Task 36 Brief

Life Cycle Sustainability Assessment of Hydrogen Energy Systems

Authors: A. Valente, D. Iribarren, J. Dufour (IMDEA Energy, Spain)
With additional inputs from: P. Zapp (Forschungszentrum Jülich, Germany), K. Espegren (IFE, Norway), P. Masoni (ENEA, Italy), and Y. Ishimoto (IAE, Japan)

TOPIC: The goal of IEA HIA Task 36 was to facilitate decision-making in the hydrogen energy sector through sustainability assessment of hydrogen energy systems. Experts from 5 different countries (Spain [Operating Agent], Germany, Japan, Norway, and Italy) worked within the framework of this task. It was successfully completed in the period 2015-2017, with effective dissemination of the key results: review of Life Cycle Assessment (LCA) studies, social acceptance, harmonization protocols, sustainability framework, and application to relevant case studies.

KEY FINDINGS

- From an extensive literature review of about 100 studies involving more than 500 original LCA case studies of hydrogen energy systems, common methodological choices were found [1]. For instance, the review succeeded in finding relevant trends in methodological choices in LCA of hydrogen energy systems, especially regarding the frequent use of system expansion and secondary data under production-oriented attributional approaches.

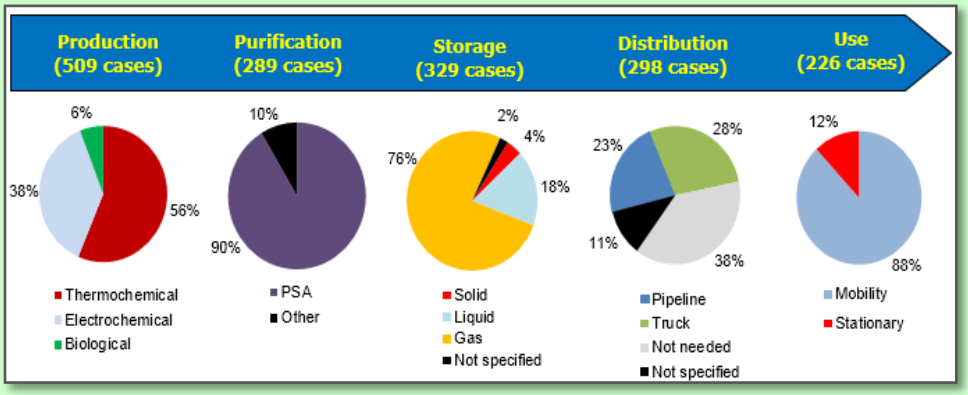

Figure 1. Technical features of the reviewed case studies according to the life-cycle stage.

- Protocols and libraries of harmonized carbon, energy and acidification footprints were developed [2–5]. Overall, harmonization was found to affect more significantly the thermochemical and biological hydrogen categories than the electrochemical one. Nevertheless, misinterpretation risk was found in every technological category. The sources of potential misinterpretation were found to be usually associated with inconsistencies in terms of system boundaries (e.g., hydrogen compression) and, when applicable, multifunctionality approach.
- The levelized cost of hydrogen was identified as an appropriate indicator to characterize the economic performance of hydrogen energy systems. Two variants were distinguished: with and without the internalization of externalities [6]. For instance, this economic life-cycle indicator was calculated to compare the economic performance of renewable hydrogen from biomass gasification (BG_H_2) versus that of conventional hydrogen from steam methane reforming (SMR_H_2).
- The life cycle sustainability assessment (LCSA) framework developed for hydrogen energy systems robustly combines (harmonized) environmental, economic and social life-cycle indicators. In particular, the LCSA framework shown in Figure 2 was used for the robust comparison of two relevant hydrogen options: (i) conventional hydrogen from the steam reforming of natural gas, and (ii) renewable hydrogen from poplar biomass gasification [7].
- Significant advances were made concerning the evaluation of the social acceptance of hydrogen energy at the national level. In particular, a complete study was conducted for Spain through the design and distribution of a survey. Overall, the respondents were found to be willing to accept hydrogen as a key energy carrier within the energy and transport sector [8].

METHODOLOGY

- An LCSA methodological framework for hydrogen energy systems was developed by robustly combining environmental, economic and social life-cycle indicators as illustrated in Figure 2.

