

REPORT 021

Composite Materials Resource Efficiency Action Plan

December 2013



A contribution to delivering the targets in the joint government and industry Strategy for Sustainable Construction and the ambitions of the Green Construction Board



Composite Materials: A Resource Efficiency Action Plan

December 2013

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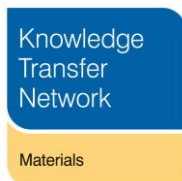


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Executive Summary

This resource efficiency action plan (REAP), sets out a series of actions which, if implemented, will result in a reduction in composite material-related waste and improved resource efficiency within the composites sector.

The composites sector recognises the increasing importance of landfill diversion, recycling and improved resource efficiency. The composites sector has seen increasing supply-chain pressure from Original Equipment Manufacturers (OEMs) to improve environmental performance and this, together with direct legislative and regulatory pressure, has driven the development of this REAP.

A Scoping Study has been prepared as part of the REAP process, which includes an overview of the sector and results of a market survey carried out for the study. The Scoping Study is available from the WRAP website.

The main focus of this REAP is on identifying actions to reduce the quantities of composite waste requiring landfill disposal, and to encourage the development of closed-loop manufacturing within the sector. The Action Plan focuses on glass fibre reinforced polymer (GFRP) rather than carbon fibre reinforced polymer (CFRP), since the tonnage of GFRP production and use is many times greater than for CFRP; and in addition the higher value by weight of CFRP waste has allowed the development of commercial recycling solutions.

The following themes have been identified as the principal action areas for the sector.

Theme	Description
Markets	Help develop commercially viable markets for GFRP recyclate
Process	Support the commercialisation of new processes for GFRP and CFRP recycling
Materials	Provide consistency in the categorisation of composite wastes
Knowledge	Disseminate information on best-practice and emerging technologies to the sector, particularly SMEs

The specific actions recommended in this REAP are listed below:

Theme	Action
Markets	Develop an exemplar business model for the recycling of manufacturing waste by UK composite component manufacturers
	Develop case studies for applications of recyclate
	Facilitate support for the development of new applications for GFRP recyclate, including assistance with identifying funding opportunities
Process	Engage with universities and facilitate cooperation with industry partners to commercialise new recycling processes, e.g. by facilitating access by industry to the prospectus of research and development capability within UK universities
Materials	Develop a grading scheme for recyclate (initially process waste, with potential to expand to cover end-of-life waste in due course)
	Evaluate practical and financial aspects of enhanced product ID labelling
	Evaluate usage patterns and wastage rates of consumables with a view to identifying barriers to recycling

Knowledge	Develop Resource Efficiency Best Practice toolkit/guidelines for SMEs, starting with waste management
	Develop a case study for resource-efficient manufacturing
	Develop a case study for recycling of manufacturing waste
	Evaluate need for a central source of benchmarking information and clearing house for data on composites for use in Life Cycle Analysis

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1 Introduction

This resource efficiency action plan (REAP) sets out a series of actions which, if successfully implemented, will result in a reduction in composite material-related waste and improved resource efficiency within the sector.

The starting point for the REAP was the interest expressed by various parties in the composites sector in improving the level of recycling within the industry. There has been much work done over many years within academia and industry on the recycling of composites; but a recognition that (particularly in the case of glass fibre reinforced polymers) a commercially viable recycling route had yet to achieve widespread adoption.

The composites sector recognises the increasing importance of landfill diversion, recycling and improved resource efficiency. A large proportion of composite components are not produced for direct sale to individual consumers, but rather are used by Original Equipment Manufacturers (OEMs) such as Boeing, Airbus, BMW etc. as part of their products. The composites sector has seen increasing supply-chain pressure from OEMs to improve environmental performance and this, together with direct legislative and regulatory pressure, has driven the development of this REAP.

A Scoping Study has been prepared as part of the REAP process, which includes an overview of the sector and results of a market survey carried out for the study. The Scoping Study is available from the WRAP website.

2 Scope of this Action Plan

The main focus of this REAP is on identifying actions to reduce the quantities of composite waste requiring landfill disposal, and to encourage the development of closed-loop manufacturing within the sector. A Stakeholder Group was established, with membership comprising industry bodies (e.g. Composites UK) and representatives from individual companies in the field of composites design, manufacturing and supply. The issue of waste minimisation and recycling was highlighted by the Stakeholder Group and the Scoping Study as being the most pressing resource efficiency concern. This does not preclude the REAP developing to focus more on energy-related issues in the future.

