Operational LCA guidance for hydrogen production: methodological approach and first results

Aleksandar Lozanovski[1,*], Michael Held[1], Michael Faltenbacher[2], Oliver Schuller[2], Paolo Masoni[3], Angelo Moreno[3]

[1]University of Stuttgart, Department Life Cycle Engineering, Chair of Building Physics, 70771 Echterdingen, Germany

[2]PE International AG, 70771 Echterdingen, Germany

[3] ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Rome, Italy

*Aleksandar.Lozanovski@lbp.uni-stuttgart.de

Abstract One main point of criticism addressed to LCA studies is the lack of harmonization in data sets compiled by different LCA practitioners. Reasons for these differences are varying methodological decisions made along the LCA study execution, such as the definition of the goal and scope, allocation rules, and system boundary definition, as well as in the modelling approach. For this reason the International Reference Life Cycle Data System (ILCD) Handbook is prepared by the Institute for Environment and Sustainability, through the European Platform on LCA to offer general step-by-step guidance for LCA practitioners. Since the ILCD Handbook describes the general approach for LCA studies, it has to be translated into a tailor-made guidance document. The following paper discusses the methodological approach of the guidance document on hydrogen production.

1 Introduction

A key aspect during performing a Life Cycle Assessment (LCA) study is the definition of certain methodological choices during the goal and scope phases (e.g. allocation, system boundary definition, modelling, etc.). These choices may be made differently during the LCA execution which affects the comparability of different studies on the same product.

The definition of these methodological choices requires a deep knowledge of the technical system analysed as well as of the LCA method. There is a general

agreement, not only in the LCA community that there is a need for provisions, rules and data, which support a LCA in their sector of interest. In order to meet this need, the Institute for Environment and Sustainability, through the European Platform on LCA, has recently published the International Reference Life Cycle Data System (ILCD) Handbook [1]. The ILCD Handbook offers step-by-step guidance for LCA practitioner. As it is generally applicable to different decision-contexts and sectors, the handbook needs to be "translated" to derive product-specific criteria and guidelines to facilitate LCA application in different industry sectors. Therefore, the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) asked to develop a tailor-made guidance document on hydrogen production and fuel cell technology, as well as related training materials and courses for LCA studies to specify the ILCD Handbook for the application on hydrogen production and fuel cell technology.

This specific operational guidance document on hydrogen production is in advanced draft status going through public consultation and will be finished by the end of 2011. The guidance document allows e.g. developers to assess their own technology. To increase the availability of data in this field, future data sets can be made available through the ILCD Data Network [2]. These tasks, together with the development of similar rules for fuel cells by another partner, are carried out in the framework of the FC-HyGuide project (www.fc-hyguide.eu), funded by the FCH JU.

2 Preparation of the guidance document

Preparation, consultation and review are the main components of the creation process of the guidance document. In a staged approach the document is developed and consulted by involving different stakeholders like the technical expert group, the advisory board, the review panel, and the public. Some of the various stakeholder groups are involved several times at different steps of the guidance preparation.

The several steps and interconnections are shown in Fig. 1. The first step is to prepare a draft guidance document, which is commented by the Advisory Board. Second step is to hold a workshop including the advisory board and review panel, as well as other LCA and technical experts. The comments gathered are used to prepare the advanced guidance document in close cooperation with the advisory board. After the advanced guidance document is established it is due to public

consultation, where various groups are addressed. The medium chosen for inviting people to the public consultation is by E-Mail newsletter. The following E-Mail newsletter lists are used for invitations to the public consultation:

- Joint Research Centre - Platform on LCA newsletter
- New European Research Grouping on Fuel Cells and Hydrogen (N.ERGHY)
- European Industry Grouping for a Fuel Cell and Hydrogen Joint Technology Initiative (NEW IG)
- European Hydrogen Association newsletter
- EcoInvent / Eco-indicator list
- Rete Italiana (Italian LCA network) newsletter
- UNEP / SETAC list
- PE International AG newsletter.

