FRP CIRCULAR ECONOMY STUDY

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Industry Summary - August 2018

Composites UK Trade Association | Scott Bader | Renuables LCA // MATERIALS // ENERGY | National Composites Centre | Innovate UK

GRP waste: offcuts, shredded and ground material
Photos courtesy of Filon Products Ltd

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A more detailed version of this report can be made available to interested parties on request.

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COVER IMAGES

Cover images courtesy of:

- **Left:** Aircraft scrap - Stella Job
- **Right:** Wind turbine blade disposal - Agecko

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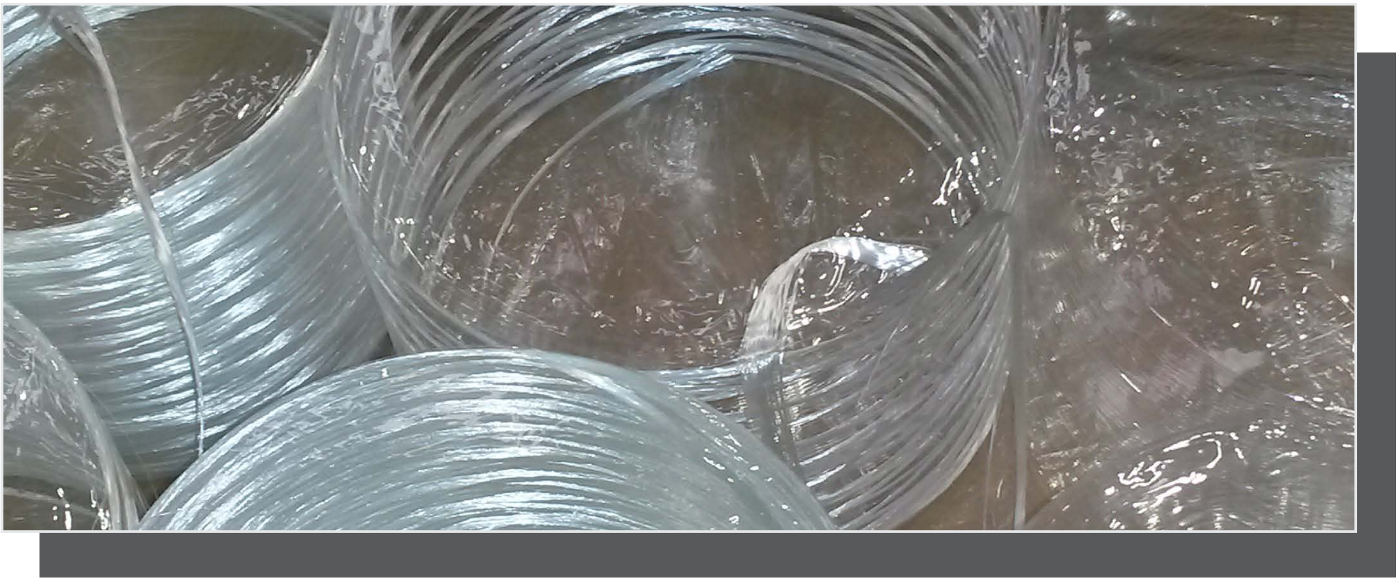
PURPOSE AND SCOPE

This study investigates the best way forward for disposal / recycling of waste fibre reinforced polymer material (FRP) in terms of cost and environmental impact, in the UK. The intention is to direct R&D spending and commercial investment to accelerate the most environmentally and economically sustainable solutions.

The material being considered in this study is primarily glass fibre reinforced polymer (GFRP) which uses a thermoset resin. It may also be relevant to thermoset carbon fibre reinforced polymer (CFRP) which is currently uneconomical to recycle by pyrolysis.



Scrap at Scott & Fyfe

SUMMARY

Around 6,200 tonnes of glass fibre reinforced polymer (GFRP) production waste and possibly 75,000 tonnes of GFRP end of life (EOL) waste is generated in UK each year. In addition there may be around 1,600 tonnes of carbon fibre / carbon fibre reinforced polymer (CFRP) production waste (very little EOL waste). An understanding of the breakdown of material constituents and volumes is very helpful in identifying the right disposal solutions. There are also at least 11,000 tonnes of E-glass fibre waste from earlier stages of the supply chain.

