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

D5.1 Report on requirements from FCH actors

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Executive Summary

This document, which is presented as deliverable 5.1 ‘Report on requirements from FCH actors’, is part of HyTechCycling project, provides a first analyse on the needs and worries of the different FCH actors in life time of FCH products.

It is necessary in fact to underline that despite the Fuel Cells and Hydrogen (FCH) technologies are on the brick of having an important growth worldwide, there are still many obstacles that prevent a large commercialization of FCH. Principal obstacles are the lack of specific regulations, the recycling and dismantling stage, the lack of information on FCH technologies and their important potential market.

Continuous involvements of all FCH actors: from the industry manufacturer to the recycling centres, through the distributors and end-users allow to overcome these barriers and from their comparison allows the optimization and implementation of procedures related to the FCH end of life.

This was done in the form of questionnaires - the document reports the main results from FCH manufacturers, recycling centres and end users – and through a Workshop organized in Brussels, at FCH-JU headquarter.

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Abbreviations

AB	Advisory Board
AFC	Alkaline fuel cell
ATEX	Appareils destinés a être utilisés en ATmophere EXplosibles
AWE	Alkaline Water Electrolyser
EFCF	European Fuel Cell Forum
BIR	Bureau International of Recycling
BoP	Balance of Plant
CHP	Combined heat and power generation
DMFC	Direct methanol fuel cell
EFCF	European Fuel Cell Forum
EoL	End-of-Life
EU	European Union
FC	Fuel Cell
FCE	Fuel cell electric
FCH	Fuel Cell and Hydrogen
FCH-JU	Fuel Cell and Hydrogen Join Undertaking
ISO	International Organization for Standardization
LCA	Life Cycle Analysis
LCC	Life Cycle Costs
LME	London Metal Exchange
LVD	Low voltage directive
MCFC	Molten carbonate fuel cell
MEA	Membrane Electrode Assembly
NiO	Nichel oxide
NOx	nitrogen oxides
PAFC	Phosphoric acid fuel cells
PED	pressure equipment directive
PEM	Polymer Electrolyte Membrane
PEMEC	Polymer Electrolyte Membrane Electrolyser Cell
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PEMWE	Polymer Electrolyte Membrane Water Electrolyser
QR	Quick Response (truck)
RC	Recylicng Center
REE	Rear Earth Elements
SOEC	Solid Oxide electrolyte Fuel Cell

SOx	sulfur oxides
SOFC	Solid Oxide Fuel Cell
UL	University of Liubliana

1. Introduction

1.1 Study background

FCH technologies have a wide range of uses. Indeed, they are expected in the near future to decarbonize energy and transport sectors in the EU. More and more FCH technologies are used in light duty vehicles and substitute in a broad scope of applications -such as diesel and petroleum gas. Moreover, telecommunication application represents a high potential market for these technologies.

Nevertheless, the market will only boom if all the FCH actors are involved and face the existing barriers. It requires a harmonization of procedures considering all actors involved in lifetime of FCH products. Indeed, HyTechCycling project aims to bring real engagement from FCH actors in order to validate the new technologies and strategies in the phase of recycling and dismantling.

In the present report, an analysis of FCH actors' needs and worries concerning end-of-life is given. To identify their requirements and concerns, questionnaires were spread among the actors of different stages of FCH products. Moreover, the preliminary data and results collected during the first year of HyTechCycling project were presented during the first workshop in September 2017 (26th September 2017 at FCH-JU headquarter) with the involvement of the main FCHs actors.

1.2 Goals and targets

For each FCH lifetime actor considered- from industrial manufacturers to recycling centres, through distributors and end-users, opinions and concerns have been collected. The main goal is to provide a reference list of needs on end-of-life procedures from FCH actors and to involve them on this issue.

Moreover, one of the additional objectives is to achieve an efficient dissemination for each actors' category. The more the project is known by these actors the more efficiently the project will reach its objectives.

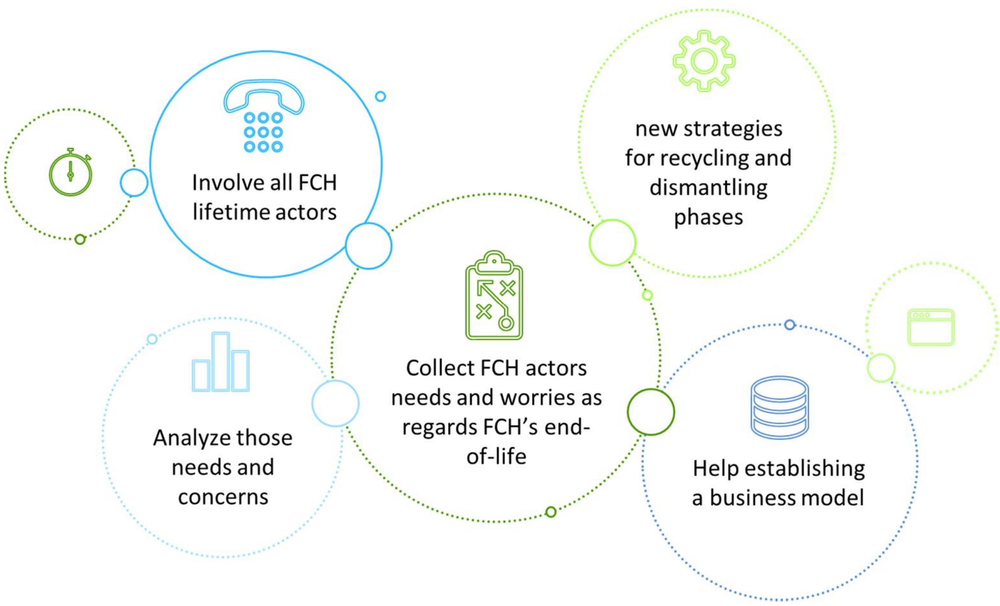

Figure 1. Goals and target groups for the HyTechCycling analysis.

The figure 1 reports the main goals to reach: collect and analyse needs and worries regards end of life, get support on business model, collect support in new strategies for recycling and dismantling phases.

1.3 Methodology in the study

This study and the workshop aim mainly to have a first outlook of needs from FCH actors and to prepare a document with requirements, inputs and preferences in new technologies and strategies. For these purposes, a questionnaire for each FCH actors' category has been established (see Annex I, II, III, IV attached). Indeed, each category has specific worries and needs depending on their main activity and their market position. Thus, the survey has been diffused among the Advisory Board (AB) and other stakeholder' contacts. The objective is to obtain a wide scope of answers that covers all the FCH technologies considered in the study and all the FCH technologies' uses as regards the end-users.

2. Survey definition

The keys to collect information on FCH technologies recycling and dismantling needs include distinguishing the different categories of actors. Indeed, in lifetime of FCH products, four categories of actors have been considered:

- The industrial fuel cells and electrolysers manufacturers.
- The authorized distributors and logistics companies.
- The end-users of FCH technologies -who are customers of manufacturers-
- The recycling centres.

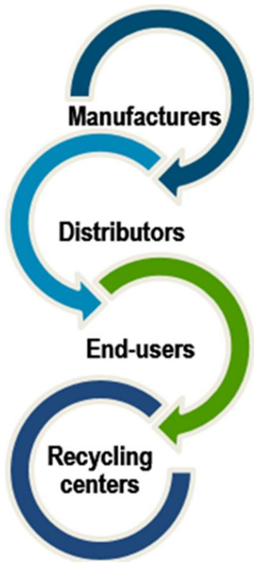

Figure 2. The four FCH actors considered in lifetime of FCH products.

2.1 Survey implementation

For each questionnaire, a draft has been completed and approved by the other partners. Following the approval, the questionnaires were adapted to a Google Form format. Indeed, the use of GForms presents many advantages. For instance, it allows an efficient analyse of the survey results. Moreover, the multiple choices configuration guides the answers. As a result, it concedes a great standardization in the answers, and consequently a better analysis.

The questionnaires were first intended to be filled out by phone. Nevertheless, after several tries, it appears that only one person over the total 29 persons contacted by call at the beginning of the survey agreed to fill the questionnaire on the phone. Mainly, those questioned prefer to receive the questionnaire by e-mail. Indeed, they are more likely to answer it if they do not feel pressure that may cause a phone call. Besides, they often need time to integrate all the information concerning the whole project, to decide if they accept to participate and also to discuss the answers internally.

As a result, the approach followed was divided into two steps. First, an e-mail that aims to explain the broad lines of HyTechCycling project, to present the questionnaire and to expose the benefits from sharing some information. Regarding the questionnaire, it is shared with the actors through a GForm link in the e-mail.

Figure 3. Survey implementation process.

2.2 Survey structure

Each questionnaire is divided in several parts depending on the category of FCH actors it concerns. Refer to the appendix for the entire questionnaires. Why should the FCH actor spend time answering these questions? He needs to feel concern by the questionnaire. For this purpose, a general presentation of the issue -short but targeted- is given.

"***Fuel cell and hydrogen technologies are on the brick of having an important growth worldwide for they offer low level of emissions, high conversion efficiency, flexibility and silent operation. In Japan, FCE Vehicles have already conquered the mass market and it is spreading to Korea, China, Germany and the USA. Nevertheless, it remains some points that need clarifications that the European HyTechCycling project aims to bring to light. New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and dismantling are being developed to help face the issues of End-of-Life FCH technologies. As a result, by filling this present questionnaire, you can contribute in these advances."***

Figure 4. Introduction of the questionnaire.

Then for each category, specific questions have been developed. Nevertheless, they were mainly referring to the same section. As a result, the questionnaires were divided in different part as illustrated in Figure 5. First, general information are required for all- such as the location of the company, the number of employee and the main activity. In addition, regulation topic is common to all actors. Indeed, even at different scales, all actors need to obey regulations whether they are European or national. For instance, questions about the product, the Life Cycle Assessment (LCA), and the eco-design complete the survey intended to industrial manufacturers. Distributors are asked about their general concerns and their opinion about reverse logistics. As regards end-users needs, they mainly concern their end-of-life strategy. Finally, recycling centres' questions focus on FCH recycling technologies and strategies.

Furthermore, in the aim of dissemination and catching the actors' interest, the existence of deliverables D 2.1 and D 2.2 [1, 2], was communicated through the questionnaire.

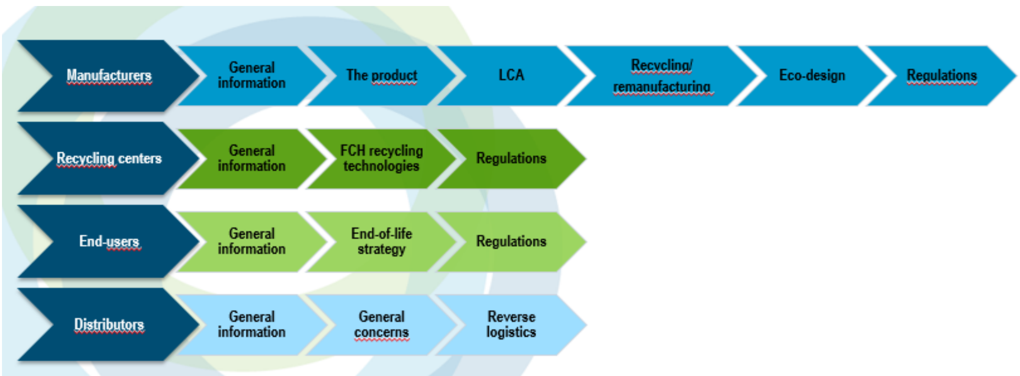

Figure 5. Questions categories for each actor.

2.3 Survey target

The persons contacted for this survey are from the AB, and from the main stakeholders of the sector. The stakeholders list has been spread to all the partners in order to complete the list. As a result, the actors reached are from a wide range of European countries and they differ in their main activity. For these reasons, the results of the questionnaire are more relevant.

Among the **63 companies** contacted for the survey, 54% of them were manufacturers, 24% were recycling centers, 16% end-users and 6% companies considered as other. The latter are mainly associations or organizations, directly or indirectly involved in Hydrogen Technologies and recycling -such as EFCF the European Fuel Cell Forum- through which it was possible to access to a broader network of manufacturers, recycling centers, end-users and distributors.

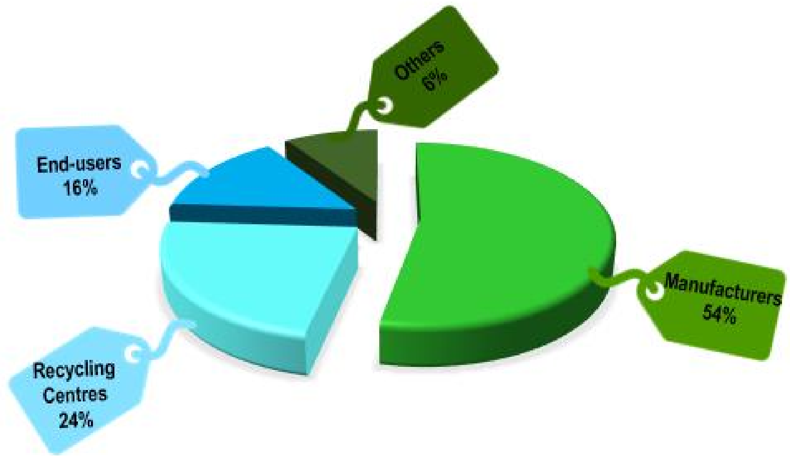

Figure 6. Distribution of FCH actors considered in the survey.

Different FCH actors, located in different countries, have been reached for the survey, Countries across the European continent have different national regulations that are important to be aware of to implement a good harmonization of regulations.

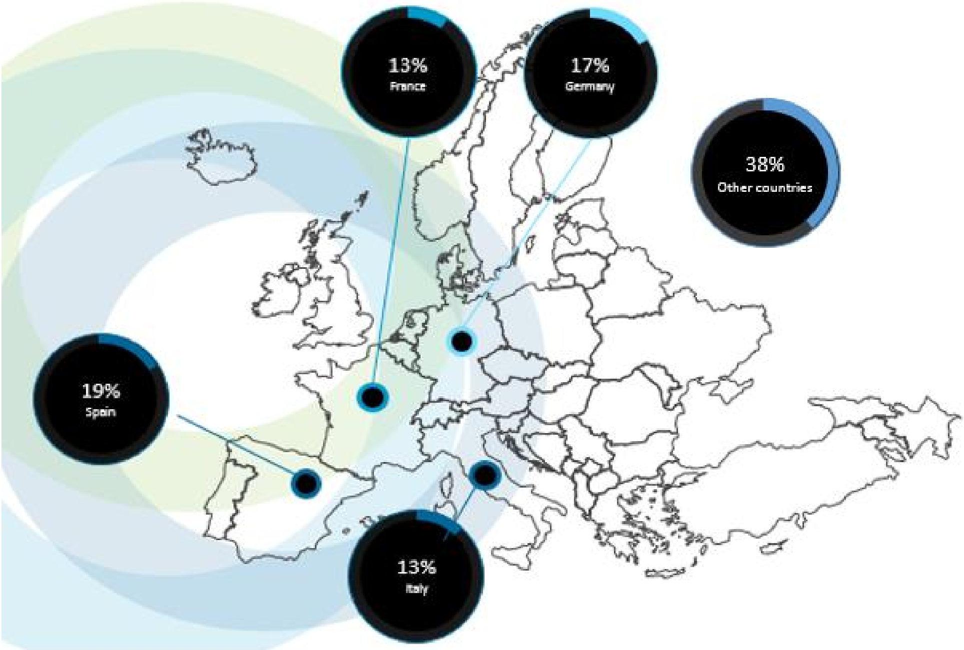

Figure 7. Geographical distribution of FCH actors considered in the survey.

Figure 7 gives the distribution of these actors depending on their country. As a result, it appears that the country more contacted during the survey is Spain -with 12 companies- followed closely by Germany, Italy and France with respectively 11, 8 and 8 companies. Thus, it may underline an uneven level of involvement among the European countries in the FCH technology development and their recycling and recovery. The important number of Spanish partners in this project also explains the high rate in Spain.

3. Survey results

The survey covered main of FCH actors, and mostly companies near to the market concerning manufacturers. The data analyzed in this report was principally compiled from a Google Form platform and then treated on Excel.

Among 63 stakeholders contacted -whether it is by e-mail and/or by phone-, 20 answered the questionnaire: 9 of them were FCHs manufacturers, 6 recycling centers and 5 end users. The end-users contacted until now are Energy Utilities, also involved in European Project.

3.1 Manufacturers

The questionnaire was divided into five topics (see Annex I_Survey for Manufacturers):

- General information.
- The product.
- LCA.
- Recycling/remanufacturing.
- Eco-design.
- Regulations.

3.1.1 General information

This section aims to collect global information such as the name of the company, the location, the main activity and the number of employee. The objective was to reach at least one manufacturer per sector considered:

- PEMFC
- DMFC
- AFC
- PAFC
- MCFC
- SOFC
- AWE
- PEMWE
- SOEC

From all of them, 3 manufacturers are PEMFC developers, 2 are involved in SOFC development, and respectively 2 manufacturers develop AWE, 1 PEMWE and 1 hydrogen boilers.

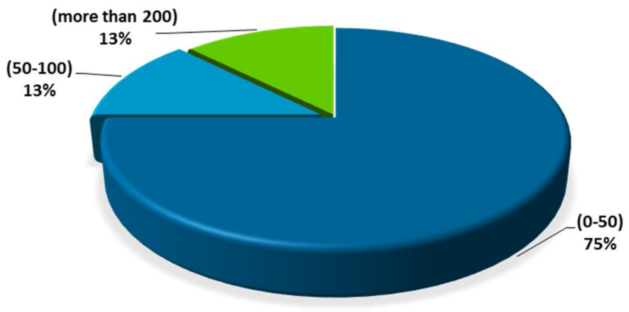

Figure 8. Manufacturers' enterprise dimension, number of employees: a) 0-50; b) 50-100; c) more than 200.

3.1.2 The Product: Information about the technology produced

The main objective is to collect information on the technologies manufactured and so specific details on: quantity of Rare Earth Elements (REE) group materials present in FCHs' components (g/kW), identification and quantity of hazardous materials, BoP components manufacturing and tracking methods used by the manufacturers of the FCH technologies systems.

In relation to REE group materials present in PEMFC, the interviewees report the use of critical raw materials, mainly Pt based and REE, confirming that the presence of Pt poses problems mainly due to an increasing cost of materials and a decreasing availability that could impact in the system production and could limit its commercialization. Only one manufacturer reports a PGM's quantity presents in the stack of 0.9 g/kW, with the company's goal of reducing content to targets reported on SET-Plan 2020 (target 0.5 g/kW).

In relation to hazardous materials, the FCHs interviewees report some hazardous materials such as: nickel and nickel based oxides used in SOFCs and raney-nickel in AWEs; asbestos used in AWEs and potassium hydroxide in the electrolyte of AWEs.

Many data are still considered sensitive and therefore not communicated by companies until now interviewed.

75% of the FCH manufacturers interviewed did not manufacture BoP components, one of them states that some components are developed within the company and others through subcontracts.

The products are tracked with different methods:

- QR code: 25%
- Serial code: 25%
- Internal code: 50 %
- Barcode: 0%

3.1.3 Life Cycle Analyses

The objective of the questions proposed was to learn more about LCA at different stages: manufacturing and operation phases. The questions performed by UL provide useful information for the deliverables on LCA analysis. However, this section constitutes one of the hardest parts to obtain information from manufacturers. Mainly, it falls under the confidential and classified matter.

The questionnaire proposed is divided into two information requests: the first related to manufacturing stage and the second to operation stage.

1. Manufacturing stage

The main information that comes from the questions is related to:

☐ Input materials, list of all materials used in the product with masses of used materials.
☐ Energy flows (electricity, fuels, heat) needed in manufacturing stages of considered FCH technologies.
☐ Emissions to air, water, and soil as a result of the maintenance of the manufacturing line.
☐ Wastes that come from manufacturing phase.

The majority of manufacturers is reluctant to give technical details and more detailed information about their systems. Only one PEMFC manufacturer have listed the presence in 10 kW stack of: 11 kg Aluminum, 1.6 kg Steel, 1.1 kg Copper 16 kg Graphite composite, 2 kg Polymers, 1.5 kg other.

The energy flows were confidential information for all manufacturers interviewed.

The possible emissions to air, water and soil as a result of the maintenance of the manufacturing line was confidential information for 6 manufacturers. Three others declared that there are no emissions during manufacturing line.

As regards wastes result, four types of waste can be noted:

- Waste water which is treated according to local regulation.
- Metallic scrap from metallic bipolar-plates and electronic components.
- NiO wet paste for SOFCs.
- Graphite composite for PEMFC with graphite bipolar-plates.

2. Operation stage

This part discusses on:

- ☐ Energy's type during operational stage.
- ☐ Other materials used.
- ☐ Energy efficiencies in different operating regimes.
- ☐ Emissions to air, water and soil as result of operation stage.

The energy used during the operation stage is based on electricity and fuel. The other materials needed are water for 75% and air. For the MW electrolyser, less than 224 l/h are used, for the PEM systems less than 1 l/Nm_3H_2 of water.

The energy efficiency is around:

- 60-70% for SOFC.
- 69% (5.1 kWh/ N m_3 H_2) for PEMWE.
- 45-65% for PEMFC.

The possible emissions to air, water and soil are:

- Pure oxygen and waste water coming from the water treatment plant for PEMWE operation phase.
- Similar to condensing boiler, with the exception of SOx and NOx for hydrogen boiler.
- Only water for SOFC.

3.1.4 Recycling and remanufacturing process

The last, but not least important, stage is the End-of-Life (EoL) with the main scenarios [3]:

- Reuse as parts/material in the same product (avoiding of virgin mass flow).
- Reuse in other product (allocation of environmental impacts – mass allocation method).
- Recycling of materials in the same product (avoiding of virgin mass flow, additional energy input for recycling).
- Recycling in other product (allocation of environmental impacts – mass allocation method).
- Energy extraction process (avoiding energy input – electricity, producing heat, higher environmental impacts).
- Landfill of parts and system (higher environmental impacts – worst case scenario)

In this part, the manufacturers interviewed, expressed they needs and worries as regards FCH technologies' end-of-life. According to their answers, mainly some facts could prevent the recycling of FCH technologies and constitute a limitation for a new business model:

- Lack of cooperation between manufacturers and waste separation companies.
- Current low volumes partly prevent economic viability.
- Difficulty/investment to recover components vs the cost of purchasing.
- Lack of established infrastructure.

Concerning the first point, only one manufacturer questioned has already an agreement with a recycling center. Nevertheless, they are unanimously in favor of establishing a sort of "convention" between manufacturers and recycling centers. This agreement will assure manufacturers to buy the recycled materials. Moreover, they all agree in reusing FCHs recycled materials and/or components bought to recycling centers. Thus, all this testifies the commitment of manufacturers as regards end-of-life issues and their deep will to act.

3.1.5 Eco-design

Eco-design for resource efficiency can benefit consumers by making products more durable or easier to repair. It can help recyclers to disassemble products in order to collect valuable materials. It can contribute to save resources that are valuable for the environment and economy. Market signals are, however, not always sufficient to make this happen, in particular because the interests of producers, users and recyclers are not necessarily aligned. It is, therefore, essential to promote and boost improved product design, while at the same time preserving the internal market and enabling innovation.

