HyTechCycling

The Hytechcycling project till now

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Location:
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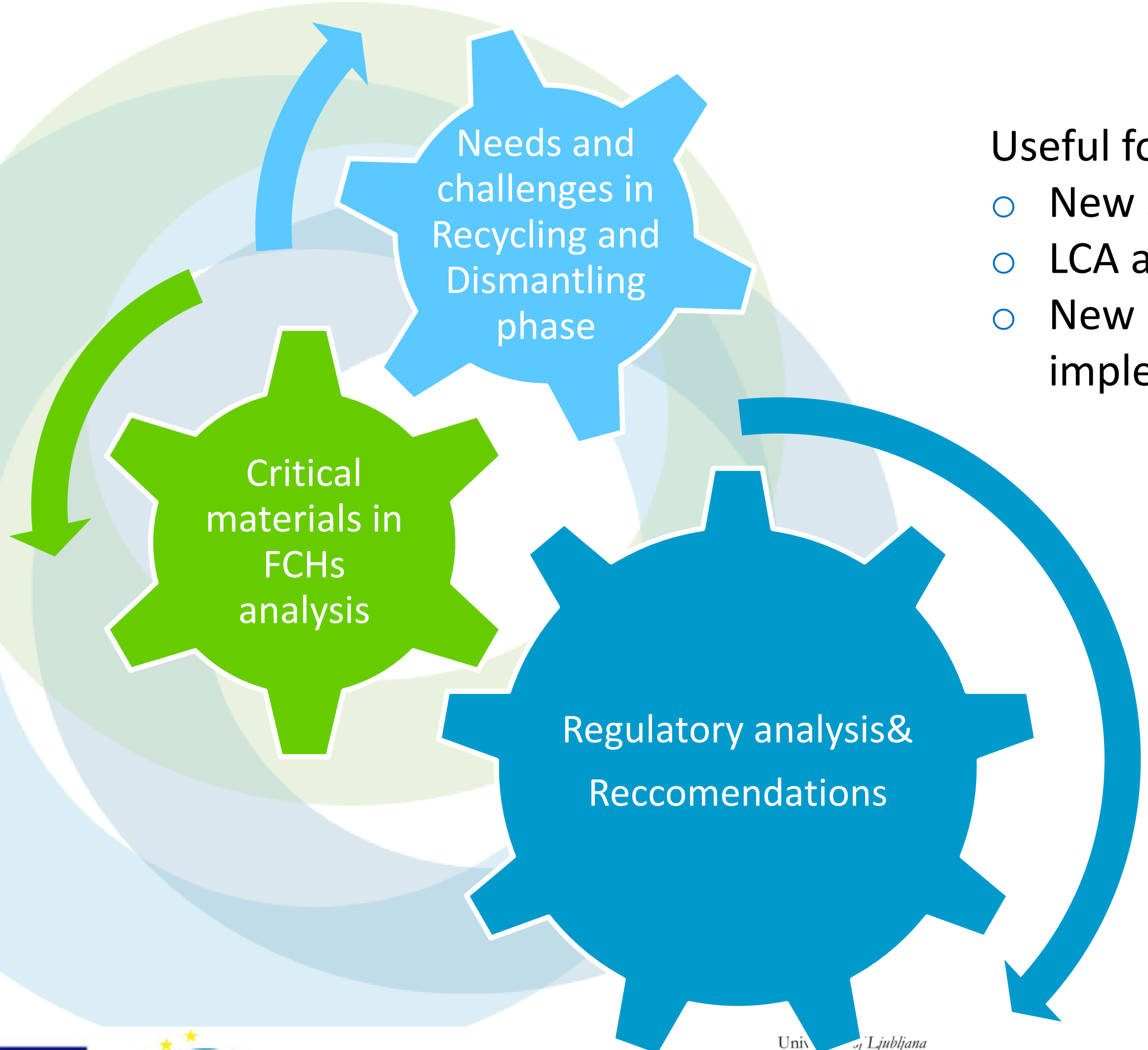
Objectives



Useful for identification of

- New strategies and technologies
- LCA analysis
- New business model and implementation roadmap

Objective

Identification of critical materials used in the manufacturing of FCH products according to different criteria: their **function** as component, **environmental** aspect as material classification, **cost** as material value, **criticality/scarcity** as material criticality and current recycling and dismantling technologies.

