Operational LCA guidance for fuel cells

Paolo Masoni, Alessandra Zamagni, Angelo Moreno – ENEA
Sergio Ulgiati, Silvia Bargigli - Parthenope University
Michael Faltenbacher, Oliver Shuller - PE INTERNATIONAL

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1. The problem

- The Fuel Cells and Hydrogen Joint Undertaking (FCH-JU):
  - “Sustainability is a key driver of the FCH JU activities and it is necessary to assess the new developments towards these goals. Life Cycle Assessment will therefore be applied throughout the FCH JU on a programme level.”

However, the present main critics addressed to LCA are:

- **Weak comparability** among different studies on the same product
- **Complexity** of the method, which hampers its applicability in the industrial context.
1.a. Weak comparability

- ISO standards leave a high degree of freedom to practitioners: **subjectivity** linked to some methodological choices (e.g. allocation, system boundary definition, modelling, etc.)

- ILCD Handbook (HB) addresses this question, providing **guidance** on all the LCA process, from the definition of the Decision Context, to specific requirements for review process.

- However, ILCD HB is necessarily still **generic** as it applies to all possible sectors, technologies, decision contexts, LCA applications.
1.b. Complexity

• LCA is necessarily a **complex method**, as in a generic life cycle system many parameters can affect the final results.

• However, when a sufficient **knowledge** of a specific product/technology/system is available, the practitioner can **focus** her/his efforts on the real **relevant aspects** of the life cycle.

• This is the only possible way to reduce the complexity of an LCA study, keeping a sufficient **scientific robustness** to the results (**relevance** of results).
ILCD Handbook
Third tier of harmonisation

3rd tier

Guidance document for performing LCAs on Fuel Cell Technologies FC-Guide

Specific guidance for a product group.

2nd tier

General guide for Life Cycle Assessment
- General guide for Life Cycle Assessment (LCA) - Detailed guidance (this document)
- General guide for Life Cycle Assessment (LCA) - Provisions and action steps

 Documentation, Nomenclature, Terminology

1st tier

ISO 14040, 14044

Provisions depending on the decision context and application

General rules
<table>
<thead>
<tr>
<th>PART I – GENERAL INFORMATION</th>
<th>PART II - GUIDANCE ON PERFORMING LCA OF FUEL CELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ABOUT THIS DOCUMENT</td>
<td>9. INTERPRETATION AND QUALITY CONTROL OF THE STUDY ON FUEL CELLS</td>
</tr>
<tr>
<td>2. HOW TO USE THIS DOCUMENT</td>
<td>10. REPORTING OF THE STUDY ON FUEL CELL</td>
</tr>
<tr>
<td>3. INTRODUCTION TO LCA</td>
<td>11. CRITICAL REVIEW OF THE STUDY ON FUEL CELL</td>
</tr>
<tr>
<td></td>
<td>REFERENCES</td>
</tr>
<tr>
<td></td>
<td>ANNEX I - LCA STUDY REPORTING TEMPLATE</td>
</tr>
<tr>
<td></td>
<td>ANNEX II – DOCUMENTATION OF THE RESULTING DATA SET ACCORDING TO ILCD</td>
</tr>
<tr>
<td></td>
<td>ANNEX III - DATA COLLECTION TEMPLATE</td>
</tr>
<tr>
<td></td>
<td>ANNEX IV - EXAMPLE FROM CASE STUDIES ON FUEL CELL</td>
</tr>
</tbody>
</table>
Output

• Prepare and make available to the final user knowledge and a pre-elaborated set of information, ready to be used:
  • **FC Guide** (information and provisions)
  • **Templates**: Data collection, Data documentation, Reporting
  • **Examples** from case studies
  • **Training**

• Target: technology developers, LCA practitioners

  “less and correct”
ILCD compliance

• **Data quality**: completeness, representativeness (technological, geographical and time-related), uncertainty and methodological appropriateness and consistency.

• **Method**: LCI modelling and other method provisions, and the consistency of their use.

