New technologies and strategies for fuel cells and Hydrogen Technologies in the phase of recycling and dismantling

Grant No. 700190

WP5.Harmonization of procedures considering all actors involved in lifetime of FCH products.

D 5.4 Recommendations and guidelines on the introduction of new technologies and strategies for recycling and dismantling of FCH products in the EU

Status: F

(D: Draft, FD: Final Draft, F: Final)

Dissemination level: PU

(PU: Public, CO: Confidential, only for members of the consortium (including the Commission Services))

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 700190. This Joint Undertaking (JU) receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and N.ERGHY.

Document Change Control

Version Number	Date of issue	Author(s)	Brief description of changes
V01	15/04/2019	Marcelo Liendo	Final version

Executive Summary

This deliverable compiles recommendations and guidelines for the actors of FCH. The main purpose of the document is to define measures and to present action guidelines in order to adopt the new technologies and recycling strategies developed in the project in a feasible manner taking into account the regulatory, economic, technical and environmental aspects.

The document is focused on defining specific actions for each stakeholder involved in the proper management of the waste actor of FCH. The suggested measures are intended for the following actors of the FCH market:

- Manufacturers including their suppliers.
- Authorized distributors and logistics companies.
- Final users of FCH products.
- Recycling centres.

The document addresses from a reflexive analysis the measures that must be valued by each actor in a particular way to promote the environmental sustainability of the products of FCH.

Contents

Abbreviations

EoL	End-of-Life
EU	European Union
FCH	Fuel Cell and Hydrogen
RC	Recycling Centre

1. Introduction

This document compiles recommendations and guidelines for the actors involved in the Fuel Cells and Hydrogen (FCH) technologies life. It aims to define, as a summary, how to adopt the new technologies and recycling strategies developed in the project in a feasible manner considering regulations and also economic, technical and environmental aspects.

The document is structured to define concrete actions for each stakeholder involved in the proper management of FCH waste actor. Firstly, the needs and challenges raised by the HyTechCycling project are presented. Then, the document is broken down by the specific target groups are detailed below:

- Manufacturers including their providers.
- Authorized distributors and logistics companies.
- Recycling centres.
- Final users of FCH products.

The structure of this document summarizes the contents of the dissemination strategy used by the Consortium to define recommendations and guidelines on the introduction of new technologies and strategies for recycling and dismantling of FCH products in the European Union (EU).

The document does not intend to be an exhaustive list of measures for each actor, but an invitation to a reflection that allows the adoption of concrete action measures to advance the environmental sustainability of the FCH products.

2. Needs and challenges

As a result of the HyTechCycling project, a list of needs and challenges has been developed [1] and evaluated. This list is presented below. From a general point of view needs for all recycling technologies are:

- To develop specific protocols or mechanisms for the recycling of FCH technologies, adapted to the materials that compose it and to the later uses made of recycled materials.
- To develop guidelines for the recycling centres, elaborated by manufacturers and recycling centres, in order to ensure the proper recycling process, with information related to the materials presented, where they are located physically and also safety related issues.
- To ensure that the processes employed are economically attractive to all agents involved in the life of products in order to facilitate the implementation of FCH technologies and their EoL. Additionally, it is needed to develop processes more efficient from the energy use consumption, as far as the operational cost of the recycling centres depends among other topics of the electricity price.
- To adapt technologies to legal requirements, or if the technology is not able to cover the legal requirements, look for other technology able to do it.
- To develop proper tracking strategies with the involvement of the manufacturers, integrators and recycling centres, in order to avoid improper recycling processes and the speculation of black markets with some specific materials as platinum.
- To reduce the environmental impact of recycling processes, reducing the impact of FCH technologies throughout their lives.
- To boost the participation of end users, by creating guidelines, promoting the importance of the recycling, and creating a direct link between end users, recycling centres and manufacturers.
- To promote a complete system economically sustainable, where the costs for the EoL are properly and faired covered.
- To promote the modularity and the reuse of the components in the FCH technologies at the same time that the markets for the secondary raw materials are detected and boosted.
- To evaluate the re-adaptation of the recycling centres as an important topic, understanding that the process may last years in the worst case scenario.