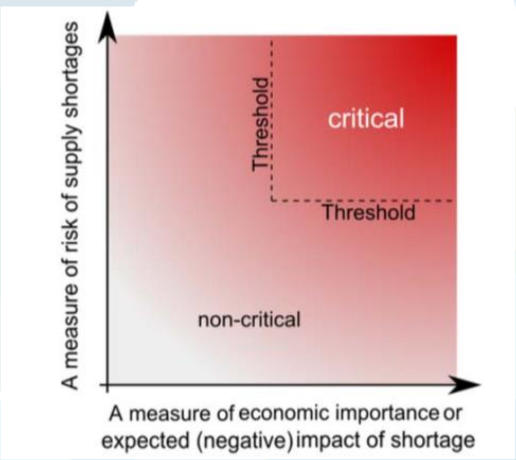
Main results

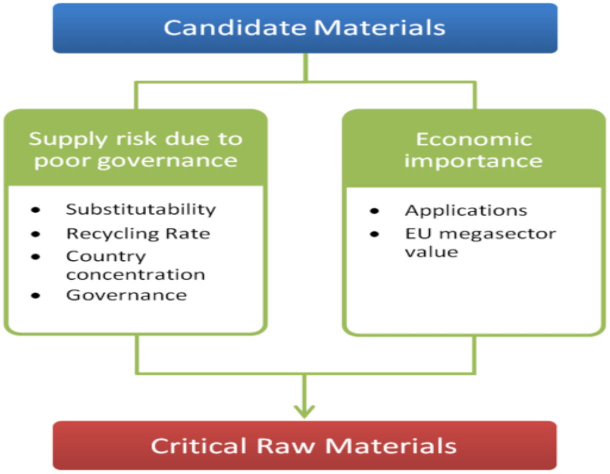
- **SOFCs** materials mainly consist of **Rare Earth Elements** (REE), classified as critical, costly and hazardous.
- **PEMFCs** materials are mainly low-to-medium in cost with the exception of **Pt or Pt-alloy catalysts**. Concerning critical materials, Pt and graphite are significant in weight and volume in the stack.
- **PEMWEs** materials are more expensive compared to the PEMFCs. The oxygen evolution reaction catalysts are based on **REE** while the hydrogen evolution reaction catalysts are based on **Pt**.
- **AWEs** materials are mainly cheap with the exception of anode and cathode catalysts, which are also classified as critical for the EU states. **Ni-based catalyst** and asbestos diaphragms, used in older types of AWEs, are classified as carcinogen.

CRITICAL RAW MATERIALS IDENTIFICATION

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

1. **Hazardousness** – 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:
   - Economic importance or expected (negative) impact of shortage,
   - 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.

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.

List of critical materials-SOFC

Solid Oxide Fuel Cells

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

Main results

- **SOFCs** materials mainly consist of **Rare Earth Elements** (REE), classified as critical, costly and hazardous.

List of critical materials-PEMFC

Polymer Electrolyte Membrane Fuel Cell

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

Main results

- **PEMFCs** materials are mainly low-to-medium in cost with the exception of **Pt or Pt-alloy catalysts**. Concerning critical materials, Pt and graphite are significant in weight and volume in the stack.

List of critical materials-PEMWE

Polymer Electrolyte Membrane Water Electrolyser

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

Main results

- **PEMWEs** materials are more expensive compared to the PEMFCs. The oxygen evolution reaction catalysts are based on **REE** while the hydrogen evolution reaction catalysts are based on **Pt**.