The Action Plan focuses on glass fibre reinforced polymer (GFRP) rather than carbon fibre reinforced polymer (CFRP), since the tonnage of GFRP production and use is many times greater than for CFRP; and in addition the higher value by weight of CFRP waste has allowed the development of commercial recycling solutions.

This focus on GFRP does not imply that there are no resource efficiency issues associated with CFRP, and does not preclude the industry from actively taking steps to improve the environmental performance of CFRP. However, the main purpose of the REAP is to address market failures and CFRP recycling is currently served by a commercial market and supply chain – hence the focus on GFRP.

3 List of Stakeholders and Contributors

Individuals and representatives of the following organisations have contributed to this Action Plan:

- Brett Martin
- British Marine Federation
- CCP Composites
- Composites UK
- Exel Composites
- Filon
- Hambleside Danelaw
- IIT
- KS Composites
- Materials Knowledge Transfer Network
- NetComposites
- Paul Marsh
- Production Glassfibre
- Scott Bader
- University of Birmingham
- University of Nottingham
- University of Ulster
- URS
- Vestas
- WRAP

4 Policy and Legislative Framework

In terms of waste management and end-of-life issues, the following regulations and guidance are of particular relevance to the development of this REAP.

4.1 Waste Framework Directive

The revised EU Waste Framework Directive (WFD 2008/98/EC) has been transposed into UK law as the “Waste (England and Wales) Regulations 2011”, the “Waste (Scotland) Regulations 2012” and the “Waste Regulations (Northern Ireland) 2011”. The regulations legally enshrine the waste hierarchy, i.e. that waste producers should take all reasonable measures to apply the following waste hierarchy as a priority order -

- prevention;
- preparing for re-use;
- recycling;
- other recovery (for example energy recovery);
- disposal.

4.2 Landfill Tax

One of the most important factors affecting waste management in the UK is the Landfill Tax. This is a tax on the disposal of waste to landfill, and as such, it encourages efforts to minimise the amount of waste produced and the use of non-landfill waste management options, which might include recycling, composting and recovery. There are two rates of landfill tax: a standard rate, and a lower rate for inert materials. Most composite waste is likely to attract the standard rate of tax, currently £72 per tonne as of 1st April 2013, and due to rise to £80 per tonne in 2014 (with the Government having committed to this as a floor until at least 2020). Coupled with the landfill operator’s gate fee and transportation costs, this means that disposing of waste to landfill is likely to cost somewhere in the range of £125 per tonne from 2013, and this provides a significant cost driver to developing alternative waste management routes.

4.3 Waste Electrical and Electronic Equipment (WEEE) Directive

In the UK, producers of WEEE are obligated under the WEEE Regulations (SI No. 3289) to register with an approved producer compliance scheme and need to finance the cost of treating and recovering the types of products imported or manufactured. The WEEE Directive was recast in 2012 such that the costs payable by manufacturers will be more closely related to the ease of recycling of the products they manufacture, and this is intended to act as an increased driver to enhancing the recyclability of WEEE. This recast will be transposed into national legislation in due course, and may encourage manufacturers of WEEE to favour materials which are able to be recycled. This may impact on the use of composites in the WEEE sector by favouring composites which can demonstrate recyclability.

4.4 End-of-Vehicle Life Directive

The EU End-of-Life Vehicle (ELV) Directive aims to reduce the amount of waste from vehicles when they are finally scrapped. In particular, it includes tightened environmental standards for vehicle treatment sites, requires that last owners must be able to dispose of their vehicles free of charge, sets rising reuse, recycling and recovery targets and restricts the use of hazardous substances in both new vehicles and replacement vehicle parts. The UK has transposed the Directive through its ELV Regulations 2003, 2005 and 2010. The UK is required to divert at least 95% (by weight) of ELV from landfill, including recycling at least 85% and energy recovery of an additional 10%. This has acted as a significant driver to improving recycling performance in the automotive composites sector, as a recycling route must be available if composites are to significantly substitute for metals in this sector.

