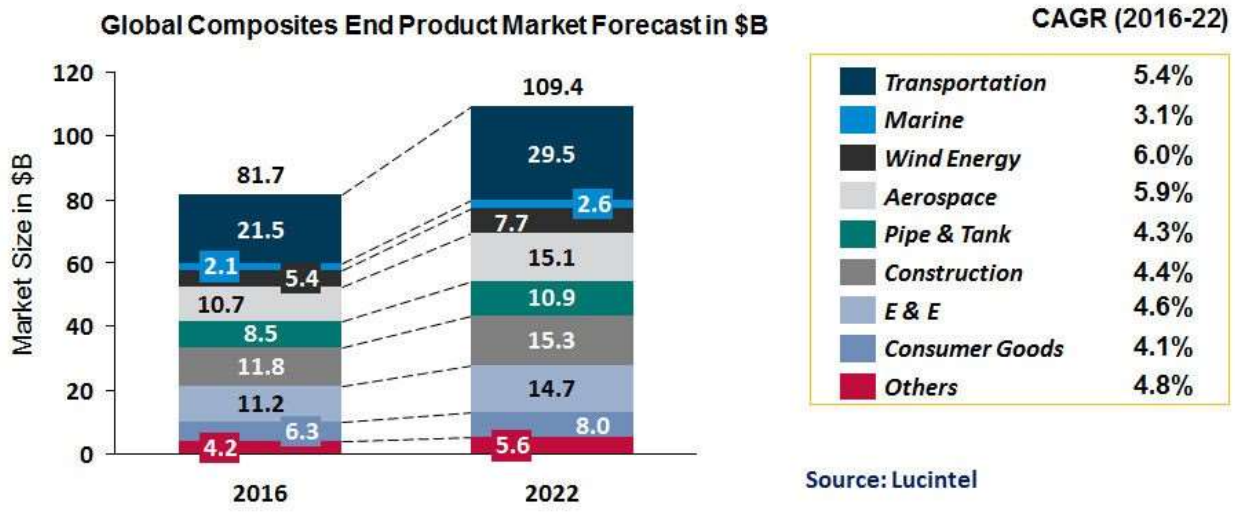


Figure 1: Global Composites End Product Market Forecast. Courtesy of Lucintel.

Figure 2: UK Composites End Product Market Forecast. Courtesy of CLF.

Figure 1 shows the predicted global market for composite products and Figure 2 shows the predicted UK market for composite products. The total global picture shows growth from $81.7 billion in 2016 to $109.4 billion in 2022, representing a compound annual growth rate (CAGR) of 5%. The total UK picture shown in Figure 2 demonstrates that £2.3 billion worth of composite products were made per year in 2015 and the industry aspired to produce £12.5 billion per year in 2030, representing a CAGR of 12%.

The breakdown of the global growth figures into industry sector data shown in Figure 1 is more clearly demonstrated in Figure 3, which shows the sector's share in 2016 along the horizontal axis versus the sector's share of global growth through to 2021. As can be seen, the construction sector is on a similar level of market share to aerospace.