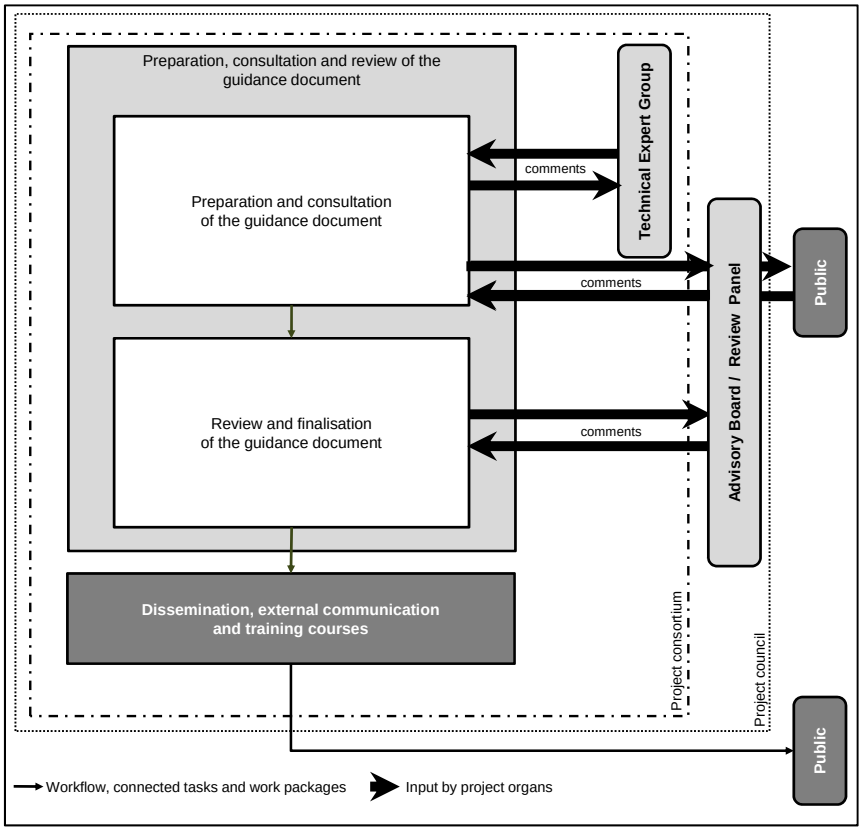

Fig. 1: Major steps during creation of the guidance document

Once the document is developed, it is to be checked by the review panel regarding its appropriateness, quality, and completeness. After the review of the guidance document, two training courses and other activities, for dissemination and exploitation of the document, are foreseen.

3 Existing provisions

Several provisions already exist and are used as basis for the preparation of the guidance document. These provisions are:

- ISO 14024: 1999 Environmental labels and declarations – Type I environmental labelling – Principles and procedure [3]
- ISO 14025: 2006 Environmental labels and declaration – Type III environmental declarations – Principles and procedures [4]
- ISO 14040: 2006 Environmental management – Life Cycle Assessment – Principles and framework [5]
- ISO 14044: 2006 Environmental management – Life Cycle Assessment – Requirements and guidelines [6]
- ISO 14687: 2007 Hydrogen fuel – Product specification [7]
- SAE J2719: 2005 Hydrogen quality guideline for fuel cell vehicles [8]
- International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance [1]
- International Reference Life Cycle Data System (ILCD) Handbook - Review schemes for Life Cycle Assessment [9]
- International Reference Life Cycle Data System (ILCD) Data Network – Analysis of existing environmental impact assessment methodologies for use in Life Cycle Assessment [10]

4 First results

To prepare the guidance document and therefore to predetermine provisions, a closer look on existing hydrogen production technologies is taken. There are different ways to produce hydrogen. In 2008 more than 96 % of the produced hydrogen is based on fossil fuels (49 % natural gas, 29 % liquid hydrocarbons, 18 % coal, 4 % electrolysis and others) [11]. The main production technologies are:

- Steam reforming

- Catalytic reforming (refinery)
- Gasification
- Partial oxidation
- Electrolysis
- Others.

As the various technologies produce hydrogen at different quality levels it is important to determine this within the guidance document. Therefore, the hydrogen properties are classified and divided into some that have to be stated, like purity, aggregate state, pressure and temperature and some that are optional e.g. impurities are appointed. Furthermore, information regarding the descriptions of the producer and the production system are addressed, e.g. the amount of hydrogen produced and geographical circumstances.

