Understanding Composites:

Demonstrating the need to support high value composite treatment routes

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What is the issue?

Composites create light and durable components that have no high-value end-of-life prospects.

Because of their inherent characteristics of strength and light weight, composites have increasingly become the material of choice for many sectors across the globe. Composite materials have become the favoured solution to tackle the challenge of light-weighting in the transportation industry – with the goal of reducing carbon emissions and supporting the sustainability of the sector. The material often has a low energy demand in comparison to metals with similar durability characteristics[1] and aids in developing lighter products that reduce fuel consumption[2] either in-use or when in transit for delivery.

But the most significant disadvantage to the use of composites is the limited options for their recovery and recycling – with the consequence that the majority of composites are currently landfilled.[3]

Some EU Member States as well as the United Kingdom have imposed landfill taxes to discourage the landfilling of composites, while others such as Germany have put a stop to landfilling by imposing bans. Meanwhile France is looking at producer responsibility legislations on these materials, driving businesses to think differently about how composites are used and where these materials ends up.

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[1] https://www.springerprofessional.de/en/the-effect-of-lightweighting-on-greenhouse-gas-emissions-and-lif/16419118

[2] https://www.grantadesign.com/download/pdf/automotive_guide.pdf

[3] https://windeurope.org/wp-content/uploads/files/policy/topics/sustainability/Discussion-paper-on-blade-waste-treatment-20170418.pdf

What is the current state of play?

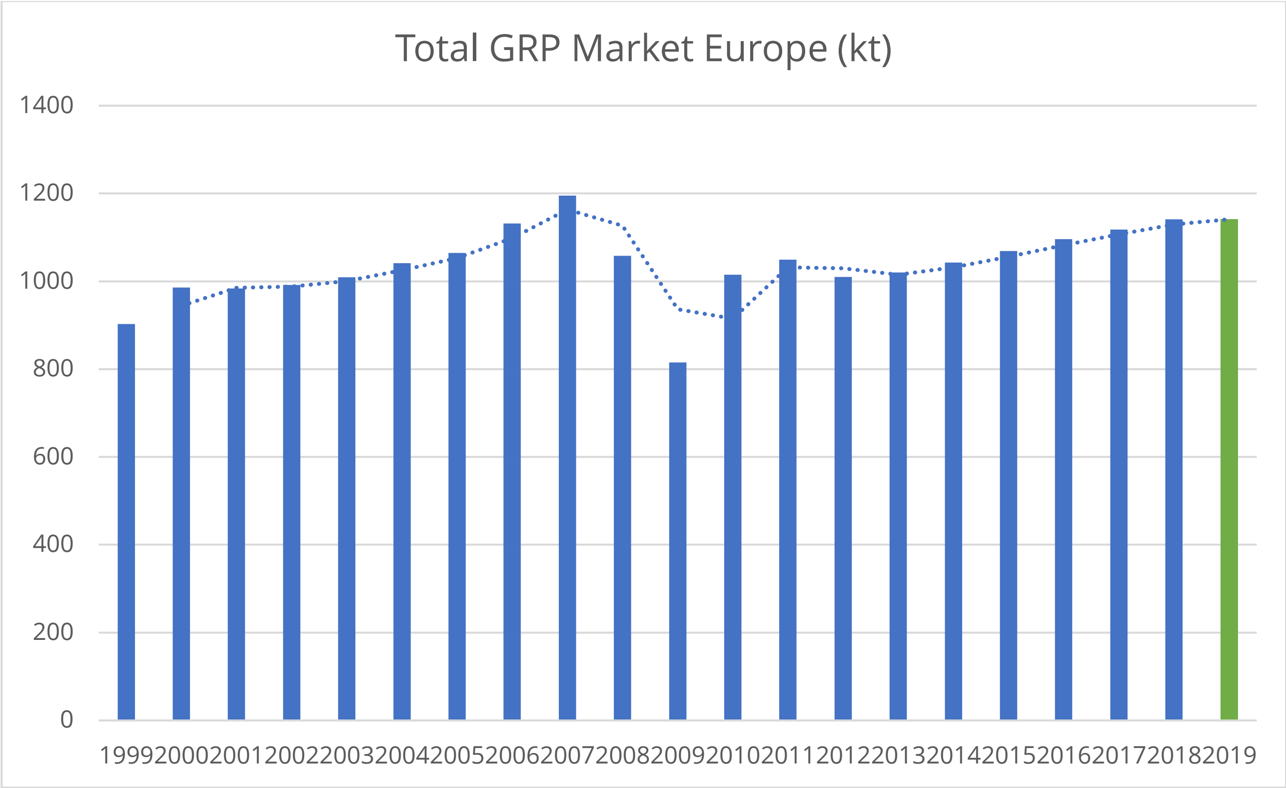
The use of composite materials has grown in the past few years, and in 2020 the market was estimated at a value of US$95.89 billion.[4] The dominant material in this group is glass reinforced polymer (GRP) which makes up 99% of all composite products. In many countries, GRP has shown significant sales growth, with the Asia Pacific market being the fastest-growing market.[4] In Europe, the annual production volume is around 1.141 million tonnes[5], a volume that has seen slower growth since 2015. Composites are used in a wide range of industries such construction, aeronautical and renewables; with more countries committing to switch to more renewable energy sources (specifically wind power), it is likely that production volumes will increase in the future. Globally, the total installed capacity of onshore wind power will near 5,044 GW while offshore wind power will near 1,000 GW by 2050.[6]