4.5 Corporate social responsibility (CSR)

CSR policies and Environmental Management Systems (EMS) such as ISO14001 may commit producers or users of composite materials to achieving high levels of recycling or recovery of waste. For example, the aerospace

sector is investing considerable sums in maximising the recyclability of materials, driven partly by economics but also as part of their corporate commitments (e.g. Airbus undertook a voluntary approach to develop solutions for aircraft nearing permanent retirement with a dedicated demonstration project called PAMELA-LIFE).

4.6 Environmental accreditations

There are a wide range of environmental accreditations for materials and products, including for buildings and infrastructure. Typically, project proponents are rated based on gaining credits for various aspects of environmental performance. Some of these credits will relate to the choice of materials, and whether or not these materials have a recycled content or can be readily recycled or recovered at the end of their life. Environmental accreditations for construction products include BES 6001 and the BRE “Responsible Sourcing” criteria (which forms part of the BREEAM green building accreditation scheme). In addition, the increasing adoption of Building Information Modelling (BIM) software (mandatory on all Government building projects by 2016) will require product manufacturers to present increasing amounts of data on their products, which will include environmental information and carbon footprinting.

5 The UK Composites Industry

In the context of this REAP, “composite materials” can be defined as a mixture of two or more physically different constituents, each of which largely retains its original structure and identity, that when combined give certain properties that are superior to the properties of the individual components. Fibre reinforced polymer (FRP) composites consist of a bulk material (the 'matrix' or polymer), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the composite. This reinforcement is often in fibre form.

The main fibre types of relevance to this study are glass fibres and carbon fibres, although alternative fibres (e.g. aramid, natural materials and polymer fibres) are also in use.

5.1 Manufacturing Processes and Materials

Glass fibre is manufactured by the continuous drawing of molten glass through bushings to form thin filaments, with individual filaments bundled together. These bundles of filaments, referred to as strands, are then combined to form “rovings” (thicker bundles) which can be chopped into varying lengths, or woven into a fabric-like structure. Chopped strands can also be bonded together to form non-woven mats.

Carbon fibre is most commonly manufactured from polyacrylonitrile fibre, which is heated under tension in air and then in an inert atmosphere. Process conditions can be varied to produce fibres with a variety of properties. Individual fibres are bundled to form a “tow”, which can be woven or chopped into varying lengths. Aramid fibres (e.g. Kevlar™) are formed from aromatic polyamides and offer increased strength and are sometimes used either alone or in conjunction with carbon fibres, but applications in construction are not widespread.

The use of natural fibres (such as flax and hemp) in composites is growing and non-woven natural fibre composites have been used in the automotive sector for 20-30 years.

There are a range of matrices used in FRP manufacturing. Matrices can be either “thermosetting” (i.e. they cannot be re-melted once cured) or “thermoplastic” (capable of being re-melted).

The most common thermosetting matrices are:

- Polyesters;
- Vinylesters;
- Epoxies; and
- Phenolics.

There are a wide range of thermoplastic matrices, including:

- Polypropylene;
- Polyethylene terephthalate (PET);
- Polyamide; and
- Polyphenylene sulphide (PPS).

As in the case of fibres, a number of alternative resin materials (some derived from natural materials) are under development but are yet to be widespread in use.

In addition to the main components of fibre and matrix, other substances such as fire retardants, fillers, pigments and gel coats can be included in the manufacturing process.

Semi-finished products include pre-impregnated materials (“pre-preg”), which is a combination of fibre and partially cured matrix resin that is supplied as sheets, rolls or tapes that can be laid-up and fully cured to give a finished product. “Curing” describes the process whereby a thermosetting matrix chemically cross-links and the final shape of the composite is formed.

A variety of processes are used to transform primary or semi-finished materials into a finished component:

- Hand lay-up

- Spray-up
- Vacuum bag moulding
- Resin infusion
- Resin transfer moulding
- Autoclave moulding
- Pultrusion
- Compression moulding
- Filament Winding

5.2 Applications

The main end-use sectors for FRP composites at present are:

- Aerospace;
- Automotive;
- Marine;
- Construction (including wind farms); and
- Other (sporting goods, electronics, etc.).

5.3 Market Size

Recent information on the UK composites market is included in a supply chain study carried out by Ernst & Young (E&Y) for UK Trade and Investment and published in 2011¹. This report estimated the value of the UK composite sector by material and by sector.

