Training Course

Case study
Hydrogen

29 September 2011, Bologna

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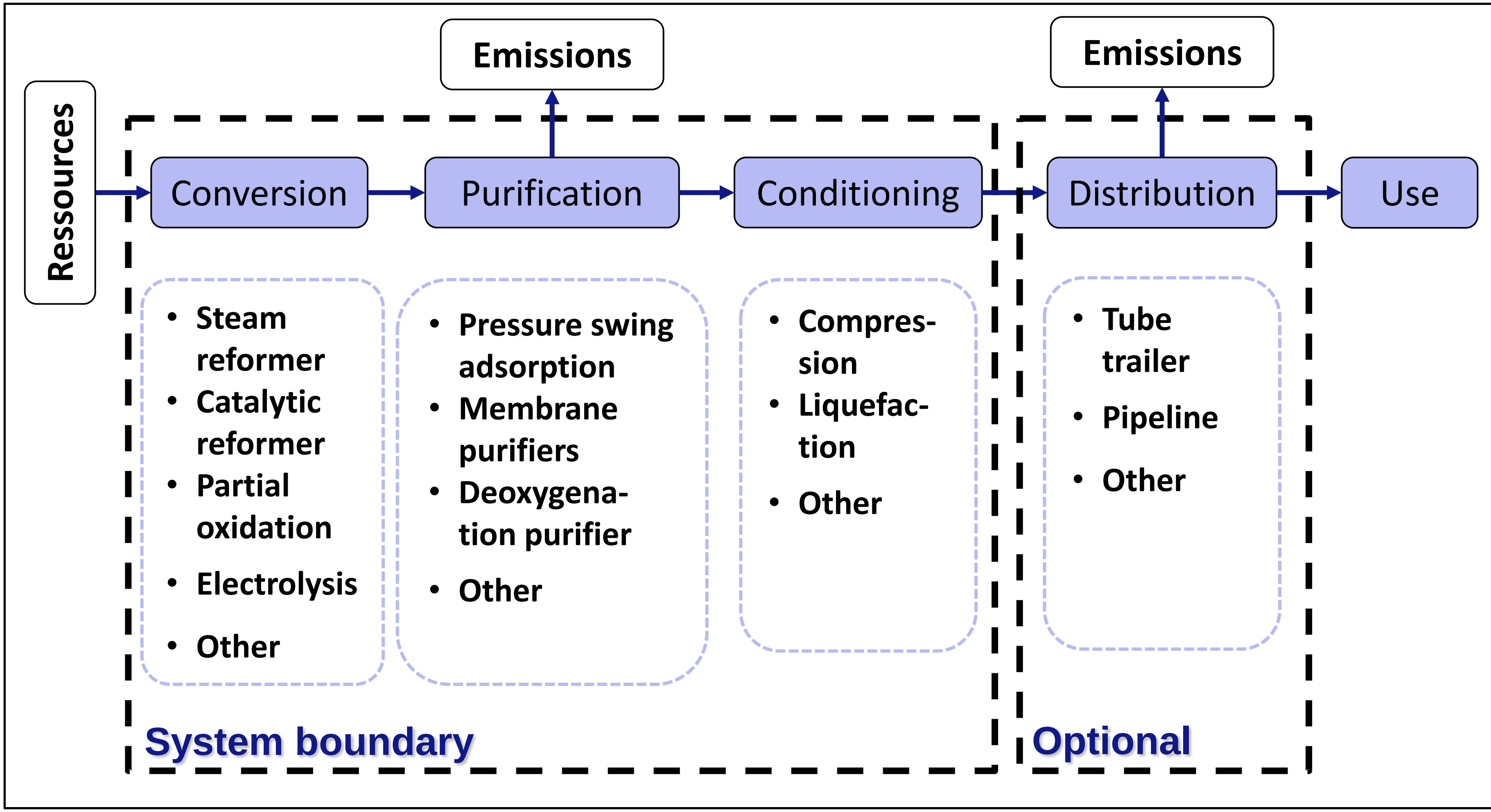
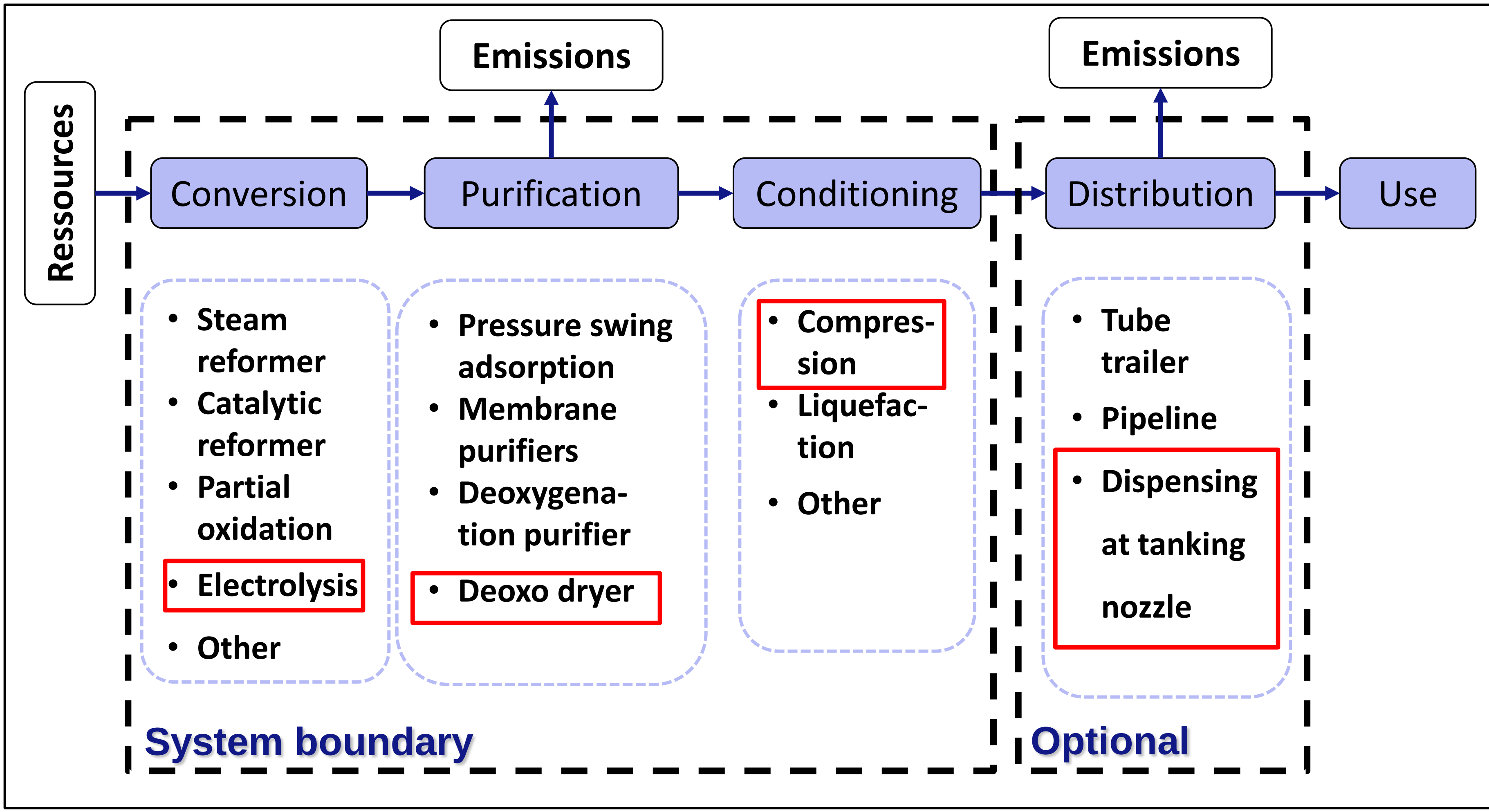
PE INTERNATIONAL

