

HORIZON EUROPE PROGRAMME
HORIZON-JTI-CLEANH2-2024

GA No. 101192342

Direct seawater electrolysis technology for distributed hydrogen production



SWEETHY - Deliverable report

D10.2 – Screening Life Cycle Assessment



Deliverable No.	D10.2	
Related WP	WP 10	
Deliverable Title	Screening Life Cycle Assessment	
Deliverable Date	2026-03-31	
Deliverable Type	REPORT	
Dissemination level	PU	
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Reviewed by	SWEETHY partners	2026-03-30
Approved by	Olesia Danyliv (RISE)	2026-03-31
Status	FINAL	2026-03-31

Document History

Version	Date	Editing done by	Remarks
V1.0	2026-03-11	Uniben Tettey	Initial version
V1.1	2026-03-23	Uniben Tettey/Kristin Fransson	Updated results and added results from idea generation workshop
V1.2	2026-03-30	Olesia Danyliv	Small wording corrections in the document
FINAL	2026-03-31	Olesia Danyliv	Approved for submission



Project Summary

SWEETHY will develop an advanced technology for direct seawater electrolysis that will be able to produce hydrogen (H₂) and oxygen (O₂) under intermittent conditions accounting for the coupling to renewable power sources (especially wind, PV). The electrolyser will be based on an anion exchange membrane (AEM) operating in natural or alkaline seawater, and the SWEETHY technology will be developed along three dimensions:

- a) Materials optimisation. To meet the specific requirement of seawater environment the project will focus on corrosion resistance and selective PGM-free electrocatalysts for hydrogen and oxygen evolution reactions, on AEM with high selectivity for transporting hydroxide anions and anti-fouling properties as well as on novel anti-corrosion coatings for bipolar plates and porous transport layers prepared by plasma spraying and electrodeposition.
- b) Electrolyser stack prototyping. The project will exploit a novel stack architecture, which uses hydraulic cell compression to host the advanced materials and to produce H₂ at high pressure. Beneficial functions of the targeted unique stack are related to scalability and maintainability that will be tremendously improved in comparison to conventional AEMWE stacks.
- c) Sustainability analysis. The project will conduct studies (life-cycle assessment (LCA), techno-economic analysis (TEA)) to evaluate circularity of the electrolyser system and its integration into renewable-power systems and to explore an efficient by-product utilisation way through industrial symbioses. These studies will feed back to materials optimisation and stack development. Complementing LCA, social LCA, and techno-economic analyses/optimisation by qualitative work ensures both environmental, economic, and social sustainability.

Combining these three dimensions, SWEETHY will utilise Mediterranean seawater from the coast of Messina, Italy, to test its electrolyser with the goal to withstand more than 2000h of operation to produce 20 gH₂/h with a degradation rate lower than 1%/100h. In addition, SWEETHY will demonstrate how the operation of the electrolyser can ensure an optimised revenue concerning by-products and grid services.



Public summary

In this report, the potential environmental impacts of a proposed direct seawater electrolysis technology for hydrogen production within the SWEETHY project based on anion exchange membrane water electrolysis (AEMWE) were assessed by performing a screening life cycle assessment (LCA). The screening LCA is mainly based on literature data for similar state-of-the-art systems and follows the ISO 14040/44 standards and guidelines related to hydrogen technologies. The aim is to identify potential environmental hotspots along the value chains to support eco-design and integrate a life-cycle perspective early in the project.

Three different AEMWE systems identified in literature, one with stack based on platinum group metals (PGM) and the other two based on PGM-free stack with variations in their configurations are assessed in this screening LCA. The studied systems are not designed for seawater electrolysis application as will be the case for the proposed SWEETHY electrolyser system. The functional unit is defined as production of 1 kg hydrogen with purity over 99% at a pressure of 20 bar over a complete system lifetime of 25 years. The system boundary covers raw material extraction and processing, production of stack (including replacements over the defined system lifetime) and rest of system as well as the use phase of the system for hydrogen production. As the goal at this stage is to support the eco-design and sustainable development of the proposed technology, other maintenance and end-of-life stages are not assessed here but will be explored in a full LCA later in the project.

The results show that the use phase dominates in the environmental impacts of all the studied systems compared to impacts from the stack and rest of system components. For the studied systems, most of the impacts in the use phase emanates from the use of potassium hydroxide for the electrolysis process. The impact from the use of potassium hydroxide can be largely reduced if it is recirculated in the system and this will be explored in the full LCA study. The electricity input also seems to significantly influence the environmental impacts of the studied systems depending on the source and location. The results also indicate that among the studied systems, the PGM based system has significantly higher environmental impacts compared to the PGM-free stack based systems.

Overall, this study highlights the potential environmental hotspots along the considered life cycle stages of the studied electrolyser systems and provides early-stage information to support decisions on material selection for the different system components and how the different components and materials in the proposed SWEETHY electrolyser system could be designed to optimise both the technical and environmental performance for a more sustainable development and scale-up.



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Abbreviations & Definitions

Abbreviation	Meaning
AEM	Anion exchange membrane
AEMWE	Anion exchange membrane water electrolysis
BPP	Bipolar plates
BoP	Balance of plant
eLCA	Environmental lifecycle assessment
H₂	Hydrogen
PEMWE	Proton exchange membrane water electrolysis
PGM	Platinum group metals
sLCA	Social lifecycle assessment
SWE	Seawater electrolysis
TEA	Techno-economic assessment



1 Introduction

SWEETHY is a project aiming at developing an advanced technology for direct seawater electrolysis that will produce hydrogen and oxygen with the use of renewable electricity. The technology builds on an anion exchange membrane (AEM) operation in natural or alkaline seawater. The project focuses on materials optimization and development of a stack prototype. To assure sustainability and social acceptance, several sustainability assessments will be performed within the project. This report comprises the screening Life Cycle Assessment (LCA). The aim of the screening LCA is to provide intermediate results on environmental performance of the system and included materials, to support eco-design and to integrate a life-cycle perspective early in the project. The report will also serve as a basis for the full LCA that will be performed later in the project.



2 Method

The screening LCA follows the methodology in ISO14040 (ISO - International Organization for Standardization, 2006a) and 14044 (ISO - International Organization for Standardization, 2006b) as well as the LCA checklist for Clean Hydrogen Joint Undertaking projects (Santucci et al., 2024) (see Appendix C) and guided by the SH2E guidebook for LCSA (Martín-Gamboa et al., 2023). Note that the screening LCA will be limited in scope and may not follow all parts of the above standards and guidelines. The full LCA, that will be conducted later in the project will comply with the standards and guidelines to full extent.

2.1 Goal and scope

The goal of this screening LCA is to evaluate the potential environmental impacts of the proposed electrolyser system from a life cycle perspective based on state-of-the-art systems mainly from literature and to identify where the hotspots occur along the different life cycle stages. The results are intended to support eco-design of the proposed system and also serve as a basis for the full LCA that will be performed later in the SWEETHY project.

2.1.1 Target audience

This screening LCA study is mainly intended for internal use within the project consortium to support the eco-design and overall development of the proposed electrolyser system.

2.1.2 Studied systems

The studied systems cover the proposed seawater electrolysis technology, including the AEM electrolyser system as well as the rest of the system (RoS) to achieve the balance of plant (BoP), required for the production of hydrogen. More details about the studied systems are presented in section 3.

2.1.3 Functional unit

The functional unit is defined as 1 kg of produced hydrogen with purity over 99% at a pressure of 20 bar over a system lifetime of 25 years. Assuming full operation over the system lifetime will result in about 21999 tonnes of hydrogen production. As AEM electrolyser systems are still under development, the lifetime is uncertain and generally expected to be lower than that of systems based on proton exchange membrane (PEM), which are more established. Stack lifetime for AEM systems are estimated to be between 20000 – 60000 hours of operation and expected to reach higher operation hours as they are still under development (Riemer et al., 2024; Wei et al., 2024). In this study, stack lifetime of 30000 hours is assumed for the base case of the studied systems and lifetimes of 60000 and 80000 hours are also explored in a sensitivity analysis. The reference flow is thus defined as the amount of materials for the studied systems and input energy and resources to fulfil the defined functional unit.

2.1.4 System boundaries

As the goal of this study is to assess the environmental implications of the studied electrolyser system and identify potential hotspots, the system boundary here is defined to cover raw material extraction and processing, production of stack and rest of system as well as the use phase of the system for hydrogen production (see



Figure 1). Stack exchanges during the expected lifetime of the studied systems are included, but other maintenance and end-of-life activities are not included in this screening LCA.

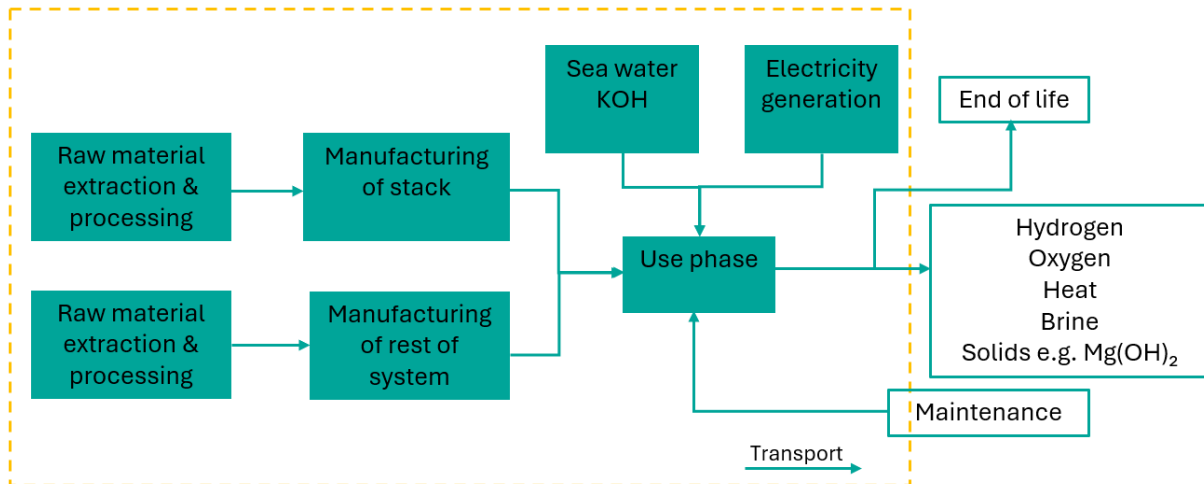


Figure 1 System boundary of the study.

2.1.5 Cut-off criteria

As much as possible, all relevant inputs and outputs for the studied systems are included in the analysis and no cut-off rule as relates to exclusion of input and output flows is applied in this study.

2.1.6 Environmental impact categories

For the screening LCA, the potential environmental impacts of the studied electrolyser systems are based on the Environmental Footprint 3.1 (EF 3.1), as implemented in Simapro version 10.3.0.1 (Pré Consultants, n.d.). The EF 3.1 method is one of the widely used methods and advocated by the EU Commission (Andreasi Bassi et al., 2023). Impact assessment categories from EF 3.1, including climate change (total, fossil, biogenic, land use and land use change), ozone depletion, acidification, eutrophication, photochemical ozone formation, resource use, water use, particulate matter emissions, ionising radiation, ecotoxicity and human toxicity are used to present a broad view of the environmental profile of the studied systems.



3 Inventory analysis and modelling

The compiled data and assumptions used for the environmental impact assessment of the different materials and components of the studied systems are presented below. Three types of AEM electrolyser systems are assessed in this screening LCA. The main differences between the studied systems are in the composition of the stacks. One of them is based on platinum group metals (PGM) while the other two are PGM-free with variations in the raw materials that are used.

Data for the modelling is taken mainly from literature in combination with datasheets and personal communication with project partners. The literature data sources that are most widely used are (Wei et al., 2024) for the stacks, and (Gerhardt-Mörsdorf et al., 2024) and (Krishnan et al., 2024) for the rest of the system components. The LCA modelling is performed in SimaPro, version 10.3.0.1 (Pré Consultants, n.d.) and generic data is taken from the Ecoinvent database, version 3.11 (Wernet et al., 2016). The used Ecoinvent datasets mainly represented global (Glo) average market data for raw materials and their processing while EU average market data for electricity generation based on specific locations was assumed for the operation of the system during the use phase. The datasets used in this study to model the different components and materials of the studied systems are presented in Appendix B.

3.1 Stack

Component sizes and materials in the studied stacks are based on a stack power of 1 kW for each of the considered options. The inventory data for the components and materials are presented in Table 3.1-Table 3.3 for the different stacks. The cited literature reports 1.18E+02 kg of stainless steel in the bipolar plate (BPP) of the PGM stack but since this may be overestimated, an alternative of the PGM stack (PGM_rev) based on the same amount of stainless steel in the BPP of the PGM-free type 1 stack (see Table 3.2) is also considered in this study.