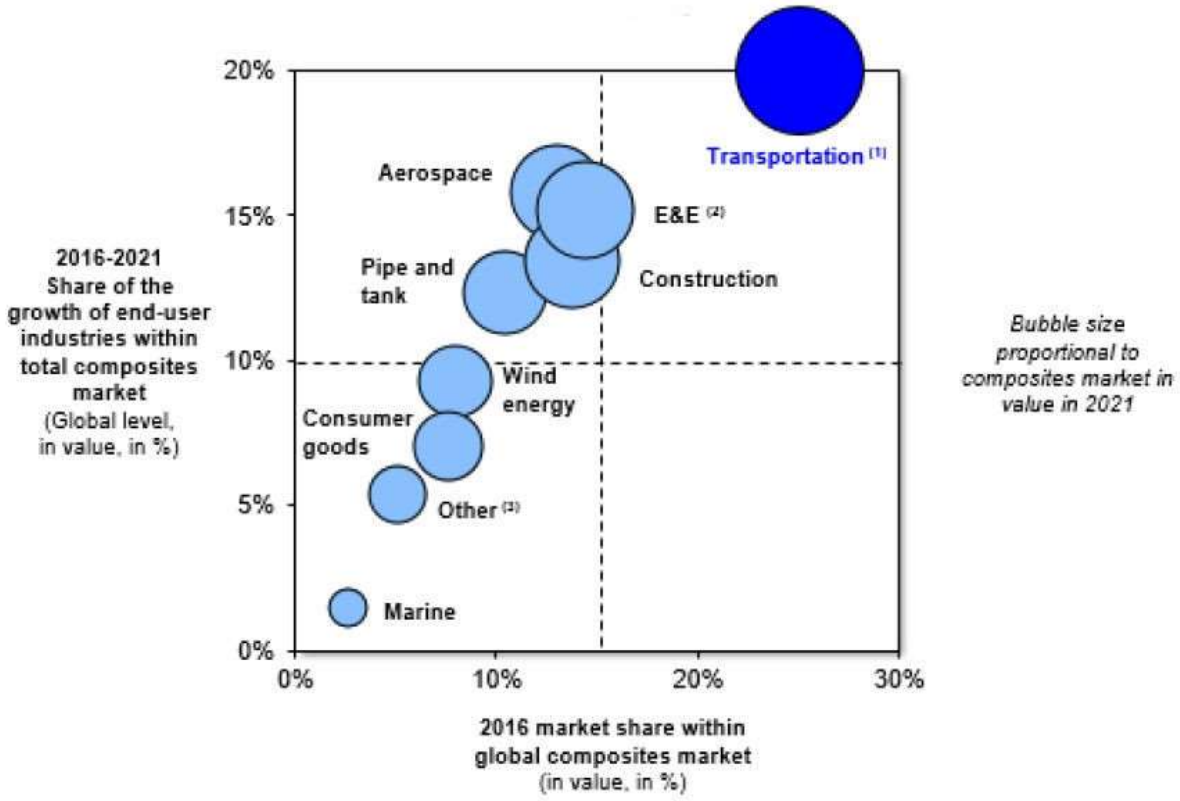
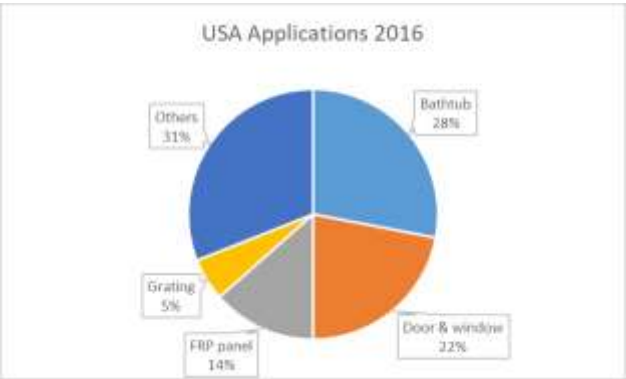
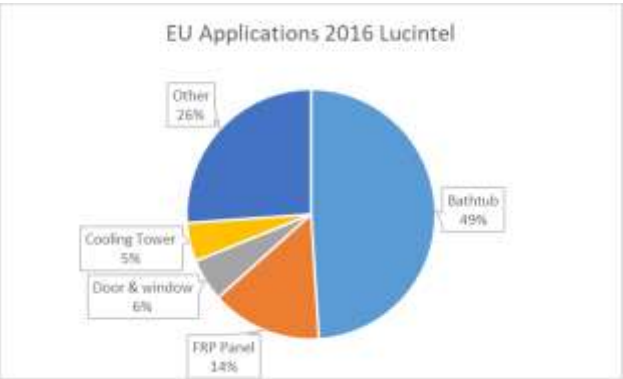


Figure 3: Global Composites Market Value and Share. Courtesy of Lucintel.

In addition, in 2017 the NCC commissioned a study on the composites in construction market with Lucintel. The market share at that time against 2016 data of USA $1.5bn and EU $800m was split:





With materials totally dominated by glass-fibre and liquid resin (rather than prepreg) processes.

Across the sector a growth of circa 4% CAGR was projected with significant growth around new application areas, in the USA at least, of:

- Composite Poles (utilities)
- Composite Rebar
- Composite Bridge Deck

In terms of process and materials accelerated growth was projected for infusion type processes (6.5% CAGR) Strong growth was also shown for Carbon Fibre materials (8% CAGR) albeit against a very small current market share (2%). The key drivers for the USA being a combination of increased house building and supporting infrastructure, increased infrastructure spending particularly for repair of existing bridges after a period of low-investment, the superior durability of composites over traditional materials.

Recent industry figures published by Innovate UK on behalf of Department of Business, Energy, Innovation and Skills (BEIS) in March 2018 suggest that the composite materials market in the UK is of the order of £7bn turnover pa and second in overall size compared to the next largest sector, metallics at £14bn. The data refers to the manufacture of materials in their primary form and does not, therefore, include subsequent processing of these materials. Predicted annual growth (2016-2022) is around 8%. The report suggests that around 34% of the composite materials manufactured in the UK is utilised in the construction sector with key driver being durability, sustainability (reduction of environmental impact) and material functionality.

5. Roadmapping Methodology

The methodology used for this roadmap follows the procedures typically used for other roadmaps that have been produced.

It is acknowledged that the construction industry is very broad and the number of current and potential applications very large. The roadmapping process thus focused on key applications and industry drivers in order to identify where the main opportunities lie.

To reach as wide and diverse an audience as possible, 3 workshops were held and an online survey was sent out. 30 delegates attended across the 3 workshops and an additional 13 responses were collected through the online questionnaire, giving a total contribution from 43 construction professionals.

Each of the three workshops focused on a sector of the construction market and drew experts from within that supply chain. The same methodology was used at each workshop. The 3 focused sectors are:

- Infrastructure
- Buildings - commercial and residential
- Industrial and utilities

The first stage of the process involved experts identifying the key industry drivers and challenges for the construction sector - this would enable us to then tie each application under consideration in to these drivers. This would highlight the reasons for considering composites for each application.

The experts were then asked to list all applications (current and potential) on post-it notes and place these under one of 3 headings:

- What we do well - little room for improvement
- What could we do better?
- New application opportunities

From the lists under ‘what we could do better’ and ‘new applications’, experts were asked to cast 4 votes on those applications where they though a major step-change was possible and would bring most benefit to UK plc.

