SH2E

SH2E Spring School (20-24 May 2024)

Environmental life cycle assessment of hydrogen systems & SH2E LCA guidelines

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Javier Dufour – IMDEA Energy / Rey Juan Carlos University

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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.

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INTRODUCTION TO LCA AND HYDROGEN ENERGY SYSTEMS

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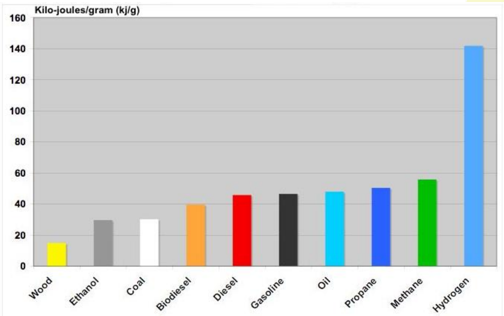

$$2H_2 + O_2 \rightarrow 2H_2O$$

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

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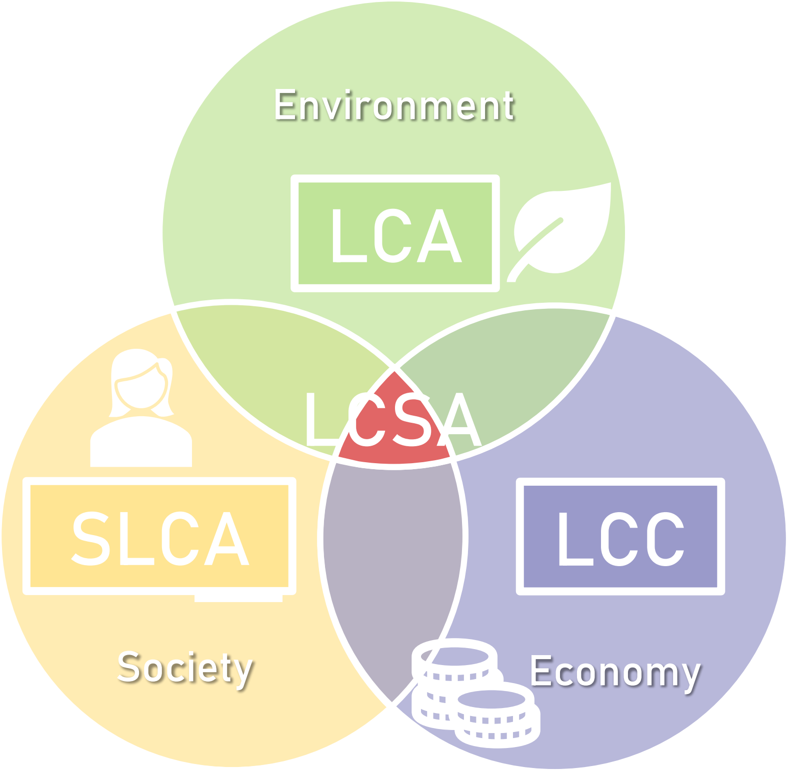

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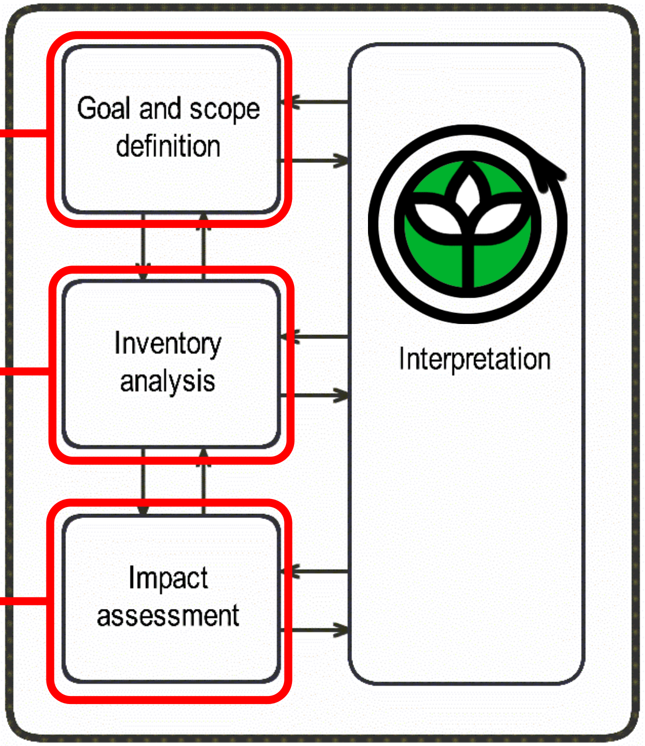
Introduction

Functional unit
System boundaries
…

Data collection

Assessment method
Classification
Characterisation
…



ISO 14040:2006
ISO 14044:2006

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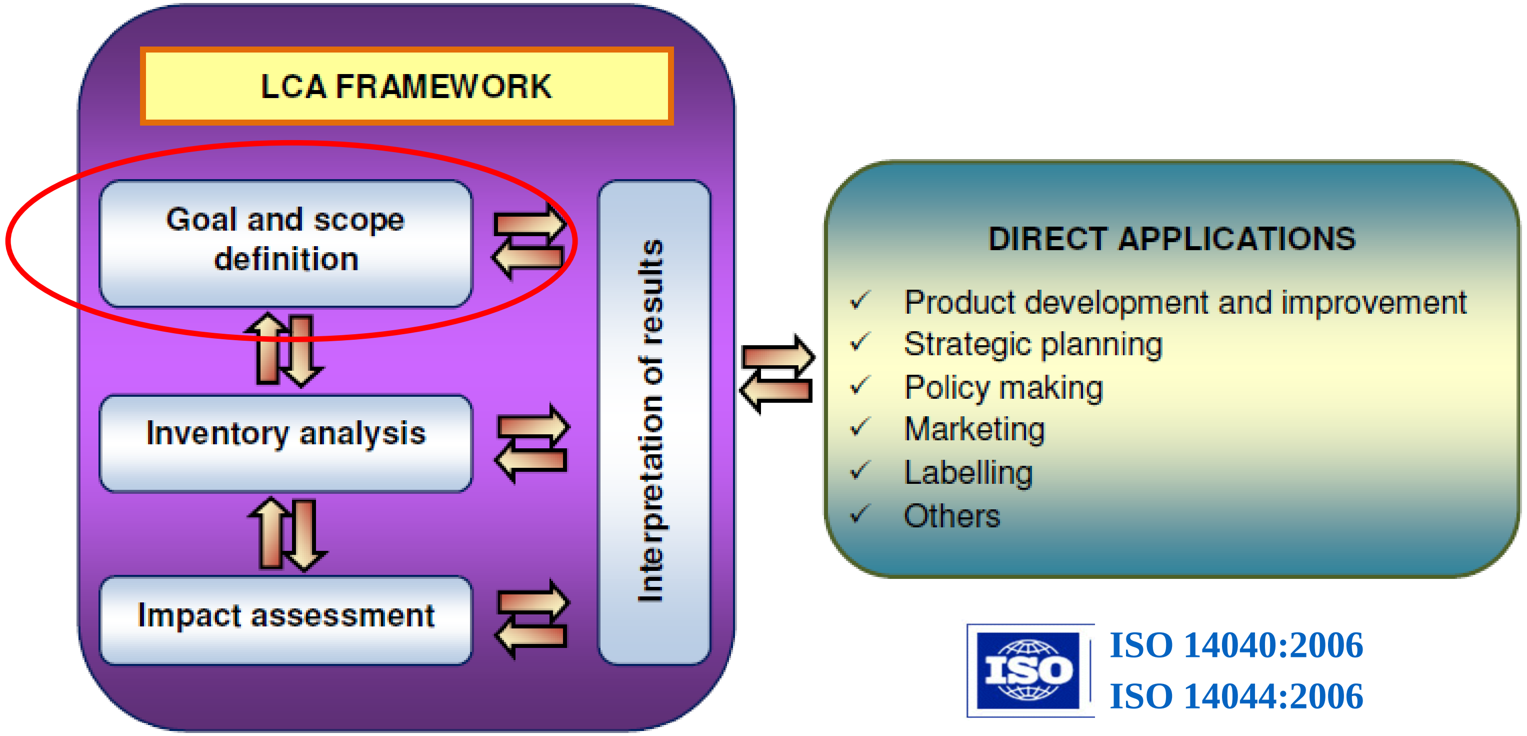

- The **goal** sets the expected application, the reasons behind the study, expected audience, etc.

- The **scope** addresses issues such as the product system, its function and boundaries, the functional unit, etc.

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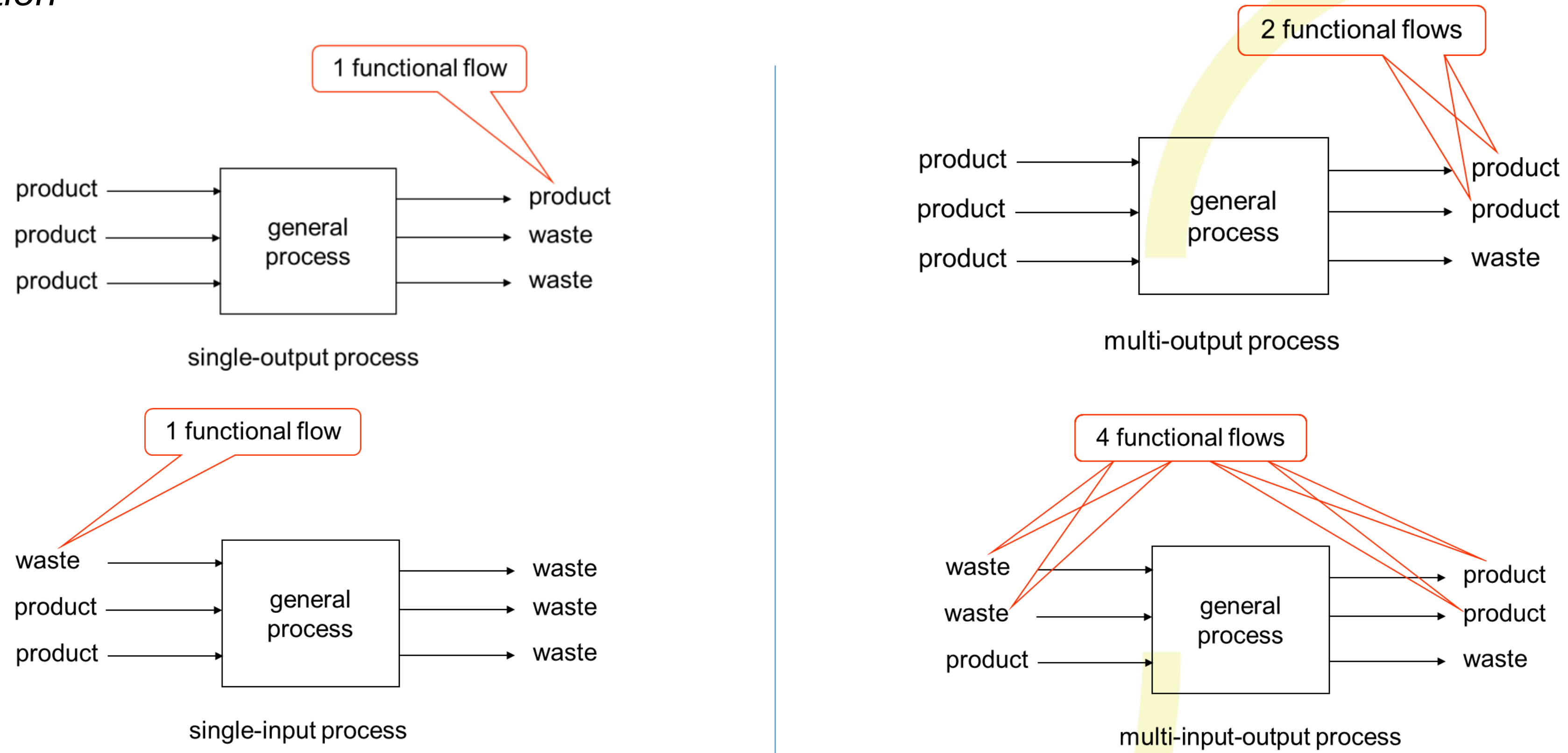
Introduction