FRP waste in construction and automotive markets is likely to grow steadily. Wind turbine blade waste could grow to over 10,000 t p.a. in 2030’s, though re-lifing of wind farms could delay this. Aircraft EOL CFRP waste is likely to increase in the next 5-10 years to thousands of tonnes p.a. However, it is expected that the value of CFRP for recycling by pyrolysis and solvolysis will increase so that it becomes viable to separate it.

Market drivers for finding better disposal solutions for FRP waste include rising landfill costs, increased circular economy thinking, policy and legislation and markets for products containing recyclate. Both economically and environmentally, the most significant effect of (and driver for) creating commercially viable recycling routes for composites, is the breaching of new markets. Although GFRP can be deemed to be recycled in cement kilns, the creating of more circular, higher value recycling routes would open up markets, particularly in the mainstream automotive industry, but also in construction and other sectors.

FRP waste has value for energy recovery from the resin, as a mineral feedstock for cement (from the fibres and any filler) and as reinforcing fibres, to the extent that they can be reclaimed. The main disposal options are landfill, energy from waste (EfW), cement kiln and mechanical recycling.

Both EfW and cement kiln could be considered recycling routes, as in addition to energy recovery, the mineral content is recycled into aggregate and clinker respectively. However EfW incinerator bottom ash would not meet the description of recycling in the EU Waste Framework Directive.

Costs for disposal by landfill, EfW and cement kiln are typically comparable at around £140 / t, since waste management companies tend to charge the same rate regardless of route. As EfW capacity in UK grows, which is rapidly occurring at present, and older plants have paid off capital costs, EfW fees may reduce.

The empirical cost scenarios modelled indicate that mechanical recycling is marginal for low fibre content FRP, though may be financially viable with a gate fee comparable to landfill. The cost model for recycling looks more promising for high fibre content materials, e.g. infused composite, where significant profits may be possible, though there are challenges to achieve effective processing methods.

Environmental impacts are dominated by the benefits of what is replaced, especially the extent to which mechanical recycling results in replacing virgin fibre and combustion of resin replaces coal as fuel or contributes to electricity generation.

Overall, it can be concluded from environmental impact study that the industry should promote recycling routes which reclaim the value of the fibres, especially where fibre content is high. It is recognised that this takes time, requires matching of waste streams and will be more challenging for EOL waste which is contaminated or of unknown provenance. We should concurrently promote cement kiln recycling, but in such a way that we can easily divert the most promising waste streams to mechanical recycling as the opportunity arises. Where EfW is used, e.g. because cement kiln route is prohibited due to halogenated fire retardants, and no mechanical recycling route is available, we should prefer plants where heat is recovered as well as electricity generated and ash recycled.

Impacts could be further optimised by reclaiming fibres as much as possible for re-use in composites and using the leftover resin powder in cement kilns to replace coal, with a large scale, centralised operation to reduce energy impacts. However, technical and logistical advances would be required before a business model to support this could be proven.

Much can be learnt from current and previous activities around the world which have led to FRP regrind being incorporated into construction board, polymer concrete or cast products, spray up and moulding compounds. From this existing global experience, there are clearly numerous challenges involved in setting up mechanical recycling processes and these challenges will be more easily overcome by companies which are familiar with working with recyclates and who already have some of the equipment needed to process the materials.

It is expected that as solutions become established for manufacturing waste, waste management companies will divert EOL waste to those solutions as well. Waste from the rooflight manufacturers which are clustered around the Midlands, and from the larger hand lay GFRP manufacturers represent good opportunities to source larger, more consistent volumes to develop solutions.
Thermal and chemical processes are not close to commercialisation for GFRP at present, but it may be that a thermal recovery process, such as the catalysed fluidised bed with post-treatment of fibres, as developed at University of Strathclyde, could have potential, both on cost and environmental grounds.

