Environmental assessment of hydrogen vector applied to mobility

51th LCA discussion forum
THE ROLE OF ENVIRONMENTAL LIFE CYCLE THINKING IN LONG-TERM (ENERGY) STRATEGIES

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Outlook

• Goal and scope
  • partners involved
  • context and objectives
  • scenarios assessed and functional unit

• Literature review and first LCA results

• On the way to transition LCA
Study goal and scope
Who is involved?

- Client
- Consultancy agencies
- Steering comity
- Critical review panel
Context - why H2 in mobility?

**Taking advantage of electrical mobility**
- Without fumes
- No noise motor
- Smooth driving

**While benefiting from hydrogen**
- Long running life: fuel tank until 600 km
- High speed charging: 5 min
- Security: no electricity storage
Why doing this study?

- Building life cycle thinking awareness and mobilising the H₂ sector

- Contribute to guide public funding decisions on H₂ production and use options in mobility
Study objectives

• Identify most impacting life cycle stages of 4 different options for H₂ use in mobility
• Compare those options

For illustration purpose: comparison with non H₂ mobility options
• thermal engine vehicle
• electricity vehicle
Functional units

• Full life cycle
  • One kilometer transport by the vehicle passenger car vehicle type Golf A4, transport cycle NDEC

• Cradle to gate
  • one kg of H₂ at the factory gate at 30 Bar
Four scenarios selected detailed analysis, excel calculator to assess all combinations.

Legend:
- Transport
- Input/Output flows + potential coproducts

System boundaries

Production
- Biogas from wastes
- Natural gas (CH₄)
- Co-product of chlorine
- French electric mix
- French electric mix 2030
- 100% wind farms

Steamreforming → CO₂
Steamerforming → Hydrogen
Hydrogen → Electrolysis

Gaseous at 200 bar
Solid

Storage
- On site - 0 km
- Local - 30 km
- Centralized 500 km

Transport (by truck)

Distribution
- Filling station
- Recompression

Use phase
- Light vehicle (350 bar)
- Light vehicle (700 bar)

Integration in the vehicle
- Fuel cell

Production

Dismantling
End of life

Fuel cell recycling

Fuel cell
Four selected scenarios

Scenario 1: local production biogas steam reforming

Scenario 2: centralized production from natural gas steam reforming

Scenario 3: centralized production from electrolysis from mix FR

Scenario 4: production from electrolysis on site from mix FR 2030
**Impact assessment method : ILCD**

<table>
<thead>
<tr>
<th>Impact category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
</tr>
<tr>
<td>Ozone depletion</td>
</tr>
<tr>
<td>Human toxicity, cancer effects</td>
</tr>
<tr>
<td>Human toxicity, non-cancer effects</td>
</tr>
<tr>
<td>Particulate matter</td>
</tr>
<tr>
<td>Ionising radiation, human health</td>
</tr>
<tr>
<td>Ionising radiation, ecosystems</td>
</tr>
<tr>
<td>Photochemical ozone formation</td>
</tr>
<tr>
<td>Acidification</td>
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<tr>
<td>Terrestrial eutrophication</td>
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<tr>
<td>Freshwater eutrophication</td>
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<tr>
<td>Marine eutrophication</td>
</tr>
<tr>
<td>Freshwater ecotoxicity</td>
</tr>
<tr>
<td>Land use</td>
</tr>
<tr>
<td>Water resource depletion</td>
</tr>
<tr>
<td>Minerals, fossils and renewable resource depletion</td>
</tr>
</tbody>
</table>

**Main data sources**

- Electric mix 2030 : ADEME 2012
- H₂ production : Felder 2007
- Vehicle and fuel cell : Felder 2007 and adaptation of ecoinvent 2.2
- Other data and background data : ecoinvent 2.2

*to be adapted with primary data from manufacturers*
Literature review and first results
Climate change impact – full life cycle

Warning – to be modified - preliminary results
Climate change - H₂ production cradle to gate

Climate change [kg CO₂-eq/kg H₂]

- **Biogas reforming**: 7.4%
- **Natural gas reforming**: 10%
- **Electrolysis mix FR**: 5.1%
- **Electrolysis mix FR 2030**: 3.1%

**Infrastructures**

**Electricity**

**Heat from gas (fossil of biogenic)**

**Direct emissions at H₂ factory**

**CH₄ production for H₂ (fossil of biogenic)**

**Upstream transport**

*Warning – to be modified - preliminary results*
Climate change - literature review – H2 production

Warning – to be modified preliminary results scopes might differ

Electrolysis

Natural gas reforming
Climate change impact – full life cycle

Warning – to be modified preliminary results

<table>
<thead>
<tr>
<th>Method</th>
<th>CO2-eq/km</th>
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</thead>
<tbody>
<tr>
<td>Biosgas reforming</td>
<td>139</td>
</tr>
<tr>
<td>Natural gas reforming</td>
<td>167</td>
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<tr>
<td>Electrolysis mix FR</td>
<td>117</td>
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<tr>
<td>Electrolysis (mix 2030)</td>
<td>98</td>
</tr>
<tr>
<td>Diesel vehicle</td>
<td>264</td>
</tr>
<tr>
<td>Electric vehicle</td>
<td>101</td>
</tr>
</tbody>
</table>

Warning – to be modified preliminary results

- Infrastructure (vehicle, maintenance, road infrastructures, etc.)
- Use phase direct emissions
- Upstream (fuel, storage, transport, distribution)
Intermediary conclusions and next steps

• Main impacting stages for climate change:
  • H₂ production
  • Infrastructure (vehicle, road construction)
• Lowest climate change impact scenario: electrolysis with FR 2030 electricity mix
• Final results to be released in August 2013
• No scenario ranking homogeneity for the other impact categories
• Data to be refined especially on
  • infrastructure: vehicle production & material composition of the fuel cell
  • H₂ production from biogas reforming

primary data being collected from manufacturers
On the way to transition LCA
From attributional LCA to transition LCA

Environmental sustainability
✓ towards 100% renewable energy production
✓ limiting CO2 atmosphere concentration to 350ppm based on per capita emission quota
✓ sustainable land use
✓ ...

$$\text{global impacts} = \text{population} \times \sum_{\text{service}} \left( \frac{N_{\text{service}} \times I_{\text{service}}}{FU_{\text{service}}} \right)$$

<table>
<thead>
<tr>
<th>Term of the equation</th>
<th>Unit</th>
<th>Definition</th>
<th>Example</th>
<th>Related concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_{\text{service}} )</td>
<td>[Impact] / [FU]</td>
<td>Impacts of the service per Functional Unit</td>
<td>Impacts (climate change, resource consumption, etc.) per km of transport by car</td>
<td>Environmental efficiency</td>
</tr>
<tr>
<td>( A_{\text{service}} )</td>
<td>[FU]</td>
<td>Total amount of the service used by the population</td>
<td>Total amount of kilometers for car transport</td>
<td>Environmental sobriety</td>
</tr>
<tr>
<td>( N_{\text{service}} = \frac{A_{\text{service}}}{\text{population}} )</td>
<td>[FU]/person</td>
<td>Use intensity of the service per person</td>
<td>Average car transportation distance per person</td>
<td>Equity and human rights</td>
</tr>
</tbody>
</table>
Thank you for your attention !