# LCA and cost analysis

## Deliverable 2.6

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# D2.6 LCA and cost analysis

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# Executive summary

The main goal of this document is to present the methodology and results obtained by performing a Life Cycle Assessment (LCA) of the system proposed within ELY4OFF, analysing each of its components from cradle to end of utilization from an environmental impact point of view. Final results show the impact over the environment, and also a comparison between two additional different configurations: renewable electricity from a wind turbine and a similar system connected to the electricity grid.

Due to the fact that the ELY4OFF system is a real case located in Spain, further replicability will benefit from the results obtained in this LCA. Future business cases and implementation roadmap for green hydrogen-based systems in a total off-grid environment are also in need of real results, which are introduced in the present Deliverable.

In the second part the CAPEX and OPEX concepts are discussed for the electrolyser installed within ELY4OFF.

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# 1 LIFE CYCLE ASSESSMENT

LCA is the most accepted methodology for estimating the potential environmental impacts associated with a product, process, or service throughout its entire life cycle, from raw material extraction and processing, through manufacturing, transport, use and final disposal [5,6]. This methodology was applied to calculate the environmental impact of ELY4OFF system considering all the life cycle stages of the installation. The practice of LCA is regulated according to ISO 14040 and 14044 standards [7, 8]. Based on these ISO standards, the LCA process is based on four separate stages: (i) goal and scope definition, (ii) inventory analysis, (iii) impact assessment, and (iv) interpretation of the results. The LCA software GaBi ts version 8.7 was utilized to perform the assessments [12].

## 1.1 Goal and scope of the study

The main objective of the LCA development including an environmental impact report is to inform the general public and the policy-makers of significant environmental effects of the ELY4OFF project, identifying possible ways to minimize those effects, and describing reasonable alternatives to those projects. This work provides valuable information about the planning process and strategies of decisions that shape the newly developed hydrogen technologies. Also, an LCA may be used for many different applications such as marketing, product development, product improvement, strategic planning, etc [13]. Main goals of the study are:

- Gaining insight into the value chain of newly developed hydrogen technologies;
- Getting information about the environmental impacts of these technologies, over their whole life cycle;
- Informing the market which the environmental impacts are related to a specific application.

The ELY4OFF system has the aim of hydrogen production; thereby the functional unit has been defined as 1 kg of produced hydrogen at 20 bar pressure and 55 °C with a quality of 99.999%. The functional unit is a key element that quantifies the performance of a product system and gives a reference for the input and output flows in a LCA study [14]. All systems within this assessment are compared on the basis of the functional unit considering the time of the study is as the operational life of the system. The boundaries established for the study of the system includes the five ELY4OFF subsystems which are shown in Figure 1: PEMWE, DC/DC converters, fuel cell, batteries, and hydrogen storage. These boundaries are expanded including electrical production in the subsequent sections of this Deliverable.

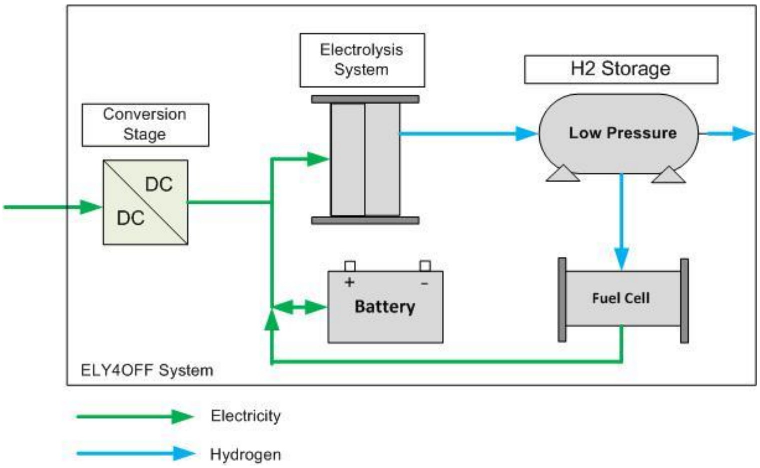


*Figure 1. Ely4off Configuration*

The type of analysis was cradle-to-end of utilization, covering raw materials production, the transport of the system from the manufacturing stage to the operation site and its operation during 20 years. The end of life assessment of the systems is not included in the development of this study due to the lack of information regarding the recycling process for some of the most critical materials [15]. Because of this fact, and with the aim of keeping the consistency of this LCA, there is not any consideration regarding this phase. ELY4OFF system is designed for being a totally autonomous installation and therefore neither material exchange nor human labour was considered for the phase when the installation is in use.

The most updated version of the ReCiPe 2016 Midpoint method was selected to carry out this study [16]. The ReCiPe methodology integrates midpoint and endpoint approaches, which are both characterization methods with indicators at different levels. The midpoint categories provide information on environmental impacts, such as climate change or ozone depletion, while the endpoint impact categories provide information at the end of the cause-effect chain (human health, biodiversity, resources) [17]. ReCiPe 2016 has been adopted worldwide, with a relatively low uncertainty at the midpoint level results [18]. According to the criteria defined for selecting the impact assessment methods, ReCiPe 2016 is chosen to assess the hydrogen production system. Seven hierarchic midpoint categories were taking into account:

- Climate change
- Ozone depletion
- Human toxicity: non-cancer
- Terrestrial acidification
- Fine particulate matter formation
- Photochemical oxidant formation: ecosystem quality
- Mineral resource scarcity

## 1.2 Life cycle inventory

Life cycle inventory (LCI) is the LCA phase that includes the compilation and quantification of everything related to the system of interest throughout its life cycle, in accordance with the ISO 14040 standards [10]. LCI analysis seeks to identify and quantify all the unit processes that are within the boundaries of the defined system. Data collection was performed for the foreground system using different sources, including data through direct interviews with the manufacturer, project documentation, reviews of scientific articles, and technical information, in that order of priority. For the background system, the data present in the Gabi ts database [12] was used.