Content

A) Introduction on hydrogen production systems



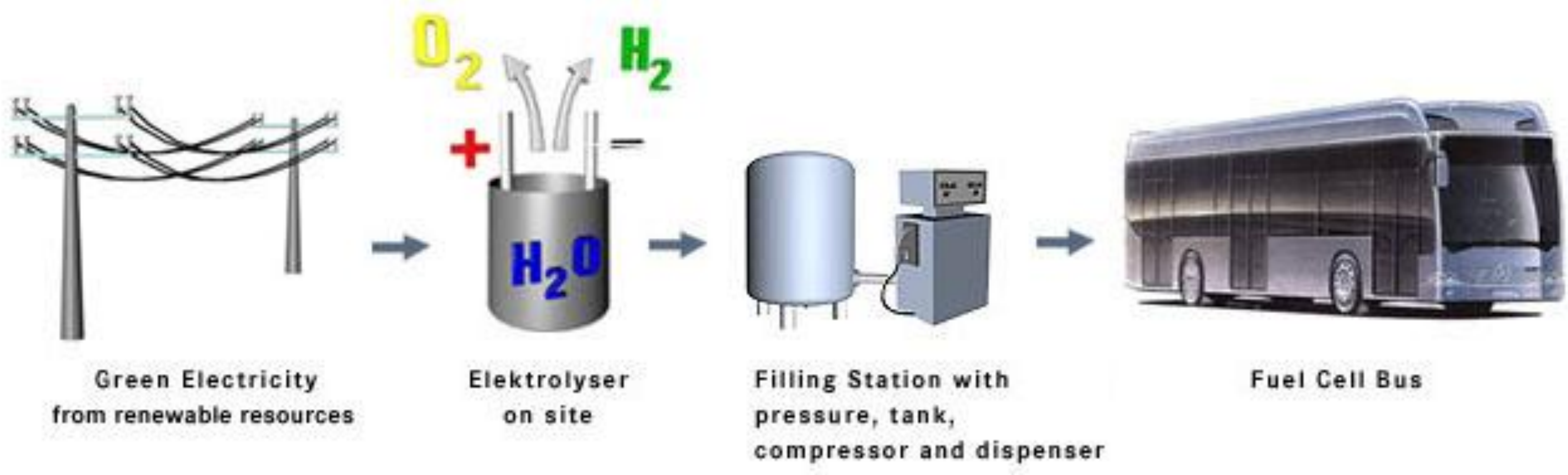
Introduction on hydrogen production systems - Case Study



Example: Electrolyser

Hydrogen service station
Hamburg-Hummelsbüttel
CUTE-Project

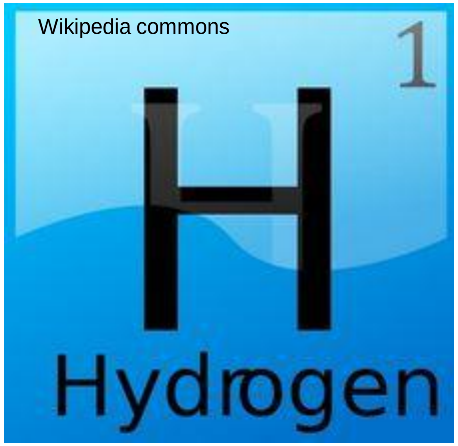
Example: Electrolyser



Source: www.fuel-cell-bus-club.com

Product related information

- State the hydrogen properties



Product related information - Case Study

- 99.995 % purity (SAE J2719)
- Gaseous
- 440 bar @ 85°C (350 bar @ Ambient temperature)

Description of hydrogen producer and the product system

State information regarding the hydrogen producer and production system (capacity, number of sites, technology used, geographical coverage)

Description of hydrogen producer and the product system - Case Study

- Overall H_2 production capacity
- Number of sites
- Production technologies used
- Geographical coverage by region

- Literature study on several electrolyser manufactures
- Several sites with 60-100 Nm^3/h production capacity across Europe and manufactures
- Alkaline -Water electrolysis
- EU-27

