Re-COMP PILOT 2024

Report on the Pilot Project for the Disassembly, Recycling and Upcycling of End of Life (EOL) Vessels - July 2024

Led by South Hams District Council in partnership with Blue Parameters Ltd, Creekside Boatyard, and South Devon College

Report prepared by Blue Parameters Ltd [July 2024]

Table of Contents

Background

In 1950, a UK boat builder called W & J Tod Ltd produced what is believed to be the first Glass Reinforced Plastic (GRP) boat in Europe, a 12 ft dinghy for rowing, sailing or motoring. An example of this – the BC50 – can be found in the National Maritime Museum Cornwall in Falmouth. The marine boatbuilding industry quickly adapted to the use of this material, initially for the design and build of recreational vessels, followed by small commercial vessels. A proliferation of types and sizes soon became widely available.

As recreational water sports became more popular, the manufacture of canoes, sculls and eights, surfboards and windsurfers moved to using GRP. Its benefits were clear; it was cheaper, more adaptable and efficient to build with, often saved weight and was inherently far more water resistant than wood. Neither did it corrode as metals did when in contact with seawater, and multiple products could be produced in volume from male and female moulds. This allowed smaller companies to offer a wider range of products.

From a commercial point of view, the marine industry was now able to offer a range of lower maintenance vessels, which also proved to have a long lifespan averaging about 45 years. As production was also streamlined, waiting and delivery times were also considerably shorter. From the 1970s onwards, sailing, cruising and racing activities accelerated at pace, and local harbours became crowded. This gave rise to the creation of marinas that were specifically designed to moor high numbers of recreational craft of all kinds.

In 1984 in the USA, Carbon Fibre (FRP) was used to build a 54 ft sailing yacht, followed in the early 1990s by its use for rigs and spars. As a material it is far more expensive to use than GRP, and so it is still only used for high end sailing yachts and is predominant in Grand Prix Racing Yachts. It has greater mechanical and structural properties than GRP and is lighter, using less resin in its structures.

Blinkered Optimism

The use of GRP was hailed as a revolutionary product (which it was) and it was transformative for the marine industry. However, as with the adoption of asbestos as a building material, there was no prescience for the consequences in the future.

The extension of vessel life resulted in delayed awareness of the issue we now face. The problem is exacerbated by a lack of regulation over the disposal of GRP and FRP, particularly in the UK, with landfill being the easy and cheap method when the quantities involved were much lower. The use of GRP for caravans, furnishings, and in building has also accelerated, followed by its use in wind turbines. The use of FRP is now very common in the aviation and automotive industries.

Reality Bites

There is no requirement in the UK to register ownership of a vessel, insure or hold qualifications for its operation. Most marinas are privately run, and estuarine and harbour moorings are widely available to the public (and a valuable source of revenue to those who operate them).

The most damaging consequence of this has led to many vessels being abandoned by their owners when they reach the end of their life (EOL) or are too expensive to run. Selling them on at this stage is not viable as, over time, vessels will depreciate (unless they are meticulously maintained). Nonetheless, there are an alarming number of recreational craft for sale though online sites like eBay, where they change hands for a few hundred pounds. Often, these are bought by uninformed and optimistic new owners, who are left with something they cannot afford to moor or maintain.

It is a simple matter to either sell on or walk away from a vessel. As there is no registration system, it is very difficult to trace owners or hold them accountable. Harbour authorities, marinas, boatyards and sailing clubs are all in similar situations. It is an expensive and time-consuming process to reach the stage where they can dispose of these vessels. Currently, the only option is to break them up and send them to landfill. This method of disposal is also the go-to for excess composite waste and resins that are a byproduct of boat building.

Consequences

It is not known how many yachts, powerboats, and other small craft have been abandoned in the UK, but it is a figure likely to be in the thousands. The Green Blue and the RYA have set up an EOL Vessel register where anyone can go online and report a vessel and its location.

The most immediate challenge for any marina, harbour authority or council is that any recovery and disposal of an abandoned vessel is the cost. It is not something that is (or can be budgeted for). Aside from financial cost, the process can be time consuming and involve multiple stakeholders.

Abandoned Vessels and their Impact

The impact of abandoned vessels is clear-cut and obvious; it is the pollution to the water body through the leaching of chemicals, oils and fuels. Over time, as a vessel's structure and hull deteriorates, it is also the leaching of micro plastics and decomposing composite waste.

There is also a knock-on effect, as any abandoned vessel is likely to lead to others being left in the same area. In one local estuary in the Plymouth area, one small, abandoned vessel just two years ago has now become five.

The environmental impact of abandoned vessels relates to a lack of accountability to the owners, denying opportunities to bring a case or prosecution for this act (which is a breach of environmental law). Essentially, this results in the maritime version of fly tipping, but with a wider and deeper environmental impact.