3. FCH actors

Recapitulating the project content the FCH life actors must be identified [2]. According to the previous work performed by the HyTechCycling project, these actors are:

- The **FCH system manufacturer**. Under the "manufacturer" concept the suppliers (the virgin material supplier and components factories) and the final FCH producers are also included.
- The **authorized distributors and the logistics companies** that are actors that carry out the commercialization and transport of the FCH products to deliver them to the end-users and can take care of the inverse logistics to collect the waste to the recyclers or manufacturers.
- The **final end-users** of the FCH products that consume them and with their use generate the waste produced by the manufacturers.
- The **recyclers** that recover the materials contained in the waste and obtain second-generation raw materials that are reintroduced in the productive cycle.

Each of these actors has a specific and differentiated role in the cycle of FCH products that requires the description of particular measures adapted to their role. Only then, by focusing on specific measures for each actor, a coordinated and controlled action that optimizes the efforts of each actor to create an integrated strategy can be established, contributing to the environmental sustainability of the FCH products. In this deliverable, a harmonized compendium of guidelines to be followed by each FCH actor with respect to recycling and dismantling is introduced.

4. Manufacturers

The manufacturers of FCH products define in their production systems the materials and components that make up their products. Also, they select their suppliers and the technologies they use to produce the FCH product. Moreover, they establish the technical specifications, the ecological design, the sustainability objectives at the company level in order to improve the performance of their products and determine the life cycle of their products and their ecological footprint. Adopting these decisions with the perspective that the products placed on the market will be transformed into waste at its End-of-Life (EoL) is extremely important.

A series of guidelines that should guide manufacturers' decision-making to adopt a more environmentally sustainable production process is presented in this chapter.

4.1 Ecodesign

Taking into account the life cycle of the FCH products, their environmental behaviour and the impact they generate on the environment and on the health of the people should be estimated.

The ecodesign can be defined as the actions oriented to the environmental improvement of the product in the initial stage of design, by improving the function, selection of less impactful materials, application of alternative processes, improvement in transportation and use, and minimization of the impacts in the final stage of treatment.

Ecodesign consists of the consideration of environmental criteria during the design and development of products and services, at the same level in which other criteria related to quality, legislation, costs, functionality, durability, ergonomics, aesthetics, health and safety are taken into account.

As a result, ecodesigned products are innovative, have better environmental performance and quality at least as good as their equivalent competence in the market. Therefore, the use of ecodesign is increasingly important for business, offering clear advantages for those companies that apply it.

Ecodesign adopts an integrating vision of the relationship between products and services and the environment at different levels:

- The entire life cycle of the product (good or service) is taken into account. The environmental impacts produced by a product are not limited only to its manufacture, use or when it becomes waste, but considers also all the generated impacts throughout its life cycle. This includes the extraction and transportation of the resources needed for the manufacture of the product, its production, distribution, use, maintenance, reuse and the treatment of its waste.
- The product is considered as a system. All the elements that allow the product to develop its function (such as consumables, packaging, energy systems, etc.) must be taken into account.
- All the environmental impacts generated by the product system are taken into account throughout its life cycle. This multi-criteria vision allows to avoid possible transfers between different categories of environmental impacts (for example, depletion of resources, global warming, toxicity, etc.); increasing some environmental indicators when the intention is to decrease them.

The Ecodesign Directive [3] sets standards for the definition of ecodesign requirements for energy-using products in order to guarantee its free circulation in the internal market, from the perspective of the life cycle.

Although it did not directly introduce binding requirements for specific products, the Directive allowed the Commission, assisted by a Committee, to establish implementing measures on specific products and their environmental characteristics (such as energy consumption, waste production, water consumption or extension of useful life) after carrying out an impact assessment and consulting interested parties.

The purpose of this Directive was to reduce the environmental impact of products throughout their life cycle, including the selection and use of raw materials, manufacturing, packaging, transport and distribution, installation and maintenance, use and end of life. If these impacts are taken into account in the design phase, there are great possibilities to facilitate environmental improvement in a cost-effective manner, also in terms of the efficiency of resources and materials, thus contributing to the sustainable use of natural resources.

With the 2005 Ecodesign Directive, it only applied to energy-using products. In order to extend it to other significant products from the environmental point of view, its scope of application in 2008 was extended to all the products related to energy [4]. The products related to energy are those that have an impact on energy consumption during its use. They include products that consume energy and other products such as window frames, whose insulation properties influence the energy needed to heat and cool buildings and appliances that consume water and whose consumption influences the energy needed for heating.

