Recycling of plastic composites

Photo: Exel Composites Oyj
Photo on previous page: Ekin Muovi Oy

Photo: Exel Composites Oyj

Composites offer superior properties in terms of strength, light weight and long service life. They have enabled completely new types of products that are significantly better compared to those of traditional materials such as steel, aluminium or wood.

In transport, for example, composite structures have led to more energy and environmentally efficient solutions due to their light weight and long life. The properties of composites are crucial for the development of a more environmentally friendly future, as they can be used to find more efficient solutions to utilise renewable energy and reduce the use of fossil raw materials.

Due to the nature of the composite material recycling has been challenging, as the material is usually very durable both mechanically and chemically. However, an efficient and effective method has been found for recycling composites. The use of waste composite as both a raw material and a fuel source in cement kilns is a technically and economically viable recycling method. This utilisation of both the material and energy contained in the composite is widly recognized and is currently being used also in Germany.

By processing composite waste in a cement kiln, both the material and energy of the composite can be utilised

What are composites?

A composite consists of two or more dissimilar materials each with individual physical and chemical properties. These materials form a functional whole, the properties of which a single material would not be able to have.

Reinforced thermoset composites are one of the important composite materials. Reinforced plastic consists of two parts, a resin matrix, i.e. plastic, and a reinforcement. The reinforcement is often made of glass, carbon or aramid fibre. Typical properties of reinforced plastics include a low weight, good resistance to corrosion and thermal fluctuations, high strength in relation to weight, good impact strength, insulation, antimagnetism, long-term durability, customizability for a specific purpose and they are virtually maintenance-free.

Applications of plastics composites

- Aeronautics and defence: parts of aircraft, helicopters, spacecraft and satellites, bullet-proof vests, helmets and other protective equipment
- Automobiles and transport: parts of cars, trams and trains, motorhomes and caravans, motorcycles
- Infrastructure and construction: repair of buildings and roads, construction of bridges, building materials, special architectural constructions, swimming pools and wall panels; structures for information network
- Corrosion resistance and electricity: tanks, pumps, fans, chemical processing, wastewater treatment, electronics industry components
- Watercraft: various boats and ships
- Renewable energy: generator rooms and blades of wind turbines, solar panel structures
- Consumer products: sports and leisure products such as golf and tennis rackets, bicycles, skis and poles.

Photo: Muovityö Hiltunen Oy

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Why recycle?

Modern society has understood that the earth's resources are not infinite and therefore thoughts about efficiency have increased in recent decades. Reducing material use, recycling and various forms of utilisation have become more common in our society, and technological development has enabled more efficient use of different materials. It is also now possible to recycle composites.

Recycling is a generic term for a long process in which used materials are collected, transported, modified for use and then utilised by various means. Composites are challenging to recycle because they are combinations of several materials. However, there are effective ways to exploit them.

EU waste directive

One of the key objectives of EU waste policy is to move towards an eco-efficient recycling and recovery society. The Finnish Waste Act is based on the EU Waste Directive, where the main objective is to prevent waste generation and reduce the amount and the harmfulness of waste. The directive lays down a waste hierarchy aimed at reducing the quantity and harmfulness of waste, increasing recycling and other recovery of waste and reducing landfill. The different levels of the EU waste hierarchy are presented below.

Legislation on recycling and recovery targets have been issued in accordance with the Waste Act.

One important regulation is the landfill ban for biodegradable waste and other organic matter, entered force on 1.1.2016. For composites, the regulation means that landfill disposal has not been allowed since the beginning of 2016 in Finland.

EU Waste Hierarchy Image

Recycling composites in a cement kiln

Cement manufacturing process

The process of cement production begins with the quarrying of limestone, after which it is crushed and sorted. In addition to calcium carbonate from limestone, silicon oxide, iron oxide and alumina are required for the manufacturing process. Raw materials are obtained also from by-products of other industries. Raw materials are combined in the correct proportions and fed to the raw powder mill, where they are finely ground.