End of Life (EOL) Vessels

These are vessels that are approaching or have reached the end of their operational life and are not for resale or repurposing. They can range from a 8ft dinghy to a 45 ft sailing yacht Whilst they cannot be classed as abandoned vessels as such, nonetheless they require a disposal solution that is both practical and cost effective.

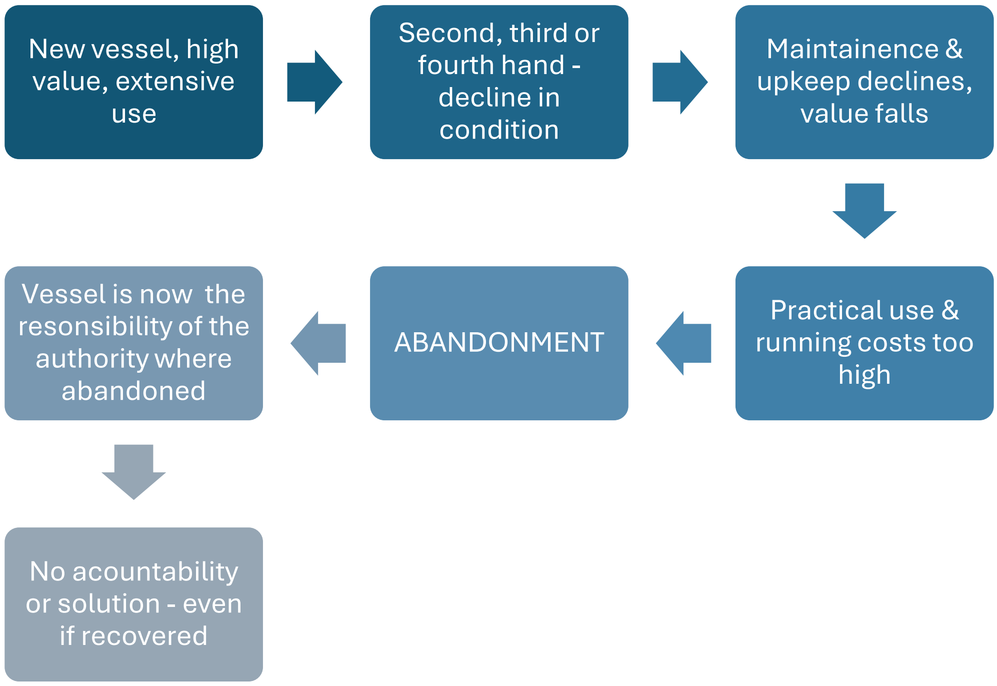
Executive Summary

The challenge associated with both abandoned and EOL vessels is that, until the implementation of this pilot, there was no available or practicable solution within the UK. On the other hand, the automotive industry is highly regulated and together with manufacturers' responsibility, there are nationally available breakers' yards, and a good resale market for parts.

A high proportion of cars can be recycled many times over. It is almost impossible to buy a car or abandon one as there is a legal requirement pertaining to registration.

Cars are also required to have to have an annual MOT, unlike recreational vessels where there are no legal requirements to check that they meet certain safety and environmental standards during the course of their life. This is another reason why so many vessels reach a point where it is not safe, practical or economical to run and use them.

The Current Cycle



Currently, even if a vessel can be disposed of responsibly, where this can take place remains an issue. There are a few small companies listed as boat breakers, which is exactly what they are. However, they tend to remove the high value and recyclable parts of the vessel, before sending the hull, superstructure and internal fittings to landfill. Only a very small proportion is converted from waste to energy (which in itself is not an efficient disposal method if waste has to travel any distance). A very small amount of GRP goes to reinforce concrete used in construction – but in the long term this will itself be a problem.

Until last year, the response of the wider marine sector, GRP manufacturers, and municipal authorities to address this issue was, at best, noncommittal. South Hams District Council (SHDC) has, however, committed some funding which has enabled this pilot to be undertaken.

It is also unfortunate that the standard industry response is to ask how much it will cost. Currently, the state of play is for the GRP (both virgin and contaminated) to be collected by a contractor and disposed of - inevitably into landfill. There are some counties (Cornwall being an example) which have a zero-landfill policy, so all non-recyclable waste is taken out of the county for incineration.

In 2019, the cost of landfilling composite waste in the UK was £29,000,000 GBP and would have filled a large area. It is known that the decomposing of composite waste can take hundreds of years, during which time chemicals, microfibres and plastics will be leaching into the soil system.

In Germany, concerns over long-term damage, and the cost of dealing with any potential clear up in the future, have led to a complete ban on the landfilling of composite waste. As a result, the cost of disposal there has risen from about 150 euros per ton to over 1100 euros per ton.

At a time when landfill sites are becoming more limited, an increasing quantity of wind turbine blades will need to be disposed of, running into thousands of tons. When this occurs there will need to be sites which can deal with this waste in an efficient manner. These will come at a high cost, as the industry and those needing to provide facilities will be trying to catch up.