FCHs manufacturers and developers are required to implement and provide evidence of eco-design. The possibility to repair, remanufacture or recycle a FCH technology system and its components and materials depends on large part on the initial design of the product. It is therefore crucial that these aspects are taken into account when investigating possible eco-design implementing measures.

The eco-design is an important field in the study of end-of-life. Indeed, eco-design aspects must be taken into account for FCH technologies to be optimally recycled and disassembled. It must be taken into account in the total FCH technologies lifecycle.

First, the material choice is a burning issue. FCH technologies require some critical and hazardous material. According to the manufacturers questioned:

- ☐ 83% of them have reduced the quantity of hazardous materials.
- ☐ 30% of them have reduced the quantity by 30%.
- ☐ 83% of FCHs manufacturers are interested in rethinking the design of their product in order to optimize the recycling and dismantling phases.
- ☐ 100% agree to standardize their fabrication process.

The design harmonization and standardization provides multiple benefits. It simplifies the dismantling and recycling process, consequently it reduces the costs. In addition, it helps improve the products' quality and durability.

3.1.6 Regulations

As reported in previous deliverables, some current Directives about end-of-life include FCHs products or have to be taken into account with a FCH system, but the creation of a more detailed FCH relevant regulation is needed due to the lack of specific legislations. 50% of the manufacturers questioned are not aware of European and national legislations as regards FCH technologies and their recovery. This fact reflects a lack of awareness in relation to as regards the European framework.

The manufacturers follow specific ISO regulations in the manufacturing process as ISO 22734-1:2008 (defines the construction, safety and performance requirements of packaged or factory matched hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyze water to produce hydrogen and oxygen gas).In parallel also specific directives on components are followed:

- PED (Pressure Equipment Directive 97/23/EC).
- ATEX (Directive 94/9/EC concerning equipment and protective systems intended for use in potentially explosive atmosphere).
- LV (Low Voltage Directive 2014/35/EU related to protection of electrical equipment).

As it was proposed in the deliverable 2.3 *Regulation framework analysis and barriers identifications* [2], the idea of organizing working group to think about regulations concerning recovery and dismantling FCH technologies was proposed to the manufacturers considered.

As an answer, 75% of the manufacturers questioned are interested in participating in this working group, useful to discuss and define new end-of-life regulations. This is a quite positive fact that illustrates the manufacturers' involvement.

3.2 Recycling centers

The questionnaire was divided into 3 topics (see Annex II_Survey for recycling centers):

- General information.
- FCH recycling technologies.
- Regulations.

3.2.1 General information

The table below reports the five European recycling centers and one association that have answered the questionnaire, their main activities, location and the dimension (also figure 10):

Location	Main Activity	Number of employees
Spain	Industrial waste Hazardous waste	0-50
Germany	Precious metal recycling	100-200
Spain	Spent batteries management and treatment	0-50
Switzerland	Industrial waste Plastic waste	0-50
France	Industrial waste Batteries	50-100
Belgium	Electronic devices Industrial waste Automotive catalysts, industrial catalysts	+200

Table 1. Recycling centres involved in the questionnaire.

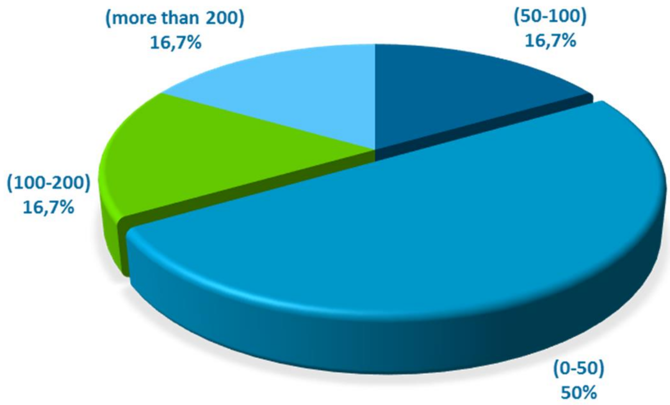

Figure 9. Recycling centres: number of employees' repartition.

3.2.2 FCH recycling technologies

The objective was to gather information about the knowledge on hydrogen technologies. The proposed questions are useful in order to see if Recycling Centers (RCs) have the suitable technology for the FCH recovery at end of life, if there is interest and therefore also the willingness to invest on FCHs recycling and recovery, if there is a particular reluctance to deal with FCH end-of-life systems.

Mainly for RCs have already treated with FCHs, it has been asked which FCHs' type they have worked, from which manufacturers, what processes have been followed and whether specific difficulties have been experienced.

In addition, as many recycling centers are concerned with the recovery of precious metal from automobile sector, it is also possible to understand what are the quantities limit of Pt per cells economically advantageous in order to recover Platinum.

The survey analysis reports:

- ☐ 50% of the Recycling Centers (RC) have the technology required for FCH's recovery.
- ☐ 60% think about investing in technology for recycling FCH.
- ☐ Whereas, for the other 40%, it will depend on the market potential and the method employed.
- ☐ 84% of RC questioned have no reluctance in treating any material that composed FCH technologies.
- ☐ 40% thinks that the components should be distributed between specialized centers.

According to the RC questioned, the costs, the amount of material to treat in order to reach a sufficient plant size for profitability and the lack of logistics in place nowadays are factors that could prevent the recycling of FCH technologies. The cost for the treatment compare to the materials' value inside is one barrier for recycling FCH technologies. However, finding out another second application able to deal with whole or part of FCHs equipment could be one way for preventing the recycling.

According to one RC, for a shipment of 20 cells the break-even Pt content is about 10g/cell; for a shipment of only 5 cells, the break-even Pt content is about 40g/cell. This is at today's metal prices.

Only one RC has already treated FCH technologies for a PEMFC manufacturer and it did not face any specific difficulty, with integrated smelting-refining.

3.2.3 Regulations

In this section, RC expressed their needs and worries concerning regulations of FCH technologies' end-of-life. **They are unanimous: a clear regulation is needed.** Up to now, end-of-life bureaucracy complexity depends on the country. As a result, it generates great differences inside the EU.

100% are interested on a "convention" instituted between recycling centers and manufacturers. This agreement would assure the manufacturer to buy the recycled material.

3.3 End-users

The questionnaire was divided into 3 topics (see Annex III_Survey for end users):

- General information.
- End of life FCHs.
- Regulations.

3.3.1 General information

13 FCH end-users were contacted for this survey; 7 of them agreed to answer the questionnaire. Table 2 gives a description of their location, number of employees and activities.

Location	Main Activity	Number of employees
Germany	Energy: combined heat and power generation (CHP)	0-50
Switzerland	Energy: CHP	
Denmark	Energy: Renewables (mainly wind)	+200
Denmark	Transport Energy: CHP	0-50
France	Transport Industries Energy: CHP and injecting H in gas grid	+200
France	Transport Energy: CHP and injecting H in gas grid	100-200
Germany	Energy: CHP	100-200

Table 2. End-users who answered the questionnaire.

Main end users' areas of activity: some end-users contacted work on multisector (industries, energy, transport), 86% in Energy Sector (CHP).
According to end-users' answers, energy is the most represented field, especially CHP. Then transport appears like the second main activity for end-users.
FCH technologies' end-users are usually big groups of energy or transport fields, as a result, the number of employees is quite important.

3.3.2 End-of-life strategy

The way to collect end-of-life FCH technologies is important as regards logistics issues. According to their responses to the questionnaire, most of them (84%) do not return them to manufacturers and 43% return them to recycling centers. Different strategies are set up:

- ☐ Partly treated as normal industrial waste by craftsmen.
- ☐ Partly, transport back to the company for treatment and analysis followed by professional disposal via expert companies also involved in recycling.

67% of end-users interviewed have starting to analyze end-of-life of the products, but they consider essential to analyze the extent to which system lifetime (max. linked to stack lifetime) is profitable, in order to have a good estimation of the minimum quantity of platinum per cell to reach rent-ability. Here above the explanation given to this statement:

"1. We are currently manufacturing in small volumes and plan a significant increase in the next years. If we achieve the planned 40 000 h stack lifetime and planned 15 years system lifetime, reuse does currently not make sense, because recycled components will always be < 10 % of totally produced volume.

2. We expect significant changes and improvements in the next 5 years in our technology. Therefore, a stack will at its EoL (i.e. after 40 000 h) be of a very status of technology and no one would like to buy a refurbished stack such an old version anymore. It's like a recycled mobile phone or television after 5 years. Therefore, one would have to go via the raw materials, where the suppliers say, that it does not make sense for them yet, as the raw materials are abundant and cheap and volumes are small, yet."

This statement raises numerous issues:

- The economic viability of FCH recycling and dismantling.
- The use of critical materials.

The other expectation as regards end-of-life deals with the recovery of precious metal from the product that is then recycled into a new product: "*Recycling of precious metals like Pt is an important factor to keep the cost low and guarantee availability when lager volumes are being sold. Furthermore the product itself needs to be designed in a way that a proper recycling of all material is provided for*".

The logistics behind such a process for the industry (e.g. critical volumes) is certainly key to the success of a recycling strategy.

3.3.3 Regulations

End-users' awareness concerning regulation seems more mitigated. As well as they will to collaborate with recycling centers.

Thus, it brings to light the lack of information about European and national regulations over FCH technologies.

3.4 Distributors

Distributors and logistics companies were the most difficult stakeholders to get in touch with. Different approaches were set up and are following. The questionnaire was divided into 3 topics (see Annex IV_Survey for distributors):

- General information.
- Fuel Cell and Hydrogen technologies concerns.

- Reverse logistics.

The activity is ongoing and in the next months, the main work will be to reach most of distributors and logistic companies (through direct FCHs actors contacts) and adapting and implementing the questionnaire in order to collect the most available information. The results will be present during the 2nd workshop and in the next D5.2 Report on feedback to new technologies and strategies and focus of new business model from FCH actors.

3.5 Preliminary conclusions

The survey's first objective was to collect requirement and worries from FCH lifetime actors as regards FCH end-of-life. However, it was not the only goal to reach. Calls and e-mail sent were also dedicated to maximizing the interest of FCH technology actors to end-of-life issue and spread information about the project and his first results. The questionnaire dissemination was a quite long process. Indeed, FCH actors' interest is not easy to catch. For most of them, FCH end-of-life issue is not on their top priority yet.

On the other hand, part of the actors contacted for the questionnaire are interested in the project. In addition, a great involvement can be perceived from them. Nevertheless, some sensible information was quite hard to obtain -such as questions related to LCA, and in particular the list of all materials used in the product with their masses. Indeed, this last question often falls within the sphere of confidentiality.

Despite it will not be an easy process, this survey makes clear that the FCH actors would be prone to collaborate so as to handle end-of-life issues. They are for most interested in joining a working group in order to discuss dismantling and recycling strategies. Even if the number of organizations interviewed is limited, it still reflects the will of the main FCH actors for the companies near to the market have given their opinion.

4. Information collected during the workshop and through a second questionnaire

The first workshop organized the 26th of September in Brussels was a successful and learning day.

Figure 10. First HYTECHCYCLING WORKSHOP at FCH-JU headquarter.

Figure 11. First HYTECHCYCLING WORKSHOP at FCH-JU headquarter.

There were also relevant industry partners present at the WS highly interested on the project, on his results and willing to collaborate. Their attendance was mostly due to the interest the project represent for them, they wanted to know what we are working on. HyTechCycling is a pilot project in the field of hydrogen technologies recycling phase and there are great expectations on one side and huge responsibility on other hands for all partners included.

The FCH actors' answers provide some interesting directions and perspectives for the progress of this project. A follow up questionnaire was sent to the participant of the workshop in order to collect additional and more specific feedbacks (Annex V_WS additional questions). As a result of these activities, it was possible to collect important information from the stakeholders, in particular some expectations as regards the regulations, the business models and their worries concerning FCH end-of-life are summarized in this section.

Limitations for the business model of the recycling of FCH technologies:

- ☐ Need of Cooperation between manufacturers and waste separation companies. The clearer and more transparent the material is engineered and developed – taking into account its complete life cycle and thus its recycling as well – the better it is for all actors involved in recycling. The recycled material will be according to the usual recovery chain reclaimed and re-sold (LME etc.). A direct link between recyclers and manufacturers does not exist, this could be achieved through organisation of regular meetings, once or twice a year, where different actors of the industry talk to each other, present novelties, exchange useful data.
- ☐ Complexity in reuse some materials: RCs always give the materials back to producers, due to the regulation (at least in some European countries, like Spain), is very difficult. The FCHs must be classified as "non-waste" and, this is almost impossible to ask for, due to the different legal and administrative procedures in each country.
- ☐ Technology and specific materials needed for the stack and other BoP components.
- ☐ The lack of logistics. Logistics is paramount to the entire process. In the recycling industry profitability above all ensures the existence of a well-structured chain, where collection, transport and recovery of end of life products are justified since – behind the obvious environmental friendly goal – profit and social wellbeing are generated.
- ☐ Need to find another second application able to deal with whole or parts of the FCH equipment's.
- ☐ At the moment, the critical mass of material to be recycled is not reached in order justify adequate capacity of the recycling plant and guarantee profitability for the recycling business.

Concerns related to regulations

- ☐ Transboundary waste movements.
- ☐ Harmonisation of waste regulation in EU countries. Clarification of the "waste" and "end of waste" status and its harmonisation within different countries it is necessary to develop the market. Once a material, device, etc is classified as waste, before being use as "raw material" again, it has to be declassified as a waste. Depending on the country, this step could be not possible.
- ☐ A clarification on the treatment of residues.

Proposal to address barriers and develop the recycling potential

- ☐ Interested in an "agreement" between manufacturers and recycling centres to assure manufacturers to buy the recycling materials and reuse it.
- ☐ Rethink the design of the product to optimize the recycling and dismantling phases.
- ☐ A harmonization in FCH fabrication process.

- ☐ Involve all relevant actors in working group which aim is to envision potential strategies and shape regulative proposals concerning recovery and dismantling of FCH technologies.
- ☐ Investment amount will depend on the market.
- ☐ Engagement of the end users: approving an appropriate European legislative frame, creating friendly patterns to enable contact, communication and delivery to recycling centres, monitoring processes attentively. The idea of a small bonus for end users should be double-checked in order to incentivize the active participation of some of the stakeholders, as end users.

5. Conclusions and next steps

This preliminary analysis allowed to meet some of the top players in the Hydrogen and Fuel Cell sector. The interest shown up to now has been high; a sign that despite being still a sector with some obstacles, the major FCH stakeholders are attentive and ready for a new phase.

This new phase is necessary starting from agreements and collaborations, more implemented between FCH manufacturers and recycling centers, trying to re-define design according to process and product optimization specifications, reducing the use of specific materials. In end-of-life management, FCHs providers have to focus on waste management strategies stemming from the stack, in order to implement and make easier recycling processes in the short term. This will lead to greater environmental awareness and will allow developing a sensitivity to the product.

A strict involvement of end users and logistic/distribution companies is necessary in order to implement new strategies for recycling and dismantling.

The cooperation between all the actors is indeed necessary, as we have seen so far on several fronts:

- Cooperation in specific FCH regulations
- Cooperation in Eco-design and harmonization in FCH fabrication process
- Cooperation in implementation of new strategies and technologies in recycling and dismantling phase.

The objective of the next activities will be to gather more information also involving logistics companies and gathering more feedback on new technologies and strategies, focusing on a new business concept and model.

6. References

[1] A. Lotrič, M. Sekavčnik, B. Jurjevčič, M. Drobnič, M. Mori, and R. Stropnik, "Deliverable 2.1 Assessment of critical materials and components in FCH technologies"

[2] A. Valente, M. Martín-Gamboa, D. Iribarren, J. Dufou, "Deliverable 2.2 Existing end-of-life technologies applicable to FCH products"

[3] Mori M, Stropnik R., Lotrič A.., Drobnič B., Sekavčnik M., "D4.1 LCA approach in the end of life cycle of FCH technologies"

[4] S. Fiorot, F. Cartasegna, L. Castrillo, D. Iribarren, "D 2.3 Regulation framework analysis and barriers identifications"

Annex I_ Survey Manufacturers

HyTechCycling: questionnaire for manufacturers

Fuel cells and hydrogen technologies are on the brick of having an important growth worldwide for they offer low level of emissions, high conversion efficiency, flexibility and silent operation. In Japan, FCE Vehicles have already conquered the mass market and it is spreading to many other countries such as Korea, China, Germany and the USA.

Nevertheless, it remains some points that need clarifications that the European HyTechCycling project aims to bring to light. New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and dismantling are being developed to help you – as manufacturers facing the issues of End-of-Life FCH technologies. As a result, by filling this present questionnaire, you can contribute in these advances and you will be able to benefit from the deliverables and the business models that the project aims to deliver.

*Required

Company information

1. **Name of the company** *

____

2. **Location** *

____

3. **Main Activity** *

Tick all that apply.

- [ ] PEFC
- [ ] DMFC
- [ ] AFC
- [ ] PAFC
- [ ] MCFC
- [ ] SOFC
- [ ] AWE
- [ ] PEMWE
- [ ] SOEC
- [ ] Other: ______________________

4. **Number of employees** *

Mark only one oval.

- ( ) 0-50
- ( ) 50-100
- ( ) 100-200
- ( ) +200
- ( ) Other: ______________________

Your product

5. **Quantity of platinum group materials present in FCHs' components? (g/kW)** *

6. **What hazardous material is present in FCHs' components? Quantity?** *

7. **How do you track your products?** *
Mark only one oval.
   - QR code
   - Barcode
   - Other:

8. **Are the BoP components manufactured by your company?** *
Mark only one oval.
   - Yes
   - No
   - Other:

LIFE CYCLE ASSESSMENT

Manufacturing stage

9. **List of all materials used in the product with masses of used materials (at least approx. values if there is not exact data)** *

10. **What is your energy consumption (electricity, fuels, heat) in manufacturing stage of the product ?** *

11. **What are the possible emissions to air, water, soil as a result of maintenance of manufacturing line ?** *

12. **What kind of wastes result in manufacturing phase ?** *

Operation stage

13. **What type of energy is needed for the operation stage ?** *

Tick all that apply.

- [ ] fuel
- [ ] electricity
- [ ] Other:

14. **Other materials needed for operation (water, etc...) with masses ?** *

15. **What is the energy efficiency at different operating regimes ?** *

16. **What are the possible emissions to air, soil, water as a result of operation stage ?** *

Recycling/Remanufacturing process

17. **In your point of view, what will prevent the recycling of FCH technologies (limitations for the business model)?** *

18. **Interested in reusing recycled materials (bought FCH components/materials to the recycling centers)?** *

Mark only one oval.

- Yes
- No
- Other:

Eco-design

19. **have you reduced the quantity of hazardous materials?** *

Mark only one oval.

- Yes
- No

20. **How much ?** *

21. **Would you be interested in rethinking the design of your products in order to optimized the recycling and disassembling phases?** *

Mark only one oval.

- Yes
- No
- Other:

22. *Mark only one oval.*

- Option 1

23. **Would you be interested in a harmonization in FCH technologies' fabrication process? (in order to facilitate the recovery process)** *

Mark only one oval.

- Yes
- No
- Other: ____________

Regulations

24. **Are you aware of European and national legislations as regards FCH technologies and their recovery?** *

Mark only one oval.

- Yes
- No
- Other: ____________

25. **Do you have any agreement with recycling centers?** *

Mark only one oval.

- Yes
- No
- Thinking about it
- Other: ____________

26. **Are you following some specific regulations in the manufacturing process?** *

Mark only one oval.

- Yes
- No
- Other: ____________

27. **Exemples ?**

____
____
____
____
____

28. **Would you be interested if a « convention » is instituted between recycling centers and manufacturers to assure the manufacturer to buy the recycled materials?** *

Mark only one oval.

- Yes
- No
- Other: ____________

29. **Would you be interested in participating in a working group to think about regulations concerning recovery and dismantling of FCH technologies?** *

Mark only one oval.

- Yes
- No
- Maybe
- Other: ____________

Distributors

30. **Do you have any distributors? (Please give us some contacts)** *

31. **Raw materials distributors?**

32. **Final product distributors ?**

Clients

33. **In which sector are your clients ?** *

Tick all that apply.

- [ ] Transpor
- [ ] Energy
- [ ] Industry
- [ ] Other: ____________

34. **Could you share some contacts ?**

Workshop

35. **Would you be interested in participating to a workshop with other manufacturers, recycling centers, FCH technologies end-users and some distributors ?** *

Mark only one oval.

- ◯ Yes, on Tuesday, September 26th in Brussels
- ◯ No
- ◯ Other: ______________________

Comments

36. **Feel free to add some comments, questions or suggestions !**

____
____
____
____
____

Thank you for your time !

Annex II_ Survey Recycling Centers

HyTechCycling: questionnaire

Fuel cell and hydrogen technologies are on the brick of having an important growth worldwide for they offer low level of emissions, high conversion efficiency, flexibility and silent operation. In Japan, FCE Vehicles have already conquered the mass market and it is spreading to Korea, China, Germany and the USA.

Nevertheless, it remains some points that need clarifications that the European HyTechCycling project aims to bring to light. New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and dismantling are being developed to help you – as recycling centers- face the issues of End-of-Life FCH technologies. As a result, by filling this present questionnaire, you can contribute in these advances.

*Required

Company information

1. **Name:** *

____

2. **Location:** *

____

3. **Main Activity** *

Tick all that apply.

- [ ] cars
- [ ] electronic devices
- [ ] industrial waste
- [ ] Other: _______________

4. **Number of employees** *

Mark only one oval.

- ( ) 0-50
- ( ) 50-100
- ( ) 100-200
- ( ) +200

FCH Technologies

5. **Do you have the technology required for Fuel Cells & Hydrogen technologies' recovery?** *
Mark only one oval.

   - Yes
   - No

6. **Do you think about investing in technology for recycling FCH?** *
Mark only one oval.

   - Yes
   - No
   - Other: ____________________

7. **How much will it cost? / How much are you ready to invest?** *

   ____

8. **Should the components be distributed between specialized centers?** *
Mark only one oval.

   - Yes
   - No
   - Other: ____________________

9. **Do you have any reluctance in treating any material that composed FCH technologies?** *
Mark only one oval.

   - yes
   - no
   - Other: ____________________

10. **What will prevent the recycling of FCH technologies (limitations for the business model) ?** *

   ____
   ____
   ____
   ____
   ____

11. **What are the quantity limit of Pt/cells from which it is economically viable for you to treat FCH technologies ?** *

   ____

12. **Are you used to treat BoP components (i.e. compressors, humidifiers, electrical and electronic components, valves and piping) ?** *

Mark only one oval.

- Yes
- No
- Other: ______________________

13. **Have you ever treated any FCH technology?** *

Mark only one oval.

- Yes
- No
- Other: ______________________

14. **Which type ?**

Mark only one oval.