Description of hydrogen producer and the product system - Case Study

- Specific production technology
- Production capacity
- Any on-site electricity production
- Location of site
- Construction year
- Technical service life
- Type of production site
- Storage type

- Alkaline -Water electrolysis
- Capacity: 60 Nm^3/h
- No on-site electricity or heat production
- EU-27
- 2003-2006
- 10-30 years depending on component
- On-site, small scale
- High-pressure storage, multi-bench systems

B) Goal of the Life Cycle Assessment study on hydrogen production

Intended application(s)

- Describe the intended application(s)

FC-Hy Guide

Intended application(s) - Case Study

- Test of practical applicability of developed guidance document on performing LCA on hydrogen production **!**

In actual application, e.g.:

- Environmental evaluation of an hydrogen production system using electrolysis production technology.
- Evaluation of primary energy demand (renewable + non-renewable) of the product system.

Method, assumptions and impact limitations

- Detail any assumptions or limitations

Method, assumptions and impact limitations - Case Study

- CML2010 methods for LCIA used
- Investigated midpoint categories:
  - Global Warming Potential (GWP)
  - Acidification Potential (AP)
  - Eutrophication Potential (EP)
  - Photochemical Ozone Creation Potential (POCP)
  - Non-renewable and Renewable Primary Energy Demand (PED non-renewable + PED renewable)
- Endpoints are not investigated

Reasons for carrying out the study explanation

- Describe the reason for carrying out the study

Reasons for carrying out the study
Case Study

- Micro level study based on situation A to evaluate environmental impacts and energy demand of hydrogen production by decentralized water electrolysis
- Generic literature based study which has not to be as accurate as possible, but to check applicability of the hydrogen guidance document with a case study

Target audience explanation

- Describe the target audience

Target audience
Case Study

- LCA-practitioners, technical experts
- Focus is on technical information

Comparisons intended to be disclosed to the public - Case Study

- Non comparative study
- Disclosed to the public
- Third party critical review mandatory, but not performed due to case study character

Commissioner of the study

- Identify the commissioner of the study and name all organisations that have any relevant influence on the study

- Project team HyGuide
- Guidance document development team

C) Scope of the Life Cycle Assessment study on hydrogen production

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Functional unit / Reference flow

- The functional unit is defined as a “quantified performance of a product system for use as a reference unit” (ISO 14040)

  - Define the functional unit or the reference flow

Hydrogen

Functional unit / Reference flow Case Study

- Functional unit: 1 MJ of hydrogen (net calorific value (NCV))
- Reference flow: 1 MJ of hydrogen (net calorific value (NCV)) with 99,995 % purity and 350 bar @ ambient temperature

Multi-functionality explanation

- Analyse if there are any co-products created and/or generated heat used by another process in order to identify if multi-functionality exits

Multi-functionality
Case Study

- Water electrolysis (no chlorine-alkali-electrolysis) so no direct co-products except of oxygen
- Co-product oxygen is released to the environment; no technical usage; no impacts allocated to oxygen

→ no multi-functionality within the system boundaries

System boundary, relevant flows and cut-off

- Define the system boundary
  - The system boundary shall be consistent with the goal of the study (ISO 14040)
  - The premises the system boundary is based on shall be identified and explained
  - Show the chosen system boundary in a flow chart

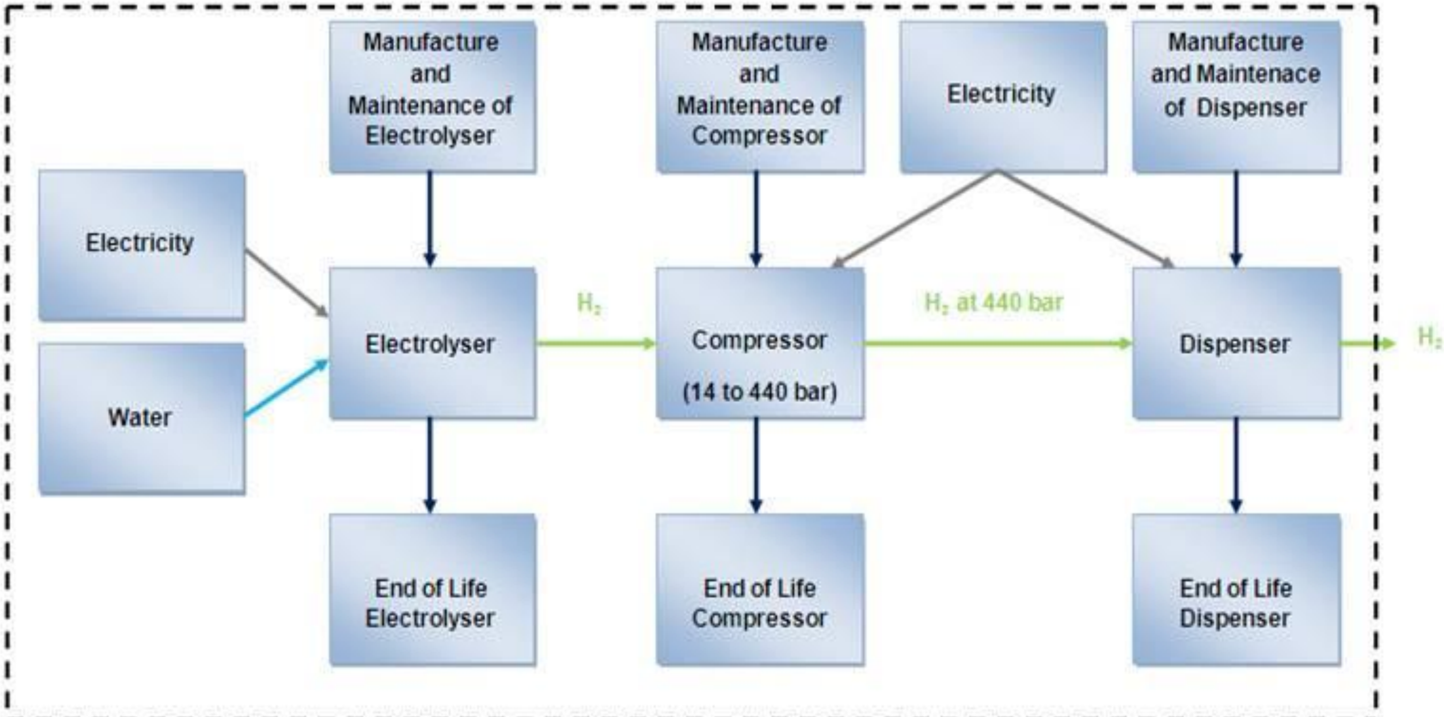
- State relevant flows
- State the flows which are cut-off