This section includes a list of the material inventory with the mass of raw materials, together with the main assumptions and hypothesis taken along the study.

### 1.2.1 PEMWE

PEMWE is a very promising option for direct coupling to renewable energy systems due to its dynamic response behaviour which is of key importance [19]. ELY4OFF relies on PEM technology to show that PEMWE is able to be directly coupled to photovoltaics in order to cover different demands of hydrogen by the end user. The ELY4OFF system electrolyser is characterized by:

- Maximum hydrogen generation capacity: 28 kg/day* (assuming 24 hours operation)
- Power at maximum load: 62 kW** (not all systems are operational 100% of the time so this is maximum power requirements)
- Electrolyser self-pressurization up to 20 bar
- Fast response
- CE compliant

* Assuming 24 hours operation.
** Not all systems are operational 100% of the time so this is maximum power requirements.

The life cycle inventory of the PEMWE is shown in Table 1.

*Table 1. LCI including the main materials and masses of the PEMWE.*

| Equipment | Component | Material | Weight (kg) |
|---|---|---|---|
| PEMWE | Membrane | Nafion | 0.623 |
| | Anode catalyst | Platinum | 0.00426 |
| | | Synthetic graphite | 0.0054 |
| | Cathode catalyst | Platinum | 0.003 |
| | | Synthetic graphite | 0.0027 |
| | Anode and Cathode GDL | Synthetic graphite | 0.25 |
| | | Titanium | 0.25 |
| | Bipolar Plate | Titanium | 649 |

| | | | |
|---|---|---|---|
| | Pressure Plate | Stainless Steel | 1760 |
| | Dryer | Copper | 150 |
| | | Aluminium | 400 |
| | | Steel shet | 877 |
| | Refrigerant chiller | Copper | 0.2 |
| | | Stainless steel | 466 |
| | Pipes | Stainless steel | 7.52 |
| | | Steel sheet | 1.5 |
| | Sensors | Stainless steel | 8 |
| | Valves | Stainless steel | 602 |
| | Pumps | Steel sheet | 215 |
| | | Cast iron | 195 |
| | | Stainless steel | 195 |
| | | Epoxy resin | 1.51 |
| | | Copper | 0.284 |
| | Cards | Tin | 0.0958 |
| | | Iron | 0.0616 |
| | | Lead | 0.05 |
| | Cables | Cooper cable 1-wire | 259 |

## 1.2.2 DC DC Converters

The conversion devices are a key element within the configuration system, allowing direct coupling between the photovoltaic field and the electrolyser [20]. The power conversion is from DC to DC, levelling the output voltage of the solar source (up to 800 V) to the required in the stack (up to 140 V), achieving high efficiencies and rapid response thanks to the innovative internal configuration (prototype) and an operation based on Maximum Power Point Tracking (MPPT). For this purpose, a total of 13 converters are utilised whose life cycle inventory is shown in Table 2.

*Table 2. LCI including the main materials and masses of the DC DC Converters*

| Equipment | Component | Material | Weight (kg) |
|---|---|---|---|
| DC/DC | Screws | Steel billet | 1.95 |
| | Plastics | Polypropylene | 2.6 |
| | Metallic components | Steel billet | 28.6 |
| | Cables | Cable 1 wire | 7.15 |
| | | Epoxy resin | 19.63 |
| | | Copper | 3.692 |
| | Cards | Tin | 12.454 |
| | | Iron | 0.8008 |
| | | Lead | 0.65 |
| | Paper | Graphic Paper | 0.13 |
| | Connectors | Polyurethane | 2.925 |
| | | Zinc | 1.755 |

| | | | |
|---|---|---|---|
| | | Nickel | 1.17 |
| | Transformer | Iron | 8.333 |
| | | Steel slab | 3.952 |
| | | Copper | 3.328 |
| | | Stainless steel | 0.416 |
| | | Paper | 0.208 |

### 1.2.3 Batteries

The lead-acid batteries of the ELY4OFF system are specially designed for renewable energy storage applications which require regular deep cycling. The battery bank is formed by 24 individual lead-acid batteries of 2 V with a capacity of 1990 Ah. The life cycle inventory of the batteries is shown in Table 3.

*Table 3. LCI including the main materials and masses of the batteries.*

| Equipment | Material | Weight (kg) |
|---|---|---|
| Batteries | Lead | 1240 |
| | Water | 332 |
| | Sulphuric acid | 207 |
| | Polypropylene | 207 |
| | Glass fibres | 41.5 |
| | Antimony | 20.7 |

### 1.2.4 Fuel cell

The fuel cell installed is used in full with the operation of the lead-acid batteries, to keep the electrolyser operational. The fuel cell starts up when the lead-acid batteries are in a low state of charge and there is not radiation enough. The fuel cell type is proton exchange membrane and has a rated electrical power of 4.5 kW. The life cycle inventory of the fuel cell is shown in Table 4.

*Table 4. LCI including the main materials and masses of the fuel cell.*

| Equipment | Material | Weight (kg) |
|---|---|---|
| Fuel cell | Steel billet | 47.53 |
| | Steel billet | 4.61 |
| | Copper | 14.8 |
| | Aluminium sheet | 0.4 |
| | Acrylonitrile-Butadiene-Styrene | 4.45 |
| | Platinum | 0.0075 |
| | Ruthenium | 0.02 |
| | Synthetic graphite | 0.1 |
| | Nafion | 0.1 |

### 1.2.5. Storage tank

The hydrogen storage system consists of a low-pressure H2 tank at 20 bar. To estimate the hydrogen availability in the system, it includes a pressure sensor. The life cycle inventory of the hydrogen storage system is shown in Table 5.