Although this regulatory regulation is a significant step forward, it is not enough to reduce the ecological footprint of society. Perhaps, it would be necessary to extend this regulation to other products that do not consume energy or are not related to it but that, nevertheless, have a high environmental impact due to the consumption of raw materials, because of the dangerousness of its components or because of the of waste that the product generates with its use.

The FCH products have components based on critical materials that have been already analysed in the scope of the project [5] and that require the attention of the manufacturers in the design phase of their products in order to promote the environmental sustainability of their processes.

Remarking the design phase so that the FCH technologies are a more sustainable product should be a commitment of all the actors and not only of manufacturers. The final users of the product should demand that the FCH equipment will be more sustainable and will be willing to assume the costs and the benefits, both private and public, of these decisions since these actions involve externalities that exceed them and that should be covered.

All government levels, from European to regional, must implement effective and efficient policies to influence the decisions of the actors that contribute to the ecodesign of FCH products. Experience in other products makes it necessary to extend ecodesign to products such as FCH technologies.

The Recycling Centre (RC) must work together with the manufacturers in order to achieve a better design the FCH products. Although the ecodesign of the FCH products is a decision that is born from the manufacturer, all the actors are able to influence their behaviour so that they can make more environmentally sustainable decisions.

4.2 Redesign techniques for material compatibility

This step consists of redesigning the current process to maximize the potential of reuse of components, to increase the compatibility of materials for their subsequent recycling and to boost the efficiency in the disassembly processes that favour the recovery of the materials contained in the FCH products.

Manufacturers must re-evaluate their production processes based on their analysis. The project of a new process is developed to meet technological changes, alterations in customer expectations, legal changes, the obsolescence of systems and equipment, correct the verified malfunctions and incorporate the necessary improvements with the new objectives to achieve more environmentally ambitious strategies.

The conception of the new process begins with the redesign team reviewing all the work done in the previous steps, the problems to be solved, the innovation to be carried out and the criteria and objectives set for the redesign.

Based on this information and after pursuing other practices through the comparative evaluation of similar organizations that can provide support to the project to be developed, the redesign team elaborates the map of the new process, more optimized in relation to the current one, incorporating the maximum possible improvements.

The use of recyclable materials by manufacturers if the recycling processes are not able to separate and recover them properly may be meaningless.

The redesign of techniques should aim to facilitate the reuse of components and parts recovered from the FCH products and also to favour the recycling of the components that the use of the product has rendered useless. This links with the previous section, the ecodesign must contemplate when the product becomes waste.

Manufacturers select the materials considering their own characteristics and that they have to act together for specific purposes in the functionality of the FCH. The third dimension of this design system is proposed. A way to favour the disassembly, the reuse of components and the compatibility of materials for future recycling are also proposals to be followed by manufacturers.

The best way to demonstrate this new perspective is through examples. The manufacturers in the production of the FCH use plastics because their physical and chemical properties behave properly during the useful life of the product. It is true that most plastics are recoverable but by mixing different types of plastics in the same product, the opposite effect to the desired one can be achieved.

It is useless if the plastic of the FCH product is recyclable if the parts and components are not easily separable. The different types of plastics to be recycled must be melted in the RC and due to the chemical properties, they have different melting points. If its separation is not possible either by mechanical or chemical processes, these plastics waste can only be valorised energetically.

A powerful conclusion can be drawn from this point: **the task of favouring by increasing the recyclability of the materials that make up the products recycling is unfruitful if the disassembly and reuse of its components are not favoured**.

Therefore, the investigation of the materials considering their interrelation and synergy of their benefits, both from the point of functional view as in the phase of its recycling must be the starting point to advance in the sustainability of the products.

But for this, we must continue the effort undertaken to be sure to continue counting, as up to now, with the support of the industrial sector (both manufacturers and end-users) betting on lines of research future and the approach of new techniques that allow to maintain and to increase the level of recyclability of FCH products. For the specificity of the materials that make up an FCH, considered in their integration and interaction both during its useful life phase and in the potential reuse of components and recycling of materials, it is considered that this line in its approach is very different from others that might seem similar as ecodesign. It is necessary to advance in the complementarity of the materials and components to increase the sustainability of the FCH products.

In the next section, the modularity of components and homogeneity of the materials to favour the recycling of FCH waste will be analyzed.