Table 3.1 Components and materials for the 1 kW PGM stack based on (Wei et al. 2024)

Component	Material	Value	unit
Bipolar plate	Steel, Cr-steel 18/8	1.18E+02 ¹	kg
Gasket	Tetrafluoroethylene	1.24E-03	kg
Anode	Iron (III) phosphate	3.08E-01	kg
	Anionic resin	3.69E-02	kg
	Nickel, 99.5%	1.66E+00	kg
	Nafion	4.26E-04	kg
Membrane	Anionic resin	1.93E-01	kg
Cathode	Ruthenium	7.10E-04	kg
	Carbon black	5.93E-01	kg
	Platinum	1.60E-03	kg
	Nafion	4.26E-04	kg
Nickel forming	Steel, Cr-steel 18/8	1.66E+00	kg

¹ An alternative (PGM_rev) based on same amount of stainless steel in the BPP of PGM-free type 1 is also assessed.



Table 3.2 Components and materials for the 1 kW PGM-free type 1 stack based on (Wei et al. 2024)

Component	Material	Value	unit
Bipolar plate	Steel, Cr-steel 18/8	4.40E+00	kg
Gasket	Synthetic rubber	9.57E-03	kg
Anode	Nickel foam	7.73E-02	kg
	Nickel	3.74E-03	kg
	Iron	3.74E-03	kg
Membrane	Polysulfone	2.43E-02	kg
Cathode	Nickel	1.12E-02	kg
	Molybdenum	1.25E-03	kg
	Carbon black	3.00E-02	kg
Conductive plate	Steel, Cr-steel 18/8	6.62E+00	kg
Support material	Steel, Cr-steel 18/8	4.49E-01	kg

Table 3.3 Components and materials for the 1 kW PGM-free stack type 2 based on (Wei et al. 2024)

Component	Material	Value	unit
Bipolar plate	Steel	2.68E+00	kg
Gasket	Synthetic rubber	1.02E-01	kg
Anode	Steel	1.44E-02	
	Iron	5.00E-04	kg
	Nickel	5.00E-04	kg
	Hydroxide	1.50E-03	kg
Membrane	Polystyrene	4.15E-03	kg
Cathode	Nickel	8.01E-03	kg
	Nickel felt	1.25E-03	kg
	Molybdenum	1.25E-03	kg
Monopolar plate	Steel	1.34E+00	kg
End plate	Steel, Cr-steel 18/8	9.20E+00	kg

3.2 Rest of system

Apart from the stacks, other components are necessary for the system to be operational. These are covered under rest of system and include the balance of plant (BoP) such as heat exchangers, data cables and electronics, and pumps as well as a foundation and housing for the system. The inventory



data used for the rest of the system in this study is based on (Gerhardt-Mörsdorf et al., 2024; Fransson et al., 2025) for a 5MW proton exchange membrane water electrolysis (PEMWE) system. These components are expected to be similar for the studied AEMWE systems with no significant differences (Riemer et al., 2024). The same components for the rest of the system are assumed for all the studied systems and the inventory is presented in Table 3.4. The number of stacks are given for use of the system over a lifetime of 25 years, including stack exchanges. For the base case, stack lifetime of 30000 hours is assumed.

Table 3.4 Components for a complete of system of 5000 kW capacity

Component	Value	Unit
Stacks	40000 ¹⁾	pcs
Anode gas water separator	660.3	kg
Cathode gas water separator	356.3	kg
Feed pump	2	pcs
Circulating pump	2	pcs
Stack cooling heat exchanger	1340.4	kg
Condenser	1157.7	kg
Dry cooler	1	pcs
Cooling water circulating pump	2	pcs
Power cables	50	m
Data cables	2000	m
Control unit	1	pcs
Power electronics	1427.5	kg
Foundation	4.5	m ³
Housing	2	pcs

¹⁾ Based on stack power of 1 kW and assumed lifetime of 30000 hours for the base case.

3.3 Use phase

For the use phase of the studied systems, sea water and potassium hydroxide as well as electricity input are needed for the hydrogen production. The data used to model the use phase of the studied systems in this screening LCA are presented Table 3.1 and estimated based on key performance indicators (KPIs) for the SWEETHY project. Apart from hydrogen, oxygen and excess heat as well as solid by-products such as magnesium hydroxide are also generated. The implications of the excess oxygen and heat generated are also considered in this study. For magnesium hydroxide, the



possibilities for its use will be explored in connection with the industrial symbiosis task later on in the project as part of the full LCA. For the base case in this analysis, the electricity input is assumed to be from wind power for the 3 different locations considered in the project, namely, Sweden, Italy and France. The electricity input is modelled with the Ecoinvent datasets “high voltage {SE/IT/FR}| electricity production, wind, >3MW turbine, onshore | Cut-off, S” with climate impacts of 27.7, 32.2 and 26.6 kg CO₂-eq/kWh for Sweden, Italy and France, respectively. Seawater is taken as input from nature.

Table 3.5 Dataset used to model the use phase of the studied systems

Description	Value	Unit
Input		
Seawater	17.9	kg
Potassium hydroxide	1.003	kg
Electricity	53	kWh
Output		
Hydrogen	1	kg
Oxygen	7.94	kg
Brine	8.94	kg
Magnesium hydroxide	0.072	kg
Heat	15.56	kWh



4 Results and discussion

The results are first presented for the studied systems for all the assessed impact categories based on the EF 3.1 method. Results are also given for selected impact categories i.e. climate change (climate impact) as well as resource use - minerals and metals, which are considered to be of large importance for the project and a breakdown is provided for the different components of the studied systems for a better understanding of the environmental profile over the considered life cycle stages.

4.1 Results for the studied systems

The results for all assessed impact categories for the studied systems are presented in Table 4.1 for the base case, assuming a stack lifetime of 30000 hour over 25 years. The results show that the PGM stack based system has the most impacts in all the assessed impact categories compared to the other 2 PGM-free stack based systems. Comparing the PGM-free stack systems between each other, it shows that the PGM-free_1 system has slightly higher impacts than the PGM-free_2 system for most of the assessed impact categories. The PGM_rev stack system with the adjusted amount of stainless steel in the BPP also results in higher environmental impacts in the assessed impact categories compared to the PGM-free stack based systems.

Table 4.1 Environmental impacts for production of 1 kg hydrogen with the studied systems

Impact category	Unit	PGM	PGM_rev	PGM-free_1	PGM-free_2
Acidification	mol H+ eq	7.46E-02	6.62E-02	4.33E-02	4.30E-02
Climate change	kg CO2 eq	7.86E+00	6.32E+00	6.17E+00	6.17E+00
Climate change - Biogenic	kg CO2 eq	2.89E-02	1.04E-02	1.10E-02	1.13E-02
Climate change - Fossil	kg CO2 eq	7.81E+00	6.29E+00	6.15E+00	6.14E+00
Climate change - Land use and LU change	kg CO2 eq	1.35E-02	1.16E-02	1.13E-02	1.13E-02
Ecotoxicity, freshwater - part 1	CTUe	1.07E+02	1.03E+02	1.01E+02	1.01E+02
Ecotoxicity, freshwater - part 2	CTUe	3.88E+01	2.45E+01	2.29E+01	2.27E+01
Ecotoxicity, freshwater - inorganics	CTUe	1.45E+02	1.27E+02	1.23E+02	1.23E+02
Ecotoxicity, freshwater - organics - p.1	CTUe	4.18E-01	3.37E-01	3.27E-01	3.26E-01



Ecotoxicity, freshwater - organics - p.2	CTUe	4.25E-01	3.70E-01	3.37E-01	3.36E-01
Particulate matter	disease inc.	5.46E-07	4.29E-07	3.93E-07	3.93E-07
Eutrophication, marine	kg N eq	9.77E-03	8.19E-03	7.31E-03	7.30E-03
Eutrophication, freshwater	kg P eq	5.06E-03	3.71E-03	3.53E-03	3.52E-03
Eutrophication, terrestrial	mol N eq	1.06E-01	8.96E-02	7.61E-02	7.60E-02
Human toxicity, cancer	CTUh	2.24E-08	2.06E-08	2.05E-08	2.05E-08
Human toxicity, cancer - inorganics	CTUh	3.69E-09	2.34E-09	2.28E-09	2.26E-09
Human toxicity, cancer - organics	CTUh	1.87E-08	1.82E-08	1.82E-08	1.83E-08
Human toxicity, non-cancer	CTUh	2.25E-07	1.96E-07	1.94E-07	1.94E-07
Human toxicity, non-cancer - inorganics	CTUh	2.13E-07	1.85E-07	1.83E-07	1.83E-07
Human toxicity, non-cancer - organics	CTUh	1.15E-08	1.09E-08	1.06E-08	1.06E-08
Ionising radiation	kBq U-235 eq	6.38E-01	5.26E-01	5.13E-01	5.12E-01
Land use	pt	4.51E+01	3.67E+01	3.54E+01	3.53E+01
Ozone depletion	kg CFC11 eq	4.05E-08	3.89E-08	2.57E-08	2.57E-08
Photochemical ozone formation	kg NMVOC eq	3.29E-02	2.77E-02	2.38E-02	2.38E-02
Resource use, fossils	MJ	9.80E+01	8.00E+00	7.76E+01	7.75E+01
Resource use, minerals and metals	kg Sb eq	2.75E-04	2.40E-04	2.27E-04	2.26E-04
Water use	m ³ depriv.	7.40E-01	6.26E-01	5.97E-01	5.98E-01

Figure 2 and Figure 3 show the potential impacts from climate as well as resource use, minerals and metals of the studied systems. The climate and resource use impacts are similar for the PGM-free stack



systems and also lower compared to the PGM stack alternatives. The climate impact is about 21% lower and the resource use impact is about 18% lower for the PGM-free systems compared to the PGM system. When compared to PGM_rev system, the climate impact is about 2% lower while the resource use impact is about 5% lower for the PGM-free systems. These differences seem to stem from the variations in the stack configurations between the PGM and PGM-free systems. From an overall system perspective, the impacts for all the studied systems are mainly dominated by the use phase, constituting about 76-97% of the total climate impact and 80-98% of the total impact from resource use, minerals and metals.

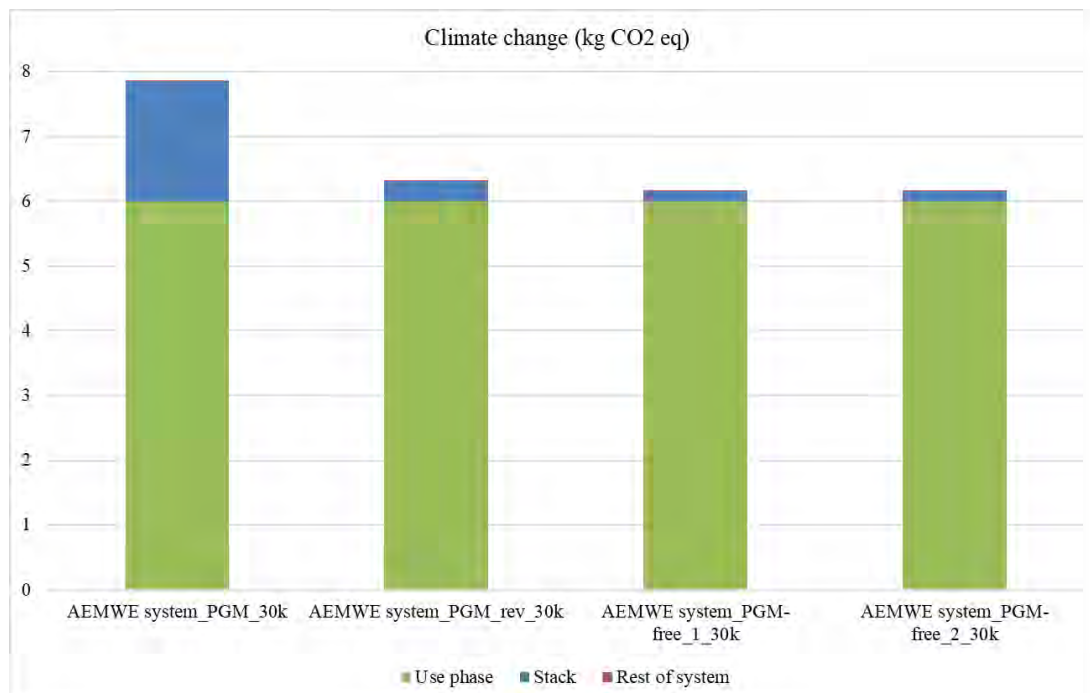


Figure 2 Climate impact for production of 1 kg H2 with the studied systems.