System function



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Introduction

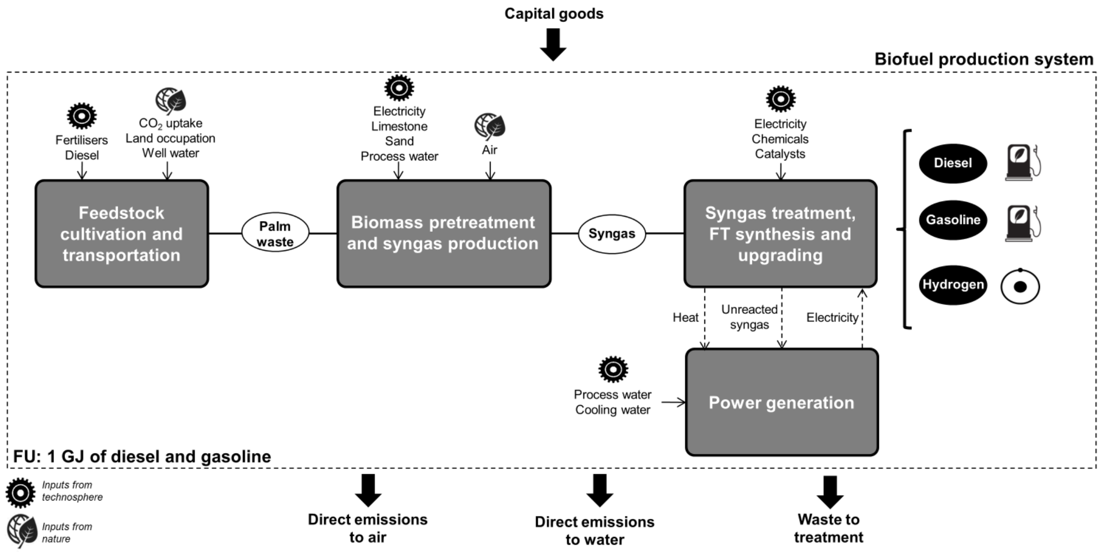
Functional unit

Quantification of the function of a system

Also a reference to which the system's inputs and outputs can be related

Comparative/non-comparative studies

System boundaries



https://doi.org/10.1016/j.scitotenv.2021.148961

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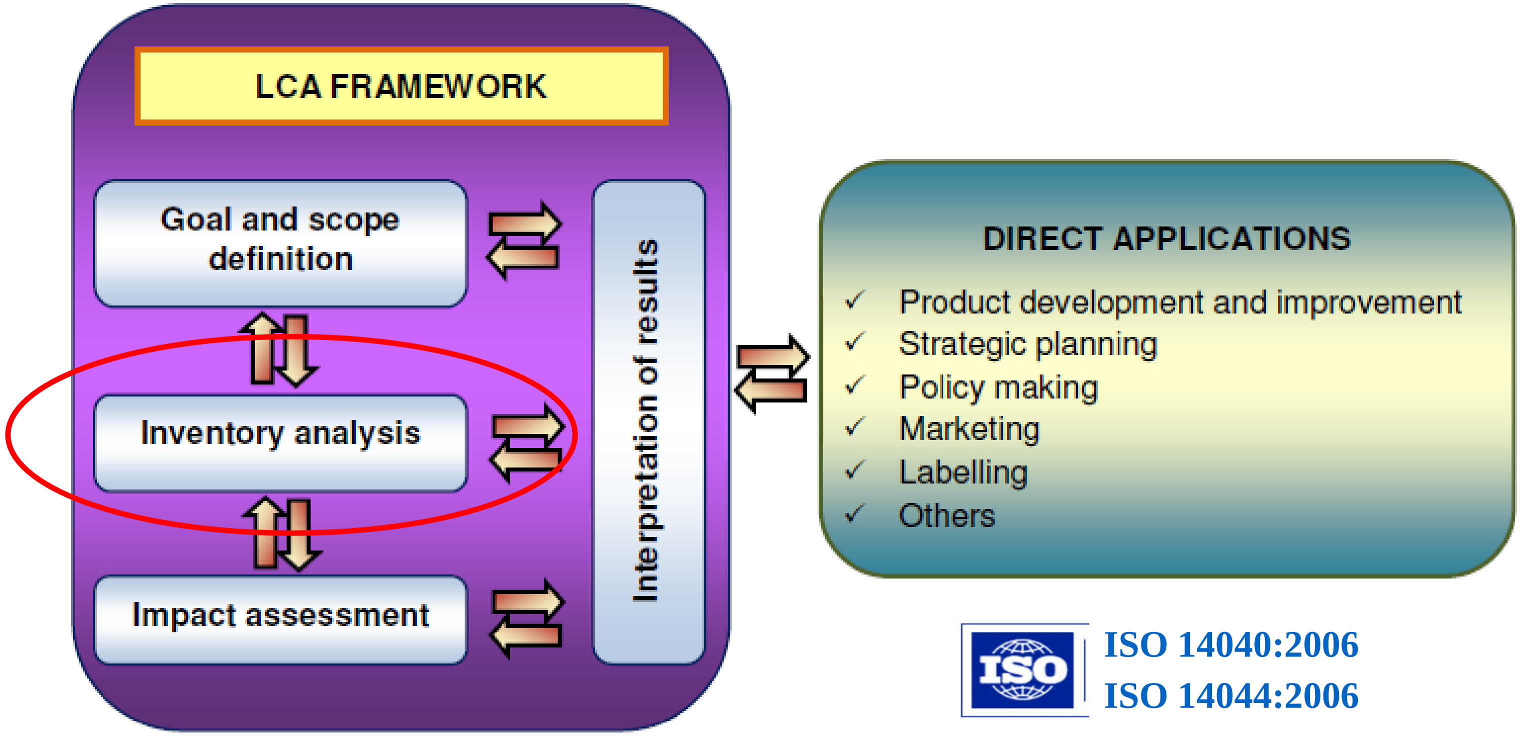

- Collection of **data** and calculation procedures needed to fulfil the goal of the study
- Additional use of **databases**

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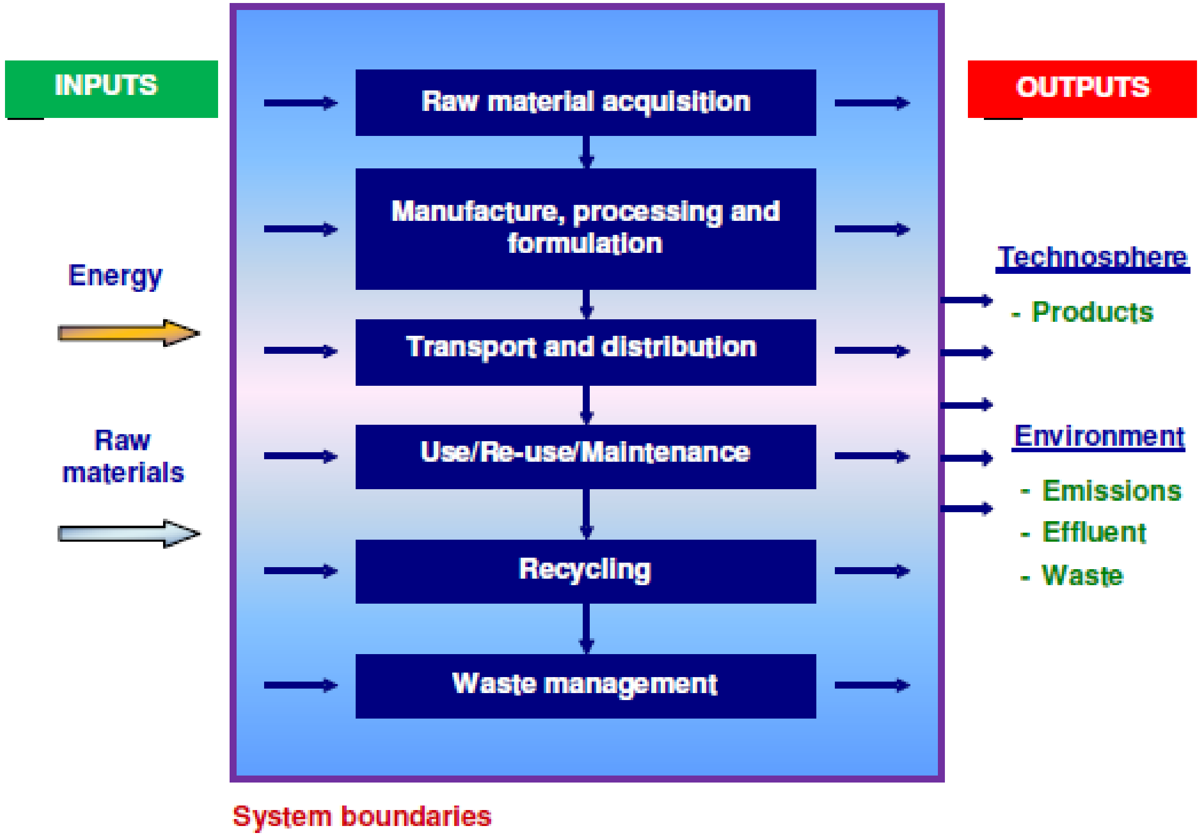