4.1 Goal definition

The next step is to define the goal of the study according to the ISO 14040. This includes the sections:

- Intended application(s)
- Method, assumptions and impact limitations
- Reasons for carrying out the study
- Target audience
- Comparisons intended to be disclosed to the public
- Commissioner of the study.

On one side, all of these subchapters of the LCA on hydrogen production need to be defined as loose as possible to be applicable in industry, on the other side as strict as possible to gain comparable results.

4.2 Scope definition

The next important step of an LCA is the scope definition. The scope definition comprises of the following sections:

- Function, functional unit and reference flow
- Life Cycle Inventory modelling
- System boundaries and cut-off criteria
- Definition of relevant flows

- Life Cycle Impact Assessment methods and categories
- Type, quality and sources of required data
- Data quality requirements
- Comparisons between systems
- Identification of critical review needs
- Intended reporting.

4.2.1 Function, functional unit and reference flow

One of the major points within the scope phase is the definition of the functional unit and the reference flow. As the properties of the hydrogen are important for the definition of the functional unit and reference flow information on purity, pressure and temperature should be included.

4.2.2 Multi-functionality

Another important methodological question is how to deal with multi-functionality. To face multi-functionality a hierarchical approach is described in the ILCD Handbook. The hierarchy mentioned in the ILCD Handbook is [1]:

1) Sub-division
2) System expansion
3) Allocation.

4.2.3 System boundaries

Fig. 2 presents the system boundaries chosen for the hydrogen production. The whole production (conversion) should be included whereas purification, conditioning and distribution are optional.

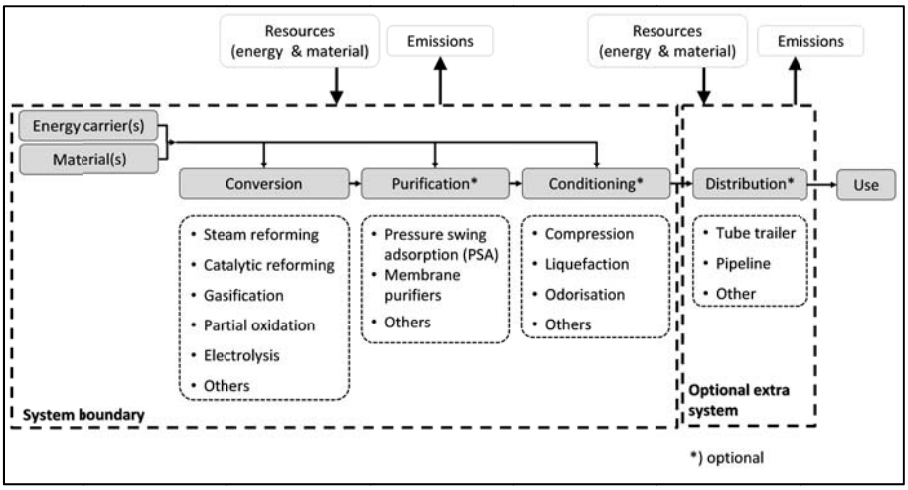

Fig. 2: System boundaries towards other systems and the nature

4.2.4 Impact categories

Following impact categories and environmental indicators are demanded:

- Global Warming Potential (GWP)
- Acidification Potential (AP)
- Eutrophication Potential (EP)
- Photochemical Ozone Creation Potential (POCP)
- Primary Energy Demand (PED), renewable
- Primary Energy Demand (PED), non-renewable

4.2.5 Comparison of different systems

An important point regarding LCA in general and hence also regarding the LCA of hydrogen production is the comparison of different systems. If different systems are compared there are certain points that have to be harmonised. These are:

- The functional unit shall be the same or at least similar
- The scope definitions have to be addressed consistently (assumptions, data quality)
- The cut-off shall be the same also for mass and energy, next to the overall environmental impact
- Additionally a critical review is necessary.