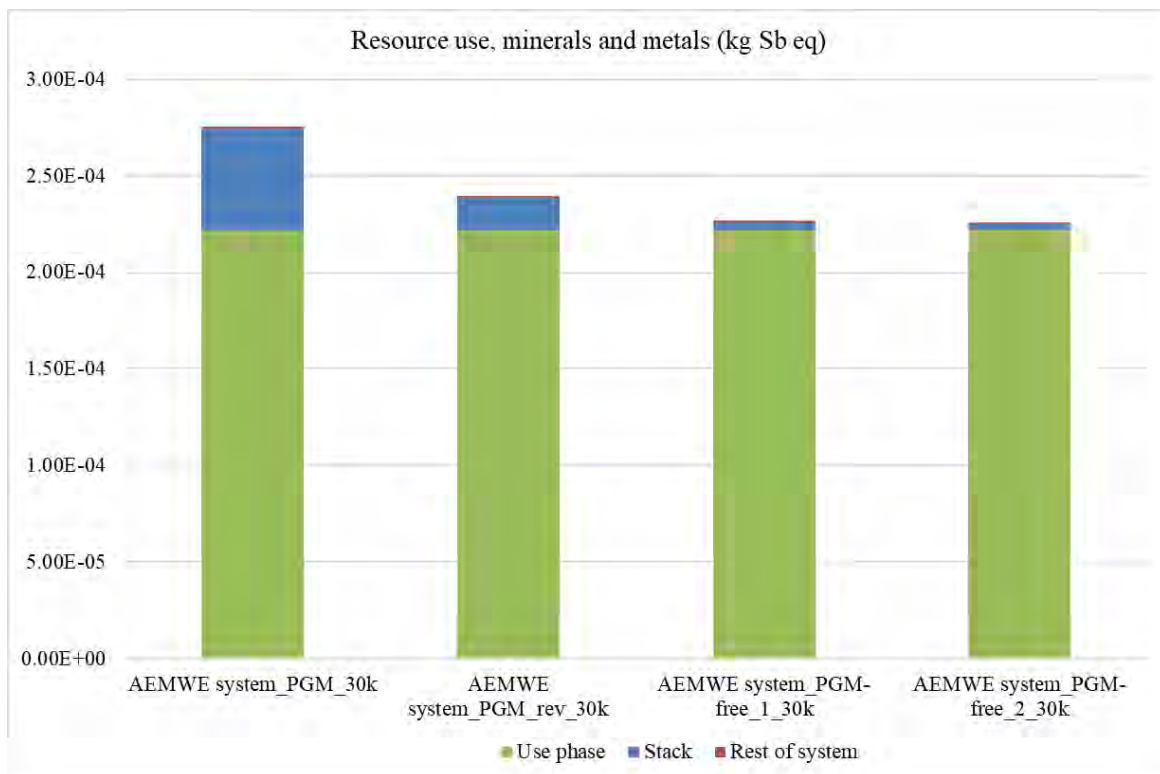


Figure 3 Resource use, minerals and metals for production of 1 kg H₂ with the studied systems.

4.2 Results for the studied stack configurations

Results at the stack level for the different stack configurations are presented in Figure 4 and Figure 5 for the climate as well as resource use, minerals and metals impacts, respectively. The PGM stack results in the most impacts compared to the PGM-free alternatives. The climate impact of the PGM stack is about 91% higher than that of the PGM-free stacks. The significantly high impacts from the PGM stack stems mainly from the high amount of stainless steel material in its bipolar plate component compared to those for the PGM-free alternatives (see Table 3.1 - Table 3.3). However, with the PGM-free alternative (with the same amount of stainless steel in the BPP as the PGM-free_1 stack), the climate impact is about 49% higher than that of the PGM-free alternatives.

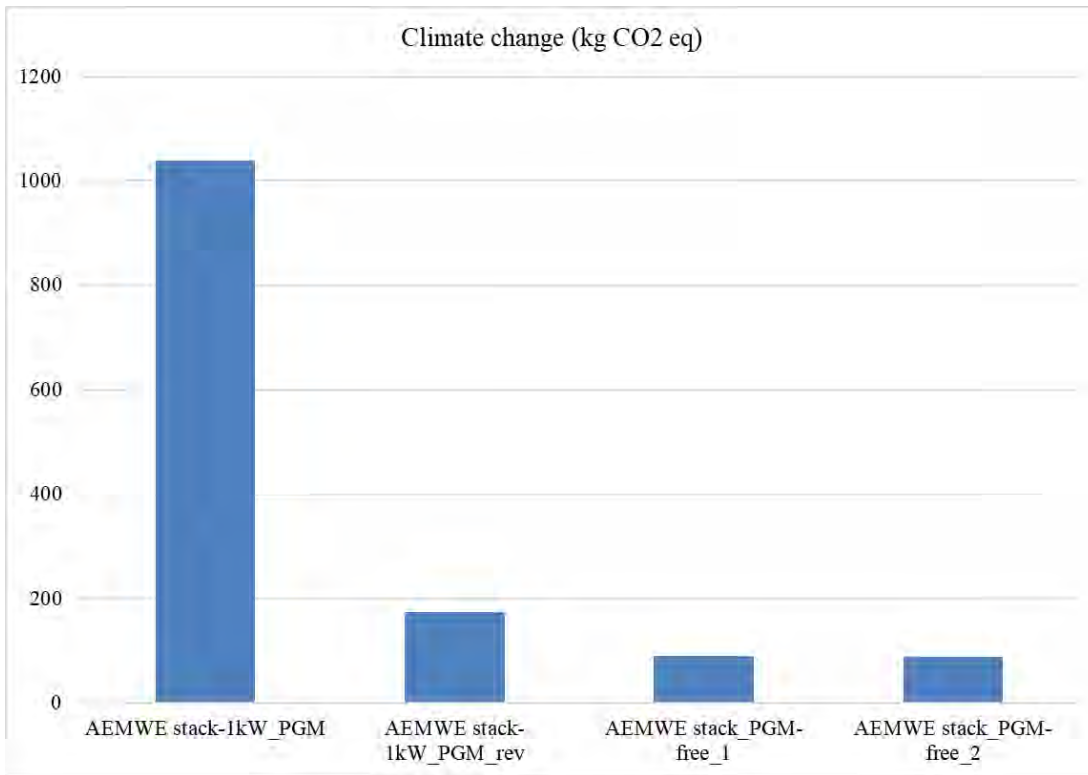


Figure 4 Climate impact for the studied stack configurations.

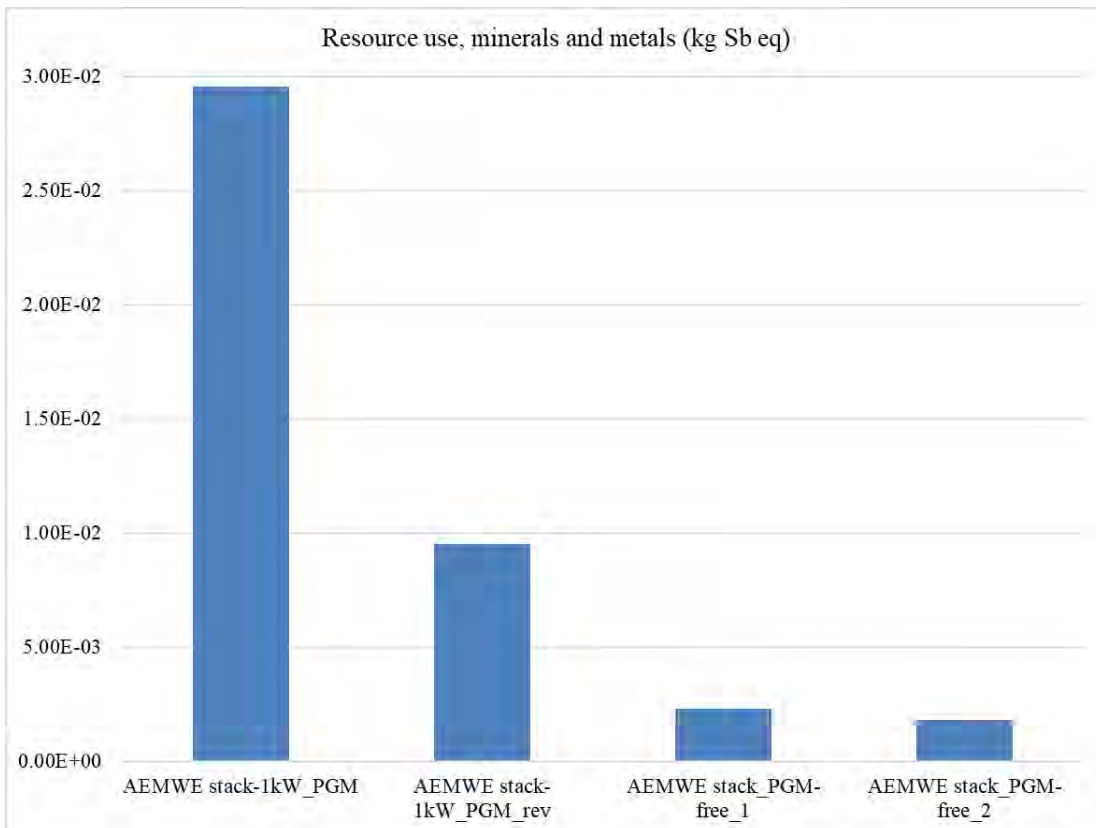


Figure 5 Resource use, minerals and metals for the studied stack configurations.



The contribution of the different components of the studied PGM stack alternative are presented in Figure 6 and **Error! Reference source not found.** for the climate and resource use, minerals and metals impact categories. Stainless steel and manufacturing process for the bipolar plate of this stack contributes the most (86.5%) to the climate impact. This is followed by the cathode with about 9.3% of the total climate impact of the PGM stack. For the cathode, most of the impacts come from the platinum. The same trend in the results are observed for the resource use, minerals and metals impact category with bipolar plate dominating, followed by the anode but with different shares of the total impact.

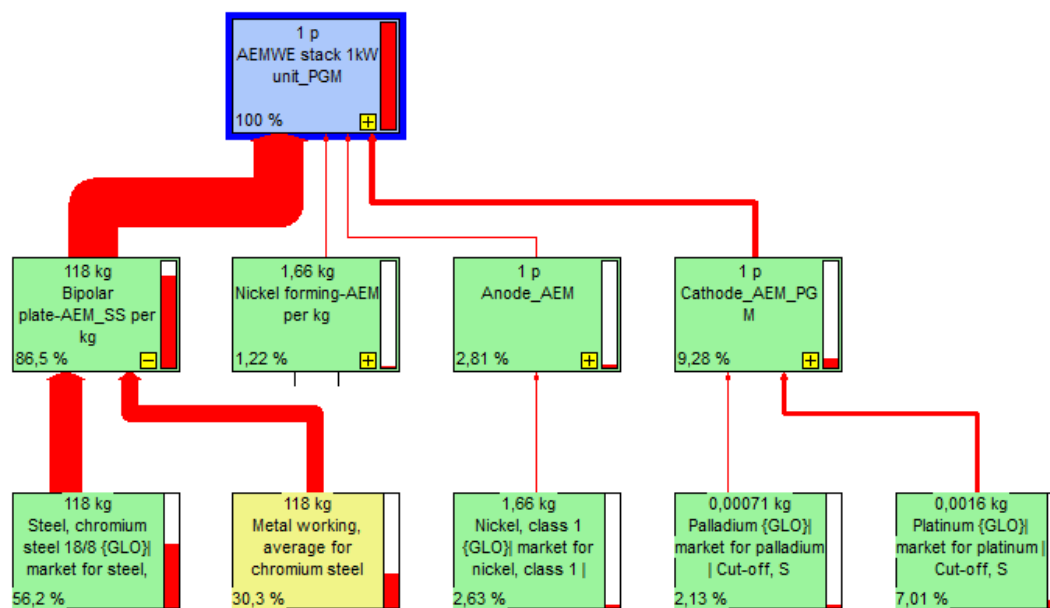


Figure 6 Relative contributions of the different components of the PGM stack to climate impact. Only processes/components contributing more than 1% of the total impact are shown in this figure.