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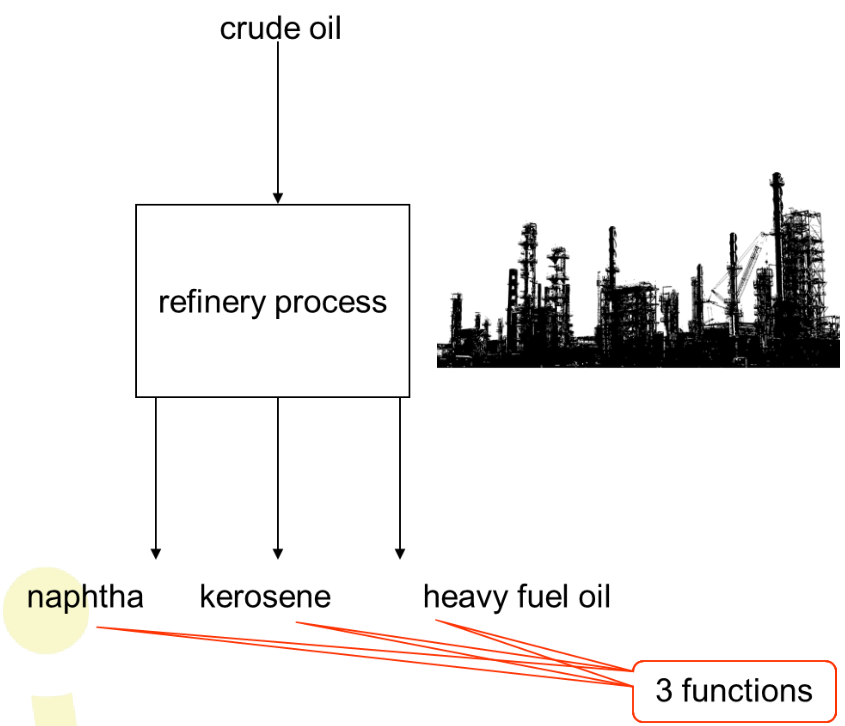
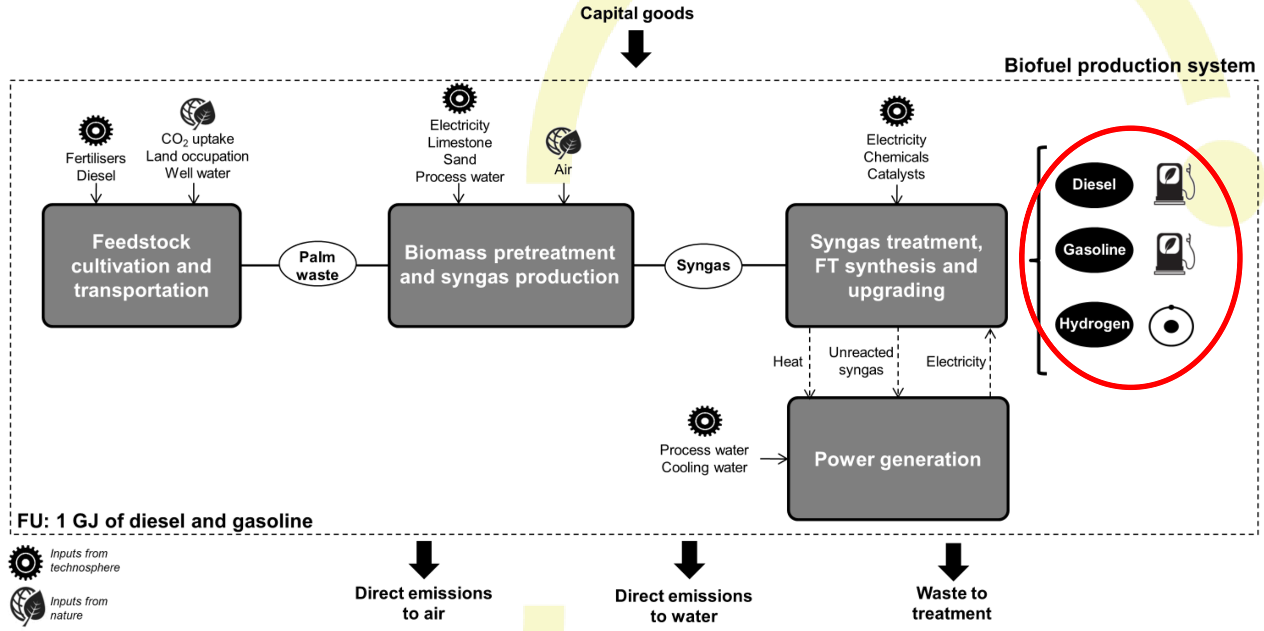
Introduction

Multifunctional systems: avoid/implement allocation





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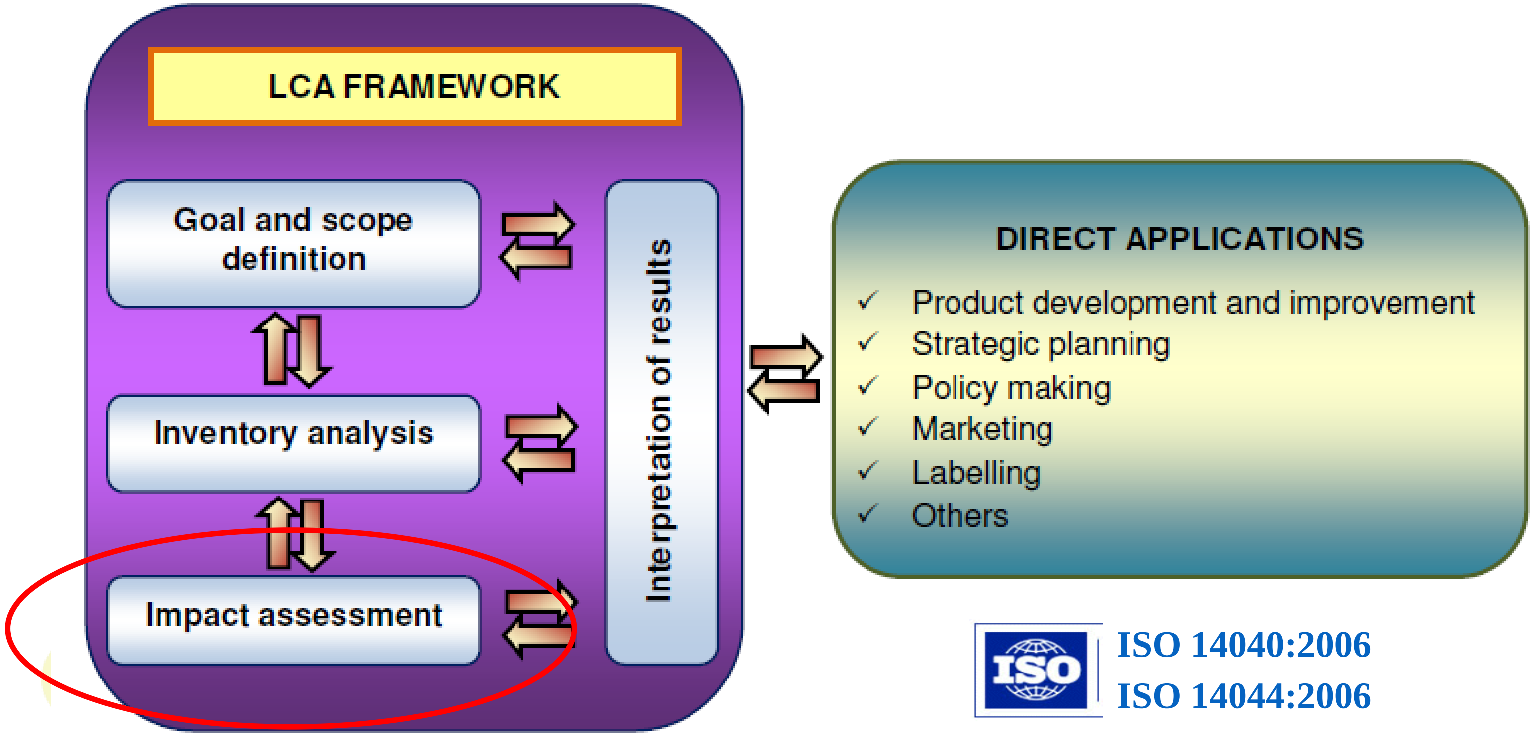

ISO 14040:2006
ISO 14044:2006

Computation of indicator results for a set of impact categories, leading to the **environmental profile** of the product system

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Introduction

- Selection of impact categories, indicators and characterisation models
- Classification: assignment of inventory results to the selected impact categories
- Characterisation: computation of indicator results

Methods

European: CML, EF, ILCD, EPD, IMPACT, EDIP, EPS, Environmental Prices, Ecological Scarcity, etc.

Global: ReCiPe (endpoint/midpoint; I/H/E)

North American: BEES, TRACI

Single issue: VDI, IPCC, USEtox, etc.

Table 5
Environmental life-cycle profile of 1 GJ of synthetic diesel and gasoline.

Indicator	Value	Units
Global warming	7.65	kg CO_2 eq
Fine particulate matter formation	0.25	kg $PM_{2.5}$ eq
Terrestrial acidification	0.70	kg SO_2 eq
Freshwater eutrophication	$1.21 \cdot 10^{-2}$	kg P eq
Fossil resource scarcity	28.58	kg oil eq

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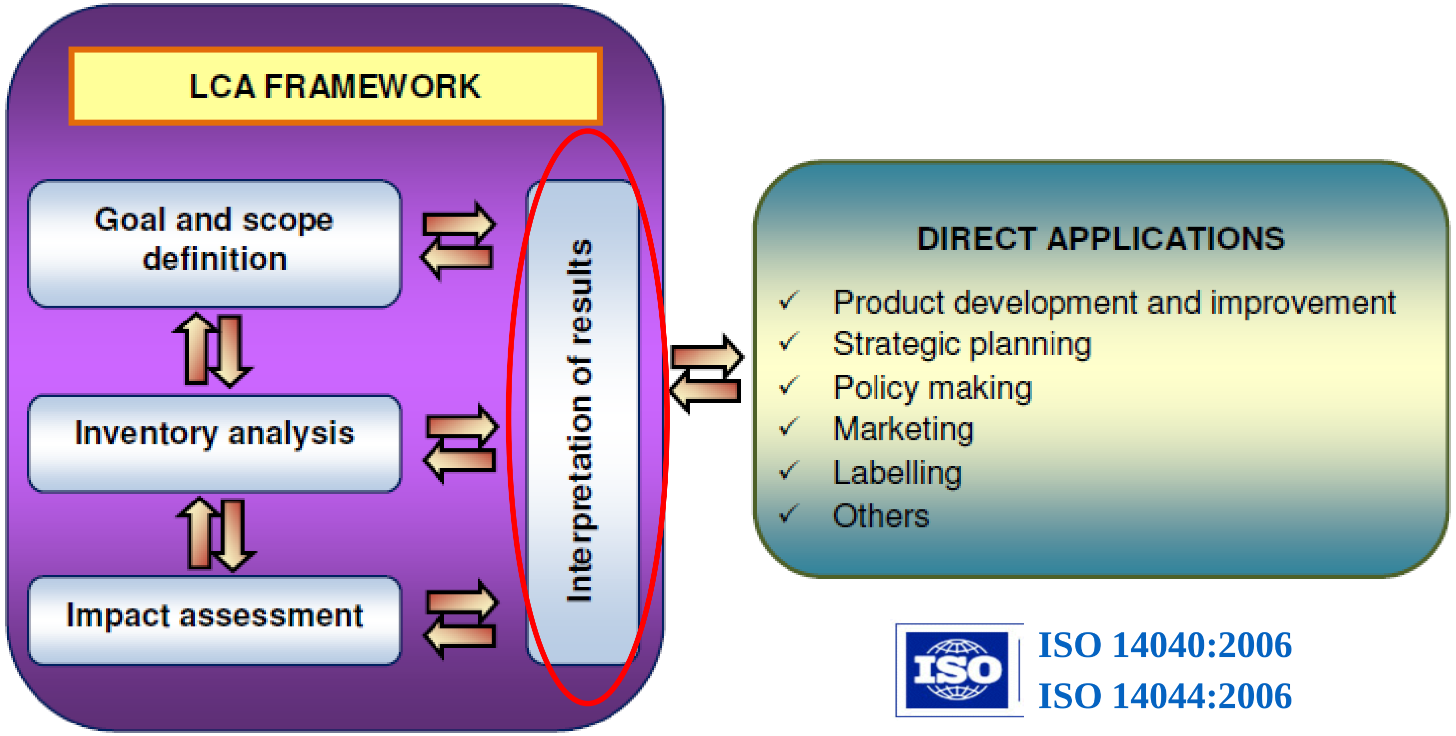

- Summary and discussion on inventory and assessment results to draw **conclusions and recommendations** for decision-making support according to the defined goal and scope
    - Identification of hotspots
    - Further analysis (e.g. sensitivity analysis)
    - Conclusions, limitations & recommendations