The top 8 applications were then selected for the 2 following deep-dive sessions. The aim being to develop individual application roadmaps. During each session, experts in groups of around 4 were asked to identify what we need to do to exploit these applications. They were asked to consider:

- Key drivers for the application
- Barriers/blockers
- How do we overcome these blockers?
- Timescales
- Potential value to UK plc

The experts spent around 15 minutes at each application and then moved on to the next. 8 applications were considered over the 2 deep-dive sessions in each workshop.

Individual application roadmaps will be developed from the findings, and common cross-application issues/themes highlighted. These, combined, will give a list of actions to be developed by the CLF construction group into an action plan to enable the industry to progress in a more dynamic and competitive manner.

As with other roadmaps, once the first report was drafted, comments were sought from others in the field to validate the findings and so that ownership comes from the entire community. This was done through completion of a short survey questionnaire.

Experts were then asked to consider their vision for the composites in construction sector for 2030 - to be summed up in one or two short sentences. These were then compared and a common vision statement developed to lead the action plan to deliver against the roadmap findings.

The key findings from the roadmap activities are presented in the next section in two ways:

- Cross-sector industry drivers/challenges, and recommended actions
- Key applications identified as presenting a significant opportunity for UK industry, challenges to overcome and recommended actions

6. Roadmapping Results

6.1 Industry drivers/challenges and recommended actions

The following key industry drivers/challenges were identified and ranked in perceived importance/priority. Key issues were highlighted and actions required identified.

Sustainability/circular economy is starting to be recognised as a key factor for the construction sector and the importance of these issues is likely to increase over the coming 5-10 years.

Driver/challenge	Key issues	Recommended Action
Economics	Must be cost effective Global competitiveness Economic viability	Need to understand whole life costs Whole life cost procurement is essential
End-user confidence	Lack of awareness of composites Confidence in availability of materials Use of composites vs competitive materials	Development of material data Development of standardised materials Guidance on performance in service Marketing of case studies across construction media platforms
Risk / standards	Do building regs cover FRP composites? Appropriate standards reduce risk Correct standards offer improved H&S Standards are deemed as important but many are not appropriate for use	Work with CLF Regs Codes & Stds group Gap analysis of regs, codes and standards for construction applications
Fire/smoke/toxicity (FST)	Need materials for non-combustible applications Education of specifiers, insurers and approvers needed Redrafting of Building Regs and current specification for wall construction above 18m from Brokenshire statement Inconsistency of codes between sub-sectors Cost of large-scale fire testing and vagaries of testing	Development of FST products Appropriate standards for application of combustible materials Good practice guide on Fire performance Logical approach to Fire safety in new building regs and codes

Skills/education	Designers/engineers/architects often have little knowledge of FRP composites Manufacturing skills shortage Lack of skills on-site Reliance on migrant labour	Work with CLF workforce development group Integration of teaching material in undergraduate courses FRP composite introduction into schools programmes
Durability	Design life prediction Anti-corrosion properties are a key benefit Repair and vandalism	Need evidence of long-term durability in a range of environments Guidance on inspection and maintenance of FRP composite structures
Supply and Demand	Confidence in the supply chain needs to be established Operational efficiency Client familiarity is an issue	Demonstrator projects Move towards automated manufacture Promotion of case studies across construction media platforms
Circular economy	Negative perception of plastics in the environment Offer reduction of CO2 in build and use compared to concrete. Becoming an increasingly important factor to consider	Work with CLF sustainability group Recycling routes need to be agreed Reuse of materials needs to be understood Independent LCA data required
Terminology	'Composite' is misunderstood in construction	Need commonality in terminology used
Digital	Not a driver but a factor to consider – this is an enabler.	

6.2 Vision statement

"A construction sector that understands the benefits and synergies of the multitude of materials available."

The following were also presented as ideas for discussion:

- Enabling multi-material solutions for smarter/enhanced infrastructure sustainability.
- UK is a global leader in the beneficial use of composites to enable efficient, low-cost, reliable infrastructure.
- FRP Composites are considered as a 'traditional' material.
- Mainstream use of FRP as a recognised viable and widely available material choice in the design, fabrication and construction of infrastructure in the UK.
- Composites are used in construction when it is most appropriate to solve the presented problem.
- Ensuring that the construction industry use the most appropriate material for an application.
- Teaching how to build successfully with composites for a sustainable future.

- Providing acceptable materials for buildings.
- To facilitate the manufacture and delivery of carbon-neutral products across the 3E for a significant proportion of builds, sharing knowledge across sectors.
- Designers and architects understand the value and application of composites as a construction material.
- Appropriate, widespread, beneficial use of FRP to enable a durable low carbon solution to the UK housing challenge.
- 100% recyclable composite with zero fire, smoke and toxicity.
- Building a better future with composites.
- Understanding where to use composites in buildings.
- Exploiting composites in construction.
- Tomorrow's world today - without costing the earth.
- 100% renewable energy efficient building made of zero carbon footprint materials.
- A vibrant sector of construction composites research and delivery.
- Attracting and exciting new engineers and engineering.
- A well-integrated composites sector spanning multiple sectors.

6.3 Individual application roadmaps

What we currently do well in the UK

At the workshop, the following applications were listed as current and no substantial input required.

- Footbridges
- CFRP (carbon fibre reinforced polymer)plate strengthening/ structural strengthening
- Permanent formwork
- Cladding
- Surface finishes
-

With these applications, although there are demonstrators in the market and some supporting information is available, there are still blockers with standards/regulations, the procurement process, cost and LCA (life cycle analysis) data.