4.3 Modularity of components and homogeneity of materials

The modular design or modularity is the design based on the modulation of components that allows optimizing the assembly time. Thanks to the modular components that are transportable, removable and reorganizable multiple functionalities are promoted and their reuse when generating a new use different from the initial one is ensured.

A modular system allows functional partition into scalable and reusable modules consisting of isolated, self-contained functional elements. Here a new perspective is introduced. Note that the modularity should not only focused on manufacturing but also in favour of its disassembly and recycling. By making the components for the same functionality of homogeneous materials, the reuse of the component is favoured, the useful life of the product is lengthened and the recycling of unusable components by being composed of the same material is improved.

The modular design allows the maximum use of the materials thanks to the standardized measurements of the FCH systems. A modular FCH system allows the dismantling of the whole equipment with relative ease keeping the qualities of the materials practically unchanged, leaving them ready for later reuse. As the design has been modulated in reference to the standardized measurements, many of the disassembled pieces are left even with their original measurement. Other materials due to scarcity or limited resources of raw materials may come from the recycling industry.

Many materials and manufacturing systems can be polluting or use compounds or substances harmful to health or the environment, either in the process of extracting the raw material, in the manufacturing process, in the putting on site or even during the useful life of the material.

Taking this criterion into account, the substances used in the manufacture of the materials used, the finishing or protection treatments, the raw materials used or the systems used to produce the materials reduce their impact because they are reused or reused with standardized production processes and more sustainable.

Advancing the modularity and homogeneity of the components of the FCH waste is a direct way to achieve more sustainable FCH products.

4.4 Strategies to replace critical materials.

The elements or factors that make a material critical must be considered in the definition of the strategy to achieve the objectives set. Each factor must be a dimension of this strategy. The scarcity of the materials, their high value, the effects that this material produces on the environment and the health of the people, their recyclability, among others, are all factors that must be combined in an integrated way to increase the sustainability of the FCH products.

The strategies for each actor according to the role and the operation performed by raw materials suppliers, FCH components' suppliers, FCH factories, FCH users, and waste managers and specialized recovery centre have been analyzed during the development of the HyTechCycling project [2].

The strategy to address the challenges of critical materials must be based on three pillars:

- First of all, the chain of value of manufacturing FCH products should be analyzed to enhance the recyclability of materials and components used in manufacturing. In all cases, extraction, separation and processing must be done in an environmentally sound manner.
- Second, the substitutive materials from those critical ones must be developed. Research that leads to substitutes for materials and technology will improve flexibility and help satisfy the material needs of a circular economy.
- Third, recycling, reuse and more efficient use. It could significantly reduce the global demand for newly extracted materials by means of research and development in recycling processes efficient from the energetic use and also from the secondary raw material use.

Together with well-designed policies will help make recycling economically viable over time. It can also help to manage the risk of supply of critical materials since the recycling of multiple materials is possible.

Although research and development is not the main mechanism to encourage the diversification of the source of critical materials, **research into more efficient forms and environmentally friendly separation and processing technologies have the potential to increase the supply of new and new sources, reducing costs and reducing environmental impact**.

Summing up the strategy is to diversify the source of critical materials, develop substitutes and improve recycling.

5. Authorized distributors and logistics companies

In this section, the guidelines and measures considered in the project for authorized distributors and logistics companies from two fundamental perspectives: the inverse logistics and the considerations applicable to the shipment of FCH waste are analyzed.

5.1 Inverse or Reverse Logistics

Reverse logistics consists of the systematic recovery of products or their containers, either by reusing them or by recycling them.

Some of the activities of reverse logistics seek, in some way, improvements and greater benefits in the production processes and supply markets. Processes of return of excess inventory, returns of customers, obsolete products, surplus inventories of seasonal demands, etc., and activities of withdrawal, classification, reconditioning and re-shipment to the point of sale or to other secondary markets, are some of the operations that can be framed within the reverse logistics. The other great activity of this type of logistics has markedly ecological connotations: recycling.

Commonly, recycling is known as the process of reusing materials to be used again as a raw material in other manufacturing processes. In general, this process produces some loss by the mixture of materials or the degradation of these. In spite of this, there is a certain consensus when it is pointed out as one of the most promising options in the future to solve the problem of excess generation of waste.