- PEFC
- DMFC
- AFC
- PAFC
- MCFC
- SOFC
- AWE
- PMWE
- SOEC
- Other: ______________________

15. **From which manufacturer ?**

____

16. **Process followed ?**

____
____
____
____
____

17. **Any specific difficulty ?**

Mark only one oval.

- yes
- no

18. **Examples:**

Regulations

19. **What are your needs/worries concerning regulations of FCH technologies' End-of-Life?** *

20. **Are you aware of European and national regulations on FCH technologies?** *
Mark only one oval.

- yes
- no
- Other:

21. **Would be interested by these following reports?** *
Tick all that apply.

- « Assessment of critical materials and components identification of FCH technologies and mapping of recycling technologies »
- « Existing EoL technologies applicable to FCH products"
- No

22. **Would you be interested if a « convention » is instituted between recycling centers and manufacturers to assure the manufacturer to buy the recycled materials?** *
Mark only one oval.

- Yes
- No
- Other:

Workshop

23. **Would you be interested by participating to a workshop that will gather many european recycling centers, FCH manufacturers, end-users and distributors ?** *
Mark only one oval.

- Yes, on Tuesday, September 26th in Brussels
- No

Comments

24. **Do you have any comments, suggestions, questions ?**

____

____

____

____

____

Annex III_ Survey End-users

Questionnaire for end users

Fuel cell and hydrogen technologies are on the brick of having an important growth worldwide for they offer low level of emissions, high conversion efficiency, flexibility and silent operation. In Japan, FCE Vehicles have already conquered the mass market and it is spreading to Korea, China, Germany and the USA.

Nevertheless, it remains some points that need clarifications that the European HyTechCycling project aims to bring to light. New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and dismantling are being developed to help face the issues of End-of-Life FCH technologies. As a result, by filling this present questionnaire, you can contribute in these advances.

*Required

Company information

1. **Name of the company** *

____

2. **Location (Town, COUNTRY)** *

____

3. **Main activity** *

Tick all that apply.

- [ ] Transports
- [ ] Industries
- [ ] Energy: CHP
- [ ] Energy: Injecting H in gas grid
- [ ] Other: ________________________

4. **Number of employees** *

Mark only one oval.

- ( ) 0-50
- ( ) 50-100
- ( ) 100-200
- ( ) + 200
- ( ) Other: ________________________

Suppliers

5. **How many suppliers do you have ?** *
Mark only one oval.

- ⬭ 0-5
- ⬭ 5-10
- ⬭ 10-15
- ⬭ 15-20
- ⬭ +20

End-of-Life Fuel Cells and Hydrogen technologies

6. **How do you collect end-of-life FCH technologies ?** *

____
____
____
____
____

7. **Do you return them to their manufacturer ?** *
Mark only one oval.

- ⬭ Yes
- ⬭ No

8. **Do you return them to recycling centers ?**
Mark only one oval.

- ⬭ Yes
- ⬭ No

9. **Are you thinking about End-of-Life products ? (business model)** *
Mark only one oval.

- ⬭ Yes
- ⬭ No

Regulations

10. **Are you aware of European and national legislations as regards FCH technologies and their recovery ?** *
Mark only one oval.

- ⬭ Yes
- ⬭ No

11. **Do you have any agreement with recycling centers?** *

Mark only one oval.

- Yes
- No

12. **Are you tinking about it ?** *

Mark only one oval.

- Yes
- No

13. **What are your expectations as regards a business model in the recovery of your product ?** *

14. **Do you have any concerns as regards FCH end-of-life ?** *

15. **Would you be interested by these following reports ?** *

Tick all that apply.

- [ ] Assessment of critical materials and components in FCH technologies
- [ ] Existing end-of-life technologies applicable to FCH products
- [ ] No

Workshop

16. **Would you be interested in participating to a workshop with other manufacturers, recycling centers, FCH technologies end-users and some distributors ?** *

Mark only one oval.

- Yes, in Bruxelles on Tuesday, September 26th
- No

Comments

17. **Please feel free to add any suggestion or comment:**

Thank you for your time !

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Annex IV_ Survey Distributors

HyTechCycling: questionnaire for distributors

Fuel cell and hydrogen technologies are on the brick of having an important growth worldwide for they offer low level of emissions, high conversion efficiency, flexibility and silent operation. In Japan, FCE Vehicles have already conquered the mass market and it is spreading to Korea, China, Germany and the USA.

Nevertheless, it remains some points that need clarifications that the European HyTechCycling project aims to bring to light. New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and dismantling are being developed to help face the issues of End-of-Life FCH technologies. As a result, by filling this present questionnaire, you can contribute in these advances.

*Required

Company information

1. **Mail address:** *

2. **Name of the company:** *

3. **Location:** *

4. **Main activity:** *

5. **Number of employees** *

Mark only one oval.

- 0-50
- 50-100
- 100-200
- +200

Fuel Cell and Hydrogen technologies :

6. **Do you have any concerns or worries about FCH technologies' recycling and dismantling ? ***

Reverse logistics :

7. **Would you be interested in planning a return flow of end-of-life products from end-users to manufacturers ? ***

   Mark only one oval.

   - Yes
   - No
   - Other:

8. **Do you have a special request about FCH technologies' logistic ? ***

Workshop

9. **Would you be interested in participating in a workshop in Brussels on September, 26th ? ***

   Mark only one oval.

   - Yes
   - No

Comments :

10. **If you have any comments or suggestions, do not hesitate:**


info@hytechcycling.eu
Workshop
26TH OF SEPTEMBER • BRUSSELS
Participation of FCH:
Manufacturers, Recycling Centers, End-users, Distributors
To discuss FCH end-of-life strategy
HyTechCycling

Annex V_ WS additional questions

WS questions for FCH technology lifetime actors

1. How could the communication network among the different companies related with the FCH technologies life be improved?

2. Do the recycling centers need more information, more help, to facilitate their part of the job? Do the recycling centers offer the recycling material to the manufacturing companies?

3. Is it possible to reuse any piece from the BoP? If yes, is it being done? Why is not being done if it is possible to reuse some pieces?

4. Do the manufacturers need any kind of quality controls or guarantees to use recycled materials?

5. How can end users be introduced in the recycling network? How to facilitate their interaction?

6. What is your opinion about logistics related with this issue? Is there any kind of past experience that you think it could be useful in a situation like this one, where there is neither a responsible nor a defined chain of actions?

7. Interested in being involve in a working group to think about business models, regulations etc.?

8. Which is the role of end users and how to boost an active participation and how are they going to be engaged in a business model?

9. Why, from your experienced point of view, could it be valuable a business model?

Annex VI_ppts 1° WS

HyTechCycling

Workshop Programme

FCH END-OF LIFE

26th September
FCH JU headquarter, White Atrium building, Common Meeting Room 1
Avenue de la Toison d'Or 56-60
1060 Brussels, Belgium

9:00 -9:30

Welcome coffee and registration

9:30 - 9:50

General presentation of the project. - **FHA**

9:50 - 10:10

Results from "Assessment of critical materials and components in FCH technologies" and discussion with the stakeholders.- **UL**

10:10 – 10:30

Results from "Existing recycling technologies applicable to FCH products" and discussion with the stakeholders - **IMDEA Energy**

10:30 – 10:50

Results from "Regulatory Framework analysis and barriers identifications" - **EnviPark**

10:50 – 11:00

Questions and/or comments

11:00 – 11:30

Coffee break

11:30 – 11:50

Results from "Recommendations and perspective on EU regulatory framework" and discussion with the stakeholders. - **EnviPark**

11:50 – 12:10

Results from "Needs and challenges in the phase of recycling and dismantling" and discussion with the stakeholders - **FHA**

12:30 – 12:50

Analysis of the first results of the questionnaires to FCH manufacturers, recycling centers, distributors and end users - **EnviPark**

12:50 – 13:10

FCH lifetime actors' needs as regards business model. **FHA introduces the discussions and invites actors to give their opinion.**

13:10 – 13:30

Conclusionsthe discussions and invites actors to give their opinion

HYTECHCYCLING project introduction

Workshop

Brussels, 26th of September 2017

Summary

Å Nowadays, the development of the FCH technologies does not take into account their **recycling and dismantling**, nor their possible re-uses inside a future context of commercialization.

Å Some **critical materials** that are used are:

- o PEMFC and PEMWE: **Platinum group materials as Iridium, Platinum or Ruthenium.**
- o SOFC: **Rare-Earth compounds as Lanthanum and Yttrium**.
- o Alkaline electrolysers: **Platinum** and **Asbestos**

Å A lack of strategies around the End of Life of this technologies exists. There is also an absence in the reuse of this products.

Å There is a market for business models derivate from material saving and recycled raw materials.

University of Ljubljana

Objectives

HyTechCycling project has as objective preceed the implementation of the technologies, facilitating the development of future actions and avoiding problems related to the implementation and regulatory framework in the recycling and dismantling of the FCH technologies, including both the electrolysis production systems from renewables resources and their use as fuel cells integrated in their different applications.

FOUNDATION FOR THE DEVOLOPMENT OF NEW HYDROGEN TECHNOLOGIES IN ARAGON

University of Ljubljana

ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

HyTechCycling in numbers

5 European partners

3 years long

0,5 M€

Topic **FCH-04.1-2015 Recycling and Dismantling Strategies for FCH Technologies**, in the frame of the **Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU)**

Partners

FOUNDATION FOR THE DEVOLOPMENT OF NEW HYDROGEN TECHNOLOGIES IN ARAGON

University of Ljubljana

institute imdea energy

GRUPO LÓPEZ SORIANO

ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

Work Packages

WP 1. Project Management & Coordination.

WP 2. Regulatory analysis, critical materials and components identification and mapping of recycling technologies.

WP 3. New strategies and technologies.

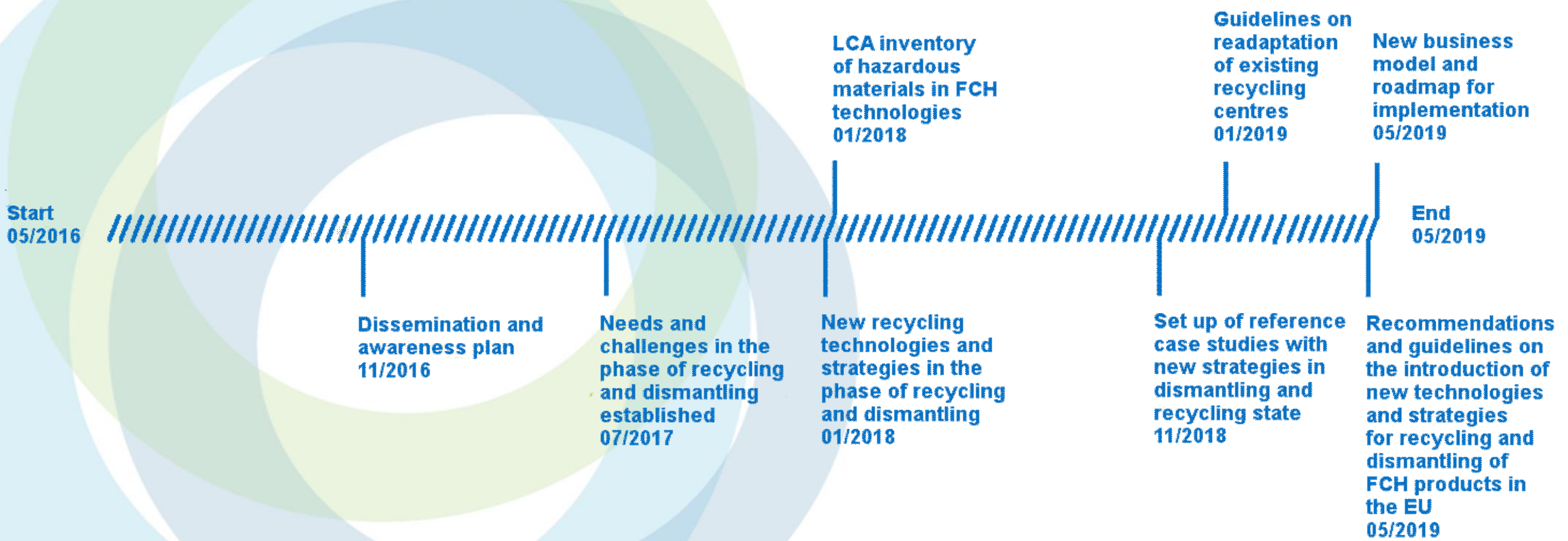
WP 4. LCA for FCH technologies considering new strategies & technologies in the phase of recycling and dismantling.

WP 5. Harmonization of procedures considering all actors involved in lifetime of FCH products.

WP 6. New business model and implementation roadmap.

WP 7. Dissemination & Exploitation.

Project milestones



University of Ljubljana

FOUNDATION FOR THE DEVOLOPMENT OF NEW HYDROGEN TECHNOLOGIES IN ARAGON

ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

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

HyTechCycling

Thank you for your attention.

More info:
www.hytechcycling.eu

FCH JU Workshop, 26 September 2017, Brussels, Belgium

HyTechCycling

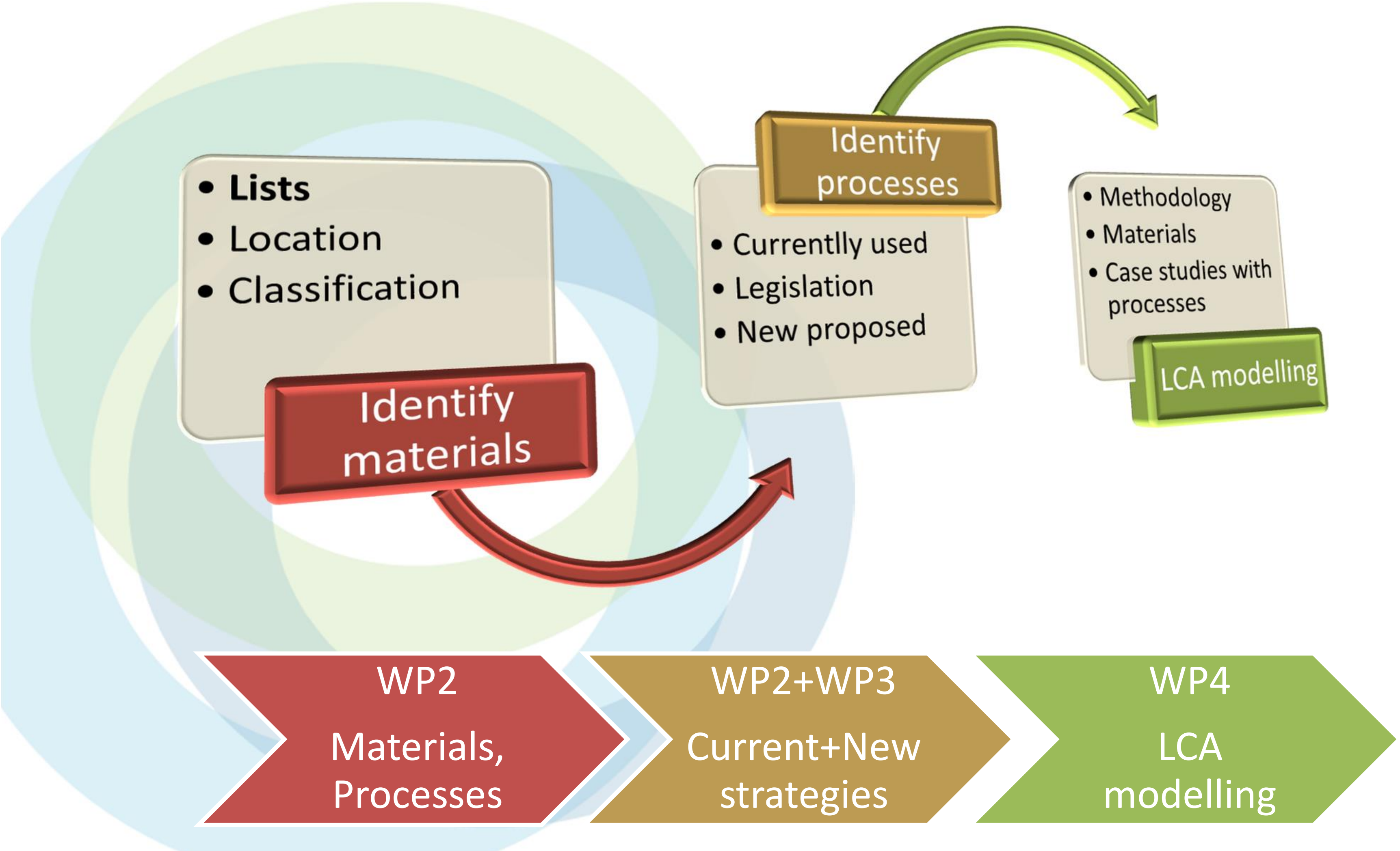
ASSESSMENT OF CRITICAL MATERIALS AND COMPONENTS IN FCH TECHNOLOGIES TO IMPROVE LCIA IN END OF LIFE STRATEGY

Andrej Lotrič [a], Rok Stropnik [a], Boštjan Drobnič [a], Boštjan Jurjevčič [a], Mihael Sekavčnik [a], Ana María Férriz Quílez [b] Mitja Mori [a]

[a] University of Ljubljana, Faculty of Mechanical Engineering, Aškerčeva 6, SI-1000, Ljubljana , Slovenia

[b] Aragon Hydrogen Foundation, Parque tecnológico Walqa, Ctra. N-330a, Km. 566, 22197 Huesca, Spain

Put the task into prospective



University of Ljubljana

FOUNDATION FOR THE DEVOLOPMENT OF NEW HYDROGEN TECHNOLOGIES IN ARAGON

HyTechCycling

Motivation and objectives

Motivation

Resons for low level of commercialization of Fuel Cells and hydrogen technologies (FCH) is among all the **recycling and dismantling stage**:

Å no **uniform lists** of critical materials

Å no **established pathways** for recycling processes

Å incomplete **legislation**, lack of uniform guidelines and directives

Objectives of the task and beyond

Å Assess the **criticality of materials** used in core components of the FCH technologies under consideration (AWE, PEMWE, PEMFC, SOFC).

Å Form **a list of relevant materials** that will serve as an input for Life Cycle Assessment (LCIA table in LCA).

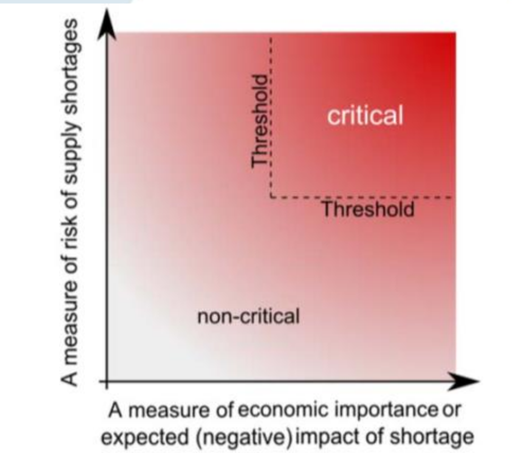
Å To **link** the materials and processes lists to LCA modelling stage

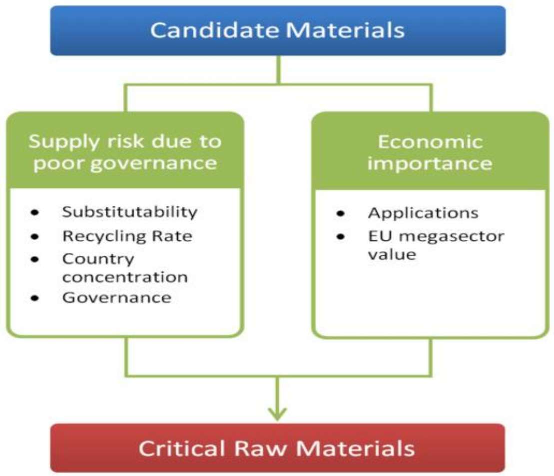
HyTechCycling

Methodology

Three main criteria were defined to obtain list of critical materials:

1. **Hazardousness** ï Material properties that make it dangerous, or capable of having a harmful effect, to human health or the environment [1], [2].
2. **Scarcity or criticality** - The **EU Criticality methodology** [3] is a combination of two assessment components:
   - Å Economic importance or expected (negative) impact of shortage,
   - Å Risk of supply or poor governance.





[1] Agency for Toxic Substances and Disease Registry (ATSDR): Methodology Used to Establish Toxicity/Environmental Scores for the Substance Priority List.
[2] W. M. Liu J, Goyer RA, "Toxic effects of metals.," in Casarett and Doull's toxicology: the basic science of poisons., 2008, pp. 931–979.
[3] European Commission, "Report on critical raw materials for the EU: Report of the Ad hoc Working Group on defining critical raw materials," 2014.

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HyTechCycling

Methodology

Three main criteria were defined to obtain list of critical materials:

1. **Hazardousness** ï Material properties that make it dangerous, or capable of having a harmful effect, to human health or the environment [1], [2].
2. **Scarcity or criticality** - The **EU criticality methodology** [3]. Results of 20 EU critical raw materials:

Antimony	Beryllium	Borates	Chromium	Cobalt	Coking coal	Fluorspar
Gallium	Germanium	Indium	Magnesite	Magnesium	Natural Graphite	Niobium
PGMs	Phosphate Rock	REEs (Heavy)	REEs (Light)	Silicon Metal	Tungsten	

EU-20 critical raw materials.

3. **Price** - Prices of elements and their compounds list was estimated from actual price on the market.

[1] Agency for Toxic Substances and Disease Registry (ATSDR): Methodology Used to Establish Toxicity/Environmental Scores for the Substance Priority List.
[2] W. M. Liu J, Goyer RA, "Toxic effects of metals.," in Casarett and Doull's toxicology: the basic science of poisons., 2008, pp. 931–979.
[3] European Commission, "Report on critical raw materials for the EU: Report of the Ad hoc Working Group on defining critical raw materials," 2014.

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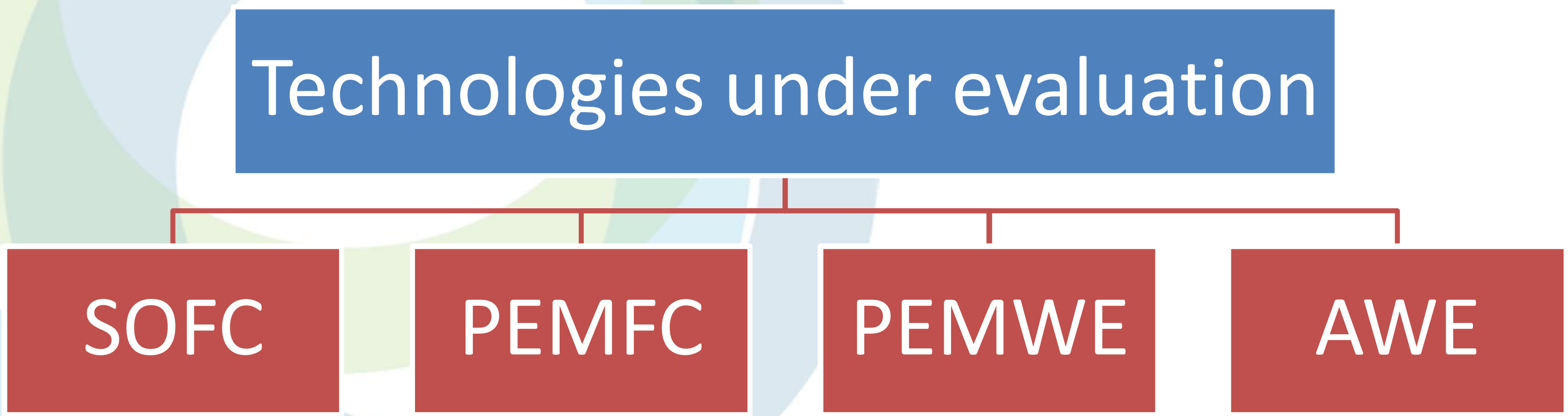
List of critical materials - BoP

Å FCH technologies under evaluation are broken down to their **core components**.
Å Materials are compared according to **function** (or location) in the core components, **environmental aspects**, **costs**, **criticality**.
Å **Balance-of-Plant (BoP) components** are also included since their impact on the environment could prove to be non-negligible (i.e. due to their bigger mass).