Figure 1: GRP production volume in Europe (in '000 tonnes)[5]

[4] https://www.grandviewresearch.com/industry-analysis/composites-market

[5] https://compositesuk.co.uk/system/files/documents/2019%20European%20Market%20Report.pdf

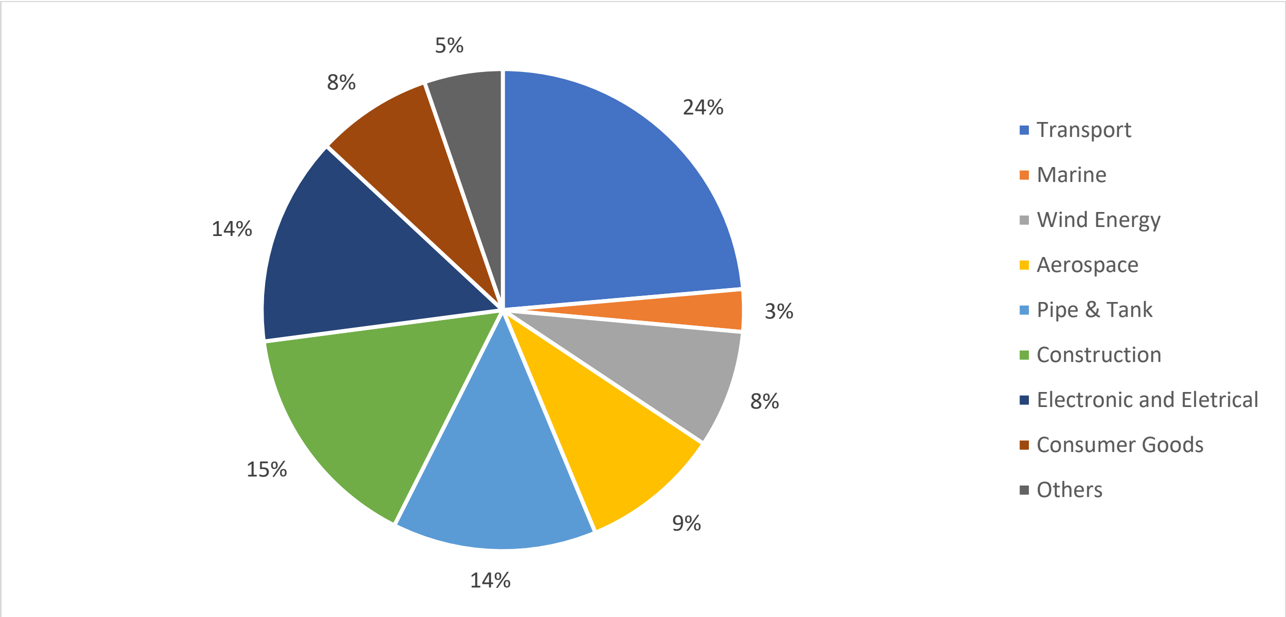
[6] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf



In terms of market size the transport sector is the dominant user of composites, with an estimated global market share of US$22.4 billion in 2020.[7] The second is construction, followed by pipes and tanks, then electronic and electrical, as shown in Figure 2.