In the case of FCH products, inverse logistics is a key topic because of the specificity of the use of these products. In a developing market, these products are placed on the market through distribution chains where different actors operate. The manufacturers place a product that with its use will become a waste, but it is the logistics companies that make it reach the end-user. Therefore, these operators participate in the extended responsibility of the producer. They are those who make them reach the end-user, have direct contact with the product and know where the waste is generated at the end of its useful life.

Reverse logistics includes all operations related to the reuse of products and materials. It refers to all the logistics activities of collection, disassembly and processing of materials, used products, and/or their parts, to ensure a sustained ecological recovery. It is the process of efficiently planning, implementing and controlling the flow of raw materials, inventory in progress, finished products and information related to them, from the point of consumption to the point of origin with the purpose of recapturing them, creating value, or discarding them.

As it is possible to see in these concepts there are several important topics to consider. Reverse logistics not only refers to the treatment of goods, products and packaging but also refers to the materials and waste origin.

This new term implicitly implies a greater environmental commitment in the supply chain, which favours the development of a cleaner product (or service). Another aspect of interest is that reverse logistics has as an economic strategic objective, that of adding monetary value is the most evident in the implementation of this concept in companies.

To reduce the pollution generated in companies and to determine the impacts derived from their products and services, it is necessary to provide them with effective tools - reverse logistics management systems - that are easy and quick to implement, and that, on the other hand, side, do not increase your production costs.

Undoubtedly for companies, reverse logistics will be a key topic not only for environmental reasons but to efficiently manage the products introduced for different reasons in the chain, if they want to recover the maximum value.

Just as the existence of the direct supply chain is considered, which manages the forward flow of materials and products, in the Reverse Supply Chain, the management of the products and materials returned by customers is considered for their proper treatment, either by the manufacturer or the corresponding supplier.

This is implicitly established from the definition of reverse logistics, which guides the entire flow of products and materials from the point of consumption (customers) to the point of origin (manufacturers, suppliers) to recover the value they still have such products or materials, and give the appropriate destination to the waste

Involving these actors in the proper management of the waste of FCH is a way to make efficient its waste management system. Reverse logistics is a key element in the collection of waste, in the application of the waste hierarchy and in the possibilities of reusing components and materials.

5.2 Transport, shipment and safety considerations regarding handling FCH technologies

The mixture of the different types of waste generated from the FCH technologies decreases their recycling and recovery potential with the consequent waste of raw materials and an increase in waste management costs.

It is convenient to separate the waste that is generated according to its characteristics. This increases the possibilities of recycling or reuse of some of them and simplifies the management of the rest. All this saves on the acquisition of raw materials and environmental management.

The transport of the waste must be carried out by authorized waste transporters, with adequate means to enhance the reuse of components and the recycling of fractions and materials.

Another important issue is to have the appropriate containers and packaging to carry out the storage and transfer of the waste. This will avoid not only possible accidents in transport but also prevent health problems for people.

In the previous section, we promote the inverse logistics of the FCH products; this implies the dual nature of the companies that operate the transport. They must be able to transport both products and waste. This not only optimizes waste management costs but also contributes to the overall efficiency of the distribution and transport system of FCH products.

6. End-users of FCH products

The central player in the life cycle of the product is the user of the FCH equipment. With end-users behaviour, he defines the willingness to pay and the possibilities that the producers of FCH technologies can transfer the cost of the management of the waste generated by their use.

This actor is the point of origin of the recycling chain and the producer of the waste. With end-user behaviour, the actual application of the waste hierarchy is determined. In the EoL, the end-user could decide whether the destination of the old FCH devices is a recovery centre (remanufacturer) or the waste manager for final disposal. And even more, having decided on the final operation of the waste, it contributes to make it perform with greater or lesser possibilities of success.

The end-user is the final stage of the distribution chain and the beginning of the inverse logistics chain in waste management.

For all these reasons, this actor must be a key element in the policies aimed at the correct management of FCH waste.

The actions and measures aimed at increasing and favouring the inverse logistics in the FCH waste part of the need to plan the segregation of generated waste, taking into account the following aspects:

- Separate the waste according to its physical and chemical characteristics.
- Separate solid waste from liquids.
- Separate special waste from non-special and inert waste.

The correct management of waste requires the complicity of its producer. The end-user must be informed of the nature and composition of the waste produced at the end of the product's life cycle. It must be known which should be the process to follow with the waste, how to store it and to whom waste must be delivered for proper management.