BoP components	Main Materials
Blower or compressor	Metals, plastics
Humidification membrane	Metals, plastics, polymers
Pumps	Metals, Teflon, rubbers, plastics
Regulators	Metals, plastics, rubbers
PCBs	Metals, plastics, semiconductors, precious metals
Power conditioning system	Metals, plastics, semiconductors, precious metals
Deionising filter	Metals, plastics, resins
Pipes	Metals, plastics, rubbers
Valves	Metals, plastics, nylon, Teflon
Gaskets (piping system)	Paper, plastics, rubbers
Thermal insulation system	Mineral wool, fibreglass
Heat exchangers	Metals
Sensors	Plastics, precious metals, semiconductors, glass
Water condensers	Stainless steel

List of critical materials - Core

Materials are compared according to **function** (or location) in the core components, **environmental aspects**, **costs**, **criticality**.



List of critical materials - SOFC

Solid Oxide Fuel Cells (SOFC)

Component	Material	Material classification	Material value	Material Criticality
Electrolyte	Yttria-stabilised zirconia	Non-hazardous	Medium	High
Anode	Nickel-based oxide doped with YSZ	Hazardous (Cat. 1 carcinogen)	Medium	High
	Nickel	Hazardous (Cat. 1 carcinogen)	Medium	High
Cathode	Strontium-doped lanthanum manganite	Hazardous (Irritant)	Medium	High
Interconnect	Doped lanthanum chromate	Hazardous (Irritant, harmful)	Medium	Medium-High
	Inert metals/alloys	Non-hazardous	High	Medium-High
Sealant	Glass/Glass-ceramic	Non-hazardous	Low	Low
	Mineral	Non-hazardous	Low	Low
	Precious metals	Non-hazardous	High	High
Substrate	Ceramic	Non-hazardous	Low	Low

List of critical materials – PEMFC

Polymer Electrolyte Membrane Fuel Cell (PEMFC)

Component	Material	Material classification	Material value	Material Criticality
Electrolyte	Perfluorosulphonic acid (PFSA)	Non-hazardous	Medium	Medium
	Sulfonated polyether ether ketone (s-PEEK)	Non-hazardous	Medium	Low
	polystyrene sulfonic acid (PSSA)	Non-hazardous	Low	Medium
	polybenzimidazole (PBI) doped with H_3PO^4 *	Hazardous (corrosive)	Medium	Low
Anode and Cathode - GDL	Carbon cloth or paper treated with hydrophobic agent	Non-hazardous	Low	Low
	Metallic mesh or cloth (e.g. stainless steel)	Non-hazardous	Low	Low
Anode and Cathode (catalyst layer)	Platinum or Pt-alloys	Non-hazardous	High	High
	Catalyst support (carbon, metal oxides, carbides, etc.)	Non-hazardous	Medium	Low
Interconnect	Synthetic graphite or graphite composites	Non-hazardous	Low	Medium
	Stainless steel	Non-hazardous	Low	Low
Sealant	Thermoplastic	Non-hazardous	Low	Low
	Elastomer	Non-hazardous	Low	Low

* used only in HT PEMFC

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List of critical materials - PEMWE

Polymer Electrolyte Membrane Water Electrolyser (PEMWE)

Component	Material	Material classification	Material value	Material Criticality
Electrolyte	Perfluorosulphonic acid (PFSA)	Non-hazardous	Medium	Medium
	Sulfonated polyether ether ketone (s-PEEK)	Non-hazardous	Medium	Low
Catalyst layer - Cathode	Pt or Pt-alloys	Non-hazardous	High	High
Catalyst layer- Anode	Iridium and Ir-alloys	Hazardous (irritant, harmful)	High	High
	Ruthenium and Ru-alloys	Hazardous (toxic, carcinogen)	Medium	High
Anode and Cathode - GDL	Thermally sintered Ti	Non-hazardous	Low	Medium
	Ti or stainless steel mesh	Non-hazardous	Low	Medium
	Synthetic graphite or graphite composites (only possible on cathode side)	Non-hazardous	Low	Medium
Interconnect	Coated titanium or Ti-alloys	Non-hazardous	Low	Medium
Sealant	Thermoplastic	Non-hazardous	Low	Low
	Elastomer	Non-hazardous	Low	Low

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List of critical materials - AWE

Alkaline Water Electrolyser (AWE)

Component	Material	Material classification	Material value	Material Criticality
Electrolyte	Potassium Hydroxide	Hazardous (corrosive)	Medium	Low
Anode	Precious metals	Non-hazardous	High	High
	Plastic	Non-hazardous	Low	Low
Cathode	Raney-Nickel	Hazardous (carcinogen)	Medium	High
	Plastic	Non-hazardous	Low	Low
Interconnect	Plastic	Non-hazardous	Low	Low
Sealant	Thermoplastic	Non-hazardous	Low	Low
	Elastomer	Non-hazardous	Low	Low
Diaphragm (membrane)	Asbestos	Hazardous (carcinogen)*	Low	Low
	Polymers	Non-hazardous	Medium	Low

* only in older types of AWEs

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Most critical components

Type	Component	Material	Material classification	Material value	Material Criticality
SOFC	Electrolyte	Yttria-stabilised zirconia	Non-hazardous	Medium	High
	Anode	Nickel-based oxide doped with YSZ	Hazardous (Cat. 1 carcinogen)	Medium	High
		Nickel	Hazardous (Cat. 1 carcinogen)	Medium	High
	Cathode	Strontium-doped lanthanum manganite	Hazardous (Irritant)	Medium	High
	Interconnect	Doped lanthanum chromate	Hazardous (Irritant, harmful)	Medium	Medium-High
		Inert metals/alloys	Non-hazardous	High	Medium-High
	Sealant	Precious metals	Non-hazardous	High	High
AWE	Electrolyte	Potassium Hydroxide	Hazardous (corrosive)	Medium	Low
	Anode	Precious metals	Non-hazardous	High	High
	Cathode	Raney-Nickel	Hazardous (carcinogen)	Medium	High
PEMWE	Catalyst layer - Cathode	Pt or Pt-alloys	Non-hazardous	High	High
	Catalyst layer- Anode	Iridium and Ir-alloys	Hazardous (irritant, harmful)	High	High
		Ruthenium and Ru-alloys	Hazardous (toxic, carcinogen)	Medium	High
PEMFC	Catalyst layer	Platinum or Pt-alloys	Non-hazardous	High	High
	Interconnect	Graphite or graphite composites	Non-hazardous	Low	High

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Most critical components

Å SOFC: mainly consist from REE, which makes this FCH technology critical from the perspective of the EU states. Classified as rather costly and hazardous.

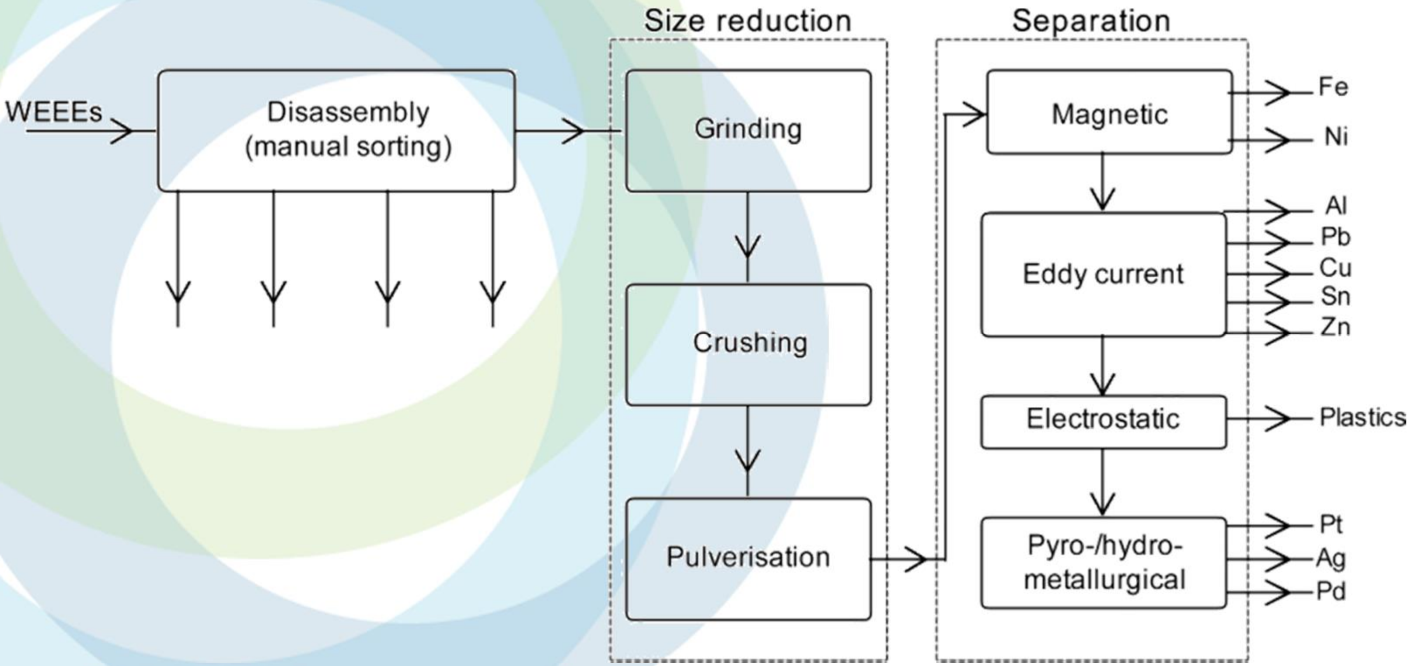
Å PEMFC: mainly low-to-medium in cost with the exception of Pt or Pt-alloy catalysts. Pt and graphite are classified as critical and semi-critical for the EU states. Majority of the materials classified as non-hazardous.

Å PEMWE: more expensive compared to those used in the PEMFCs. The OER catalysts are based on REE while the HER catalysts are based on Pt. These materials are classified as critical and high in costs. Mainly non-hazardous with the exception of the REE used for OER catalysts.

Å AWE: mainly low in costs with the exception of both the anode and the cathode catalysts, which are also classified as critical for the EU states. Classified as rather hazardous since the alkaline electrolyte in liquid form is used. Also, Ni-based catalyst and asbestos diaphragms, used in older types of AWEs, are classified as carcinogen.

End of Life strategies?

- The recovery of high-value and hazardous materials is a priority for the EoL strategies.



Common steps in EoL strategies (based on Waste electrical and electronical equipment).

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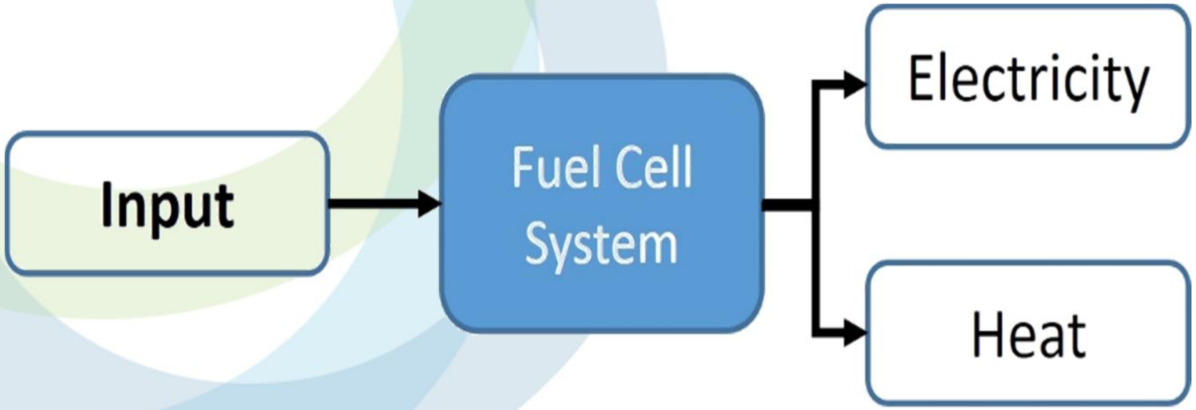
Life Cycle Assessment Approach

- **Scope**: cradle to grave LCA approach
- **Software:** Thinkstep Gabi version
- The ILCD characterisation factors of ILCD 1.0.8 2016 midpoint are used
- **Functional unit**: 1kWh of exergy.
- Multi functionality of the system



Sketch of a FC unit as a multi-functional process

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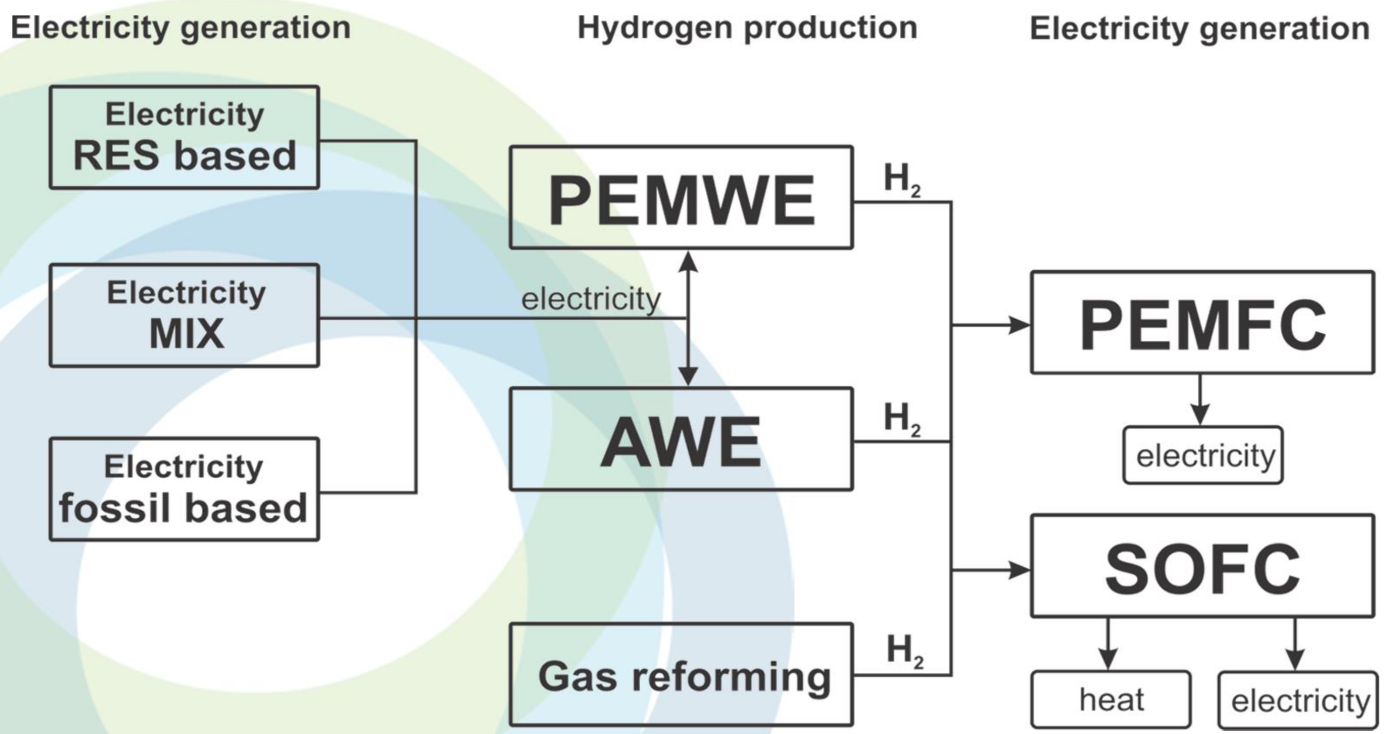
Life Cycle Assessment



The structure of the considered system with all considered technologies

- The list of critical materials will be used to form the LCIA table that will be used in the LCA numerical model.

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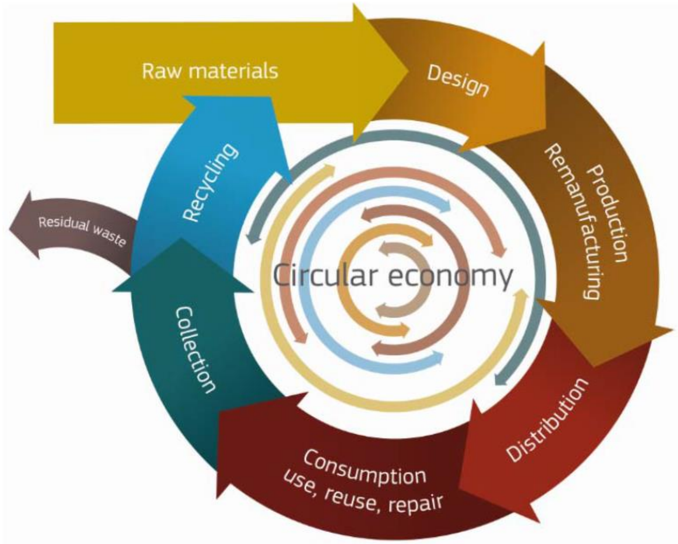
Near future work

- Determine all **possible/feasible recycling and dismantling technologies** applied to FCH technologies under consideration.
- **LCA approach**:
  1. **Critical materials** will be assessed with LCA methodology to get a first impression of their environmental impact.
  2. Afterwards a **reference model** will be built for each considered FCH technology.
  3. Different **scenario analyses** will be done to evaluate the influence of reuse, recycle and other possible EoL scenarios (landfill as the worst case).



Circular economy envisioned by the European Commission.

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LCA Materials- Inventory

Material	FCH Technology	Library of material properties
yttrium	SOFC	Flow- Gabi DB
zirconium	SOFC	
nickel	SOFC, AWE	
strontium	SOFC	Flow- Gabi DB,Ecoinvent
lanthanum manganite	SOFC	lanthanum, lanthanum oxide
lanthanum chromite	SOFC	lanthanum, lanthanum oxide
silver	SOFC, PEMFC	
palladium	SOFC, PEMFC	
gold	SOFC, PEMFC	
platinum	SOFC, PEMFC	
plastics	AWE	
Potassium Hydroxide	AWE	
asbestos	AWE	Ecoinvent 3.1
Teflon	AWE, PEMWE, PEMFC	
Rubber (e.g. Viton, Kalrez, Silicone, ...)	AWE, PEMWE, PEMFC	
PFSC (Nafion)	AWE, PEMWE, PEMFC	DB standard scope Gabi 2017
PEEK	AWE, PEMWE, PEMFC	DB standard scope Gabi 2017
PSSA	AWE, PEMWE, PEMFC	
stainless steel	PEMWE, PEMFC	
Iridium	PEMWE	
Ruthenium	PEMWE	
Titanium	PEMWE	
carbon	PEMFC	
graphite	PEMFC	

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

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http://hytechcycling.eu/

Thank you for your attention!