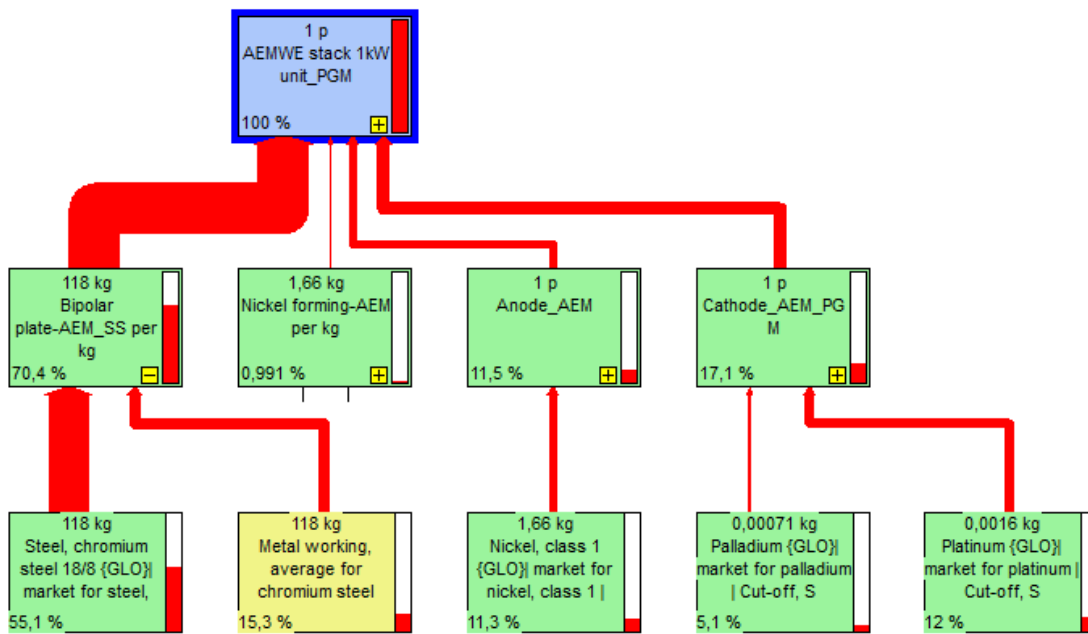


Figure 7 Relative contributions of the different components of the PGM stack to resource use, minerals and metals. Only processes/components contributing more than 1% of the total impact are shown in this figure.

The contribution of the different components of the studied PGM_rev stack alternative are presented in Figure 8 and Figure 9 for the climate and resource use, minerals and metals impact categories. The results show that most of the impacts stem from platinum (42%) and palladium (13%) in the cathode. This is followed by stainless steel and manufacturing process for the bipolar plate with about 19.3% of the total climate impact of the PGM_rev stack. For the impacts for resource use, minerals and metals, most of the impacts emanate from the cathode (53%), followed by the anode (35.5%).

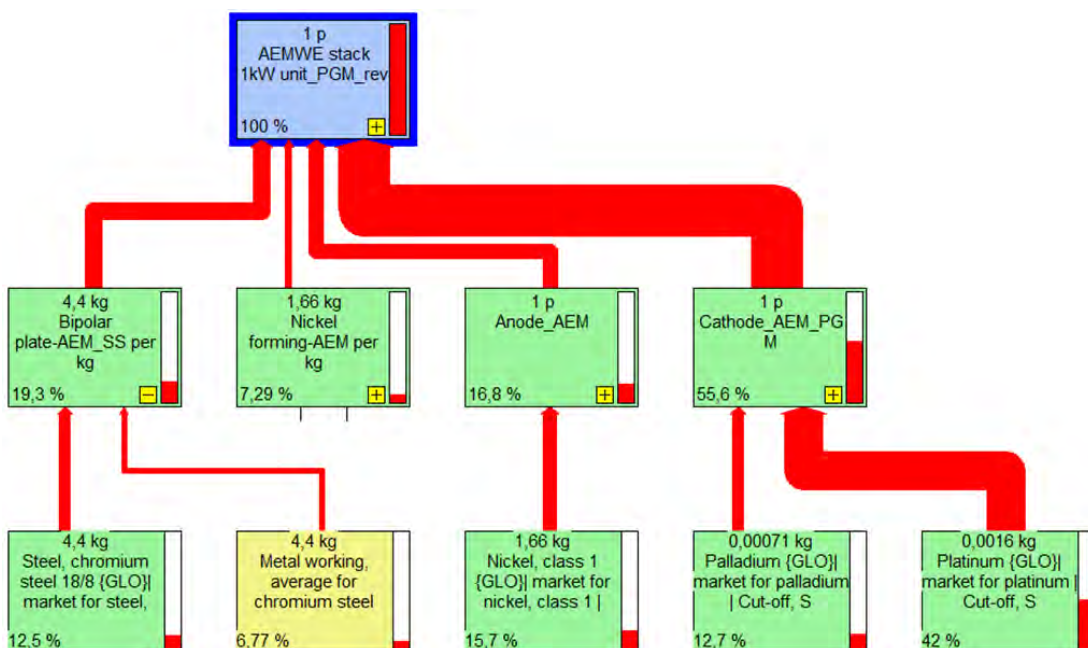


Figure 8 Relative contributions of the different components of the PGM_rev stack to climate impact. Only processes/components contributing more than 1% of the total impact are shown in this figure.

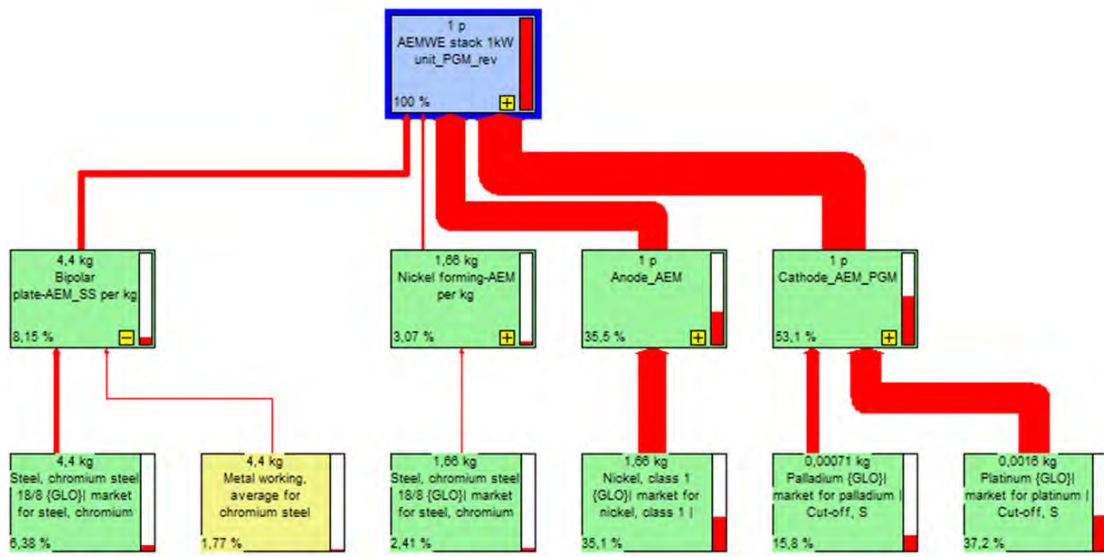


Figure 9 Relative contributions of the different components of the PGM_rev stack to resource use, minerals and metals. Only processes/components contributing more than 1% of the total impact are shown in this figure.

Figure 10 and Figure 11 show the relative contribution of the different components of the studied PGM-free_1 stack for the climate and resource use, minerals and metals impact categories. For this stack, stainless steel and manufacturing process for the conductive plate of this stack contributes 56.4% to the climate impact, followed by the bipolar plate with 37.5% of the total climate impact also from stainless steel and the manufacturing process. Here, notably the anode contributes about 1.7% of the total climate impact of this stack, mainly from nickel. For the resource use, minerals and metals impact category, the conductive plate still dominates but followed by the bipolar plate both based on stainless steel but with different contributions to the total impact.

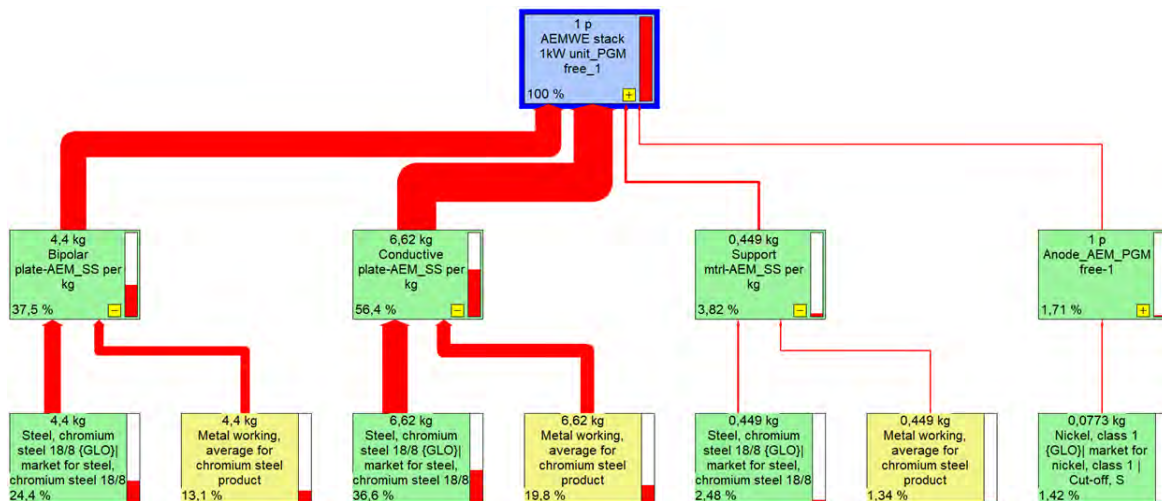


Figure 10 Relative contributions of the different components of the PGM-free_1 stack to climate impact. Only processes/components contributing more than 2% of the total impact are shown in this figure.

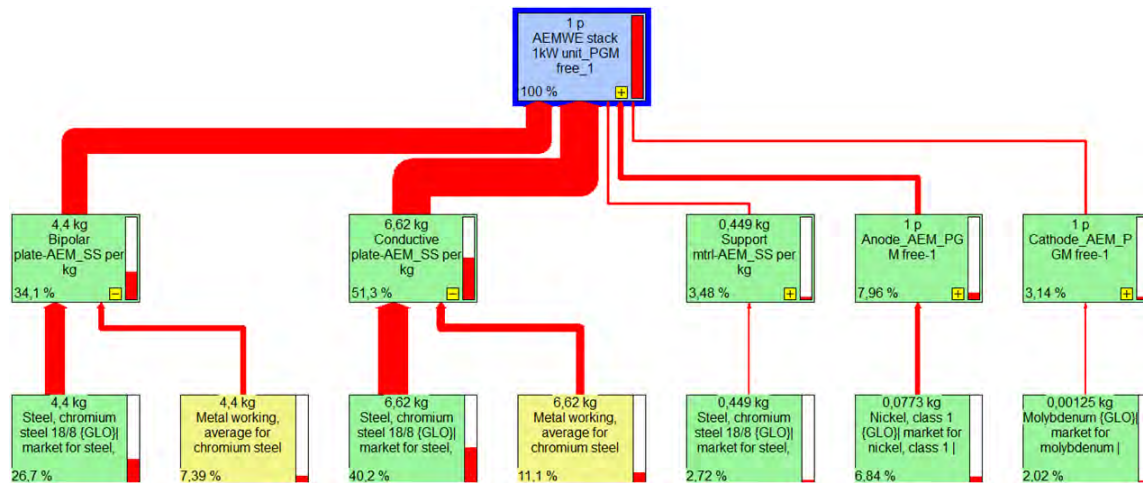


Figure 11 Relative contributions of the different components of the PGM-free_1 stack to resource use, minerals and metals. Only processes/components contributing more than 2% of the total impact are shown in this figure.

Similarly, the climate and resource use, minerals and metals impact categories are given in Figure 12 and Figure 13, respectively for the studied PGM-free_2 stack. For this stack, stainless steel and the manufacturing process for the end plate component dominates the climate impact (79.6%), followed by the bipolar plate (13%) and monopolar plate (6.5%) both also from stainless steel and the manufacturing process. For the resource use, minerals and metals impact category, the end plate dominates with 90% of the total impact, followed by the bipolar plate component (3.9%) based on stainless steel and cathode component (3.7%) based on nickel.