Cement clinker production begins with preheating and pre-calcification of the powder, after which it is fed into the furnace. A cement kiln is a rotary kiln about 100 m long. During the combustion process lime, silicon, aluminium and iron oxides are converted into calcium compounds and sintered into cement clinker when the temperature rises to 1 450 °C. At the end of the kiln, the cement clinker is rapidly cooled forming the consistency of coarse gravel.

Cement is finally made by grinding the clinker, gypsum and any other materials as required. The ground product is sorted, and the coarse particles are directed back to grinding. The finely ground finished cement is transferred to storage silos, from where it is transported to customers in a tanker truck or packed in sacks.

Utilisation of plastic composite in cement production

In a cement kiln, the plastic and combustible fibres contained in the composite burn releasing the energy needed by the cement kiln to heat the aggregate. The fibreglass of the composite melts and mixes with other aggregates. The composition of fibreglass largely corresponds to the raw materials required for cement production.

The recycling process begins with the separate collection of composites. From the quality point of view, accurate sorting of the composite at its place of origin is important to ensure that no harmful substances end up in the recycled fuel production plant and cement kiln. In order to maximise the calorific value of the fuel, it is important that it is dry, i.e. the sorted composite at the place of origin must be protected from the weather.

The recycled fuel manufacturer processes and grinds the collected composite waste to a pre-agreed size. Other recycled fractions are added to the processed reinforced plastic fraction in order to precisely adjust the composition of the recycled fuel to suit the burning process of the cement plant. At the cement plant, the fuel and materials contained within the reinforced plastic replace other raw materials and fossil fuels normally used in combustion, such as petrocoke.

The composition of glassfibre reinforced plastic waste is ideal for cement production

How can plastic composites be recycled or utilised?

Incineration in a waste-to-energy plant

Utilization of composite in a waste-to-energy plant is possible, however the reinforcements and fillers end up as ash. Additional costs arise from the treatment and final disposal of ash. Energy is obtained from this process, for example, for heating homes.

Recycling in a cement kiln

When processed in cement kilns, about two-thirds of the glassfibre reinforced plastic is used as a raw material for cement and the remaining one-third of the waste acts as fuel. The method is recycling, as it is mostly the reuse of material. Processing reinforced plastic in a cement kiln has been proven to be a viable solution and produces zero ashes. Unlike other recycling methods for composites, it is both technically and economically efficient.

Other methods studied

Mechanical recycling

In mechanical recycling, the waste composite is crushed and ground into a fine material that can be reused, for example, as a filler in another composite. The method is simple, but in general, commercial fillers are cheaper and technically better than crushed reinforced plastic. Additionally, crushing waste composites into a fine enough material requires specialised equipment.

Pyrolysis

In pyrolysis, the composite is heated in an oxygen-free state at a temperature of 700–1 000 °C. As a result, the matrix material, reinforcing fibres and fillers can be separated. In the process, organic material breaks down into liquid and gas, which can be utilised as fuel or a source of chemicals. Fibres and other fillers can be reused. The method is used to recycle carbon fibre composite and can also be applied to the recycling of fibreglass reinforced plastic.