• **Nomenclature**: correctness and consistency of applied nomenclature (flows and processes, use of units, etc.) and terminology.

• **Review**: review type, review methods and documentation.

• **Documentation**: documentation extent, form and format.
1. **Workshop** for defining the main methodological choices
2. Adaptation of the ILCD handbook provisions to the specific cases
3. **Workshop** with experts
4. Drafting the guide and **open consultation** (completed)
5. Implementation of comments and document **review by an expert panel** (in progress)
6. Case studies to test the guide (in progress)
7. Refining the guide based on the case studies feedback
8. Training on the guide
• Decision context:
  • “A”: micro-level decision support -> Attributional modelling

• Applications:
  • Internal use: KEPI for Ecodesign; weak point analysis of a specific FC
  • External use: criteria for EPD; development of a carbon footprint
  • Internal/external use: comparison of specific modules of FC; benchmarking.
FC: Main methodological choices

- Modular approach (see later)
- Scope: FC stack and/or FC System
- Functional Unit:
  - Exergy used to measure the performance of a FC with a single parameter, when both electricity and thermal energy are valuable products of the FC.

\[
MJ_{ex} = MJ_{el} + \varsigma_{th} \times MJ_{th}
\]

where \( \varsigma_{th} = 1 - (T_a/T_m) \)

- \( T_a \): ambient temperature
- \( T_m \): thermodynamic mean temperature
- \( T_o \): temperature of delivered heat
- \( T_r \): return flow temperature.
Why a modular approach

FCs are **complex systems**, with a wide range of functions, depending on the specific applications (e.g., stationary, transport, portable) and a wide range of possible fuel production processes.

An LCA framework needs to take into consideration this variability and to be **flexible** enough to allow assessing the technology at different levels.

It consists in analysing the technology in terms of its main parts, which may represent the whole or a portion of the life cycle of the product analysed. **Modules** can be duly **combined** to evaluate complex systems (based on the modularity concept of the ISO 14025)
FC System and its modules

Source: EC/TS 62282-1
System boundaries for FC system

- **Energy Resources**
  - Manufacturing FC stack
    - Anode
    - Cathode
    - Matrix
    - Catalyst
    - Other
  - Manufacturing BoP
    - Fuel delivery system
    - Thermal management system
    - Power management
    - Air delivery system

- **Material Resources**
  - Wastes

- **Operation**
  - Emissions
  - Fuel
  - Emissions

- **End of Life**
  - Material recycling
  - Material recovery
  - Disposal

**System boundary**
System boundaries for FC stack

- **Energy Resources**
- **Material Resources**

Manufacturing FC stack
- Anode
- Cathode
- Matrix
- Catalyst
- Other

Manufacturing BoP
- Fuel delivery system
- Thermal management system
- Power management
- Air delivery system

Operation

End of life
- Material recycling
- Material recovery
- Disposal

Emissions

Fuel

Wastes
## Examples of relevant flows

<table>
<thead>
<tr>
<th>Unit of product</th>
<th>Components</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell stack</td>
<td>Anode, cathode, matrix, steel parts, electrolyte.</td>
<td>Electricity consumption; Industrial gases for processing; Process water; Chemicals (raw powders and solvents. E.g. $\text{K}_2\text{CO}_3$, Oppanol, Cr powder, Ni powder).</td>
<td>Emissions to water, air.</td>
</tr>
<tr>
<td>Stack assembled and start up</td>
<td></td>
<td>Electricity and fuel consumption for the start-up; process water</td>
<td>Emissions to water, air.</td>
</tr>
<tr>
<td>Stack operation phase and maintenance</td>
<td></td>
<td>Fuel consumption.</td>
<td>Emissions to water, air.</td>
</tr>
</tbody>
</table>
• identifying the data that needs to be collected,
• planning when, where, and how data are to be collected and by whom,
• identifying and treating data gaps,
• the actual data collection (measurement or retrieval from book, experience, expert, etc.),
• documenting the resulting data, together with possible sources of error, bias or lack of knowledge,
• validating the data collection system, the collected data and its documentation,
• communicating the data and its documentation.