The collection of the waste by distributor or manufacturer helps to identify the responsibility for its management.

The end-user can contribute to closing the cycle in a circular economy by comparing products that can be easily recycled or products that contain recycled materials or components. Products with recycled content are those where the product was manufactured with recycled materials collected from a recycling program or from waste recovered during the normal manufacturing process. Recyclable products are those products that can be collected, processed and manufactured into new products after they have been used. These products do not necessarily contain recycled materials.

Regardless of the income that the recovery can bring, it allows reducing the volume of waste generated and favours the awareness of the end-user.

For this end-users must be provided with the necessary means to make it possible to collect separately each type of waste, taking into account the considerations outlined above. The location and number of suitable container or containers to facilitate the segregation of generated waste have to be provided to end-user**. The end-user must be sensitized, trained and encouraged about the need to segregate waste.**

If the final users of the FCH products participate in the economic returns from the recycling of these residues, it is likely that they will be involved more and better in the correct management of the waste.

The problems derived from a correct decision of the final destination of the FCH residues can be linked to the lack of information of the end-user. Knowing what effects this waste has on the environment and on the health of people contributes significantly to deciding an appropriate destination for the waste.

Applying pictographic signs of hazards signs such as those used for chemical products or for the waste of electrical and electronic equipment contributes visually to identify these residues that should be done with them.

Another issue that does not favour the correct management of waste is that the end-user makes regular use of the product that becomes waste and this regular use decrease the perception that the end-user has about the environmental end health concerns. That is why the actions and measures of public policies should be directed to the sensibility of the final user of FCH products.

7. Recycling centres

The RC is also a key player in the EoL of products. RC actions stimulate the interaction and exchange of secondary raw materials and components with manufacturers throughout the entire supply chain. The RCs play a fundamental role in promoting the circular economy by reintroducing recovered materials to the economy, leading to a significant reduction in costs, energy requirements, emissions, resources, and waste generated throughout the life cycle of the FCH products.

The RC receives the old devices and verifies the general conditions and the main components to identify the mechanisms that determined the failure of the FCH systems. Depending on the conditions of the FCH systems when it is receipted, it must be classified as recoverable or not recoverable. The recoverable systems are partially (or, in some cases, completely) disassembled, and then the damaged components are repaired/replaced. The remanufactured system can be redistributed to customers or the distributor and returned to the business cycle.

With respect to non-recoverable FCH systems, complete non-destructive disassembly process is a necessary practice to allow the direct reuse of as many components as possible (after simple operations). For non-reusable components directly, according to the European Waste Framework Directive, waste management begins to prioritize the preparation for reuse. In this sense, **when it is economically feasible, the reconditioning, remanufacturing and repair operations are carried out at the component level; then, the components are tested to re-enter the FCH market. The practice of reuse allows saving energy, costs, landfill space and natural resources.**

Non-reusable components and parts are subjected to mechanical and/or chemical treatments for the recovery of valuable materials. These treatments may be mainly carried out in the RC (according to the new technology and/or existing technologies available), which encourages closed loop recycling (use for applications in the FCH sector). The waste manager collects the components and parts for which the recovery of material is not possible or is not economically convenient.

7.1 New recycling process

In previous documentation of the project [2] [6] the new recycling processes and the conditions of re-adaptation of the RC to implement these new technologies in their processes have been analyzed. The new recycling processes imply for RCs a change that must be properly managed.

The implementation of these novel recycling technologies involves the restructuring and redesign of facilities for existing plants or the configuration and design for new plants. These tasks will require the intervention of experts in both the treatment of new technology and auxiliary industries for the integration or new implementation of technology.

They will also involve obtaining permits and licenses to manage FCH waste. Moreover, the novel processes will cause that the operators require a period of adaptation and training for its personnel in order to work in the new tasks of operation and maintenance and perform performance tests to prove the correct operation of the facilities.

The new recycling processes offer new opportunities to manage waste that until now could not be treated in a conventional manner, or allow to segregate fractions that until now were treated mixed or allow to obtain purer materials with better yields due to the amount of waste processed.

But this also implies that new by-products and waste are generated as a consequence of the new recycling processes. This must be taken into account for a correct analysis of the environmental impacts generated by the new recycling processes.