Figure 2: Market share (in %) of different sectors in the composite market[7]

[7] https://compositesuk.co.uk/system/files/documents/Recycling%20Report%202016.pdf



The increase in the production of composite materials inevitably means the amount of waste composite material is also growing, both from production waste and end of life (EoL) waste. However, because of the way the materials are intertwined to produce something that is lightweight, strong and durable, composites are very difficult to recycle. Composites are often thermoset, epoxied and polymerised.[8] These processes are irreversible and therefore make recycling challenging.

30-50% of the carbon fibre reinforced polymer (CFRP) loss is seen at the production stage i.e. ends up as manufacturing waste - in the UK in 2016 this was estimated at 2,000-3,000 tonnes - while GRP manufacturing waste is estimated at 10% of manufacturing weight (total manufactured GRP estimated at 150,000 tonnes in the UK and Ireland in 2014).[9] ETIP Europe has reported that 683,000 tonnes of composite waste will be generated in 2025, with the biggest contributor being the building and construction industry (Figure 3).[10]

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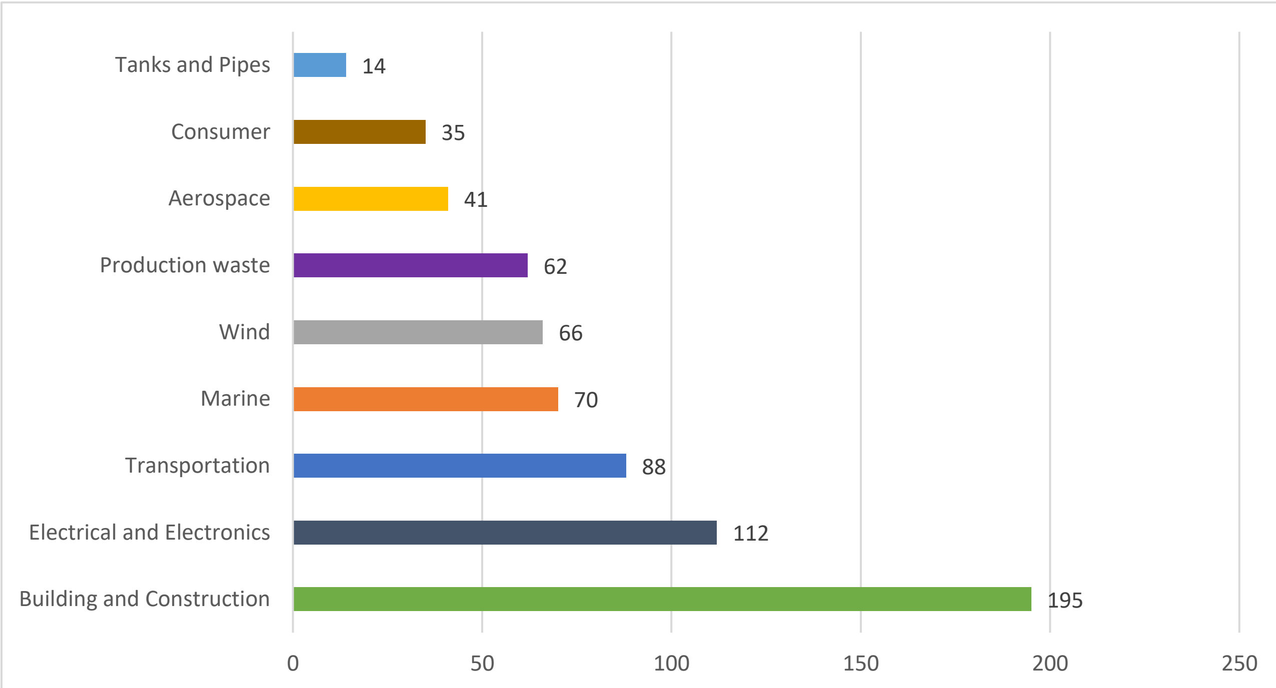
[8] https://pubs.rsc.org/en/content/articlelanding/2020/mh/d0mh01085e#!divAbstract

[9] https://compositesuk.co.uk/system/files/documents/Recycling%20Report%202016.pdf