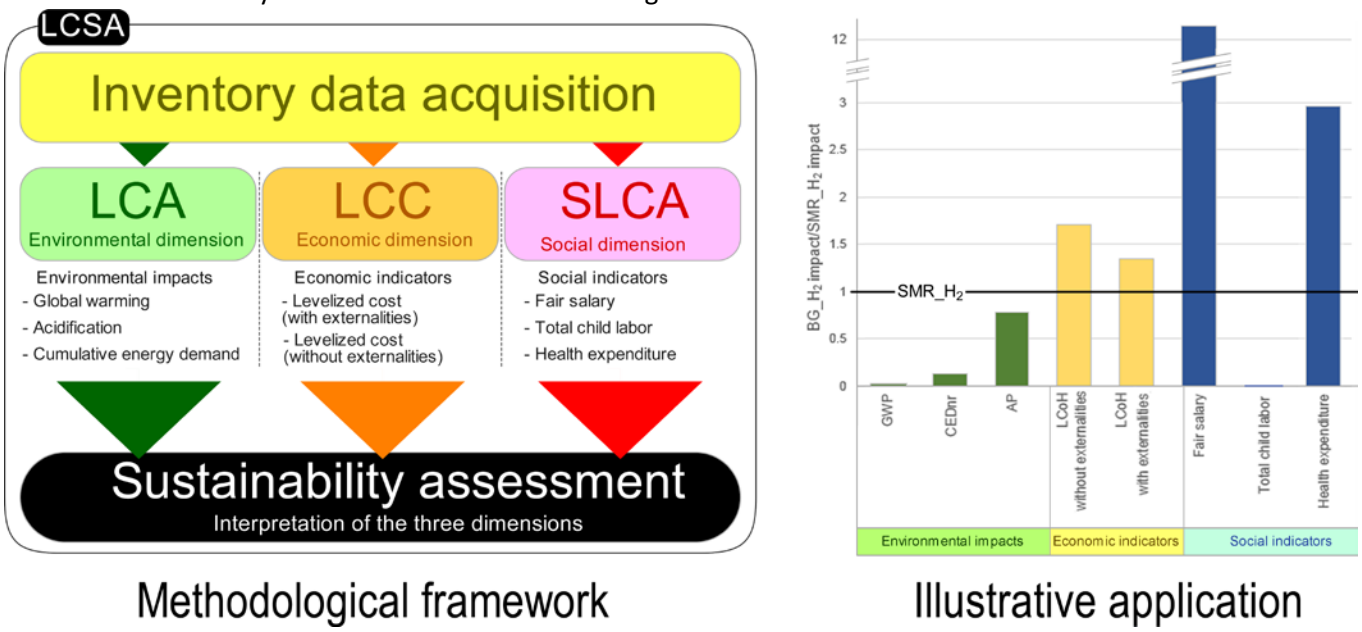

Figure 2. LCSA framework for hydrogen and application to hydrogen from biomass gasification vs. conventional hydrogen.

- **Key references:**

[1] Valente A, Iribarren D, Dufour J. Life cycle assessment of hydrogen energy systems: a review of methodological choices. Int J Life Cycle Assess 2017;22:346–63.

[2] Valente A, Iribarren D, Dufour J. Harmonised life-cycle global warming impact of renewable hydrogen. J Clean Prod 2017;149:762–72.

[3] Valente A, Iribarren D, Dufour J. Harmonising methodological choices in life cycle assessment of hydrogen: A focus on acidification and renewable hydrogen. Int J Hydrogen Energy 2019;44:19426–33.

[4] Valente A, Iribarren D, Dufour J. Harmonising the cumulative energy demand of renewable hydrogen for robust comparative life-cycle studies. J Clean Prod 2018;175:384–93.

[5] Valente A, Iribarren D, Dufour J. Cumulative Energy Demand of Hydrogen Energy Systems. In: Muthu S, editor. Energy Footprints of the Energy Sector, Singapore: Springer; 2019, p. 47–75.

[6] Valente A, Iribarren D, Gálvez-Martos JL, Dufour J. Robust eco-efficiency assessment of hydrogen from biomass gasification as an alternative to conventional hydrogen: A life-cycle study with and without external costs. Sci Total Environ 2019;650:1465–75.

[7] Valente A, Iribarren D, Dufour J. Life cycle sustainability assessment of hydrogen from biomass gasification: A comparison with conventional hydrogen. Int J Hydrogen Energy 2019;44:21193–203.

[8] Iribarren D, Martín-Gamboa M, Manzano J, Dufour J. Assessing the social acceptance of hydrogen for transportation in Spain: An unintentional focus on target population for a potential hydrogen economy. Int J Hydrogen Energy 2016;41:5203–8.

TASK INFO

Sub-task code	Sub-task name	Main activities
A	Addressing environmental challenges in LCA of hydrogen energy systems	• Literature review • Identification of the main sources of uncertainty • Recommendations on functional unit, impact assessment method, etc.
B	Economic analysis of hydrogen energy systems	• Literature review • Harmonization of assumptions and data • Cost evaluation and comparative analysis • Definition of Life Cycle Costing (LCC) framework
C	Social indicators for the assessment of hydrogen energy systems and integrative approaches for LCSA	• Literature review of social indicators and databases • Screening of social indicators • Development of Social Life Cycle Assessment (SLCA) framework • Integration of LCA, LCC and SLCA into a robust LCSA framework • Evaluation of social acceptance
D	Collaboration with IEA HQ analysts	• Effective collaboration between Task 36 experts and IEA analysts