There was some discrepancy with the survey comments for footbridges and structural strengthening applications and these should be reviewed further to gain a better understanding of the issues.

Key opportunities - Application roadmaps – recommended actions

Individual roadmaps were developed for application areas identified as requiring significant support in each workshop (see appendix). The following list presents those offering a strong opportunity for the UK, key benefits they offer and actions required to enable a step-change to take place. It is recommended that an action plan for each application is developed working with relevant end-users for each.

Application	Key benefits	Recommended action	Timescale	Value to UK
Station platforms	Standard system design Can be modified during service Speed of construction	Demonstration project Development of standard system	Immediate	Medium
Rail sleepers	Uses waste materials Approved by TFL (Transport for London) Speed of installation	Demonstration on a scheme – HS2 later phases	Immediate	High
GRP rebar / reinforcement for concrete	Corrosion resistance Reduced cement content – reduced CO_2 Automated manufacture	Certification process (as for steel) Demonstrator Market size data How to recycle LCA data	Immediate	High Reduce import of steel Tech transfer across construction sector
Embedded technology	Pull from asset owners	UK strategy for implementation – BEIS Lack of standards	Depends on application – station platforms immediate	High Exportable technology
Rail bridges	Speed of installation Replaces use of concrete	Govt targets for procuring from alternative materials Public project – HS3?	HS3 immediate Long-term	High 50-100 per year
Primary structural members	Durability Reduced maintenance Reduced foundation costs Integrated panel	Guides and standards Govt mandate to consider alternative materials	<5yr	First to market – exportable opportunity
Decorative building fabric	Retrofit – improve performance of building Incorporation of services Aesthetics	Accreditation to increase confidence Alignment of standards	Immediate	UK becomes global authority – exportable product

Modular building	Energy efficiency Reduced installation time and costs Low maintenance	Specification and supporting standards Joining technology WLC (whole life cost) data	2-5yrs	High – opportunity for market diversification
GRP fencing	Speed of installation Low maintenance FRP has passed blue/red book security testing Lightweight – H&S improved Aesthetics	Standard revision Market awareness Cost Colour stability confirmation	Immediate – need supporting evidence to enable a step-change	Only 3 UK suppliers so opportunity for supply chain development

7. Appendices

7.1 Appendix 1: Workshop attendees

Building - Commercial and Domestic, BRE, 9th April 2019

Name	Company
John Hutchinson	Architect
James Henderson	Atkins
Deborah Pullen	BRE
Kara Ebanks	BSI
Ian Wallis	BSRIA
Peter Holland	Exel Composites
Bharat Ghandi	Filon Products
Malcolm Hannaby	Innovate UK
Mark Ireland	MTC
Katy Riddington	NCC
Chris Talbot	Network Rail Buildings Team
Mike Mapston	Project Utopia
Tim Edmunds	Tufeco
Jose Toereo	University College London
Mark Evernden	University of Bath

Infrastructure, Jacobs, 5th April 2019

Name	Company
Sheena Hindocha	KTN
Lee Canning	Jacobs
Bryan Harvey	Jacobs
Martin Halpin	Contractor
Julien Sellier	Structeam
Craig Dawson	GEIC
Martin Burr	Network Rail

Industrial and Utilities, University of Birmingham, 14th May 2019

Name	Company
Simon Eves	Pipex
Richard Brine	Elemy
Kara Ebanks	BSI
Ian Campbell	Core6
Jonathan Howard	Dura Composites
Julia McDaid	Cubis Industries
Pamela McEwen	Haydale
Kenny Shea	Velox

Online survey responses

Company
Tony Gee and Partners
MWH Treatment
Dura Composites Ltd
Lifespan Structures
STRUCTeam
Plura Composites Ltd
Hankuk Carbon UK Ltd
Atkins Ltd
Design & Display Structures Ltd
IMCD UK Ltd
Filon Products Ltd
University of Sunderland

7.2 Appendix 2: Workshop results

Industry drivers/challenges

The following key industry drivers/challenges were identified across the 3 workshops and ranked in perceived importance/priority:

1. Economics
    a. Must be cost effective
    b. Global competitiveness
    c. Economic viability
    d. Whole life costs

2. Risk / safety
    a. Improved health and safety in construction
    b. Improved health and wellbeing

3. Fire/smoke/toxicity
    a. Need material development for non-combustible applications
    b. Education needed of specifiers, insurers and approvers

4. Regulatory driven
    a. Risk reduction
    b. Do building regs cover FRP composites?

5. Skills/Education
    a. Few designers/engineers/architects have appropriate knowledge about composites
    b. Manufacturing skills shortages
    c. Lack of skills on-site - current labour force need retraining to use composites
    d. Reliance on migrant labour

6. Durability
    a. Anti-corrosion properties
    b. Design life prediction
    c. How to prove long-term durability in a range of environments
    d. Repair and vandalism - need guidance on inspection and maintenance

7. Supply and demand
    a. Confidence in the supply chain needs to be established
    b. Operational efficiency
    c. Client familiarity is an issue - need to get to the stage of acceptance