[10] https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

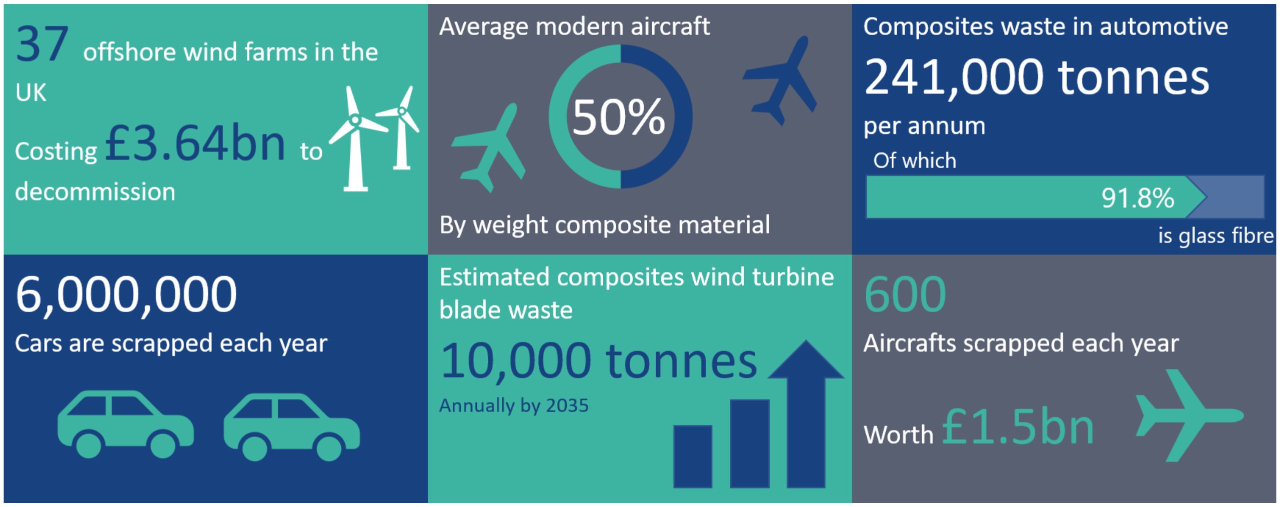
Figure 3: Estimated composite waste per sector in thousands of tonnes in 2025 in Europe[9]



To put this problem into perspective, 12,000 commercial aircraft[6] are predicted to be discarded in the next two decades, each 50% composed of composites by weight. Additionally, six million cars are discarded annually, creating a total of 214,500 tonnes of composite waste - the equivalent of 1,500 blue whales. And by 2030, the amount of composite waste created, across all the industries, will be around 900,000 tonnes.[11]

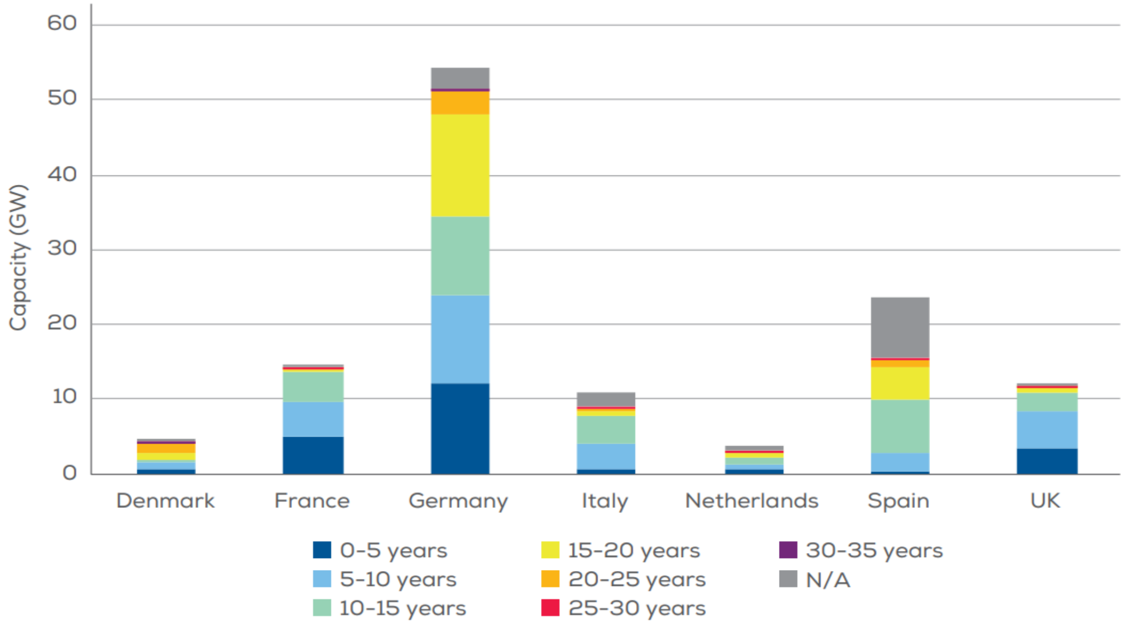
[11] tps://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf

Figure 4: Global composite waste statistics and the financial implications in GB£[12]



With the standard lifespan of a wind turbine being around 20 to 25 years, decommissioning of onshore and offshore turbines is also becoming a major problem.[13] This 25-year lifespan can be further reduced by the increasing opportunities to replace older turbines with newer models that provide higher output capacities. The variety of ages of the existing wind fleet are shown in Figure 5.

Figure 5: Age of onshore wind fleet in Europe[13]



[12] https://www.composites.media/tackling-the-challenge-of-composites-recycling/

[13] https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf

What have been the actions to date?

Government actions

Landfill taxes or bans can enable changes from current disposal practice to more circular solutions. Within Europe, there are varying levels of landfill taxes for composites, meaning there is no Europe-wide drive to develop circular solutions for composite wastes. At a national level, Germany, Austria, Finland and the Netherlands have banned composites from landfill. France is also considering introducing a recycling target for wind turbines in its regulatory framework, to align with other European legislations. Additionally, the wind industry has been at the forefront of dealing with end-of-life waste by working on an international guideline for dealing with decommissioned turbines.[13]

Extended producer responsibility (EPR) is another policy that can be implemented in sectors that use composite materials. EPR gives producers the responsibility to deal with the disposal of post-consumer products, either by physically dealing with the waste or by investing in processes to deal with it. EPR schemes have been applied to electronic equipment and the solar industry, have been discussed in both Germany and France for the wind industry.[14]

Business actions

Such legislation is driving businesses to think of about three of the four main business drivers (Figure 6): revenue growth, reduced costs and lower risks. As these regulations can have a significant impact on profitability through an increase in the cost to dispose of the EOL composites or through paying EPR tariffs, thinking ahead about how legislation can affect operational costs can reduce future risks. Strategies can vary from finding

[14] doi:10.1016/S0034-3617(03)00839-7

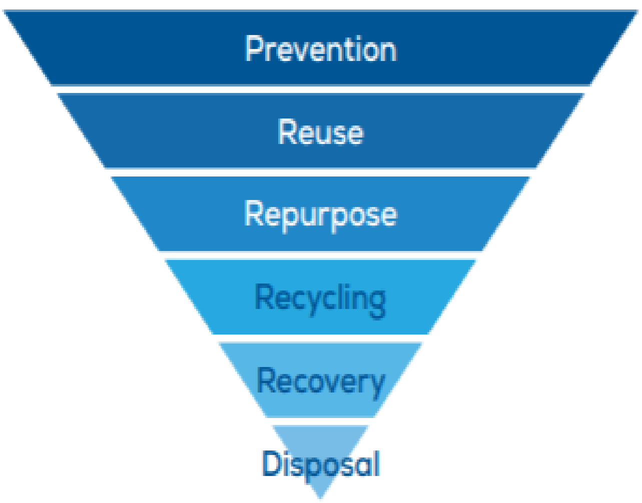
recycling options that product high value products to generate revenue to finding the cheapest disposal options to reduce costs.

Increased landfill costs and EPR regulations could have significant design, manufacturing and financial implications on businesses. This forces organisations to think about how better to reduce inefficiencies in creating composite products, how to reclaim EOL composites and how to find financially sound ways of disposing of composite materials.

What can be done?

The European Waste Framework Directive requires EU Member States to apply a waste management hierarchy as depicted in Figure 6:

Figure 6: European Waste Management Hierarchy[15]



Composites are considered recyclable. Within this activity, there are seven existing options: gasification, solvolysis, high voltage pulse fragmentation, pyrolysis, mechanical grinding and cement co-processing.

