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RETRACKING PROJECT

Verso l'economia circolare: tracciabilità dei manufatti in Compositi Fibro Rinforzati

Krožni ekonomiji naproti: sledljivost izdelkov iz kompozitov, ojačanih s steklenimi vlakni

Towards the Circular Economy: The Traceability of Fibre Reinforced Composite Products

La relazione conclusiva relativa alla mappatura del flusso dei rifiuti CFR / Poročilo o zaključkih v zvezi s količinami in kakovostjo tokov odpadkov KOV

Report on mass flow analysis and quality of FRP waste

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1. INTRODUCTION

Based on the data, provided by an American Composite Manufacturers Association (ACMA, 2019), the first **fibre-reinforced polymer (FRP)** composite material was produced less than a century ago (in the mid-1930s). This was a fiberglass fabric and polyester resin composite which was experimentally used for production of a boat hull. Since then the use of FRP composite materials has boosted and became very extensive in different industrial branches including aerospace, marine, construction and engineering, electrical, automotive, domestic appliances, furniture, and sports equipment. The share of FRP uses in different branches is given in Figure 1 published in the report "Composites Market Size, Share & Trends Analysis Report, 2018 – 2024".

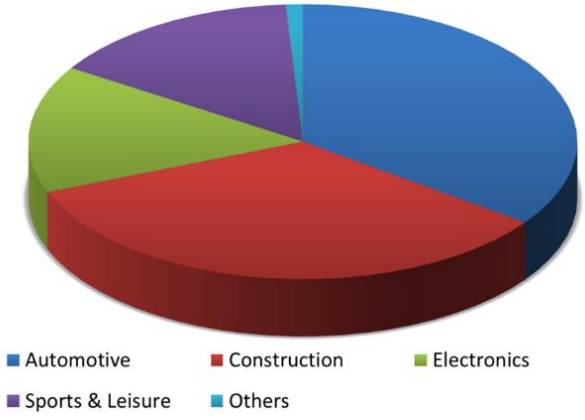

Figure 1: Composites Market Share in diffrent industrial branches

The global industry and market for FRP composites has grown substantially in the last decade. For example, it was predicted that the global market of thermoset fibre composites was going to grow from US$41.98 billion in 2016 to US$57.98 billion by 2021. Annual increase in demand for carbon fibre has in the last decade increased from 16,000 to 140,000 tonnes by the end of 2020 (Anne-Fein et al., 2017).

1.1. WHAT ARE FRP, HOW AND WHY THEY ARE PRODUCED?

FPR are materials, which composition is based on the use of combination of different types of fibres, which can be glass, carbon, aramid or natural as reinforcing component in otherwise mostly polymer matrix. Fibres are continuous or discreet, incorporated in a matrix of thermosetting or thermoplastic polymer binder with fibre concentrations in the

range of 12%–60% by volume (Reynolds et al., 2010), and inorganic fillers (also known as "extenders") on average the range of zero to 20% by volume. However, in some types of FRP content of inorganic mineral fillers (for example calcium carbonate, talcum, or mica powders) can amount up to 50% of the composite weight (Yazdanbakhsh and Bank, 2017). **Glass fibre reinforced polymer (GFRP)** is a group of composite materials, which are reinforced by the use of glass fibres.

The main advantages of FRP products in comparison to traditional materials (for example wood, metal, concrete) include lower densities, i.e. light weight, higher mechanical strength in selected directions, simple production, shaping and installation, high durability and resistance to chemical attack and in use in aqueous environments. Disadvantages typically include higher production costs, lower temperature and fire resistance, and difficulties related to disposal of waste from production and at end of life of products. Simplified schematic presentation of mass flow and FRP composite life cycle (including different production options) is presented in the Figure 2 (Fleischer et al., 2018).

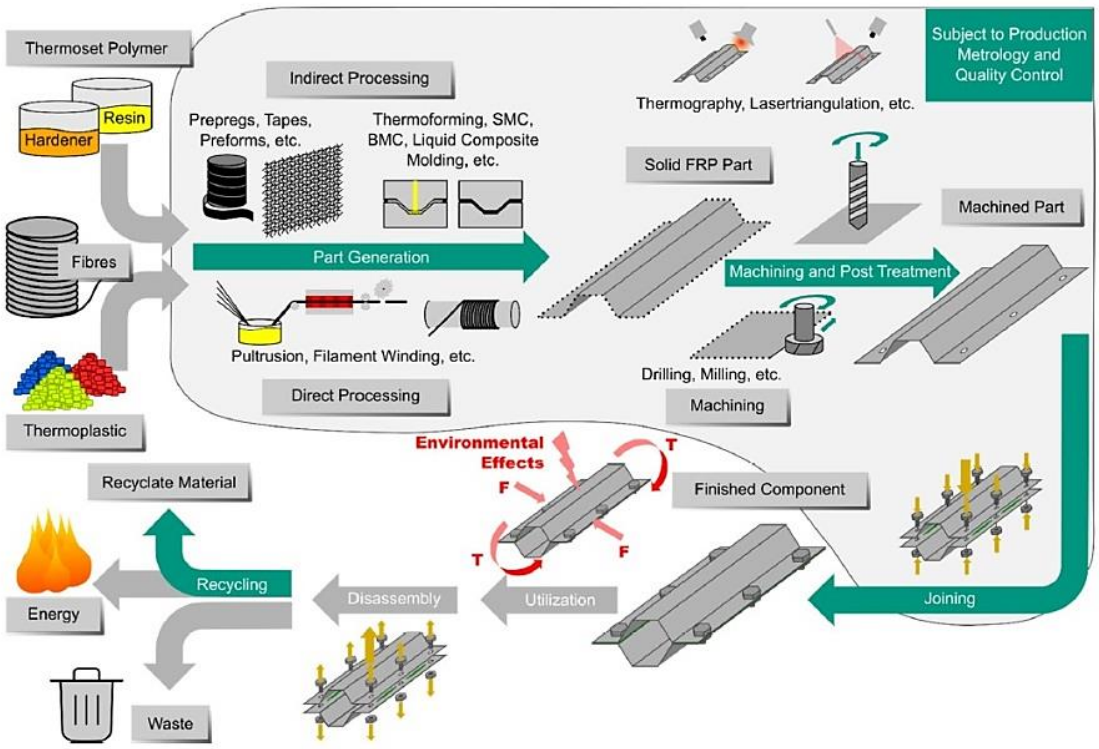

Figure 2: Mass flow and simplified life cycle of FRP products (Fleischer et al., 2018)

1.2. PRODUCTION PROCESSES

FRP forming includes a wide range set of technologies, which are either complementary or very distinguishing. Below are presented the most **important production processes of FRP**, including GFRP.

The most common and probably the oldest forming process is so called **"Hand lay-up"** (Figure 3). Hand Lay-up starts with the fibreglass fabrics being manually laid and wet with resin in mould coated with the releasing agent. After curing the product is extracted from a mould. Hand Lay-up is widely used for small series products or for large products of complicated shapes.

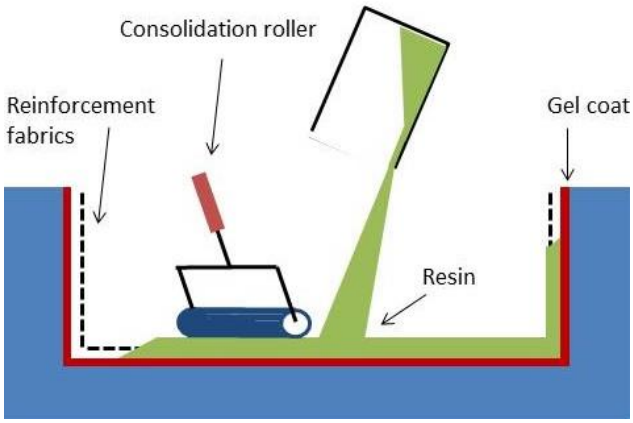

Figure 3: A simplified sketch of Hand lay-up forming process of FRP production (source: ZAG internal - documentation)

Hand Lay-up process, which is employed for at least 50 years, has been upgraded with addition of new production phases which assure the better properties of final products FRP composites, i.e. vacuum bag and autoclave moulding.

"Vacuum bag moulding" (Figure 4) is a process where the atmosphere pressure is exploited to secure contact with the mould and to expel air during curing. The sheets of fibre fabrics are laid-up and placed in an open mould. The material is covered with release film, breather material to enable flow of the resin over the product and the vacuum bag. The lay-up is cured with a continuous vacuum to extract entrapped gasses from laminate. This is a very common process in the boat and aerospace industries as it enables precise control over moulding due to a slow cure cycle that is anywhere from one to several hours.

"Autoclave moulding" is regarded as more advanced production process comparing to vacuum bag moulding. For further product improvement, beside vacuum, also the external pressure for curing is applied. After evacuating the bag in a pressure vessel (Figure 5), an

overpressure of typically 1.5 MPa is generated. Even though process is refinement of the Vacuum bag moulding, its application can be limited by the size of the pressure vessel.

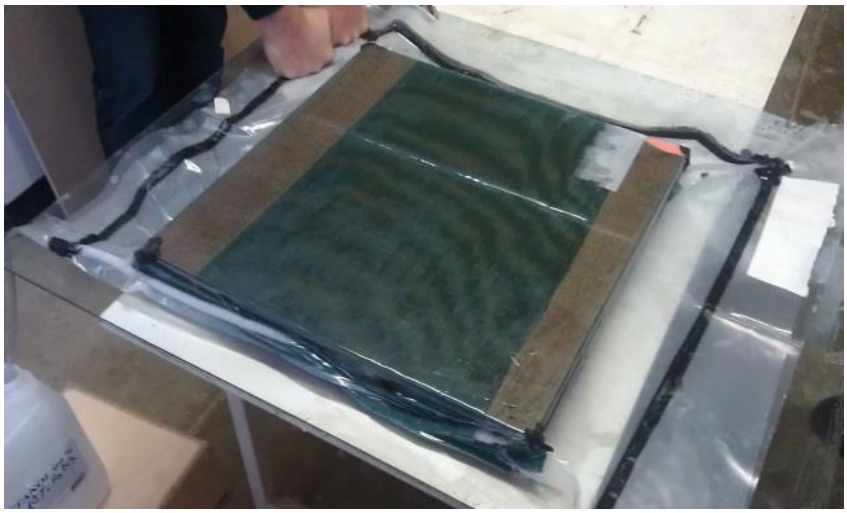

Figure 4: Preparation of simple FRP plate by vacuum bag moulding (source: ZAG internal photo-documentation)

Figure 5: An example of autoclave moulding setup (source: JaviRD on Wikimedia Commons)

The main common feature of above described production processes is that they require manual work and cannot be fully automated.