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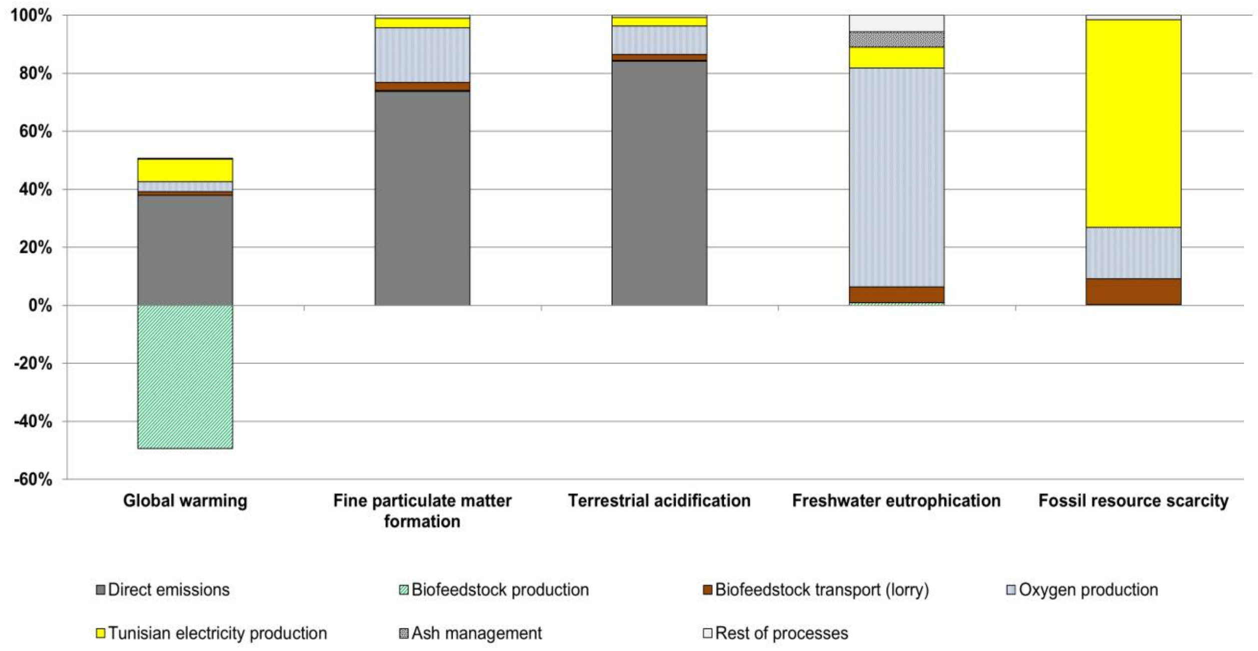

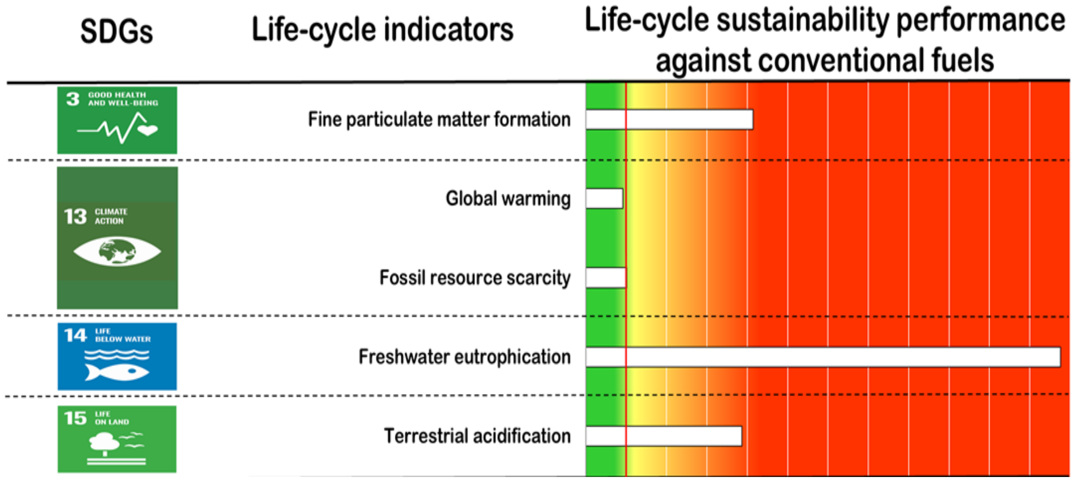

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CONTEXT AND
SH2E LCA GUIDELINES

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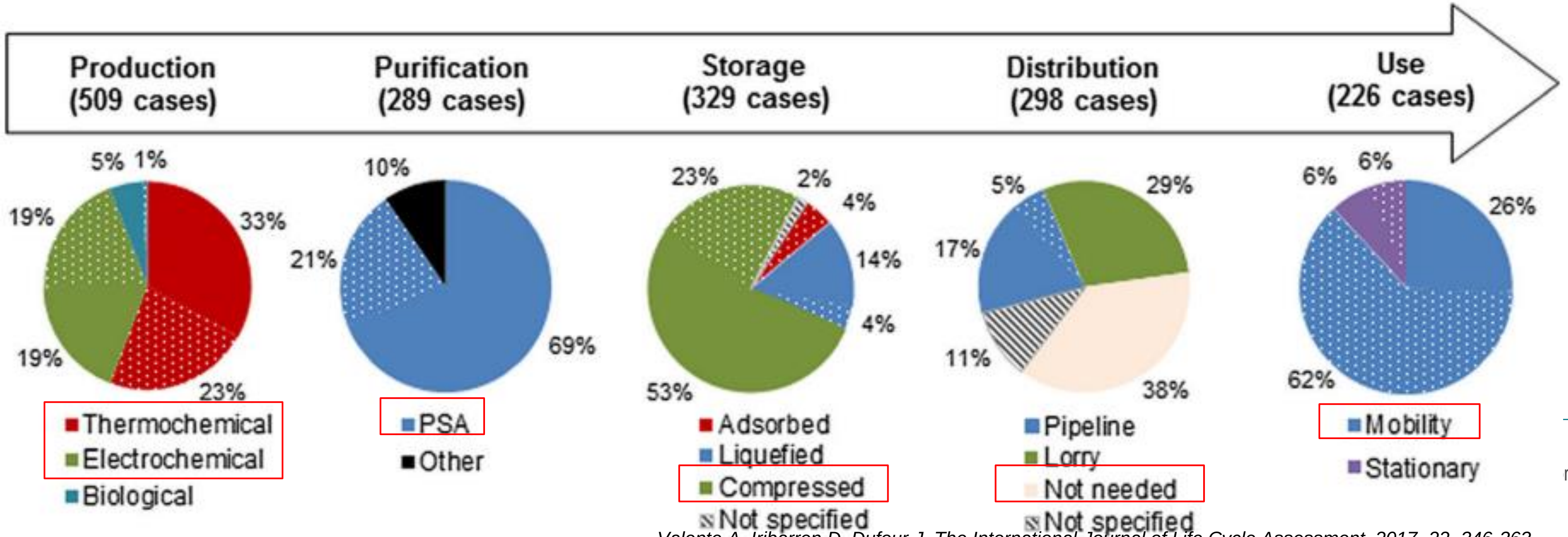
Main trends observed in the literature review on LCA of hydrogen

- System boundaries
- Functional unit
- Multifunctionality approach
- Life-cycle impact assessment method
- Life-cycle indicators

Technical choices according to the life-cycle stage (white dots represent case studies that include capital goods)



Valente A, Iribarren D, Dufour J. The International Journal of Life Cycle Assessment, 2017, 22, 346-363

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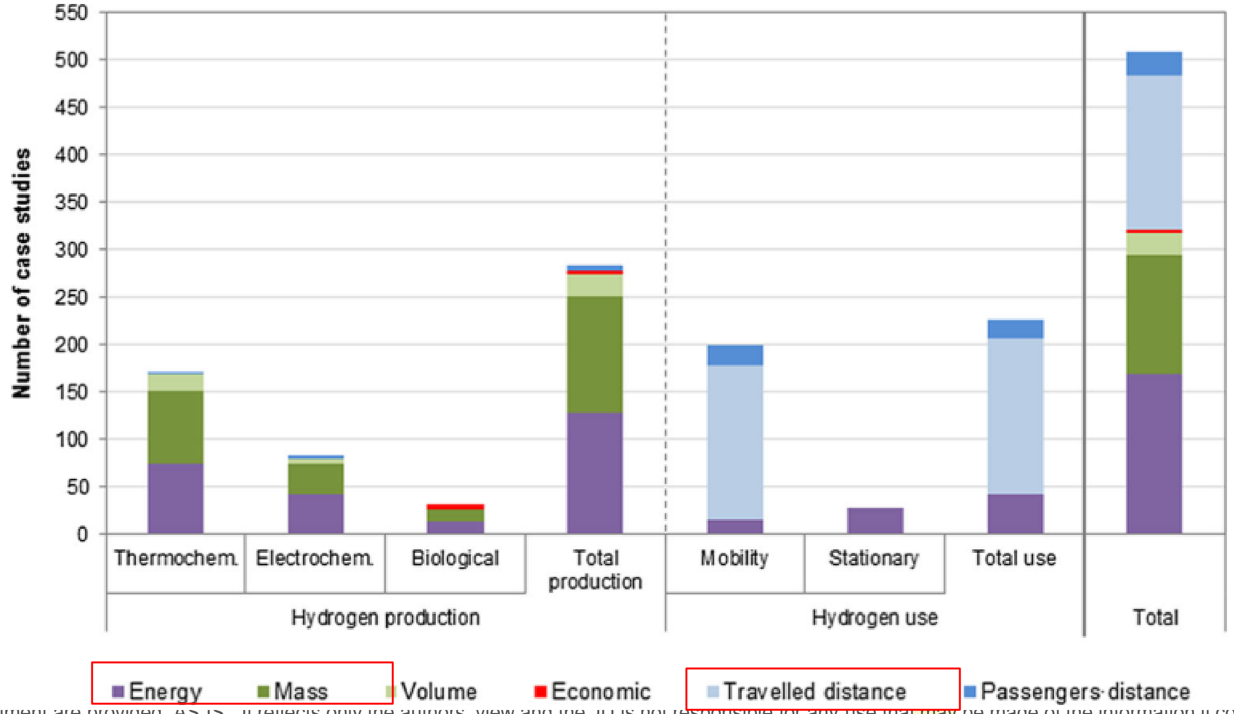
Main trends observed in the literature review on LCA of hydrogen

- System boundaries
- **Functional unit**
- Multifunctionality approach
- Life-cycle impact assessment method
- Life-cycle indicators