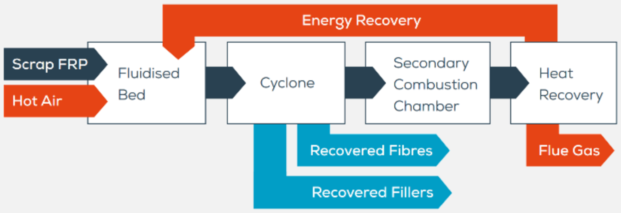
[15] https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

However, some sectors do attempt to reduce, reuse and repurpose composite waste. In the case of the wind sector, the composite blades have been used for playground and street furniture or as part of building structures (see Figure 7). Unfortunately, this is not done on a large scale.

Figure 7: Repurposing wind turbine blades as a bike shed in Denmark[5]

The options for recycling composites cover a range of processes from burning, mechanical sorting and chemical processes.[16] These are shown below:

Fluidised bed/ Gasification

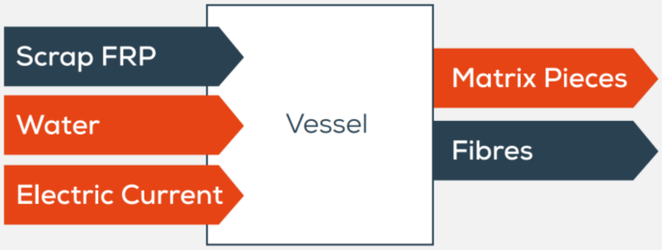


The fluidized bed or gasification process can treat mixed material. The fibres extracted are of low quality and there is still a lot of work required to scale it up.

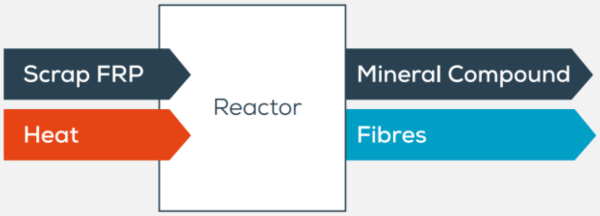
[16] https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf

High voltage pulse fragmentation

High voltage pulse fragmentation uses electricity to separate components in a composite. This process can extract short fibres at a relatively high quality. This is pilot scale only at present.



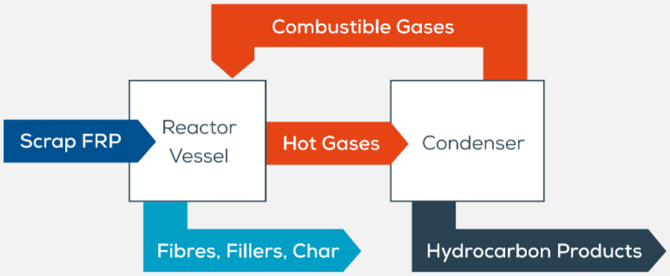
Solvolysis



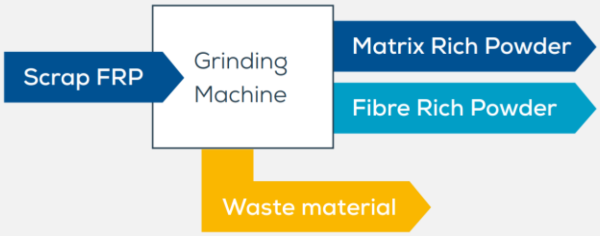
Solvolysis involves the use of solvents and pressure to break the bonds within a composite. This process allows for both fibre and resin to be retrieved. However, this has a high energy consumption and requires a large volume of solvent.

Pyrolysis

Pyrolysis methods use a thermal recycling process to recover fibre in the form of ash and powder in the form of hydrocarbon products, which are then used as fillers or additives. This process requires high investment and has a high running cost; however, it is currently the only economically viable option.



Mechanical grinding



Mechanical grinding technologies can be used for both GRP and CFRP. This process is cheap and has low energy requirements. The final products from this process are short fibres and ground powder that can be used as reinforcements and fillers. Unfortunately, this process is still not competitive with using virgin raw materials for the same application and there is a 40% material waste generation.

Cement co-processing

Cement co-processing is the most popular option for glass fibre recycling. Here the polymer is burned as fuel for cement mixers, reducing the carbon footprint of cement production by almost 16%. The process is quite straightforward and easily scalable.

