SH2E Spring School (20-24 May 2024)

Life cycle sustainability assessment of hydrogen systems & SH2E LCSA guidelines

Diego Iribarren (IMDEA Energy)

Co-funded by the European Union

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007163. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Life cycle sustainability assessment of hydrogen systems & SH2E LCSA guidelines

TABLE OF CONTENT

1. Introduction to LCSA and hydrogen energy systems
2. SH2E LCSA guidelines
3. Application of the SH2E guidelines

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INTRODUCTION TO LCSA AND HYDROGEN ENERGY SYSTEMS

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Introduction

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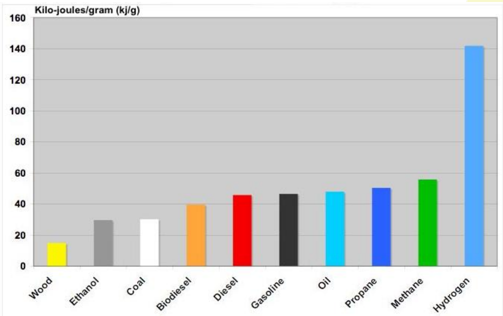

$$2H_2 + O_2 \rightarrow 2H_2O$$

Identification of potential bottlenecks along the hydrogen supply chain under environmental, economic and social aspects.

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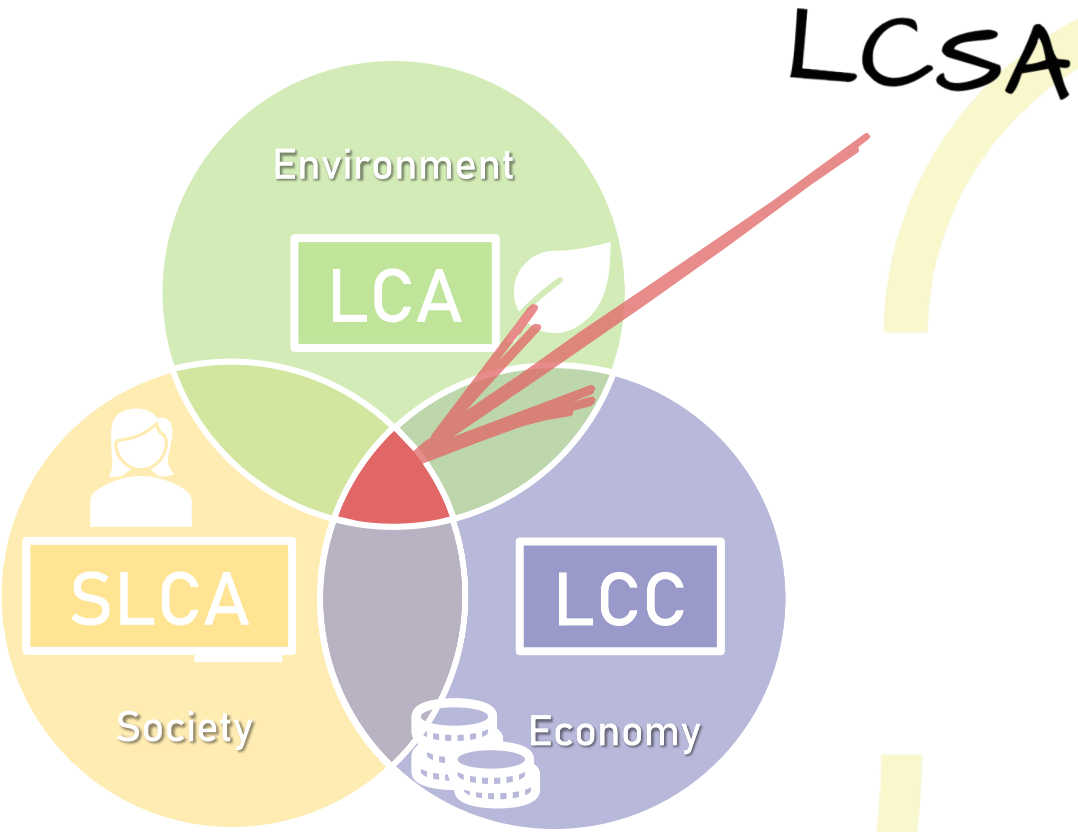

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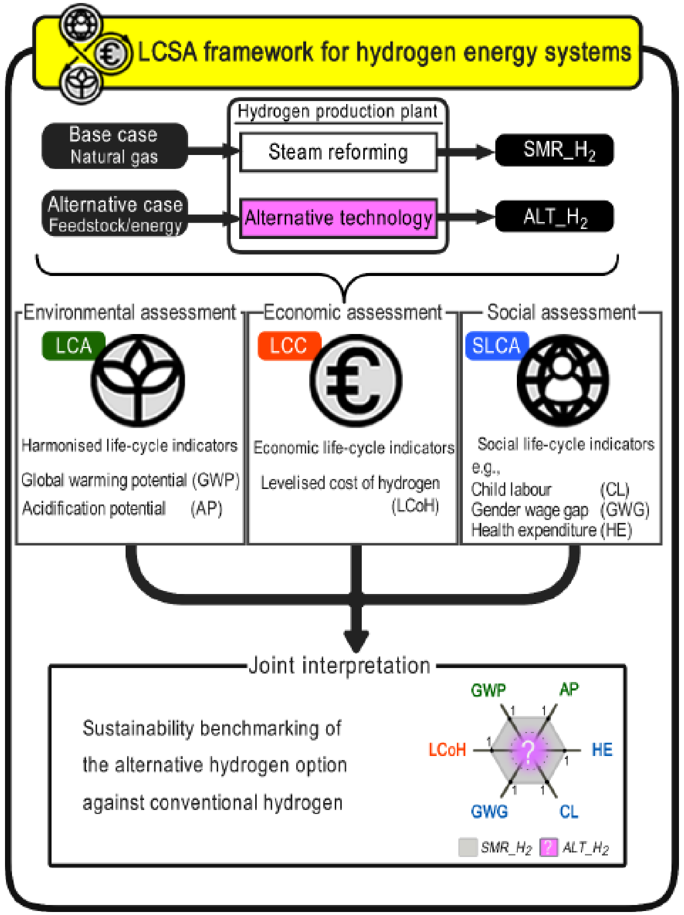

https://doi.org/10.1016/j.scitotenv.2020.144132

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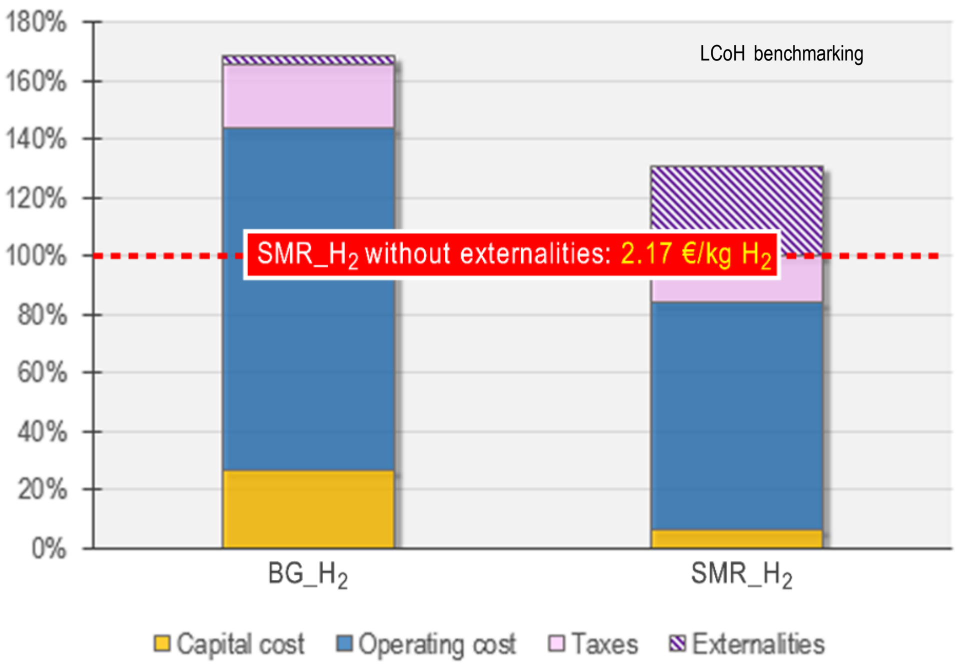