Choice of functional unit according to the type of case study



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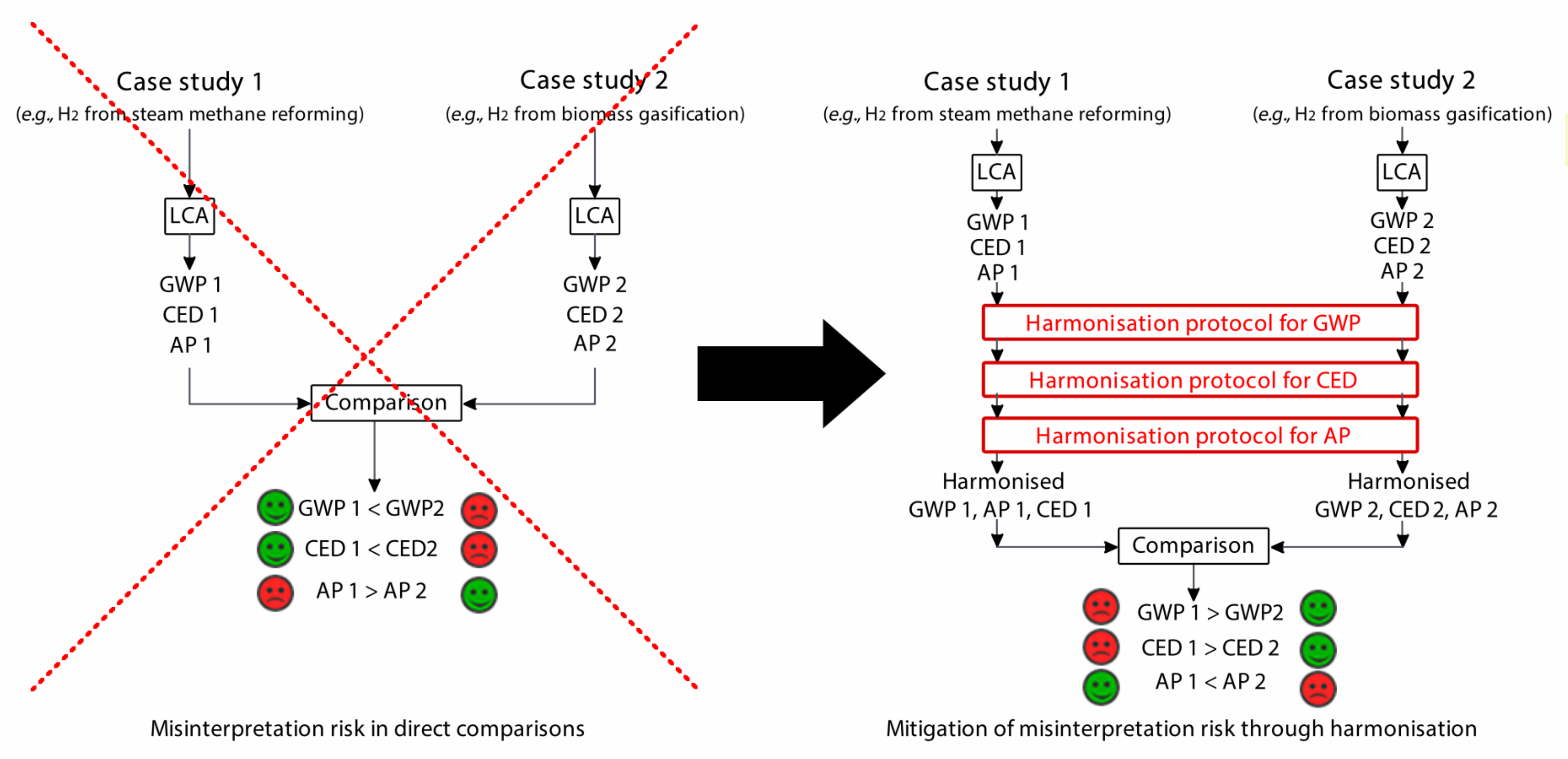

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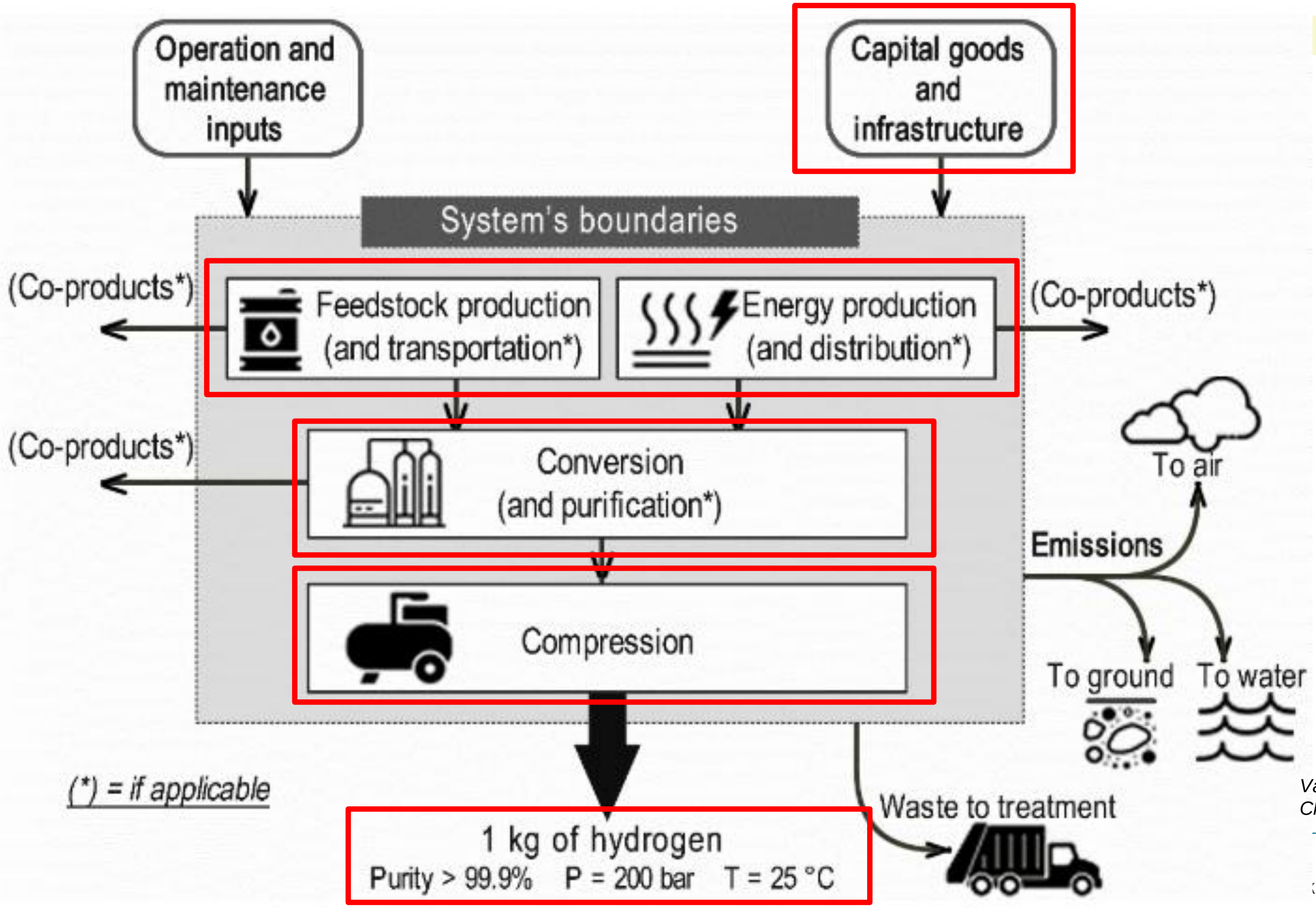
Harmonised hydrogen energy system



Valente A, Iribarren D, Dufour J. Journal of Cleaner Production, 2017, 149, 762-772

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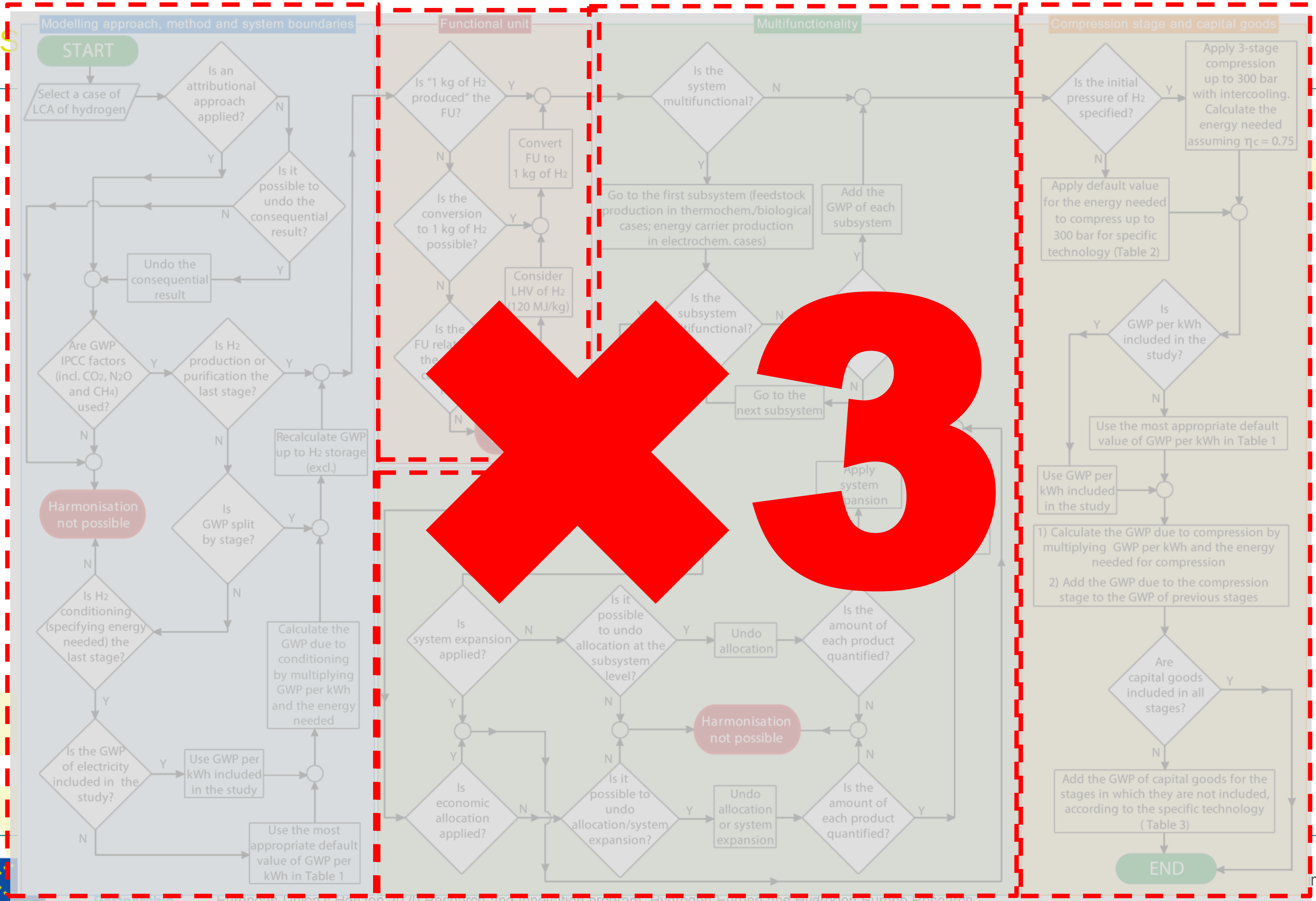

Valente A, Iribarren D, Dufour J. Journal of Cleaner Production, 2017, 149, 762-772
Valente A, Iribarren D, Dufour J. Journal of Cleaner Production, 2018, 175, 384-393
Valente A, Iribarren D, Dufour J. International Journal of Hydrogen Energy, 2019, 44, 19426-19433