*Table 5. LCI including the main materials and masses of the hydrogen storage.*

| Equipment | Component | Material | Weight (kg) |
|---|---|---|---|
| Storage | Hydrogen tank | Steel billet | 1700 |
| | Sensors | Stainless steel | 8 |

## 1.3 Energy scenarios

PEMWE is an energy demanding element using electricity and heat. This heat is also provided by the electricity generated on the own system. For the required input flows, 9 kg of H2O is considered to be necessary to produce 1 kg of H2 and 50 kWh of electricity considering an efficiency of the 67% with respect to the LHV of the system despite this value depends on the operating current density, environmental conditions, ambient temperature, and use profile.

For the study of the system, it has been considered a hydrogen production of 900 kg per year during 20 years of operation. This value is not accurate due to the intrinsic intermittency of any renewable installation but it is the reference value based on the mathematical model developed by technicians in a previous stage of the project. For all scenarios and with the aim of being able to compare them with each other from the environmental point of view, the same quantity of hydrogen produced has been considered. During the operational time, it has been assumed that there is no replacement in the installation.

The three energy scenarios included in this Deliverable were compared in terms of the previously chosen environmental indicators, and major contributors to environmental impacts were identified. Within this study, a comparative assessment is carried out considering the following scenarios:

1. Use of photovoltaic panels to obtain off-grid electricity: Photovoltaic scenario
2. Use of wind turbines to obtain electricity: Wind scenario
3. Direct connection to the grid: Grid scenario

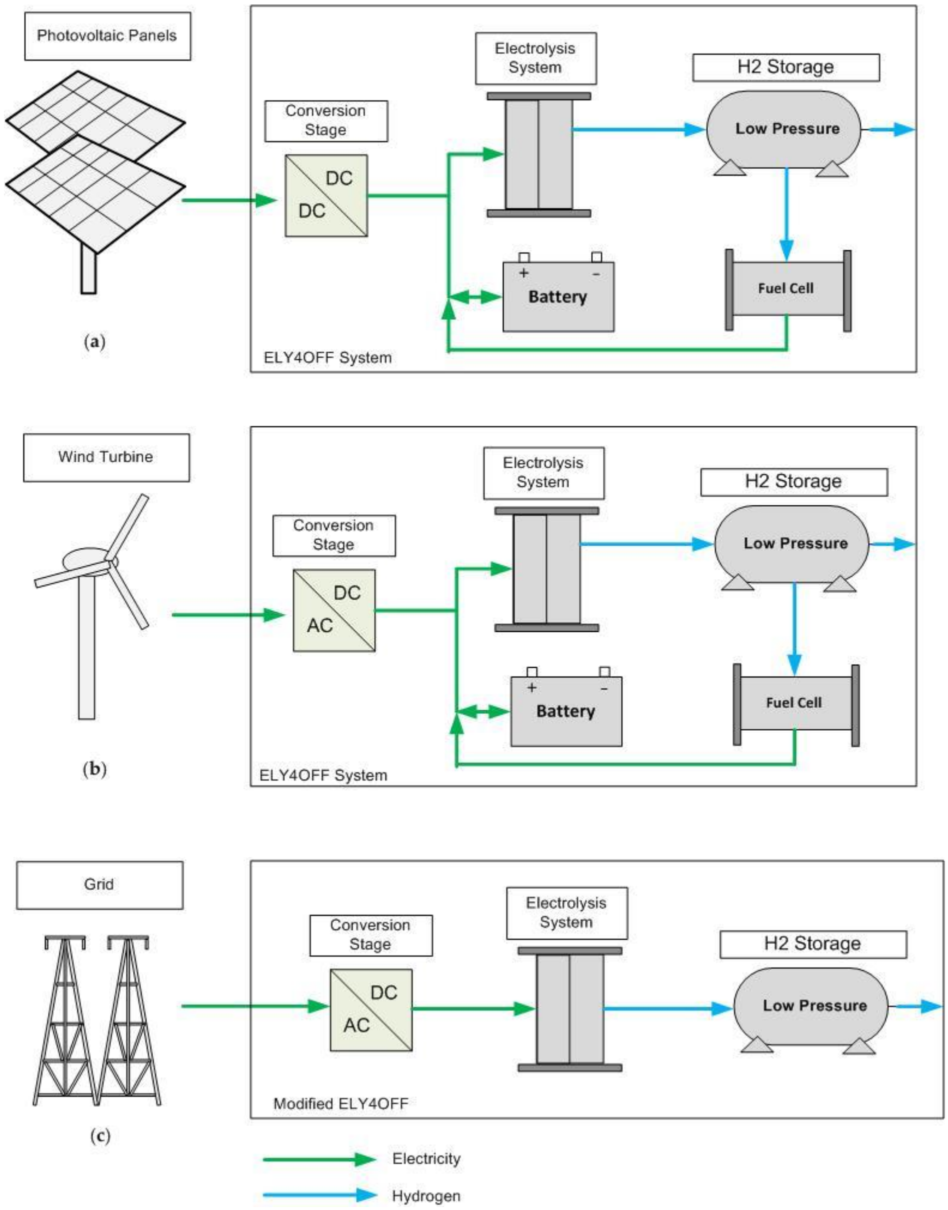


*Figure 2. Scheme of the three energy scenarios analyzed in this study. (a) Photovoltaic scenario (b) Wind scenario (c) Grid scenario*

A scheme of the equipment included in each scenario is shown in Figure 2. For the three cases studied is considered the same energy demanded for the system. Regarding the photovoltaic and wind scenario, it was considered that the installation of the ELY4OFF remains unchanged, keeping unaltered all the equipment except the conversion stage, being required an inverter instead of a converter in the wind scenario. However, in the case of the grid scenario, more modifications were made to the installation. The backup fuel cell and the batteries were eliminated due to the unnecessary when connecting to the grid. In addition, although the existence of converters is no longer necessary in the wind and grid scenario, the presence of inverters is. It was considered that from the point of view of the life cycle analysis, these inverters will have similar characteristics among them and that the converters of the photovoltaic scenario have.