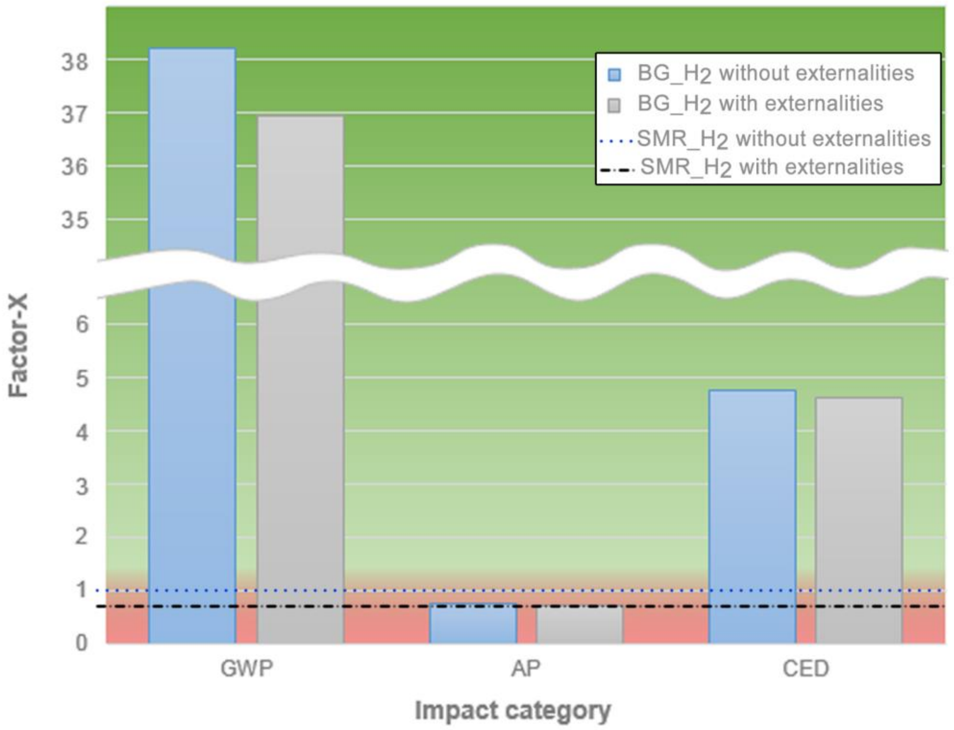

https://doi.org/10.1016/j.scitotenv.2018.09.089

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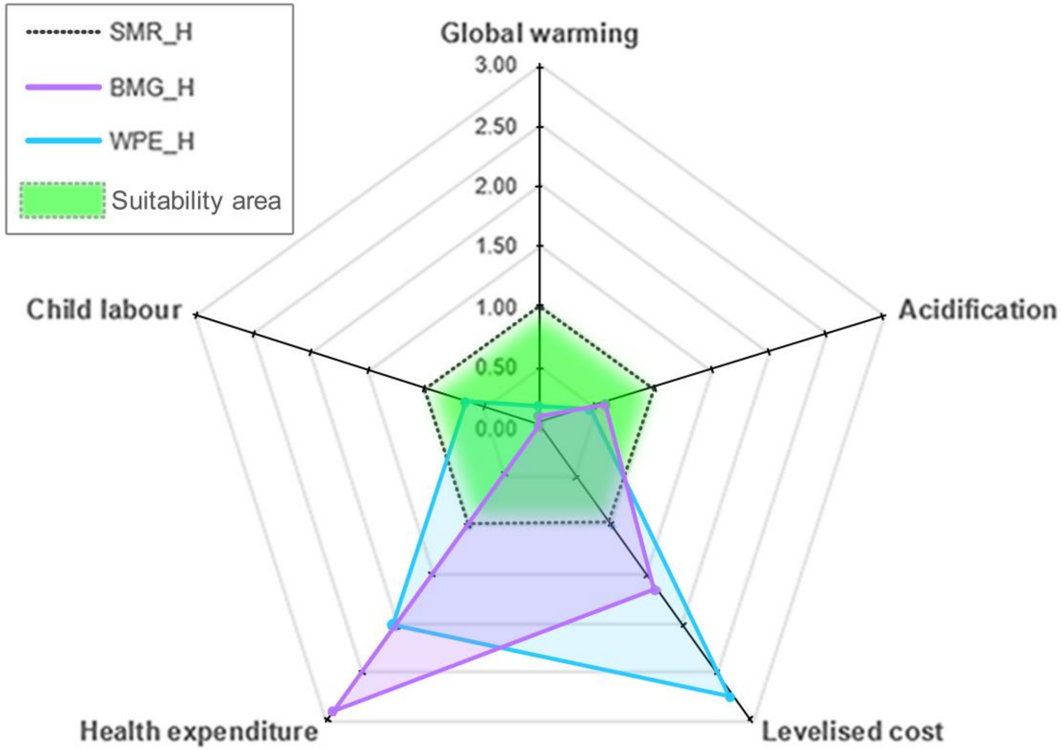

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Introduction

Production	Transport	Distribution	Use
Region *a*, technology *x*	Lorry	Pipeline	Mobility
Region *b*, technology *y*	Sea	Lorry	Industry
Region *c*, technology *z*	Railway	Railway	Households
…	…	…	…

Which solutions are **sustainable**?

LCSA
- **LCA** (e.g. carbon footprint)
- **LCC** (e.g. levelised cost of hydrogen)
- **S-LCA** (e.g. child labour)

Sustainability interpretation

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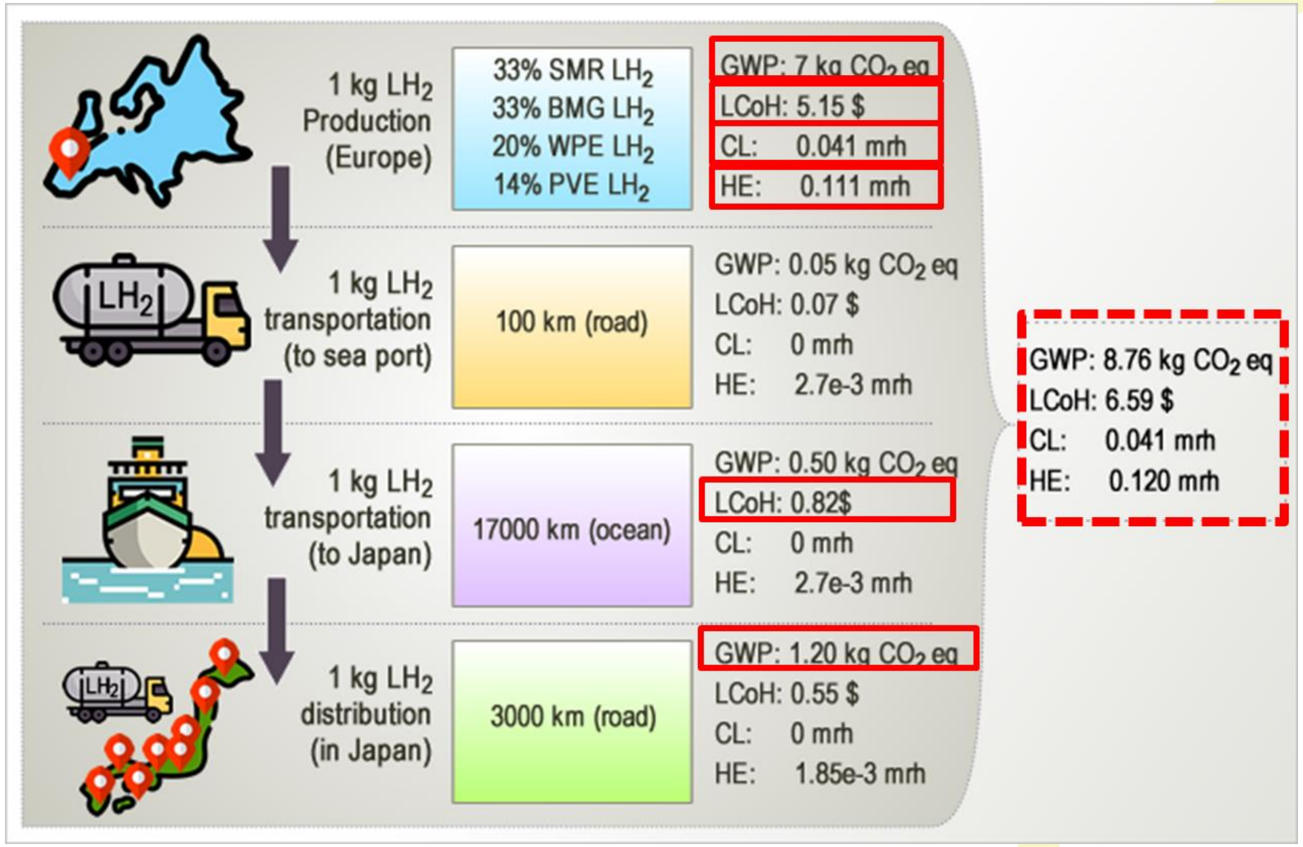

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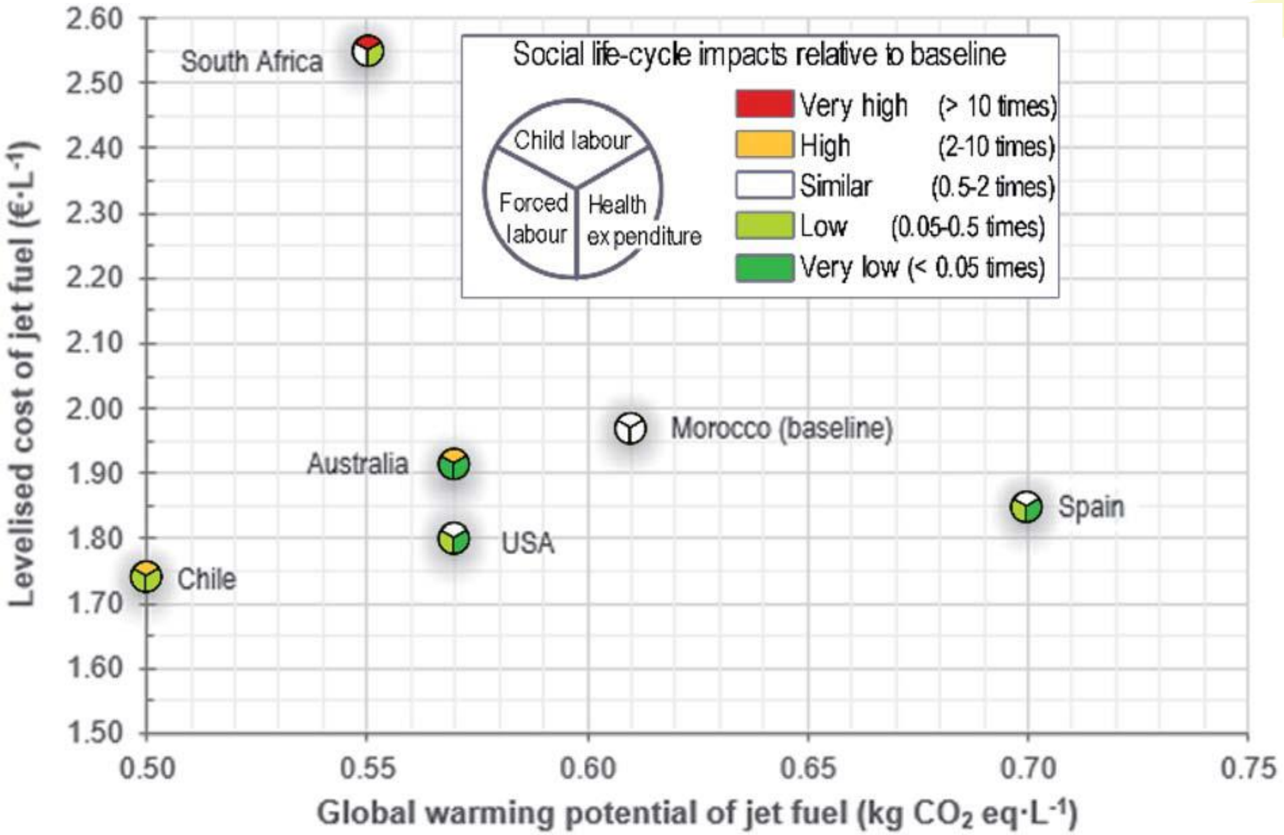

https://doi.org/10.1039/D0SE00179A

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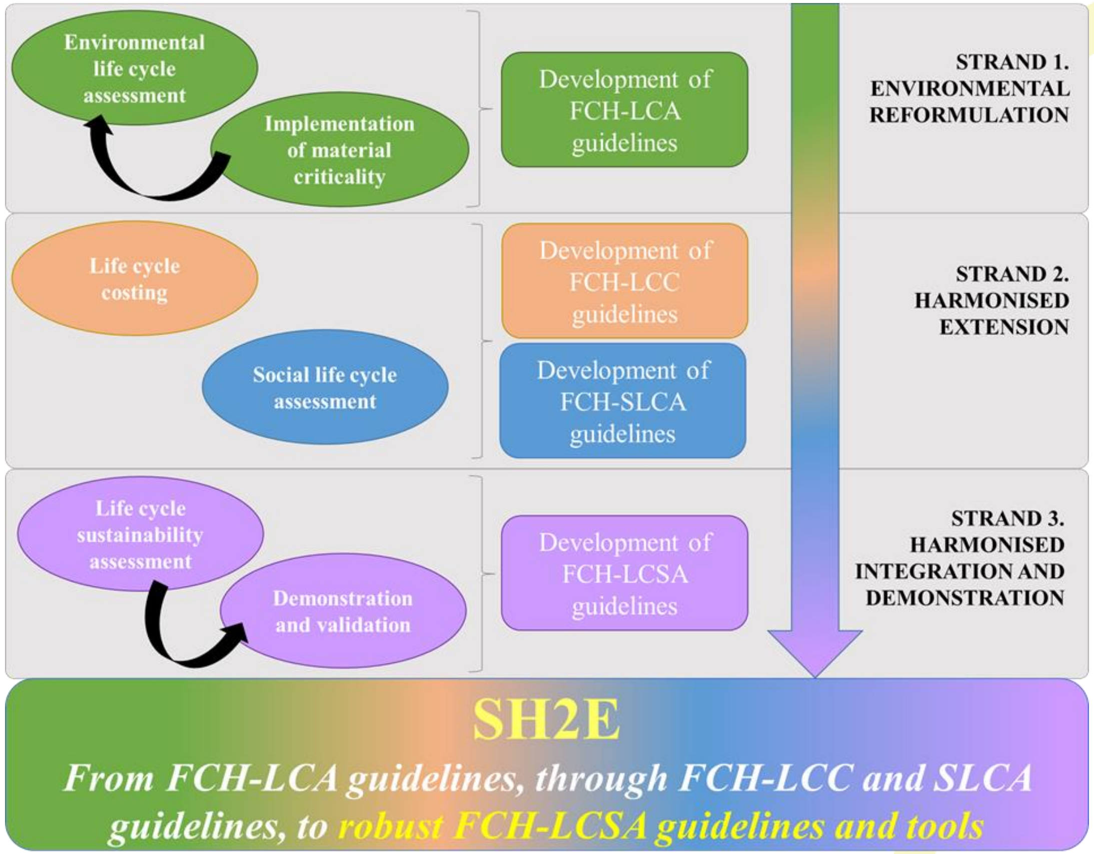