Additionally, there are synergistic factors with existing processes that can contribute to more efficient recycling processes of other types of waste. Testing and demonstrating that a recycling process is capable of obtaining recovered raw materials can help to use it for other fractions of waste of a similar or compatible nature.

All these issues and others analysed by previous work of the project make the implementation of the new recycling processes complex for RC. This section aims to serve as a guide for the development of the same providing a simplifying view of the issue.

7.2 Implementation of reverse logistics

As it has been indicated in previous sections, the RCs are the final destination point of the waste when the FCH become waste.

Necessarily the design of a reverse logistics system must establish the connections to remove the waste generated in the end-users and deliver it to the waste plants.

Involving the end-user to activate the appropriate channels that take the waste to the recycling centres involves the direct collaboration of manufacturers and recyclers.

This collaboration involves defining the roles that each actor assumes in the system and how the costs of managing this waste are financed. The manufacturers are due to the "polluter pays principle" those members of the FCH life responsible for financing the waste management but this cost coverage will depend on numerous factors: the ability of manufacturers to transfer costs to end-users, the market value of the materials contained in the waste and waste collection costs among others.

That is why a harmonized regulation that clearly defines the roles of each actor and the obligation to exercise them becomes an axial element in which the definition of the reverse logistics system must turn.

A successful implementation of a reverse logistics system requires a proactive participation of the RCs to capture waste from the generation points thereof and to transform the materials contained in them into second generation raw materials.

7.3 Re-adaptation of centres

The processes of re-adaptation of the RCs to manage the waste must be based on an adequate analysis of the composition of the waste materials of the FCHs, adequately determining a mass balance of the materials that compose them.

It must identify the technologies that can treat the different materials and study the costs of these procedures.

The income of this technology will be analysed through an economic and financial study and compared with all the technologies identified and possible. Finally, the technology will be selected according to the criteria of efficiency, performance and quality of the materials that can be obtained from the processes of each technology.

A market study should be conducted to identify the potential customers that receive the materials produced, establishing the technical specifications that require the material (weight, granulometry, format, packaging, etc.) and the price they wish to pay for it.

With all this information, the technology to be used is determined and its costs and the income that will be generated with the treatment of the new waste are analysed.

It is important to influence the preparation for the reuse of the components and reusable parts. As already indicated in the section dedicated to the manufacturers the modularity of the components of the FCH products favours the reuse and the recycling in the waste plants.

The re-adaptation of the RCs will involve the management of organizational changes that must be taken into account when assuming this adaptation. The new way of working with the waste and the new materials to be obtained must be managed so as not to mix the existing materials that hinder their reintroduction into the market.

It will also require new efforts to commercialize these new recovered materials in markets in which the waste plants did not operate. **This will require a process of developing new sales channels for these materials.**

Finally, **once the process has been implemented, the process must be monitored to monitor that it is being carried out in accordance with the plan and to detect possible deviations and corrective measures so that the process is successful.**

8. Conclusions

In this deliverable, the issues that are important to involve the actors of the FCH market have been delineated. From its particular perspective, the elements that should be considered in the development of policies aimed at increasing the environmental sustainability of the production of FCH and the management of the waste generated from its use have been analyzed.

To move in the right direction the roles that each actor must play must be correctly defined, by anticipating their interactions and creating incentives for their behaviour to be appropriate.

In relation to the manufacturers, it is necessary to advance in a greater recyclability of the materials and components that make up the FCH, to make products that are more modular and that contain more homogeneous materials, starting from a conception based on ecodesign, which foresee the extension of its useful life by reusing parts and components that are reused and that are manufactured with less hazardous materials for the environment.

The distributors and logistics operators in the reverse logistics system must be involved in order to bring producers, end-users and recycling plants closer to the products and waste, favouring the efficiency of the system.

The end-users of the product are key actors in the system because they use the product and generate the waste. With their action, they decide the treatment and apply the waste hierarchy. For this reason, environmental awareness must be influenced so that they can perceive the environmental and health problems that derive from the improper management of their waste.

The RCs have the responsibility of transforming waste into recovered materials. They must carry out their work in a way that respects the environment and contributes to returning to the economy components and raw materials that may be the consumption of additional natural resources.

It is the individual action of each actor but consciously added in a coordinated action that defines a system that allows the circular economy to become a reality.

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