System boundary, relevant flows and cut-off explanation

Examples of possible relevant flows

Technology	Input	Output
Electrolysis	Electricity	Hydrogen
	Tap water	Oxygen
	Supply material (e.g. potassium hydroxide for electrolyte)	
	Operating supplies and spare parts	

System boundary, relevant flows and cut-off Case Study



„Well To Tank“ production of hydrogen

Cut-off of 5% in terms of environmental relevance was applied

Type, quality and sources of required data and information – Case Study

Shall: Include all product inputs and outputs to and from the foreground system to other technical systems.

Shall: Take into account all resources from nature and emissions to nature of the foreground and background system. Exceptions are allowed in accordance with the cut-off criteria

Shall: Use data which reflects the technology actually used and represents the region the process takes place

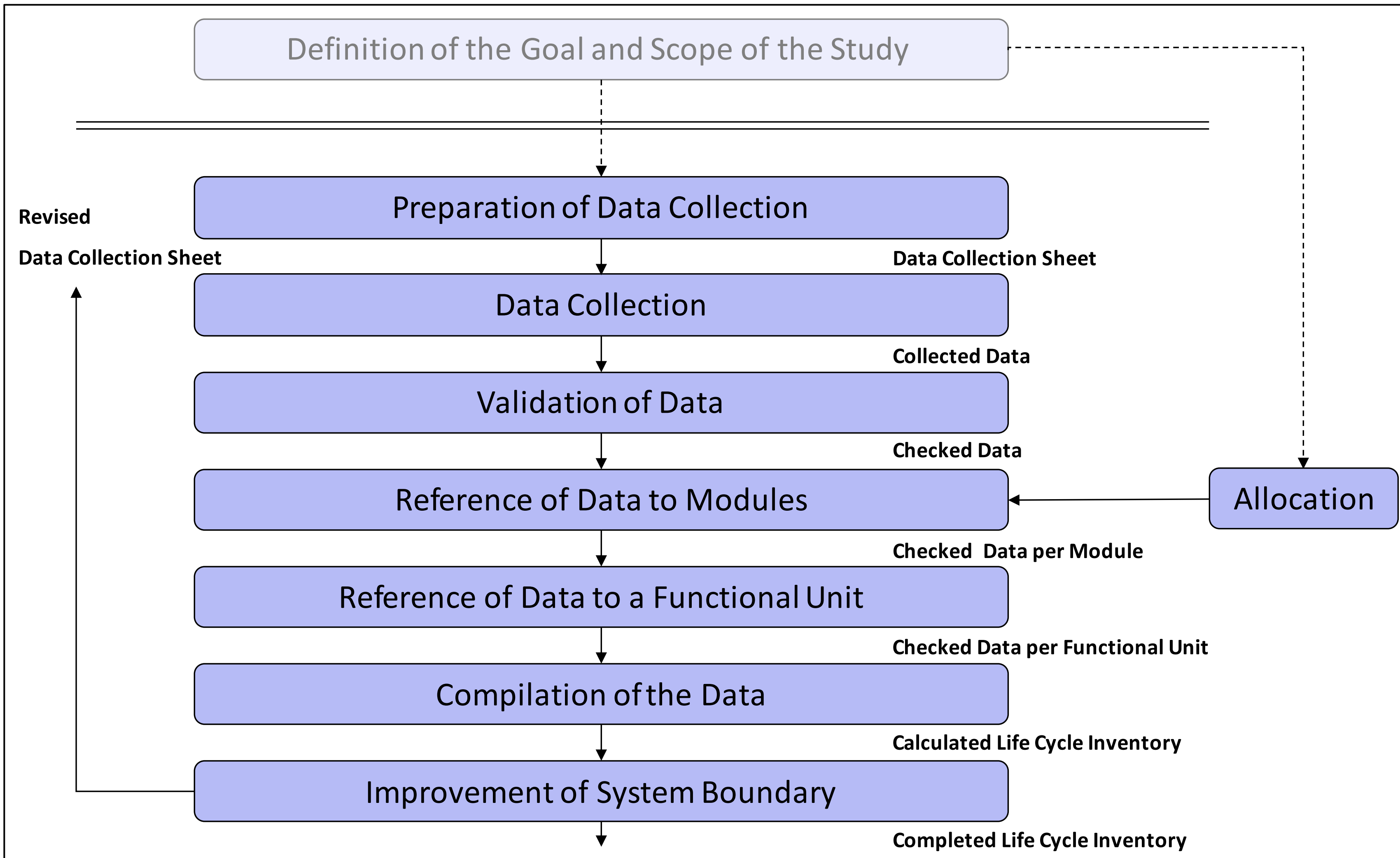
Should: If specific data are not available, comparable data can be used.

Shall: Describe the closing of data gaps using comparable data in the LCA report.