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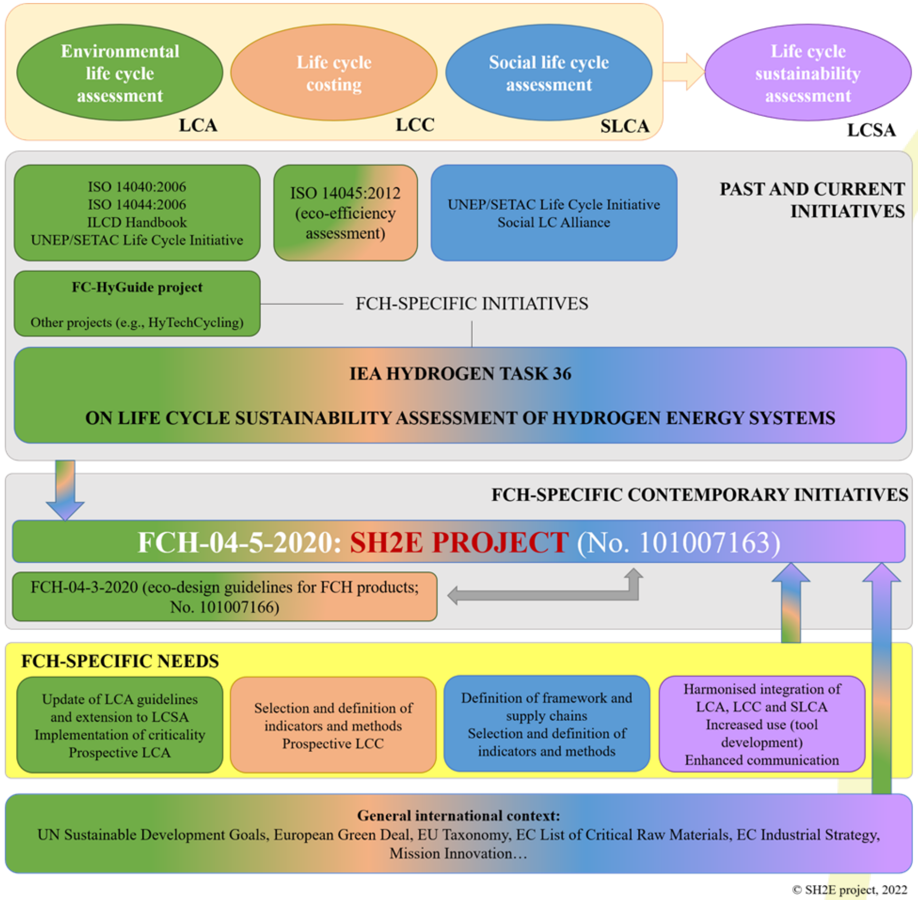

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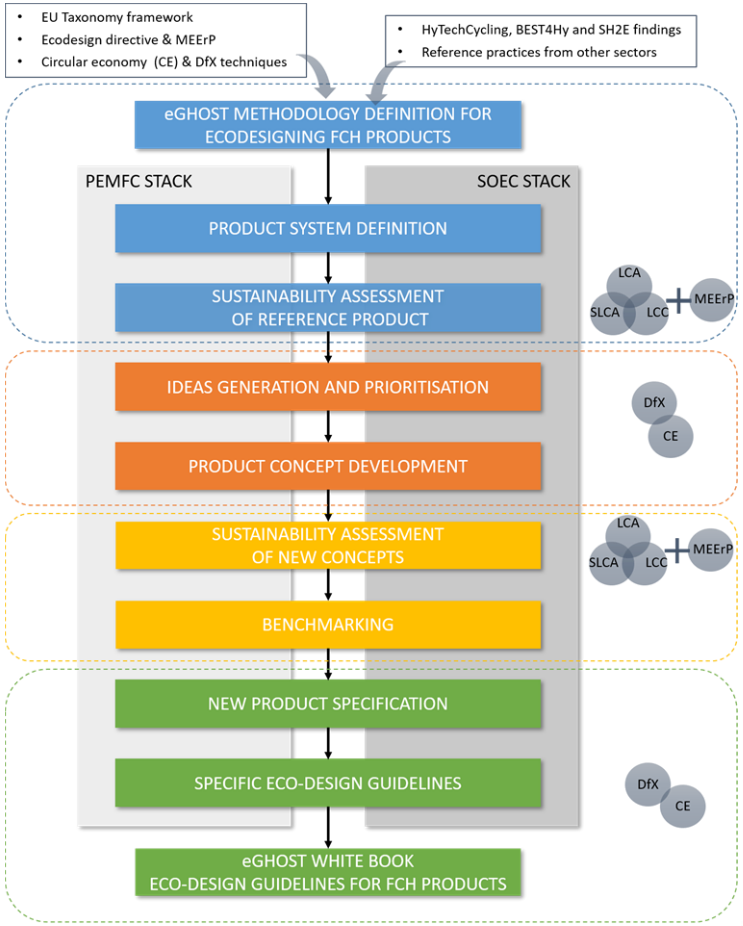
Introduction

eGHOST



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Grant No. 101007163

Project start date: 01.01.2021
Project duration: 42 months
Project Coordinator: IMDEA Energy

D5.1 SH2E guidebook for LCSA

WP5 Joint integration into an LCSA framework

TASK LEADER / WP LEADER	IMDEA Energy
DELIVERABLE LEADERS	IMDEA Energy
REVIEWER	FHa
STATUS	F
DISSEMINATION LEVEL	PU
DELIVERABLE TYPE	R
DUE DATE	M36

SH2E LCSA GUIDELINES

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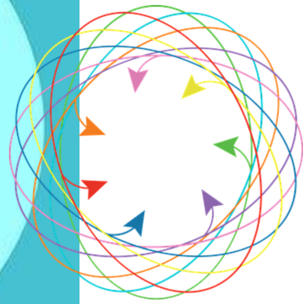
SH2E LCSA guidelines

OBJECTIVE

The key objective is to provide robust **guidelines for LCSA of FCH systems** by consistently integrating the LCA, LCC and SLCA guidelines previously developed in SH2E.



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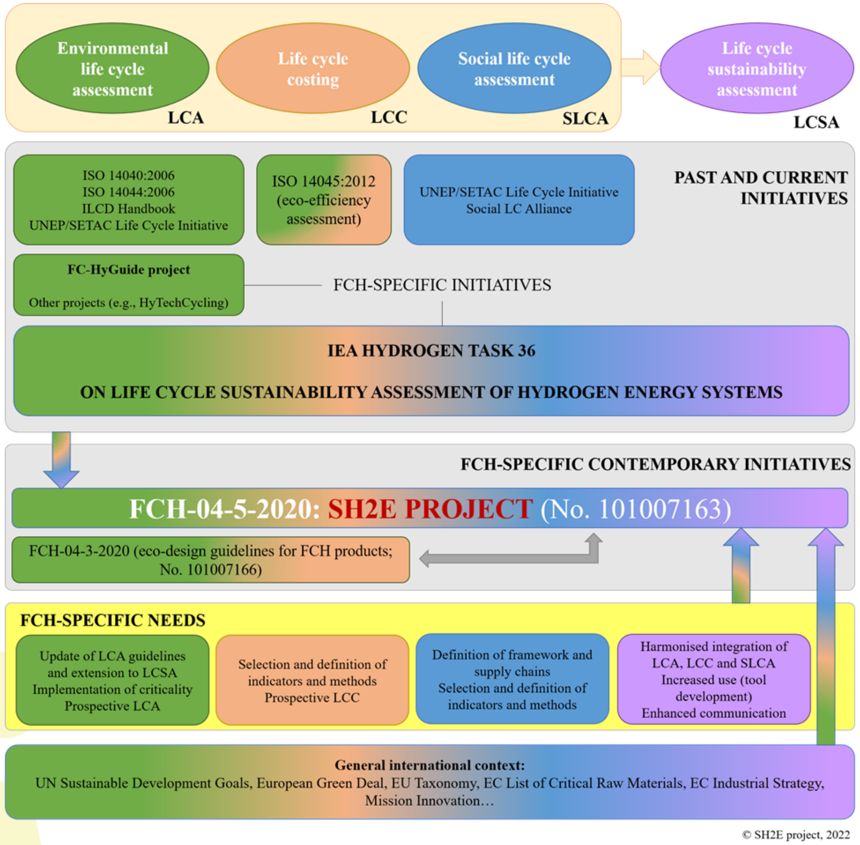
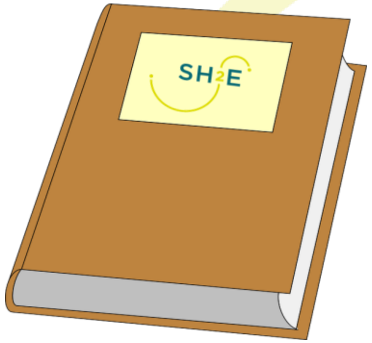
SH2E LCSA guidelines

METHODOLOGY





- 1 document of FCH-LCA guidelines
- 1 document of FCH-LCC guidelines
- 1 document of FCH-SLCA guidelines
- 1 document of FCH-LCSA guidelines
- 1 integrated FCH-LCA/LCC/SLCA/LCSA software tool
- 2 FCH systems assessed and benchmarked from a life-cycle sustainability perspective

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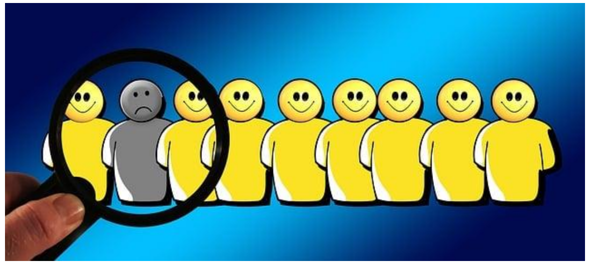
SH2E LCSA guidelines

METHODOLOGY

- Based on the SH2E LCA/LCC/SLCA guidelines and their application, commonalities and acceptable/unacceptable discrepancies were identified



Model asymmetry

It is essential to acknowledge that –throughout the LCSA process– some decisions may prove challenging to harmonise across the three sustainability domains commonly encompassed by LCSA (Valdivia et al. 2011, 2021). This document acknowledges that **model asymmetries** may exist where certain aspects or data may not seamlessly align across all sustainability dimensions within the LCSA framework. These asymmetries are point-by-point acknowledged in these guidelines to provide transparency and guidance to LCSA practitioners (UNEP, 2017). It is imperative for practitioners to be aware of such asymmetries and exercise caution when attempting to integrate data or assessments that may not perfectly align across all dimensions (Costa et al., 2019).