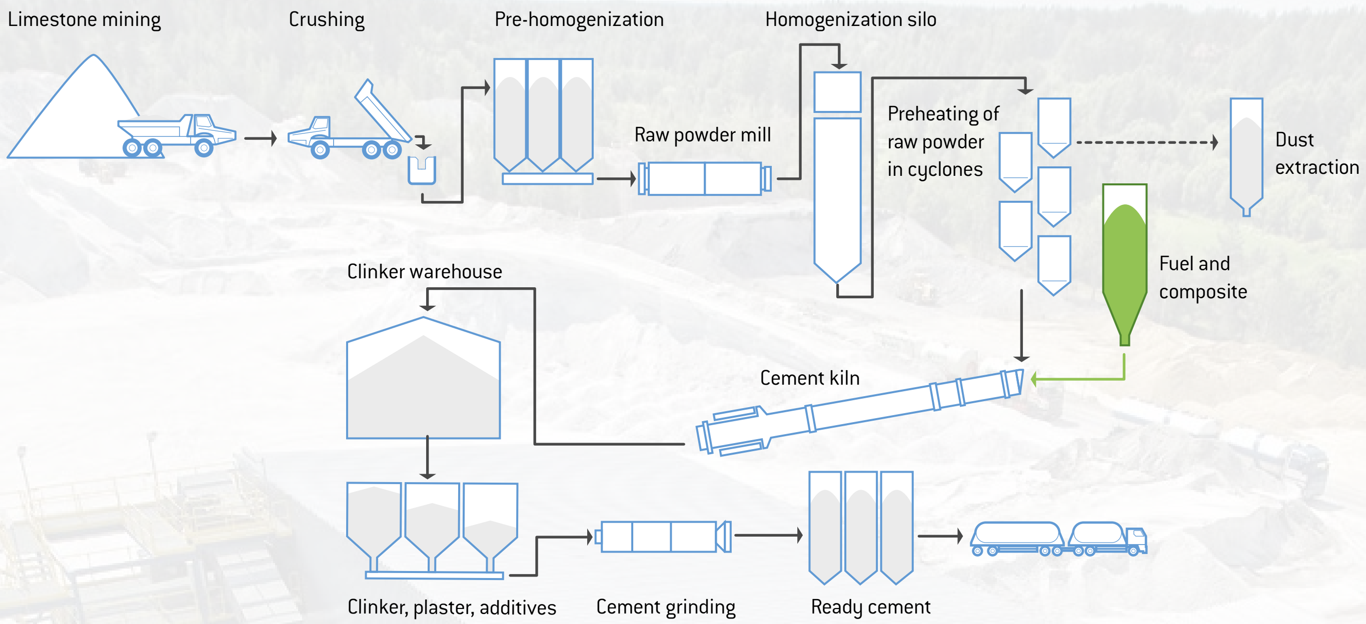
Fluidized bed burning

The composite is burned in a bed of sand with the help of hot air. The matrix material burns to release heat, whilst fibres and fillers are removed along with the combustion gases. The fibres can be reused, but their mechanical properties deteriorate as a result of processing. The advantage of the method is that the process tolerates impurities and mixed composites.

Solvolysis

Solvolysis is a chemical process that involves the breakdown of the resin matrix by reaction with a solvent. In the context of composite recycling, this refers to the chemical recycling methods that deploy solvents to depolymerize plastics back into their constituent monomers or other chemicals as well as the recovery of high grade fibres with minimal degradation.

Cement manufacturing



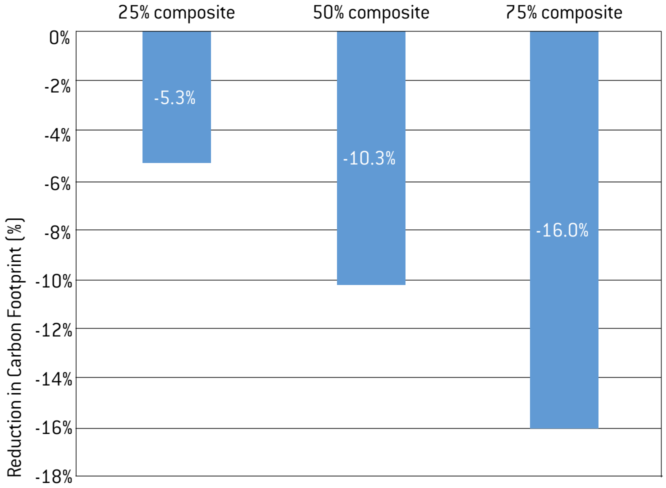
In the background, the fuel supply unit where composite waste is collected for processing.

Example of the environmental impact of cement production

Environmental impacts can be measured with many different indicators. Life cycle assessment (LCA) is a tool for assessing the significance of adverse impacts on the environment. LCA is used to determine the environmental impacts of recycling composites in cement kiln combustion. ETH University in Switzerland has studied the environmental impact of cement clinker using LCA analysis.