4.3 Life Cycle Inventory analysis

The Life Cycle Inventory analysis comprises of several steps like the identification of processes within the system boundaries, the data collection as well as the use of generic data, whereas the most important point is the data collection. Following factors have to be taken into account:

- One start-up and shut-down sequence should be included
- Regular maintenance should be included
- Auxiliaries like pressurised air, etc. should be included
- If seasonal influences exist they should be included (either measured or estimated) and balanced out
- The period measured should be long enough to cover business as usual operations without irregularities.

4.4 Life Cycle Impact Assessment

The classification and characterization are essential parts of the Life Cycle Impact Assessment. Normalisation and weighting are optional elements which are not necessary in terms of the LCA of hydrogen production. The impact categories shall be chosen according to the ILCD Handbook “Recommendations based on existing environmental impact assessment models and factors for Life Cycle Assessment” [12], whereas is has to be noted that this document is currently in a draft version.

4.5 Interpretation and quality control

The main parts of this section are the identification of hot spots and various checks (completeness, sensitivity and consistency) to prove the reliability of the study. All of these parts are described briefly in the guidance document so that the user knows e.g. how to perform a sensitivity analysis.

4.6 Reporting of the study

For the reporting an own report template is created and is recommended within the guidance document.

4.7 Critical review

Defining a mandatory critical review contradicts the aim of the guidance document to reduce the effort needed for a LCA process. Hence, to balance between the priorities, the following hierarchy is defined in the guide and to be considered:

- For internal studies a critical review is not mandatory, but recommended
- A critical review is necessary if the study is comparative or intended to be disclosed to the public.

If a critical review is conducted the reviewer should be:

- Independent
- Experienced in LCA methodology
- Experienced in verification and audit practice
- Having technical expertise related to the analysed hydrogen production system
- The reviewer may be integrated in the study from the beginning.

5 Results and discussion

Writing a guidance document for performing LCA of a special field like the hydrogen production is demanding as there are certain priorities that are contrary but have to be matched. The guidance document should keep the needed effort for the LCA as low as possible. On the other hand, to achieve comparable studies the methodological definitions need to be very strict, which leads to a more difficult LCA. To address both aspects methodological questions are discussed within the scope of the ILCD Handbook, the advisory board and review panel. Additionally technical experts and representatives of the industry are involved via the workshop held and the public consultation.

6 References

[1] European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data system (ILCD) Handbook – *General Guide for Life Cycle Assessment – Detailed guidance*. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010.

[2] European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data system (ILCD) Data network – Core database. Luxembourg. Publications Office of the European Union; 2010.
[3] International Organization of Standardization. DIN EN ISO 14024, Environmental labels and declarations - Type I environmental labelling - Principles and procedures, 13.020.50; 1999.
[4] International Organization of Standardization. DIN EN ISO 14025, Environmental labels and declarations - Type III environmental labels - Principles and procedures, 13.020.50; 2006.
[5] International Organization of Standardization. DIN EN ISO 14040, Environmental Management - Life Cycle Assessment - Principles and Framework, 13.020.10; 13.020.60; 2006.
[6] International Organization of Standardization. DIN EN ISO 14044, Environmental Management - Life Cycle Assessment - Requirements and Guidelines, 13.020.10; 13.020.60; 2006.
[7] International Organization of Standardization. ISO 14687, Hydrogen Fuel, Product Specification, 71.100.20; 2007.
[8] Society of Automotive Engineers. Information Report on the Development of a Hydrogen Quality Guideline for Fuel Cell Vehicles; 2005.
[9] European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data system (ILCD) Handbook – *Review schemes for Life Cycle Assessment.* First edition March 2010. Luxembourg. Publications Office of the European Union; 2010.
[10] European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data system (ILCD) Handbook – *Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment*. First edition March 2010. Luxembourg. Publications Office of the European Union; 2010.
[11] Suresh, B., Schlag, S., Kumamoto, T., & Ping, Y.. Hydrogen. *Chemical Economics Handbook.* <http://www.sriconsulting.com/CEH/Public/Reports/743.5000/>, (Accessed 14.04.2011)
[12] <http://lct.jrc.ec.europa.eu/>, (Accessed 14.04.2011)