8. Circular economy
    a. Recycling routes need to be agreed
    b. Reuse of materials
    c. Ethics/social responsibility
    d. Risk of leaching from polymers in landfill?
    e. Negative perception of plastics in the environment

    f. Global warming
        i. Reduction of CO2 in build
        ii. Reduction of CO2 in use

9. Digital
    a. Not as a driver, but it is a factor to consider

Vision statement

The following comments were given as input to development of the overall vision statement for the industry:

- A construction sector that understands the benefits and synergies of the multitude of materials available.
- Enabling multi-material solutions for smarter/enhanced infrastructure sustainability.
- UK is a global leader in the beneficial use of composites to enable efficient, low-cost, reliable infrastructure.
- FRP Composites are considered as a ‘traditional’ material.
- Mainstream use of FRP as a recognised viable and widely available material choice in the design, fabrication and construction of infrastructure in the UK.
- Composites are used in construction when it is most appropriate to solve the presented problem.
- Ensuring that the construction industry use the most appropriate material for an application.
- Teaching how to build successfully with composites for a sustainable future.
- Providing acceptable materials for buildings.
- To facilitate the manufacture and delivery of carbon-neutral products across the 3E for a significant proportion of builds, sharing knowledge across sectors.
- Designers and architects understand the value and application of composites as a construction material.
- Appropriate, widespread, beneficial use of FRP to enable a durable low carbon solution to the UK housing challenge.
- 100% recyclable composite with zero fire, smoke and toxicity.
- Building a better future with composites.
- Understanding where to use composites in buildings.
- Exploiting composites in construction.
- Tomorrow’s world today - without costing the earth.
- 100% renewable energy efficient building made of zero carbon footprint materials.
- A vibrant sector of construction composites research and delivery.
- Attracting and exciting new engineers and engineering.
- A well-integrated composites sector spanning multiple sectors.

Application roadmaps

Infrastructure roadmap workshop results

What we currently do well in the UK

The following applications were listed as current and no substantial input required.

- Footbridges
    - One-stop-shop smaller FRP footbridges
    - Guidance documents are now available
    - Multiple case studies now in the UK – we've seen step change.
    - Modular - Standard design manual would help
    - Supply chain is generally outside the UK. Opportunity for UK supply chain to develop as demand increases
- Strengthening CFRP plate and wrapping
    - Opportunity to increase market share
- Permanent Formwork
- Sewer liners
- Innovation, 'special projects' and diversity of applications
- Troughing and trench cover plates
- Non-structural and semi-structural
- Secondary structural parts
    - Fencing, decking and posts

What we currently could do better in the UK

The following applications were listed as current but requiring substantial input/support in order to enable a step-change. They are listed in order of priority (as deemed by the experts in the room). The top 4 priority applications were taken and road-maps developed for each.

Applications:

- Overdecking at station platforms
- Station platforms
- Rail sleepers
- Road Bridges
- Sensors
- Bonding technology (still an issue)

Future applications

The following applications were listed as future potential applications, road-maps developed for each.

- GRP (glass reinforced polymer) Rebar
- Embedded technology (5G, heating, sensors, structural health monitoring)
- Rail bridges

Key opportunities - Application roadmaps – Infrastructure

Individual roadmaps were developed for 8 application areas (see appendix). The following present an immediate opportunity for the UK and should be pursued as a priority.

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Overdecking of station platforms	Minimum disruption Design life Speed of application	Awareness in the UK Standards No collaboration with the supply chain	Awareness within the construction industry PAS development Focus on easy wins	<2years 5-10 years	Low volume Limited (less than £1m/yr)

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Station Platforms	All-FRP structure Standard system design Adaptability - can be modified during life Modular – speed of installation	Lack of champions for FRP use within major asset owners No incentive to use FRP Lightweight could be a detriment Lack of skills/knowledge within contractors	Need a good case study of cost savings Education of contractors and consultants in design and build Develop a standard system	< 2 years	Unknown

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Rail sleepers	Uses waste materials Approved by TFL Easy and quick	Customers/rail sector Long time to get product approval as product	Need to identify a scheme bringing technology and purchasing guys together	1-5 yrs	High

	to install Overall project costs reduced Safety Replacement to creosote timber	specific Cost?	 Education of purchasers Define performance requirements (done on EW rail project) Show LCA HS2 scheme?		

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Road bridges	Off-site construction Whole life costs Low maintenance	Lack of appetite from Highways England Need footbridges first Design limitations	Raise awareness Identify opportunities where FRP is applicable Education of composites sector of where to look for opportunities	5-10yrs It can be done now - low volume	Low 10 bridges per year?

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
GRP Rebar	Safety Fatigue resistance Reduced cement content Widely used overseas Corrosion resistant Good strength	Failure mode of FRP is brittle Standard and regulation of the supply chain Cost Can’t shape easily Lack of	Educate industry and construction consultants Quality Assurance and consistency Certification process needed (as for steel)	UK plant being built 5-10 yrs (widely used overseas)	Not currently made in the UK Immediate opportunity

	to weight ratio Modular Automated manufacture	awareness	Share case studies in construction media Work with construction training organisations to develop skill set		

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Embedded technology - 5G - Heating - Sensors - SHM (structural health monitoring	Loss of opportunity out of UK Ease of maintenance Customer experience and expectation IOT Internet of Things), big data, future proof Structural health monitoring of FRP structures - pull from asset owners	Cost New tech - lack of standards Future software and hardware - compatibility through whole lifespan Requirement definitions from users	UK strategy for implementation - BEIS Cross sector collaboration - tech transfer Find first adopters/champions - define requirements, share story and information	Some lower hanging fruit than others - stations platform heating 5-10yrs	High