The move towards disposal solutions which include energy recovery is a driver for including more bio-based content in resins, so that the combustible portion is first generation bio-derived, rather than fossil derived.

We need to progress the development of the cement kiln route and the several opportunities for mechanical recycling of which we are aware. It would be good to set up a nationwide scheme, e.g. with discounts for Composites UK members to incentivise and promote uptake. This would initially focus on cement kiln recycling but, as mechanical recycling routes develop, would enable more consistent waste streams to be diverted to those.

Appropriate funding is needed to develop recycling routes, and a range of UK Government funding opportunities are currently under consideration. We will also benefit from continuing to collaborate internationally.

Image: Aircraft scrap. Taken by Stella Job

GFRP WASTE QUANTITIES AND CONSTITUENTS

FRP waste is generated during manufacturing and at end of life (EOL). The constituents and form of the waste differs, with primary groupings most effectively separated by process, rather than market sector.

Waste volumes were estimated for GFRP, by process, for UPR (unsaturated polyester resin) and the other main resins used. The methodology used can be inferred from Table 1 and the notes there. The calorific value is based on resin / combustible content. The fibre content affects recycling value.

The estimated data is anecdotal, based on interviews with experienced industry professionals but serves as a good basis for estimating available waste volumes.

	Total	UPR hand lay	UPR Spray up	UPR continuous sheet	UPR pul-trusion	UPR SMC	UPR BMC	UPR infusion	UPR RTM	UPR filament winding	epoxy infusion	other epoxy	phenolic [c]	vinyl ester [c]
% resin (inc. combustible additives)		66%	50%	65%	36%	30%	30%	40%	50%	60%	40%	44%	50%	50%
% glass fibre		34%	20%	35%	46%	23%	15%	60%	30%	40%	60%	56%	50%	50%
% filler (non-combustible)		0%	30%	0%	18%	47%	55%	0%	20%	0%	0%	0%	0%	0%
Resin supplied to this process (t)	**59,300**	24,000	7,000	7,000	2,000[a]	5,000	2,000	3,000	3,000	1,000	3,500[b]	800	500	500
GFRP composite produced (t)	**117,757**	36,364	14,000	10,769	5,556	16,667	6,667	7,500	6,000	1,667	8,750	1,818	1,000	1,000
Process waste (%)		6%	3%	12%	7%	4%	4%	3%	3%	3%	3%	10%	5%	5%
Process waste (t)	**6,216**	2,182	420	1,292	389	667	267	225	180	50	263	182	50	50
Calorific Value (Mj/kg)		20	15	20	11	9	9	12	15	18	12	13	15	15
Typ fibre length (mm)		50	50	50	long	25	25	long	long	long	long	long	varies	varies
% containing halogenated FRs		5%	5%	80%	70%	1%	1%	5%	5%	0%				
Factor to EOL		0.5	0.5	0.9	0.8	0.8	1.5[d]	0.6	0.6	0.4	0.2	0.6	0.7	0.7
End of life product	**75,659**	18,182	7,000	9,692	4,444	13,333	10,000	4,500	3,600	667	1,750	1,091	700	700

Table 1: UK GFRP estimated typical constituents and volumes by resin and process

Notes: % resin, fibre, filler are by mass. Blue rows indicated calculated values. The estimated data is anecdotal, based on interviews with experienced industry professionals. a) pultrusion value allows for imported pultrusions used in UK manufacturing. b) 70% of the epoxy infusion value is for offshore wind blades, much of which has recently started in manufacturing. c) for phenolic and vinyl ester resins, a nominal figure of 500t resin has been assumed in each case, with 50/50 fibre and resin, as volumes are relatively small. d) BMC EOL factor increased to allow for imported BMC parts.