However, **"Pultrusion"** and **"Filament winding"** are automatized processes. They share the similar impregnation process of the fibre bundles and / or fabrics with resin in a bath (in the Figure 6).

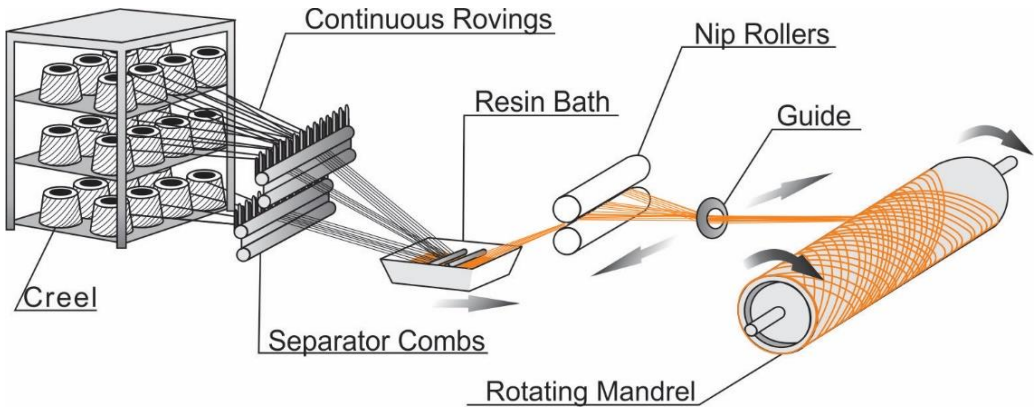

Figure 6: Schematic presentation of pultrusion of FRP production (Source: The internal documentation of ZAG)

Further on, the processes can be slightly different from case to case. In pultrusion the fibres are cured in a heated closed die and pulled through die forming the rough part shape, while in a case of filament winding the winder take care for winding the resin impregnated continuous fabrics or fibres onto the mandrel in specific orientations. The mandrel is often of circular cross section and two main types of winding orientations - helical and polar are often applied. Products are often cured at room temperature. After curing the mandrel is usually extracted, leaving a final product.

The pultrusion (Figure 7) is very efficient process of production anisotropic, constant cross-section components like ladders, handrail systems tank, pipes, etc., while the filament winding is suitable for the production of large, constant cross section products like pipes with diameters of above 3 m.

Figure 7: The photo of the finished FRP rods at the end of the pultrusion process (source: internal photo-documentation of the Trival Kompoziti d.o.o.)

For the production of small parts reinforced with the chopped fibres and of close tolerances the **"Resin transfer moulding"** (Figure 8) is applied. Forming starts with the fiberglass fabrics assembled, preformed and closed in a mould into which the resin is injected. Such formation proceeds at elevated temperature and pressure.

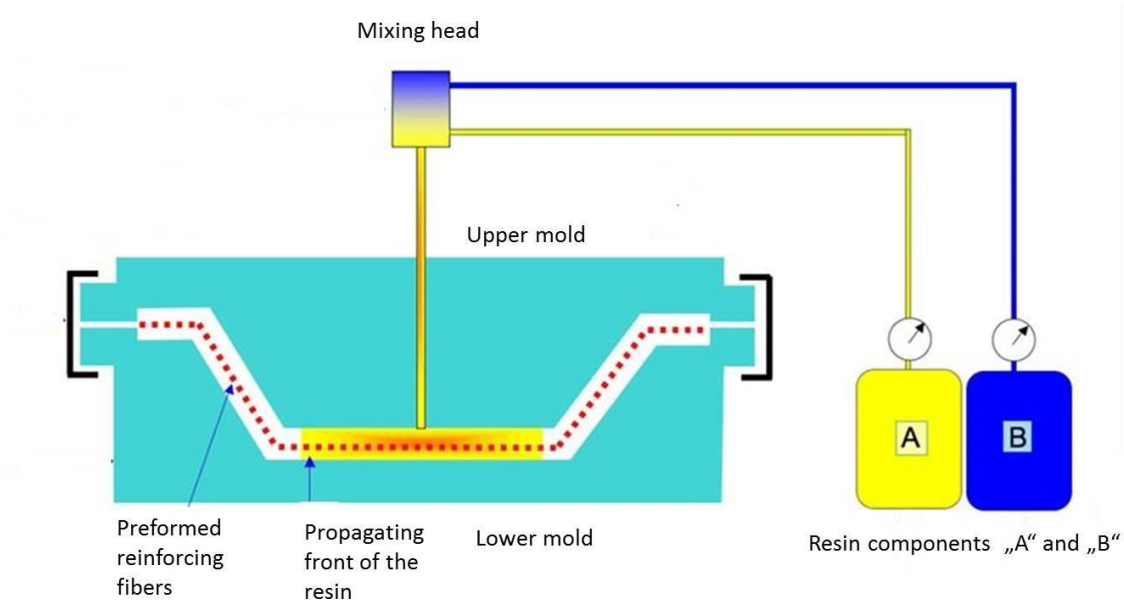

Figure 8: The scheme of production of FRP product with Resin Transfer Moulding (source: Laurensvan Lieshout on Wikimedia Commons)

"**Chopper gun lay-up**" process of GFRP production can be seen in Figure 9. Here the fibreglass bundles are pushed through a hand-held gun that both chops the strands and wet them with resin. The wetted fibres are shot onto the arbitrary shaped mould surface. The thickness of the lay-up is controlled by the human operator. This process is applicable for large products like vessels and it is also cost effective. On the other hand, such products have poor dimensional tolerance, which means that production of large pieces and complicated forms can be limited.

The presented fibre reinforced composite forming processes are just a small part of processes suitable for forming the fibre reinforced composites, which are not all applicable to all products. Some processes can be also easily combined and adapted to the new combined production processes.

Figure 9: The lay-up of the glass fibre / resin mixture with the chopper gun (source: photo on www.graco.com)

1.3. PROBLEM OF FRP WASTE

Currently most of FRP waste generated worldwide ends up in landfills or are incinerated as alternative fuel. Preferential and increasing use of thermosetting polymer composites, which are in comparison to thermoplastic polymer composites even harder to recycle or reuse, is leading us to the conclusion that problems and amount of the FRP waste generated will continue to rise. Beside environmental issues of waste accumulation this is also leading to higher costs for both industry and waste management companies.

The example of controversy of FRP waste treatment is also seen in the field of end-of-life vehicle Directive (2000/53/EC). This directive requires that from 2015, 85% by weight end-of-life vehicle must be reusable or recyclable with a total recovery of 95%. According to that only 5% to 10% of a vehicle can be landfilled or used for energy recovery, respectively. However, FRP waste from dismantling of vehicles is currently not efficiently recycled due to a lack of availability of recycling technology, and therefore waste management companies are unable to meet these legislative demands.

The example of boats, which are traditionally made from FRP materials, is also prominently showing the need for FRP waste recycling solutions. International Council of Marine Industry Associations (ICMIA) estimated that there are more than 6 million boats in Europe alone, which are approaching end-of-life (ICMIA, 2019). FRP wastes from boat dismantling are labelled with the same waste code (EWC) as waste from dismantling of vehicles (Commission Decision 2000/532/EC). This means that similar rules and demands for recycling rates should be achieved for boats and vehicles. However, this is currently not possible due to non-existing recycling solutions for FRP waste.

Another growing problem represent FRP based waste materials from dismantling of electric wind turbines. The number of wind turbines is increasing rapidly worldwide, and since a

large part of the rotor blades and the wind turbine structure itself is made from FRP this will require recycling solutions for end-of-life turbines. It is estimated that by 2050, according to the current trends, there will be 2,000,000 tonnes of wind turbine waste generated annually worldwide (Liu and Barlow, 2017).

Important source of FRP waste is the scrap from the production and manufacturing processes – industrial scrap. It is estimated that for example in aerospace companies from 30% to 50% of materials in aircraft production are scrapped due to the way it is manufactured (Rybicka et al., 2015). Typically, in highly efficient production processes 3 to 5% of total FRP material is wasted while in less efficient processes, like for example hand lay-up, on average 15% of material is wasted as scrap (Yazdanbakhsh and Bank, 2014).

A typical material flow model for an example of FRP production in Continuous lamination process is given in Figure 10. A generation of waste from production is estimated to 47% of total mass of input materials. Wastes are generated initially in cutting of fibres and preparation of resin, then in the stage of curing, demoulding and cutting of the products.

The total combined volume of end-of-life products and production waste generated by the glass fibre FRP thermoset composites in Europe has reached 304,000 tonnes (metric tons) in 2015 (Tittarelli et al., 2013).

Landfilling and disposal of FRP waste was in most EU countries strictly regulated and reduced due to EU legislation. The EU's Landfill Directive (1999/31/EC) severely restricted the quantity of landfilled organic waste materials. Because FRP materials consist of organic binders and resins, they are in some cases regarded as organic waste and are therefore restricted from landfilling.

Due to growing restrictions in landfilling of FRP waste in EU and due to the latest political situation regarding the waste plastic exports ban in China the cost of disposal of FRP waste is increasing. According to personal communication of between RETRACKING partners and stakeholders the cost can reach up to 150 € per tonne or m^3 for non-hazardous FRP waste, while the cost for disposal of hazardous FRP waste can be much higher.