Solutions

Until recently the only option for dealing with composite waste was by a process known as pyrolysis, and this was mainly used for carbon fibre reinforced polymers (CRP) waste, which has a higher reuse value. However, the quality of the fibres recovered was low, due to the intense heat required to burn off the resins. It was also costly in terms of energy use, and the carbon footprint from having to transport it to facilities. Until recently, Boeing were flying 350 tons a year from Seattle to the UK, whilst other sources were shipped in containers from New Zealand.

More recently, BM Longworth, a UK company, have developed a process called DEECOM® which uses, heat pressure and steam to treat both FRP and GRP composite waste. The quality of the fibres recovered is higher, and even the polymers can be collected and potentially reused. The energy use for this process is far lower than for pyrolysis and the system can be scaled up to deal with varying quantities of material. They are also able, for instance, to reuse CRP fibres to make carbon tape for use in the manufacture of tennis rackets and bike frames.

The Local Challenge – South Hams

Following the declaration of a Climate Emergency in 2019, South Hams District Council (SHDC) committed to taking decisive action to manage and reduce carbon emissions. This included the reduction of organisational carbon emissions to net-zero by 2030 and to work towards achieving net-zero across the district by 2050.

To drive down emissions in its marine sector, the Council embarked on an ambitious programme of decarbonisation activities. Funded through the UK Shared Prosperity Fund, this includes projects that focus on promoting green marine growth and behaviour change.

End-of-use vessels were identified as an area of ongoing concern within South Hams. Vessel abandonment, sinking and stranding are regularly reported within its three main estuaries, the Dart, Salcombe-Kingsbridge and Yealm. SHDC recognises the environmental and financial impacts arising from this issue.

These estuaries sit within the South Devon National Landscape and deliver important 'ecosystem services' to the local natural communities. Maintaining clean water is essential to the quality of life within these estuaries.

The impact of GRP breakdown on our nearshore and coastal ecosystems has long been suspected, together with the potential for GRP to be harmful to aquatic life. The risk of GRP becoming a new contaminant in the food web has also been acknowledged. However, it is only recently that pioneering research by the University of Brighton (Journal of Hazardous Materials, July 2024) has been able to show extensive fibreglass contamination of both oyster and mussel populations in a busy South of England sailing harbour.

Furthermore, the financial costs associated with dealing with end-of-use vessels mainly fall on stakeholders within the local area. In South Hams, this includes harbour authorities (such as Salcombe Harbour Authority, Dart Harbour and River Yealm Harbour Authority), as well as a local boatyards and marinas.

In 2023/24, SHDC had an opportunity, and a modest amount of funding, to run a small-scale pilot project that would highlight legacy vessel disposal issues and potential recycling solutions, whilst at the same time support Dartmouth-based Creekside Boatyard with their ambitions to diversify into clean marine activities.

This pilot project aimed to explore with Creekside Boatyard and environmental consultants Blue Parameters Ltd, any opportunities for the development of a commercially viable recycling and re-use process for the components used in boat manufacture, most notably composite hull materials.

For SHDC, this pilot also offered an opportunity to raise awareness among the local community of the current and future challenges posed by end-of-use vessels as well as help to promote behaviour change within the marine business and boating communities. This pilot aligns with Council's aim to make the South Hams an exemplar for other local authority areas by showing what can be achieved. Indeed, it has become clear through the extent of wider UK engagement with this pilot that there is a significant appetite to explore this issue and any potential solutions that extends far beyond South Hams.

The Disassembly Process

In 2022, an early attempt was made within the UK to address the composite waste challenge. This initiative, which launched at the Green Tech Boat Show that year, in Plymouth, was unable to proceed due to a lack of funding.

In 2023 South Hams District Council (SHDC) looked to set up a pilot project in this space funded by the UK Shared Prosperity Fund (UKSPF). Working with project partners Creekside Boatyard, Dartmouth, Blue Parameters Ltd and South Devon College, and supported by BM Longworth, SHDC were able to implement this pilot project, which began in March 2024.

The aim was to take a complete EOL vessel and put it through a disassembly process, recovering and separating out all component parts that could be recycled or reused (right down to individual screws).

The process was fully recorded by the project team. Data gathered included time taken and energy used in the process, as well as a listing of all the vessel's constituent parts. The monetary value of all recovered and reusable material will be recorded over the coming months.

The vessel was lifted out of the water, and any marine growth was washed and scraped off. The keel was removed, and the vessel was lowered onto a cradled trailer and moved into the containment workshop to start the dismantling process. As far as could be, all externally mounted paraphernalia was removed by hand.

Creekside Boatyard took the necessary precautions to comply with Health and safety regulations for dealing with hazmat waste. The methodology was also fully documented so that a guide to replicating the disassembly process can be produced going forward.

This novel piece-by-piece disassembly approach was combined with the removal of a sample section of the composite hull, which was then taken offsite to be put through the DEECOM® process by BM Longworth. This was the first time the process had been carried out on contaminated composite waste.