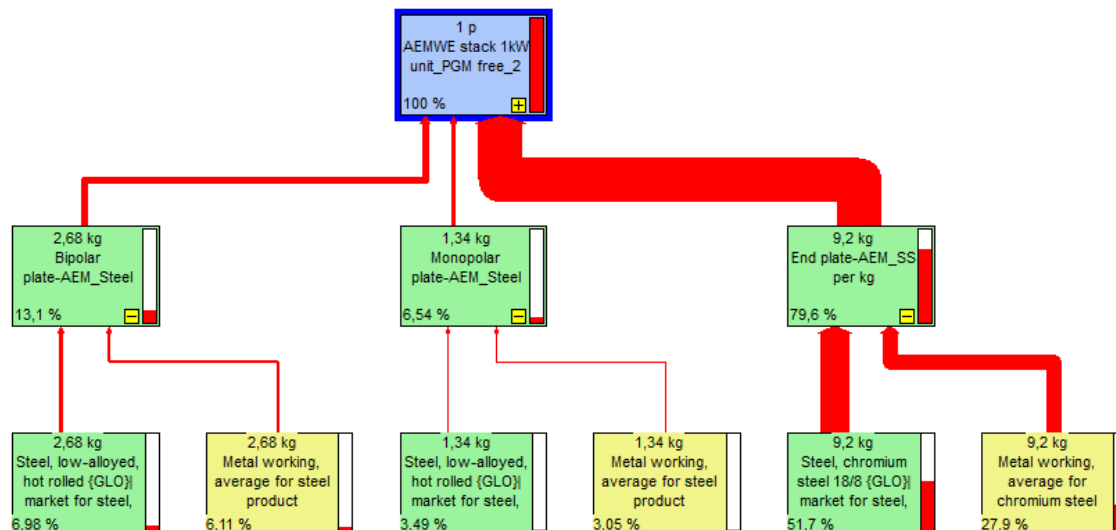


Figure 12 Relative contributions of the different components of the PGM-free_2 stack to climate impact. Only processes/components contributing more than 3% of the total impact are shown in this figure.

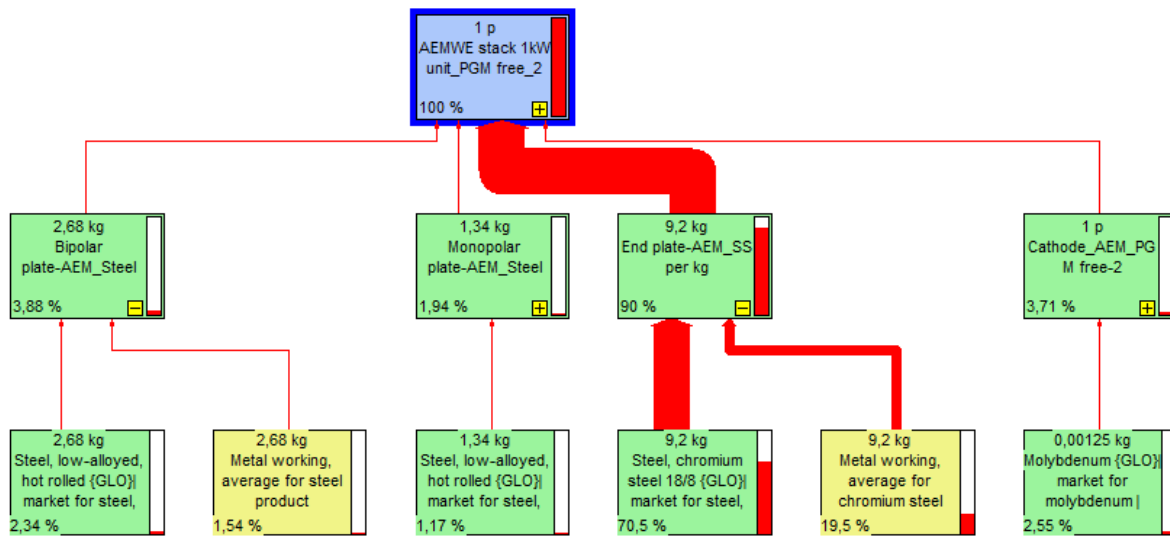


Figure 13 Relative contributions of the different components of the PGM-free_2 stack to resource use, minerals and metals. Only processes/components contributing more than 1% of the total impact are shown in this figure.

4.3 Results for rest of the system

The relative contributions of the components for the rest of system are presented in Figure 14 and Figure 15, respectively for the climate and resource use, minerals and metals impact categories. The results show that power electronics, dry cooler and housing have the largest contributions to climate impact while power electronics dominate the impact for resource use, minerals and metals, followed by housing and the dry cooler components. In this screening LCA, the same components for the rest of system is assumed for all the studied electrolyser systems.

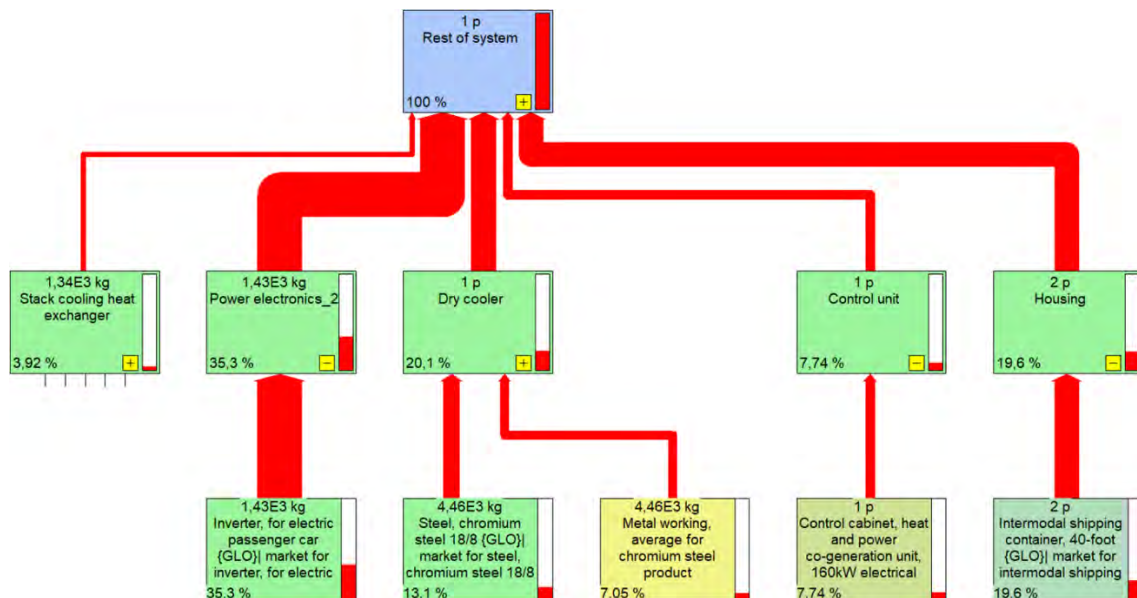


Figure 14 Relative contributions of the different components of the PGM-free_2 stack to climate impact. Only processes/components contributing more than 3% of the total impact are shown in this figure.

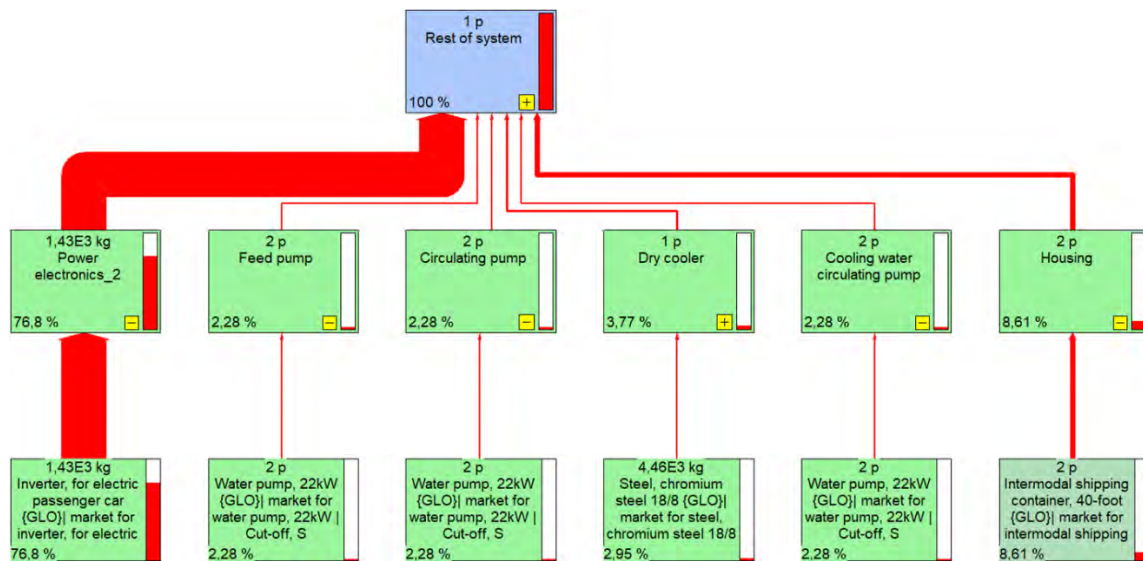


Figure 15 Relative contributions of the different components of rest of system to resource use, minerals and metals. Only processes/components contributing more than 2% of the total impact are shown in this figure.

4.4 Results for the use phase

Results for the climate as well as resource use, minerals and metals impact categories are presented in Figure 16 and Figure 17, respectively for 1 kg hydrogen production during the use phase. For the base case, electricity generation is based on wind power. The climate impacts are dominated by the use of potassium hydroxide while electricity input dominates the impact category for resource use, minerals and metals. Potassium hydroxide can be recirculated in the system for hydrogen production but due to lack of specific data on the required amount details for the recirculation at this stage of the project, this has not been taken into account. The impact from the use of potassium hydroxide for the studied systems is therefore overestimated and seen as a conservative approach but this will be explored further in the full LCA later in the project.

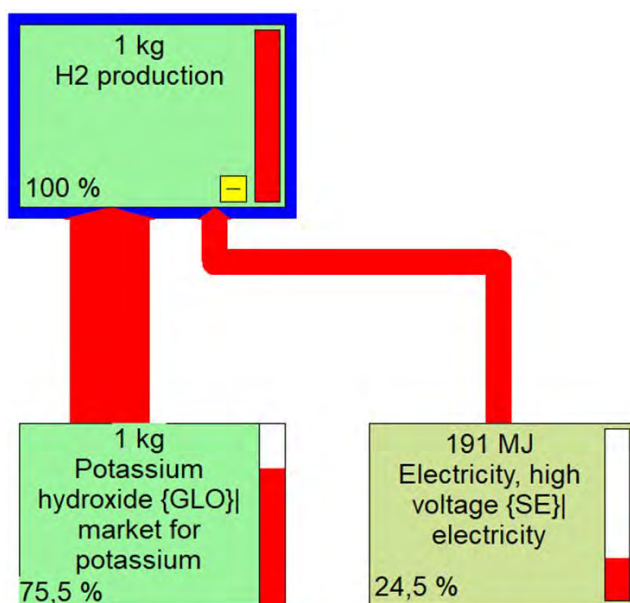


Figure 16 Relative contributions to climate impact during the use phase for 1 kg H2 production.

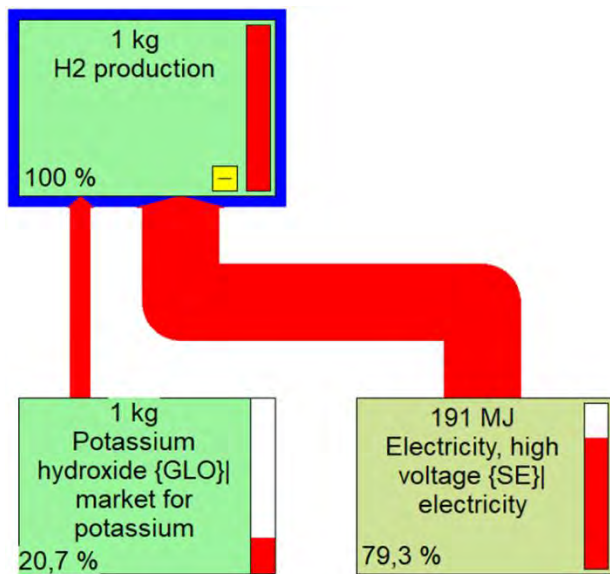


Figure 17 Relative contributions to resource use, minerals and metals during the use phase for 1 kg H2 production.

4.5 Sensitivity analysis

4.5.1 Electricity input for hydrogen production during use phase

As the system level results indicate (see for example Figure 2 and Figure 3 above), the use phase dominates the environmental impacts of the studied systems. Most of the impacts seem to emanate from the use of potassium hydroxide and the electricity input. In a sensitivity analysis, different sources of electricity based on solar and average grid electricity for different locations are also considered to assess their influence on the environmental impacts during the use phase, compared to the wind power electricity assumed for the base case. Figure 18 - Figure 20 show how the climate impact varies with different electricity sources for production of 1 kg hydrogen with the studied systems assumed to be in Sweden, France and Italy. Electricity from wind results in the lowest climate impact in all cases while average EU electricity results in the highest impact for Sweden and France with the average country specific electricity mixes giving slightly lower impacts than the respective solar generated electricity. For Italy, the highest climate impact occurs when average Italian electricity mix is used.