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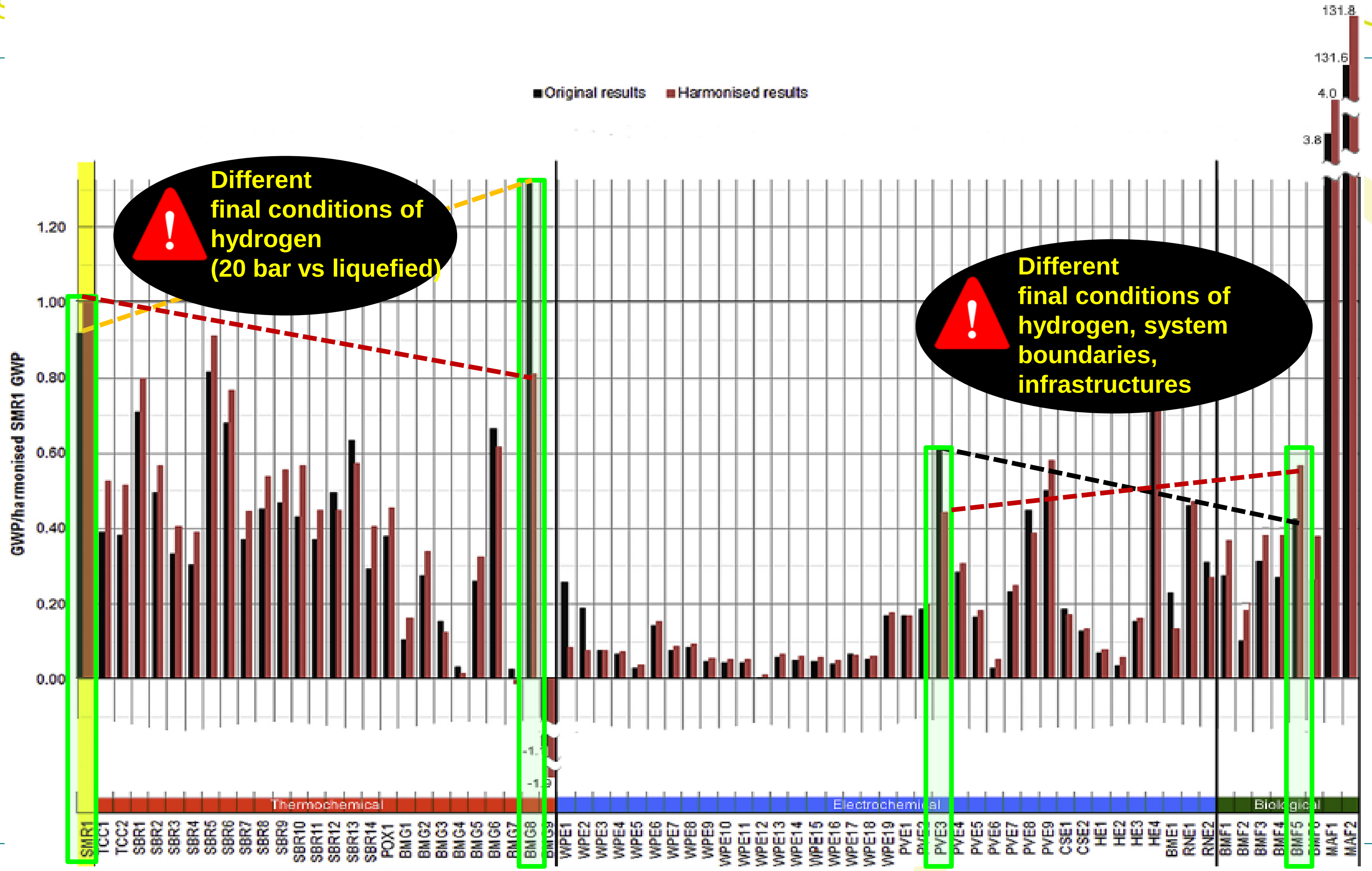

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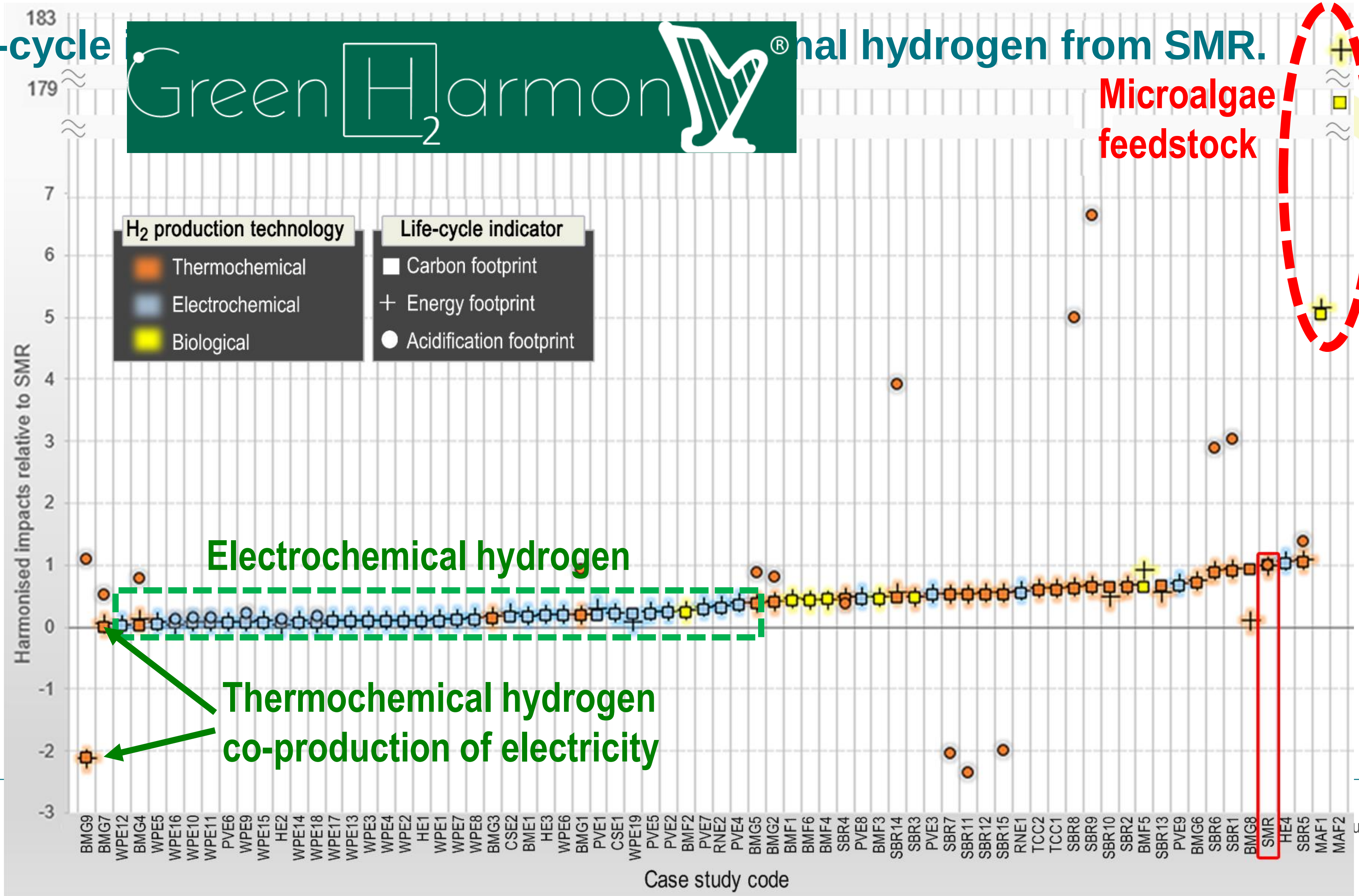
Harmonised life-cycle i… …nal hydrogen from SMR.



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SUSTAINABILITY ASSESSMENT
OF HARMONISED HYDROGEN
ENERGY SYSTEMS

SH2E

Grant No. 101007163

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

D2.2 Definition of FCH-LCA guidelines

WP2 Reformulation of current guidelines for Life Cycle Assessment

TASK LEADER / WP LEADER	IMDEA Energy / GD
DELIVERABLE LEADERS	Eleonora Bargiacchi, Gonzalo Puig-Samper, Felipe Campos-Carriedo, Sumanth K.R. Maddula, Diego Iribarren, Javier Dufour (IMDEA Energy)
REVIEWER	Emmanuelle Cor (CEA)
STATUS	F
DISSEMINATION LEVEL	PU
DELIVERABLE TYPE	R
DUE DATE	30/06/2022 (M18)

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In the green boxes, requirements are presented.

In the light blue boxes, recommendations are presented.

In the yellow boxes, supplementary information is reported.

Method readiness level	Meaning	Symbol
5	In LCA software and databases	●●●●●
4	In databases, data available	●●●●○
3	Stable	●●●○○
2	Discussions	●●○○○
1	First ideas	●○○○○

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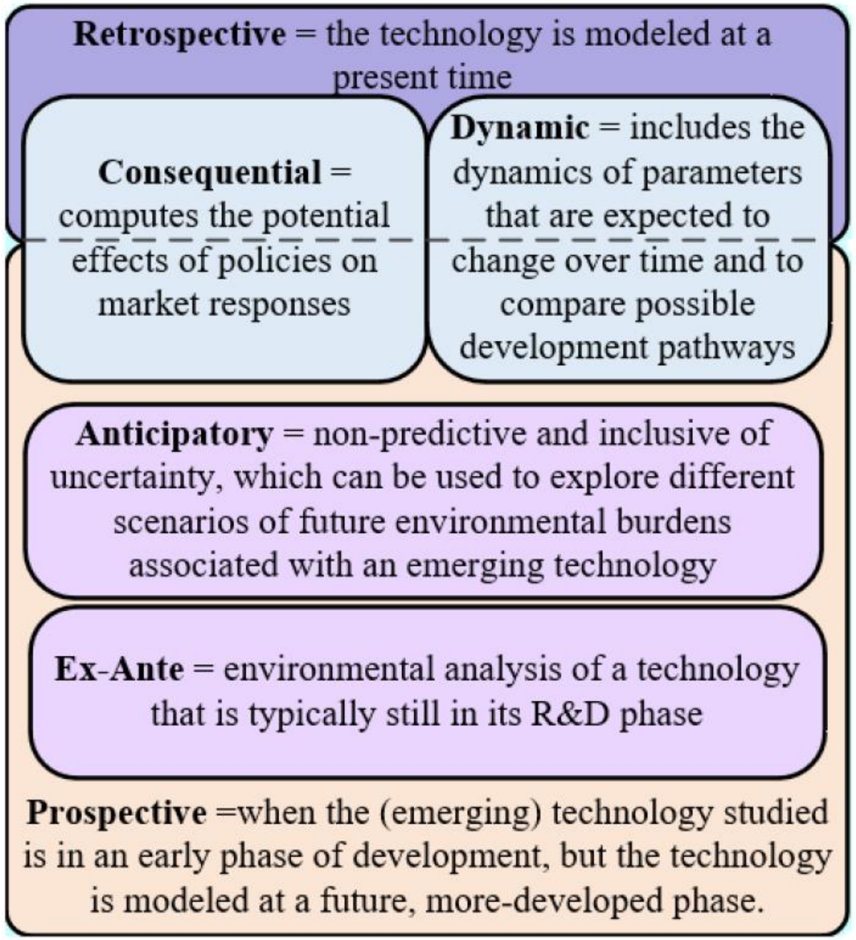

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Box 4. Prospectivity I

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

1. The system must be modelled at a future time. ●●●●●
2. The foreground data for 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.