For modeling the photovoltaic and wind scenario electricity production, data from the GaBi database was used [12]. In this database are collected both the manufacturing and operation life cycle phases, being important to note the uncertainty associated with this point. Regarding the photovoltaic scenario, the data set includes the following average efficiencies per photovoltaic technology: Mono-Silicon 51.5 %, Multi-Silicon 41.4 %, Cadmium-Telluride 5.1 %, Copper-Indium-Gallium-Diselenide 2.0 % while in the ELY4OFF system only one type of photovoltaic panel technology is used: Multi-Silicon, so the use of the data set does not accurately represent the actual installation.

In the wind scenario, with the idea of being able to extrapolate it to future installations, a data set is used which includes an average onshore and offshore wind model. If more accurate results would be needed at this point, it would be necessary to remodel the system, but this is outside the scope of the study. For modeling the grid mix scenario, the Spanish grid mix of 2018 published by Red Eléctrica de España in February 2019 was used [21]. The electricity demand coverage used was: nuclear 23%, wind 21%, coal 14%, hydro 14%, combined cycle 11%, cogeneration 12%, solar photovoltaic 3% and solar thermal 2%. It has been considered that the grid mix remains unchanged during the scope of the study. It must be taken into account that the energy mix is decisive for obtaining the results. The determining effect of the electric mix of a given country on the emissions associated with hydrogen produced through electrolysis was previously published, showing its great impact over the final results. [22]

# 2 LCA. RESULTS AND DISCUSSION

## 2.1 ReCiPe impact categories of the ELY4OFF system.

Interpretation of LCA studies is assessed by the Life cycle impact assessment (LCIA), translating the emissions and resource extractions into a limited number of environmental impact scores using characterization factors [23]. Table 5 displays the seven impact categories selected with their corresponding midpoint characterization factor and the unit. These factors indicate the environmental impact per unit of emission released or resource used.

*Table 6. Impact assessment categories with their corresponding midpoint characterization factor and unit considered in this study.*

| Impact Category | Midpoint characterization factor (CFm) | Abbrev. | Unit |
|---|---|---|---|
| Climate change | Global warming potential | GWP | kg CO2 eq. |
| Ozone depletion | Ozone depletion potential | ODP | kg CFC-11 eq. |
| Human toxicity: non-cancer | Human toxicity potential | HTPnc | kg PM2.5 eq. |
| Terrestrial acidification | Terrestrial acidification potential | TAP | kg SO2 eq. |
| Fine particulate matter formation | Particulate matter formation potential | PMFP | kg PM2.5 eq. |
| Photochemical oxidant formation: | Photochemical oxidant formation potential: | EOFP | kg NOx eq. |

| | | | |
|---|---|---|---|
| Ecosystem quality | ecosystems | | |
| Mineral resource scarcity | Surplus ore potential | SOP | kg Cu eq. |

Table 6 present the impact assessment results per functional unit of the manufacturing stage of the ELY4OFF system for the seven impact categories selected The contribution to the impact indicators of the use phase is practically non-existent compared to the manufacturing phase, so from this point, only reference to this phase will be made.

*Table 7. Impact assessment results per functional unit considering the emissions associated with the manufacturing stage of the ELY4OFF system.*

| CFm (unit) | Batteries | Converters | Storage | PEMFC | PEMWE | Total |
|---|---|---|---|---|---|---|
| GWP (kg CO2 eq.) | 0.134 | 0.015 | 0.064 | 0.013 | 1.890 | 2.116 |
| ODP (10-7 kg CFC-11 eq.) | 0.567 | 0.063 | 0.200 | 0.070 | 4.880 | 5.780 |
| HTPnc (10-1 kg 1,4-Db eq.) | 0.303 | 0.056 | 0.036 | 0.149 | 3.200 | 3.744 |
| TAP (10-3 kg SO2 eq.) | 1.380 | 0.086 | 0.178 | 0.115 | 8.480 | 10.239 |
| PMFP (10-3 kg PM 2.5 eq.) | 0.807 | 0.027 | 0.066 | 0.040 | 3.005 | 3.945 |
| EOFP (kg NOx eq.) | 0.115 | 0.013 | 0.092 | 0.020 | 2.180 | 2.420 |
| SOP (10-1 kg Cu eq.) | 0.015 | 0.013 | 0.192 | 0.030 | 2.390 | 2.640 |

Analyzing the results shown in Table 6, it is observed that the manufacture of the PEMWE is the main source of emissions of the entire installation. In all impact categories, the contribution of the PEMWE accounts for more than 82% of the total emissions with the exception of particle formation, where it occupies 76%. In two of the impact categories (EOFP and SOP), its value increases for 90% of the total. The next equipment of the installation with the higher amount of emissions associated are batteries, with values that vary from 0 to 13 percent, highlighting their contribution to PMFP, being responsible for 20% of the total. Regarding the rest of the components, no remarkable high impact emissions were detected, and in any case exceed 4% of the emissions in any category of impact. Figure 3 displays the relative contributions of each subsystem to the environmental GWP results for the studied system.

