Introduction to portfolio of Hydrogen Production, Distribution and Storage projects

Nikolaos Lymperopoulos, Project Manager

www.fch-ju.eu
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:50 – 14:10</td>
<td>Introduction to portfolio of Hydrogen Production, Distribution and Storage projects</td>
</tr>
<tr>
<td></td>
<td>Hydrogen production, distribution and storage</td>
</tr>
<tr>
<td></td>
<td>Nikos Lymberopoulos</td>
</tr>
<tr>
<td></td>
<td>Question and Answer Session</td>
</tr>
<tr>
<td>14:10 – 16:00</td>
<td>Session on Hydrogen Production, Distribution and Storage</td>
</tr>
<tr>
<td></td>
<td>PANEL 5</td>
</tr>
<tr>
<td></td>
<td>Energy: Hydrogen Production, Distribution and Storage</td>
</tr>
<tr>
<td></td>
<td>Moderators: Nikos Lymberopoulos, Eden Mamut</td>
</tr>
<tr>
<td>14:10-14:40</td>
<td>BOR4STORE</td>
</tr>
<tr>
<td>14:40-15:10</td>
<td>ELECTROHYPEM</td>
</tr>
<tr>
<td>15:10-15:40</td>
<td>UNIFY</td>
</tr>
<tr>
<td>15:40-16:00</td>
<td>Storage Study – Nikos Lymberopoulos</td>
</tr>
</tbody>
</table>
• Energy - RTD - $H_2$ Production & Distribution

Public Awareness, Education

Market Support (SME Promotion, Demand Side Measures, etc.)

Demonstrations

- Vehicles & Infrastructure
- Low Carbon Supply Chain
- System Readiness Manufacturability
- Backup/UPS
  - Off-road H2 Vehicles
  - Micro/Portable FC

Technology, Sustainability & Socio-Economic Assessment Framework

- Specific PNR & Harmonised RCS

Research and Technological Development

- Stack & Subsystems
- Processes & Modules
- Periphery & Components
- Systems & Integration & Testing

Components

- New Technologies
- Material & Design & Degradation & Durability

Long-term and Breakthrough Orientated Research

- Transport & Refuelling Infrastructure
- Hydrogen Production & Distribution
- Stationary Power Generation & CHP
- Early Markets

Technology, Sustainability & Socio-Economic Assessment Framework
### 2008-2013 MAIP Targets

#### Energy - H₂ Production & Distribution

<table>
<thead>
<tr>
<th>Application Area</th>
<th>Targets 2010</th>
<th>Targets 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Volume</td>
</tr>
<tr>
<td>Hydrogen Production &amp; Distribution</td>
<td></td>
<td>Cost and Technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of H₂ delivered at refuelling station &lt; €5/kg (€ 0.15/kWh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improved system density for H₂ storage (9 %wt of H₂)</td>
</tr>
<tr>
<td>Appropriate H₂ supply chain (including fuel purity) to match Transport, Stationary and Early Markets requirements. For 2015 10 - 20% of general H₂ demand should be produced via carbon free/carbon lean processes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FCH JU Funding by Action Categories</th>
<th>Breakthrough research</th>
<th>Research &amp; technological development</th>
<th>Demonstrations</th>
<th>Support actions</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Areas</td>
<td>€m</td>
<td>€m</td>
<td>%</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Production &amp; Distribution</td>
<td>17-20</td>
<td>16-19</td>
<td>12-15</td>
<td>0</td>
<td>45-54</td>
</tr>
<tr>
<td>Actual</td>
<td>43</td>
<td>9.6</td>
<td>52.6</td>
<td>12.1%</td>
<td></td>
</tr>
</tbody>
</table>
2008-2013 MAIP Targets