According to the study, the carbon footprint of clinker can be reduced by up to 16%, depending on the amount of reinforced plastic used. The adjacent image shows the effect of the amount of fibreglass composite on the carbon footprint of cement clinker. The reference value used in the calculation is for coal, which is normally used in the process.

The impact of composite waste on the carbon footprint of cement at a cement plant



Reference: EuCIA

The carbon footprint of clinker can be reduced by up to 16 percent with the help of composite waste

In the photos from left to right: Profile waste, cutting waste, crushing and finished crushing. Photos MAMK.

Facts	Background
Composites can be recycled	Today recycling reinforced plastic in cement kilns is proven to be the best and most efficient recycling system both technically and economically.
Recycling thermoset plastics back into their original raw materials is not easy	Recycling the resin back into original raw materials or other chemicals is challenging, but not impossible.
Environmental impact and carbon dioxide emissions can be reduced with the use of composites	Composite structures usually achieve lighter solutions than traditional materials, such as steel or aluminium. Low weight is beneficial, for example, in transport, which reduces fuel costs and carbon dioxide emissions. The long service life also reduces the overall carbon footprint. After use, composites can be recycled in cement kilns, making use of both the energy and materials they contain. At the same time, the environmental impact of cement production is also reduced.
Processing in cement kilns is a better method than waste incineration	When co-processed in a cement kiln, the fibreglass contained in the reinforced plastic melts and mixes with other raw materials, reducing the amount of virgin raw materials used in cement production. Plastic material and combustible fibres are converted into the energy that the furnace needs to heat inorganic matter. In a waste-to-energy plant, the incineration of reinforced plastic generates a significant amount of ash containing inorganic material, which makes its utilisation difficult and incurs treatment costs. The incineration temperature of a cement kiln is significantly higher than that of a waste-to-energy plant, ensuring complete utilisation of the energy content of the glassfibre reinforced plastic.
Recycling composite waste in cement kilns is an approved recycling method in the EU	The recycling of composites in cement kilns is fully compatible with the Waste Directive 2008/98/EC. Since the method consists mainly of reusing material instead of energy recovery, the method is recycling.

Recycling of composite waste in Finland:
The KiMuRa route ready

KiMuRa is a composite recycling route created as a project led by the Composite Group of the Finnish Plastics Industries Federation. This enables the collection and utilisation of composite waste in Finland (KiMuRa being an acronym for the Finnish words for Recycled Crushed Raw Material - see https://www.plastics.fi/kimura for further information). The project received support from the Ministry of the Environment in connection with the Plastics Roadmap, the goals of which the project implements in several ways.

Seven companies manufacturing composite products from different parts of Finland participated in the project: Ekin Muovi Oy, Exel Composites Oyj, Fenix Marin Oy, Muovilami Oy, Muovityö Hiltunen Oy, NCE Oy, and Patria Aerostructures Oy.