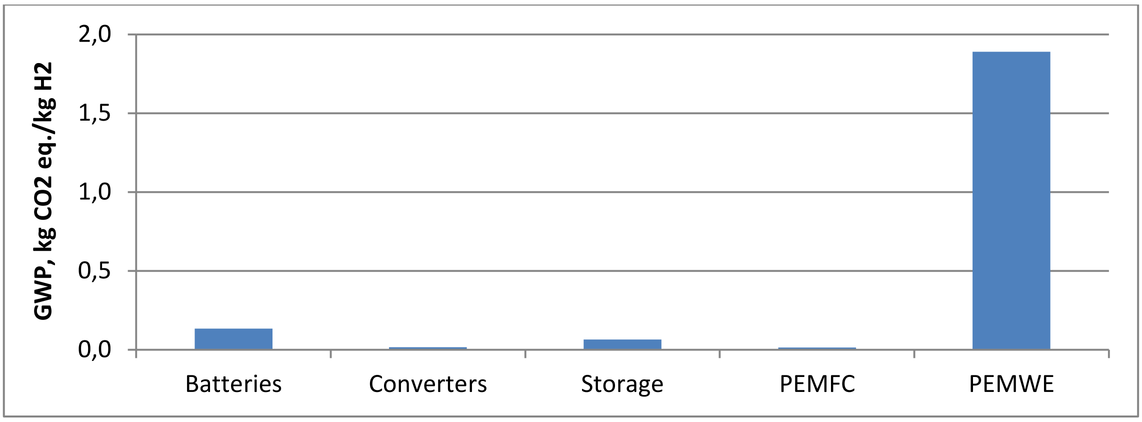


*Figure 3. Global warming potential (ReCiPe2016, kg CO2 eq./kg H2) of the manufacturing stage of the ELY4OFF system.*

According to these results, 89% of emissions are due to the PEMWE, followed by 6% for batteries and 3% for storage. The total GWP emission of the manufacturing stage of the ELY4OFF system is 38160 kg of CO2 eq.

## 2.2 Comparison of electrolysis based on different energy scenarios

The assessment between the three energy scenarios has been carried out through a comparative LCA, which implies that the comparison of the environmental profiles of different systems is made on the basis of equivalent functions.

The results of the impact assessment of the three studied energy scenarios are collected in Table 7, separating these results for each of the scenarios studied.

*Table 8. Impact assessment results per functional unit considering the total emissions associated with the production of hydrogen using the ELY4OFF system and different electricity production methods.*

| CFm (unit) | Photovoltaic | Wind | Spanish grid mix |
|---|---|---|---|
| GWP (kg CO2 eq.) | 4.59 | 2.50 | 6.51 |
| ODP (10-7 kg CFC-11 eq.) | 11.57 | 6.82 | 16.64 |
| HTPnc (10-1 kg 1,4-Db eq.) | 13.84 | 4.53 | 4.21 |
| TAP (10-3 kg SO2 eq.) | 17.86 | 11.16 | 18.43 |
| PMFP (10-3 kg PM 2.5 eq.) | 7.12 | 4.37 | 6.18 |
| EOFP (kg NOx eq.) | 6.31 | 2.74 | 14.28 |
| SOP (10-1 kg Cu eq.) | 3.24 | 2.87 | 2.64 |

In order to have a reference value that can be used to make a comparison, as A. Mehmeti reported [24], the emissions associated with hydrogen production by SMR process is 12.13 kg CO2 eq./kg H2, so with the ELY4OFF system, there would be a significant decrease of emissions. Using the photovoltaic ELY4OFF system, a reduction of 7.54 kg is achieved for each kg of hydrogen produced, which represents 62% less GWP emissions.

With the idea of having a broader view of the results, these were divided into the stage of electrical production and the manufacturing stage of the ELY4OFF system. Figure 4 shows the associated emissions of both the electrical production and the manufacturing stage of the system for the three scenarios studied.

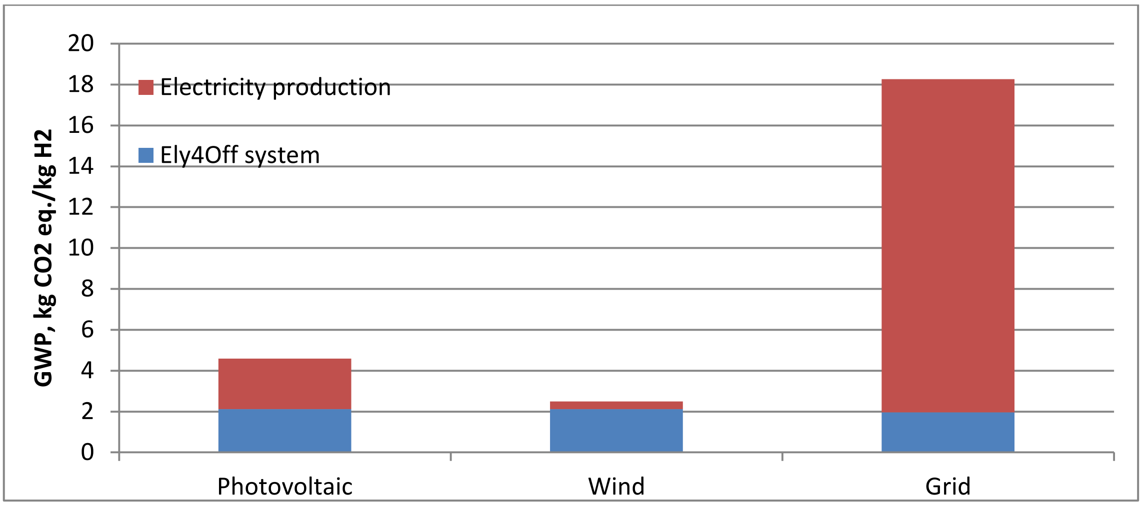


*Figure 4. Global warming potential (ReCiPe2016, kg CO2 eq./kg H2) of the three systems studied.*

In the photovoltaic scenario, 46% of the GWP emissions come from the manufacturing stage of the system and 54% from the obtaining of electricity. In the wind scenario, almost 85% of the GWP emissions come from the manufacturing of the ELY4OFF system, and in the grid scenario GWP emissions are increased by more than seven times and almost four times compared to the photovoltaic scenario.

The LCA results demonstrated that the wind-powered scenario had lower emissions considering all the midpoint characterization factors. Focusing on GWP, Figure 4 shows that a reduction of 54% GWP emissions are obtained with the use of wind turbines considering the ELY4OFF installation unaltered compared with the photovoltaic scenario. However, if the electricity is obtained from the grid mix, GWP emissions increase by 42% compared with the photovoltaic scenario despite a 7% decrease in the manufacturing stage of the modified ELY4OFF system.

