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Life Cycle Assessment of a new portable hydrogen fuel cell: Preliminary streamlined results

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Introduction: E.LI.GE Project

This project (http://projects.ciemat.es/web/elige) proposes a new way for portable energy generation. in the 1-100W power range. It is based on a hydrogen fuel cell (FC) with high power density. The key concept of the project is the integration of the current collectors in the electrodes to decrease both weight and volume of the distribution plates and the end-plates. which largely contribute to reduce the FC power density. The new completely passive design also eliminates the weight and volume of unnecessary auxiliary systems and their associated power consumption. to make of this system a viable alternative for powering portable devices.

The main general objectives of E.LI.GE are the following:

- Fabrication of electrodes for portable FCs, which have special characteristics to accomplish with the requirements. In particular, water permeable anodes and air-breathing cathodes are being developed.
- Assembly of membrane-electrodes-current collectors with low internal resistance and low compression requirements. These assemblies allow to increase the power density of portable FCs.
- FC stack plane, light and with high energy density. The stack works in plane configuration to adapt the characteristics of the electrodes (Figure 1).
- Portable application (hydrogen + FC), which is being demonstrated and tested (Figure 2).

Figure 1. FC scheme and main parts.

Figure 2. Application in a mini-airship developed in CIEMAT.

Materials & Methods

An environmental assessment has been done by means of the calculation of the Product Environmental Footprint (PEF) from a Life Cycle Assessment (LCA) approach.

This preliminary study presents the EF results of the manufacturing process of the FC. excluding the hydrogen suppliers. Then. the selected parts to be analysed have been the following:

- Anode, which include the majority of the components: PolyEther Ether Ketone (PEEK) plates, membranes, silicon joints, screws, washers, nickel drain, plastic frame and electrodes.
- Cathode: Joints, metal frames, aluminum plate, drain and electrodes.
- Membrane of Nafion ®.
- Metallic FC locking cap, formed by screws. nuts and studs.
- Plastic gas connectors.

Total weight of the FC is around 58 grams.

Results & Discussion

Table shows contribution to each impact category of FC part. The impact categories acronyms and their units are the following: CC (Climate Change, kg CO_2 eq), OD (Ozone Depletion, kg CFC-11 eq), HTnc (Human Toxicity non-cancer, CTU_h), HTc (Human Toxicity cancer, CTU_h), PM (Particle Matter, kg $PM_{2.5}$ eq), IR (Ionising Radiation, kBq U^{235} eq), POF (Photochemical Ozone Formation, kg NMVOC eq), AC (Acidification, mol_c H^+ eq), TEU (Terrestrial Eutrophication, mol_c N eq), FEU (Freshwater Eutrophication, kg P eq), MEU (Marine Eutrophication, kg N eq), FEC (Freshwater Ecotoxicity, CTU_e), LU (Land Use, kg C deficit), WRD (Water Resource Depletion, m^3 water eq), MFD (Mineral, Fossil & Renewable Resource Depletion, kg Sb eq).

Categories	**Anode**	Cathode	Membrane	Metals	Connectors
CC	**2.07E+02**	2.67E-01	1.90E-03	1.57E-02	2.82E-02
OD	**1.51E-05**	2.75E-08	8.98E-11	6.35E-10	2.70E-09
HTnc	**4.12E-05**	1.05E-07	8.32E-10	1.33E-08	7.39E-09
HTc	**1.04E-05**	6.84E-08	2.93E-10	1.65E-08	1.30E-09
PM	**1.64E-01**	1.80E-04	6.76E-07	8.12E-06	1.19E-05
IR	**1.16E+02**	7.01E-02	4.49E-04	2.43E-03	6.44E-03
POF	**8.30E-01**	6.39E-04	3.04E-06	5.69E-05	7.68E-05
AC	**2.27E+00**	2.18E-03	6.98E-06	6.60E-05	1.29E-04
TEU	**2.99E+00**	2.24E-03	1.00E-05	1.43E-04	2.23E-04
FEU	**8.84E-02**	1.31E-04	7.27E-07	9.22E-06	8.98E-06
MEU	**2.89E-01**	2.09E-04	1.04E-06	1.38E-05	2.21E-05
FEC	**8.87E+02**	3.90E+00	1.77E-02	2.83E-01	1.20E-01
LU	**1.87E+02**	3.69E-01	1.69E-03	1.95E-02	2.08E-02
WRD	**1.48E+00**	1.15E-03	7.63E-06	4.57E-05	1.70E-04
MFD	**1.59E-03**	4.07E-06	4.17E-08	3.66E-07	2.62E-07

