IEA HIA Task 28: Large-scale Hydrogen Delivery Infrastructure

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Background to and Objectives of the Task

- Today fuel cell vehicles are commercial or close to market introduction.
- Internationally, various hydrogen infrastructure initiatives are on the way, but further efforts are required to facilitate full-scale FC EV rollout.
- Initiatives and smaller-scale demonstration and R&D projects would benefit from further alignment and harmonization.
- It is necessary to investigate and compare international activities and knowledge on large-scale H₂ delivery infrastructures (HRS and H₂ supply).
- Moreover, in many countries with large and growing shares of fluctuating renewable energy sources (RES), H₂ offers solutions for integrating RES.
- Task 28 analyses the comprehensive knowledge on infrastructure for transport, and pays some attention to H₂ as energy storage for RES, so to better understand synergies of the combined potential of both options.
- Outcome will be a state-of-the-art overview comparing and evaluating pathways towards large-scale H₂ delivery infrastructures for mobility, showing opportunities for synergies with RES storage applications.
- Report is to inform industry, policy and research stakeholders about chances and challenges of H₂ infrastructure, and help decision-making.
Timing and Outcome

- **Timing**
  - Task scheduled from June 2010 – December 2013 (extension under discussion)

- **Structure (subtasks):**
  A. Scenarios (map major H₂ transport infrastructure initiatives worldwide and develop future outlooks)
  B. Evaluation of hydrogen refueling station concepts (technology mapping of main pathways)
  C. Analysis of hydrogen delivery pathways (economic evaluation of main pathways identified)
  D. Hydrogen for integration of RES (PtG, energy storage, etc.)
Task Participation

- **Current team:**
  - Netherlands: ECN (Operating Agent), Shell
  - USA: ANL and Proton OnSite
  - Japan: Tokyo Gas and Nissan
  - Denmark: Danish Gas Technology Centre and H₂ Logic
  - Australia: Talent with Energy / AAHE
  - France: GDF-SUEZ, TOTAL and Air Liquide
  - Germany: NOW
  - Norway: HYOP

- **Links with all European H₂ Mobility initiatives, the Scandinavian initiatives and the Japanese initiative HySUT**
Subtask A: Major H₂ Infrastructure Initiatives

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>S.Korea</th>
<th>USA California</th>
<th>Germany</th>
<th>UK</th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-2020</td>
<td>100</td>
<td>43</td>
<td>68</td>
<td>100</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>2020-2025</td>
<td>1000</td>
<td>168</td>
<td>100</td>
<td>400</td>
<td>330</td>
<td>185</td>
</tr>
<tr>
<td>2025-2030</td>
<td>500</td>
<td>900</td>
<td>1150</td>
<td></td>
<td></td>
<td>&gt;&gt;185</td>
</tr>
</tbody>
</table>

- Overview of HRS projections in major initiatives on market development

- Comprehensive overview of countries in conjunction with projections on FCEVs
- Analysis based on projections on station sizes and ramp-up FCEV fleet/sales scenarios, etc.
Subtask B: Technical Evaluation of HRS Concepts

- Description HRS standardization requirements based on public H₂ Mobility Germany technical specification document

<table>
<thead>
<tr>
<th>Distribution option</th>
<th>HRS size</th>
<th>Very small ≤ 80 kg/day</th>
<th>Small ~ 200 kg/day</th>
<th>Medium ~ 400 kg/day</th>
<th>Large ~1000 kg/day</th>
<th>Very large ≥ 1000 kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site electrolysis</td>
<td></td>
<td>On-site power requirement may become an issue: 400 kg/day ≈ 1 MW</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-site reforming</td>
<td></td>
<td>Costly to capture CO₂</td>
<td></td>
<td>Required footprint is an issue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGH₂ truck</td>
<td></td>
<td>Delivery of 300 kg up to about 1000 kg per truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH₂ truck</td>
<td></td>
<td>Relatively large boil-off for demand levels in early markets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGH₂ pipeline</td>
<td></td>
<td>Due to high investments pipelines are not likely in early markets unless already available</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- Detailed discussion of concepts based on list of important technology requirements
Currently, total 285 HRS of which 82 publicly accessible
- Significant differences in breakdown of delivery options: on-site reforming almost absent in Europe but important in Asia, and CGH$_2$ relatively unimportant in North-America
Subtask C: Analysis of HRS Component and System Costs

- Clear definitions regarding cost factors and HRS cost breakdowns are important
- Work in progress:
  - Cost of distribution
  - Indicative cash flow analyses
Subtask D: Integration of Fluctuating RES by H₂

High level view on role of hydrogen (work in progress):
- Integration of wind and solar power into wider energy system is problem already today, but major challenge in future
- Power to Gas (e.g. injection of H₂ in natural gas grid) and large-scale H₂ (underground) storage are promising energy storage solutions
Subtask D: Snapshots from Discussion and Draft Report

Appendix C. Overview of Power-to-Gas projects

<table>
<thead>
<tr>
<th>Case</th>
<th>&quot;Less fuel&quot;</th>
<th>&quot;Standard Northeast&quot;</th>
<th>Investment electrolysis 700 €/kW</th>
<th>Investment electrolysis 500 €/kW</th>
<th>Price driven electrolysis operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolysis full load hrs</td>
<td>3.052</td>
<td>3.052</td>
<td>3.052</td>
<td>3.052</td>
<td>5.600</td>
</tr>
<tr>
<td>Tonnes H₂ per year</td>
<td>32.044</td>
<td>32.044</td>
<td>32.044</td>
<td>32.044</td>
<td>59.100</td>
</tr>
<tr>
<td>Share for power plant</td>
<td>38%</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
<td>39%</td>
</tr>
<tr>
<td>Specific Revenue to break even [€/kg H₂ fuel]</td>
<td></td>
<td></td>
<td>2.50</td>
<td>2.08</td>
<td>2.06</td>
</tr>
</tbody>
</table>

Falkenhagen (GER) PtG Plant. Source: E.ON

Ameland (NL) PtG Project. Source: Draft Report

Study Integration of Wind H₂. Source: NOW
Key Overall Findings and Messages

- All hydrogen delivery options are technically feasible - there are no technical issues that cannot be overcome
- There is no blueprint for the type of hydrogen delivery infrastructure that needs to be rolled out - everything is possible
- Best practical and economic combination depends on specific national, regional and local circumstances
- Most major car OEMs have FCEV commercialization plans
- Several hydrogen infrastructure initiatives are on the way
- Many demonstration projects involving electrolysis, PtG and H₂ storage are running or are planned, prove technical feasibility of and show economical perspectives for the integration of RES
- With both transport and energy storage applications, however, specific technical problems remain to be solved and further political support will be required
Thank you very much for your attention!

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