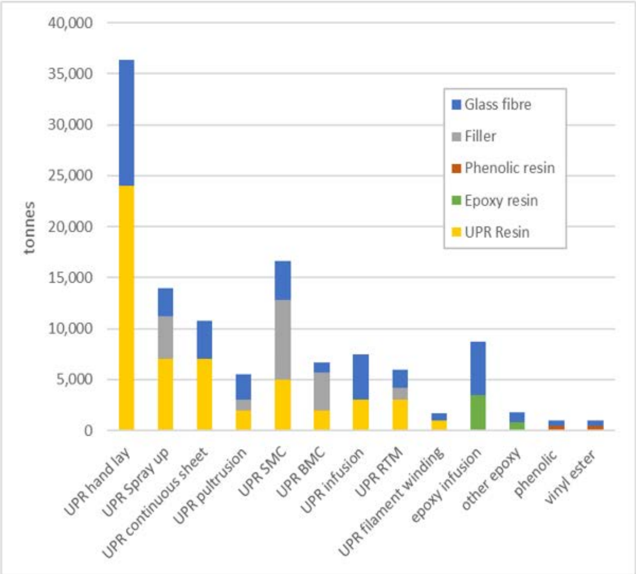


Figure 1: Estimated GFRP produced in UK by process: quantities and constituents

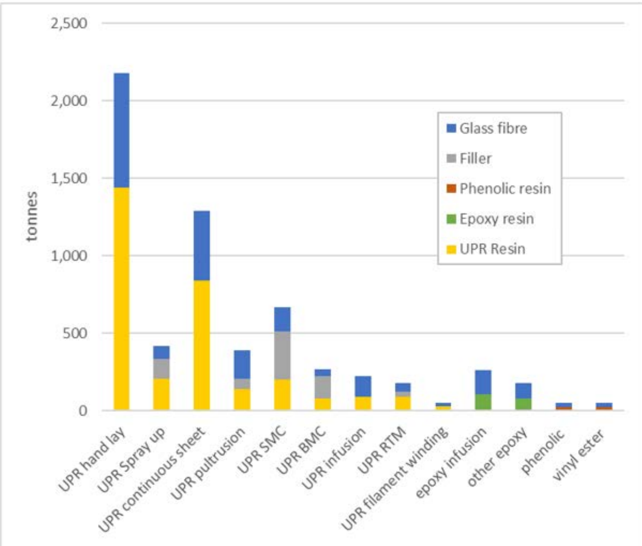


Figure 2: Estimated UK GFRP process waste: quantities and constituents

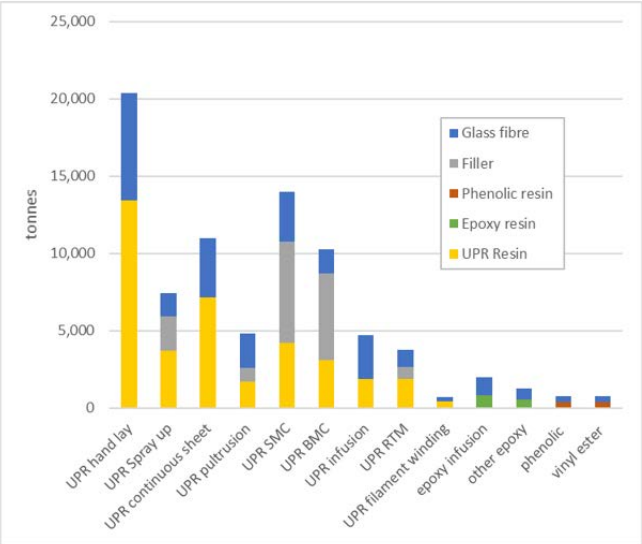


Figure 3: Estimated UK GFRP end of life & process waste: quantities and constituents

COMPARISON OF ENVIRONMENTAL IMPACTS

The LCA component of this study has been produced with reference to the ISO 14040 but has not been critically reviewed. Further information on data sources and assumptions can be made available on request to Composites UK.

Taking three case studies to represent typical GFRP composite materials as below:

- SMC (sheet moulding compound) as is often used in automotive and some construction applications, assumed 30% / 23% / 47% resin / glass fibre / filler.
- Continuous sheet, as used in rooflights, or hand lay GFRP, used for a multitude of purposes and the largest process by volume. These have comparable constituents, assumed 65% resin, 35% glass fibre (CS/HL).
- Infusion, as used in wind turbine blades and many boats, assumed 40% resin, 60% glass fibre.