Anode is the main contributor to the EF because of its composition. Anodic plates are made of PEEK. This special material is synthetized in laboratory, by reaction of 4,4'-difluorobenzophenone (DFBP) with hydroquinone (HQ) in the presence of potassium carbonate, and then dried under vacuum at 100°C for 24 h. The highest contributor of EF is this last process, because of the high electricity consumption. Figure 3 shows the relative impact of the synthetization of PEEK in terms of CC.

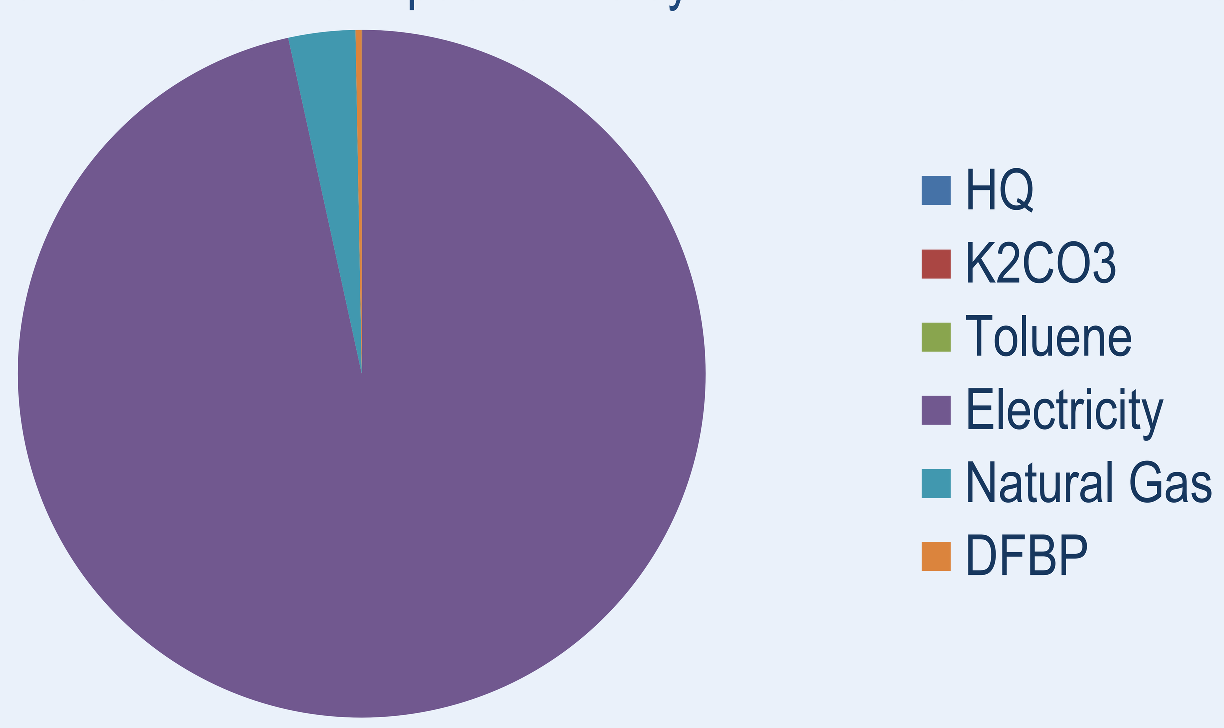

Figure 3. Relative contribution in CC of materials and processes to synthetize PEEK, comparably to the rest impact categories

Conclusions & Further Developments

Preliminary results, in a streamlined way, show the great influence of the selection of new materials in the whole environmental footprint.

The integration of the rest of the parts, such as the hydrogen supplier; and technical data, as the total useful life or the final power density, will allow for obtaining more accurately results in order to compare to another FC devices.

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