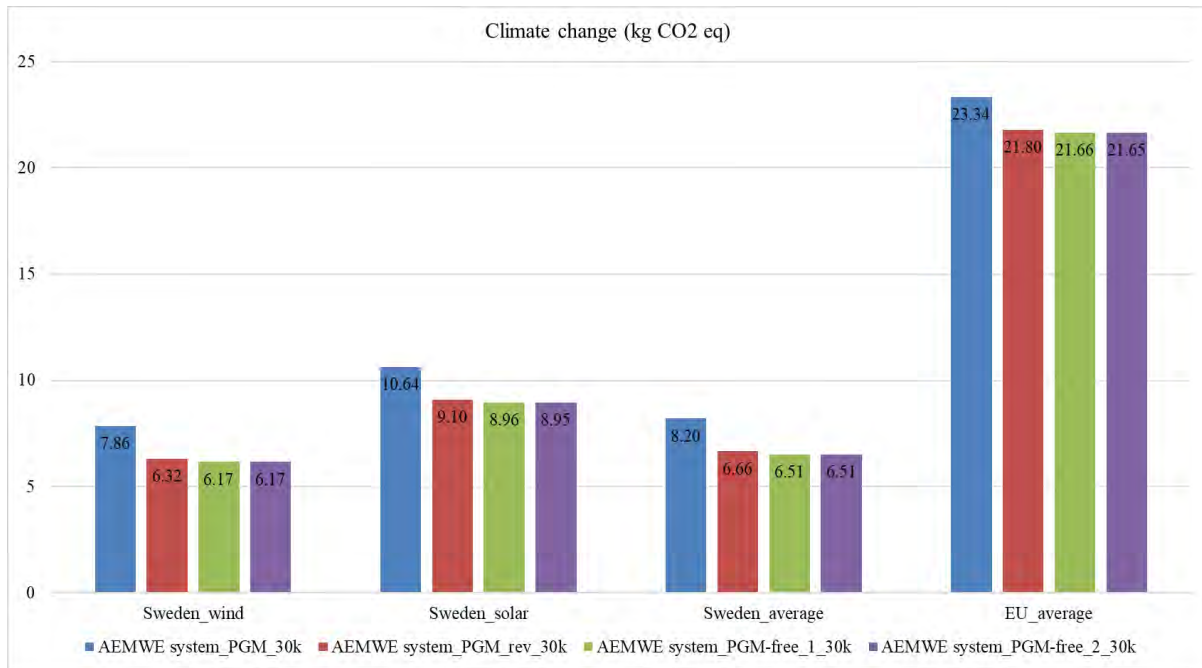


Figure 18 Climate impact for 1 kg H2 production with different electricity sources for Sweden.

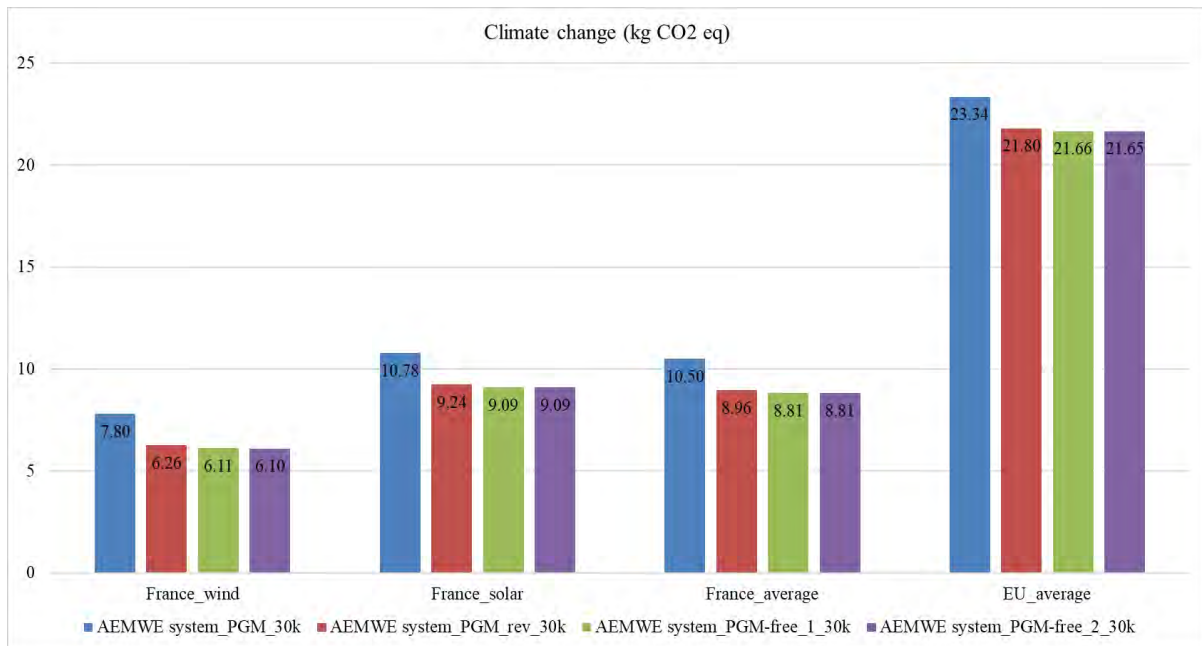


Figure 19 Climate impact for 1 kg H2 production with different electricity sources for France.

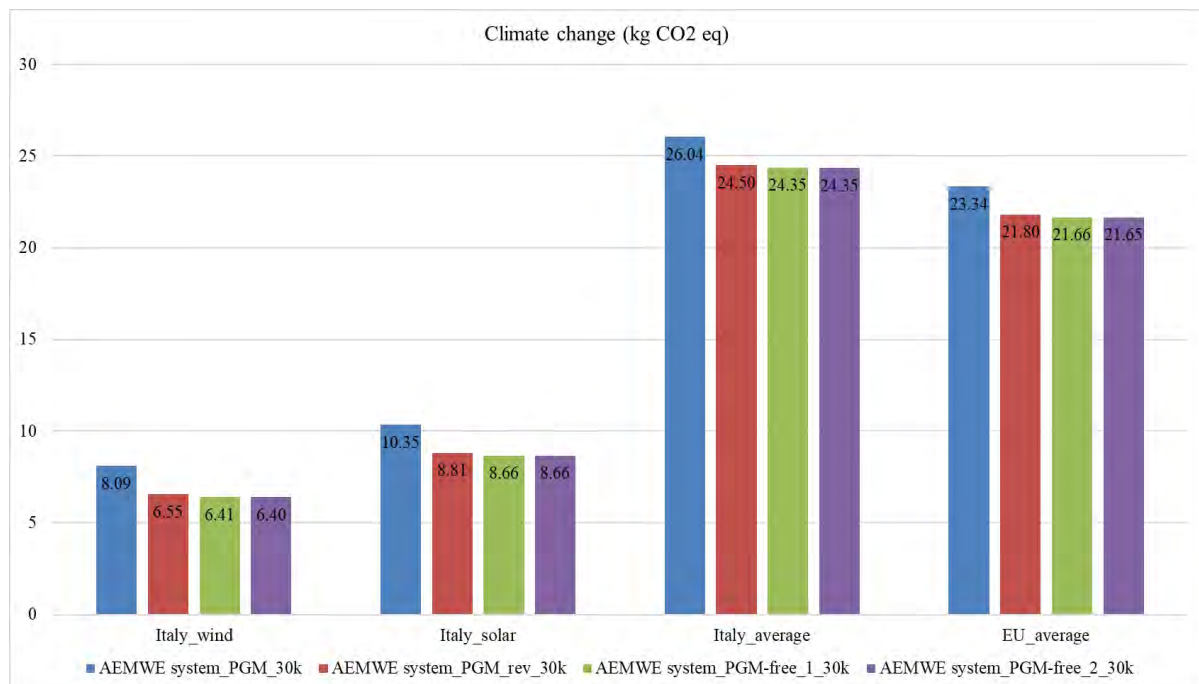


Figure 20 Climate impact for 1 kg H₂ production with different electricity sources for Italy.

4.5.2 By-products from hydrogen production

By-products such as oxygen and heat usually accompany water electrolysis for hydrogen production. As the studied electrolyser systems here are based on direct seawater electrolysis, solid by-products such as hydroxides of magnesium and calcium are also generated as precipitates. In this screening LCA, the potential benefits of such solid by-products are not assessed but they will be explored in the full LCA study in collaboration with Task 10.3 that deals with industrial symbiosis. The potential impacts of brine generated as output from the system are also not considered here but will be assessed in the full LCA with specific data for the SWEETHY system. Oxygen could for example be used in steel industry or for water treatment while the generated heat could be reused for the electrolyser system or for other applications such as in a district heating system. To show the potential benefits for reuse of the oxygen and heat at this stage, a simplistic assessment is made without considering processes for recovery, storage, transformation, transportation or any other such that may be necessary before the by-products are practically usable. It is simply assumed that the oxygen replaces an equivalent amount of virgin production of oxygen and the heat is assumed to replace European average heat generation based on natural gas. The Ecoinvent datasets “Oxygen, liquid {RER}| market for oxygen, liquid | Cut-off, S” and “Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | Cut-off, S” are used in the assessment. The results are presented in Figure 21 and Figure 22, showing significant reduction in the climate impacts for the studied systems. The negative bars show the benefits or avoided impacts while the positive bars show the net impacts due to the use of the considered by-products.

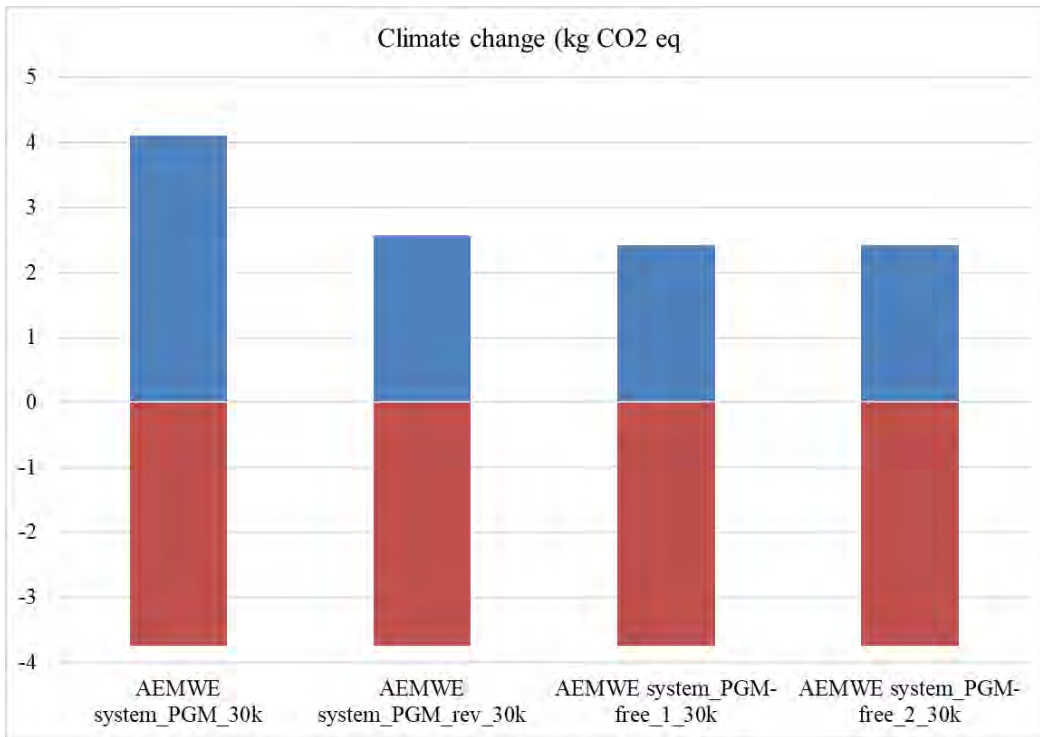


Figure 21 Climate impact for 1 kg H2 production assuming oxygen by-product substitutes virgin oxygen production.