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SH2E LCSA guidelines

THE GUIDELINES

In the green boxes, requirements are presented.

In the light blue boxes, recommendations are presented.

In the yellow boxes, supplementary information is reported.

Box 30 General decision flow for multi-functionality in LCSA of hydrogen production systems

1. The multi-functionality approach selected by the LCSA practitioner must be consistent across sustainability dimensions. Any differences must be transparently acknowledged, explicitly stated and justified.
2. Subdivision must be preferred.
3. If subdivision cannot be applied, system expansion is the second preferable option.
4. If it is not possible to apply system expansion in environmental LCA and SLCA, physical allocation based on energy content needs to be applied when only energy (-carrier) products are involved. If not possible, physical allocation based on number of moles must be selected. Otherwise, economic allocation is suggested. If there is no economic relevance or the previous alternatives are not possible, mass allocation should be applied, and the limitations of this application should be stated. If the recommended allocation methods are not suitable for the investigated system, allocation factors should be defined based on causal relationships or activity variables, such as worker hours or added value.

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SH2E LCSA guidelines

THE GUIDELINES

Box 36 Environmental life cycle impact assessment method and categories

As part of the scope of the LCA, the selected impact assessment method with the impact categories must be included and justified. As for any LCA, compatibility between the inventory flows and the flows applied in the calculation method must be verified. The use of the latest version of the Environmental Footprint method (prepared by JRC) is required (currently version 3.1), and the impact categories based on a materiality assessment. In case it is decided not to include a specific impact category, this must be justified. The characterisation factors provided by the method provider should be checked.

Example: (from SH2E deliverable D6.3, regarding the prospective LCSA of a high-temperature hydrogen production system)

"The Life Cycle Impact Assessment (LCIA) method selected for the study was the Environmental Footprint version 3.1 (EF 3.1, latest available), developed by the Joint Research Centre (JRC) and recommended "as a common way of measuring environmental performance" by the European Commission."

Box 37 Economic life cycle impact assessment method and indicators

The calculation method used for the life cycle costing of FCH products must be clearly stated and defined.

- In case of hydrogen production, the LCoH indicator (levelised cost of hydrogen) must be used (expressed in economic units per functional unit, e.g., €/kg H_2).
- In case of hydrogen use in mobility applications, the TCO indicator (total cost of ownership) must be used, expressed in economic units per functional unit (€/p·km if the main function is the transport of passengers or €/t·km if the main function is the transport of goods).

Example: (from SH2E deliverable D6.3, regarding the prospective LCSA of a high-temperature hydrogen production system)

"The LCoH indicator was calculated, as required by the SH2E LCC guidelines for hydrogen production systems. The formula specified in the guidelines was applied, and the value of cost of capital (r) was assumed to be equal to the discount rate of 5% […] The LCoH from SOE is 7.64 €$_{2023}$/kg of hydrogen."

Box 38 Social life cycle impact assessment method and categories

The calculation method used and the social indicators for the SLCA of FCH products must be clearly stated and defined. It is required to use the Reference Scale Approach (Type 1) for the assessment of FCH systems, while the impact categories to be assessed must be in line with the goal of the study and the materiality assessment. In this sense, a transparent description of the justification of impact category selection must be included.

Example: (from SH2E deliverable D6.3, regarding the prospective LCSA of a high-temperature hydrogen production system)

"The Social Life Cycle Impact Assessment (SLCIA) method selected for the study was the PSILCA method [29]. […] The impact categories specifically assessed in this study are "child labour", "contribution to economic development", "fair salary", "forced labour", "discrimination" and "health and safety."

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SH2E LCSA guidelines

HIGHLIGHTS: prospectivity

Box 4 Prospectivity I

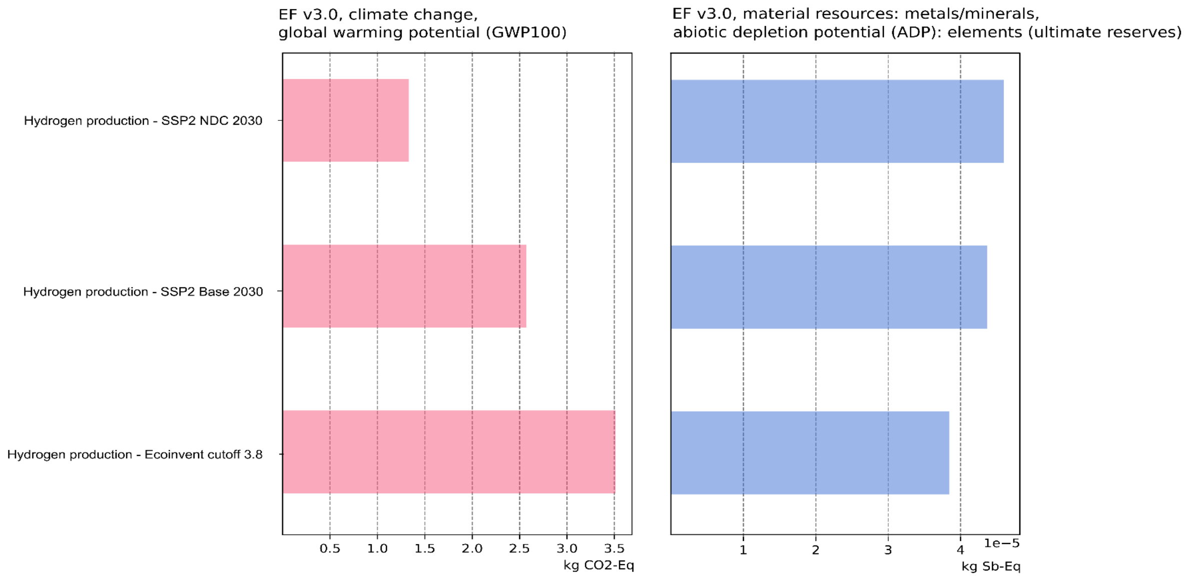
To be prospective within the context of these guidelines, an LCSA study must meet the following requisites:

1. The system must be modelled at a future time.
2. The technical/operating parameters and capital goods of the analysed product system must be prospective.

When performing a comparative study, it must be ensured that the FCH technologies under comparison are modelled at the same future time of implementation.

Example: (from SH2E deliverable D6.3, regarding the prospective LCSA of a high-temperature hydrogen production system)

"The system under evaluation was modelled based on the year 2030, when SOE technology is expected to reach full technical maturity. Thus, the SOE part of the system was modelled according to the expected technical key performance indicators (KPIs) for 2030, while the CSP operating parameters, the integrated performance of the CSP-SOE system and the modelling of the reference hydrogen production system through SMR were based on the use of process simulation tools."



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SH2E LCSA guidelines

HIGHLIGHTS: functional unit

Box 11 Functional unit in systems assessing hydrogen production

1. The functional unit used in LCSAs of hydrogen production systems must represent the mass amount of produced hydrogen (e.g. kg of hydrogen).
2. Hydrogen purity, pressure and temperature, besides geographical information of the final output of the system, must be specified together with the functional unit.

Example: (from reference [Valente et al., 2019], on LCSA and benchmarking of hydrogen production from biomass gasification)

"The two hydrogen production plants were assumed to be located in Spain […]. Both systems were assessed from feedstock production to hydrogen compression, and the functional unit (FU) was defined as 1 kg of hydrogen with 99.9 vol% purity at 200 bar and 25°C"

Box 14 Functional unit in systems assessing hydrogen use for fuels and chemicals production

1. The functional unit used in LCSAs of hydrogen use for fuels and chemicals production must represent the quantity of the produced chemical/fuel by means of a mass-based functional unit in the case of chemicals, and by either a mass- or energy-based functional unit in the case of fuels.
2. Purity, pressure and temperature of the produced chemical/fuel, besides geographical and temporal information of the final output of the system, must also be specified to guarantee a precise functional unit and fair comparisons.
3. In the case of fuels, the energy content must be clearly stated through the use of the net calorific value.

Example: (from reference [Iribarren et al., 2022], on SLCA and benchmarking of green methanol)

"The functional unit of the study was defined as 1 kg of (green or conventional) methanol produced at plant […] The green methanol system under study involves methanol production from CO_2 (directly captured from the air) and hydrogen (from wind power electrolysis) at a hypothetical plant in the USA."

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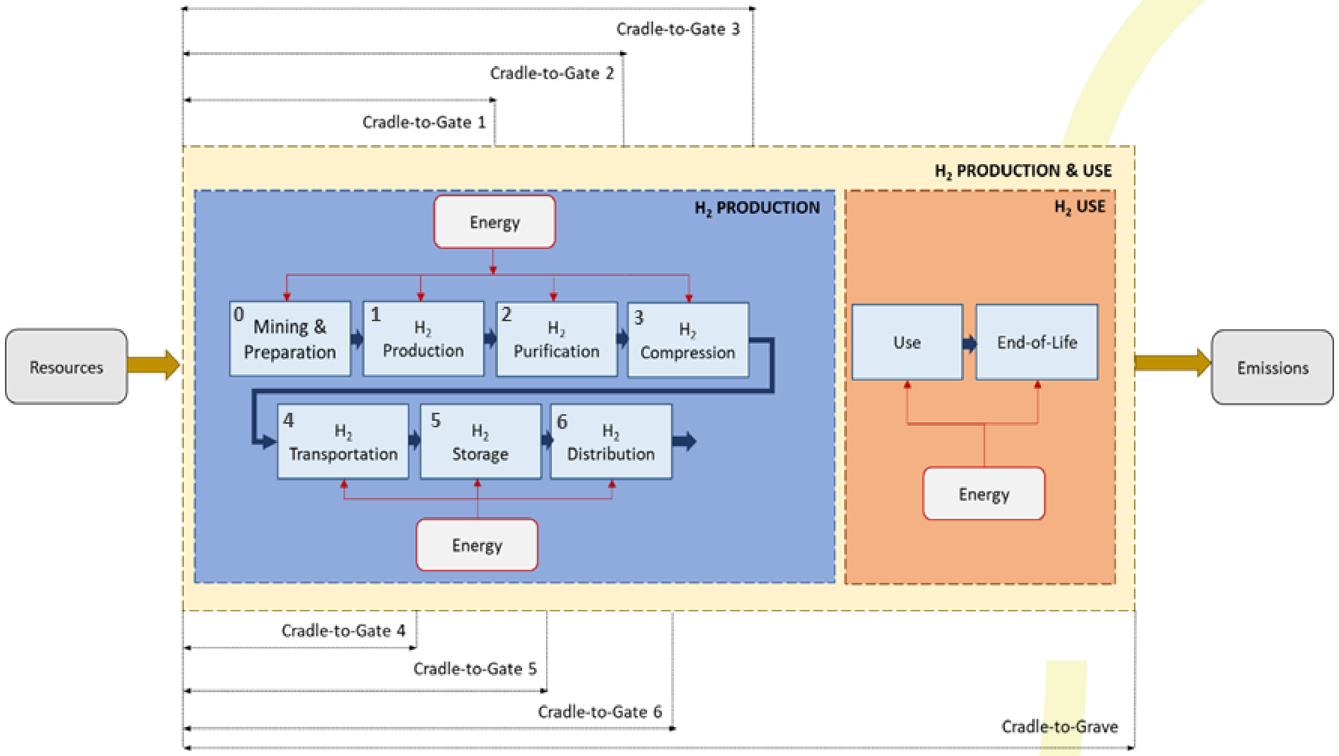
SH2E LCSA guidelines