Recovered Material Data

A Westerly GK29 sailing boat was sourced by Creekside Boatyard from the River Dart and lifted out onto the hard.

The vessel's owner was unable to undertake the maintenance needed and, as such, the vessel could be considered as EOL.

Recovered material weights and estimated values were recorded.

Recovered Material	Weight	Estimated value
Parts and Metal	2,390 kg	£1,390
Wood	27 kg	No value
Winches, Bronze & Stainless		£2,750
Electronics		£175

Energy and Carbon Footprint Values

Energy and carbon footprint values were recorded by SHDC. See Appendix One for details.

Notes on Images

The approach to this project which we called 'vessel disassembly' has demonstrated that a planned and precise approach can be time efficient.

It is clear from the images below, that a high proportion of the vessels ancillary and operating equipment was removed intact.

This will allow the option for it to be sold on rather than be sent for scrap or to be recycled – which could result in a much higher financial gain, as well as extend its working life.

Recovered Deck Hardware and Electronics

Rig, Boom, Standing and Running Rigging

Hull and Superstructure Composite Material

Sails, Ancillary Gear, Engine and Waste Material

Household and other non-recyclable waste materials are shown in green bags.

Waste Material Processing

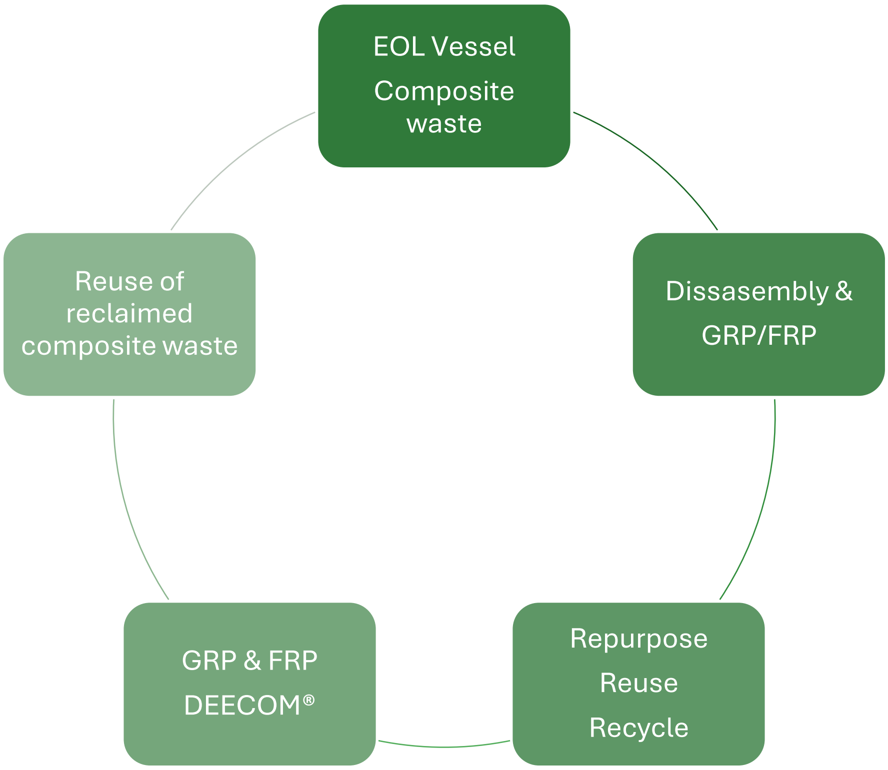
The vessel had been left unused and poorly maintained on its mooring for a long period of time. A large quantity of household and other waste (175 Kilos) had accumulated. This was recovered during disassembly and could not be recycled.

The poor state that the vessel was found in was highlighted during disassembly further demonstrates the need for a system that ensures vessels are kept on moorings in a seaworthy condition, and are fully insured, taking into account their usage and general condition.

In early 2024, an abandoned EOL vessel sank on its mooring on the River Dart. The cost of recovery (in excess of £80,000 GBP) included hiring a commercial dive team. This did not include the actual cost of disposal.

It is a common refrain that the cost of implementing stricter measures and systems for mooring vessels is too expensive. All it takes is an incident like the one above and already the cost of this has been exceeded. It has been estimated that some local authorities have spent over £1,500,000 in dealing with this issue.

Future Cycle



DEECOM® Process

Two kilos of composite from the vessel's hull were sent up to BM Longworth to be put through the DEECOM® process. All the material was contaminated and consisted of both heavy dense and lighter GRP material.

A detailed report of the process is shown in Appendix Two.

The second stage of Composite Processing using DEECOM® technology will involve an analysis of the polymer liquids and resins, which were a result of the processing. The equipment need for carrying out this analysis was undergoing an upgrade during the pilot project. Consequently, this work is planned for later in summer 2024 and will be added to this report.