(source: CASCADE project)
## Data Recovery Questionnaire for Fuel Cell LCA Guide

### Aggregate Data Needed for the Preparation of Life Cycle Inventory of MCFC Section on FC Components Production

Please fill in the questionnaires with the requested data and send it back to the following e-mail address:

[Insert email address here]

Text in the questionnaire is not mandatory.

Text in red is a question.

Text in blue is to be answered with specific data.

Text in black is input/output description.

Text in yellow is to be entered into the calculated value.

The first inventory is relative to the production of active components (anode, cathode, electrolyte, interconnect) and their assembly. Please enter the flows of raw materials which are necessary for the production of a "unit of product" of active component and specify the type of manufacturing process. The number of unit process stages can be specified for each type of active component. There are no or more anodes and cathodes for the MCFC stack. The second inventory is relative to the startup phase of the already assembled stack. Please enter the flows of materials which are necessary for the production of a "unit of product" of "Fuel cell stack after startup".

### Preliminary Raw Materials Input Refer to Interior Reforming with Supplied Syngas Stage

#### Unit Process Identification: Production of Active Components (Anode, Cathode, Electrolyte, Interconnect)

<table>
<thead>
<tr>
<th>Process</th>
<th>Production of Active Components: Unit of Product: 1 kg of anode (anode catalyst, electrolyte, interconnect)</th>
<th>Mass Allocation of Inputs (relative to the manufacture of active components, please indicate percentage of input mass contributing to one or more components)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode</td>
<td>1 kg active component</td>
<td>100% active component</td>
<td>Active Component</td>
</tr>
<tr>
<td>Cathode</td>
<td>1 kg active component</td>
<td>100% active component</td>
<td>Active Component</td>
</tr>
<tr>
<td>Electrolyte</td>
<td>1 kg active component</td>
<td>100% active component</td>
<td>Active Component</td>
</tr>
<tr>
<td>Interconnect</td>
<td>1 kg active component</td>
<td>100% active component</td>
<td>Active Component</td>
</tr>
</tbody>
</table>

#### Description of Unit Process: Insert Additional Sheet if Required

**Phase 1: Production of Active Components**

- **Active Component Production**
  - Anode Catalyst
    - 100% active component
  - Cathode Catalyst
    - 100% active component
  - Electrolyte
    - 100% active component
  - Interconnect
    - 100% active component

**Phase 2: Assembly of Active Components**

- **Anode Assembly**
  - 100% active component
- **Cathode Assembly**
  - 100% active component
- **Electrolyte Assembly**
  - 100% active component
- **Interconnect Assembly**
  - 100% active component

**Phase 3: Integration of Active Components**

- **Anode/Cathode Assembly**
  - 100% active component
- **Electrolyte/Interconnect Assembly**
  - 100% active component

**Phase 4: Integration of Active and Passive Components**

- **Complete Fuel Cell Assembly**
  - 100% active component

#### Output from Unit Processes

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (kg/unit of product)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Cathode</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Electrolyte</td>
<td>1</td>
<td>kg</td>
</tr>
<tr>
<td>Interconnect</td>
<td>1</td>
<td>kg</td>
</tr>
</tbody>
</table>

**Footnotes:**

- Data derived directly from the summarizing synergies and interferences.
- Input assessment and calculation based on the experience of the analyst.
- In case of calculation of materials lost and input/output, please specify any losses and input/output for the fuel to your supplier.
- For a specific manufacturer, please contact the manufacturer for more details.
- All input/output data are in kg unless specified otherwise.
• FC and Hy Guide documents are the first example of adaptation of ILCD HB to specific product group
  • Main difficulty: find a right balance between flexibility and simplicity
• The project provides also the first example of the process needed for developing and reaching consensus (crucial for its real adoption) on the document
• PCR-type document: similar approach as PCR for EPD but with much more details and provisions to really increase the comparability
• Guide alone is not sufficient: training, examples and templates
Thank you!

More info:

www.fc-hyguide.eu

paolo.masoni@enea.it