One point of interest is the difference in relative importance of sectors and materials when comparing either value or volumes. By value, the largest materials and sectors are carbon fibre and aerospace respectively; whereas by volume, by far the most significant material is glass fibre and the largest sectors are marine and construction. Clearly, the high value but low volume components produced for the aerospace sector are economically very important, but in terms of resource efficiency issues, glass fibre is likely to be more significant.

Table 1: UK Composites Manufacturing 2010

	Value (£M)	Weight (t)
<u>By Material</u>		
GFRP	453	87,000
CFRP	658	2,500
Metal matrix	3	35
<u>By Sector</u>		
Marine, Construction & others	374	69,000
Automotive	63	9,000
Aerospace	675	800

¹ Ernst & Young, UK Composites Supply Chain Scoping Study, April 2010

The E&Y Study estimated there to be approximately 1,500 UK companies active in the composites supply chain, of whom the vast majority (>1,450) have revenues of less than £5 million per annum from composites. The E&Y Study also reported that the composites industry is active throughout the UK with clusters of expertise in most regions. AVK (Federation of Reinforced Plastics) is the German professional association for the composites sector, and publishes an annual Composites Market Report. The latest report (for 2012) estimates overall composites production in the UK and Ireland as 134,000, considerably higher than the E&Y Study.

6 Resource Efficiency Issues and Challenges

The main resource efficiency issues affecting the sector (as identified by the market survey, Stakeholder Group and reported in the Scoping Study) relate to:

- Waste (including recycling and “closed loop” manufacturing); and
- Energy (including carbon footprint and embodied energy).

Water use is not seen as particularly problematic at present.

The majority of composite wastes arise either:

- during manufacture (“process waste”); or
- once finished products have reached the end of their useful life and are discarded (“end-of-life waste”).

There is no statistical information on the extent of composite waste arisings, and no specific code in the European Waste Catalogue (EWC) for composite waste. The total amount of waste has been estimated for this study based on (for process waste) a wastage rate of approximately 10% of current production; and (for end-of-life waste) the fact that all of the current production of GFRP will at some point become waste, and the assumption that in, say, 20 years time, the annual end-of-life waste arisings will approximately match the annual production volume at present (assuming an average 20 year product design life). It is recognised that this is a relatively crude approximation, but in the absence of more detailed information at least gives an order-of-magnitude estimate of likely arisings. Table 2 below summarises estimates of potential future waste arisings.

Table 2: Projected GFRP Waste Arisings

Source	Potential Arisings by 2030 (000 tonnes/yr)
Manufacturing waste	15+ (likely to increase considerably as production increases)
End-of-life waste (excl. wind turbines)	135
End-of-life turbine blades	20

The market survey showed that those companies who are currently concerned about energy use are focused on direct energy consumption during their manufacturing process, as reflected in their energy bills. In terms of life cycle energy impacts, composites are perceived to have a number of advantages over competing materials in terms of lightweighting (e.g. lower fuel consumption for lighter composite vehicles) and durability, and hence the carbon footprint of the material itself has received relatively little attention (although various life-cycle studies have been done). Future legislative and policy drivers may increase the importance of this issue, and the industry would benefit from taking proactive steps to address it.

The following themes have been identified as the principal action areas for the sector.

Theme	Description
Markets	Help develop commercially viable markets for GFRP recycle
Process	Support the commercialisation of new processes for GFRP and CFRP recycling
Materials	Provide consistency in the categorisation of composite wastes
Knowledge	Disseminate information on best-practice and emerging technologies to the sector, particularly SMEs

Further details and specific actions under these themes are presented in the following sections.

An important and overriding action will be to identify an organisational structure which will provide ownership and oversight of the REAP process in the longer term.

It is intended that the Stakeholder Group will continue to be responsible for implementation, under the overall management of Composites UK. The Composites Leadership Forum is planning to establish a “Sustainability” leadership sub-group, and it is planned that this body will take on ultimate responsibility for oversight of the REAP and will continue to drive forward increased resource efficiency in the sector.

It is noted that implementation of many of the actions identified in the following sections are contingent on support being obtained from various public or private sector sources, and hence the suggested timeframes may be subject to review.