HIGHLIGHTS: system boundaries



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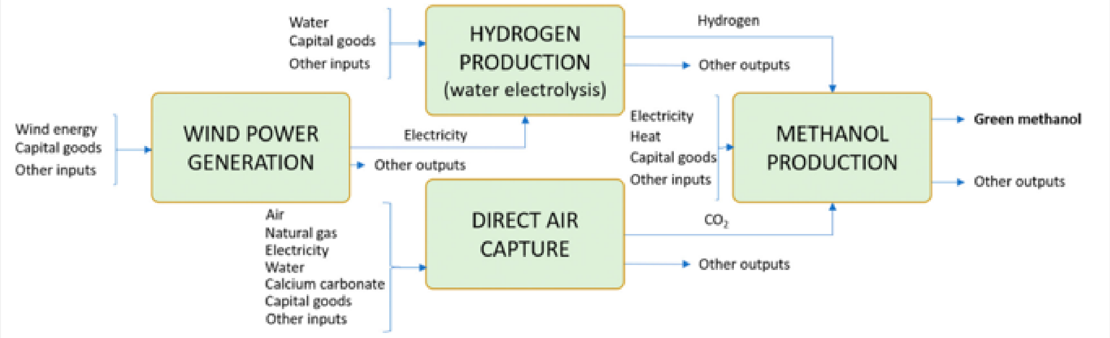
SH2E LCSA guidelines

HIGHLIGHTS: system boundaries

Box 22 System boundaries for systems assessing hydrogen production and use

1. The system boundaries of studies focusing on hydrogen production and use must be Cradle-to-Grave.
2. All the sustainability-relevant flows must be included in the assessment. If the inclusion of flows is not homogeneous across dimensions, the reasons for variations should be reported and justified.

Example: (from reference [Iribarren et al., 2022], on SLCA and benchmarking of green methanol)



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SH2E LCSA guidelines

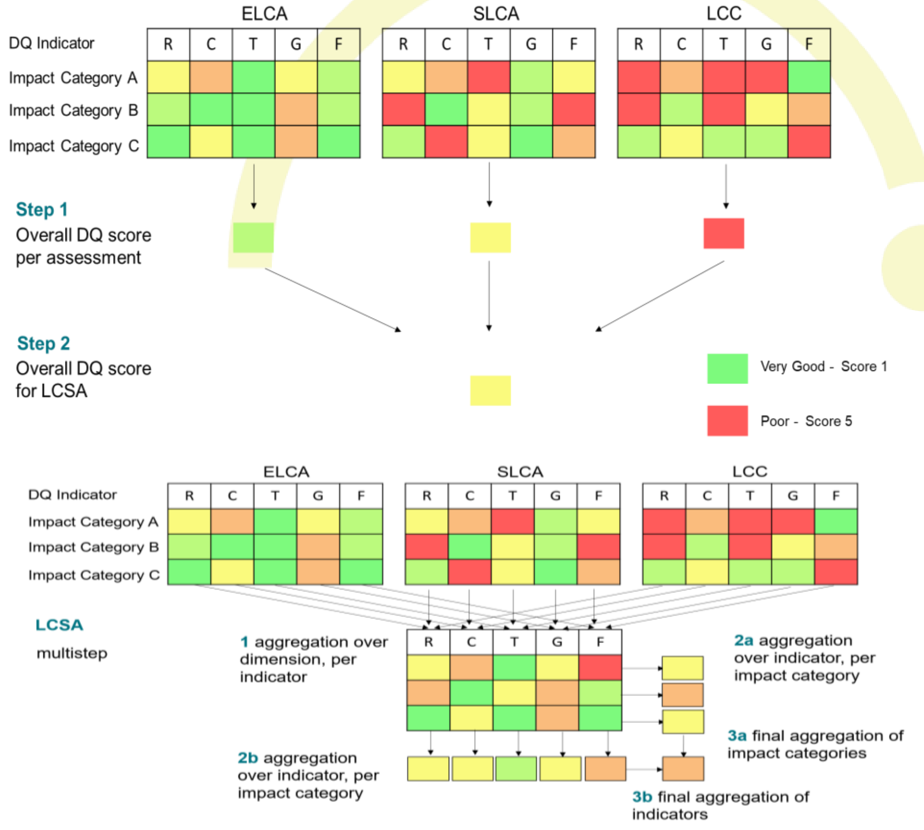
HIGHLIGHTS: data quality

Box 33 Data quality I

Data quality should be documented and a data quality system with different data quality indicators should be applied for LCSA studies in general and about hydrogen systems specifically.

Example: (from SH2E deliverable D6.3, regarding the LCSA and benchmarking of a PEMFC passenger car)

"The quality of all flows and processes was assessed in the software openLCA, using the ecoinvent data quality system. For the background processes, the ecoinvent data quality system was also applied."



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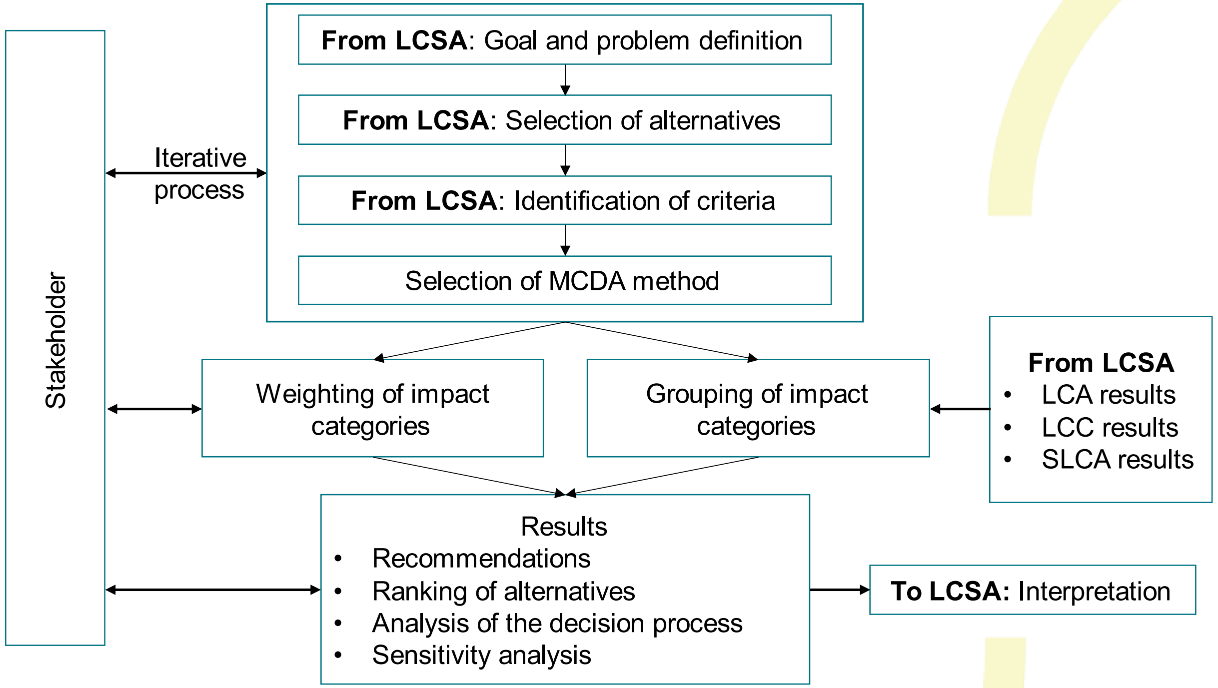
SH2E LCSA guidelines

HIGHLIGHTS: integration



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SUSTAINABILITY ASSESSMENT
OF HARMONISED HYDROGEN
ENERGY SYSTEMS

Grant No. 101007163

Project start date: 01.01.2021
Project duration: 42 months
Project Coordinator: IMDEA Energy

D6.3 LCSA application report

WP6 LCSA consultation, testing, benchmarking, and validation

TASK LEADER / WP LEADER	CEA / CEA
DELIVERABLE LEADERS	CEA
REVIEWER	IMDEA Energy
STATUS	Final draft
DISSEMINATION LEVEL	PU
DELIVERABLE TYPE	R
DUE DATE	30/06/2024 (M42)

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APPLICATION OF THE SH2E GUIDELINES

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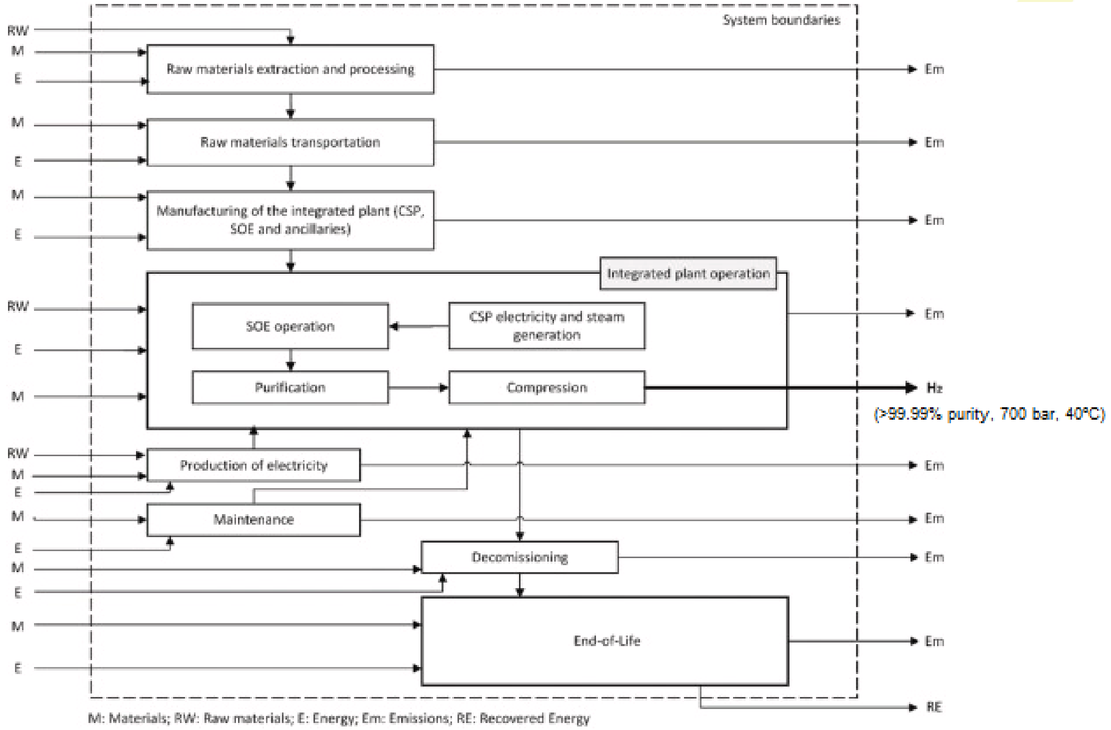
Application