The value obtained from emissions associated with the production of hydrogen by electrolysis using the grid mix is slightly lower than those recently published by other authors for other countries, where the integration of renewable energies in the energy mix is lower [24]. The importance of the electric mix as mentioned in previous sections is reflected.

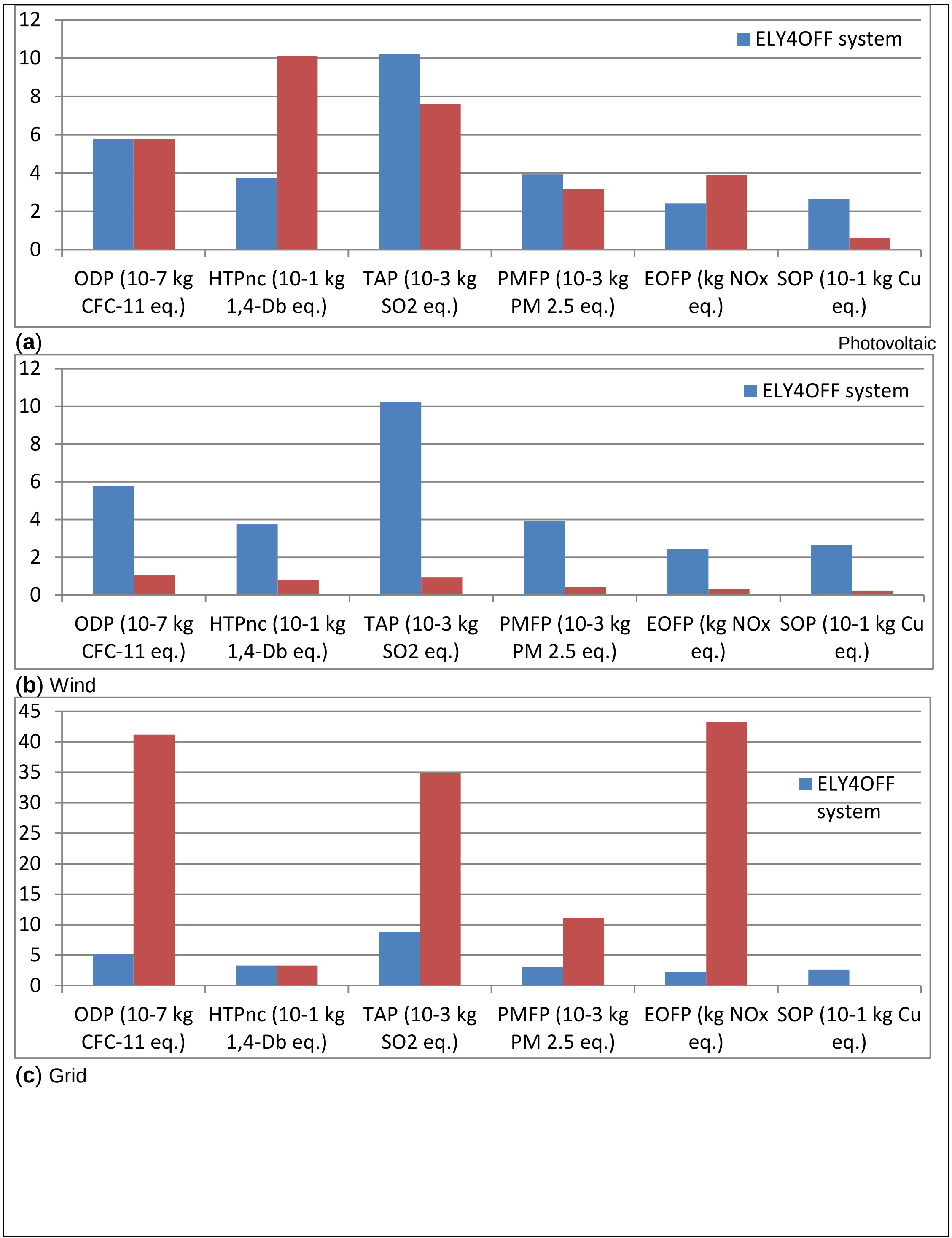


*Figure 5. Impact assessment results per functional unit from the following methods considering the emissions associated with the ELY4OFF system and the obtaining of the electricity needed for the installation: (a) Photovoltaic powered (b) Wind powered (c) Spanish grid mix powered.*

In the results obtained for the photovoltaic scenario presented in Figure 5 (a), it is shown that for the TAP, PMFP and SOP indicators the impact of the ELY4OFF system is higher than the production of electricity through solar panels, while in terms of HTPnc and EOFP, the electrical production has greater impact, especially in the case of HTPnc. The ODP values are similar for electrical production than for the ELY4OFF system.

Figure 5 (b) shows the results obtained for the wind scenario. The manufacturing stage of the system is responsible for the majority of associated emissions compared to the electrical production stage.

In Figure 5 (c), the results of the grid scenario are presented. These results show how electricity production through the grid mix has a significant high impact on four of the six indicators studied (ODP, TAP, PMFP and EOFP), accentuating this difference in terms of ODP, TAP and EOFP, in comparison to the ELY4OFF system. Analyzing the rest of the indicators, there is a greater impact of the ELY4OFF system in terms of SOP, and PMFP values are the same for both stages. These values demonstrate that, in contrast to the situation of the wind scenario, the contribution to the impact categories is absolutely decisive in the electricity production stage than those associated with the modified ELYOFF system in this scenario.

# 3 LCA. CONCLUSIONS

This study evaluates the environmental aspects of hydrogen and electricity production in an innovative small-scale production plant. The LCA methodology was applied to assess the environmental performance of this production scenario. Although the production of hydrogen through electrolysis processes is presented as a propitious solution to mitigate the effects of climate change and reduce dependence on fossil fuels, the origin of the electricity used affects notably the final results in terms of environmental impact indicators.