6.1 A – Help Develop Commercially Viable Markets for GFRP Recyclate

6.1.1 Overview

In the UK at present, the market for recycled GFRP appears to be limited to the grinding of process waste for use as filler in the manufacturer’s own product. There is no established supply chain processing third-party process waste or end-of-life waste. Some companies who carry out grinding of process waste do on occasion accept third-party waste, but this is relatively uncommon and subject to case-by-case discussions.

6.1.2 Challenges

The problem is circular, in that the lack of a valuable outlet for recyclate has prevented a supply chain from being established; whilst at the same time the lack of a supply chain means that those seeking to develop outlets may struggle to obtain material.

The following factors contribute to the underdevelopment of the composite recyclate supply chain:

- Low value of existing uses of recyclate;
- Inconsistent composition of third-party waste;

The most fundamental challenge is to develop outlets of sufficient value such that it is clearly financially viable for third-party composite waste to be collected and diverted from landfill.

Various operators have sought to develop this market, for example in the field of “plastic timber” (used for applications such as fencing, garden decking and railway sleepers). If such a market can be successfully developed, then the supply chain situation may change significantly in a short period of time in order to meet the demand.

6.1.3 Next Steps

The following next steps have been identified as part of this Action Plan.

Proposed Action	Topic narrative	Lead	Timeframe	Metric
Develop exemplar business model for recycling of manufacturing waste by UK composite component manufacturers	Lack of appreciation of the costs of waste management and the savings to be made from recycling is constraining manufacturers (particularly SMEs) from recycling.	Composites UK	2014 Q1	Exemplar business model developed and published
Develop case studies for applications of recyclate	Showcase best practice and help stimulate the market for applications of recyclate.	Composites UK	2014 Q3	Case studies published

Facilitate support for the development of new applications for GFRP recyclate, including assistance with identifying funding opportunities.	The development of a commercial demand for GFRP recyclate is critical for the development of a viable supply chain. There are potential funding sources available (e.g. AMSCI) to provide seed funding for these opportunities.	Materials KTN	2014 Q3	Funding secured for new GFRP recyclate application
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6.2 B - Support the commercialisation of new processes for GFRP and CFRP recycling

6.2.1 Overview

A number of processes exist for recycling waste composites: some are commercially proven, whilst others are subject to further research, or are not currently economically viable in the UK.

6.2.2 Challenges

Table 3 summarises the current status of recycling processes.

Table 3: Potential Composite Recycling Processes

Methods	Materials	Process Details	Operators
Mechanical grinding	GFRP	Grinding of material using hammer mill or similar with material reincorporated into composites as filler	Carried out on commercial scale (to a limited extent) in UK by Filon and Hambleside Danelaw, and in France by Plastic Omnium Research by Exeter University (RECCOMP project).
Pyrolysis	CFRP / GFRP	Pyrolysis of matrix leaving fibres which can be used	Carried out commercially for CFRP by ELG Carbon Fibre (West Midlands). Has been researched for GFRP but fibre damage is such that it has not been commercialized.
Cement Kiln	GFRP	Use of waste composites in cement kilns – organic fraction is combusted, inorganic fraction is incorporated into cement	Operating commercially in Europe (by Zajons in Germany under the label Compocycle).
Fluidised bed combustion	GFRP/CFRP	Energy recovery of resins and recovery of fibres	Developed at Nottingham University
Solvolyis	GFRP / CFRP	Use of supercritical solvents to dissolve resins, allowing recovery of resins and fibres for reuse	Several projects, including Nottingham University “AFRECAR” project and EURECOMP

6.2.3 Next Steps

The following next steps have been identified as part of this Action Plan.

Proposed Action	Topic narrative	Lead	Timeframe	Metric
Engage with universities and facilitate cooperation with industry partners to commercialise new recycling processes, e.g. by facilitating access by industry to the prospectus of research and development capability within UK universities.	For example, EXHUME project is an EPSRC funded 3 year project. The project is focusing on engaging the composite material users and manufacturers to look at ways to reuse the highly valuable parts of materials considered as waste. Research on novel processes for composites recycling is also being carried out at Nottingham University and University of Strathclyde.	Materials KTN	2014 Q1	University Composites Research Prospectus prepared and published.