THE SYSTEM



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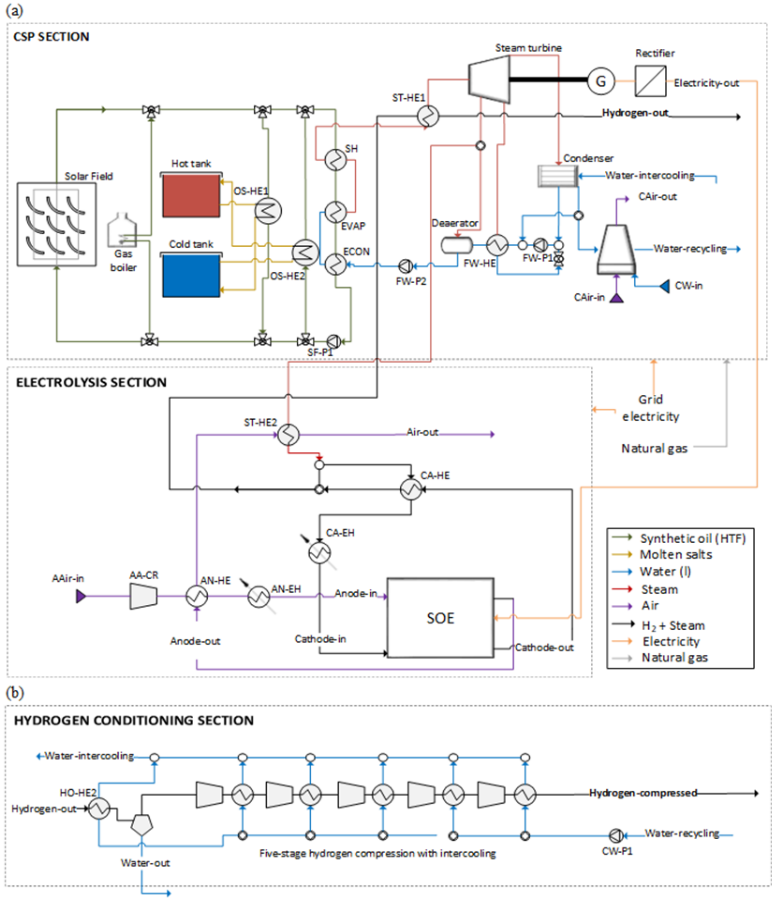
Application



THE SYSTEM

- 1 kg of hydrogen with purity ≥ 99.999% (vol), at 700 bar and 40 °C
- The SOE part of the system was modelled according to the expected technical KPIs for 2030
- The CSP operating parameters and the integrated performance of the CSP-SOE system were based on the use of process simulation tools

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Application

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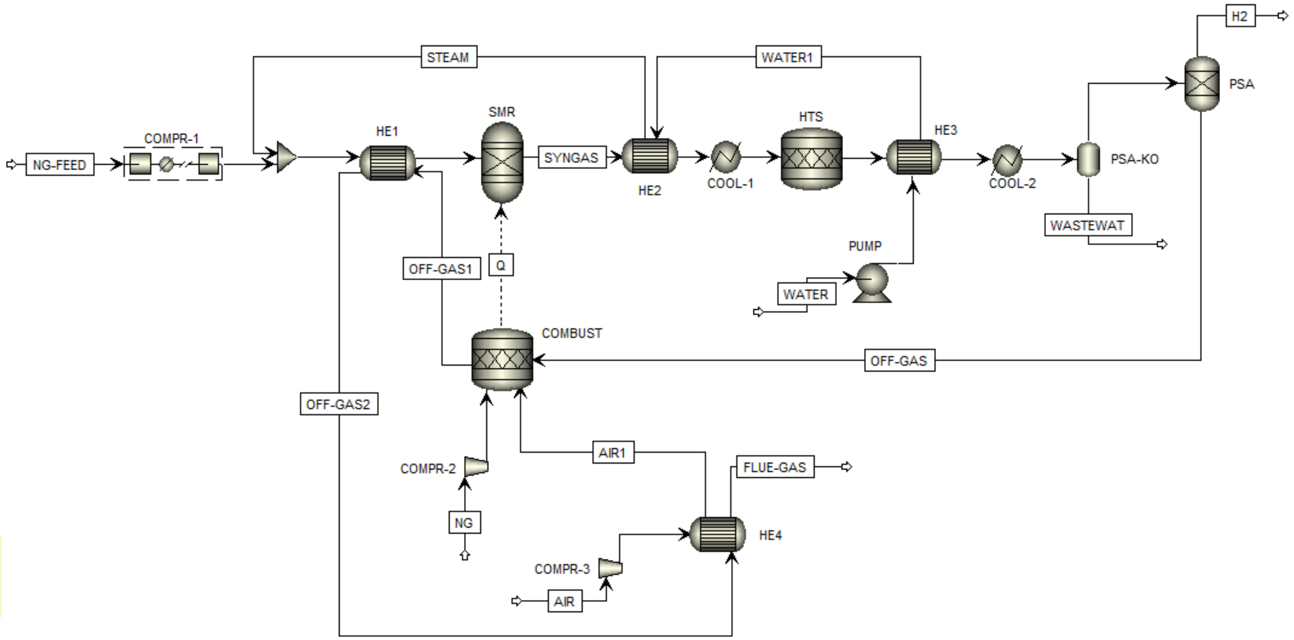

- The functional unit of the competing system for benchmarking (hydrogen from fossil-based SMR) was also defined as 1 kg of hydrogen at the same conditions

- The modelling of the reference hydrogen production system through SMR (85% efficiency in 2030) was based on the use of process simulation tools

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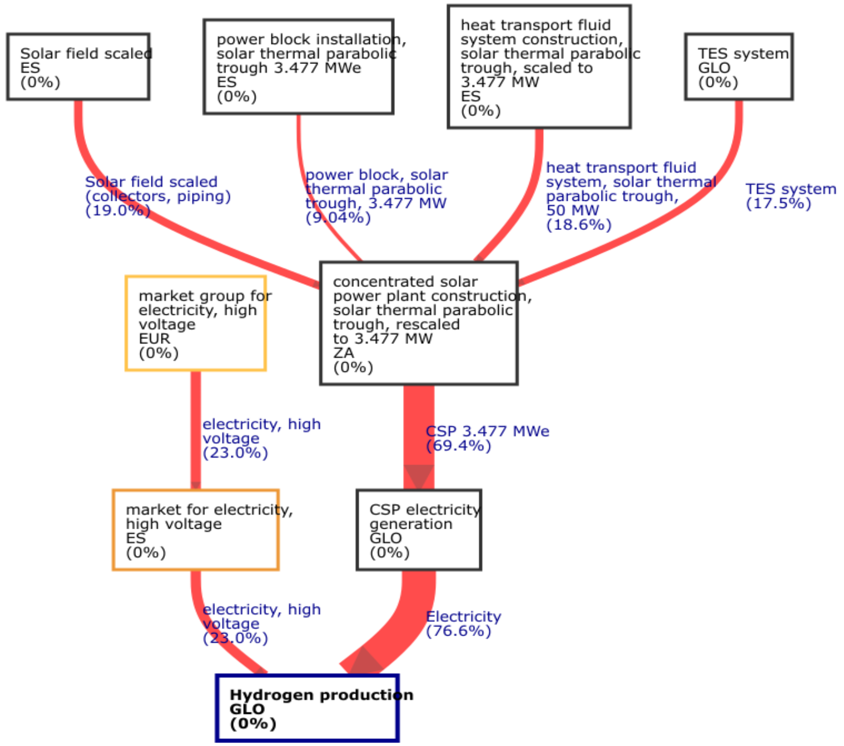
Application

ENVIRONMENTAL DIMENSION



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Clean Hydrogen Partnership

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Application

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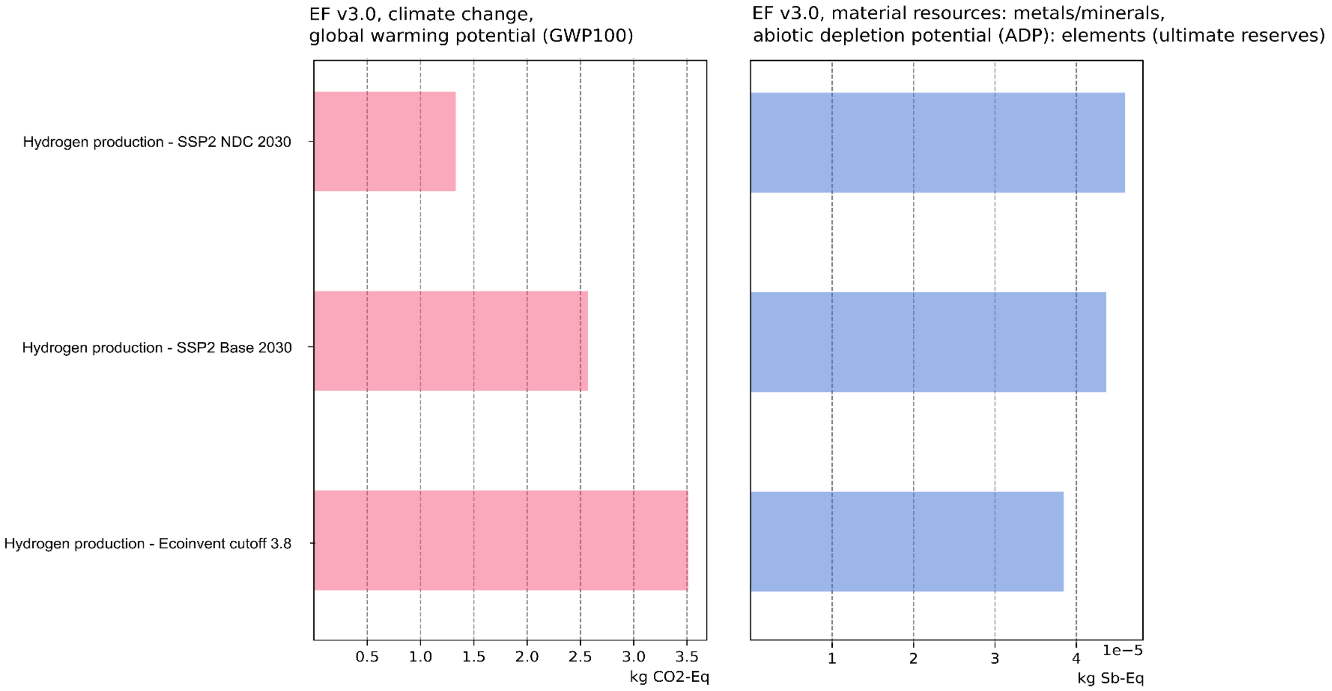