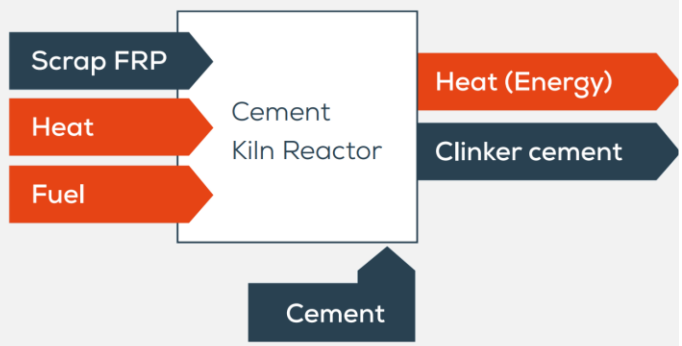
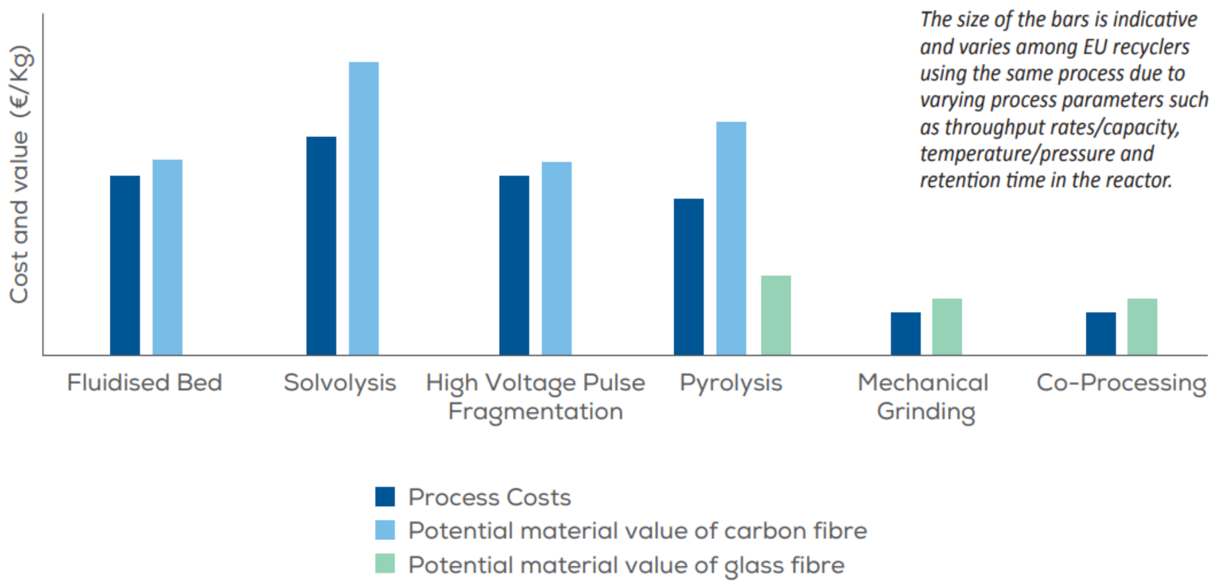


Figure 8: Estimated relative costs and values of composite recycling technologies[17]



Although this highlights that there are several possible options for recycling composites, none of the processes is operational on an industrial scale. Another factor to consider is the final product value from these different processes. The relative costs and values of these processes are shown above. The most promising option of these, in terms of the value of the final product, is the pyrolysis option, although currently the main technology in Europe is co-processing.

None of these end-of-life processes produces high value added products. While there are some companies (GES) producing items such as panels, we are only aware of one producing multi-layer products through a patented extrusion process. As part of the Ecobulk project, we have supported the business case development, advanced testing and scale-up of this process designed by Conenor.

Multi-layer extrusion process

The extrusion process produces high quality construction panels. These panels have been mechanically tested. The size and shape can be adjusted depending on the requirements. The final product options range from pillars and posts to tidal defence structures. The material formulation uses waste GRP and recycled polymers.

How do we move forward?

More research and investment are needed to develop recycling processes that produce high value added products while furthering the circularity of the different sectors. The multilayer extrusion process developed by Conenor has proved to be technically viable, meets the industry standards and can be scaled up. However, finding organisations prepared to adopt the technology and provide the significant investment required remains a big challenge. More work needs to be done to better estimate the amount of waste that will be generated in the next few years and whether that supply will be consistent.

Meanwhile, Composites UK has reported that the recycling of CFRP has seen commercial success as it has received financial support from large aerospace organisations - a support that has been lacking for GRP material.[17]

[17] https://compositesuk.co.uk/system/files/documents/Recycling%20Report%202016.pdf