Upcycling Recovered Composite Material

Through this pilot, it has been demonstrated that the DEECOM® process is able to produce recoverable GRP and FRP fibres, separate out polymer material, and clean any contamination. There are proven results and uses for FRP materials, such as the FRP tape, which has been used to make tennis rackets and bike frames.

Going forward, the intention is to upcycle the recovered fibres. We are looking to make a secondary panel using the recovered GRP fibres from the process, and then put this through mechanical testing to assess its properties. A modest amount of additional funding is required for this, and we are exploring our options.

Through this process, we would be able to create a new product which had a known production cost and applications. It may be possible that using recycled GRP like this for non-structural applications at volume is a viable option for the future.

As this project was a pilot, and the DEECOM® unit used was fairly small, there is currently no cost information for running at a large commercial scale. This will continue to be explored and we may be able to get some broad estimates later in the year.

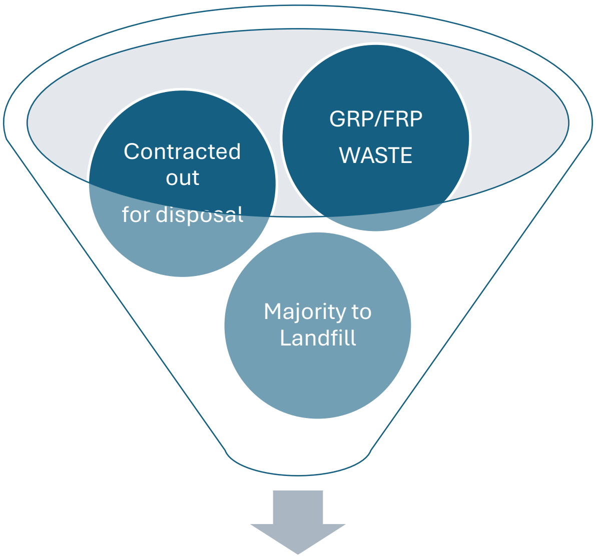
EOL, GRP & FRP Recycling – Looking Ahead

Since this began this pilot project, we have had considerable engagement with commercial recycling companies, and marina groups (such as Boatfolk), who are also interested in whether this sort of undertaking could be upscaled to a large-scale commercial operation.

As always, the first question is whether this would generate sufficient financial returns, and if so, whether financial benefits could be reaped within the necessary timescales.

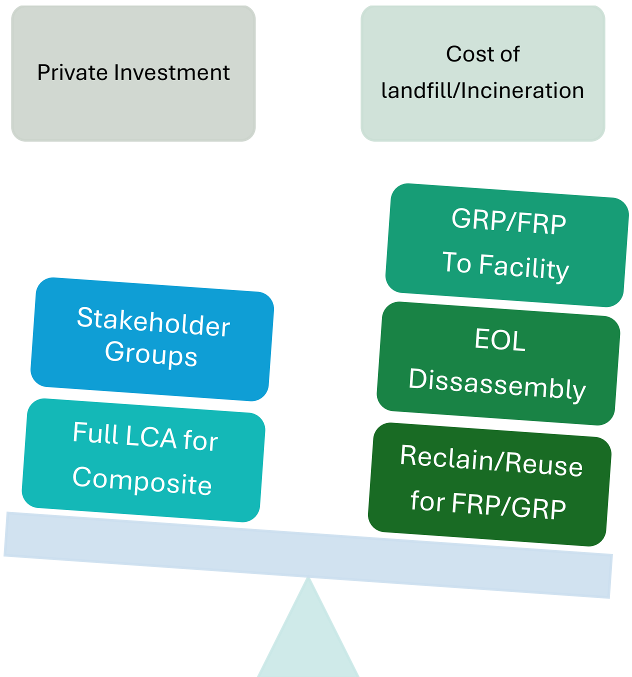
While costs remains a primary consideration for businesses wanting to upscale, it is highly unlikely that revenue streams will come quickly enough or be high enough initially.

This is one reason why we are still caught in an endless loop of landfill and incineration.



GBP £29,000,000

OR



GRP/FRP Waste Growth Curve

In the last few years, we have seen an increase in the number of EOL vessels. This is due to the average vessel life being between 40 and 45 years. The boats that were built and produced in the 1960s and 1970s are becoming no longer viable for use – and, as they will have been passed down the chain of ownership, their current owners have little incentive to dispose of the vessel responsibly (and legally).

The number of abandoned boats, ranging from small day boats to larger cruisers, are predicted to increase at an exponential rate. The same will apply to caravans, also manufactured using composite materials. A recent TV news programme in the Southwest and a news article (BBC Devon, July 2024) highlighted the number of caravans being left by the roadside or abandoned on caravan sites.

Offshore Wind

There has been a drive to accelerate the development of offshore wind at a national government level to achieve green energy targets. To date, turbine blades which needed to be replaced were often sent abroad to China and other countries for landfill (another example of ignoring a problem and passing on the consequences). This is no longer a viable option, and it is estimated that tens of thousands of tons of blades will be put into operation – and need to eventually be replaced - in the UK. The weight, size and scale of these mean that land storage will not be a realistic choice.