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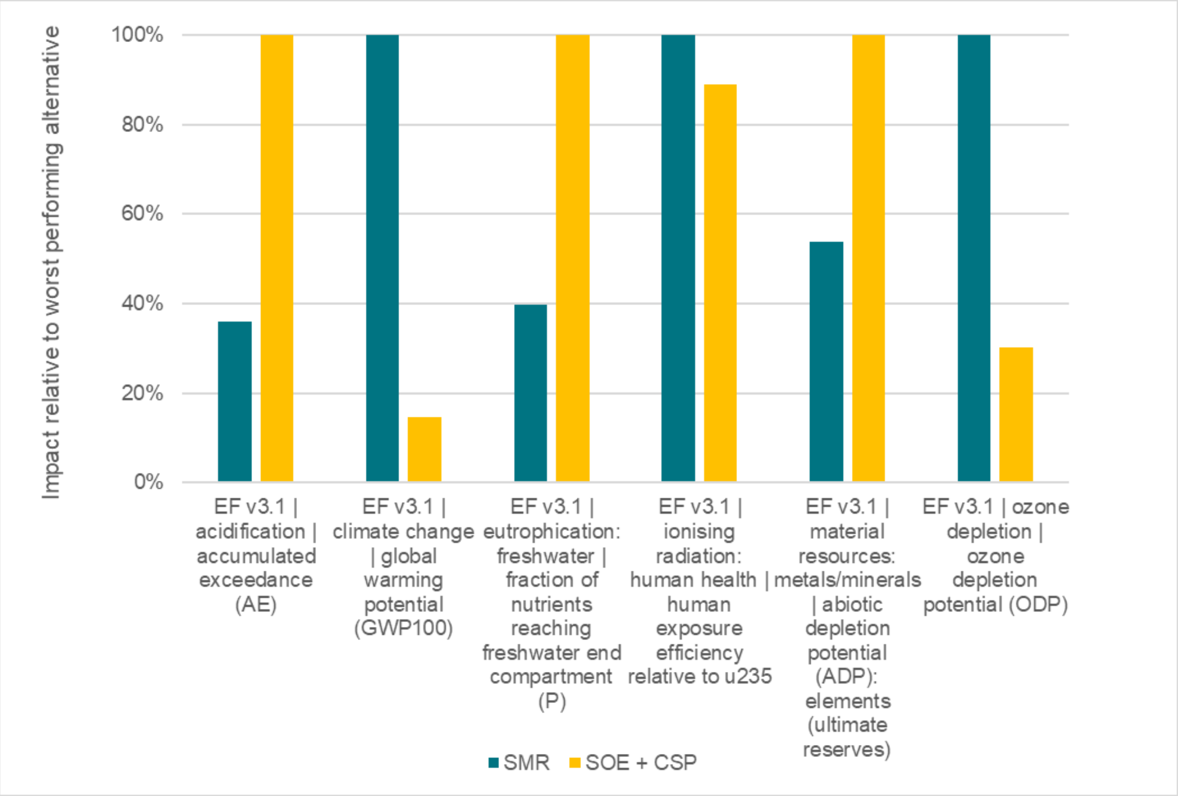

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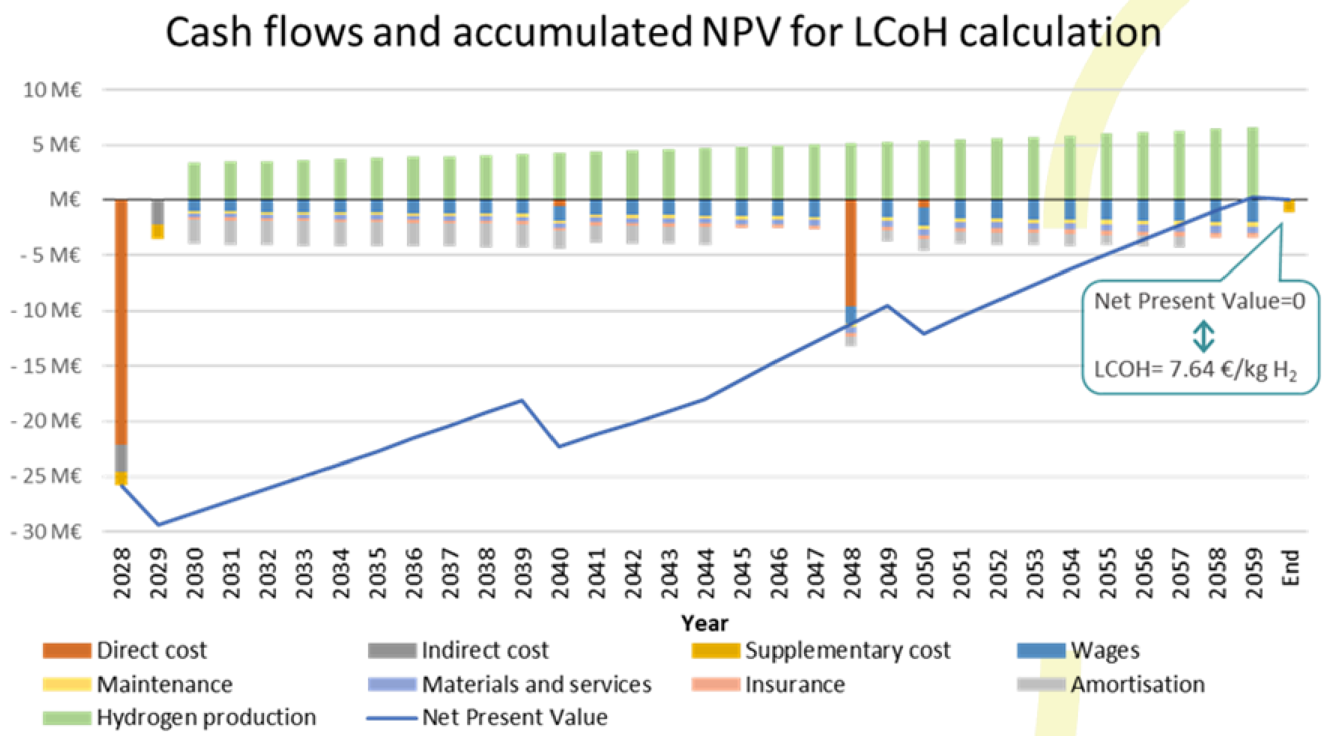
ECONOMIC DIMENSION



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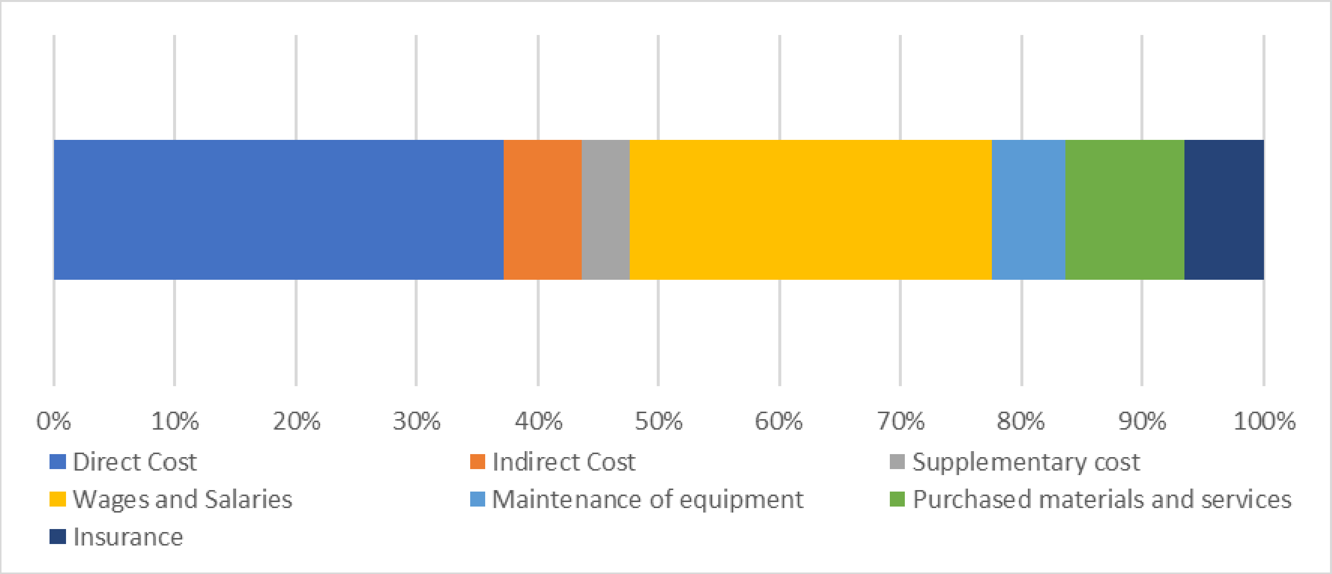

Cost category contribution to LCoH

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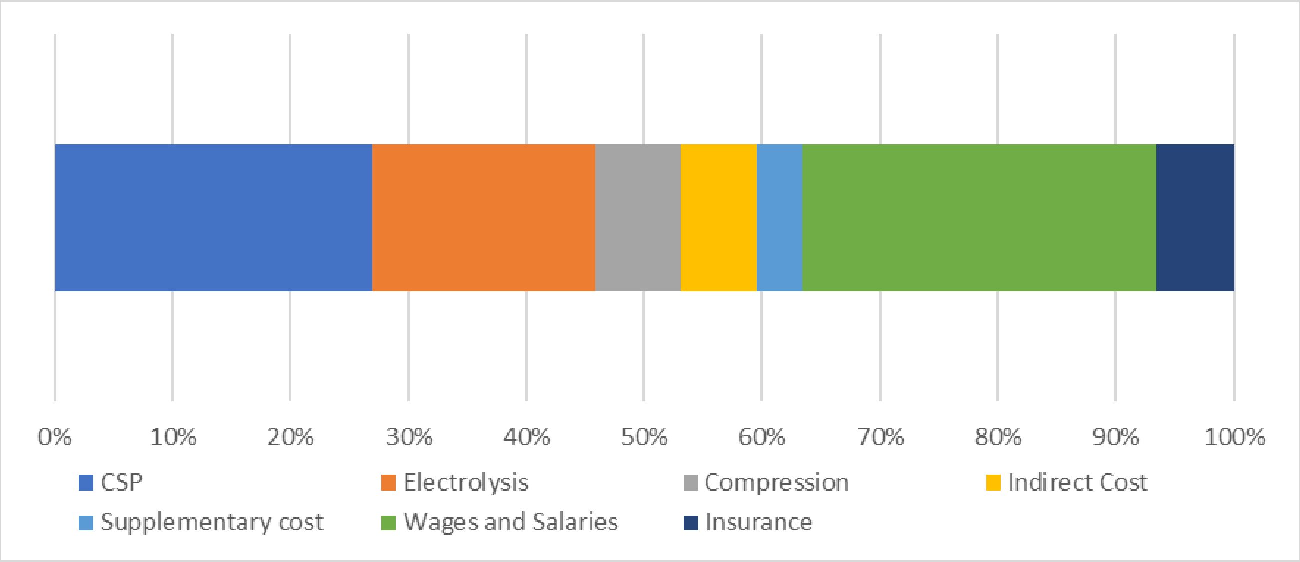