Intended reporting

- Intended Reporting:
  - Decide form of reporting (e.g. detailed report and/or data set, exec summary only)
  - Decide level of reporting (e.g. internal, external, third-party report, publicly accessible)

D) Life Cycle Inventory Analysis of the study on hydrogen production



Data collection

- Describe the data collection, e.g. how long the data were measured, in which way

Data collection – Case Study

- Electrolysis data are provided by manufacturers and operators of the units within a multi-year European demonstration project
- Several independent electrolyser sites and their associated hydrogen supply units were selected and modelled
- Electrolysers are averaged by a horizontal approach in equal shares.
- Downstream of electrolyser process chain is also averaged horizontally, in equal shares.
- Foreground data from manufacturers and operators are of high quality (measured primary data)
- Background data taken from the ELCD database if available, data gaps closed with data sets taken from the GaBi databases

Selection of of generic Life Cycle Inventory data

1. The European Reference Life Cycle Database (ELCD)

If there are no applicable data in above mentioned data base available use the following priorities:

2. ILCD compliant data sets
3. ILCD entry level data sets
4. Databases using the ILCD format (e.g. GaBi databases)
5. other LCA databases; recipes and formulations; patents; stoichiometric models; legal limits; data of similar processes, etc., but the data has to at least fulfil the ILCD flow nomenclature and conventions.

http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm

Selection of of generic Life Cycle Inventory data – Case Study

- The data shall be representative for the applied technology and for geographical and temporal coverage

- The data supplier and the quality of the background data shall be known

- The data shall be modelled consistent i.e. the processes used shall be modelled using the same methodology and for similar processes the same system boundariessystem boundary.

Consideration of re-use, recycling, and energy recovery

- State re-use, recycling and energy recovery processes within the system boundaries

a blue recycle symbol image by wayne ruston from Fotolia.com

Consideration of re-use, recycling, and energy recovery – Case Study

- The electrolyser, compressor and dispenser consist mainly of metal and a small amount of plastic (high recycling rates). EoL treatment for those parts and their components was considered
- Metals:
  - Closed-loop modelling for recycling material
  - Credit given for remaining recycling material
- Plastics:
  - Waste-to-energy modelling
  - Credit given for generated electricity with EU-27 grid mix

Calculation of Life Cycle Inventory results

- Which software are you using?

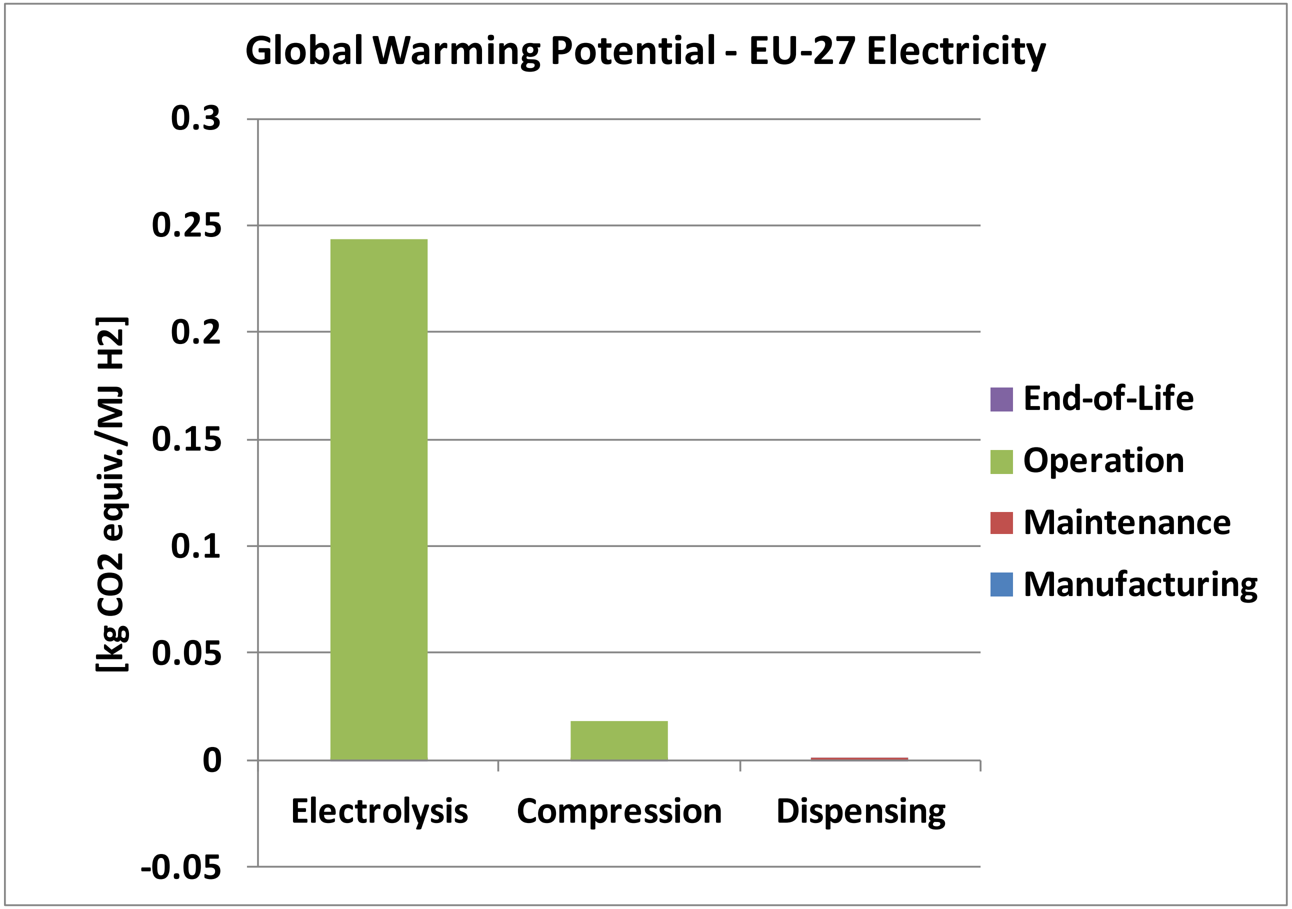
Calculation of Life Cycle Inventory results – Case Study