Management of FRP waste has another issue, which cannot be entirely controlled. **Because FRP based waste do not hold a specific waste classification number they are (usually) not separated and can be found mixed in multiple waste streams, which despite restrictions eventually end up on the landfills (CEFIC, 2006).**

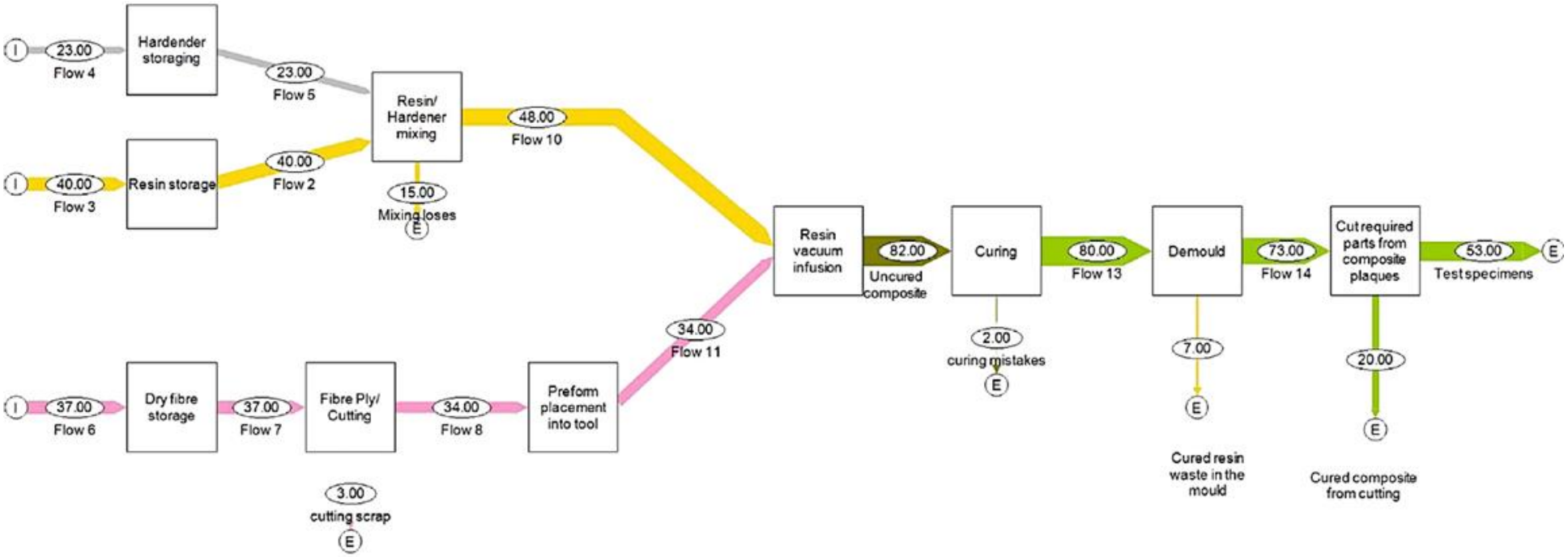

Figure 10: Example of material flow analysis in FRP production line (generated with STAN2 software); (I-Input, E-material output; adopted from Rybicka et al., 2015)

With respect to the waste hierarchy, which is prescribed in the European waste directive (Directive 2008/98/EC), landfilling is the least desired option, which should be avoided. Therefore, more suitable options in a form of recycling or reuse should be preferred in case of FRP waste, because these options are set to be higher on the priority pyramid as can be seen in Figure 11).

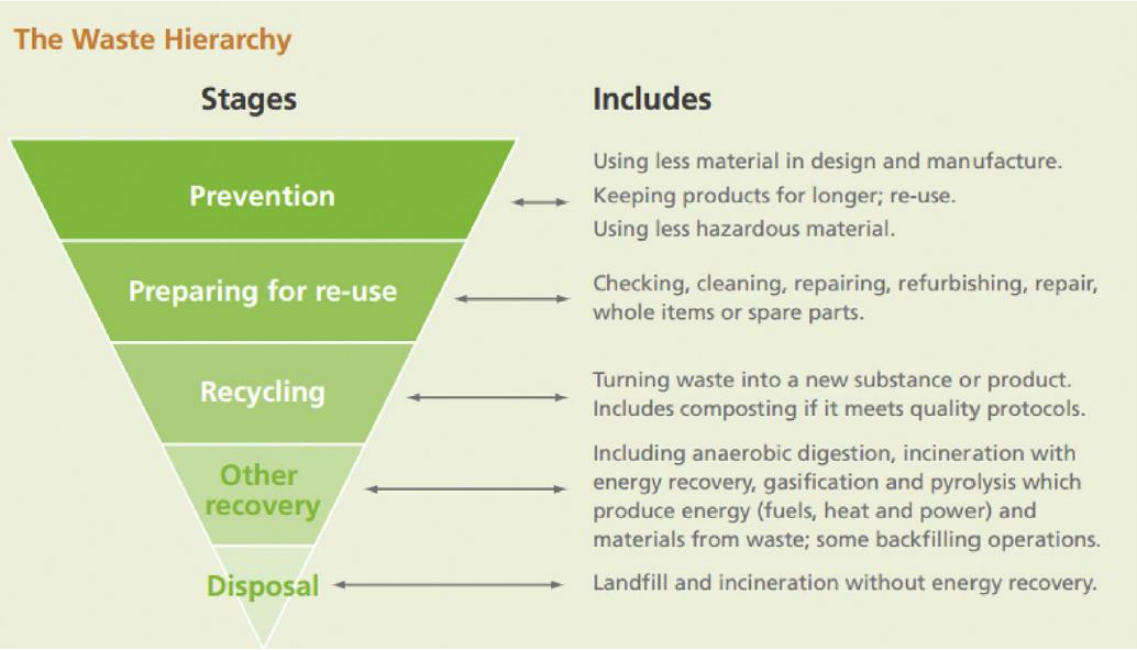

Figure 11: EU waste framework hierarchy (adopted from DEFRA (2011)

Therefore, recycling solutions, similar to RETRACKING project, are needed, urgently.

1.4. FRP RECYCLING

There is an intensive research made in the field of recycling of FRP waste materials. Different potential recycling options, which are already developed on a level of real case use, are given in a schematic presentation in a Figure 12. Recycling processes are generally divided in mechanical, thermal and thermo-chemical processes.

Mechanical recycling of FRP waste is based on size reduction and/or pulverisation processes which are performed by shredding, grinding or milling (Anane-Fenin and Akinlabi, 2017). This process is typically performed in multiple stages in which size of particles is gradually reduced. Final size grading of powdered, granular or fibrous fractions is performed by using cyclones and sieves. Powdered materials can be used as fillers for new composite (for example in sheet moulding, bulk moulding compound or dough moulding compounds) (Palmer et al., 2009).

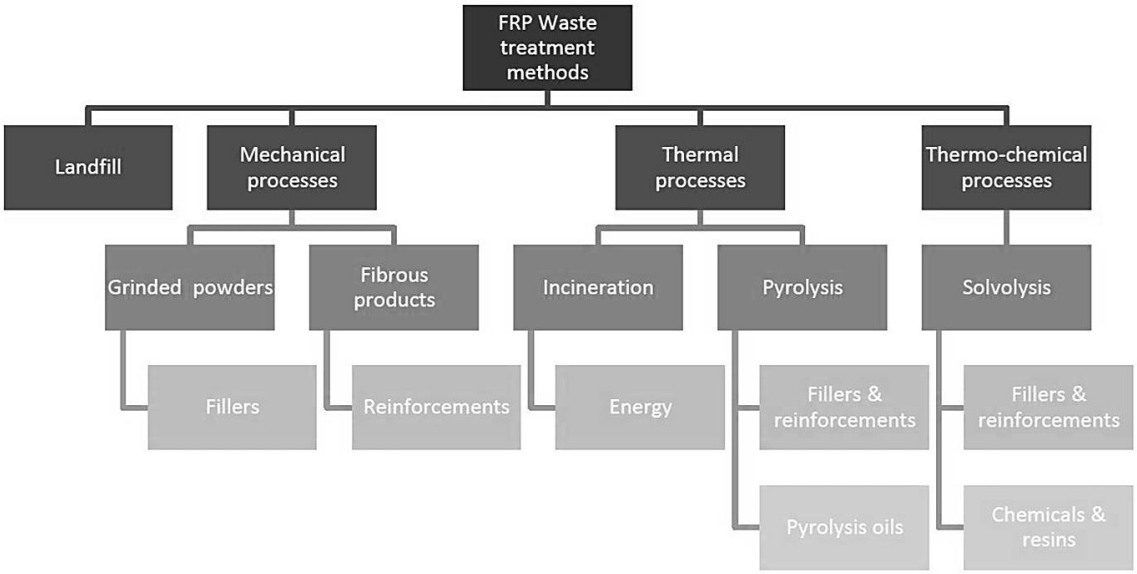

Figure 12: Schematic presentation of different FRP waste recycling technologies and processes (adopted from http://www.windfarmbop.com)

This recycling option was also used for the RETRACKING pilot production line. An example of crushed FRP waste materials from the RETRACKING pilot recycling process is given in Figure 13.

Figure 13: A mechanically processed FRP waste in a form of a fine granulate (internal photo documentation of ZAG)

Thermal processes include incineration and pyrolysis. Due to the high calorific value of resins and polymeric binders in FRP this waste materials can be processed into alternative

fuel, which can be used for example in cement production. Namely, epoxy, phenolic or polyester resins can have calorific value of 30,000 kJ/kg. The use of such alternative fuel in cement production is especially viable option. This is because ash, which is formed from combustion of FRP is composed from calcined inorganic components, such as glass fibre in the case of glass fibre FRP waste incineration, can be beneficially used as a filler in cement (Anane-Fenin and Akinlabi, 2017).

Meanwhile, in some cases of thermal processes, like for example in fluidised bed combustion or in low temperature pyrolysis or microwave assisted pyrolysis, raw fibres can be recovered for recycling by thermal degradation of polymer matrix (Allred and Busselle, 2000, Åkesson et al., 2012). Although the use of such fibres is limited since certain strength and physical-chemical stability of such fibres is reduced during thermal processing. Tensile strength is reduced for over 60%, flexural strength for 50% and impact strength for 70–80% in comparison to virgin fibre (Anane-Fenin and Akinlabi, 2017). An example of fibres, which were recovered by pyrolysis of the FRP product (construction reinforcement rod), within the scope of RETRACKING project, is given in Figure 14.

Figure 14: Fibres recovered by thermal degradation of FRP product (left) and reinforcement rod from such fibres (right).

Chemical recycling methods are based on the chemical degradation of polymeric matrix by using a solvent, in a process called solvolysis. This method has the main advantages in recovery of non or at least less damaged and cleaner fibres comparing to those revered in thermal methods. Also, organic polymer precursors can be recovered. However, from the economical point of view this type of fibre recovery is viable only in cases of fibres with

high market cost, like for example carbon fibre. Concentrated alkaline (NaOH, KOH) and / or acidic (for example HNO_3) solutions are most commonly used for solvolysis (Onwudili et al., 2013, Meng et al., 2004).