Contribution of each section to LCoH

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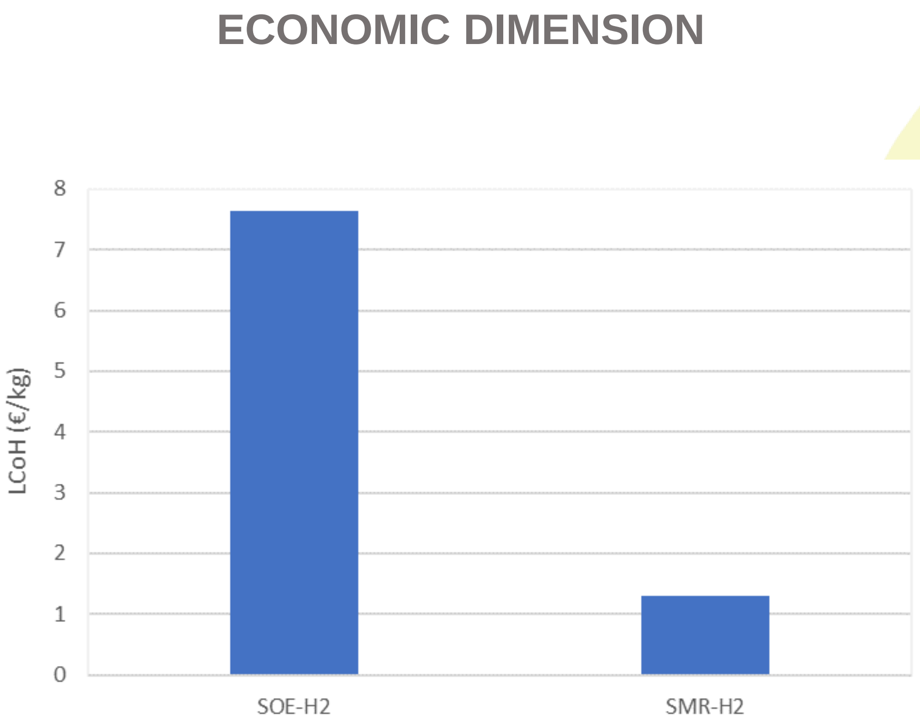

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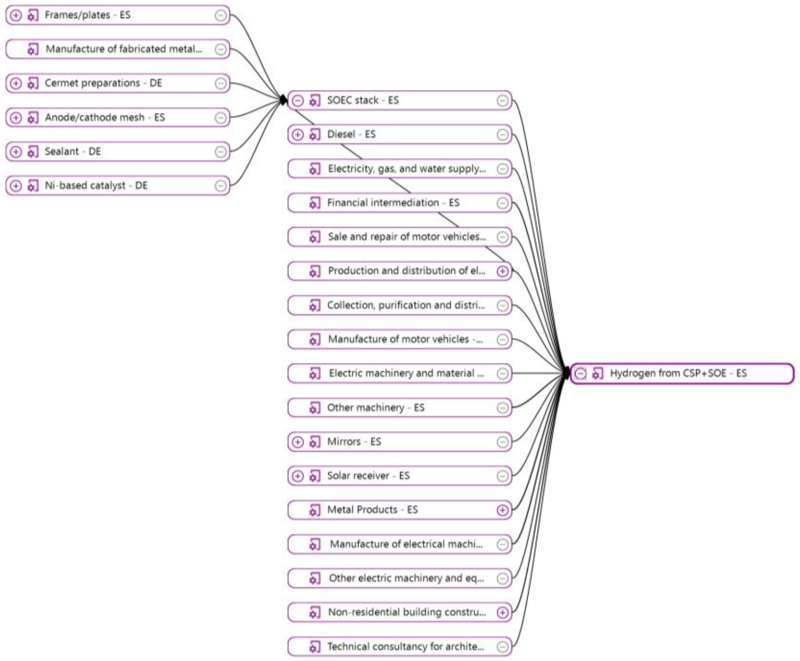
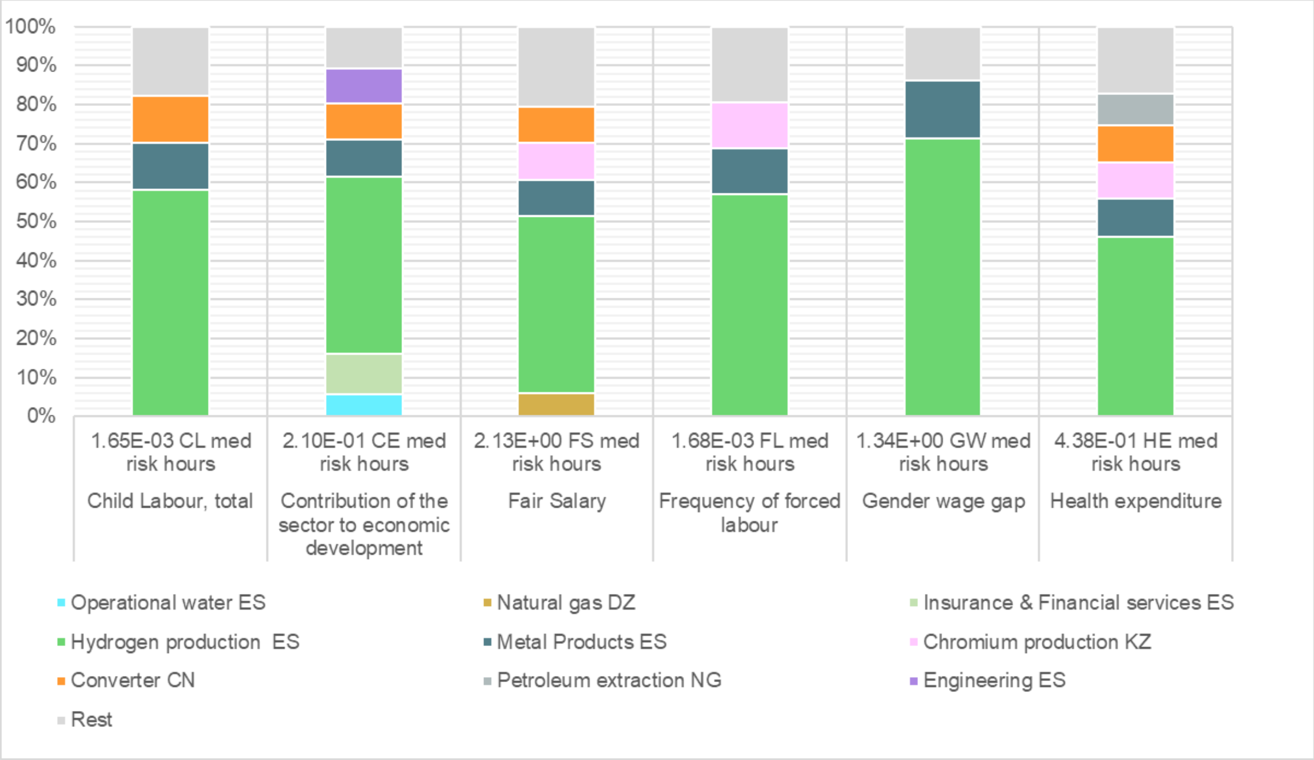


SOCIAL DIMENSION



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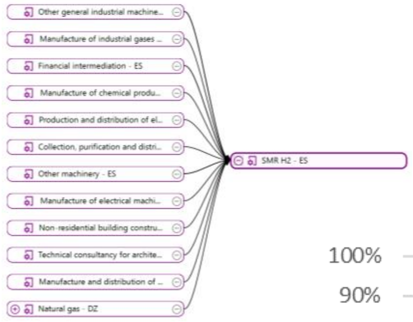
Application



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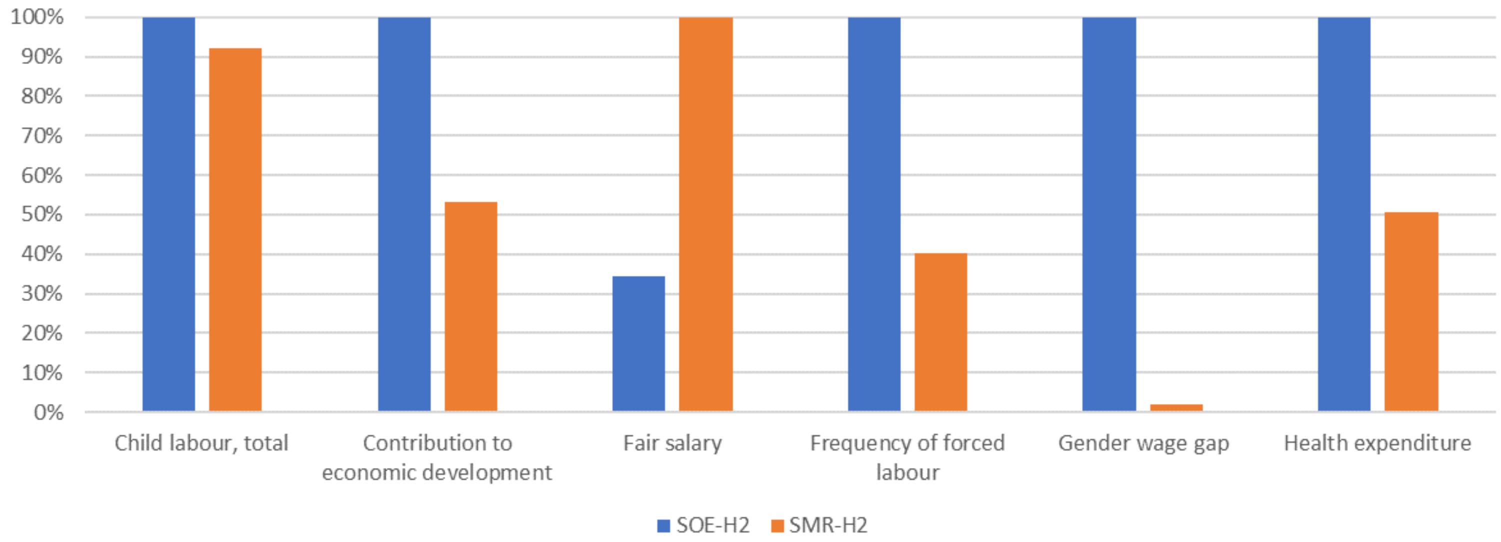

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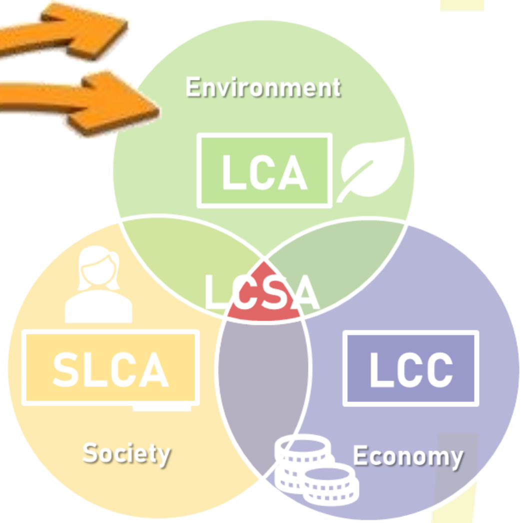
Final remarks



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SH2E

SUSTAINABILITY ASSESSMENT OF HARMONISED HYDROGEN ENERGY SYSTEMS

For further information, please visit:

http://sh2e.eu

Contact

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