

Competitor Analysis:

Recycling

The term recycling is used to describe the recovery and re-use of carbon fibre from carbon fibre reinforced composites (CFRP). In some cases the term is used erroneously to describe the re-use of virgin carbon fibre waste, which should really be termed “recovery” to differentiate the two forms of material.

Recycling entails the treatment, thermal or chemical, of carbon fibre thermoset and thermoplastic composites or composite manufacturing waste. The aim is to recover the carbon fibre in near original properties for further converting into a medium suitable for re-use.

There are primarily two methods for treating the composites and these are pyrolysis and solvolysis, or a mixture of the two. There is a third method using a fluidised bed, which in essence uses pyrolysis as it's principal converting process. The fluidised bed method lends itself particularly to composite which has had to be shredded for security purposes, such as military and aerospace parts that must be rendered unusable before they can be removed from site.

Pyrolysis.

Simply the processing of the composite part, or manufacturing waste, in a reduced oxygen atmosphere at temperatures up to 600°C.

Solvolysis.

The treatment of composites using supercritical fluids, such as water, methanol, propanol etc. under pressure and temperature.

There is also mechanical grinding, composites that have simply been ground to small particles, carbon fibre and polymer together, for use as additive in injection moulding or compression moulding.

Pyrolysis is energy intensive and burns off any polymer matrix, and original sizing material. Solvolysis similarly removes all polymer and sizing but is less energy intensive but requires high operating pressures, although there are efforts to achieve recycling at atmospheric pressure.

Both have environmental impacts that have to be managed at some considerable capital and operational cost.

Sub-critical and Supercritical Fluids, such as water, and Microwave assisted recycling have also been researched, but so far only at lab scale.

Current Recyclers.

Adherent Technologies Inc, Albuquerque, NM, USA

<https://www.adherent-tech.com>

Ostensibly the first company to recycle carbon fibre composites using a thermo-chemical process. In this respect Dr Ron Allred was the pioneer in actually proving that thermoset composites could be recycled.

ELG Carbon Ltd, Coseley, West Midlands

<http://www.elgcf.com/recycled-carbon-fibre-services/recycling-carbon-fibre>

World's first continuous pyrolysis recycling system started by Milled Carbon Ltd, invented by the author in 2003. ELG are currently the industry leader in recycling and have the highest capacity capabilities of some 2000 tonnes per year.

Karborek S.p.A. Z. I. - 73020 Martignano (LE) - ITALY

<http://www.karborekrf.it/home/en/>

Karborek, based in Puglia, Italy, took research done at ENEA in Italy in 2005 and commercialised a batch pyrolysis process using the Archimedes screw principle. Provided only a fluffy form of recyclate which took them several years to exploit. They are relatively small although they did some very good work in re-use forms. They have since enlarged their process and made it continuous.

Vartega Inc., 301 Commercial Rd. | Suite I, Golden, CO 80401

<http://www.vartega.com/>

New on the block, the leading Solvolysis proponent. Working with the Colorado School of Mines and being funded by the US Department of Energy.

CFK Valley Stadt, Stader Straße 55-63 · 21737 Wischhafen, Germany

<http://www.carbonxt.de/>

Started out in the mid 2000's. Went very quiet for several years and re-emerged with the trade name CarboNXT a couple of years ago. Their original process was batch pyrolysis, which was deemed uneconomical, and as such their hiatus saw them back on the recycling scene using a continuous process similar to ELG.