6.3 C - Provide consistency in the categorisation of composite wastes

6.3.1 Overview

The composition of a composite waste has a very significant impact on whether and how it can be recycled. At present, there is no industry-standard system for identifying or categorising process or end-of-life composite waste.

6.3.2 Challenges

The wide variety of materials manufactured (in terms of both resins and fibres) is a constraint to developing a supply chain for recycle (both process waste and end-of-life waste), since companies have no clear way of determining the properties of material received from third parties (except by analysis, which is expensive and time-consuming). Other sectors (e.g. plastics, timber) have successfully introduced schemes for labelling and/or categorising wastes in terms of its composition or quality. The use of a consistent categorisation scheme in these cases has facilitated the movement of material between parties and development of a supply chain. The first step in this process will be to develop a grading or categorisation scheme which presents a “common language” for all parties in the prospective supply chain.

6.3.3 Next Steps

The following next steps have been identified as part of this Action Plan.

Proposed Action	Topic narrative	Lead	Timeframe	Metric
Develop grading scheme for recyclate (initially process waste, with potential to expand to cover end-of-life waste in due course)	Development of a supply chain is constrained by the fact that third party users of recyclate have no means of determining or categorising the types of recyclate that are being offered. The approach is similar to that used by plastics, wood and metal recycling industries, for example, in developing a concise framework for categorising the different types of material.	Composites UK	Draft for industry comment by 2014 Q2	Grading scheme published and disseminated
Evaluate practical and financial aspects of enhanced product identification labelling	Product marking can make end-of-life recycling easier – there is a need to examine how practical and costly it would be to label composites, either physically or by electronic means.	Composites UK	2015 Q1	Feasibility Study published
Evaluate usage patterns and wastage rates of consumables with a view to identifying barriers to recycling	Consumables may represent a significant source of manufacturing waste and level of recycling seems to be negligible. More information is required to identify whether recycling is possible, and whether changes (e.g. in composition) may increase recycling.	Composites UK	2014 Q3	Survey published

6.4 D - Disseminate information on best-practice and emerging technologies to the sector, particularly SMEs

6.4.1 Overview

Despite the best efforts of several parties (e.g. Composites UK, Knowledge Transfer Network), the fragmented nature of the industry and high proportion of SMEs has limited the dissemination of best practice in waste and energy management. Some companies have been successful in greatly reducing their waste generation, and if similar proven techniques were adopted across the industry there would be significant environmental and financial benefits.

6.4.2 Challenges

There are a variety of reasons which prevent best practice from disseminating through a sector. Sometimes this is because information is not available easily enough; or the necessary actions can be considered to be “too difficult” or “not worth the effort”. Particularly in the case of SMEs with high pressure on time and cost, it is necessary to present a clear and compelling case which:

- a) Gives examples of practical actions;
- b) Shows how cost savings can be made; and
- c) Is readily available and can be implemented quickly and cheaply.

It is likely that in the future, composites manufacturers will be more frequently expected to demonstrate the environmental credentials of their products, particular with respect to carbon footprint and using Life Cycle Analysis (LCA) as a tool. It will be useful to have a central “clearing house” of publicly accessible information which can then be used by the sector as “industry standard” inputs to their own bespoke LCAs.

6.4.3 Next Steps

The following next steps have been identified as part of this Action Plan.

Proposed Action	Topic narrative	Lead	Timeframe	Metric
Develop Resource Efficiency Best Practice toolkit/guidelines for composites sector SMEs, starting with waste management	Work done by e.g. Hambleside Danelaw and others has demonstrated how waste can be minimised: this should be disseminated to as wide an audience as possible.	Composites UK	2014 Q3	Toolkit published
Develop case study for resource efficient manufacturing	Showcase best practice	Composites UK	2014 Q1	Case Study published/ produced
Develop case study for recycling of manufacturing waste	Showcase best practice	Composites UK	2014 Q1	Case Study published/ produced
Evaluate need for a central source of benchmarking information and clearing house for data on composites for use in Life Cycle Analysis	LCA information is fragmented and sometimes contradictory. Clear benchmarking will help identify improvements in practice and establish environmental credentials of composites against competing materials. The issue of LCA data does not appear to be of immediate concern to most in the sector at this time, hence it is a potential longer term action.	Composites UK	Long term (post-2014) in response to industry demand	As yet, undetermined.