- All results were calculated with the GaBi-Software

Life Cycle Impact Analysis

- Classification and characterisation
  - Show results
- Normalisation (not recommended)
  - State whether there is normalisation applied
- Weighting (not recommended)
  - State whether weighting is applied

Life Cycle Impact Analysis – Case Study



Significant impacts from Operation phase

Infrastructure is negligible

Most impacts occur during the Electrolysis. Minor impacts in the Compression, Dispensing negligible

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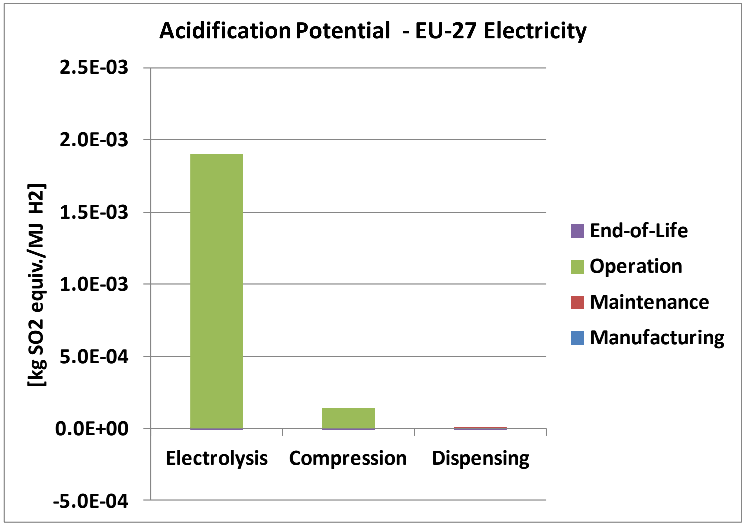
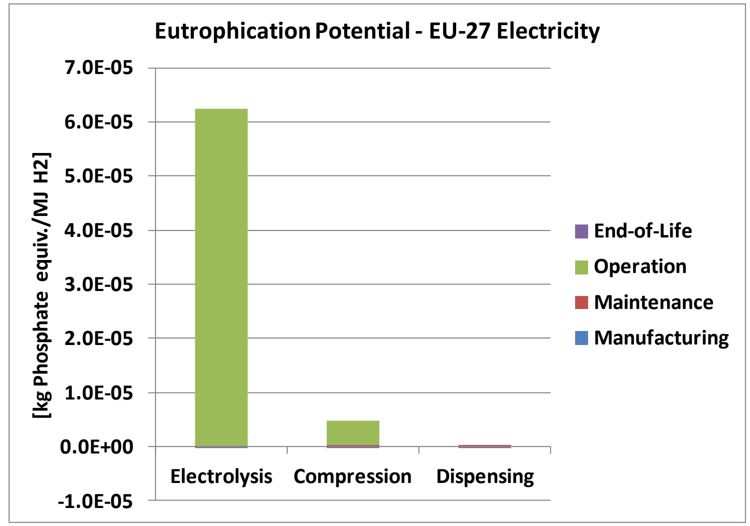
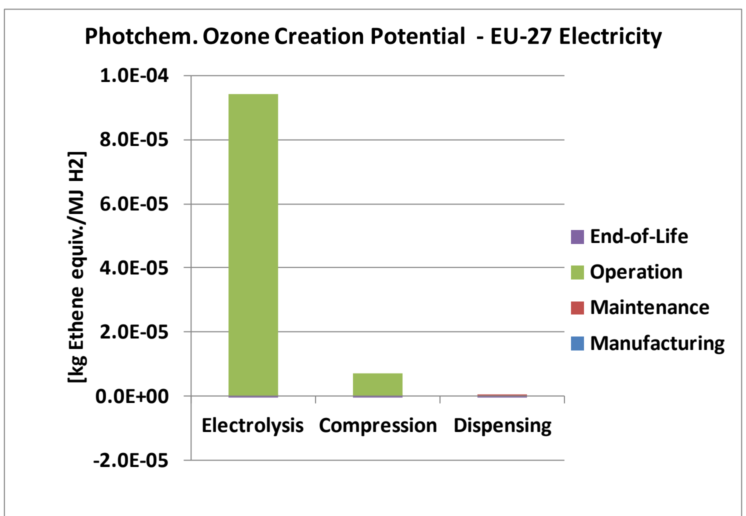
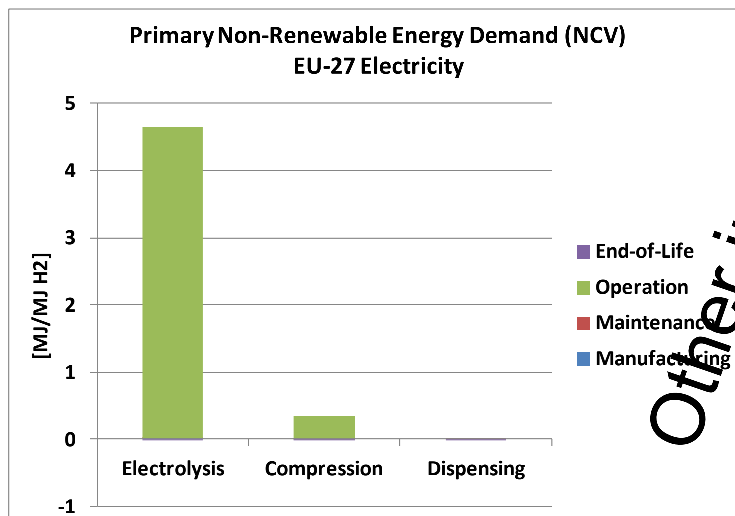
Life Cycle Impact Analysis – Case Study