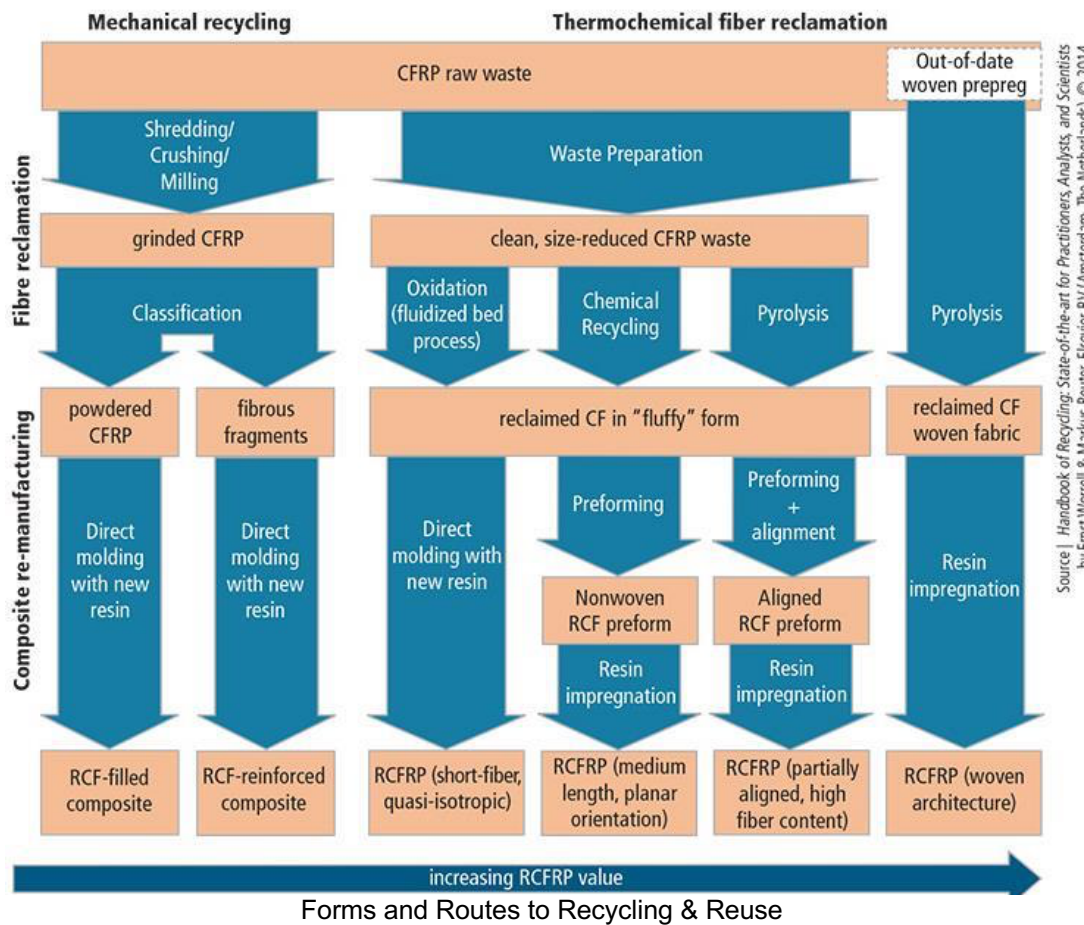
Karl Meyer is the mother company and as such is our greatest competitor when it comes to offering recycling systems.

[Recycling von Carbonfasern CFK.mp4](#)

Carbon Conversions, 150 Godley Morris Boulevard, Lake City, South Carolina 29560

<http://www.carbonconversions.com>

Material Innovation Technology developed a near net shape manufacturing process using recycled carbon fibre, some of which was supplied by Milled Carbon. The owner, Jim Stike, eventually started a small pyrolysis process and has since set up a full scale process under the auspices of Carbon Conversions in South Carolina.



Pyrolysis.

The equipment used in recycling of CFRP is, in the case of pyrolysis, fairly standard, off the shelf, self-contained units.

The process consists of CFRP waste in end of life (EOL) form or manufacturing waste. EOL waste is invariably recognisable forms of composite parts or whole items such as bike frames or compressed air cylinders. The manufacturing waste is usually off-cuts from the lay up or nesting process used in consolidating a composite part prior to curing. This material can be cured, part cured or tacky, each form has its own processing

challenges. This material has to be sorted into size, cure state and ideally, if known, matrix type. This is usually done manually since the variety of material would make an automated sorting and sizing process quite a challenge.

The sorted material is then introduced into a belt furnace and heated in two stages to remove the matrix in gaseous form to a waste gas treatment system. The resultant recyclate is then further processed, either by chopping or milling, and then vacuum bagged and boxed for end use by others. The main challenge for recycling has been the re-use of the finished product and the forms that make it easy for re-use. Milling and chopping are the staple methods. Non-wovens were first used in the early 2000's and have now become a recognised format for re-use. Pelletising the milled material to improve product flow into injection moulding machines has now become a standard re-use form.

Pyrolysis Equipment.

Unwind Station: for bobbins of tow preg and pre-preg.

Furnace: ostensibly a Low Temperature furnace with a belt.

Chopping Machine: to reduce the recyclate in size. Due to the disparate shapes of composite the resultant recyclate has varying lengths, which lead to variable chopped lengths. In the case of non-wovens this has less impact if the variability can be controlled within specific lengths.

Milling Machine: usually a hammer mill to reduce the recyclate to micron length, usually in the order of 250mu. Carbon fibre is not very friable so getting consistent milled lengths in the lower orders is problematic.

Shredder: in some cases the recyclate will need to be further reduced in size before milling to prevent fibres becoming wrapped around the hammers.

Solvolysis Equipment.

The solvolysis process is still in its early scale-up days, even though research has been going on for more than 10 years there is still no commercial process. Vartega is the current leader in this method and they have plans to scale up their process.