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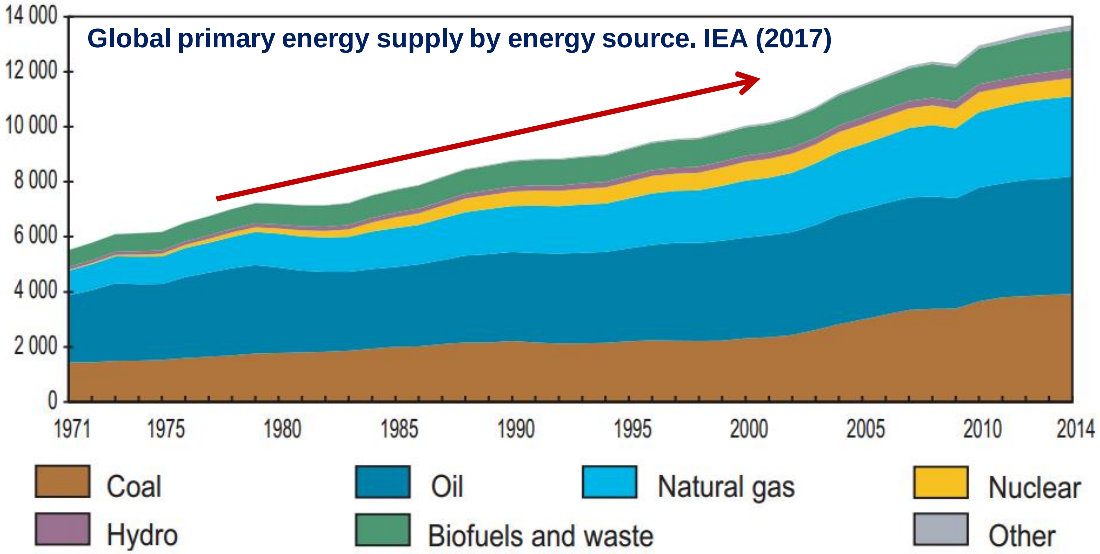
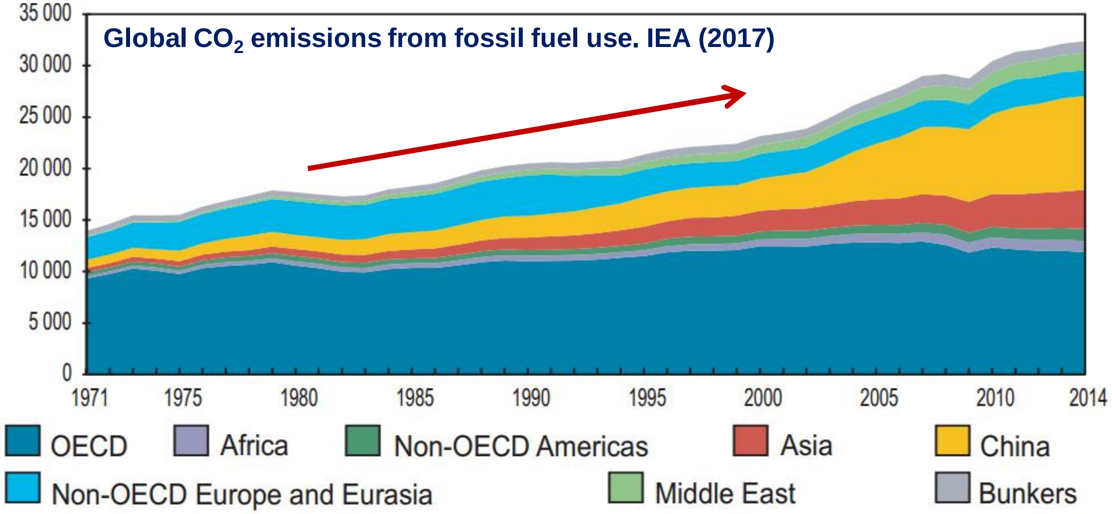
Existing recycling technologies for fuel cells and hydrogen products

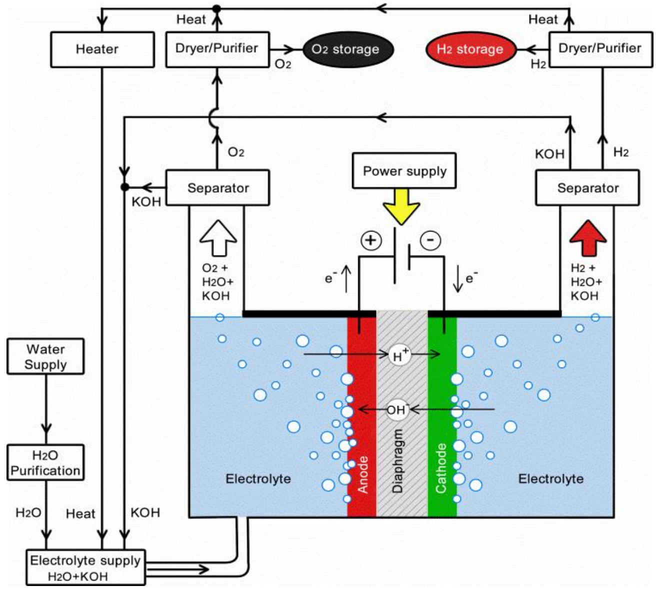
A. Valente, M. Martín-Gamboa, D. Iribarren, J. Dufour
Systems Analysis Unit, IMDEA Energy
Chemical and Environmental Engineering Group, Rey Juan Carlos University

Current energy context





Fuel cells and hydrogen (FCH) technologies



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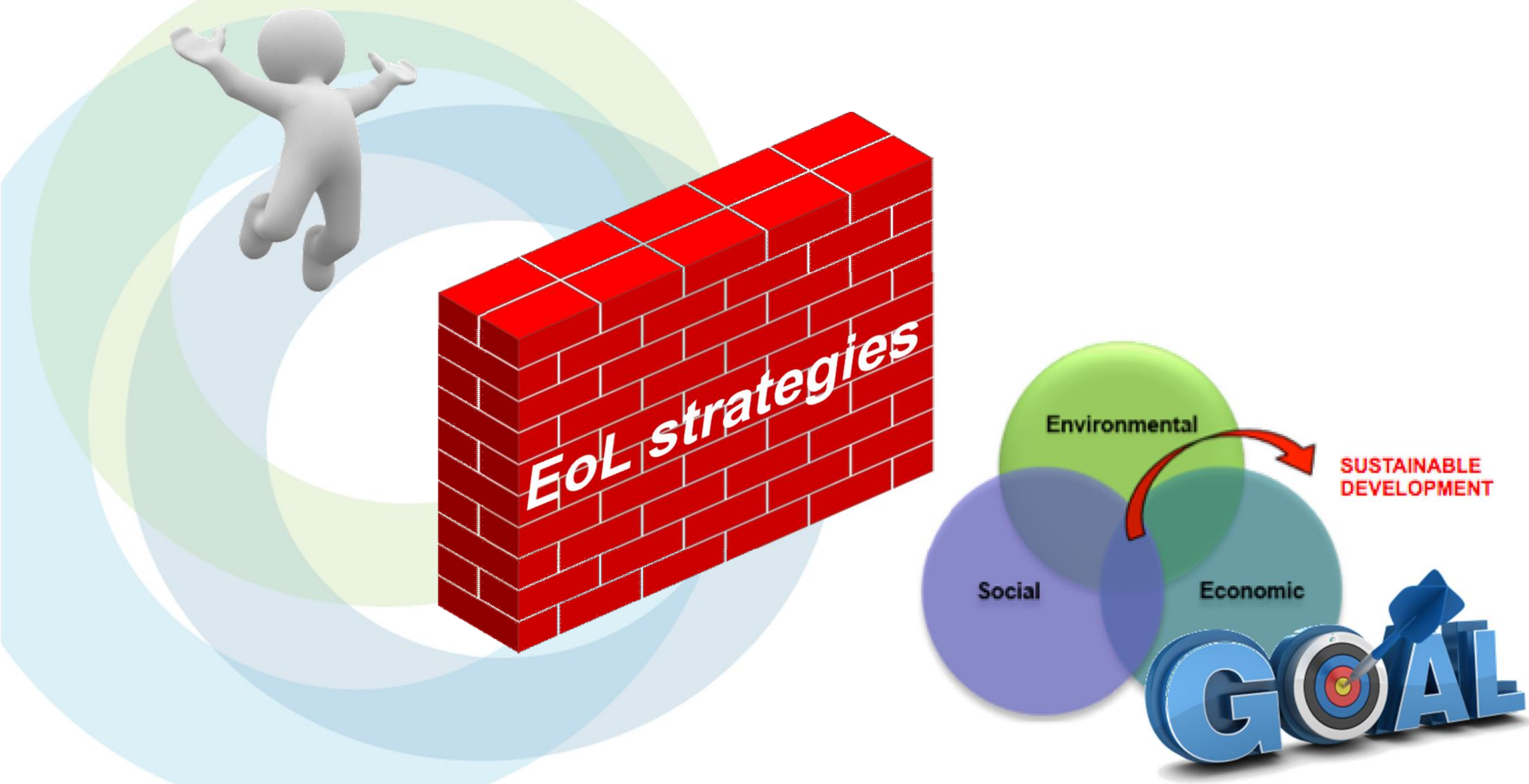
Barriers

FCH technologies



HyTechCycling Project

HYTECHCYCLING's main goal is to deliver reference documentation and studies about existing and new recycling and dismantling technologies and strategies applied to fuel cells and hydrogen technologies, paving the way for future demonstration actions and advances in roadmaps and regulations.

Scanning of existing recycling technologies that are or have the potential to be applied to FCH technologies with low modifications.

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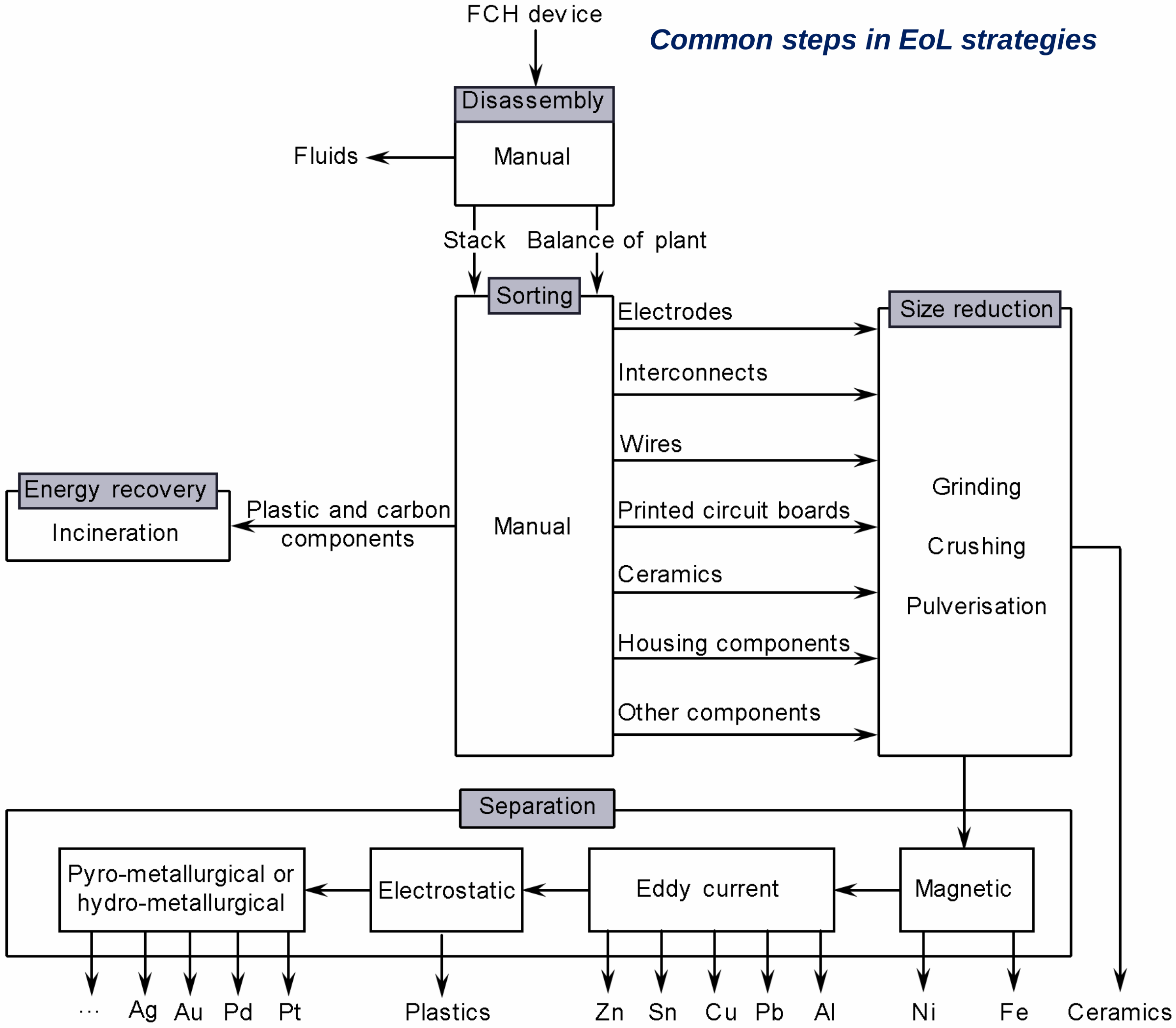
FCH devices

Main materials of the stack of the selected FCH products

	Electrolyte	Cathode	Anode	Bipolar plates	End plates	Interconnect	Sealant
PEMFC	Nafion®	Pt catalyst on carbon support	Pt catalyst on carbon support	Carbon-based	Al	Graphite; metal alloys	Plastic
SOFC	Yttria-stabilised zirconia	Ceramic perovskite	Ni; NiO	Cr steel; ceramic	Ceramic	Cr steel; ceramic	Glass-ceramic; glass
AWE	KOH	Raney-Ni catalyst and PTFE	Raney-Ni catalyst and PTFE	Polymers (diaphragm)	Raney-Ni	Plastic	Plastic

Existing EoL strategies



Treatment of **common metals**

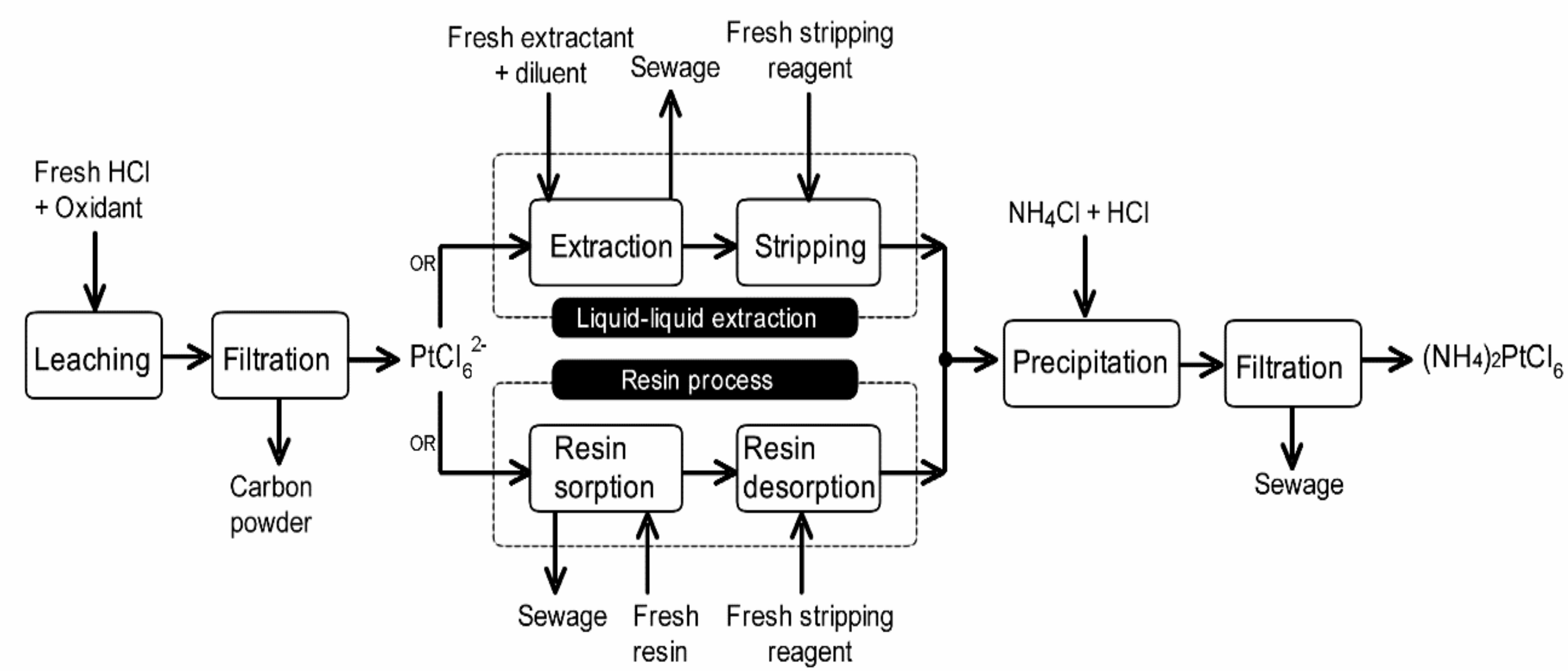
Treatment of **common plastics**

Treatment of **precious metals**

Specific treatments for **SOFC systems**

Treatment of precious metals

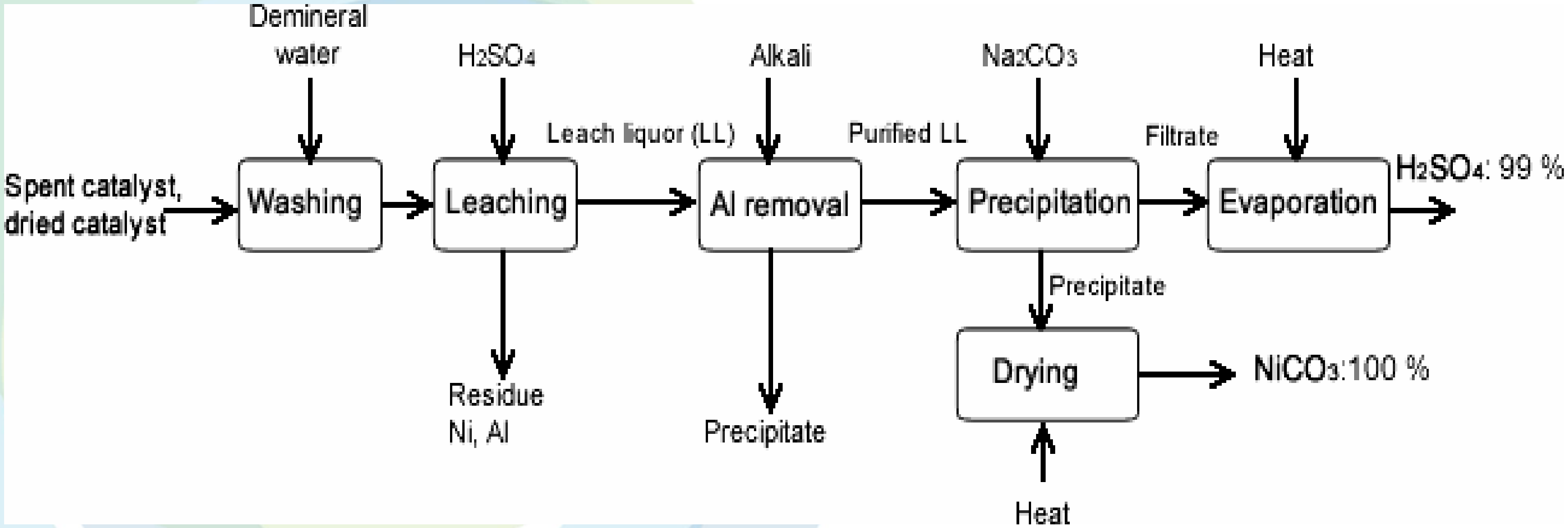
- **Hydrometallurgical** processes



Hydrometallurgical Pt-recovery process

Treatment of precious metals

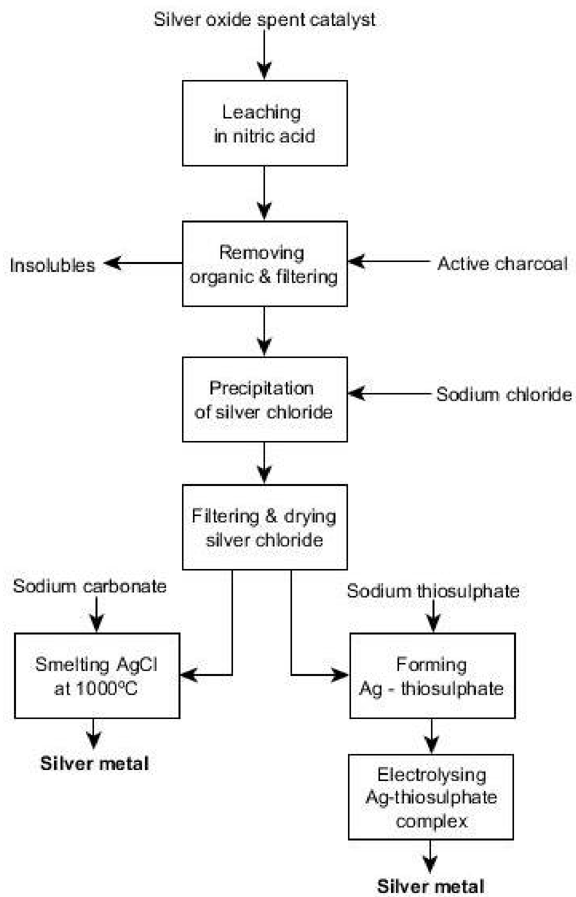
- **Hydrometallurgical** processes



Recovery of nickel carbonate from spent Raney-Ni catalyst

Treatment of precious metals

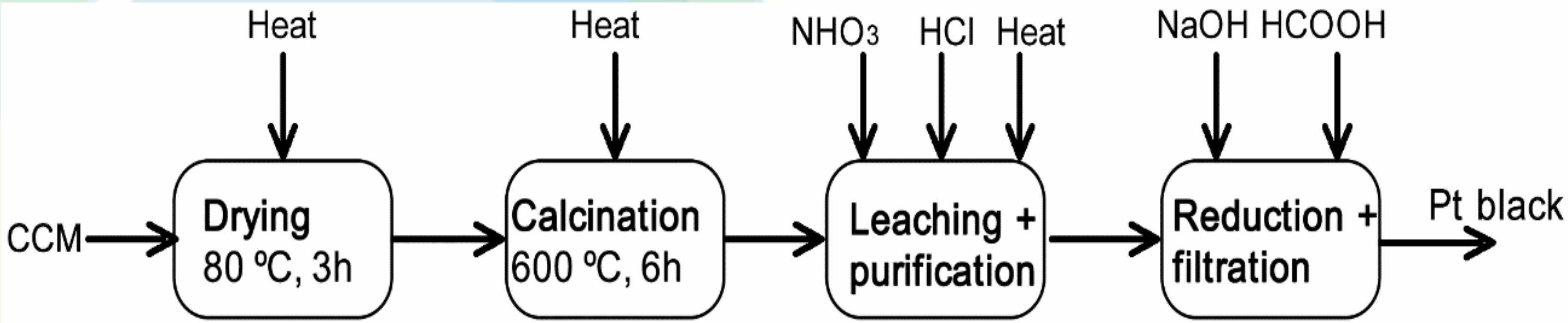
- **Hydrometallurgical** processes



Silver recovery from waste silver oxide

Treatment of precious metals

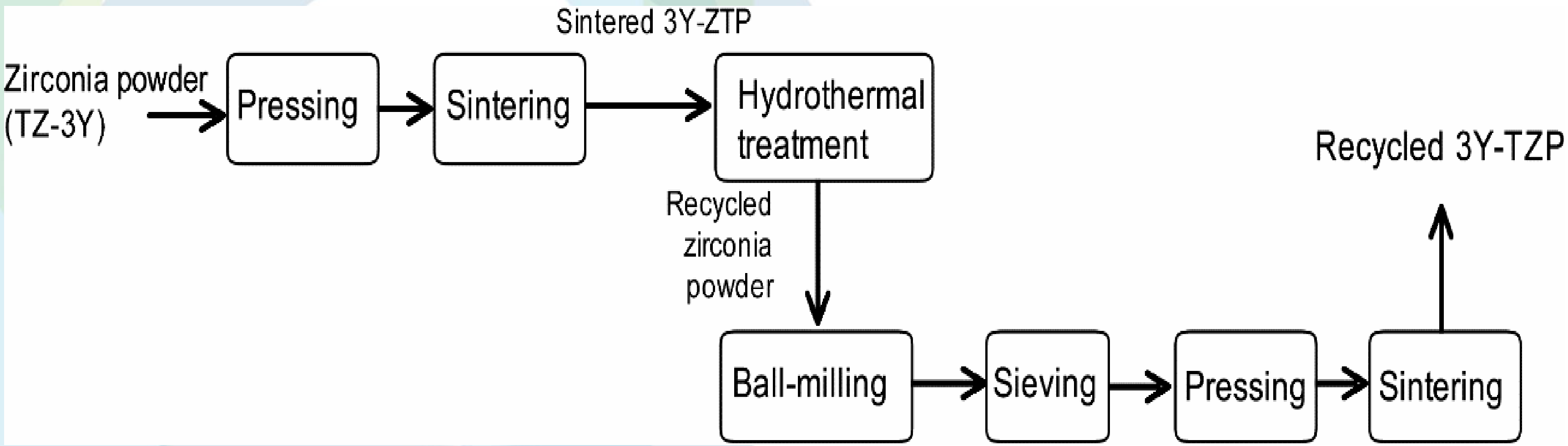
- **Pyro-hydrometallurgical** processes



Pyro-hydrometallurgical Pt-recovery process

Specific treatments for SOFC

- Recovery and recycling of **strontium-doped lanthanum manganite (tubular SOFC concept)**
- Recovery and recycling of **yttria-stabilized tetragonal zirconia polycrystals (planar SOFC concept)**