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Box 10. Functional unit in comparative LCAs

1. Comparative LCAs must ensure that the selected functional unit represents the common function of the systems and allows a fair comparison.
2. Qualitative considerations to be achieved by the evaluated systems, which can be made in the form of quantitative thresholds or qualitative statements, must be clearly defined.

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Box 11. Functional unit in systems assessing hydrogen production

1. The functional unit employed in LCA of hydrogen production systems must represent the quantity of produced hydrogen by means of a mass- (**kg of hydrogen**) or energy-based (**MJ of hydrogen**) functional unit.
2. In the case of employing an energy-based functional unit, the energy content of hydrogen must be clearly stated through the specification of the energy basis (e.g. lower heating value).
3. **Hydrogen purity, pressure and temperature must be specified** to guarantee a precise functional unit and fair comparisons.

Box 13. Functional unit in systems assessing hydrogen use for transportation

1. The functional unit employed in LCAs of hydrogen use for transportation must **represent the distance travelled for a given demand**, expressed as the passenger or freight load.
2. The considered demand must be specified together with the lifetime measured in terms of mileage.

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

1. The functional unit employed in LCAs 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 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**.

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Box 15. Functional unit in systems assessing hydrogen for electricity and/or heat generation I

The functional unit employed in LCAs of hydrogen use for electricity generation must represent the quantity of produced electricity (MJ or equivalent). The functional unit must consider the upstream efficiencies to convert hydrogen into electricity.

Box 16. Functional unit in systems assessing hydrogen for electricity and/or heat generation II

The functional unit employed in **LCAs of hydrogen use for electricity and heat generation must represent the maximum energy potential** that the system could transform into work (i.e. exergy-based functional unit).

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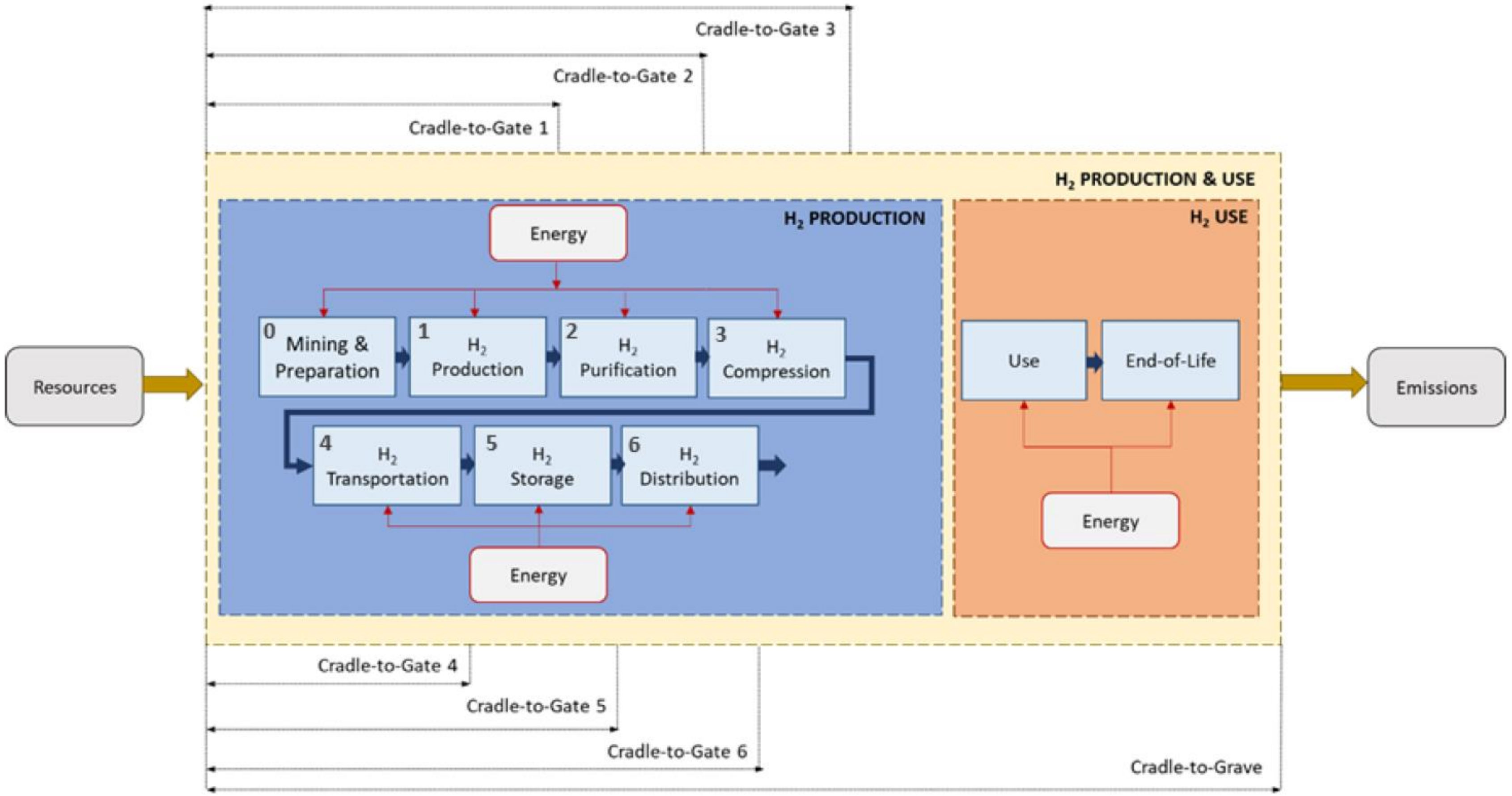

Figure 7. System boundaries for studies assessing FCH systems

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Box 19. System boundaries for systems assessing hydrogen production I

1. The system boundaries of studies on hydrogen production have to be, at least, **Cradle-to-Gate 1**.
2. All the relevant flows, according to the environmental indicators subject to assessment, have to be included in the assessment. If any is disregarded, it must be reported and justified.

Box 21. System boundaries for systems assessing hydrogen use

1. The system boundaries of studies focusing on hydrogen use have to be **Cradle-to-Grave**.
2. All the relevant flows, according to the environmental indicators subject to assessment, have to be included in the assessment. If any is disregarded, it must be reported and justified.

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Box 22. System boundaries for systems assessing hydrogen production and use

1. The system boundaries of studies on hydrogen production and use have to be **Cradle-to-Grave**.
2. All the relevant flows, according to the environmental indicators subject to assessment, have to be included. If any is disregarded, it must be reported and justified.

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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 LCA GUIDELINES

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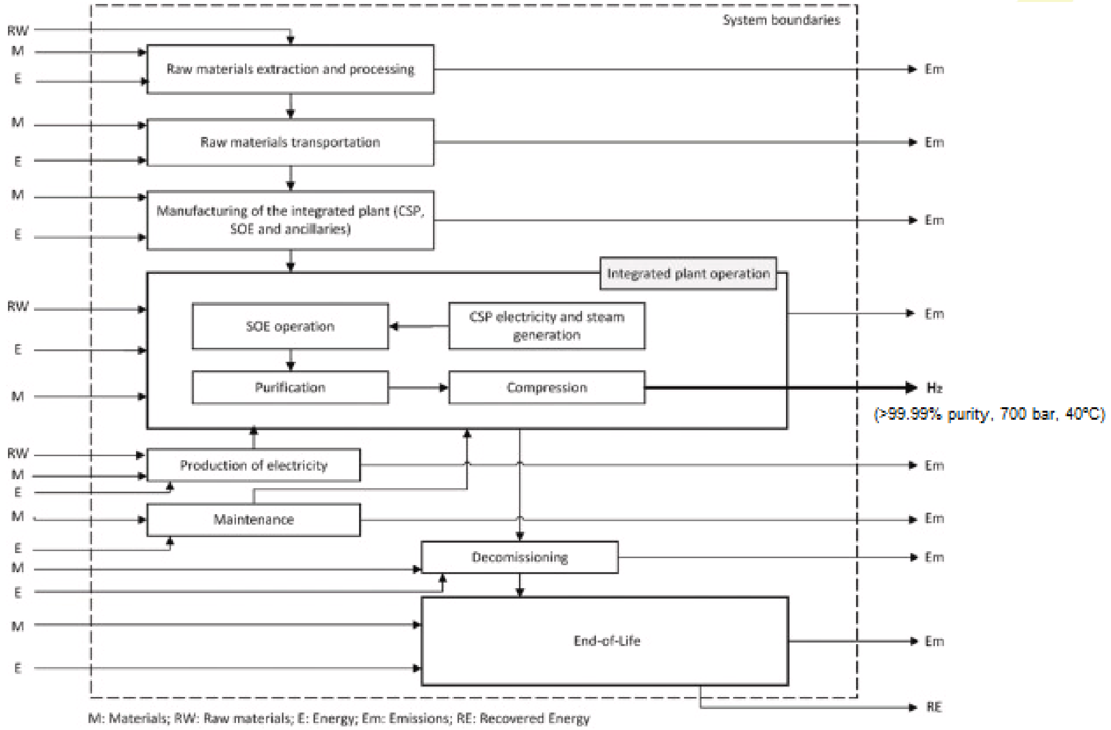
Application

THE SYSTEM



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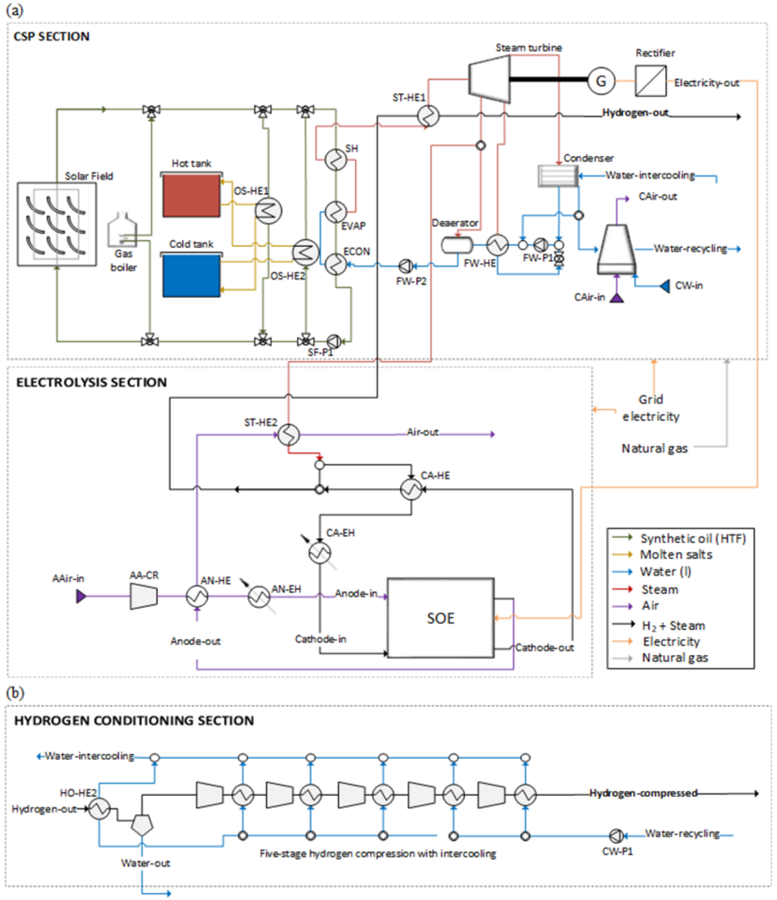