Another alternative chemical process is based on solvolysis with the use of supercritical fluid in which water is used as a solvent at temperature and pressure, where its properties are neither liquid nor vapour. In such state it has high ability to decompose FRP polymeric matrix so that non-damaged fibres can be recovered along with organic compounds, which can be recycled. Also, alcohol-water mixtures were used for this purpose at high temperature (450 °C and 25.5 MPa for alcohol, 63.3 MPa water) (Anane-Fenin and Akinlabi, 2017).

In general, chemical methods which allow recovery of fibres are more expensive in comparison to mechanical recycling and energy recovery options. Therefore, the use of such methods is viable only when fibres and chemical precursors, with high value can be recovered from the waste material. Currently, such methods are preferentially used for recovery and recycling of highly valuable carbon fibre (Naqvi, et al., 2018). As can be seen in the Figure 15, in which the carbon fibre value chain is presented, such materials are due to their costs used for high-value products. On the other hand, recovery of fibres can also be viable for recycling of aramid and certain glass fibres, which have higher market value and are more resistant to mechanical degradation and chemical attack.

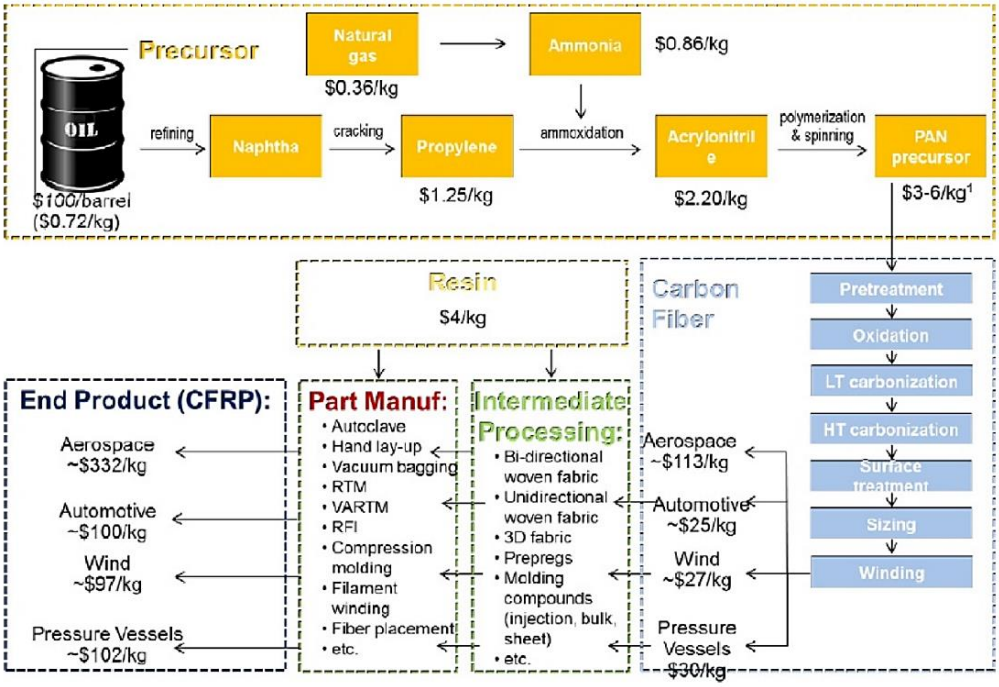

Figure 15: Carbon fibre value chain (adopted from Naqvi, et al., 2018)

General readiness of these technologies for their commercial use, and also capital investment and operational costs differ substantially between FRP recycling methods. The estimation of economic attractiveness and maturity of each technology is important, when considering its availability on the market of FRP waste recycling, given in the schematic presentation in Figure 16.

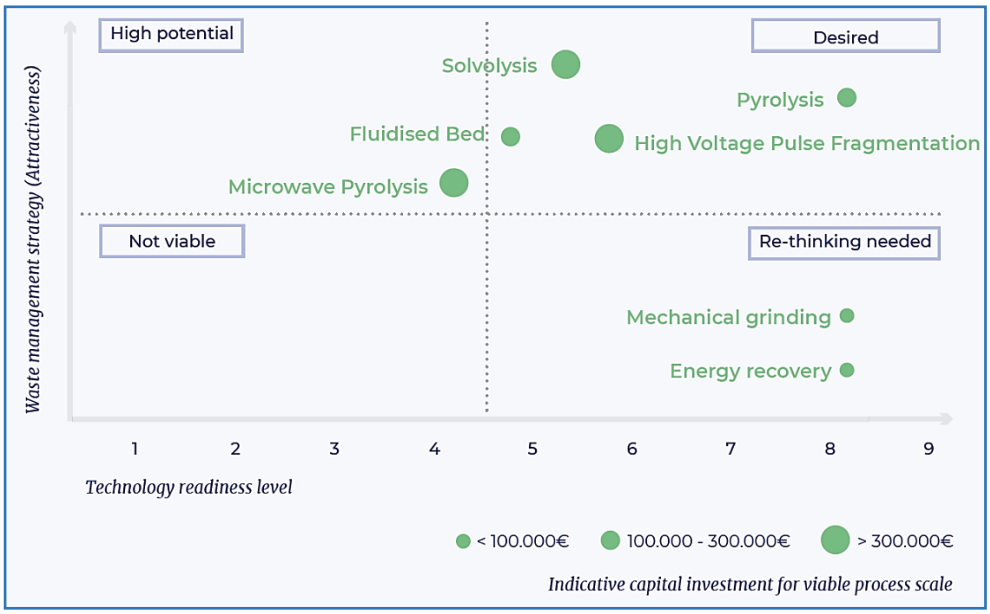

Figure 16: Attractiveness and maturity of each recycling technology (adopted from SUSCHEM, 2018)

In case of recycling of low value mixed or contaminated FRP waste the cheaper, less complicated and demanding mechanical methods or energy recovery options (either for cement production or heat generation) are preferred options.

2. MAPPING THE MASS FLOWS

The overall goal of the RETRACKING project is to increase the recycling capacity and activity of FRP within the INTERREG ITA-SI programme area. Waste from FRP composite materials can become a valuable element in the area's transition from linear to circular economy. One of the project's activities is to create the background conditions for this transition in the industrial branches that deal with FRP production and recycling. This is in line with the European document "Closing the loop - the EU Action Plan for the Circular Economy" (COM (2015) 614), because of a circular economy model for the production of secondary raw materials (SRM) for different products from recycled FRP waste.

From the technical point of recycling of FRP waste the RETRACKING project is offering an easy to apply, low cost recycling solution which is based on the mechanical processing of FRP waste and incorporation of recycled waste as a filler into a new product. However, for this goal to be achieved it is first needed to bridge the gap between the FRP and FRP-based products manufacturers, the FRP waste collectors and the FRP waste processors and recyclers in order to establish a reliable value chain that could support recycling activity. **The base for this is studying the existing mass flows of the FRP materials, products and waste in the programme area covering the whole value chain from the producers to waste collectors and processors**.

In the first step, the Retracking project identified the FRP waste streams in the programme area. Therefore, a RETRACKING waste catalogue was established (R1.WP.3.1). In the second phase a solid database of relevant stakeholders of the RETRACKING project which potentially deal with the production or management of FRP in the programme area was established. This was done by assessment of the key stakeholders in the currently existing FRP value chains and the potential new FRP value chains (with production of SRM-based products) which was the main objective of the deliverable R2.WP3.1.

The purpose of this deliverable is to follow the goal of the RETRACKING project by analysing the data about potential mass flows of the FRP materials and FRP waste in the INTERREG ITA-SI programme area. This was done by analysing the existing and publicly available databases and by obtaining the data directly from the stakeholders.

2.1. METHODOLOGY

A multistage methodology was developed and applied to obtain information and data needed for the cognitive analysis. Methodology – defining stepwise approach - for application of criteria for collection and selection of data was the following:

1. Selection of the geographical area, which was the same as INTERREG ITA-SI programme area (PA);
2. Selection of the waste codes, to define waste streams which potentially included FRP waste fractions;
3. Establishing a list of stakeholders that are potentially producing FRP and thereby generating waste from industrial processes, and a list of waste management companies (collectors, processors, public utility companies) selected according to NACE - Statistical classification of economic activities and according to the waste codes in the European waste catalogue;
4. Gathering data from the stakeholders;
5. Iterative refining and analysing data.

2.1.1. GEOGRAPHIC AREA

The determination of the geographic area, which was included into this study, was done based on the INTERREG ITA-SI programme area borders, which can be seen in Figure 17.

Figure 17: Borders of the INTERREG ITA-SI programme area included in this study

According to the EU Nomenclature of territorial units for statistics (NUTS) the regions included in this study are given in the Table 1, below (Eurostat, 2015).

Table 1: Regions according to the NUTS 2013/EU-28 included in this study as INTERREG ITA-SI programme area

CODE	NUTS 1	NUTS 2	NUTS 3
SI0	Slovenia		
SI04		Western Slovenia	
SI041			Central Slovenia
SI042			Upper Carniola
SI043			Gorizia
SI044			Coastal Carst
SI03		Eastern Slovenia	Coastal Inner Carniola
SI038			
ITH	Italy NORD-EST		
ITH4		Friuli-Venezia Giulia	
ITH41			Pordenone
ITH42			Udine
ITH43			Gorizia
ITH44			Trieste
ITH3		Veneto	Venezia
ITH35			

2.1.2. IDENTIFICATION OF POTENTIAL FRP WASTE STREAMS

The identification of the potential FRP waste streams was made within the scope of the R1.WP3.1 deliverable - The Waste Catalogue of the Programme Area.

According to the EU definition waste is any substance that those in possession intend to discard or are required to discard (Directive 2018/851). However, when dealing with FRP waste it has to be emphasized that current waste legislation, does not recognize or include ‘composite’ waste. The only reference to the ‘composite’ waste is made in relation to complex mixtures of substances from processes that are not related to the FRP production.

According to the List of Waste (LoW), as established by Decision 2000/532/EC and amended by Decision 2014/955/EU, a waste materials must be classified and labelled with a 6-digit code. The LoW contains 20 chapters, specified by two-digit codes. These chapters are further divided into sub-chapters, specified by four-digit codes and entries specified by six-digit codes, the latter defining the actual waste matter.

The 20 chapters of the LoW are categorised into three sets:

- 01 to 12 and 17 to 20 as chapters related to waste source;
- 13 to 15 as chapters related to waste type; and
- 16 as a chapter for waste not otherwise specified in the list.