Global warming potential (GWP) and primary energy were calculated for the following disposal / recycling routes:

1. Landfill
2. Recycling by grinding to fine filler (assuming it replaces calcium carbonate filler)
3. Recycling by grinding with fibre retention (assuming 60% of the original fibre content replaces glass fibre, and the rest replaces calcium carbonate filler)
4. Cement kiln (assuming resin content replaces coal for combustion)
5. Energy from waste (assuming electricity generation at plant efficiency of 30%, replacing UK energy mix, and no secondary heat reclamation)

No allowance is made for initial downsizing of large and thick sections, or for repeated rounds of recycling.

Where ‘benefits’ are included, the total is reduced by the impact of what is replaced, which can end up with a negative value, i.e. a positive impact on the environment. For example, replacing coal in the cement kiln or replacing virgin glass fibre in a product is considered here as a benefit.

The charts across show a comparison of the impacts for each disposal route as clustered bars for each case study material. Below zero is good.

Image: Automotive scrap. Taken by Stella Job

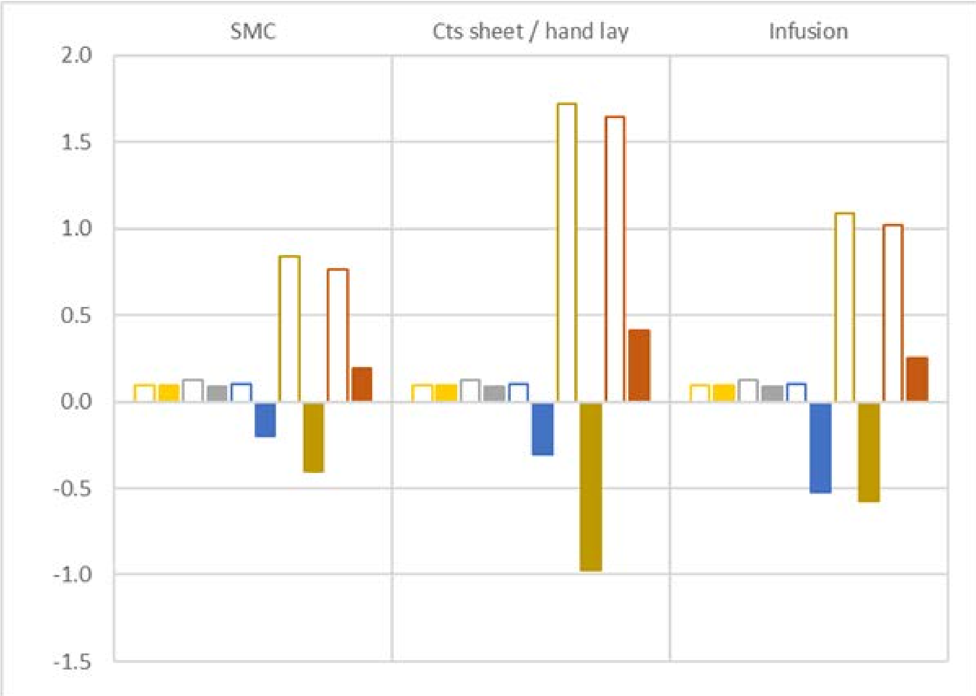


Figure 4: Global warming potential of disposal routes (kg CO2/kg)