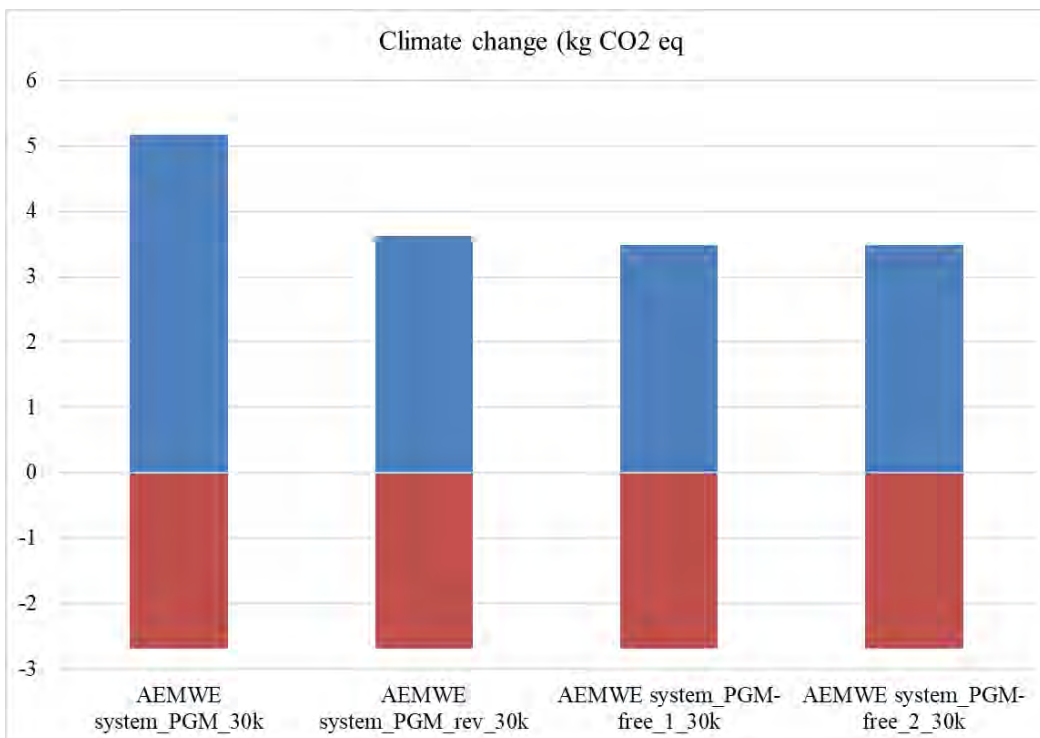


Figure 22 Climate impact for 1 kg H2 production assuming heat by-product substitutes average EU heat based on natural gas.



4.5.3 Stack lifetime

As stated earlier, AEM electrolyzers are still under development with a lower technology readiness level compared to similar technologies such as PEM electrolyzers. There are therefore uncertainties related to their lifetime and the few studies that have analysed AEM stacks reported stack lifetime of 30000 hours and this was assumed as the base case in this screening LCA. Considering that the technology is still under development, it is expected that the performance and lifetime will be improved, so in a sensitivity analysis, stack lifetime of 60000 and 80000 hours are considered to assess their implication for the studied systems. The climate impact results are presented in Figure 23, showing that for the PGM stack system, the climate impact could be reduced by up to 15%. The corresponding reduction is about 3% for the PGM_rev stack system and 1.6% for the PGM-free stack systems. The large variation for the PGM stack system is possibly linked to the high amount of stainless steel in the BPP component.

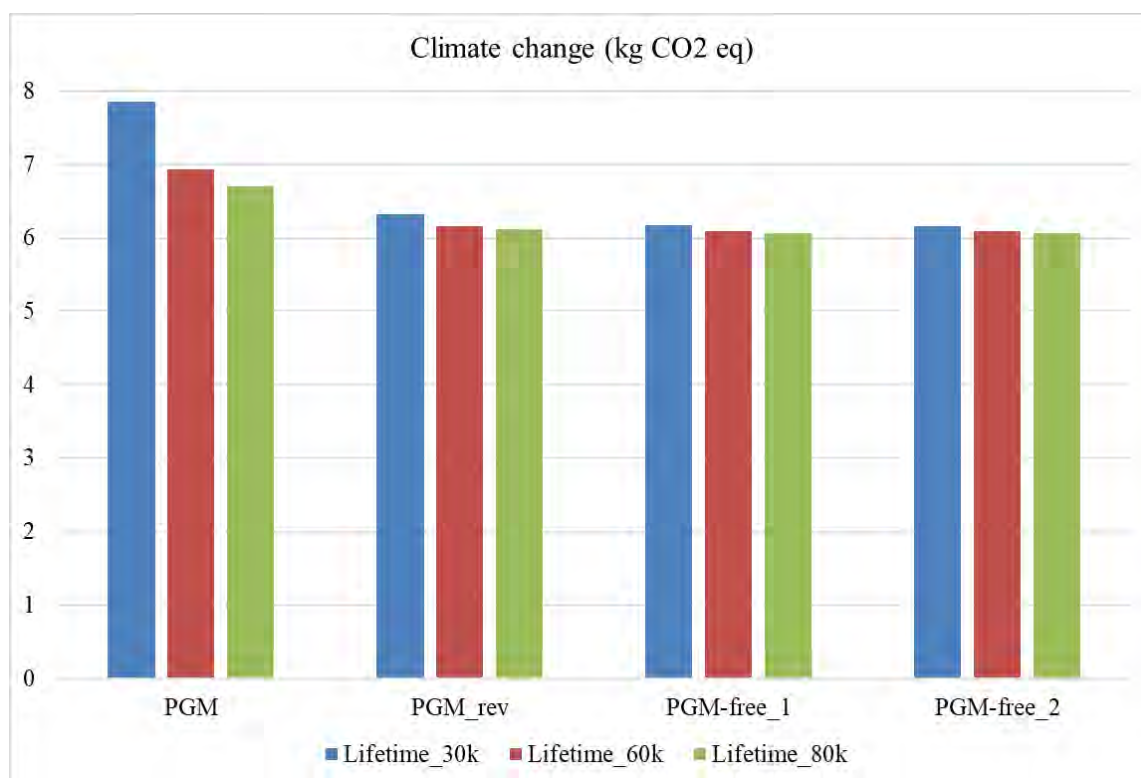


Figure 23 Climate impact for 1 kg H₂ production with different stack lifetimes.

4.6 Data quality assessment and limitations

In this study, as in LCA studies in general, several uncertainties exist that may affect the results and conclusions. Here the greatest uncertainties relate to secondary datasets used to represent e.g. raw materials extraction and manufacturing processes that may not be fully representative of the specific cases of this study. Also, for all the studied systems, the data used is mainly from literature for similar technologies and this may also introduce some level of uncertainties. For instance, in the literature data used for the stacks, the amount of stainless steel used in the bipolar plate for the PGM stack was significantly higher (118 kg) compared to PGM-free_1 (4.4 kg) and PGM-free_2 (2.68 kg). This results in a very wide variation in the results of the PGM stack compared to the PGM free alternative, and also



leads to different material hotspots and conclusion. To address this, an alternative (PGM_rev) with reduced amount of stainless steel in the bipolar plate to the same level as PGM-free_1 stack is also assessed and presented in this study for a better overview. This was done based on discussions with experts within the project consortium. Further, the use of potassium hydroxide in the studied systems during the use phase is modelled without recirculation due to lack of specific data at this stage and the results are overestimated. As much as possible the datasets are carefully selected and where possible adapted with specific data to reflect the origin of the raw material input and manufacturing process. Overall, the study only represents the studied systems and the results and conclusions should therefore be put in perspective of the assumptions, used data and limitations of the study and generalisation should not be made.



5 Contribution to project (linked) Objectives

Deliverable D10.2 contributes to specific objectives 4 (SO4) - minimize the environmental impact of the electrolyser stack and system. The results will support material selection for the prototype and contribute to SWEETHY electrolyser design solutions with lowest possible environmental impact.



6 Contribution to major project exploitable result

This deliverable D10.2 contributes to the overall sustainability goals of the SWEETHY technology.



7 Conclusion and recommendations

The screening LCA was performed with the objective to assess the climate impacts of the proposed electrolyser system and identify potential hot spots for the materials as well as parts and components of the system to support a more sustainable design, development and implementation. The study is mainly based on literature data for similar state-of-the-art systems combined with system operation data during the use phase based on the SWEETHY project KPIs. Three electrolyser systems identified from literature were assessed, one with PGM based stack and the other two based on PGM-free stack with slightly different configurations.

The results show that hydrogen production during the use phase dominates the potential environmental impacts of the studied systems in all the considered impact categories. Most of the impacts in the use phase emanates from the use of potassium hydroxide for the electrolysis process. In this analysis, the recirculation of potassium hydroxide during hydrogen production has not been taken into account due to lack of detailed data at this stage. The potential impact from potassium hydroxide is therefore overestimated and this will be further explored in the full LCA study. Still, electricity input during the use phase seems to significantly influence the environmental impacts of the studied systems depending on the source and location. Among the studied systems, the PGM based system has the most impacts in all the assessed impact categories compared to the PGM-free stack based systems. For the stacks, the various components and materials contribute differently to the environmental impacts as the configurations are distinct, especially between the PGM and PGM-free stacks. Even though the studied systems are not designed for seawater electrolysis application as will be the case for the proposed SWEETHY electrolyser system, the results provide relevant information for choice of materials for components e.g. for PGM-free compared to PGM stacks.

Overall, the screening LCA study highlights the potential environmental hotspots along the considered life cycle stages of the studied systems, providing early stage information on choice of material alternatives and how the different components and materials in the proposed SWEETHY electrolyser system could be designed to optimise both the technical and environmental performance for a more development and sustainable scale up.

The recommendations from this study are as follow:

- As the potassium hydroxide contributes significantly to the use phase impacts, alternatives with lower environmental impacts should be explored or its use should be as much as possible optimised and more efficient to reduce the amount required compared to the current 1 kg per kg hydrogen production used in this study.
- The choice of electricity with low carbon intensity is also important to further reduce environmental impacts of the use phase.
- Explore eco-design measures for components and materials with high environmental impacts and high weight in the system (e.g. stack and RoS) to optimise the size without compromising the technical functionality.
- Design for easy disassembly to promote recyclability at end-of-life.



8 Risks and interconnections

8.1 Risks/problems encountered

Lack of data and the use of literature and proxy data may introduce uncertainties in the results, which may in turn lead to risks of misinterpretation. As much as possible datasets are carefully selected and where possible adapted based on discussions and input with relevant project partners and transparently reported (See for example section 4.6).

8.2 Interconnections with other deliverables

This deliverable presents a screening LCA of the proposed electrolyser system mostly based on literature data and aims to support eco-design efforts in the technical work packages (e.g. WPs 7, 8 and 9) in the project. The results will provide input on material choice for the electrolyser configuration in Task 7.1 and electrolyte feeds in Task 7.2. The result will also provide relevant information for task 10.3 that deals with screening of systems integration and symbiotic solutions. Finally, this work will serve as the basis for the full LCA to be implemented in Task 11.1, leading to deliverable D11.1.



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10 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:

#	Partner short name	Partner Full Name
1	RISE	RISE RESEARCH INSTITUTES OF SWEDEN AB
2	CNR	CONSIGLIO NAZIONALE DELLE RICERCHE
3	CIDETEC	FUNDACION CIDETEC
4	DLR	DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV
5	IC	INSTITUT DE LA CORROSION SASU
6	SINTEF	SINTEF AS
7	PROPULS	PROPULS GMBH
8	CENMAT	CUTTING-EDGE NANOMATERIALS CENMAT UG HAFTUNGSBESCHRANKT
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The project is supported by the Clean Hydrogen Partnership and its members.

Co-funded by the European Union under Grant Agreement No. 101192342. The views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the Clean Hydrogen Partnership. Neither the European Union nor the granting authority can be held responsible for them.