Other impact categories show similar results

F) Interpretation and quality control of the study of hydrogen production

Shall: Identify significant issues

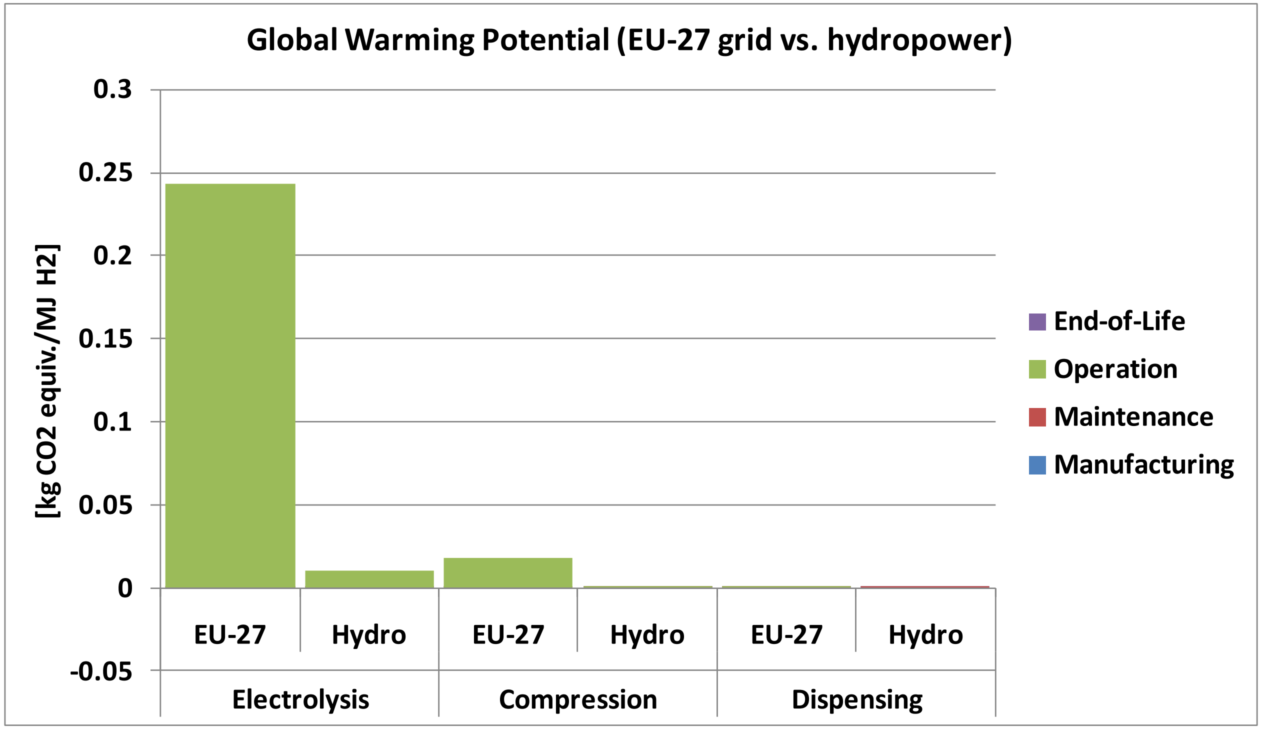
Should: Use graphs (e.g. stacked columns or pie chart) to identify the greatest contributors

Should: Be aware of potential significant issues that e.g. might be cut-off or allocated to another system