List of critical materials-AWE

Alkaline Water Electrolyser

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

Main results

- **AWEs** materials are mainly cheap with the exception of anode and cathode catalysts, which are also classified as critical for the EU states. **Ni-based catalyst** and asbestos diaphragms, used in older types of AWEs, are classified as carcinogen.

REGULATORY FRAMEWORK: ANALYSIS BARRIERS AND PERSPECTIVES

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.

REGULATORY FRAMEWORK: ANALYSIS BARRIERS AND PERSPECTIVES

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

Hazardous materials in FCHs and barriers on REACH Regulation

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

Critical raw materials

- Eco-design Directive
- Pt based & REE

Lack of specific legislation on FCH

- ELV Directive
- WEEE Directive

REGULATORY FRAMEWORK: ANALYSIS BARRIERS AND PERSPECTIVES

Hazardous waste and landfill Directives

- damage the environmental beneficial image promoted by FCH manufacturers and developers
- delay the market entry

WEEE and RoHS Directives

- large stationary systems out of scope
- avoid use of some components

Eco-design Directives

- interests of producers, users and recyclers not aligned
- promote eco-design

End-of-Life Vehicles

restrictive targets:

- reuse&recovery: 95%
- reuse&recycle: 85%

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

Hazardous and critical materials:

- Reduce their use by imposing a limited amount, otherwise imposing a socio-economic assessment to justify their use
- At the end, prohibit the use of hazardous materials

Eco-design:

- Harmonize the design process in order the facilitate the dismantling stage
- Improve the quality and durability by imposing a minimum standard
- Modular conception
- Imposing a rate of recycled materials used
- Clear labelling

Recyclability charts:

- For each sub-system, apply a dismantling and recyclability rating

Agreements:

- Develop a strong network between FCH manufacturers and recycling centres
- Win-win: manufacturers buy materials and components at a low price, recycling centres assure to have a new market

RECOMMNEDATIONS AND PERSPECTIVES ON EU REGULATIONS AND POLICIES

- 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

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RECOMMNEDATIONS AND PERSPECTIVES ON EU REGULATIONS AND POLICIES

- 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

Critical Raw Materials

Eco-design Directive

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

RECOMMNEDATIONS AND PERSPECTIVES ON EU REGULATIONS AND POLICIES

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 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 for hazardous and critical materials

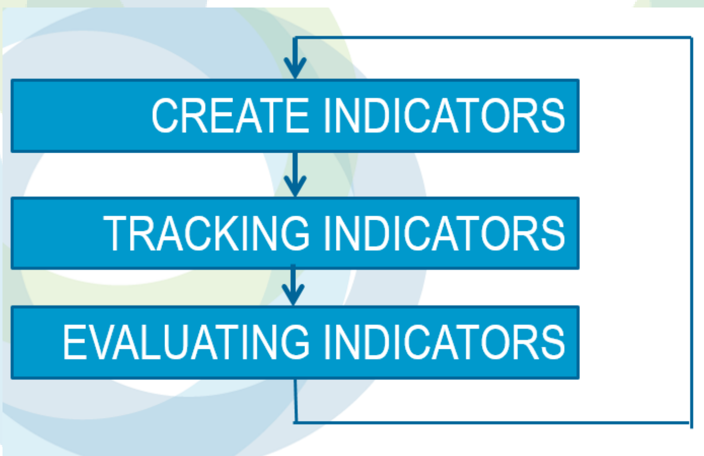
NEEDS AND CHALLENGES IN RECYCLING AND DISMANTLIG PHASE