Since FRP based wastes do not have a separate code(s) they may be found amongst different sets of chapters in accordance with source and type (CEFIC, 2006). Some FRP waste can be designated in chapter 16. Within the scope of the RETRACKING Waste Catalogue for some FRP waste the multiple waste entries are suggested. The final waste entry is determined in accordance with the waste source and how the waste has been introduced into the waste stream. According to the INTERREG ITA-SI RETRACKING project partners' expertise and professional opinion the FRP waste streams can be identified within the waste codes that are listed in Table 2.

Within the scope of the Catalogue a list of potential sources and types of FRP waste were also given to aid the potential recyclers in the recognition of potential sources and in separation processes.

Table 2: Selected waste codes according to the RETRACKING waste catalogue

EWC Code	CHAPTER / Sub chapter / specific entry
07 02 13	WASTES FROM ORGANIC CHEMICAL PROCESSES / wastes from the MFSU of plastics, synthetic rubber and man-made fibres / waste plastic
12 01 05	WASTES FROM SHAPING AND PHYSICAL AND MECHANICAL SURFACETREATMENT OF METALS AND PLASTICS / wastes from shaping and physical and mechanical surface treatment of metals and plastics / plastics shavings and turnings
15 01 05	WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTERMATERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED / packaging (including separately collected municipal packaging waste) / composite packaging
16 01 04*	WASTES NOT OTHERWISE SPECIFIED IN THE LIST / end-of-life vehicles from different means of transport / end-of-life vehicles
16 01 06	WASTES NOT OTHERWISE SPECIFIED IN THE LIST / end-of-life vehicles from different means of transport / end-of-life vehicles, containing neither liquids nor other hazardous components
17 02 03	CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATEDSOIL FROM CONTAMINATED SITES) / wood, glass and plastic / plastic
17 02 04*	CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATEDSOIL FROM CONTAMINATED SITES) / wood, glass and plastic / glass, plastic and wood containing or contaminated with dangerous substances
19 12 04	WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTEWATER TREATMENT

EWC Code	CHAPTER / Sub chapter / specific entry
	PLANTS AND THE PREPARATION OF WATERINTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIALUSE / wastes from the mechanical treatment of waste (for example sorting, crushing,compacting, pelletising) not otherwise specified / plastic and rubber
20 01 39	MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL,INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELYCOLLECTED FRACTIONS / separately collected fractions (except 15 01) / plastics
20 03 07	MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELYCOLLECTED FRACTIONS / other municipal wastes / bulky waste

2.1.3. IDENTIFICATION OF INDUSTRIAL AND WASTE PROCESSING ACTIVITIES

The exhaustive list of relevant and potential stakeholders, which are involved in the existing FRP value chains and / or are involved in generation and management of FRP waste streams, was prepared within the scope of the deliverable R2.WP3.1 *Database of the stakeholders of the programme area*. Stakeholders were divided into four groups:

- GROUP 1: Companies - producers of the FRP products,
- GROUP 2: Private companies for collection, processing and recovery of waste,
- GROUP 3: Public utilities and waste management companies,
- GROUP 4: Municipalities, ministries, directorates and governmental institutions.

The lists of stakeholders were established according to expert's knowledge and experience and with study of publicly available databases and internet pages of stakeholders.

Companies that potentially produce FRP products and are involved in FRP waste production, collection and processing were identified according to the European Classification of Economic Activities - NACE. The list of relevant NACE codes was set according to the expert's opinion and is given in the Table 3, below.

Table 3: The list of NACE codes with description of economic activities of potential producers of FRP is given in the first part of the table

NACE	*Description of activity*
13.940	Manufacture of cordage, rope, twine and netting
15.110	Tanning and dressing of leather; dressing and dyeing of fur
20.600	Manufacture of man-made fibres
21.200	Manufacture of pharmaceutical preparations
22.100	Manufacture of rubber products
22.200	Manufacture of plastics products
22.210	Manufacture of plastic plates, sheets, tubes and profiles
22.220	Manufacture of plastic packing goods
22.230	Manufacture of builders' ware of plastic
22.290	Manufacture of other plastic products
23.510	Manufacture of cement
24.540	Casting of other non-ferrous metals
29.200	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
29.320	Manufacture of other parts and accessories for motor vehicles
30.110	Building of ships and floating structures
30.120	Building of pleasure and sporting boats
30.200	Manufacture of railway locomotives and rolling stock
30.300	Manufacture of air and spacecraft and related machinery
30.910	Manufacture of motorcycles
30.920	Manufacture of bicycles and invalid carriages
31.010	Manufacture of office and shop furniture
32.300	Manufacture of sports goods
32.500	Manufacture of medical and dental instruments and supplies
32.501	Manufacture of medical and dental instruments and supplies
33.150	Repair and maintenance of ships and boats
33.160	Repair and maintenance of aircraft and spacecraft
36.000	Water collection, treatment and supply
38.000	Waste collection, treatment and disposal activities; materials recovery
38.100	Waste collection
38.110	Collection of non-hazardous waste
38.120	Collection of hazardous waste
38.200	Waste treatment and disposal
38.210	Treatment and disposal of non-hazardous waste

NACE	*Description of activity*
38.220	Treatment and disposal of hazardous waste
38.300	Materials recovery
38.310	Dismantling of wrecks
38.320	Recovery of sorted materials
39.000	Remediation activities and other waste management services
42.110	Construction of roads and motorways
45.110	Sale of cars and light motor vehicles
45.200	Maintenance and repair of motor vehicles
45.320	Retail trade of motor vehicle parts and accessories
46.190	Agents involved in the sale of a variety of goods
46.720	Wholesale of metals and metal ores
46.760	Wholesale of other intermediate products
46.770	Wholesale of waste and scrap
49.391	Other passenger land transport n.e.c.
49.410	Freight transport by road
50.100	Sea and coastal passenger water transport
52.100	Warehousing and storage
52.220	Service activities incidental to water transportation
71.129	Engineering activities and related technical consultancy
77.110	Renting and leasing of cars and light motor vehicles
78.200	Temporary employment agency activities
84.000	Public administration and defence; compulsory social security
84.100	Administration of the State and the economic and social policy of the community
84.110	General public administration activities
84.123	Regulation of the activities of providing health care, education, cultural services and other social services, excluding social security
84.132	Regulation of and contribution to more efficient operation of businesses
84.220	Defence activities
84.240	Public order and safety activities

The list of relevant stakeholders (R2.WP3.1) for the Italian part of the program area have been developed starting from two types of database:

1. The first one is the database that identifies companies producing waste in 2016 and related quantities of waste per EWC code. Two different Environmental agencies have been contacted in order to obtain databases: Waste Observatory Service of ARPAV (Environmental Agency of Veneto, for Venice province) and Waste

Observatory Service of ARPA FVG (Environmental Agency of Friuli Venezia Giulia region, for the provinces of Pordenone, Udine, Gorizia and Trieste). These two regional agencies were asked to produce the list starting from the waste codes identified in the RETRACKING project (Table 2).

2. The second one is the database that identifies companies whose economic activities (NACE) could have potentially been related to the production of glass fibre FRP. The chamber of commerce of Pordenone has been contacted in order to obtain data, which are available for a fee through the "Companies Register Service". The list of companies has been obtained starting from the NACE codes identified in the RETRACKING project (Table 3) and the list was further refined according to the waste codes identified in the RETRACKING project (Table 2).

A list of potentially relevant stakeholders from the Slovenian part of INTERREG ITA-SI has been developed by gathering of data from multiple sources.

1. The database of companies that produce FRP and generate waste from production was established on a basis of a database, which was obtained from the website of the Slovenian Environment Agency (ARSO, 2017). The companies have to report the amount of waste they generate according to the EWC classification. The data from 2017 and 2016 were used in this study (ARSO 2017). Companies were selected according to their economic activity classification code - NACE classification (SURS, 2008).
2. The database of waste collectors and processors for the Slovenian part of the programme area was prepared in a way that relevant selected EWC (for which waste collectors and processors are registered to manage) were used as a selection criteria, and different ARSO database was employed – reports about amounts of collected waste and from reports about amount of processed waste from 2016 (ARSO, 2017).
3. The list of municipal public services and utility companies from the Slovenian part of the programme area was also selected according to their address and location from the ARSO databases (ARSO, 2017).
4. The municipalities from the Slovenian part of the programme area of the INTERREG ITA-SI RETRACKING were listed from the data obtained from the Statistical Office of Slovenia (SURS).

2.1.4. GATHERING OF DATA FROM STAKEHOLDERS

In the fourth phase of this research the data for mass flow analyses were gathered directly from the most relevant stakeholders. Collection of data from the stakeholders was done through communication at the workshops and conferences, which were organised within the scope of the RETRACKING project, on-line survey and interviews. The official web pages of the most relevant stakeholders were studied and information published there was collected. The methodology for gathering of the data through direct contacts with stakeholders was divided into two parts. First part was dedicated to the companies that produce FRP and generate waste from their production activities. Second part was dedicated to the waste collection and processing companies.

For both groups of stakeholders two separate questionnaires were prepared:

1. Questionnaire for FRP producers and users (*see Annex 1.1)*,
2. Questionnaire for waste management operators (e.g. waste collectors, recovery operators, utilities and similar) ***(see Annex 1.2).***

The questionnaires were sent to the e-mail address of the most relevant stakeholders, which were according to the expert's opinion and knowledge of the RETRACKING project partners the most important beneficiaries directing the FRP mass flows in the programme area. The questionnaires were also used for direct communication at personal meetings with the representatives of the stakeholders.

3. RESULTS OF THE MASS FLOW ANALYSIS

3.1. SLOVENIAN PART OF THE PROGRAMME AREA

3.1.1. SLOVENIAN COMPANIES PRODUCING FRP

Altogether **61 potential producers of FRP waste** were identified. Their distribution according to the statistical regions was the following:

- **23 from the Central Slovenia**,
- **15 from the Upper Carniola**,
- **10 from the Gorizia**,
- **8 from the Coastal Inner Carniola**,
- **5 from the Coastal Carst**.

According to the NACE classification of economic activities the distribution of the companies is the following:

- **33 companies** are Manufacturers of different **plastic products** (22.290),
- **6 companies** are Manufacturers of **plastic plates, sheets, tubes and profiles** (22.210),
- **5 companies** are Manufacturers of **builders' ware of plastic** (22.230),
- **4 companies** are Manufacturers **of other parts and accessories for motor vehicles** (29.320),
- **4 companies** are Manufacturers of **medical and dental instruments** and supplies (32.500),
- And **9 companies** are registered under other various NACE codes.