This study demonstrates that the manufacturing process of the PEMWE is the most critical stage of the installation regarding the production of hydrogen, being the equipment with the most associated emissions with more than 90% of the total emissions of the installation. This study has also collected a comparison between different electricity production technologies to feed the electrolyser and its importance to the total impact of the installation. The use of wind turbines, followed by the use of solar panels, was presented as the best solutions with fewer associated emissions in all impact categories analysed. However, the use of electricity from the grid mix is presented as the least sustainable solution, despite having slightly fewer emissions at the installation's manufacturing stage.

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# 5 COST ASSESSMENT

## CAPEX

Whilst CAPEX is difficult to calculate for a prototype unit which is sized for a demonstration (ie smaller than would be for a commercial plant) it is still possible to look at the cost breakdown of the unit compared to a "standard" on grid system. The figure below shows how the cost has spread out.

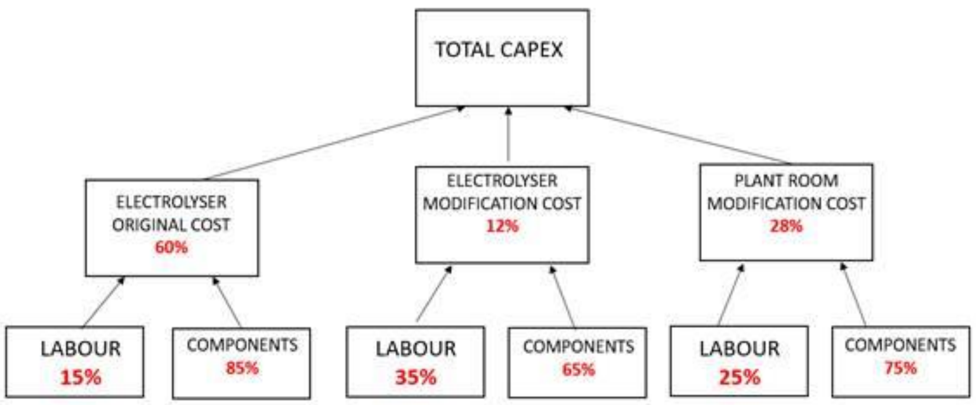


*Figure 6. CAPEX breakdown ELY4OFF vs on-grid electrolyser*

The modifications can be explained as;

ELECTROLYSER MODIFICATION COST

These are modifications to the physical plant, mainly the BoP, which were done to reduce the power used for the off grid trial. These included:

- Removal of an air compressor used for valve operation and hydrogen drying. A gas bottle was used instead
- Fitting of a more efficient pump
- Addition of passive frost protection systems (insulation jackets)

PLANT ROOM MODIFICATION COST

This includes:

- Removal of AC-DC rectifier and replacement with DC-DC unit specific to this project
- Modification of control hardware to allow the DC-DC unit to function as part of the electrolyser

In terms of the cost breakdown of the original electrolyser that can be broken down into the key systems and is shown in the pie chart below

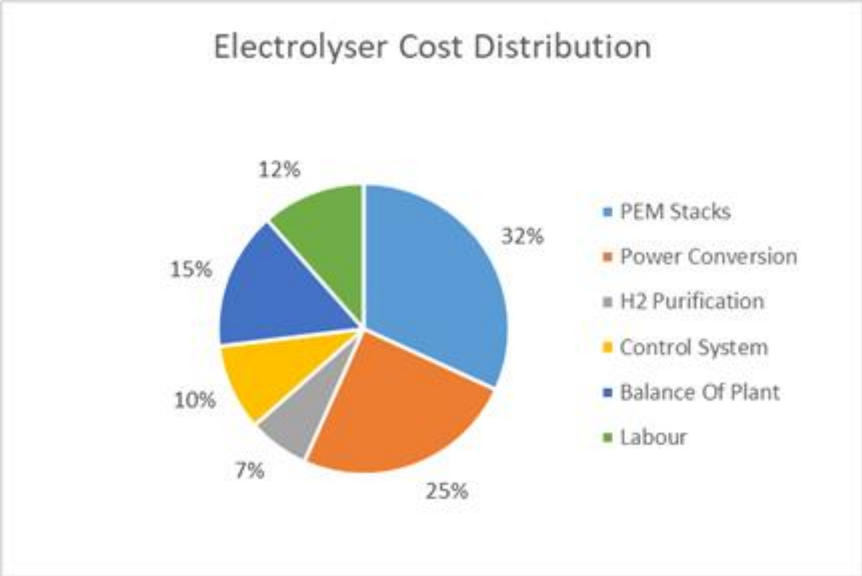


*Figure 7. Electrolyser cost breakdown*

The PEM stack makes up the majority of the cost and that can be broken down further as shown below (for a typical 1 MW system)