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Rail bridges	Hybrid materials Cost Develop standard tested product	Expert not on-hand for repair - shut rail for 3+ days - huge associated costs Cheap Carbon	Government targets for procuring bridges from alternative materials (e.g 5%)	Long-term HS3 is an immediate opportunity	50-100 per year at maturity

	National rail challenge statement	Fibre Collision derailment loading	Serial orders Client appetite Smart city model by having lighter bridges Public project e.g. HS2 to promote - work with NCC and High Speed Rail Institute		

Building - commercial and residential workshop

What we currently do well in the UK

The following applications were listed as current and no substantial input required.

- Structural strengthening
- Pods and tanks
- Building services
- Imitation of traditional materials - surface finishes
- Existing product remade in composites
- Flat roofs and roofing products
- Roofing and cladding for industrial buildings
- Complex shaped cladding
- Thermal breaks for windows and doors
- Lightweight roof structure for retrofit conservatory market

What we currently could do better in the UK

The following applications were listed as current but requiring substantial input/support in order to enable a step-change. They are listed in order of priority (as deemed by the experts in the room). The top 4 priority applications were taken and road-maps developed for each.

- Primary structural members
- Decorative building fabric
- Reinforcement in concrete
- PV integrated roof structures
- Electronic embedded panel systems
- Flood mitigation products
- Tunnel linings/strengtheners

Future applications

The following applications were listed as future potential applications. These were prioritised as below. The top 4 priority applications were taken and road-maps developed for each.

- FRP composite house/building - reduced groundworks
- FRP composite rebars
- Structural Health Monitoring - embedded sensors
- Marine engineering - jetties, piers, promenades
- Coastal erosion protection
- Monocoque structures
- Historic building conservation
- Non-rectilinear shapes
- Phase change materials (to prevent overheating)

Application roadmaps - Building

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Primary structural members	Corrosion resistance Durability Reduced maintenance Reduced primary and foundation costs Integrated panel Thermal control	Lack of recognised specifications Needs expert design skills Joining Lack of durability data End-of-life Standard design data Regulations	Need guides and standards Education of designers Government mandate to consider alternative materials Education of specifiers & insurers Accreditation of standard products	Education <5yrs Standards <5yrs End-of-life 5-10yr Insurance <5yrs	First to market = exportable technology UK becomes global authority UK workforce development

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Decorative building fabric	Retrofit - improve performance of building	Fire - Insurance - Grenfell Media -	Showcase the benefits PAS (Publicly Available	Urgent! <1 year	UK becomes global authority Exportable products and

	Aesthetics Durability Ability of composites to replicate traditional materials Lightweight Incorporation of services (wifi,sensors) Reduced cost of construction	negative coverage What solutions are available? Is the supply chain developed? Architects/specifiers using what they know	Specification) development Accreditation to increase confidence Alignment of testing standards Volume required to drive costs down - investment needed to develop UK supply chain		technology (or IP/licensing)

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Reinforcement in concrete	Through life durability Polymer concrete eliminates shrinkage CO2 issues for concrete Reduced transportation costs Reduced installation costs Possible use for FRP waste	Design process Bending Lapping required Commercial use rather than domestic End of life Traditional thinking	Govt policy to drive use of new materials Standards - development and testing How to recycle Technology is there, need to upscale Carbon footprint evidence Market value evidence	2-5 years	Potentially high value Value to environment Reduced construction costs - technology transferable across construction sector

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
PV integrated roof structure	Reduced installation costs and time	Cost - stoppage of the feed-in	Govt to mandate this for housing	To get max return on investment has	Lower CO2 emissions - govt targets

	cf retrofit PV panels Integrate other actions into the panels - pollution absorption, 5G Shift back to DC networks means lower power systems work well Integrated panel is lower FST risk Thermal generation & insulation (20% uplift) Reverse technology to keep buildings cool Local power generation	tariffs If a cell fails then have to replace whole system FST standards Reduced efficiency over time End of life	sector - consistent policy/strategy Aesthetically acceptable panels at an affordable price Bring together key people and technology to work out way forward	to be <2yrs Already been done on a small scale - needs upscaling	Full solar on every new build - in 10yrs have equivalent of a Hinckley power station UK adds value to the integration of technology & parts (rather than production of commodity product)

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Composite rebar	Durability Complex shape generation Preformed bend Reduced concrete requirements	Complex shapes Lack of knowledge Standards are for steel Cost?	Look at thermoplastic Can we employ new manufacturing techniques - 3D? Consortia needed for R&D programme. Demonstrator needed Understand	Very quick win Standards - 2-5yrs	Reduce import of steel Disruptive cost IP export potential

			size of the market		

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Structural health monitoring	Smart cities Consumer-led need for technology Asset management & maintenance planning Improved safety of buildings Use of big data and IoT Monitoring well-being in a home	Technology moving very fast Understand what the data means Failure-proof - how to repair? Cyber security, hacks, theft	Engage with future cities catapult for knowledge sharing Life-cycle costs Cross-industry tech transfer - what is already being used elsewhere	Unclear	Reduced costs - energy savings UK to innovate - export IP