In the Table 4 a summary of the data analysis about generation of waste at potential FRP producers in the Slovenian part of the programme area according to the NACE codes and geographical position of the companies is given.

Within the waste streams, which are marked by the waste codes, only a fraction of a total mass is represented by FRP waste. The exact mass of the FRP waste is not known and cannot be distinguished within each waste stream under the designated code in currently available Slovenian databases.

Table 4: Analysis of the data of potential producers of FRP in the Slovenian part of the programme area

NACE	*Number of companies*	*Statistical region*	*EWC*	*Cumulative amount of waste in tonnes*
20.600	1	*CENTRAL SLOVENIA*	*07 02 13*	*2,099.295*
	1	*GORIZIA*	*07 02 13* *19 12 04*	*33.543*
22.210	2	*CENTRAL SLOVENIA*	*07 02 13* *12 01 05* *20 01 39*	*341.761*
	1	*UPPER CARNIOLA*	*07 02 13*	*81.697*
	2	*COASTAL INNER CARNIOLA*	*19 12 04*	*0.970*
22.220	1	*COASTAL KARST AREA*	*07 02 13*	*221.770*
22.230	4	*CENTRAL SLOVENIA*	*07 02 13* *12 01 05* *20 01 39*	*81.690*
	1	*COASTAL INNER CARNIOLA*	*12 01 05*	*6.130*
22.290	12	*CENTRAL SLOVENIA*	*07 02 13* *12 01 05* *16 01 19* *19 12 04*	*177.118*
	10	*UPPER CARNIOLA*	*07 02 13* *12 01 05* *16 03 06* *20 01 39*	*484.842*
	3	*COASTAL INNER CARNIOLA*	*07 02 13* *16 01 19* *20 01 39* *20 03 07*	*159.555*
	5	*GORIZIA*	*07 02 13* *12 01 05* *19 12 04* *20 03 07*	*26.503*

NACE	*Number of companies*	*Statistical region*	*EWC*	*Cumulative amount of waste in tonnes*
	3	*COASTAL KARST AREA*	*07 02 13* *20 01 39*	*6.197*
29.320	3	*CENTRAL SLOVENIA*	*07 02 13* *12 01 05* *16 03 06*	*4.830*
	1	*GORIZIA*	*20 03 07*	*1.500*
30.120	1	*COASTAL KARST AREA*	*07 02 13*	*28.720*
30.300	1	*GORIZIA*	*07 02 13*	*2.289*
30.920	1	*COASTAL INNER CARNIOLA*	*07 02 13* *19 12 04*	*17.580*
32.300	1	UPPER CARNIOLA	*07 02 13* *12 01 05*	*1,390.650*
32.500	1	CENTRAL SLOVENIA	*20 03 07*	*0.340*
	1	COASTAL INNER CARNIOLA	*12 01 05*	*5.420*
	2	GORIZIA	*12 01 05* *16 03 06*	*50.671*
33.150	1	UPPER CARNIOLA	*20 03 07*	*43.120*
33.160	1	UPPER CARNIOLA	*07 02 13*	*0.150*

In the Table 5 is given a synthesis of information, which was obtained by contacting the representatives of 6 biggest FRP producers in the Slovenian part of the programme area. The data which were obtained from the Slovenian companies that produce FRP have shown that their business model is linear: FRP producer → user → (repair service – maintenance) → waste collector → waste processor → (landfilling, incineration, export of waste).

Table 5: A summary of information from cognitive analysis of FRP waste producers from the Slovenian part of the programme area

Composition of raw materials	*Resins: vinyl esters, polyester, epoxide, etc.* *Fibres: glass, carbon*	*Most companies did not disclose such information.*
Sources of raw materials	*On average 82 % is of EU origin, lesser amounts from China and USA.*	
Production processes	*Lamination, vacuum moulding, filament winding, hand lamination*	
Products	*High added value products prevail:* *Shipbuilding, pipes, tanks, sport equipment, motorcycle components.*	
Home market / export ratio	*From 50 to more than 95 % is exported, 63 % on average.*	*One company reported 100 % home market sells.*
Sustainability aspects	*Life span of the products is up to 50 years (30 on average).* *All companies offer repair services!*	*However, only two companies producing high added value products (ships, sport equipment, basin, tanks, motorcycles etc.) were investigated.*
Annual quantity of FRP waste	*From 1.5 to 5 % of produced waste per total production (on average 10 tonnes per SME)*	*Only larger companies from the scope of Slovenia were investigated.*
Waste management information	*Handed to the waste collector, mostly for landfilling and incineration in Slovenia!*	*One company reported separate collection of FRP at the waste collector.*
Quality of waste	*Unified composition, controlled separation of waste (fibre, inert mineral fillers, resins)*	*Only one company reported low quality of waste material due to heterogenic composition (low degree of separation).*

3.1.2. SLOVENIAN WASTE COLLECTION AND PROCESSING COMPANIES

Altogether **93 potential collectors and processors of FRP** waste were identified. Their distribution according to the statistical regions was the following:

- **35 from the Central Slovenia**,
- **22 from the Upper Carniola**,
- **14 from the Gorizia**,
- **7 from the Coastal Inner Carniola**,
- **15 from the Coastal Carst**.

According to the NACE classification of economic activities the distribution of the potential collectors and processors of FRP waste was the following:

- **18 companies** are Collectors of non-hazardous waste (38.110),
- **11 companies** deal with **Water collection, treatment and supply** (36.000),
- **10 companies** deal with **Recovery of sorted materials** (38.320),
- **8 companies** deal with **Maintenance and repair of motor vehicles** (45.200),
- **5 companies** are **Collectors of hazardous waste** (38.120)
- **4 companies** are **Manufacturers of other plastic products** (22.290),
- **3 are institutions for General public administration activities** (84.110),
- **2 companies** deal with Treatment and disposal of non-hazardous waste (38.210),
- **2 companies** deal with Treatment and disposal of hazardous waste (38.220),
- Also, there are **2 Agents** involved in the sale of a variety of goods (46.190), Wholesales of other intermediate products (46.770), and Freight transport by road companies (49.410),
- **21 companies** are registered under other various NACE codes.

In the Table 6 a summary of the data analysis about collectors and processors of waste, which potentially include FRP waste fractions in the Slovenian part of the programme area, according to the NACE codes and geographical position of the stakeholders is given.

Within the waste streams, which are marked by the waste codes, only a fraction of a total mass is represented by FRP waste. The exact mass of the FRP waste is not known and cannot be distinguished within each waste code in currently available Slovenian databases.

Table 6: Analysis of the data of waste collectors and processors in the Slovenian part of the programme area

NACE	*Number of companies*	*Statistical region*	*EWC*	*Cumulative amount of waste (ARSO 2016) in tonnes*
13.940	*1*	*CENTRAL SLOVENIA*	*07 02 13*	*118.843*
15.110	*1*	*CENTRAL SLOVENIA*	*16 03 06*	*2,312.395*
20.600	*1*	*GORIZIA*	*07 02 13*	*3,086.673*

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste (ARSO 2016) in tonnes
			19 12 04	
21.200	1	CENTRAL SLOVENIA	16 03 06	2.225
22.230	1	CENTRAL SLOVENIA	07 02 13 17 02 03	20.936
22.290	2	UPPER CARNIOLA	12 01 05 16 01 19 19 12 04	1.320
	1	GORIZIA	17 02 03	484.730
	1	COASTAL KARST AREA	19 12 04	10.865
23.510	1	GORIZIA	19 12 04	20.390
24.540	1	GORIZIA	07 02 13 12 01 05 16 02 16 19 12 04	6,639.900
35.119	1	COASTAL KARST AREA	16 02 16	692.472
36.000	4	UPPER CARNIOLA	07 02 13 12 01 05 19 12 04 20 01 39 20 03 07	21.160
	3	CENTRAL SLOVENIA	16 01 19 20 01 39 20 03 07	3,667.336
	2	COASTAL INNER CARNIOLA	20 01 39 20 03 07	603.450
	1	COASTAL KARST AREA	20 03 07	606.380
	1	GORIZIA	20 03 07	1,070.528
38.110	6	COASTAL KARST AREA	19 12 04 16 02 16 16 01 04* 20 01 39 20 03 07	349.850

NACE	*Number of companies*	*Statistical region*	*EWC*	*Cumulative amount of waste (ARSO 2016) in tonnes*
	6	*CENTRAL SLOVENIA*	*16 03 06* *07 02 13* *12 01 05* *16 01 19* *19 12 04* *20 01 39* *17 02 03* *20 03 07*	*1,402.790*
	3	*UPPER CARNIOLA*	*07 02 13* *12 01 05* *20 03 07* *16 01 04**	*8,750.814*
	2	*COASTAL INNER CARNIOLA*	*16 01 04** *16 01 19* *20 01 39* *20 03 07*	*1,490.243*
	1	*GORIZIA*	*12 01 05* *16 01 19* *19 12 04* *20 01 39* *20 03 07* *20 01 39*	*7,744.664*
38.120	*2*	*COASTAL INNER CARNIOLA*	*16 01 04** *16 01 06*	*29,310.235*
	1	*CENTRAL SLOVENIA*	*16 01 04**	*2,456.710*
	1	*GORIZIA*	*16 01 04**	*30.790*
	1	*UPPER CARNIOLA*	*16 01 04**	*73.760*
38.210	*1*	*CENTRAL SLOVENIA*	*12 01 05* *16 03 06* *20 01 39*	*59.775*
	1	*GORIZIA*	*16 01 04**	*52.645*
38.220	*2*	*UPPER CARNIOLA*	*12 01 05* *07 02 13* *16 01 19*	*347.310*

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste (ARSO 2016) in tonnes
			16 03 06 19 12 04	
38.320	7	CENTRAL SLOVENIA	07 02 13 12 01 05 16 03 06 16 01 06 16 01 19 16 02 16 17 02 03 19 12 04 20 01 39 20 03 07	77.058
	1	COASTAL INNER CARNIOLA	07 02 13 12 01 05	94.605
	1	COASTAL KARST AREA	16 01 19 17 02 03 07 02 13 12 01 05 16 02 16 16 03 06 19 12 04 20 01 39 20 03 07 16 01 06	647.231
	1	UPPER CARNIOLA	07 02 13 19 12 04	5,471.588
39.000	1	CENTRAL SLOVENIA	07 02 13	831.559
42.110	1	CENTRAL SLOVENIA	17 02 03	498.901
45.110	1	CENTRAL SLOVENIA	16 01 04*	6,578.357
45.200	3	CENTRAL SLOVENIA	16 01 04*	630.283
	3	UPPER CARNIOLA	16 01 04*	0.670
	2	COASTAL KARST AREA	16 01 04*	0.540
45.320	1	GORIZIA	16 01 04*	35.378
46.190	1	CENTRAL SLOVENIA	07 02 13	164.435