In the Southwest, activity that centres on accelerating Celtic Offshore Floating Wind has not succeeded in addressing the question of where and how to land, store or dispose of the resulting composite waste.

Once upscaled, the DEECOM® process would be able to deal with turbine blades; however, the process and infrastructure would need to be in place ahead of time. To set up anything like this retrospectively would be (as is always the case) far more expensive and would result in a local backlog at a local level of GRP waste that would comprise of turbine blades, EOL vessels and other sources.

As other parts of the country will be experiencing the same problems, the options of sending local waste to other areas to be dealt with will become limited.

The Regulatory Landscape

In the UK, we are still able to landfill GRP and FRP composite waste, which is one of the reasons why little, if anything, has been done to address the issues. For most businesses, landfill remains the cheap and easy solution.

If this changes, and the opinion is that it is likely to do so, then the industry, as well as municipal authorities, will have to come up with solutions quickly. These are likely to be expensive and time consuming. They will probably be set at the lowest level to meet regulations.

Waste disposal will also become a sellers' market. Those who have the ability to deal with hazmat waste will be able to set high prices for doing so as no other options will be available.

Partners and Stakeholders

For EOL vessels to be integrated into a larger scale project for disassembly and recycling, we would need to have awareness and support from harbour authorities, marina groups, and larger boatbuilders, all of whom are paying to deal with EOL vessels.

This would enable a larger project to deal with the logistics of identifying and getting vessels to site but would also look at repurposing the fiscal cost of dealing with them as it stands. This cost could directly fund and support a larger scale project with clear benefits.

Partner and Stakeholder Feedback

"The RYA is pleased to see on-going research and development into dealing with the challenge of end-of-life boats, particularly fibre-reinforced plastic (FRP) hulls. Boats have a long life, which is great news in sustainability terms, but that long life is delivered through using materials that are a challenge to recycle when they finally reach the end. The RYA supports projects that seek solutions to this problem and is keen to see innovative financing models alongside technical developments to aid recycling and materials re-use.

The RYA has contributed through the European Boating Association and the European Boating Industry to pathway plans for solving this complex problem. Those plans have been developed alongside the wider composite materials industry, in particular the offshore renewables sector. We support the Extended Producer Responsibility approach, which aligns with the polluter pays principle, and note the success of the APER project in France which part funds recycling and disposal routes through a levy on new boats."

Phil Horton, Environment and Sustainability Manager, Royal Yachting Association

"The RYA's environmental outreach programme The Green Blue has been working in partnership with SHDC and its project partners to promote an online national survey aimed at gathering data on the number and type of boats that are currently abandoned in the UK. This will help inform us about the recycling options for end-of-life boats and the facilities needed to meet future demand."

Kate Fortnam, Campaign Manager The Green Blue, Royal Yachting Association

“We did not have to look very far for a suitable vessel for the project as Dart Harbour had put together a list of vessels of concern and were contacting those owners that they could to get them off the river. However, it was a surprise to get hold of a Westerly GK29 as these are proven vessels, well built and have a pedigree. We did not expect an owner to let things go so far.

When we lifted the vessel out, it was clear from the marine growth underneath that she hadn’t been sailed for some time and once washed and scraped off, we started work by cutting off the keel. Once removed the vessel was lowered onto a cradled trailer and moved into our containment workshop to start the dismantle process. As far as could be, all externally mounted paraphernalia was removed by hand so we were left with what should have been a predominantly fiberglass carcase.

Despite the poor condition of the interior, we started to cut up the fiberglass hull, topsides, and deck. This was done simultaneously from each end to the weight would be balanced out. The labour was extremely hard work and without good PPE would have been personally hazardous. PPE consisted of Tyvek suits, full face respirators, gloves, helmets, ear defenders and wellington boots.   After a couple of days of sawing, grinding, chopping and cutting the vessel was now in 1m square. As much as we could we tried to save boat parts for cleaning a resale.   At the end everything was weighed, categorised and accounted for in type and quantity so realistic figures could be generated. As a result of this pilot, we have gained a better understanding of the process practicalities for effective disassembly and recycling.”

Chris Craven, Creekside Ltd
Old Mill Creek, Dartmouth, Devon

Conclusion

We have successfully demonstrated that the disassembly, reuse and recycling of EOL composite vessels at the exceptionally detailed level approach is achievable. Given its nature as a pilot project, it proved to be time efficient, and a great deal was learned during the process.

We were able to recover GRP fibres using the DEECOM® process and are looking to use these to make a small composite panel using bio resins. This will then be tested for its mechanical properties – and from this we can then look at the wider scale applications and use for this type of upcycled composite material.

There has been interest from a local company into the upscaling of the project to a large-scale commercial operation. This would not only deal with EOL vessels but would also have the potential to process GRP and FRP from other areas, such as turbine blades, and offcuts and surplus from boat manufacturing and caravans.