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Marine engineering	Hardwoods currently used for groines Reduced maintenance Tourism is key for coastal areas - can keep aesthetics in regeneration schemes Design of wave management system that generates	Leaching of composites into marine ecosystem? Durability? Scour effects need to be considered Duping a ton of granite onto the beach works for coastal protection at the moment	Need to understand the size of the potential market Demonstrator to measure durability and sustainability Are there suitable tests to understand material behaviour?	Coastal erosion is real - composites could be the best solution even if not perfect.	Unclear - need to understand size of the market

	energy and reduces impact of waves on coast Degradation of traditional materials puts degraded particles into ecosystem				

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
FRP House (reduced groundworks)	~30% cost saving Redeployable, relocatable, reconfigurable Lower environmental impact Less reliance on trades Buried services - integrated system Can build on brownfield sites	Soil conditions Initial cost Unproven durability VOCs (volatile organic compounds) - air quality Public perception and confidence No relevant building codes	Demonstrators to test and measure Needs a proper exploitation plan Piggy-back onto offsite marketing campaign	5-10 years	

Industrial and utilities workshop

<u>What we currently do well in the UK</u>

The following applications were listed as current and no substantial input required:

- Cured in place pipe (CIPP)
- Platform design
- Gratings
- Industrial housings
- Cladding
- Anti-slip flooring

- Solid sheets
- Vehicle and pedestrian trench covers
- Substitution of metalwork/concrete lightweighting structures

What we could do better in the UK

The following applications were listed as current but requiring substantial input/effort in order to enable a step-change. They are listed in order of priority (as deemed by the experts in the room). The top 4 priority applications were taken and roadmaps developed for each.

- Modular building
- GRP Fencing
- Cable trays
- Trench/access covers - closed lid, vehicle loaded
- Automated moulded grating manufacture
- Replacement of mechanical fixings with structural adhesives
- Cable troughing

Application roadmaps – industrial and utilities

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Modular building	Energy efficiency Reduced installation time and costs Durability Strength to depth ratio Energy efficiency Low maintenance Whole life costs	Fire performance Negative perception Market awareness and demand CAPEX Joining Lack of skills	Increase awareness Develop specification and supporting standards (incl fire) Investment in R&D	2-5yrs	High - opportunity for market diversification for existing UK supply chain Efficient local manufacture opportunity

Application	Key drivers	Blockers	Action needed	Timescales	Value to UK
GRP fencing	Speed of installation	Standard was written for steel	Market awareness	Product is already there,	Only 3 UK suppliers so

	H&S - lightweight Low maintenance Non-conductive Blue/red book - security testing, FRP has passed Aesthetics	Perception that GRP is less secure Cost Colour stability No client engagement	Std needed for measuring benefits of materials -energy efficiency -sustainability -durability Revision of standard - performance based	just needs to be adopted - need supporting evidence to enable a step-change 0-2, 2-5yrs	opportunity for others to get involved.

Application	**Key drivers**	**Blockers**	**Action needed**	**Timescales**	**Value to UK**
Cable trays	Corrosion resistant Non-conductive Speed of installation Lightweight - improved H&S on site Low smoke Cost	CAPEX in R&D Fire integrity System needed not just a tray Cost vs steel Is there a code/std? Niche UK penetration	Understand FST for some applications PAS development Raise awareness of benefits Prove equivalence to steel	<2 years	Limited export opp. Overseas competition - need to add value -design -assembly -qualification Strong overseas competition

Application	**Key drivers**	**Blockers**	**Action needed**	**Timescales**	**Value to UK**
Access covers - closed lid, vehicle loaded	Concrete replacement H&S Non-conductive Anti-slip Damage	Cost vs concrete BSEN124 not harmonised Lack of client awareness How to inspect and identify	Marketing of case studies Reach out to key asset owners Std for durability -collate existing	5yr Need to develop durability evidence	High import aspect

	tolerance As built cost Light-weight	failure Small suppliers - limited market penetration Durability and fatigue data	durability data Training of inspectors		

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Full structural footbridges	Asset life cycle Speed of installation C779 document Low maintenance Modular / off site construction	Skills for maintenance Conservative engineering Confidence in supply chain Cost	Identify quality UK suppliers/ installers Market understanding Proof of concept Government support - procurement opportunities Verified WLC	5+ years? Happening now for smaller footbridges	Will increase confidence in other applications Improved safety

Application	**Key drivers**	**Barriers/ blockers**	**Action needed**	**Timescales**	**Value to UK**
Railway sleepers	Recycled content Govt clean growth strategy Timber replacement Corrosion/durability	Timber sequential carbon Supply chain Fire Lack of standards No performance data End of life	Demonstrator Quality LCA data	Unknown	Exportable technology

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Thermal barrier products	Integrated product Offsite manufacture Low thermal conductivity	Regulations – FST in particular Perception Supply chain	Are there appropriate standards? Are test methods valid for FRP? Generic public demand Demonstrator		

Application	Key drivers	Barriers/ blockers	Action needed	Timescales	Value to UK
Traffic signposts and masts	Technology already exists Quick, cheap installation Improved H&S onsite No earthing needed	Cost Overseas manufacture Low demand Highways Authority approval	Testing, data Proof of concept WLC data	1-5 years 5-10 years for approval	

7.3 Appendix 3: Online survey results

Questionnaire to Guide a Vision and Roadmap for the Use of FRP Composites in Construction

- Over 40% of respondents were in a large company consisting of over 250 employees. Only 8% were in a micro-company consisting of less than 10 people. The majority of those completing the survey were manufacturers or material suppliers. 60% operated in infrastructure, 40% in building and 50% in industrial and utilities – obviously taking account for some crossover.