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste (ARSO 2016) in tonnes
			07 02 13 19 12 04	
	1	UPPER CARNIOLA	16 03 06 19 12 04	314.631
46.720	1	GORIZIA	12 01 05 16 02 16	293.642
46.760	1	GORIZIA	07 02 13 12 01 05 16 01 19	1,797.128
46.770	2	GORIZIA	12 01 05 19 12 04	19.631
49.391	1	UPPER CARNIOLA	16 01 04* 12 01 05 20 03 07	277.166
49.410	2	CENTRAL SLOVENIA	16 01 04* 16 01 19 17 02 03	723.455
50.100	1	CENTRAL SLOVENIA	16 03 06	48.801
52.100	1	COASTAL KARST AREA	19 12 04	6,629.569
52.220	1	COASTAL KARST AREA	20 01 39 20 03 07	18.300
71.129	1	GORIZIA	07 02 13 16 02 16 16 03 06 19 12 04	3,296.487
77.110	1	UPPER CARNIOLA	17 02 03	4,550.810
78.200	1	CENTRAL SLOVENIA	16 02 16 19 12 04 20 01 39	6,960.790
84.110	3	UPPER CARNIOLA	20 01 39 20 03 07	60.300

Within the study the interviews were made with representatives of the **6 most important public companies that deal with collection of waste**. The following conclusions can be drawn from the information, which were obtained:

- FRP waste are mostly **spent sport equipment, car parts, pipes and small reservoirs, plastic packaging, car trunks, bath tubs**, containers, garden tiles and furniture, and various others products at the end of life.
- Collectors do not separate or separately collect FRP waste. The quantity of FRP waste is too low for separate collection to be economically viable.
- The **FRP waste are mostly collected** as **Bulky waste** (one collector reported approximately **5 wt.% of total collected Bulky waste** represents FRP).
- Also, they are collected as **Mixed municipal waste** (collectors reported that **FRP waste fraction is varying from 2 to 5 wt. %**).
- The FRP waste are mostly **handed to the waste processors** in a form of mixed plastic, **as a fraction intended to be processed into alternative fuel**, or as a **mixed municipal was fraction intended for landfilling.**
- FRP products with long life span (like for example ships) are rarely handed to the waste collectors.

The end-of-life vehicles dismantling company was also interviewed. They reported about the problem with disposal of composite plastic materials, which are commonly incorporated in cars.

3.2. ITALIAN PART OF THE PROGRAMME AREA

3.2.1. ITALIAN COMPANIES PRODUCING FRP

Altogether **131 potential producers of FRP** waste were identified. Their distribution according to the statistical regions is following:

- **43 from the Venezia**,
- **37 from the Pordenone**,
- **32 from the Udine**,
- **15 from the Gorizia**,
- **4 from the Trieste**.

According to the NACE classification of economic activities the distribution of the companies is the following:

- **48 companies** are Manufacturers of other **plastic products** (22.290),
- **16 companies** are Manufacturers of **plastic plates, sheets, tubes and profiles** (22.210),
- **13 companies** are Manufacturers of **Manufacture of plastic packing goods** (22.200),
- **7 companies** are dealing with **Repair and maintenance of ships and boats** (33.150), and **Building of ships and floating structures** (30.110),
- **6 companies** are **Builders of pleasure and sporting boats** (30.120), and **Manufacturers of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers** (29.200), and **Manufacturers of builders' ware of plastic** (22.230)
- **5 companies** are dealing with **Remediation activities and other waste management services** (39.000),
- And **21 companies** are registered under other various NACE codes related to activities of production of plastic products.

In the Table 7 a summary of the data analysis about generation of waste at potential FRP producers in the Italian part of the programme area according to the NACE codes and geographical position of the companies is given.

Within the waste streams, which are marked by the waste codes, only a fraction of a total mass is represented by FRP waste. The exact mass of the FRP waste is not known and cannot be distinguished within each waste code in currently available Italian databases.

Table 7: Analysis of the data of potential producers of FRP waste in the Italian part of the programme area

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
22.200	1	GORIZIA	16 02 16	0.015
	5	PORDENONE	07 02 13 12 01 05 16 02 16	66.135
	3	UDINE	07 02 13 12 01 05 15 01 05 16 01 19 16 02 16 16 03 06 19 12 04 20 01 39 20 03 07	2,963.222
	4	VENICE	07 02 13 12 01 05 16 03 06 17 02 03	318.294
22.210	2	GORIZIA	07 02 13	104.510
	5	PORDENONE	07 02 13 12 01 05 19 12 04	698.900
	1	TRIESTE	07 02 13 12 01 05 16 02 16	92.860
	4	UDINE	07 02 13 16 02 16 16 03 06	3,129.477
	4	VENICE	07 02 13 12 01 05 16 03 06 17 02 03	76.520

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
22.230	3	PORDENONE	12 01 05 16 02 16	62.195
	3	VENICE	12 01 05	211.960
22.290	2	GORIZIA	16 02 16 17 02 04	1.630
	16	PORDENONE	07 02 13 12 01 05 16 02 16 20 01 39	1,058.182
	11	UDINE	07 02 13 12 01 05 16 02 16	546.073
	19	VENICE	07 02 13 12 01 05 16 01 04 16 03 06 20 01 39 20 03 07	543.316
29.200	2	PORDENONE	16 02 16	0.063
	3	UDINE	16 01 19 16 02 16	1.521
	1	VENICE	12 01 05	5.200
29.320	1	GORIZIA	16 02 16	0.017
	1	PORDENONE	16 01 19	0.480
	1	UDINE	12 01 05	9.760
30.110	4	GORIZIA	07 02 13 12 01 05 16 02 16 17 02 03 20 03 07	53.345
	2	TRIESTE	16 02 16 20 03 07	5.300
	1	UDINE	07 02 13 12 01 05	8.748
30.120	3	GORIZIA	07 02 13	2.787

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
			16 02 16	
	1	UDINE	16 02 16 20 03 07	0.591
	2	VENICE	07 02 13 12 01 05 20 03 07	2.585
30.200	1	UDINE	16 02 16	0.032
	1	VENICE	07 02 13 20 01 39	3.030
30.300	1	PORDENONE	16 02 16 20 03 07	4.865
	2	VENICE	16 02 16	0.508
30.910	3	VENICE	07 02 13 16 01 06 16 01 19	54.537
30.911	1	VENICE	16 02 16	0.058
30.912	1	VENICE	16 02 16	0.030
30.920	2	VENICE	16 01 19 20 01 39	2.777
32.300	1	PORDENONE	16 02 16	0.014
32.500	2	PORDENONE	16 02 16	0.044
	1	TRIESTE	07 02 13 16 02 16 20 03 07	206.482
	4	UDINE	12 01 05 16 02 16 16 03 06 20 03 07	74.240
33.150	3	GORIZIA	07 02 13 16 01 19	0.312
	2	TRIESTE	20 03 07	62.490
	1	UDINE	16 02 16	0.027
	2	VENICE	16 01 19 16 03 06	1.430
39.000	2	PORDENONE	17 02 03	2.390

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
			17 02 04	
	4	UDINE	07 02 13 16 02 16 16 03 06 17 02 03 20 03 07	27.823

In the Table 8 a synthesis of information, which was obtained by contacting the representatives of 6 FRP producers in the Italian part of the programme area, is given.

The data which were obtained from the Italian companies that produce FRP have shown that their business model is also linear: producer → user → waste collector → waste processor → incineration, export of waste.

Table 8: A summary of information from cognitive analysis of FRP producers from the Italian part of the programme area

Composition of raw materials	Resins: vinyl esters, polyester, epoxide, orthophthalic resins, etc. Fibres: glass, carbon, aramid, basalt, hemp	
Sources of raw materials	Most producers report 100 % EU origin of the raw materials. Import is reported from China and minor quantitates from USA.	
Production processes	Vacuum and hot press moulding, filament winding, infusion, pultrusion, lamination and wrapping	
Products	High added value products prevail: Shipbuilding and aeronautics, pipes, tanks, sport equipment, custom made construction elements and structures	
Home market / export ratio	Some companies report less than 25 % export rates.	Most companies report from 50 to 80 % export rates.
Sustainability aspects	Long life span of the products, which is up to 50 years. However, only minor or no repair services are done by the companies.	On the other hand, some companies do not have any information about life span.
Annual	On average 10 tonnes per	Companies do not have any recycling

quantity of FRP waste	*company (up to 70 tonnes)*	*options for waste from production or for end-of-life products.*
Waste management information	*Handed to the waste collectors, mostly for incineration.*	*Companies report separate collection of different types of waste from different production processes.*
Quality of waste	*Unified composition, controlled separation of waste (fibre, inert mineral fillers, resins)*	

3.2.2. ITALIAN WASTE COLLECTION AND PROCESSING COMPANIES

Altogether **114 potential collectors and processors of FRP** waste were identified. Their distribution according to the statistical regions is following:

- **39 from the Venezia**,
- **25 from the Pordenone**,
- **25 from the Udine**,
- **14 from the Trieste,**
- **11 from the Gorizia.**

According to the NACE classification of economic activities the distribution of the companies is following:

- **47 companies** are dealing with **Recovery of sorted materials**(38.320),
- **17 companies** are dealing with **Collection of non-hazardous waste** (38.110),
- **16 companies** are dealing with **Treatment and disposal of non-hazardous waste** (38.210),
- **13 companies** are dealing with **Dismantling of wrecks** (38.310),
- **8 companies** are dealing with **Treatment and disposal of hazardous waste** (38.220),
- **6 companies** are dealing with **Collection of hazardous waste** (38.120),
- And **6 companies** are registered under other various NACE codes related to waste collection, treatment and disposal activities and materials recovery.

In the Table 9 a summary of the data analysis about generation of waste at potential FRP producers in the Italian part of the programme area according to the NACE codes and geographical position of the companies is given.

Within the waste streams, which are marked by the waste codes, only a fraction of a total mass is represented by FRP waste. The exact mass of the FRP waste is not known and cannot be distinguished within each waste code in currently available Italian databases.