Objective

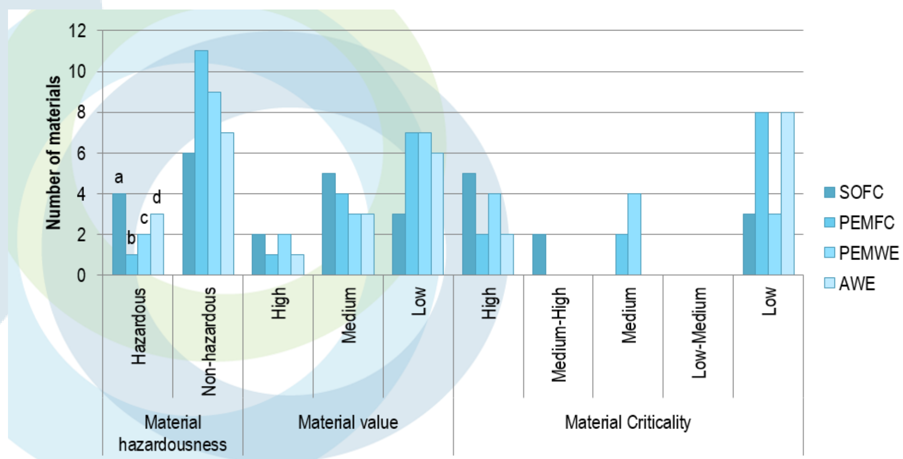
Identification of all the needs and challenges that have to face up FCH technologies, giving a clear basis where future work will be carried.

TWO MAIN ASPECTS A MANUFACTURER HAS TO TAKE IN CONSIDERATION

ECODESIGN

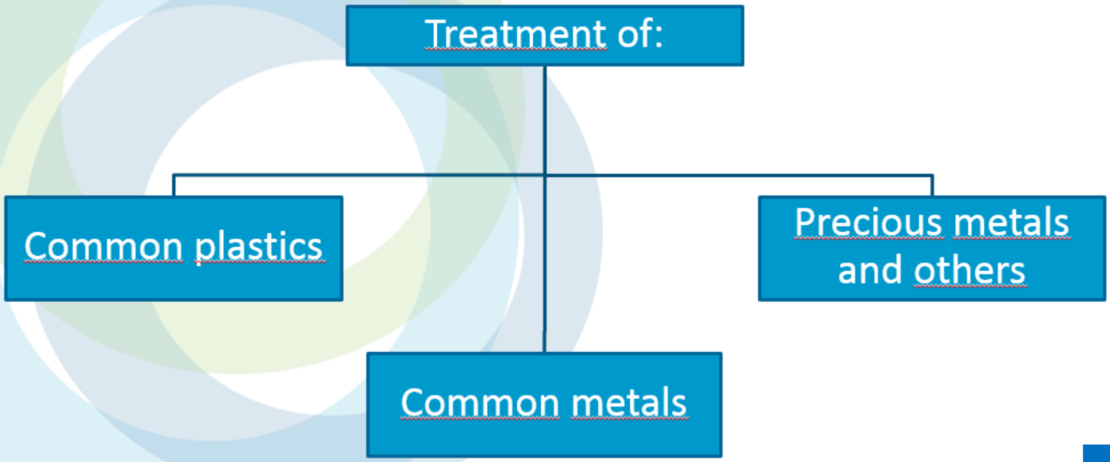


MATERIAL SELECTIONS



FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING
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

TWO MAIN ASPECTS THAT A RECYCLING CENTER HAS TO TAKE IN CONSIDERATION



- EXISTING TREATMENTS
- NOVEL TREATMENTS

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NEEDS AND CHALLENGES IN RECYCLING AND DISMANTLIG PHASE

OTHER NEEDS AND CHALLENGES

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

Extended Responsibility of Producer: Manufacturers should be an active part of the EoL processes.

Tax incentives

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.

FCH Fuel Cells and Hydrogen Joint Undertaking
Foundation for the Devolopment of New Hydrogen Technologies in Aragon
University of Ljubljana
imdea energy institute
Grupo López Soriano
Environment Park Parco Scientifico Tecnologico per l'Ambiente

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Do you have any suggestions or questions ?