Recovery of YSZ under hydrothermal conditions

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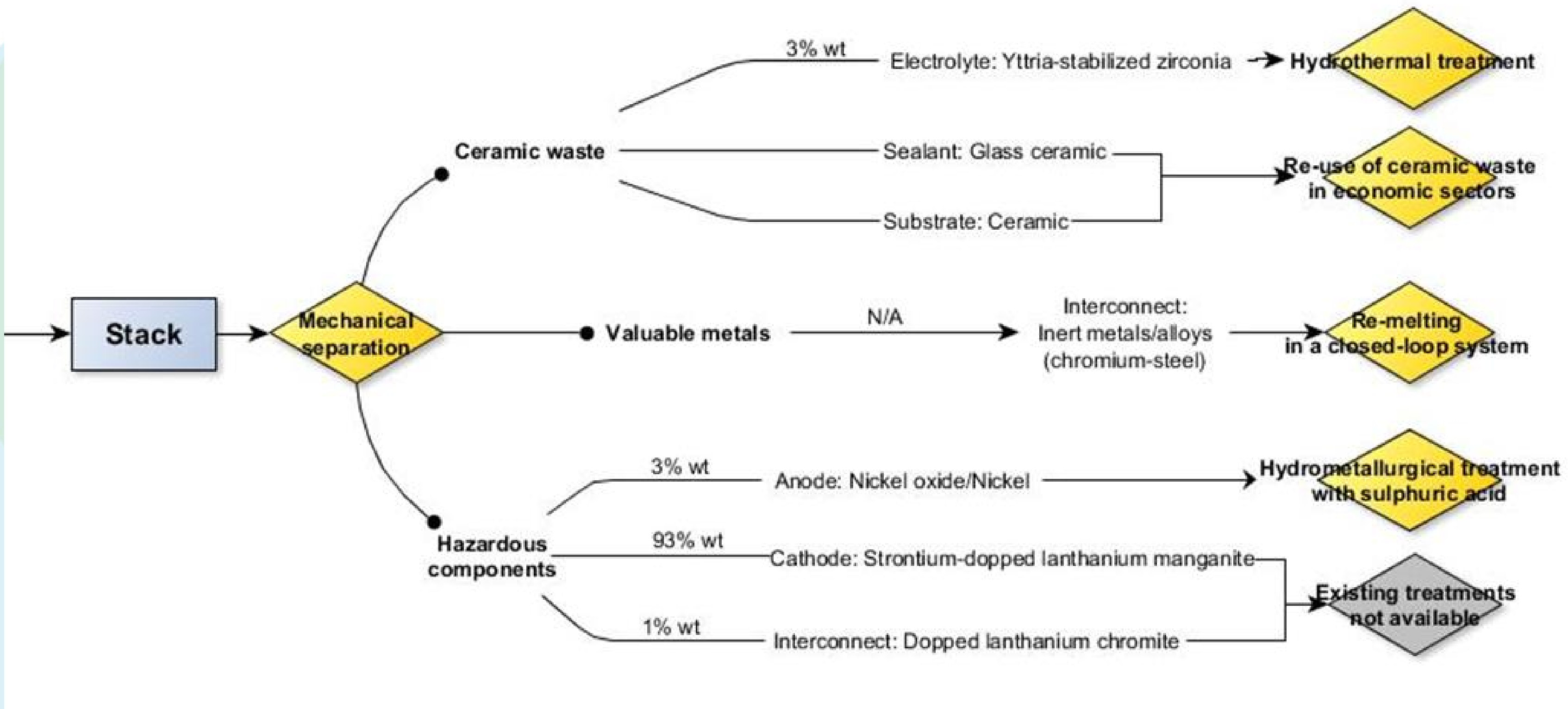
Overall strategies



EoL scheme of SOFC stacks: tubular design

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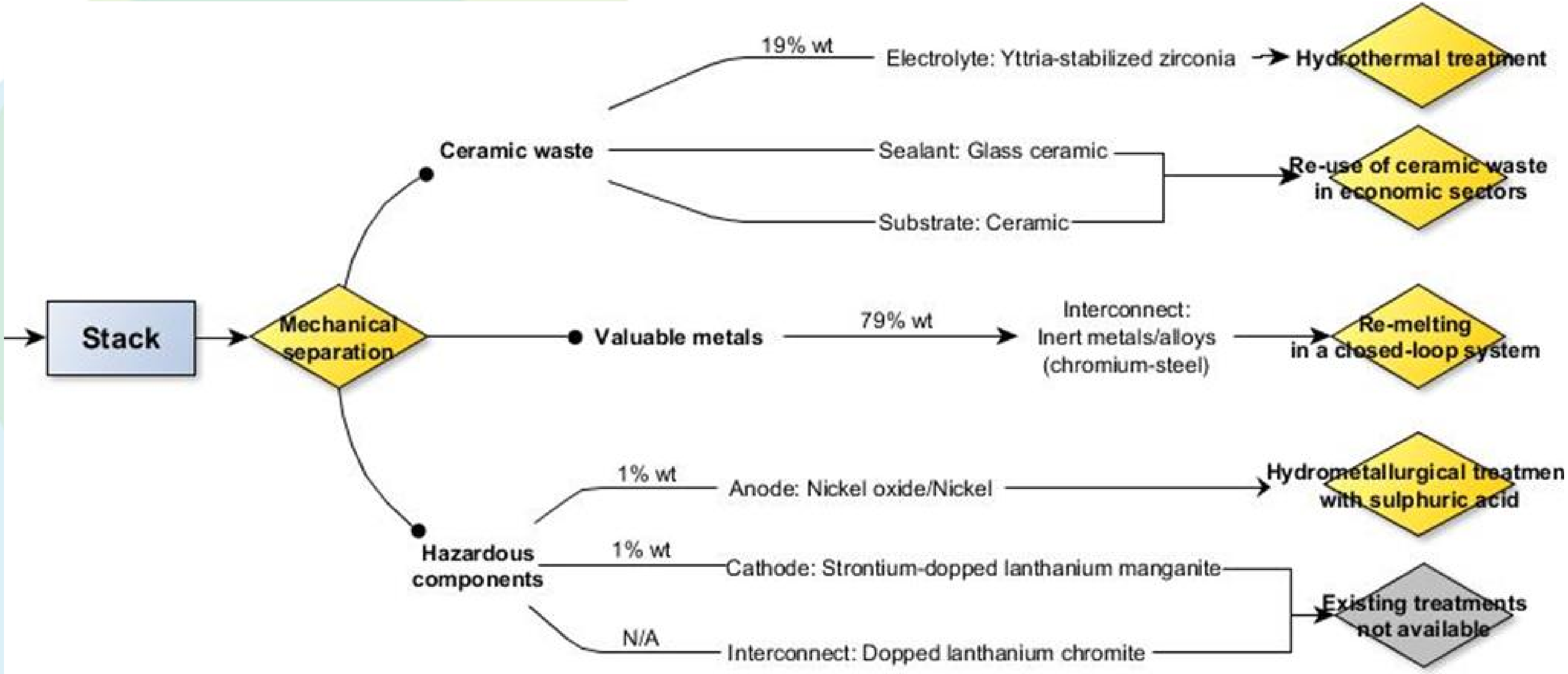
Overall strategies



EoL scheme of SOFC stacks: planar design

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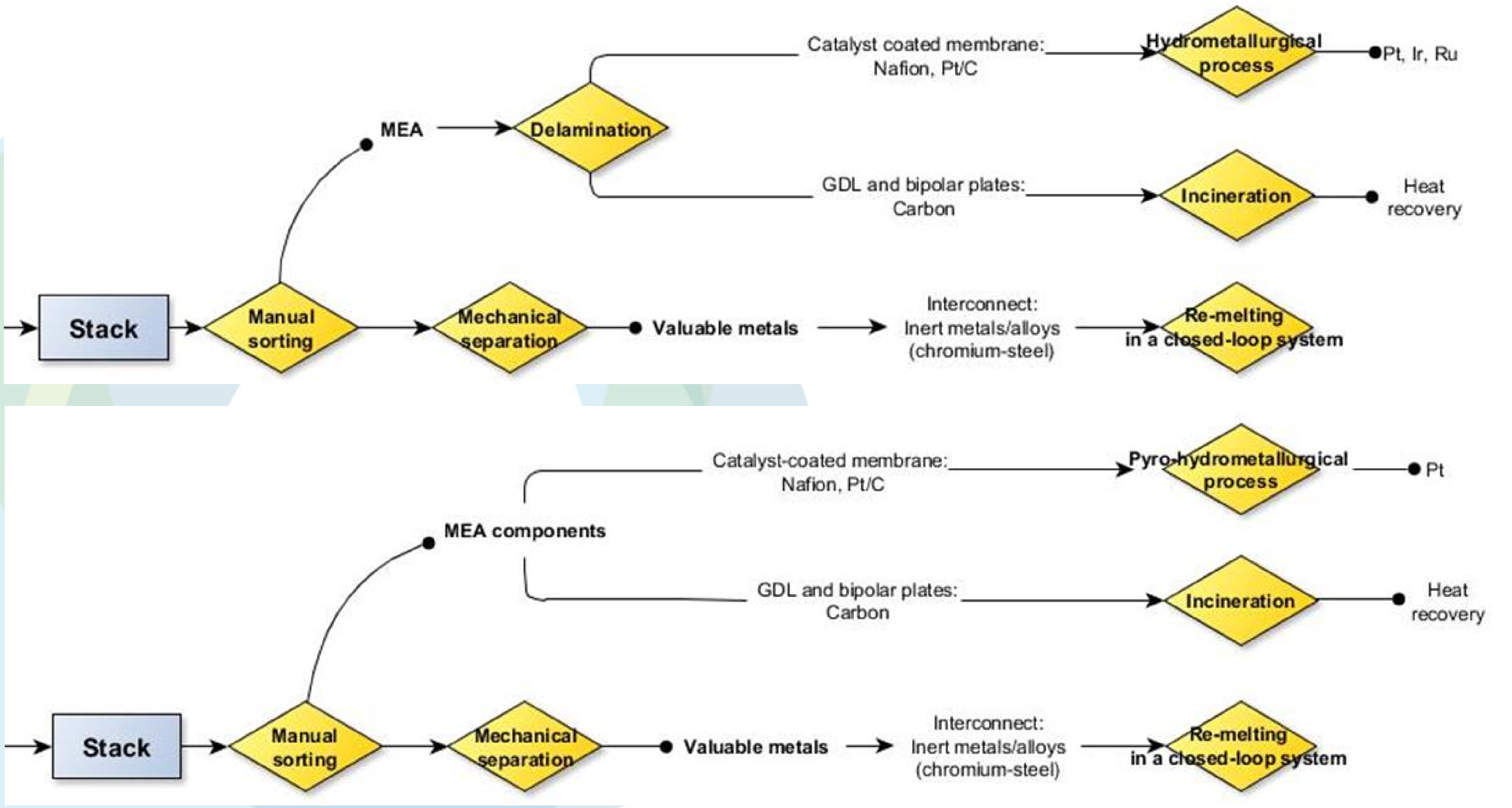
Overall strategies



EoL scheme of PEM stacks: hydrometallurgical and pyro-hydrometallurgical route

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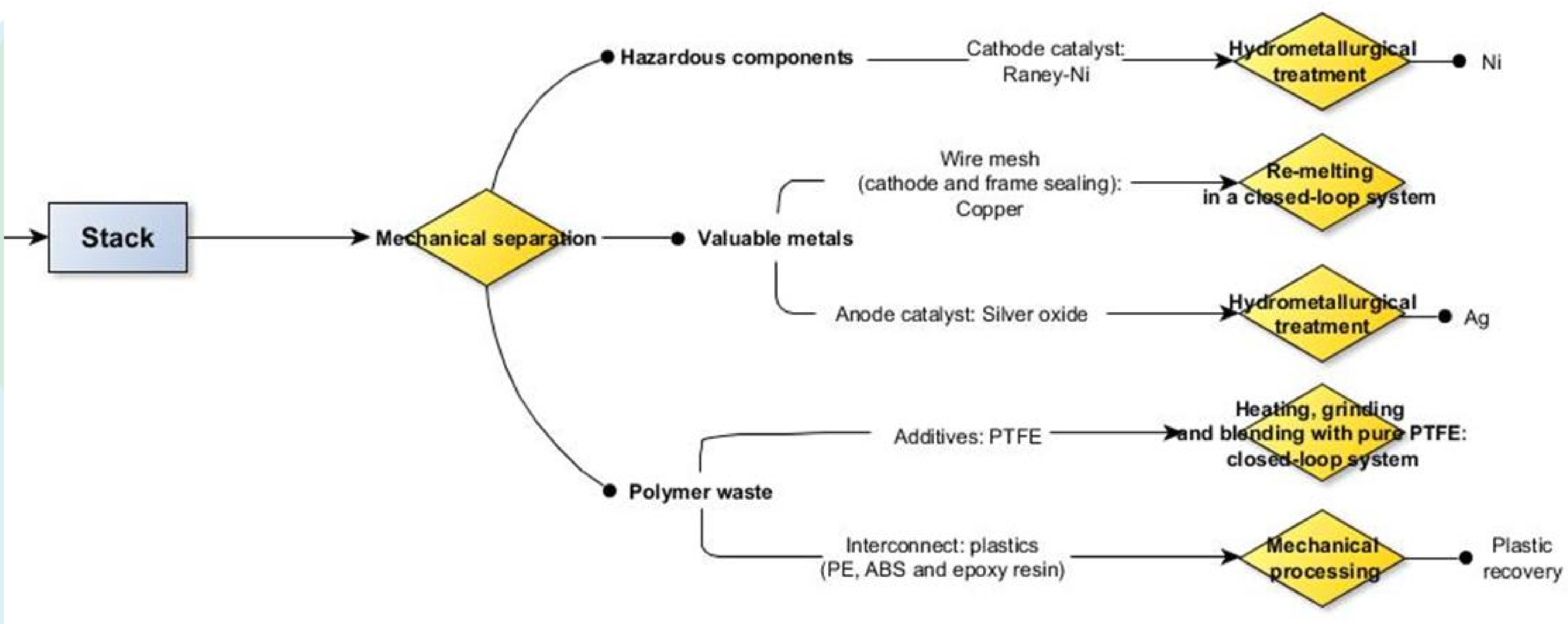
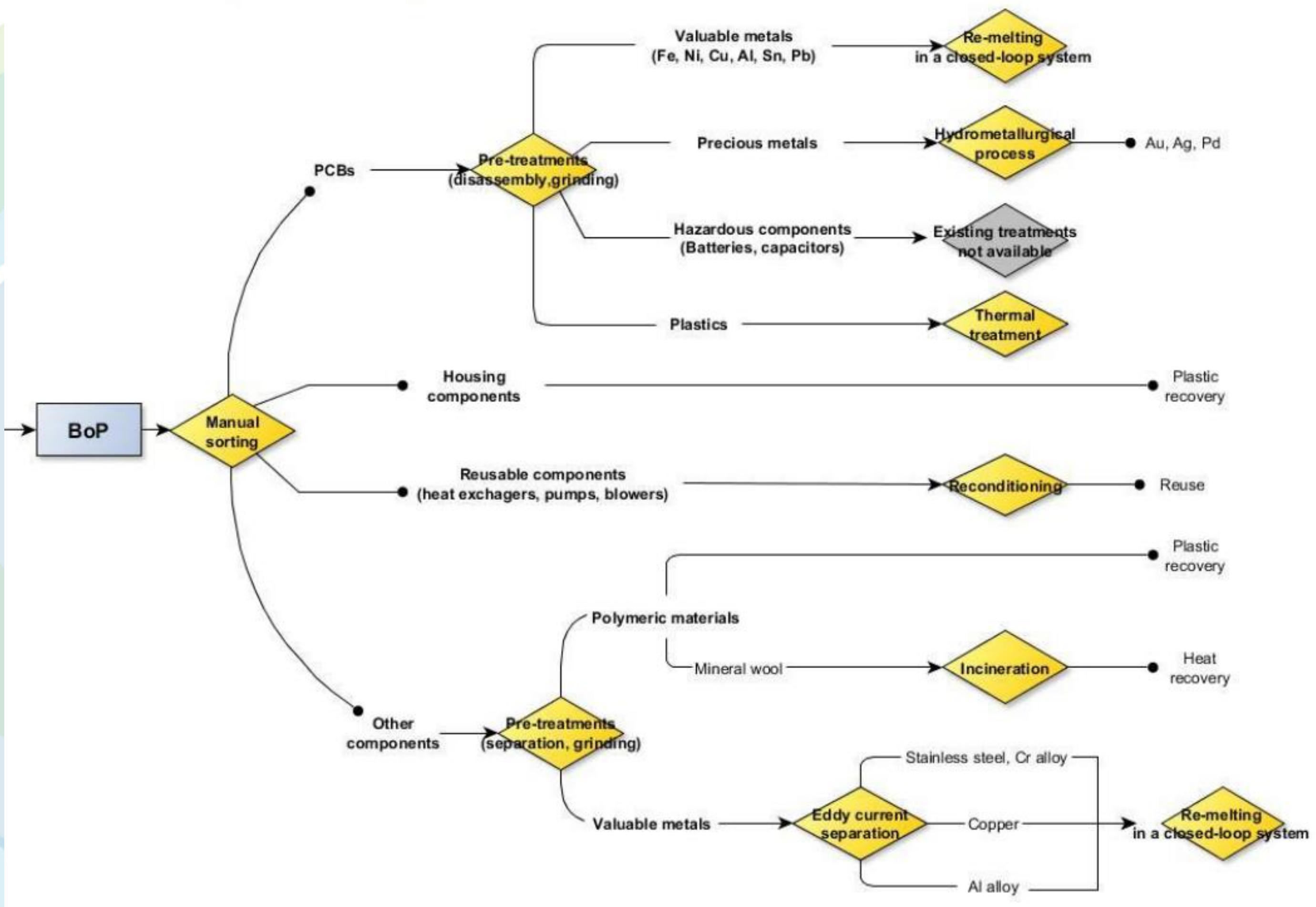
Overall strategies



EoL scheme of AWE stacks

Overall strategies



EoL scheme of BoP

Conclusions

- Lack of complete strategies for the reuse and further recovery of valuable materials from FCH products
- Urgency to develop specific EoL strategies and apply design-for-recycling and eco-design approaches
- Identification of existing EoL technologies provides a starting point

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

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Link to the deliverable:
http://hytechcycling.eu/wp-content/uploads/D2.2-EoLtechnologies.pdf

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ÅWP 2: Regulatory analysis, critical materials and components identification and mapping of recycling technologies

ÅD 2.3 Regulation framework analysis and barriers identification

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Objectives and methodology

GOAL
Commercialization and market massive introduction of FCH technologies

KEY STEP
Specific legislation regarding end-of-life and recycling

METHODOLOGY
Collect current regulations at EU level and Member states level

Identify the main regulatory barriers
Regularize the end-of-life cycle of FCH systems

FCH – Fuel Cells and Hydrogen Joint Undertaking

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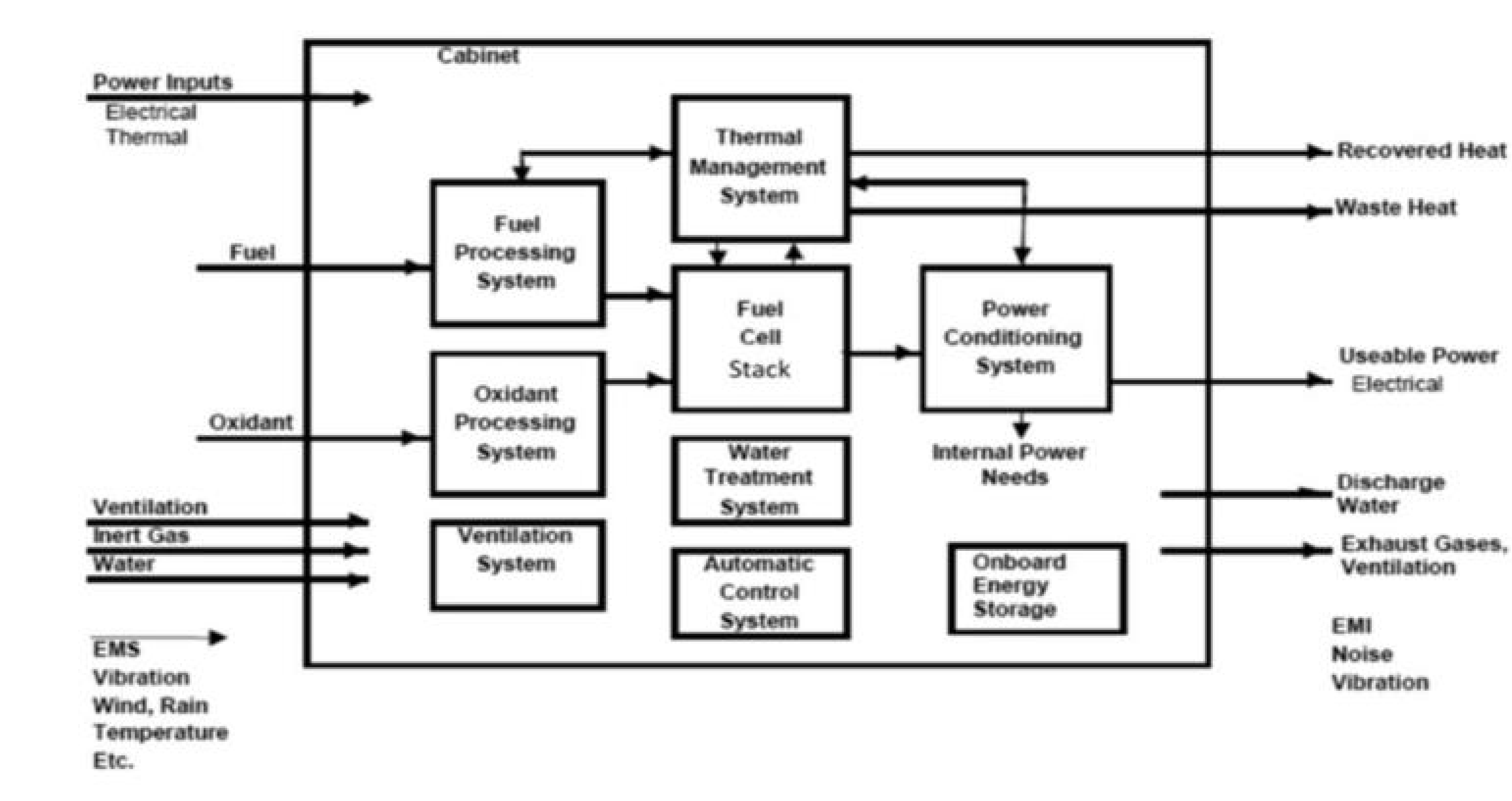
FCH system design



*Masoni P, Zamagni A. Guidance document for performing LCA on fuel cells. 2011 Sep p. 109. Report No.: D3.3.