- 58% of companies operated outside of the UK. 50% of companies carried out business that was 100% related to composites with 33% having less than 10% of their business related to composites.

- 46 % of companies were working with or assessing the use of thermoplastic matrix composites.

- The majority of respondents did not know the proportion of composites that were imported, however, 30% said 100% was imported.

Cross sector issues

How important do you consider the following to further advance applications of composites?

Most to Least Important	Consideration	Score: 1 least important – 5 most important
1	Consistent evidence/data on the value of using composites against competitive advanced materials	4.5
2	Guidance on design of composites for performance in service	4.4
3	Confidence in the availability of materials	4.3
4-	Cost of material	4.3

4-	Standard provision of material property data by suppliers	4.2
6-	Whole life cost procurement model	4.1
6-	Demonstration of capability (case studies and supporting marketing)	4.1
8-	Health and safety best practice and guidelines	3.6
8-	Understanding recycling and end of life implications	3.6
10-	Clarity of terminology	3.5
10-	Guidance on incorporating composites into multi-material structures	3.5
10-	Repair/retrofitting	3.5
13	Cost and accessibility of final product testing	3.4
14	Handling, storage and transport	3

What restricts the use of composites?

Most to Least Restrictive	Consideration	Score: 1 not restrictive – 5 most restrictive
1	End-user confidence	4.4
2	Cost	4.2

3	Regulations/codes/standards	3.8
4-	Supply and demand	3.7
4-	Material data and standardisation	3.7
6	Inspection and maintenance	3.6
7	Skills	3.5
8	Fire, smoke & toxicity	3.4
9	Durability concerns	3.2
10	Environmental concerns	3.1
11	Other	2.3

Other includes:

- No history
- Lack of capability
- Knowledge
- Lack of awareness by consultants and clients
- Lack of recyclability
- Environmental cost

What is the biggest blocker for the uptake of composites for your area of business?

Respondents were given the opportunity to write their own thoughts:

- 30% mentioned Cost
- 10 % said government and politics
- 20% said end of life, recycling and FST was an issue
- 10% said that standardisation was restricting the use of composites
- 10% said that it was an issue getting consultants and clients to consider FRP at an early stage
- 20% said there was a need for a shift in mindset and a lack of education

Respondents generally agreed that the value of business not achievable due to these restrictions was substantial but not quantifiable.

What would be the impact on UK industry if we were able to overcome this restriction?

Highest to Lowest Impact	Consideration	Score: 1 low impact – 5 high impact
1	Supporting infrastructure development	5
2-	Support economies of scale	4
2-	Strengthening the knowledge and intellectual property (IP) of UK organisations	4
4	Attracting inward investment	3.9
5	Fostering collaboration, communication and openness of supply chains	3.7
6	Improving safety in deployment of composites/composite products	3.3
7	Accessing international markets for UK innovators	3.2
8	Supporting regulation	3.1

Other includes:

- Significant growth in the application and innovation of GRP composites
- Paying attention to the public vote

Standards

“Standards and codes are well aligned to current regulations in my sector”
42% of respondents disagreed with this statement, 58% had no comment.

What are the issues and gaps with current standards?

- No standards directly applicable
- Does not include composites and the test methods applied are not relevant
- Eurocode...
- It's more a question of composites being adequately covered in product application standards for example in fencing versus steel. In addition to composites being 'disadvantaged' in standards such as EN124 for manhole and gully tops in the way composite covers are required to undertake more testing than traditional materials.
- Fire testing not always done to a consistent procedure standard
- Government needs to listen to the public vote and views

Standards are important and are appropriate in the following areas for the industry sectors being considered

Subject of Standard	**% Voted Important**	**% Voted Appropriate**
Design	90	30
Certification	100	20
Manufacturing	60	50
QA	100	20
Repair	70	50
Environmental Impact	90	20

Application roadmaps

The following applications were listed as current and no substantial input required at the workshop. The majority of survey responses suggested that there was still work to be done across all application areas.

Infrastructure

Application	**Agree (%)**	**Neutral (%)**	**Disagree (%)**
Footbridges	10	18	72

CFRP plate strengthening	27	18	55
Permanent formwork	10	45	45
Sewer liners	27	55	18
Fencing/decking/posts	9	55	36
Trench cover plates	18	64	18

Buildings

Application	Agree (%)	Neutral (%)	Disagree (%)
Structural Strengthening	50	25	63
Pods and Tanks	50	88	12.5
Building Services	25	88	25
Surface Finishes	38	50	50
Roofing Products	38	75	25
Cladding	38	38	63
Complex Shapes	50	75	12.5

Industrial and Utilities

Application	Agree (%)	Neutral (%)	Disagree (%)
Cured in place pipe	33	55.5	11

Gratings	44.5	44.5	11
Industrial housing	33	33	33
Anti-slip flooring	55.5	44.5	0
Trench covers	33	44.5	22.5
Solid sheets	22	55.5	22