THE SYSTEM

- 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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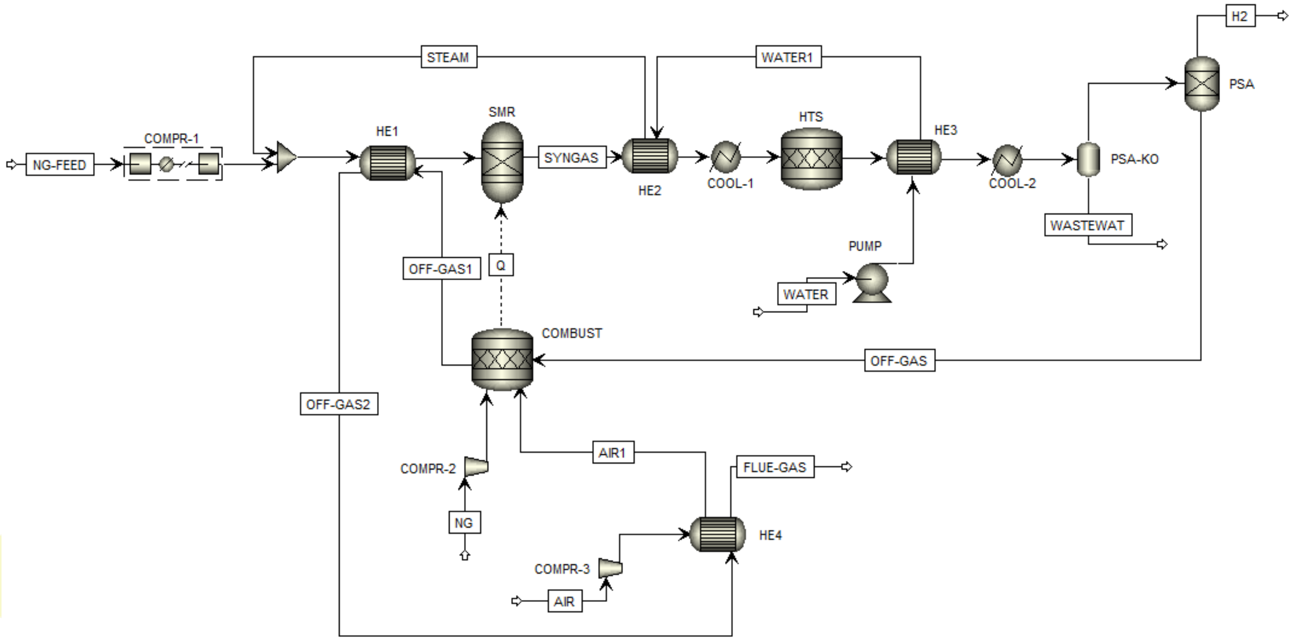
Application

THE SYSTEM

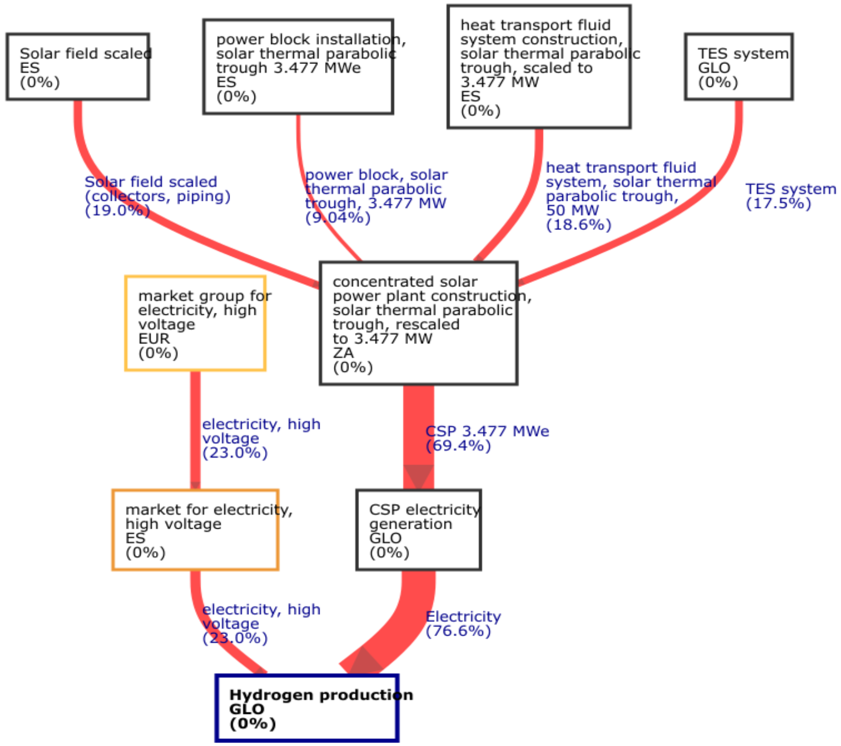


- The functional unit of the competing system for benchmarking (hydrogen from fossil-based SMR) was also defined as 1 kg of hydrogen at the same conditions
- The modelling of the reference hydrogen production system through SMR (85% efficiency in 2030) was based on the use of process simulation tools

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.

Application

ENVIRONMENTAL DIMENSION



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Application

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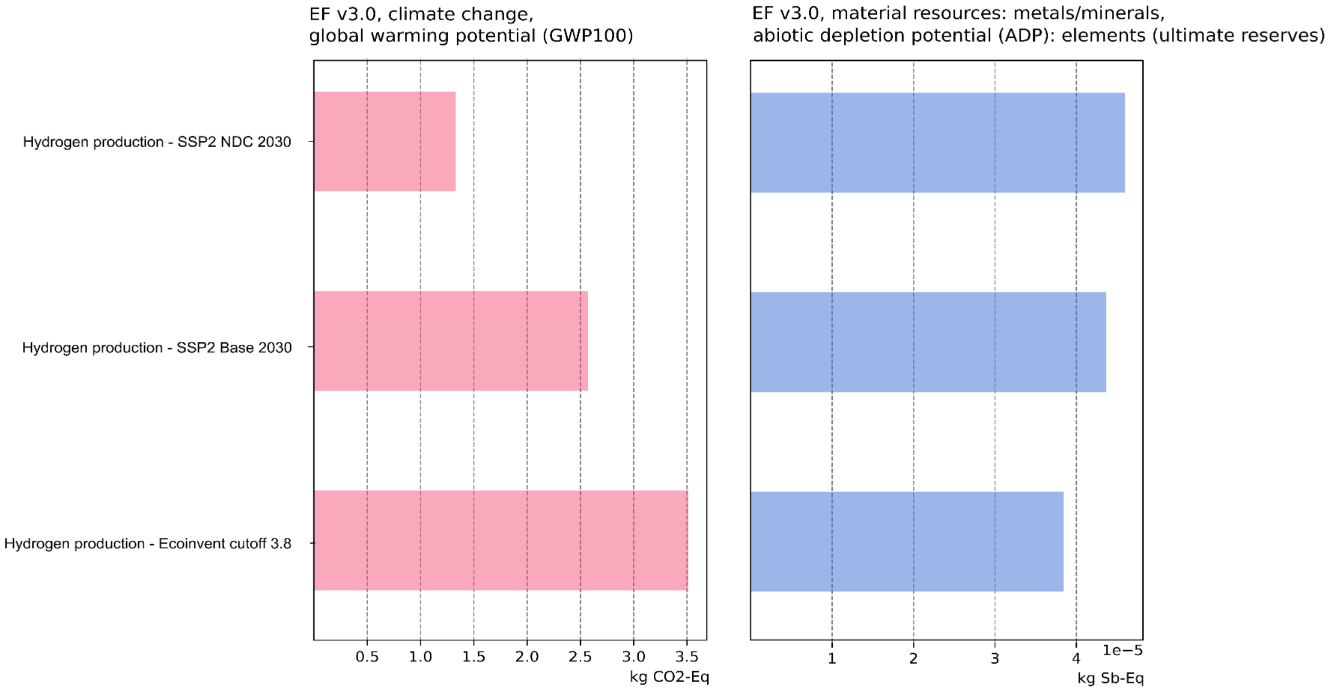

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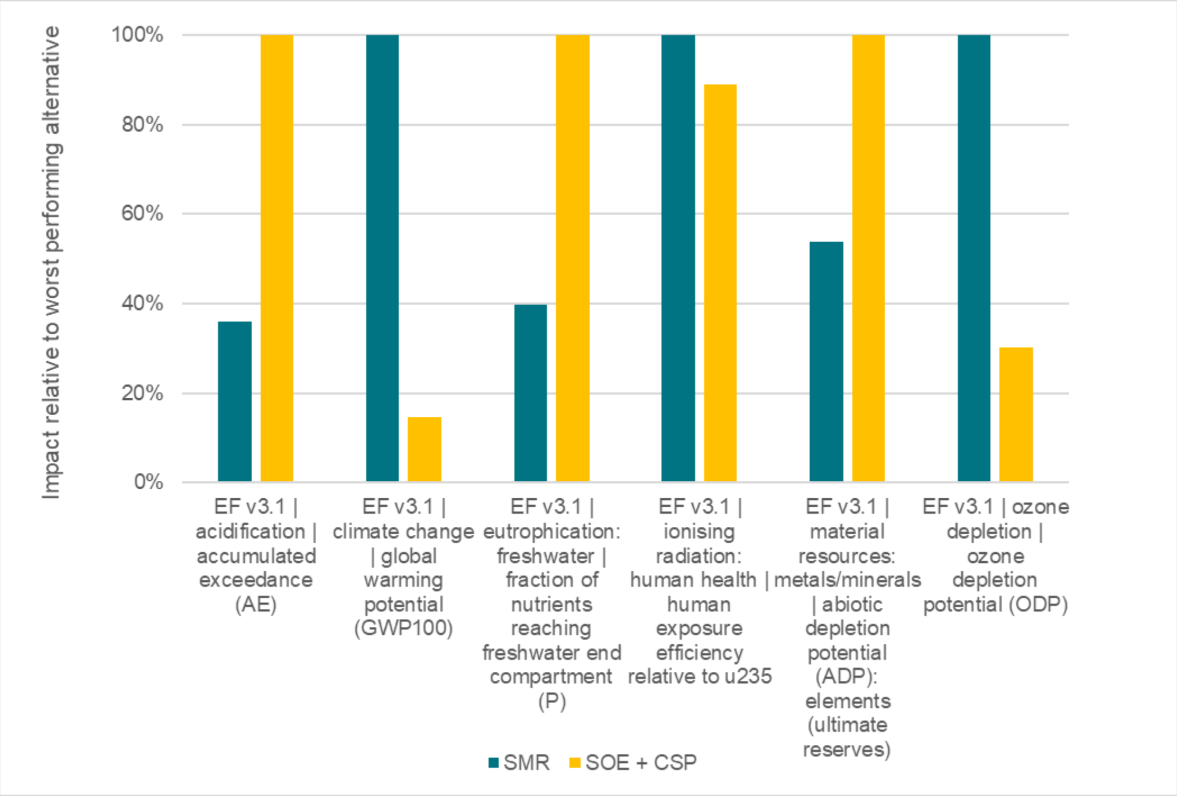
Application

ENVIRONMENTAL DIMENSION



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Final remarks

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SH2E

SUSTAINABILITY ASSESSMENT OF HARMONISED HYDROGEN ENERGY SYSTEMS

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