F) Interpretation and quality control of the study of hydrogen production

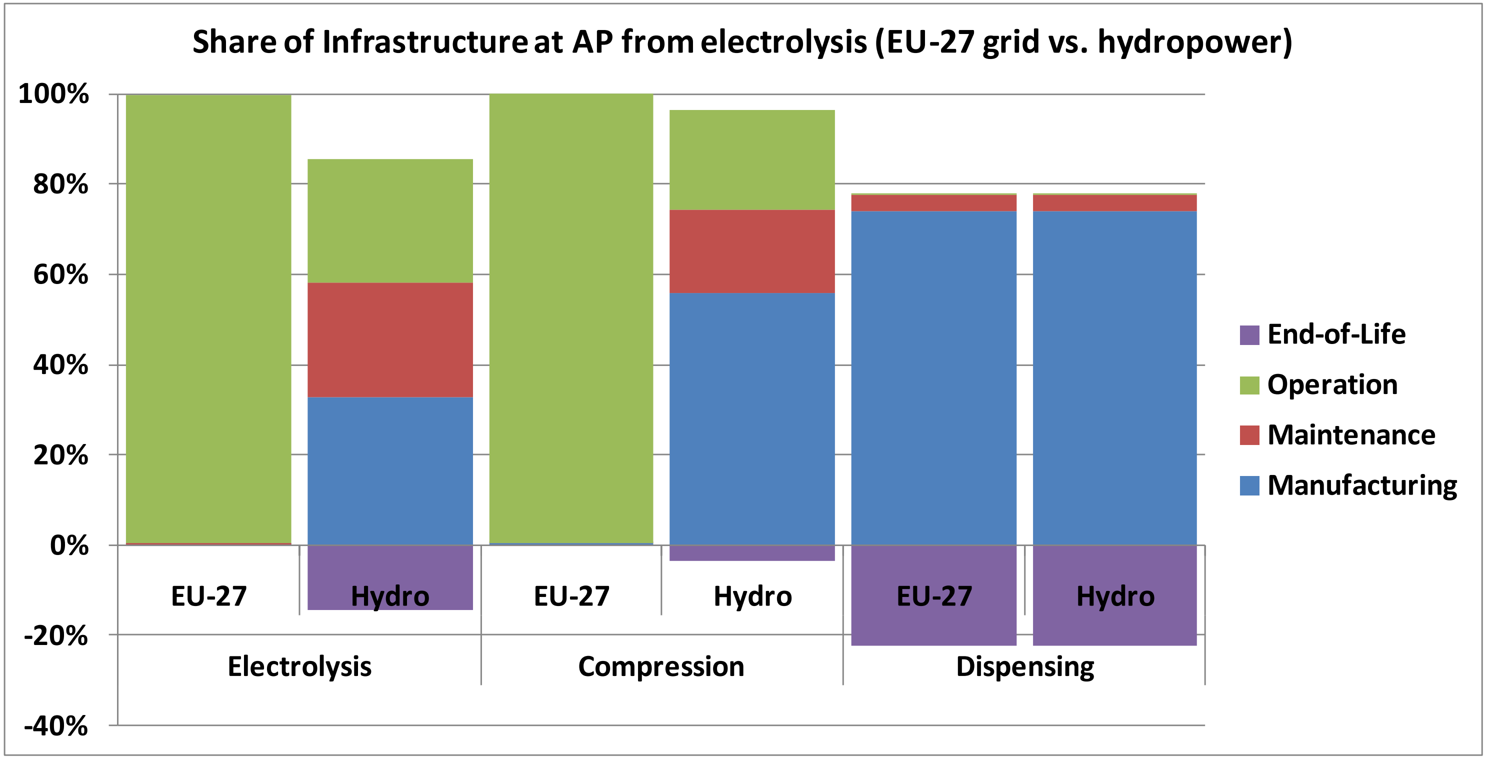
EU-27 grid and hydropower

Impacts drastically decline when renewable energy like hydropower is used



Environmental Impacts of hydrogen production by alkaline water electrolysis are strongly dependent on the electricity used
Other impact categories show similar results

F) Interpretation and quality control of the study of hydrogen production

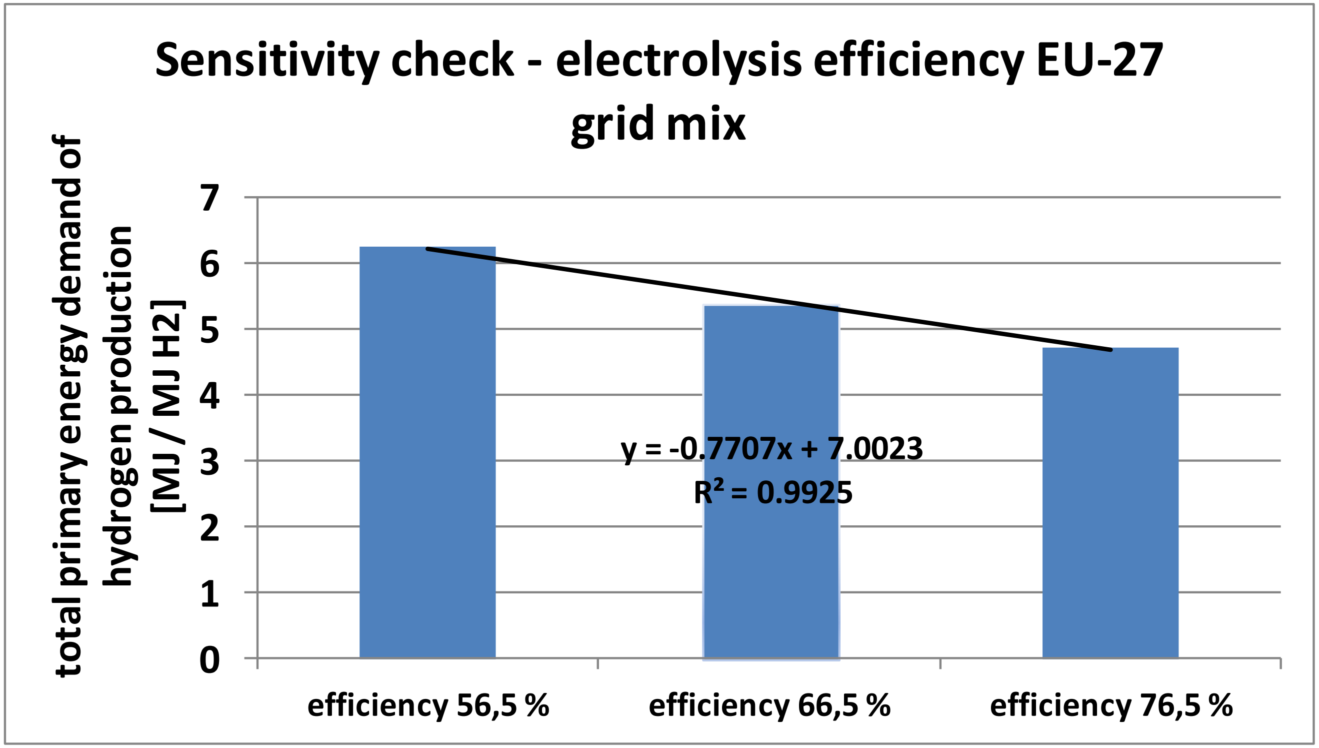


When hydropower is used total impacts decline, but relative share of infrastructure becomes more important (exemplary shown for Acidification Potential)

Evaluation of results

- ➢ Perform a completeness check
- ➢ Perform a sensitivity check
- ➢ Perform a consistency check
- ➢ Perform an uncertainty check

Sensitivity Check



The efficiency of the electrolyser is an important parameter. Altering the efficiency by +/- 10% points results in less respectively higher energy consumption with an approximately linear correlation. The diagram shows the expected results. Other impact categories follow the same correlation.

Conclusions, limitations and recommendations

Conclusions:

- The majority of the environmental impacts during the lifespan of the electrolyser occur due to electricity usage in the operation phase, especially when the European electricity grid mix is utilised.
- The share of maintenance, manufacturing and End-of-Life becomes significantly more relevant when hydropower is used instead of grid electricity. Nevertheless, the total impacts decline to very small shares in comparison to the electricity grid mix.

Conclusions, limitations and recommendations

Limitations:

- Only Global Warming Potential, Acidification Potential, Eutrophication Potential, Photochemical Ozone Creation Potential and Primary Energy Demand are considered, and conclusions are drawn from these categories.

Conclusions, limitations and recommendations

Recommendations:

- GWP can be reduced over 95%, and total primary energy demand about 60% when electricity from the grid is substituted by hydropower
- Higher efficiency of the electrolyser can reduce environmental impacts clearly
- For a more holistic approach, the study should be repeated with more impact categories like ADP and HTP. Besides a third party critical review should also be undertaken. For this case study such a review has been omitted.

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