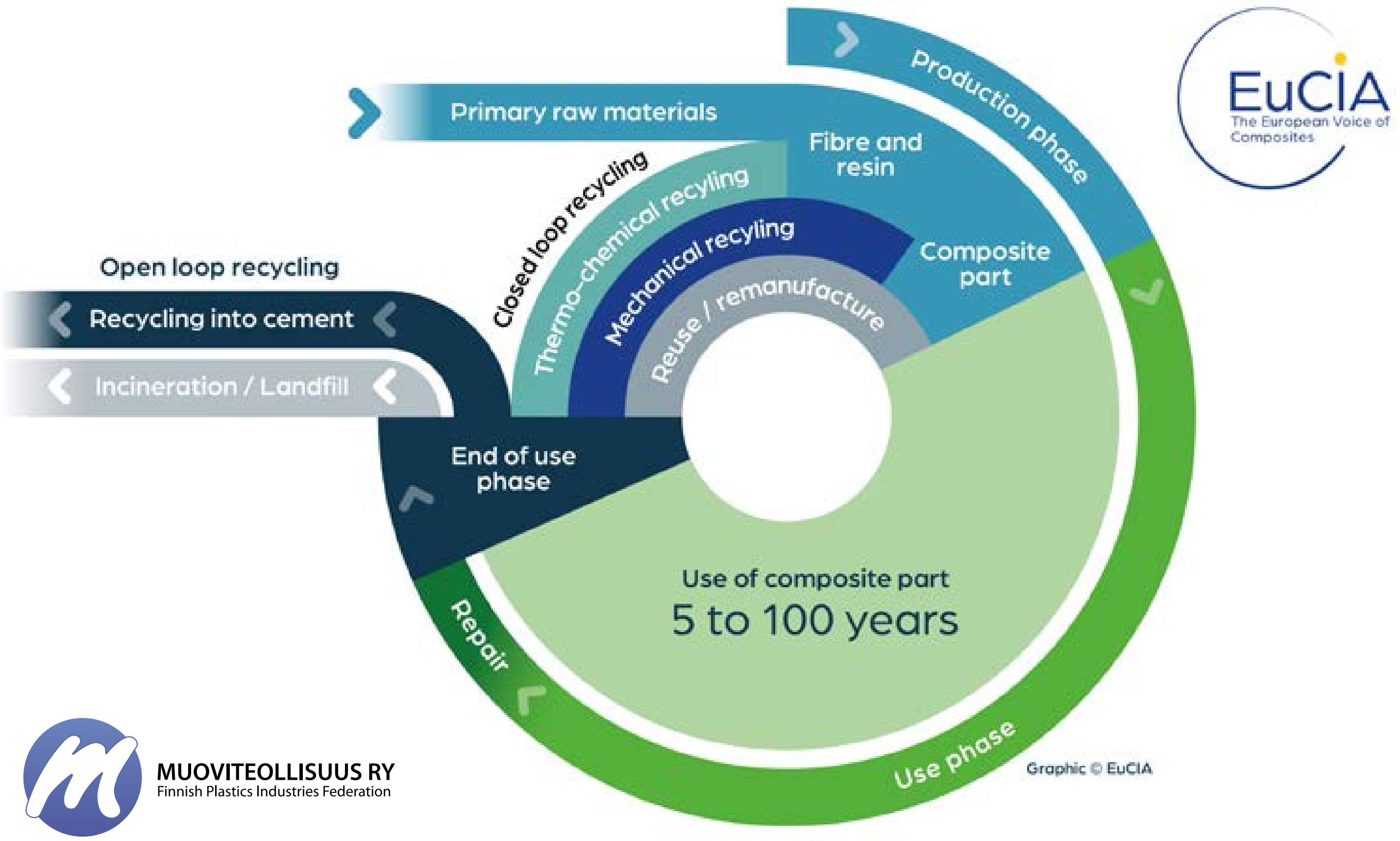
Kuusakoski Oy acts as KiMuRa's circular economy operator, while Finnsementti Oy is a beneficial user of crushed composite. The Finnish Plastics Industries Federation, the Finnish Marine Industries Federation Finnboat, the Finnish Wind Power Association and the Recycling Industries of Finland participated as expert organisations and information channels.

Finland now has a nationwide collection network for composite waste in place. All 19 Kuusakoski Oy's waste disposal points accept composite waste. From these waste points, the composite material is taken to Hyvinkää for crushing. About 25 companies manufacturing composite products deliver their waste along the KiMuRa route for recycling, in addition to which small boats, wind turbine blades and used process pipelines have been recycled through the KiMuRa route.

At present, the only economical, technically complete and industrially feasible recycling method for composite waste is its utilisation in cement production. Using this route, 100% of the collected composite waste can be used in the production of cement clinker, supplying both fuel and raw materials for the process. In the future, waste collected through functioning circular economy logistics can also be utilised via other composite recycling processes, provided that they also develop to an industrial operation level.

Based on the accumulating experience, a foundation is being created for the collection logistics of composite waste (e.g. boats) from consumers. It is also important that the results of the KiMuRa project lay the foundation for the growing need to recycle wind turbine blades in the near future, which will be faced when wind turbines reach the end of their service life.

Composites are circular



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Original design by Performer Edited design by Kulosaari Group August 2024