However, further funding will be required to achieve this. The development of wider stakeholders and expertise will also be essential to make this achievable. There are several initiatives in the UK with a focus around composites, with interests ranging from waste processing to the impact it is having on marine life. Silo projects on their own are less likely to succeed, and it should be noted that all of these share common aims: namely, to reduce and bring an end to landfilling GRP/FRP waste, prevent marine pollution, and bring LCA into more processes.

Whilst there are common goals and benefits for all stakeholders, a cohesive approach is needed, which uses areas of expertise, technology, resources and development. If this approach is taken and sound partnerships are formed, everyone will be able to benefit, and significant progress can be made.

There is an opportunity for SHDC, Blue Parameters Ltd, Creekside Boatyard and new potential stakeholders such as Gilpin Demolition to be the driving force to taking this to the next level. However, it has to be achieved through collaboration, or risk failure. This will necessitate stakeholders, who will all have a different perspective on this challenge, to accept that there will be different levels of benefit, from financial to technological developments with regard to the GRP and composite materials.

The worst-case scenario would be a single entity controlling the process, or a regulation requiring it to take place. At this point, the opportunity for innovation and participation from SMEs will have passed. Compliance with regulations that are introduced will likely lead (as has happened in the past when considering sustainability) to the minimum being achieved and to financial gain outpacing any wider environmental, sustainable and community benefits.

Appendix One: Process Emissions

Scope 1 Emissions (tCO2e)			0.065
	Litres	tCO2e	
Diesel (for crane)	25.84	0.064912	
Scope 2 Emissions (tCO2e)			**0.020**
	kWh	tCO2e	
Electricity	95.3	0.019734	
Scope 3 Emissions (tCO2e)			**1.177**
	Miles	tCO2e	
2kg material sent for composite processing	244	0.055894	
Staff Mileage	168	0.045052	
James Mileage	360	0.09654	
WTT Fuel		0.015788	
Electricity T&D		0.001707	
WTT Elec generation		0.004374	
WTT Elec T&D		0.000378	
WTT Mileage		0.011805	
Spend			
	£		
Skip Hire	615	0.8364	
Tools and Equipment	102.85	0.057596	
Waste	37.5	0.051	
Total Emissions (tCO2e)			**1.261**

*spend data factors derived from DEFRA Table 13 - Indirect emission from the supply chain, nearest product category used.
Given the inherent inaccuracies and generalisation, this part of the emissions calculation is less accurate

Material Salvaged (tonnes)	3.63	
Material Salvaged (less fibreglass/GRP) (tonnes	2.139	
Emissions per tonne of recyclable material (tCO2e)		0.59

Appendix Two: Deecom® report

Blue Parameters – Liberating glass fibres

Introduction

This report will detail the experimental processing of Blue Parameters material using the DEECOM® process. The targeted result of this trial was liberation of the glass fibres present within the material. Thus, similar processing conditions to that used in previous glass fibre composite recycling trials were used. However, there were changes to the initial trial (including re-processing), to account for the presence of residual organic material on the samples.

Experimental Procedure

Four samples were provided to Longworth, with two being thicker. Each sample also had partially varying dimensions. These samples were initially weighed then inserted into fine mesh holders (each with a rough area of 450cm^2) specifically created for each sample. This was done to ensure that fibers did not escape containment during DEECOM® processing. Note: the mesh holders were labelled 1-4 to keep track of each sample.

1st Run

The first trial utilized previous knowledge to select the process parameters, but also experimented slightly with the temperatures at which each sample was subject to. The R&D vessel used has a vertical temperature profile of elevated temperature in the upper section and lower temperatures towards the lower section. To see the effect of the different temperatures on the material, one thick and one thin sample were placed in both the upper and lower sections of the R&D vessel. Once the samples were in the position the process was run.

2nd Run

The methodology for this run involved altering the processing conditions for increased severity. The samples were kept in their mesh holders and all input into a similar elevated temperature section of the vessel.

Results and analysis

The results of the trial were evaluated through visual analysis, mass loss, and physical touch of the output material.

1st Run

The output material from this run differed between the samples in the lower and upper sections of the R&D vessel. The lower samples had no visible change and minimal mass loss, indicating the temperature was too low at this point in the vessel. The upper samples had visibly changed during processing but were still uncomplete. The fibres were still contaminated with organic material, which can be seen by the discoloration present (figure 1).

Figure 1: Output material from the upper section in the 1st run

The mass loss (table 1) reinforced these findings, showing that the samples in the lower section experienced minimal mass change, with the thick piece increasing in mass. It is reasonable to assume that this is due to water ingress. The upper section samples do show significant mass loss, indicating there was success in removing a significant amount of unwanted material. However, visual analysis showed that the desired product had still not been achieved at this mass loss.