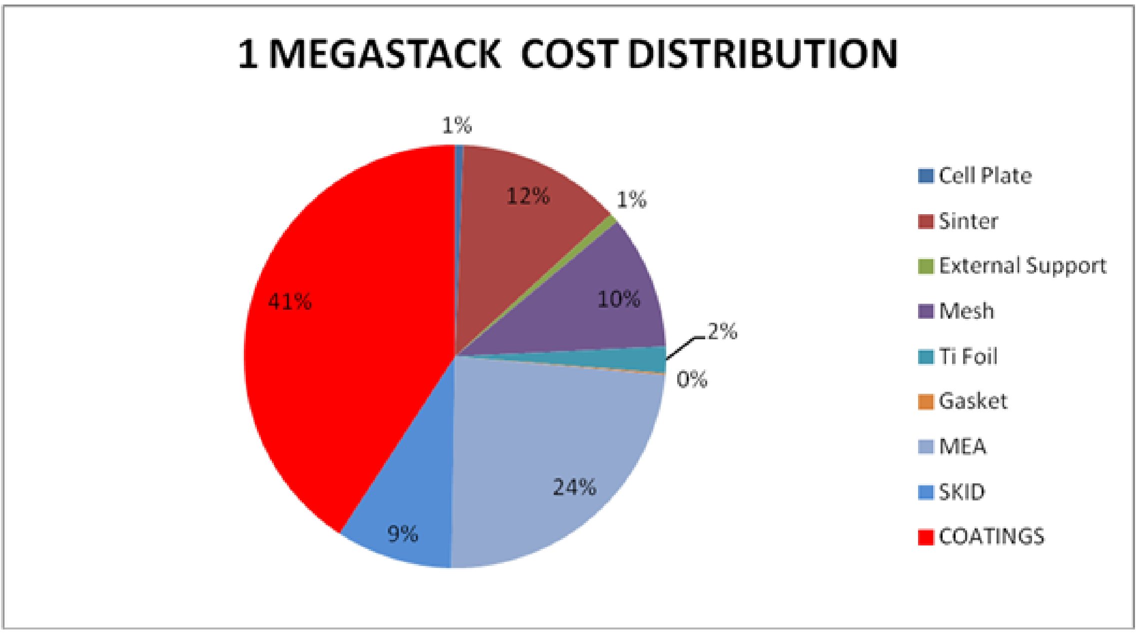


*Figure 8. Cost distribution at MW scale*

In terms of actual figures we can quote 3,130 Euro/Kw but these figures reduce significantly for commercial sized systems and can be represented by the graph below

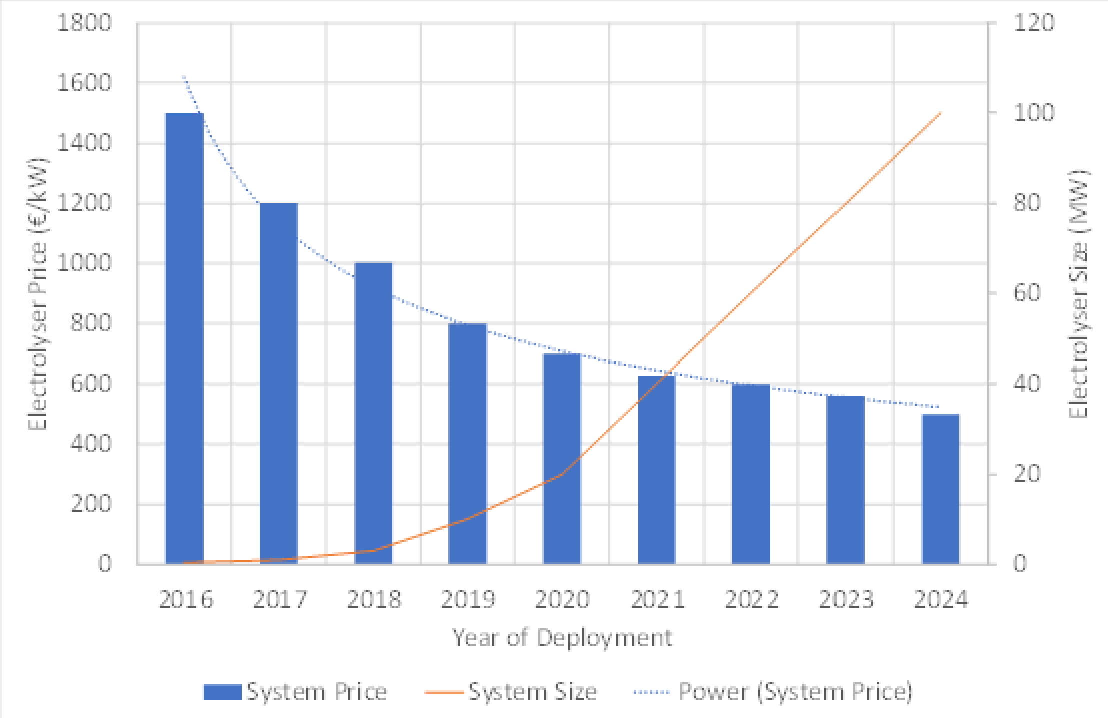


*Figure 9. Electrolyser price (€/kW) vs size (MW)*

## OPEX

As this is an off grid first of a kind system it is almost impossible to measure the OPEX values of this system and the operational costs are based on the cost of electricity per Kg of hydrogen. As this is using free renewable energy then the OPEX cost is practically zero other than the consumables used. In terms of these they can be itemised as below:

- Water purification resin
- Mixed bed resin for circulation water clean up
- Compressed air for drier operation

In an off grid system where operation is ~ 8 hours a day the resin life is expected to be in the region of 1 year (in a system that is operational for 24 hours a day these would be changed about every 6 months) The costs of the resins can be itemised as follows:

- €630 water purification resin working out at ~€1.32/kg of hydrogen
- €250 circulation resin working out at ~ €.053/kg of hydrogen

Air bottles cost ~ € 40 per refill and last approx. 2 months (in the trial this was actually higher until a leak was identified) this works out at ~ € 0.25/kg of hydrogen

In terms of the value that could be obtained from feed in tariffs vs value of the hydrogen that is considered to be out of the scope of the project.

From a cost perspective there were 2 KPIs which are presented in D5.2 As discussed above the first target isn't really relevant to an off-grid system but the €/kg has been demonstrated to be achievable for a prototype with significant reductions when scaled up to commercial levels.

| Units | Target in proposal | Target revision in D2.4 | Specific test (D5.1)? | Result | Target achieved? |
|---|---|---|---|---|---|
| **M€/(t/d)** | 6 | 6 | NO | 26 | ~~Yes~~ / No/ ~~partially~~ |
| **€/kW** | - | 3,360 | NO | 3,130 | Yes ~~/ No/ partially~~ |