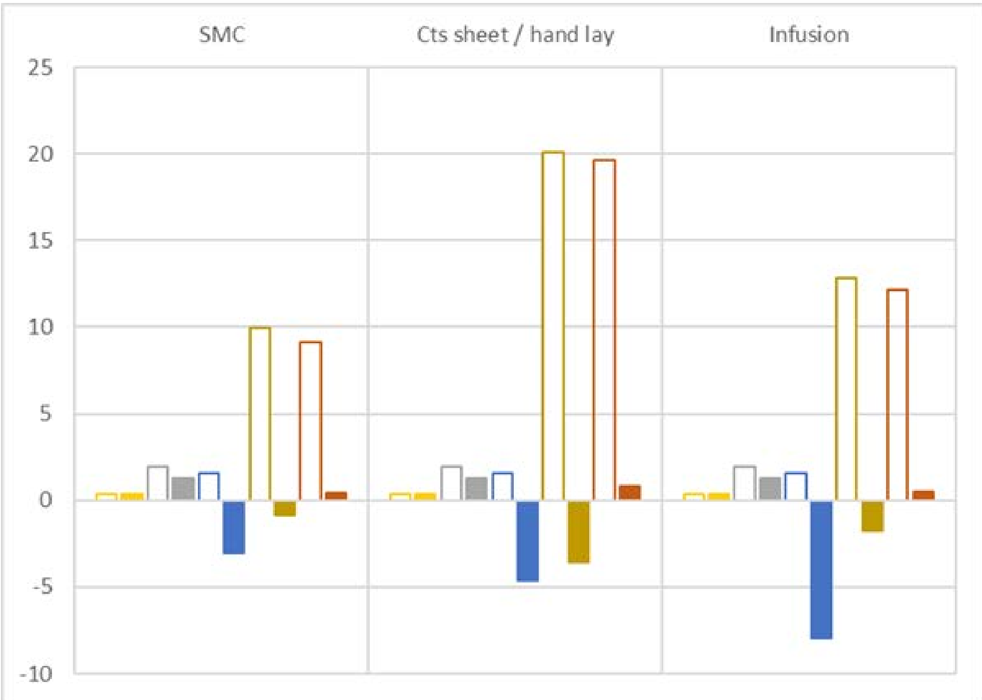


Figure 5: Primary energy associated with disposal routes (MJ/kg)

Legend for figures 4 & 5

- Landfill (no benefits)
- Recycle to fine filler (no benefits)
- Recycle with fibre retention (no benefits)
- Cement kiln (no benefits)
- Energy from Waste (no benefits)
- Landfill (inc benefits)
- Recycle to fine filler (inc benefits)
- Recycle with fibre retention (inc benefits)
- Cement kiln (inc benefits)
- Energy from Waste (inc benefits)

NEXT STEPS

COMMERCIAL DEVELOPMENT

Cement kiln route

Co-processing in cement kilns needs to be more fully investigated, in particular to understand how a scheme started by Agecko (waste management company) works and develop it to take more waste, noting that significant testing is likely to be required on the sources of waste as volumes increase.

National scheme

As suggested by Agecko, it would be good to set up a nationwide scheme, e.g. with discounts for Composites UK members to incentivise and promote uptake. This would initially focus on the cement kiln route, but as recycling routes develop, would enable more consistent high fibre content waste streams to be diverted to those.

Mechanical recycling

Some contacts have arisen through this study for specific applications, which will be followed up.

Downsizing

More work is needed to identify the most cost effective methods for downsizing / shredding FRP waste, due to abrasion on equipment in traditional shredders, and dust control is important as the fibres are an irritant. Downsizing of large items (e.g. boats, wind blades) is a particular challenge. A review of techniques developed internationally would be a starting point.

FUNDING AND RESEARCH

Areas of further research needed include:

- Company led R&D for specific applications including recyclate.
- Company led R&D for downsizing techniques, especially of large structures.
- Basic research to identify optimum methods for incorporating recyclate in different matrices. This will support and accelerate company led R&D.
- Supporting development of lower TRL solutions, to see if they can be economically scaled up. In particular, the thermal treatment with post processing developed at University of Strathclyde.
- Developing resins with bio content: As large amounts of EOL composite waste are likely to be combusted in some way, it will be much better from a global warming perspective to maximise the bio content in resins.

COLLABORATE INTERNATIONALLY

It is recommended that Composites UK and its members continue to collaborate and share research and experience internationally to avoid duplication and accelerate progress. This should include attending the Global Composites Recycling Coalition meeting organised by the American Composites Manufacturers Association at JEC each year in March, attending relevant international conferences and active involvement in the EuCIA Sustainability Group.