Table 9: Analysis of the data of waste collection and processing companies in the Italian part of the programme area

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
38.000	1	UDINE	16 02 16 19 12 04 20 03 07	1.166
38.100	1	GORIZIA	19 12 04	49.820
	1	PORDENONE	07 02 13 12 01 05 15 01 05 16 01 19 16 02 16 16 03 06 17 02 03	32.514
38.110	5	PORDENONE	16 02 16 17 02 03 19 12 04 20 01 39 20 03 07	4,148.916
	6	UDINE	16 02 16 16 03 06 17 02 03 19 12 04 20 03 07	57,484.393
	4	VENEZIA	07 02 13 12 01 05 16 01 04 17 02 03 17 02 04	2,078.424

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
			19 12 04 20 03 07	
	5	TRIESTE	16 02 16 16 03 06	71.213
38.120	1	TRIESTE	16 02 16 16 03 06	1.196
	5	VENEZIA	16 01 04 16 01 06 16 01 19 17 02 03 19 12 04 20 03 07	1,264.097
38.200	1	GORIZIA	16 01 06 16 01 19	374.215
	2	VENEZIA	16 01 04 16 01 19 17 02 03 20 01 39 20 03 07	270.314
38.210	5	PORDENONE	07 02 13 16 02 16 16 03 06 17 02 03 19 12 04	5,117.280
	4	UDINE	16 02 16 17 02 03 19 12 04	1,010.816
	8	VENEZIA	07 02 13 16 01 04 16 01 19 16 02 16 17 02 03 17 02 04 19 12 04 20 03 07	16,137.685
	1	TRIESTE	17 02 04	13.680

NACE	Number of companies	Statistical region	EWC	Cumulative amount of waste in tonnes
38.220	1	GORIZIA	16 02 16 19 12 04	285.779
	2	PORDENONE	12 01 05 17 02 03	27.973
	2	UDINE	16 01 06 16 01 19 16 02 16 17 02 03 17 02 04 20 03 07	194.025
	3	VENEZIA	16 02 16 17 02 03 19 12 04 20 03 07	2,421.336
38.300	1	TRIESTE	16 02 16 19 12 04 20 03 07	8.901
38.310	1	GORIZIA	16 01 06 16 01 19	251.802
	5	PORDENONE	16 01 06 16 01 19	5,006.667
	5	UDINE	16 01 06 16 01 19 16 03 06	3,404.819
	1	VENEZIA	16 01 06 16 01 19	566.163
38.320	7	GORIZIA	16 01 06 16 01 19 16 02 16 19 12 04	4,784.769
	8	PORDENONE	16 01 06 16 01 19 16 02 16 16 03 06 19 12 04 20 03 07	19,997.879

NACE	*Number of companies*	*Statistical region*	*EWC*	*Cumulative amount of waste in tonnes*
	6	*TRIESTE*	*16 01 06* *16 01 19* *17 02 03* *19 12 04*	*3,975.002*
	9	*UDINE*	*16 01 06* *16 01 19* *16 02 16* *16 03 06* *17 02 03* *19 12 04* *20 01 39*	*8,078.736*
	16	*VENEZIA*	*07 02 13* *15 01 05* *16 01 04* *16 01 06* *16 01 19* *16 02 16* *17 02 03* *17 02 04* *19 12 04* *20 03 07*	*72,144.481*

Within this study interviews were made with representatives of **2 companies that deal with collection of waste**. The following conclusions can be drawn from the information, which were obtained:

- Collectors do not separate or separately collect FRP waste.
- The **FRP waste is collected** as **Bulky waste (20 03 07), mixed packaging (15 01 06), composite packaging (15 01 05) and plastic (17 02 03)**.
- The quantity of FRP waste is low.
- FRP waste is mostly **waste from production processes and construction and demolition waste** from construction sites.
- The FRP waste are mostly **handed to the waste processors** in a form of mixed plastic, **as a fraction intended to be processed into alternative fuel**.

4. CONCLUSIONS

The cognitive analysis of the mass flows of FRP materials in the programme area showed the following main conclusions:

- The prevailing business models of FRP materials in the programme area is linear (extract → produce → use → discard);
- Currently there is no separate collection of FRP waste in the programme area therefore the exact quantities of the FRP waste cannot be given;
- The main value chain actors in the area are: (i) raw material producers (can be outside the area); (ii) FRP producers (can be outside of the area); (iii) FRP users (can be outside area); FRP waste (in clean or mixed waste fractions) collectors and treaters; FRP waste (mostly in mixed fraction) disposal operators (landfilling, incineration) and recovery operators (production of fuel); FRP waste (mostly in mixed fraction) exporters;
- All together 192 potential producers of FRP waste were identified and 207 waste collectors and waste processing companies covering FRP waste (mostly in mixed waste fractions). This results in all together 399 entities which could produce or hold a FRP waste either in clear waste fraction or mixed inside other waste fractions and which could be potentially used for recycling;
- Most of FRP waste is collected as bulky waste (20 03 07), mixed packaging (15 01 06), composite packaging (15 01 05) and plastic construction and demolition waste (17 02 03)
- It is expected that the quality (as well as traceability) of the FRP waste from FRP products manufacturing is better for its recycling due to known composition and consistency of the materials in comparison with the more disperse mass flows of waste FRP products such as obsolete sport equipment and similar used by individuals. The former are also more easy to separate at the source while the latter usually ends up in the mixed municipal waste.

Based on performed cognitive analysis it can be concluded that there is a potential for circular economy business model in FRP waste recycling with mechanical treatment in the programme area, especially with more uniform mass flows of waste from FRP production. The main factors of success of such sustainable and circular business models are: (i) selective collection of different FRP waste at their source; (ii) large enough quantities of selectively collected FRP waste for recycling; (iii) known composition of FRP waste (regular

evaluation of waste properties); and (iv) short transportation routes of waste to its recycler/SRM-based products manufacturer.

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6. ANNEX 1: QUESTIONNAIRES FOR STAKEHOLDERS

ANNEX 1.1: QUESTIONNAIRE FOR FRP PRODUCERS AND USERS

PART 1: General data on company

Company name:	
VAT number:	
Type of activity (NACE code):	
Contact person for questionnaire:	
E-mail:	
Company web-site:	

PART 2: Information on production and use of FRP

Are you using / producing FRP composites?	*YES*	*NO*
If YES, list the types of products that you use or produce?		

PART 3: Data on waste production / use of FRP composites

Please indicate the types of FRP based waste generated in your production / use of FRP composites - indicate the waste code in the first column and give the annual quantity (2017) in tonnes in the fourth column.

The data concerning waste quantities should be based exclusively on quantities of waste containing FRP. Please provide an estimate, if you do not know the precise quantity.

Please mark	*Waste code*	*Description*	*Annual quantity (2017) in tonnes*
	07 02 13	*Waste plastic*	
	12 01 05	*Plastics shavings and turnings*	
	*16 01 04**	*End-of-life vehicles*	
	16 01 06	*End-of-life vehicles, containing neither liquids*	

		nor other hazardous components	
	16 01 19	*Plastics*	
	16 02 16	*Components removed from discarded equipment other than those mentioned in 16 02 15*[1]	
	16 03 06	*Organic wastes other than those mentioned in 16 03 05*[2]	
	17 02 03	*Plastic*	
	*17 02 04**	*Glass, plastic and wood containing or contaminated with hazardous substances*	
	19 12 04	*Plastic and rubber*	
	20 01 39	*Plastics*	
	20 03 07	***b**ulky waste*	
If you categorise GFRP waste under other waste entries, please specify below:			

[1] *16 02 15* hazardous components removed from discarded equipment*

[2] *16 03 05* organic wastes containing hazardous substances*

Do you collect wastes containing FRP composites separately from other wastes?	*YES*	*NO*

Please properly identify handling of waste, which contains FRP composites in your company.

Type of treatment	*Yes/No*	*Please specify for which waste code*
Recovery on-site		
Handing over for recovery		
Other treatment option (please name which). _____		

Are you looking for other waste management solution? Please, specify, which.

_____

PART 4: Data on the production / application of composite reinforced with other types of fibers

Do you use / produce polymeric composites with other reinforcing fibers (carbon, aramid ...)?	*YES*	*NO*
Which types of fibres?		
Please indicate the annual quantities (2017) of waste generated from the use / production of such composites (in tonnes)		
To which of the above waste categories do you classify this fibre reinforced composites?		

ANNEX 1.2: QUESTIONNAIRE FOR WASTE MANAGEMENT OPERATORS (E.G. WASTE COLLECTORS, RECOVERY OPERATORS, UTILITIES AND SIMILAR)

PART 1: General data on company

Company name	
VAT number	
Type of activity (NACE code)	
Contact person for questionnaire	
E-mail	
Company web-site	

PART 2: Information on FRP composites-based wastes

Please indicate the types of waste from FRP composites, which you are collecting, treating or dealing - indicate the waste number in the first column and give the annual quantity (2017) in tonnes in the fourth column.

The data concerning waste quantities should be based exclusively on quantities of waste containing FRP. Please provide an estimate, if you do not know the precise quantity.

Please properly identify handling of waste, which contains FRP composites.

Please mark	*Waste code*	*Description*	*Annual quantity (2017) in tonnes*	*Recovery on-site (YES/NO)*	*Handing over for recovery (YES/NO)*	*Other treatment options (specify which)*
	07 02 13	*Waste plastic*				
	12 01 05	*Plastics shavings and turnings*				
	*16 01 04**	*End-of-life vehicles*				

	16 01 06	*End-of-life vehicles, containing neither liquids nor other hazardous components*				
	16 01 19	*Plastics*				
	16 02 16	*Components removed from discarded equipment other than those mentioned in 16 02 15*[1]				
	16 03 06	*Organic wastes other than those mentioned in 16 03 05*[2]				
	17 02 03	*Plastic*				
	*17 02 04**	*Glass, plastic and wood containing or contaminated with hazardous substances*				
	19 12 04	*Plastic and rubber*				
	20 01 39	*Plastics*				
	20 03 07	*Bulky waste*				
If you categorise GFRP waste under other waste entries, please specify below:						

[1] *16 02 15* hazardous components removed from discarded equipment*

[2] *16 03 05* organic wastes containing hazardous substances*

Are you looking for other waste management solution? Please, specify which.

_____

Do you collect wastes containing FRP composites separately from other wastes?	*YES*	*NO*
Do you collect, treat or deal with polymeric composites-based wastes with other reinforcing fibres (carbon, aramid ...)?	*YES*	*NO*
Please, specify which types of fibres?		