Table 1: Mass loss data for the 1st run

Vessel section	Sample thickness and number	Mass in (g)	Mass out (g)	Mass change (g)
Upper	Thick (2)	636	201	-435
	Thin (4)	368	136	-232
Lower	Thick (1)	657	720	+63
	Thin (3)	336	333	-3

These findings lead to the re-processing of the material (second run), to remove the organic contaminant remaining.

2nd Run

The output material from this run visibly showed liberation of the glass fibres (figure 2). As can be observed, the fibres are now distinguishably white for all the samples, which is a stark difference from the output of run 1 (figure 1). This indicates that the altered processing conditions of the second run were successful in achieving the desired targets of the trial.

Figure 2: 2nd run output material from a) sample 1 b) sample 2 c) sample 3 d) sample 4

Microscopic analysis of sample one output material can be seen in figure 3. This is representative of the microscopy taken for each sample and shows that minimal contamination is present on the glass fibres. This again indicates the trial was successful in liberating the glass fibres from the material.

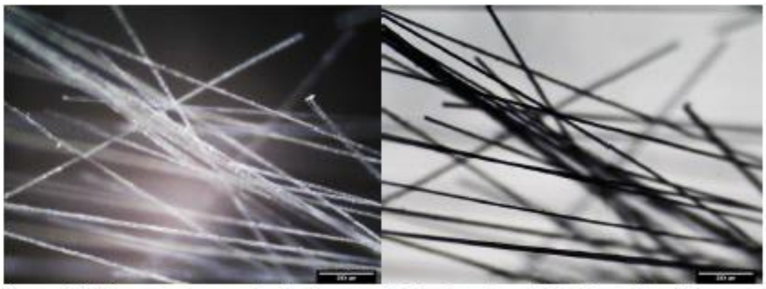


Figure 3: Microscopy analysis of sample 1 output material from the 2nd run In left) reflectance and right) transmittance mode

Further analysis of the output material (physical touch and visual) showed that there was still a minor amount of *inorganic* contaminant remaining (figure 4). A substantial chunk of this contaminant remained at the bottom of the mesh holders and was easily separated, although minimal amounts were still present on the material. This contaminant was separable from the fibres, but other pre-processing and post-processing techniques could be utilized in future to remove it. This is likely and additive to the paint coating, which is hypothesized to be an inorganic filler in the paint.

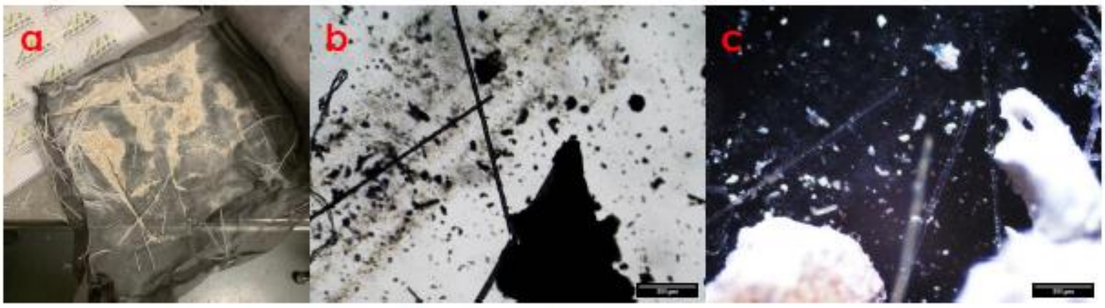


Figure 4: a) Contaminant remaining in holder b,c) microscopy of contaminant

The mass loss observed during the second run (table 2) also showed success in removing a significant amount of material from the fibres. As can be seen in table 2, samples 1 and 3 lost a lot of mass during the second run, showing their success. Samples

2 and 4, which already showed mass loss in the first run, did not show as much mass change. Sample two lost another 20g whereas sample four gained 5g, which again is assumed due to water ingress. Despite the mass gain, the visual imagery of the samples shows the fibres liberation (2d), indicating a successful run.

Table 2: Mass data for the 2nd run

Sample thickness and number	Mass in (g)	Mass out (g)	Mass change (g)
Thick (2)	201	181	-20
Thin (4)	136	141	+5
Thick (1)	720	196	-524
Thin (3)	333	147	-186

Conclusion

In conclusion, this trial was successful in achieving its aims, which was liberation of the glass fibres present within Blue Parameter material. Re-processing was required, with the second run showing the most promising results. This, however, is normal for any material that has not been trialed through DEECOM® before.

The output material showed visibly clean fibres (figure 2) for all the samples processed. There was a small issue with organic contaminant identified. Imagery and microscopy of the organic contaminant is seen in figure 4. This however was a minor issue and a significant amount of this contaminant fell to the bottom of each mesh holder, leaving only partial amounts present on the fibres. Still, there was no clear contaminant present on the microscopy of output fibres (figure 3). If the contamination did provide an issue, pre and post-processing techniques could be applied to remove it.