Vartega's Lab Scale Solvolysis System

The equipment opportunities are much the same as pyrolysis except there would be no Unwind Station or Furnace. Instead there would be a vessel similar to the one above. The larger the vessel, the larger the composite part, the less labour intensive manual size reduction required, but this would only ever be a batch process.

Chopping Machines.

A guillotine type chopping machine best lends itself to the type of material to be processed. In particular the Pierret G28R1 is built specifically to process carbon fibre.

[Leaflet G28R1.pdf](#)

The cost of these machines is in the order of €50k. The company is based in Belgium and they have an agent in the UK, Border Textiles in Cleckheaton.

Milling Machines.

The mainstay of this equipment has been the Williams Crusher, in particular the Williams Rocket Hammer Mill. They have an agency in Cambridgeshire. It is a simple mechanical machine, which is easy to maintain. Cost in the order of £25k.

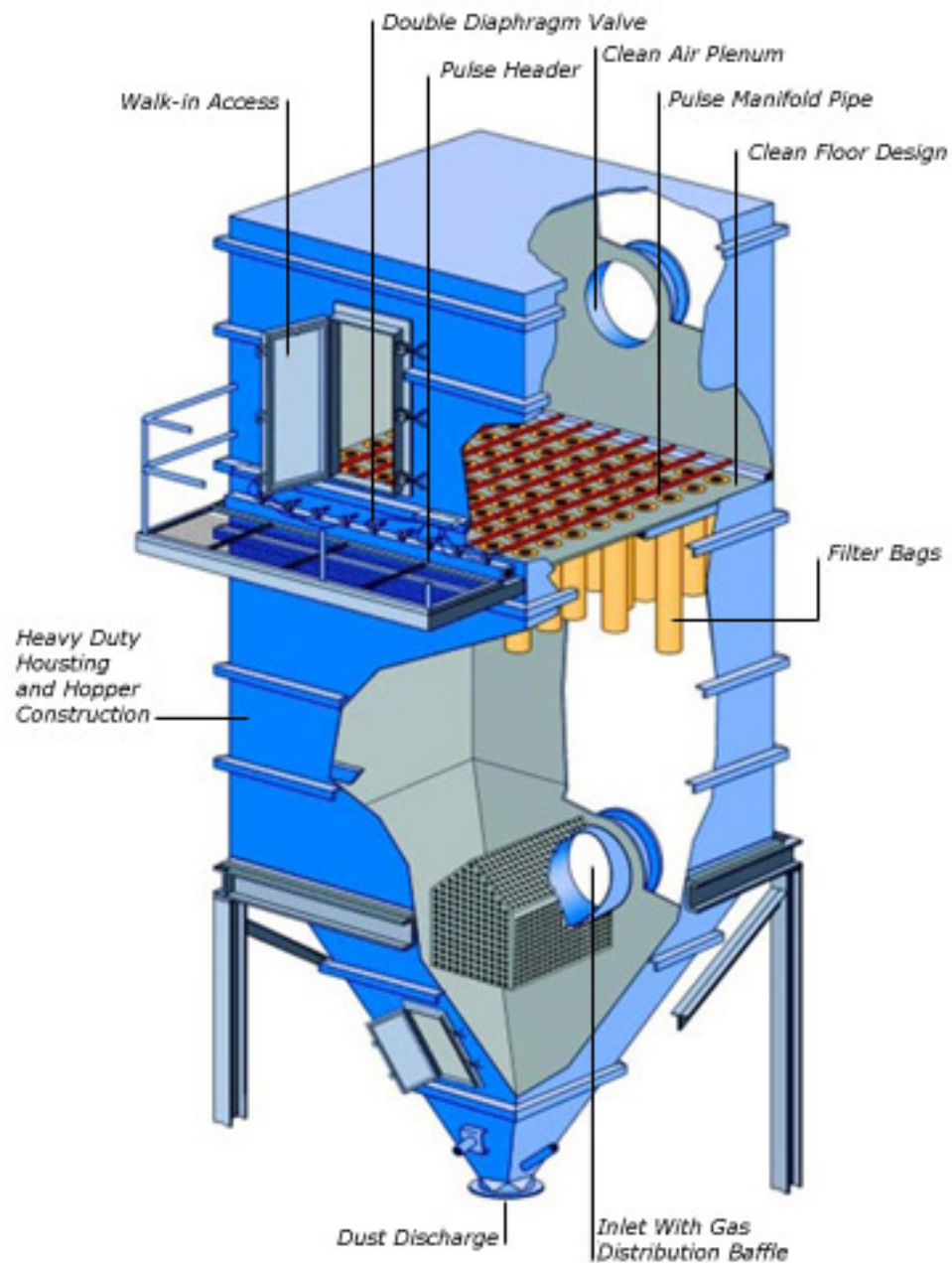


Williams Rocket Hammer Mill

Hosokawa also produce quality hammer mills but are somewhat more expensive and more complex. [Hosokawa Hammer Mill Demonstration.mp4](#)

Reverse Jet Filter

Once the recycle has been milled it is transported to a Reverse Jet Filter to be 'pulsed' into containers or direct to a Bagging and Weighing System.