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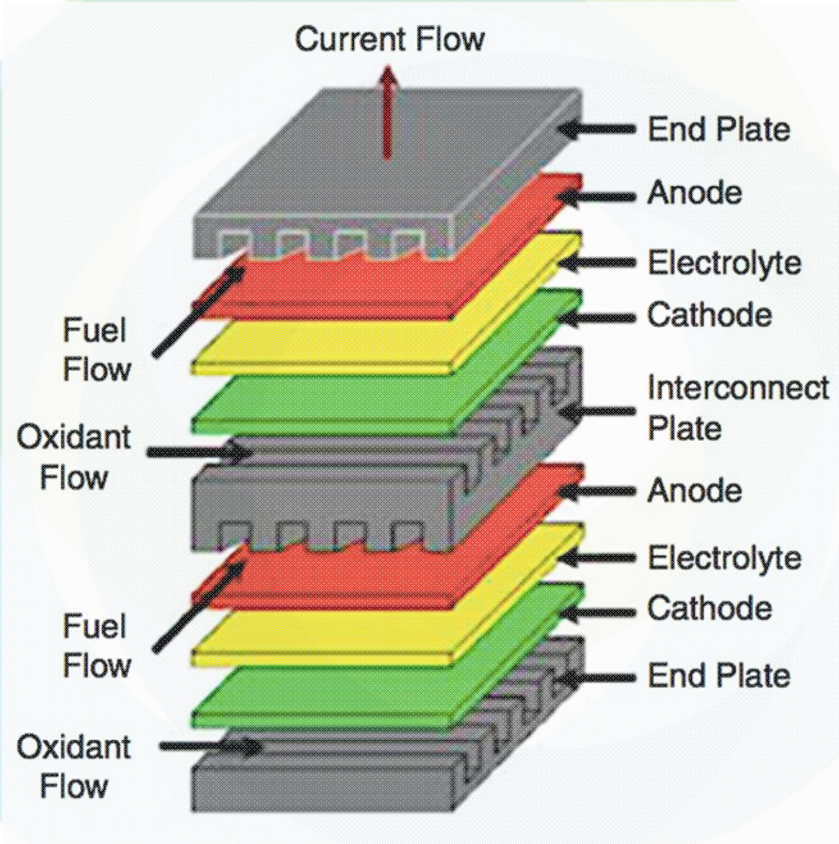
Stack system design



The FC single cell main components are:

- Contact layer,
- Cathode gas distribution layer,
- Electrolyte (in matrix),
- Anode gas distribution layer,
- Catalyst layer,
- Contact layer.

The FC stack main components are:

- Interconnect (also called bipolar or flow-field plate),
- Seal gasket,
- Current collector,
- A number of individual cells.

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BoP components

Air management: blower, compressor, metering, piping humidification, pre- heat

Fuel management: fuel pump/blower, metering, fuel cleaning, fuel processing, humidification, cooling/pre-heat

Thermal management: heat exchangers, after/start-up burner, steam generator

Recycle streams: water, fuel, CO2, liquid electrolyte

Power and system control: DC-DC, DC-AC inversion, sensor, hardware, software

External BoPs: Housing/pressure vessels, waste heat recovery.

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Short list of EU legislation

ELV Directive

- Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles.

Batteries Directive

- Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.

Packaging Directive

- Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 amending Directive 94/62/EC on packaging and packaging waste

Landfill Directive

- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

Eco Design Directive

- Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of Eco Design requirements for energy-related products.

Short list of EU legislation

WHEE Directive

- Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast).

RoHS Directive

- Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast version).

REACH

- Regulation (EC) no 1907/2006, of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency.

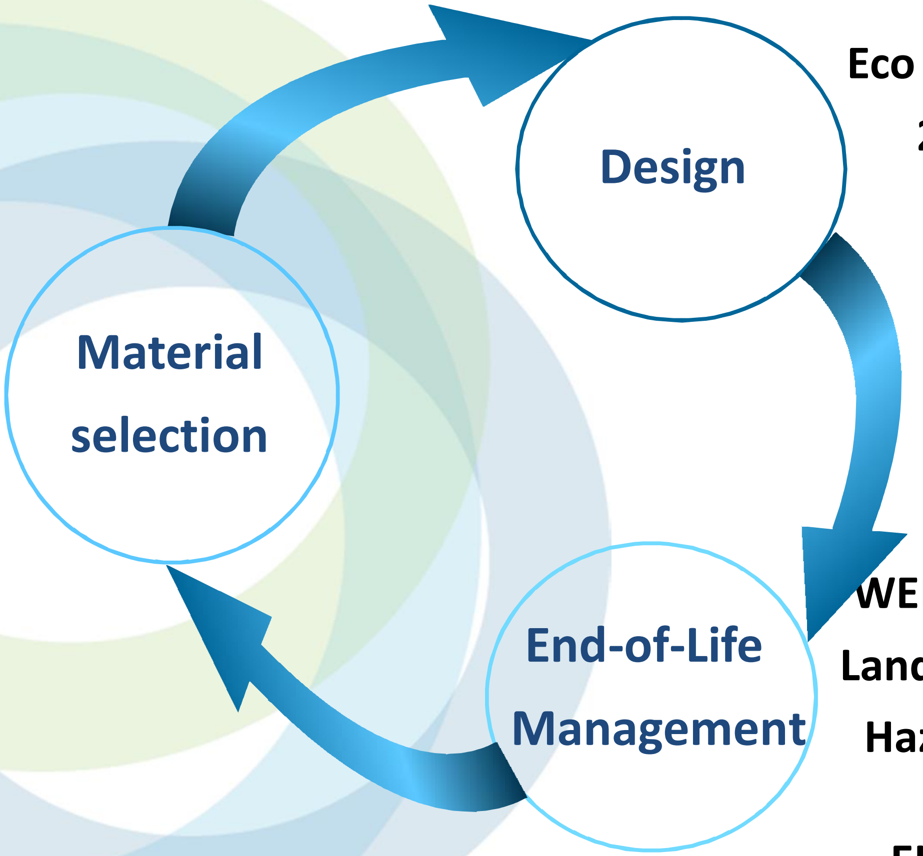
Waste framework Directive

- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

Hazardous waste Directive

- Council Directive 91/689/EEC of 12 December 1991 on hazardous waste

HyTechCycling Legislation reference to life cycle of FCH system



Eco Design Directive 2009/125/EC

REACH Regulation N° 1907/2006
RoHS Directive 2011/65/EU

WEEE Directive 2012/19/EU
Landfill Directive 1999/31/EC
Hazardous Waste Directive 91/689/EEC
ELV Directive 200/53/EC
Batteries Directive 2006/66/EC

Regulatory barriers analysis

Hazardous materials in FCHs and barriers on REACH Regulation

Å affect the deployment mainly in relation to future restriction on use of hazardous materials

Critical raw materials

Å Pt based & REE problems mainly due to an increasing cost of materials and a decreasing availability, impact in the production system and limit its commercialization.

→manufacturers must consider during design-phase.

Lack of specific legislation on FCH

Å ELV Directive

Å WEEE Directive

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Barriers identifications

Å damage the environmental beneficial image promoted by FCH manufacturers and developers

Å delay the market entry

Hazardous waste and landfill Directives

WEEE and RoHS Directives

Å large stationary systems out of scope

Å avoid use of some components

Eco-design Directives

End-of-Life Vehicles

Åinterests of producers, users and recyclers not aligned

Åpromote eco-design

restrictive targets:

Åreuse&recovery: 95%

Åreuse&recycle: 85%

of the vehicle by weight, so the FCHs developers have to guarantee the achieving goals in the end of life

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Conclusion

Propose specific FCH Directives

provide evidence of Eco-design improve the choice of materials

Reduce the use of hazardous materials

focus on strategies for end-of-life management

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D 2.4 Preliminary Recommendations and perspective on EU regulatory framework

Objectives and methodology

GOAL
specific recommendations and guidelines to adapt existing regulatory framework

1. **Implementation of existing regulatory framework and proposals for new laws**
2. **Recommendations on EU regulatory framework for stakeholders and policy makers**

Conclusion and perspectives

HyTechCycling 1. Implementation of existing regulatory framework …

- help with **innovation** of the products
- support their **market entry**
- help providers and manufacturers of the technology to **follow guidelines** to better implement the technology in accordance with the existing and implemented regulatory frameworks.

Better regulation covers the whole EU policy cycle

1. Implementation of existing regulatory framework …

"a pilot approach to help innovators ***facing regulatory obstacles*** *(e.g. ambiguous legal provisions), by setting up agreements with stakeholders and public authorities"*

*European Commission. Open invitation to submit expressions of interest, Innovation Deals, Pilot phase within the scope of the Circular Economy. [Internet]. Available from: https://ec.europa.eu/research/innovation-deals/index.cfm?pg=home

a "new way to address EU regulatory obstacles to innovation in an open and transparent manner, through voluntary ***cooperation between innovators, national/regional/local authorities and Commission*** *services to* ***better achieve EU policy objectives****"*

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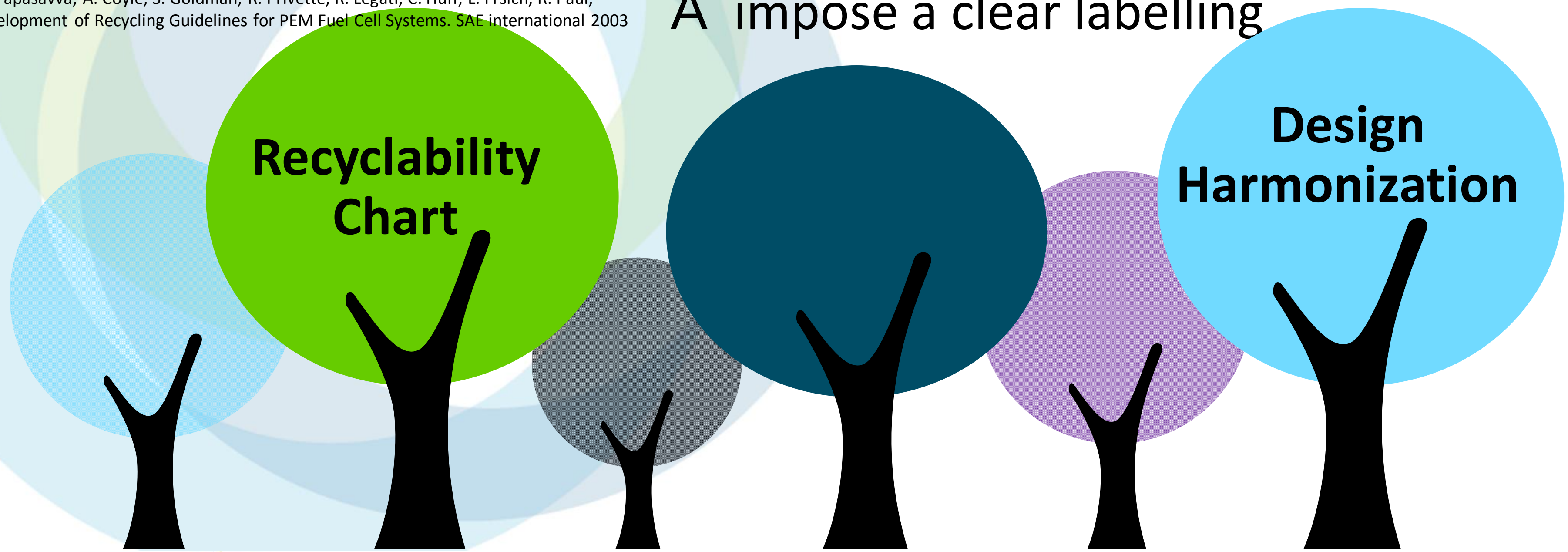
2.…and proposals for new laws

"This chart serves as a quick reference, supported by the text of the standard, to **evaluate specific choices** by design engineers and determine the implications of those choices for **reuse, recyclability and landfill potential**".

*S. Papasavva, A. Coyle, S. Goldman, R. Privette, R. Legati, C. Huff, L. Frsich, R. Paul, Development of Recycling Guidelines for PEM Fuel Cell Systems. SAE international 2003

- Improve the products durability and quality
- facilitate the dismantling and recycling process
- impose a minimum quantity of recyclable material used
- impose a clear labelling



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Agreements between manufacturers and recycling centers

assure the manufacturer to buy the recycled materials

facilitate the recycled material logistic

assure recycling centers to profit from recycling FCH technologies

increase the rate of reused components/ materials

HyTechCycling 2. Recommendations on EU regulatory framework

- collect information on large stationary
- change the scope of the Directive

REACH Regulation

WEEE and RoHS Directives

Hazardous waste and Landfill Directive

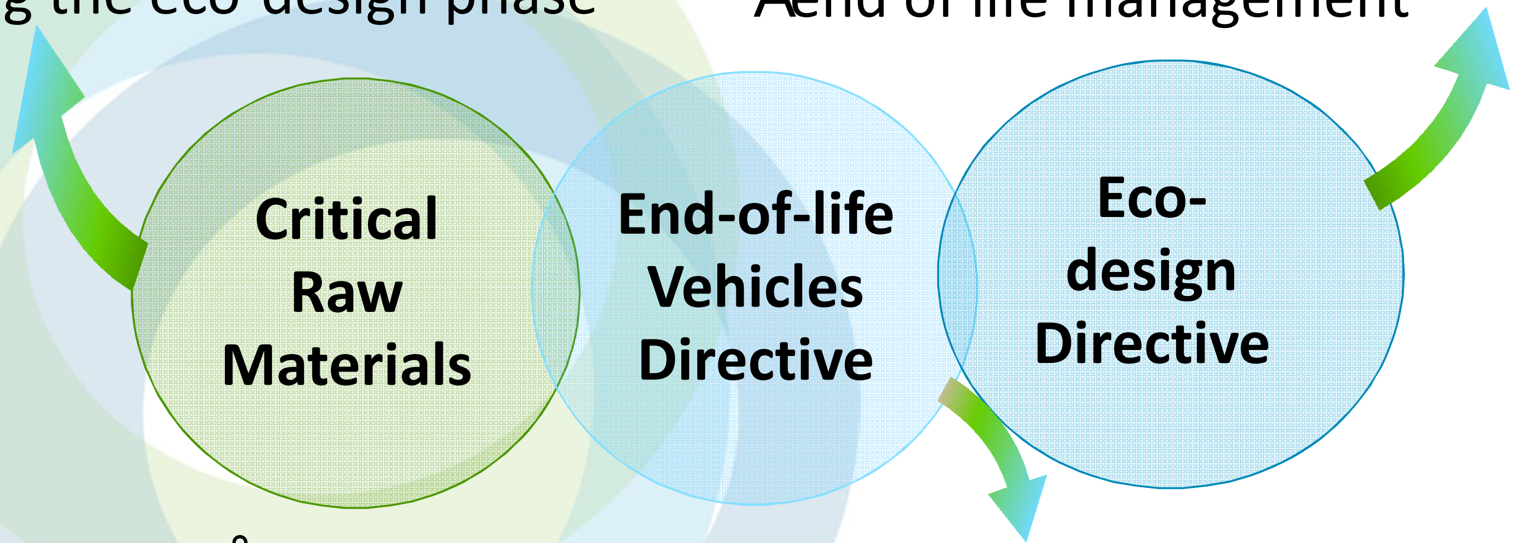
- a socio-economic assessment to justify the use of Ni or other hazardous material
- consider these socio-economic aspects

- a correct choice of material in the design phase
- perform a careful LCA in the design phase
- find a pre-treatment solution

2. Recommendations on EU regulatory framework

- substitution or reduction of critical raw materials to evaluate during the eco-design phase

- material selections and substitution
- FC manufacture and construction
- end of life management



- develop a more environmental friendly method of mining main metals
- promote recycling
- a more detailed research recycling methods

Conclusion and perspectives

As has been widely described, environmental product legislation plays a crucial and relevant role in order to ferry the fuel cell systems to the mass market.

- **Innovation Deals**
- **Working groups**
- **Agreements**

work on both materials during design and end of life management by the stakeholders

EU Policy makers: perceive the existing difficulties and barriers exist and to incorporate any changes of regulations.

Analysis of availability of substitution of hazardous and critical materials

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D.2.5. Study on needs and challenges in the phase of recycling and dismantling.

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Summary

- ÅINTRODUCTION
- ÅMANUFACTURERS
- ÅRECYCLING CENTERS
- ÅOTHER ISSUES
- ÅSUMMING UP!

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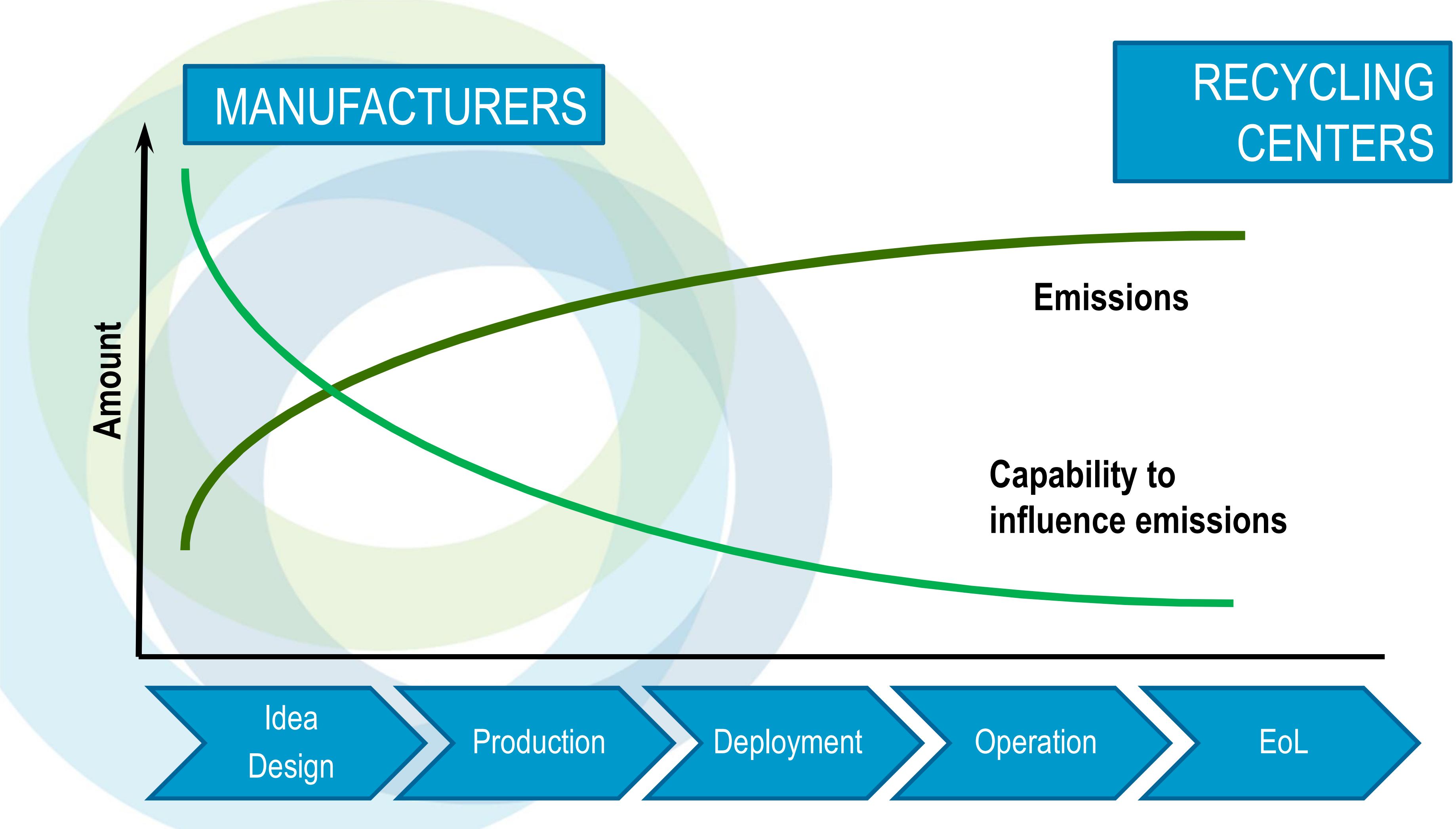
INTRODUCTION



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FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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MANUFACTURERS

ECODESIGN

MATERIAL SELECTION

MANUFACTURERS

ECODESIGN

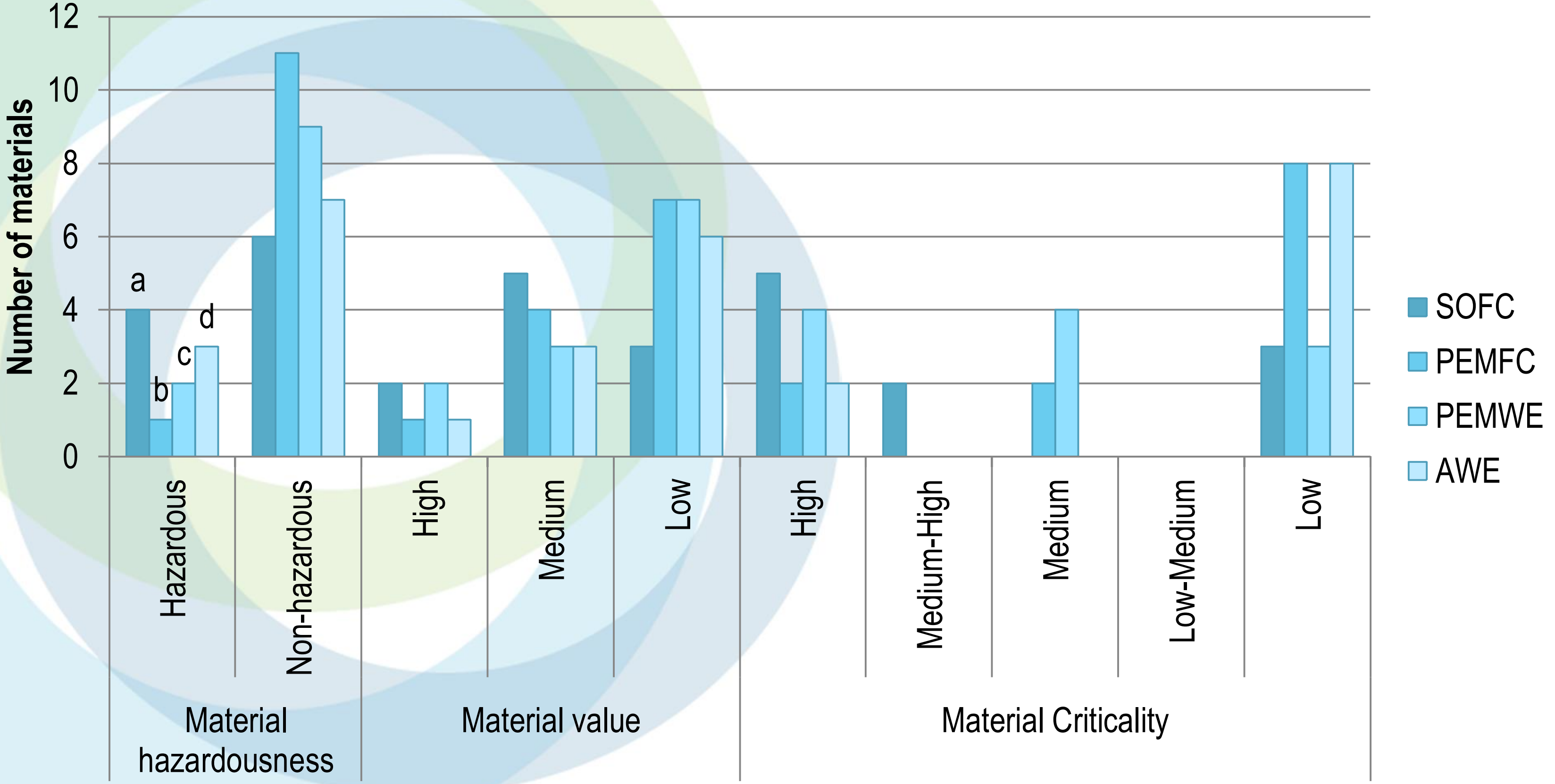
CREATE INDICATORS

TRACKING INDICATORS

EVALUATING INDICATORS

MANUFACTURERS

MATERIAL SELECTION



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RECYCLING CENTERS

- Treatment of:
  - Common plastics
  - Common metals
  - Precious metals and others

RECYCLING CENTERS

Treatment of common metals:

	Economic barrier	Legal barrier
Magnetic separation	No	No
Eddy current separation	No	No
Densimetric table	Yes	No*
Flotation	Yes	Yes

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RECYCLING CENTERS

Treatment of common plastics

	Economic barrier	Legal barrier
Thermal processing	No	No
Mechanical processing	No	No
Optical processing	Yes	No
Incineration processing (energetic valorisation)	No	Yes
Pyrolysis	No	Yes

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RECYCLING CENTERS

Treatment of precious metals and others

	Economic barrier	Legal barrier
Hydrometallurgical processes	Yes	Yes
Pyro-hydrometallurgical processes	Yes	Yes
Re-use of ceramic waste	Yes	No
Incineration of mineral wool	Yes	Yes

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OTHER ISSUES

OTHER NEEDS AND CHALLENGES

- ERP system for recyclable resources with a small-generation scale and potential environmental risk
- Tax incentives
- Regulation of the collection system

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OTHER ISSUES

ERP system for recyclable resources with a small-generation scale and potential environmental risk

Extended Responsibility of Producer.