11 Appendix B – Datasets for the system components

Table 11.1 Datasets used to model the components and materials as well as manufacturing for the PGM stack

Component	Material	Dataset
Bipolar plate	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S
Gasket	Tetrafluoroethylene	Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, S Extrusion, plastic pipes {GLO} market for extrusion, plastic pipes Cut-off, S
Anode	Iron (III) phosphate	Lithium iron phosphate {RoW} market for lithium iron phosphate Cut-off, S
	Anionic resin	Polysulfone {GLO} polysulfone production, for membrane filtration production Cut-off, S
	Nickel, 99.5%	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Nafion	Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, S
Membrane	Anionic resin	Polysulfone {GLO} market for polysulfone Cut-off, S Extrusion, plastic film {RER} extrusion, plastic film Cut-off, S
Cathode	Ruthenium	Palladium {GLO} market for palladium Cut-off, S (used as proxy)
	Carbon black	Carbon black {GLO} market for carbon black Cut-off, S
	Platinum	Platinum {GLO} market for platinum Cut-off, S
	Nafion	Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, S
Nickel forming	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S



Table 11.2 Datasets used to model the components and materials as well as manufacturing for the PGM-free stack type 1

Component	Material	Dataset
Bipolar plate	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S
Gasket	Synthetic rubber	Synthetic rubber {GLO} market for synthetic rubber Cut-off, S Extrusion, plastic pipes {GLO} market for extrusion, plastic pipes Cut-off, S
Anode	Nickel foam	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Nickel	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Iron	Cast iron {GLO} market for cast iron Cut-off, S
	Manufacturing	Metal working, average for metal product manufacturing {GLO} market for metal working, average for metal product manufacturing Cut-off, S
Membrane	Polysulfone	Polysulfone {GLO} market for polysulfone Cut-off, S Extrusion, plastic film {RER} extrusion, plastic film Cut-off, S
Cathode	Nickel	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Molybdenum	Molybdenum {GLO} market for molybdenum Cut-off, S
	Carbon black	Carbon black {GLO} market for carbon black Cut-off, S
	Manufacturing	Metal working, average for metal product manufacturing {GLO} market for metal working, average for metal product manufacturing Cut-off, S
Conductive plate	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S



Support material	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S
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Table 11.3 Datasets used to model the components and materials as well as manufacturing for the PGM-free stack type 2

Component	Material	Dataset
Bipolar plate	Steel	Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, S Metal working, average for steel product manufacturing {GLO} market for metal working, average for steel product manufacturing Cut-off, S
Gasket	Synthetic rubber	Synthetic rubber {GLO} market for synthetic rubber Cut-off, S Extrusion, plastic pipes {GLO} market for extrusion, plastic pipes Cut-off, S
Anode	Steel	Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, S
	Iron	Cast iron {GLO} market for cast iron Cut-off, S
	Nickel	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Hydroxide	NMC811 hydroxide {RoW} market for NMC811 hydroxide Cut-off, S
	Manufacturing	Metal working, average for steel product manufacturing {GLO} market for metal working, average for steel product manufacturing Cut-off, S
Membrane	Polystyrene	Polystyrene, high impact {GLO} market for polystyrene, high impact Cut-off, S Extrusion, plastic film {RER} extrusion, plastic film Cut-off, S
Cathode	Nickel	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Nickel felt	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, S
	Molybdenum	Molybdenum {GLO} market for molybdenum Cut-off, S



	Manufacturing	Metal working, average for metal product manufacturing {GLO} market for metal working, average for metal product manufacturing Cut-off, S
Monopolar plate	Steel	Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, S Metal working, average for steel product manufacturing {GLO} market for metal working, average for steel product manufacturing Cut-off, S
End plate	Steel, Cr-steel 18/8	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S

Table 11.4 Datasets used to model the components and materials as well as manufacturing for the rest of system

Component	Dataset
Anode gas water separator	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S
Cathode gas water separator	Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S
Feed pump	Water pump, 22kW {GLO} market for water pump, 22kW Cut-off, S
Circulating pump	Water pump, 22kW {GLO} market for water pump, 22kW Cut-off, S
Gaskets	Hexafluoroethane {GLO} market for hexafluoroethane Cut-off, S Polyvinylfluoride {GLO} market for polyvinylfluoride Cut-off, S Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, S Polyvinylchloride, emulsion polymerised {GLO} market for polyvinylchloride, emulsion polymerised Cut-off, S Extrusion, plastic pipes {GLO} market for extrusion, plastic pipes Cut-off, S
Stack cooling heat exchanger	Gaskets – see above row Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S



	<p>Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, S</p> <p>Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S</p> <p>Metal working, average for steel product manufacturing {GLO} market for metal working, average for steel product manufacturing Cut-off, S</p>
Condenser	<p>Gaskets – see above</p> <p>Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S</p> <p>Steel, low-alloyed, hot rolled {GLO} market for steel, low-alloyed, hot rolled Cut-off, S</p> <p>Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S</p> <p>Metal working, average for steel product manufacturing {GLO} market for metal working, average for steel product manufacturing Cut-off, S</p>
Dry cooler	<p>Pump, 40W {GLO} market for pump, 40W Cut-off, S</p> <p>Steel, chromium steel 18/8 {GLO} market for steel, chromium steel 18/8 Cut-off, S</p> <p>Metal working, average for chromium steel product manufacturing {GLO} market for metal working, average for chromium steel product manufacturing Cut-off, S</p>
Cooling water circulating pump	<p>Water pump, 22kW {GLO} market for water pump, 22kW Cut-off, S</p>
Power cables	<p>Cable, three-conductor cable {GLO} market for cable, three-conductor cable Cut-off, S</p>
Data cables	<p>Cable, data cable in infrastructure {GLO} market for cable, data cable in infrastructure Cut-off, S</p>
Control unit	<p>Control cabinet, heat and power co-generation unit, 160kW electrical {GLO} market for control cabinet, heat and power co-generation unit, 160kW electrical Cut-off, S</p>
Power electronics	<p>Inverter, for electric passenger car {GLO} inverter production, for electric passenger car Cut-off, S</p>
Foundation	<p>Concrete, sole plate and foundation {GLO} market for Cut-off, S</p>
Housing	<p>Intermodal shipping container, 40-foot {GLO} market for intermodal shipping container, 40-foot Cut-off, S</p>



12 Appendix C – LCA checklist for Clean Hydrogen Joint Undertaking projects

Table 12.1 Checklist for the practitioner performing the LCA in a Clean Hydrogen Joint Undertaking project. Please check one option for each row (Santucci et al., 2024).

Life cycle phase	Sections	Basic requirement	EF-oriented provision
Goal of the LCA study	1. Intended applications of the LCA	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	2. Application Situation	<input checked="" type="checkbox"/>	
	3. Reasons for carrying out the study	<input checked="" type="checkbox"/>	
	4. Modelling approach	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	5. Target Audience	<input checked="" type="checkbox"/>	
	6. Comparisons	<input type="checkbox"/>	<input type="checkbox"/>
	7. Influential actors	<input type="checkbox"/>	<input type="checkbox"/>
Scope of the LCA study	8. Functional unit	<input checked="" type="checkbox"/>	
	9. Reference flow	<input checked="" type="checkbox"/>	
	10. Considered stages	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	11. Flow chart (system Boundaries)	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	12. Cut-off	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	13. Impact assessment	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	14. Multi-functionality aspects	<input type="checkbox"/>	<input type="checkbox"/>
	15. Assumptions and limitations of the study	<input checked="" type="checkbox"/>	
16. Calculation	<input checked="" type="checkbox"/>		
Life cycle inventory	17. Life cycle stages (Life cycle Inventory)	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	18. Input flows (Life cycle	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	19. Output flows (Life cycle	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	20. End of Life (EoL) modelling	<input type="checkbox"/>	<input type="checkbox"/>
	21. Data sources	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	22. Data quality	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	Datasets development. If life cycle inventory data are developed within		



	the study, the following sections shall be filled in. If no inventory data are developed, please skip to section 27.		
	23. Administrative information (dataset development)	<input type="checkbox"/>	<input type="checkbox"/>
	24. Data review (dataset development)	<input type="checkbox"/>	<input type="checkbox"/>
	25. Documentation (dataset development)	<input type="checkbox"/>	<input type="checkbox"/>
	26. Data quality (for datasets)	<input type="checkbox"/>	<input type="checkbox"/>
Life Cycle Impact Assessment	27. Impact assessment method	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	28. Characterisation model, weighting and normalization	<input type="checkbox"/>	<input type="checkbox"/>
Interpretation of the LCA and reporting	29. Hotspot analysis per impact categories (LC stages, processes, flows)	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	30. Hotspot analysis based on single score (most relevant impact categories)	<input type="checkbox"/>	<input type="checkbox"/>
	31. Interpretation	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Verification and Validation	32. Submission to the reviewer	<input type="checkbox"/>	<input type="checkbox"/>
	33. Review documentation	<input type="checkbox"/>	<input type="checkbox"/>

13 Appendix D – LCA idea generation workshop

This appendix documents the results of the idea generation workshop carried out the 19th of March 2026 at Institut de la Corrosion in Brest, France. The workshop, which aimed at generating ideas focusing on environmental improvements of an AEM system for seawater electrolysis resulted in 31 ideas. Of the 31 ideas, 5 were evaluated during the workshop. The starting point was a draft early-stage life cycle assessment report.

The ideas selected for evaluation were mainly related to the use phase, on how to decrease impact from cooling, utilize excess heat, introduce AI-assisted steering of system parameters and increase current density. Also, use of coatings was suggested to decrease environmental impact. The 5 evaluated ideas were considered to have relatively high potential for decreasing environmental impact, but most of them were considered as hard to implement. Of the remaining ideas that were not evaluated, most ideas were focused on finding materials with lower impact. There were also several other use phase related ideas, such as use of green electricity for running the system.

Workshop execution

Participants in the workshop were 17 SWEETHY members representing project partners RISE, Institut de la Corrosion, SINTEF, CENmat, DLR, CNR, Propuls, Uniresearch and Cidetec. Other participants in the workshop were the 5 members of the SWEETHY advisory board, Farnaz Sotoodeh, Ulrich Rost, Philippe Mandin, Morten Møller Klausen och Jörgen Westlinder.

The participation comprised idea generation as well as evaluation, see below.

Goal

The goal of the idea generation workshop was to generate ideas about possible environmental improvements of AEM seawater electrolysis, specifically for the SWEETHY design and to some extent agree on the best ideas, both from an environmental and implementation perspective. Environmental improvement was defined as in the early-stage LCA, mostly focusing on climate impact. The programme was the following:

- Presentation of LCA methodology and early stage LCA for SWEETHY
- Brainstorming, 40 minutes
- Categorisation of ideas
- Evaluation of ideas, 40 minutes





Criteria for the evaluation of the ideas were established to:

- Environmental improvement potential
- Ease of implementation (time to technical feasibility, economic feasibility and market potential)

Idea generation

The participants were divided into 5 groups. During the idea generation, ideas were proposed, written down on sticky notes and read out loud to all participants in the group. No critique of the ideas was allowed during this part. Then, all ideas were shared with the whole group. In total, 31 ideas were generated during this part, see results section below.

Evaluation

As an introduction to the evaluation, each group chose one idea to argue for. Choice of your own ideas as well as others was allowed. Criteria for the evaluation were:

- Environmental improvement potential where 1=small improvement, 2=medium improvement, 3= large improvement
- Ease of implementation where 1=most challenging, 2= medium challenging, 3=least challenging

After discussing an idea, the group decided together on the scores for that idea.

Results

The results are given in the table below. Out of the 31 ideas, 5 were chosen for evaluation, which implied some form of first ranking. The ideas in the table are sorted with ideas who have large potential for environmental improvement and are easy to implement first.



	Idea	Description	Category	Ease of implementation (1-3)	Improvement of environmental performance (1-3)
1	Alternative cooling	Remove water cooling	Use phase	1	3
2	Use of coatings of materials with low or non-environmental impact	Such as inert ceramics	Materials	2	2
3	Waste heat utilization	Synergies between systems. May be coupled with water tank heating for small homes	Use phase	2	2
4	Adding electrolyzer on water management system -> AI for balance of electrolyser working conditions	Find a solution to avoid galvanic corrosion during rest/off phase of electrolyzer operation	Use phase	1	short term: 0-1 longterm: 3
5	Increase current density to decrease -> compact system		Use phase	1	3
6	Consider environmental impact from first design stages	Design of materials, methods	Ecodesign		



	Idea	Description	Category	Ease of implementation (1-3)	Improvement of environmental performance (1-3)
7	Reduce power consumption for any facility involved	e.g., LED lamps	Ecodesign		
8	Green electricity for material production	e.g., PV on roof of factories	Materials		
9	Green steel BPP		Materials		
10	Extract precious metals from waters		Materials		
11	Short transport for material		Materials		
12	Recycled polymer for membrane		Materials		
13	Recycling of catalyst + membrane		Materials		
14	No PFAS at all	gaskets for instance	Materials		
15	Reducing system components (dry anode)	Ex. BOP (pumps) one side recirculation	Materials		
16	Alternative to PEEK plastics	lower impact material	Materials		



	Idea	Description	Category	Ease of implementation (1-3)	Improvement of environmental performance (1-3)
17	Avoid the use of critical raw materials		Materials		
18	Understand the origin of materials for the application		Materials		
19	Optimize materials for BoP	Alternatives to stainless steel	Materials		
20	Developing new steel and Ni-based alloys with reduced Ni-content for BPP, PTL, pipes		Materials		
21	Reduce plastic content in electrolysis stack	Based on ProPuls design	Materials		
22	Non-toxic synthesis methods	e.g., environmentally friendly chemicals and processes	Manufacturing		
23	Reduce waste and classification of trash during the production processes		Manufacturing		
24	Lower KOH concentration	Less KOH use and post processing	Use phase		



	Idea	Description	Category	Ease of implementation (1-3)	Improvement of environmental performance (1-3)
25	Mix K+ and Na+ for OH- source		Use phase		
26	Increase energy efficiency	Better exploitation of renewable energy	Use phase		
27	NaOH instead of KOH		Use phase		
28	Low emission electricity		Use phase		
29	Re-use of heat generated during electrolysis in larger eco-systems	Related to industrial symbiosis	Use phase		
30	Recycling of all stack components at EoL	Steel, gaskets, Ni-catalyst, PEEK, membrane	End-of-life		
31	Loop of recycling	Ni, Pt, PGM, CRM, membrane	End-of-life		