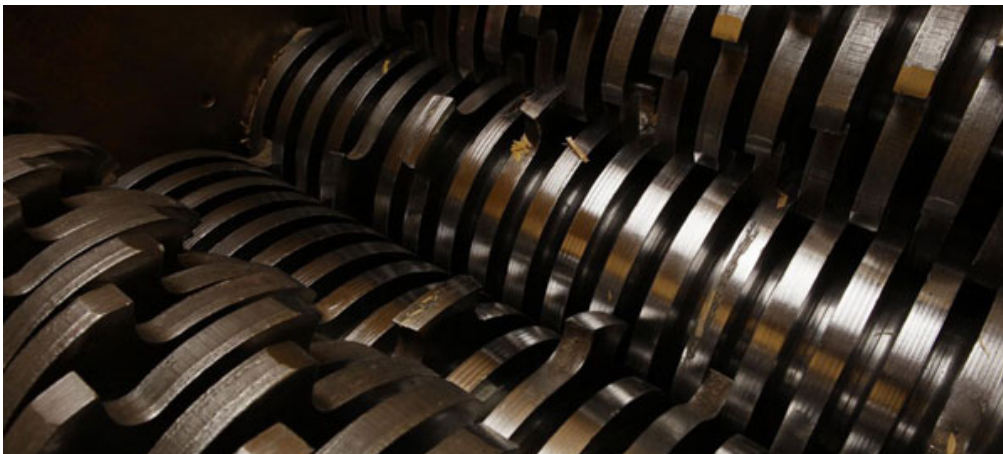
Plough Share Mixer

A Plough Share Mixer is used to turn milled product into a pelletised form for ease of use in Injection Moulding.



Shredder

Because the recyclate is sometimes in a very entangled form it cannot be fed directly to the Hammer Mill, and as such must be shredded to reduce the size.



[BAS shredder.mpg](#)

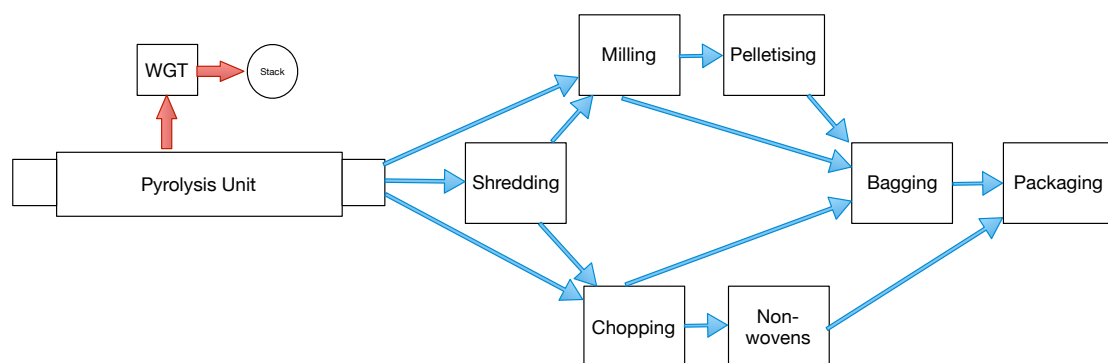
Vacuum Bagging & Weighing Unit

This has been done in the past using a variety of bagging and weighing equipment, but because of the electrical conductivity of the material, off the shelf units invariably have to be modified to meet a minimum IP65 rating.



It must be borne in mind that the bagging unit must be versatile enough to collect and bag milled, chopped and pelletised recyclate.

Suggested Pyrolysis Recycling Layout



All the Blue arrows need to be interconnected, either by a typical conveyor system or a low velocity compressed air delivery system. Because of the very dirty nature of the process, shredding, milling and chopping would be housed in separate rooms each with dedicated dust extraction. Pelletising would be carried out in a nominal clean room and Non-wovens may, depending on available space, be in a separate building altogether.

Summary.

Having had a false start in the early and mid 2000's recycling is fast becoming a hot topic again. Milled Carbon/ELG and MIT/Carbon Conversions have been the commercial mainstay throughout the years although they have struggled due to market forces and financial crises. Their outlook is much more robust.

It must be borne in mind though that the industry is still in a state of research flux, there is still much to be learned and improved.

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