Informal system, compared with high-generation scale → Chance of no using the best eco-friendly processes.

The design or production has to take into account the EoL. Holistic behaviour of the company.

Manufacturers should be an active part of the EoL processes.

OTHER ISSUES

Tax incentives

DISCUSSION

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OTHER ISSUES

Regulation of the collection system

- Recycling philosophy. End users and recycling companies connected.
- The customer needs clear and easy-to-understand recycling information.
- Continuously improvement of campaigns to reach more customer from the recycling center point of view
- Adapted methodology depending on the size of the FCH technology.

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SUMMING UP!

NEEDS	CHALLENGES
Develop specific protocols or mechanisms for the recycling of FCH technologies.	To develop recycling technologies to recover the maximum amount and type of materials.
To ensure that the processes employed are economically attractive to all agents involved.	To promote the use of treated waste of FCH technologies by manufacturer companies.
To adapt technologies to legal requirements.	Establish mechanisms, and promote them, so that end users of FCH technologies can send waste equipment to recycling centres.
To reduce the environmental impact of recycling processes.	

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ÅD 5.1: Involvement of all FCH actors in lifetime of FCH products

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Summary

Objectives

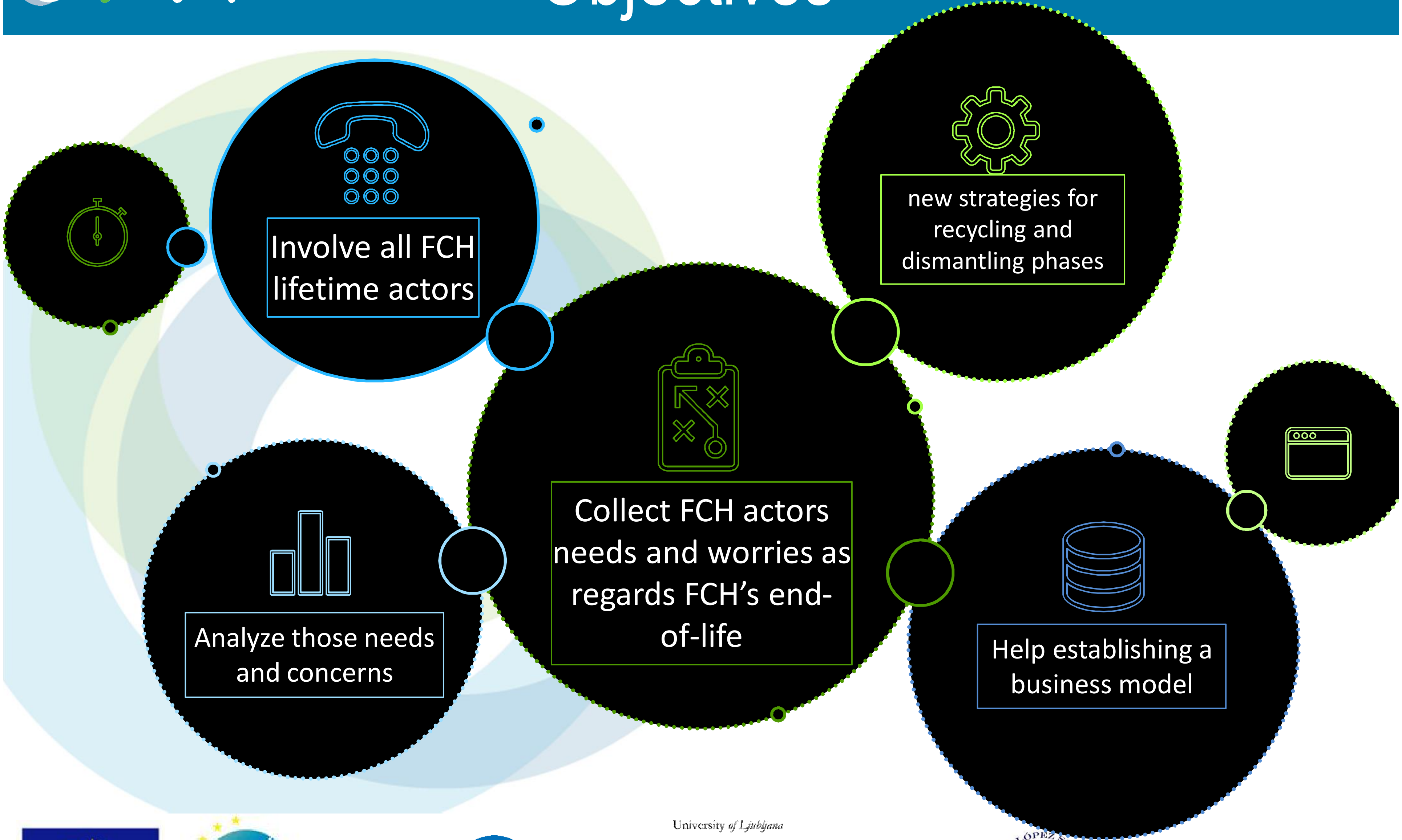
Survey definition
- Å Methodology
- Å Target

Survey Results & Analysis

Conclusion

HyTechCycling

Objectives



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Survey definition: methodology

Manufacturers	General information	The product	LCA	Eco-design	Regulations
Distributors	General information	General concerns	Reverse logistics		
End-users	General information	End-of-life strategy	Regulations		
Recycling centers	General information	FCH recycling technologies	Regulations		

FCH Fuel Cells and Hydrogen Joint Undertaking
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Survey definition: target

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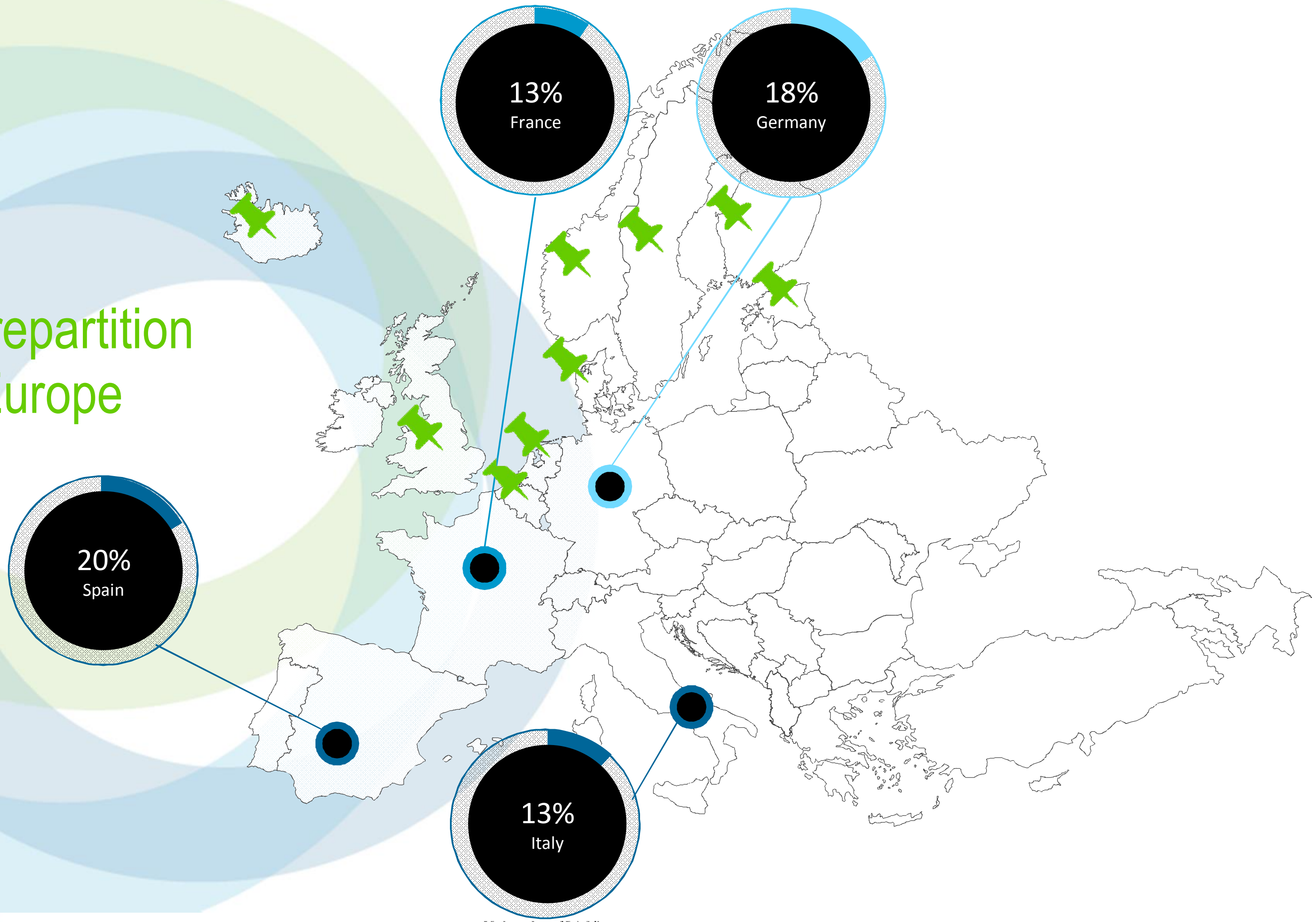
FCH actor' repartition across Europe



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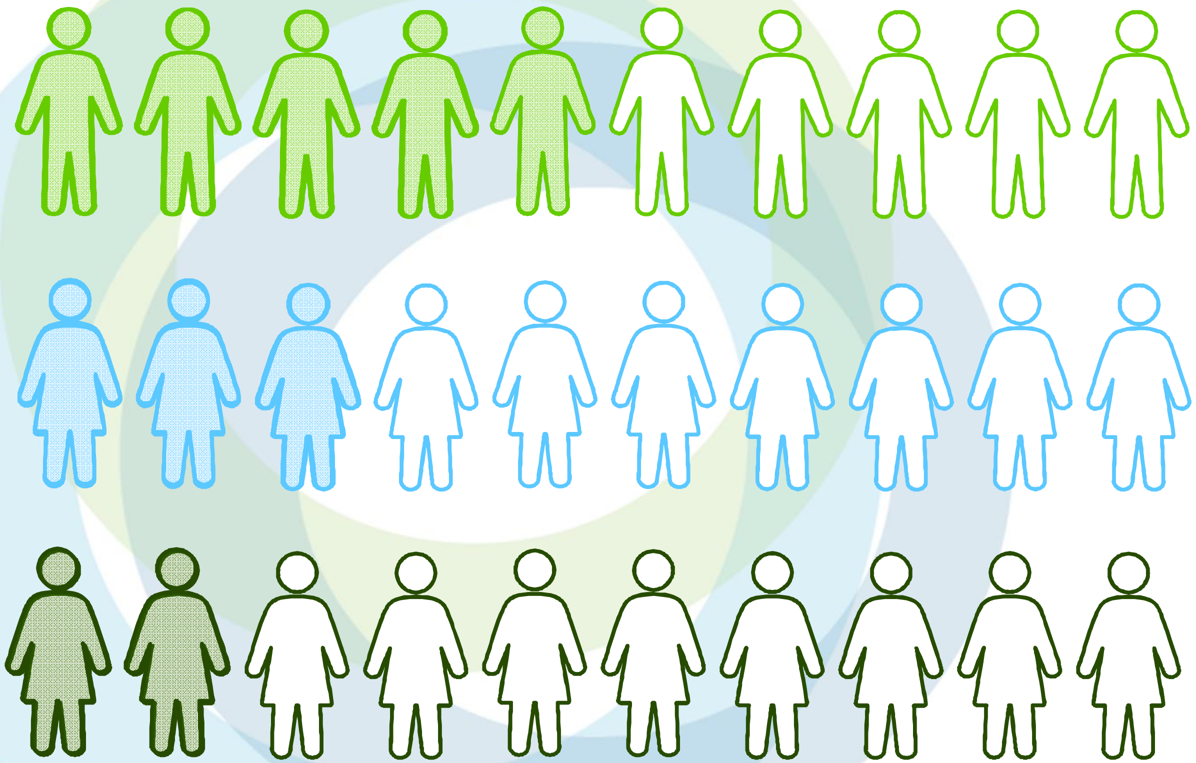
Survey results and analysis

Regulations awareness



5 out of 10 manufacturers

3 out of 10 Recycling centers

2 out of 10 end-users

are aware of European and national regulation on FCH technologies

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End-of-life issues: recycling centers' point of view

50% RC have the technology required for FCH recovery

50% think about investing in it

50% investment depends:
- on the market
- on the methods employed

33,3% agree components distributed between specialized centers

84% have no reluctance in treating FCH technology

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End-of-life issues

End-users' point of view

16,7% return to manufacturers

33,3% return to recycling centers

66,7% think about end-of-life products

Manufacturers' point of view

100% interested in buying FCH recycled materials

33,3% have an agreement with recycling centers

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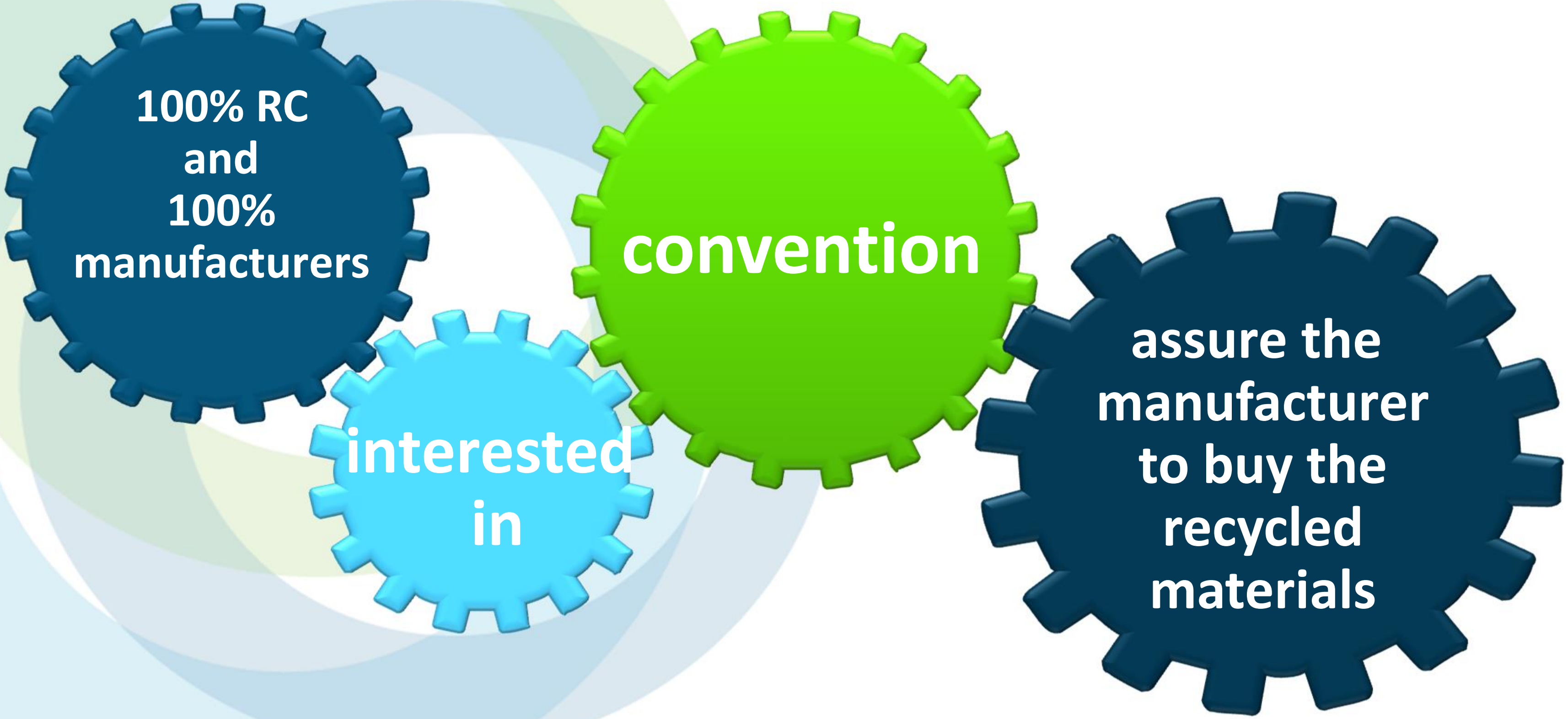
Agreement between RC and manufacturers



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Eco-design issue: manufacturers' side

have reduced the quantity of hazardous materials **83,3%**

2 have reduced it by **30%**

interested in rethinking the design of their product **83,3%**

agree to standardize their fabrication process **100%**

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Needs and worries of Manufacturers

01 The current technologies and business models

02 Cooperation between manufacturers and waste separation companies

03 Use of specific materials

04 Regulation should not jeopardize FCH development

05 Lack of logistics

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Recover precious metal from the product

Facilitate hydrogen based solutions profitability

Consider EoL in the LCA

Recycle into a new product

Reuse as much FCH materials as possible in order to reduce cost of next products, without quality decrease

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01 Need of a clear regulation

02 Erase the disparities inside the EU

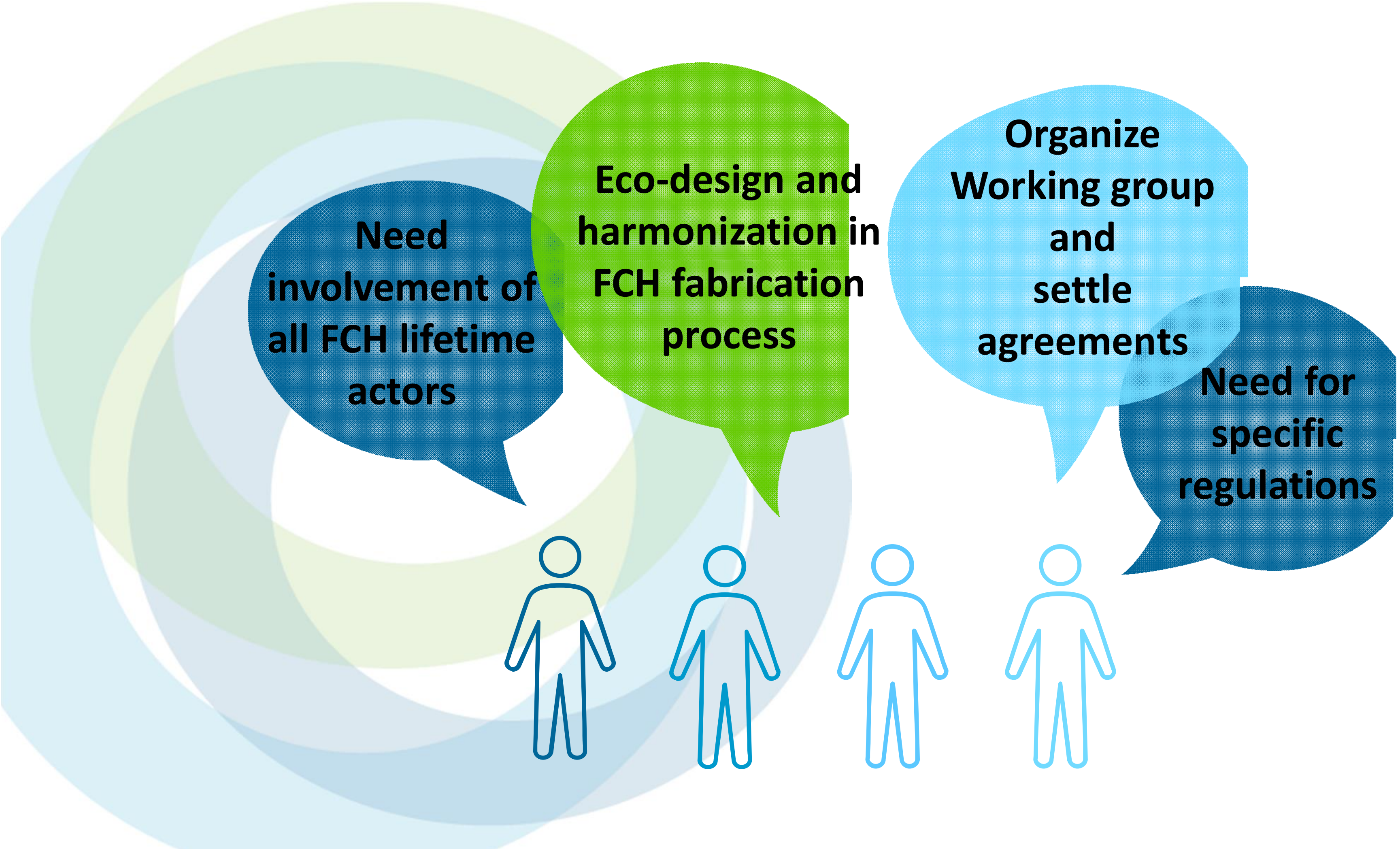
03 Worries on Transboundary waste movements

04 Clarification on the treatment of residues

05 The profitability of recycling these technologies

Needs and worries of Recycling centers

Conclusion


Need involvement of all FCH lifetime actors
Eco-design and harmonization in FCH fabrication process
Organize Working group and settle agreements
Need for specific regulations

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