- Energy - RTD - H₂ Production & Distribution

- RTD H₂
  - 43 M€
  - 10%

- CROSS-CUTTING
  - 28 M€
  - 6.4%

- TRANSPORT
  - 194 M€
  - 45.1%

- ENERGY
  - 209 M€
  - 48.5%

- FCH JU Contribution/M€
  - 432 M€

- No. FCH JU projects per pillar
  - 155 projects

- RTD H₂
  - 24 projects
  - 15.5%

- CROSS-CUTTING
  - 26
  - 16.8%

- TRANSPORT
  - 39
  - 25.2%

- ENERGY
  - 90
  - 58.1%
## Overview of Panel 5 Projects

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline electrolysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEM electrolysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RESELYSER</td>
<td>ELECTROHYPEM NOVEL</td>
<td>ADEL</td>
</tr>
<tr>
<td>High temp electrolysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HELMETH SOPHIA ELECTRA</td>
<td>SOL2HY2</td>
<td>ARTIPHYCTION PECDEMO</td>
</tr>
<tr>
<td>Concentrated solar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photo-electrochemical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reformers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass gasification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2 storage (boron+MH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNIfHY</td>
<td>HYTIME</td>
<td>BOR4STORE EDEN</td>
</tr>
<tr>
<td>H2 tanks &amp; distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2 bulk storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HyUnder</td>
<td>HyTransfer</td>
<td></td>
</tr>
<tr>
<td>Studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ELY</td>
<td>ES</td>
<td>GH</td>
</tr>
</tbody>
</table>
PROGRAMME TARGETS AND ACHIEVEMENTS

• Electrolysers - 1
  – **Alkaline** *(RESELYSER)*
    • Novel cells for variable operation minimizing gas cross-over at low current density to 25%
    • Aiming for >80% $\eta$ retention >90% over 1,000 on/off
  – **High temperature** *(ADEL, HELMETH, SOPHIA, ELECTRA)*
    • Completed: € 6-17/kg $\text{H}_2$, 1.33 A/cm², 1-5% degradation / 1,000 hours
    • Recent: 0.5-1% degradation / 1,000 hours, total $\eta$ >85% electricity -> syngas, coupling to concentrated solar source
• Electrolysers - 2
  – Study: Development of water electrolysis in the EU
  
  • Energy system R&D – interaction of el. with grid, benchmarks, test cycles
  • Electrolyser system R&D – part-load & dynamic operation for H2 customers and provision of energy services
  • Electrolyser technology - reduce capex while maintaining reliability, increase performance (catalysts, membranes, systems)

• **Concentrated Solar (SOL2HY2)**
  
  • Modelling, multi-objective design and optimisation and testing of improved critical materials solutions and processes, leading to a virtual plant model
  
  • Sulphur depolarised electrolyser (selected), solar-powered H₂SO₄ cracker (sun-tested) and heat storage (molten salts)
  
  • 3 concepts chosen, critical BoP units selected, main blocks built using Aspen Plus S/W.
Programme Targets and Achievements

- **Photoelectrochemical** (ARTIPHYCTION, PECDEMO)
  - 2.5% - 5.2% sun-to-H$_2$ conversion $\eta$, 5 - 8% aim, 5% target
  - 1,000h is aim, 10,000h target
  - 100W – 3g/h aim, 100W-100kW target
PROGRAMME TARGETS AND ACHIEVEMENTS

• Reformers -1
  – Membrane reformer, 550°C, integrating RE heat sources (COMETHY)
    • Centralised SMR $\eta > 70\%$ aim, 72% target
    • >2Nm$^3$/h aim, 2-750 Nm$^3$/h target
    • <3vol% CO, <10vol% CO target
  – Diesel, biodiesel reforming (NEMESIS2+)
    • 70% $\eta$ aim, 80% target, >1,000 h durability, 50Nm$^3$/h prototype
• Reformers -2
  – Biogas reformer (BIOROBUR)
    • 100 kg/day aim, 50-250 kg/day target
    • CO < 10 vol% aim and target
    • Materials costs for 50 Nm³/h 150 k€, target 250 k€
    • >65% $\eta$ aim and target
• Biomass gasification (UNIFHY)
  – Continous process for pure $\text{H}_2$ production from biomass (gasifier+WGS+PSA+thermal int)
    • $\text{H}_2$ cost $< € 5/\text{kg}$ for 6,000h/year operation on plant, as per target
    • 70% $\eta$ aim, > 66% target
• Biological routes (HYTIME)
  – Dark fermentation of 2\textsuperscript{nd} gen biomass, continuous process
    • 5L (6gr H\textsubscript{2}/day) reactor in operation, 50L ready for tests, 300L just purchased
    • 1-10 kg H\textsubscript{2}/d aim and target
    • 71% $\eta$ from straw, 36% from grass, <10% kitchen waste, > 75% aim
• **H₂ storage : MH**
  – *Boron hydride-based materials (BOR4STORE)*
    • 9-10 wt.% on material basis, >6 wt.%, 4% on system basis target
    • Release temp 350-450°C, 450 °C target
  – *Mg-based materials (EDEN)*
    • 7 wt.% on material basis, >6 wt.% target
    • SOFC compatible, > 1.5 lt/min release
• H₂ distribution
  – Composite material trailers (DELIVERHY)
    • Applicable safety factors from SF=3.0 -> SF=2.25
    • 52.5 MPa most suitable, >40MPa target
    • Delivery freq. \( \downarrow \times 3 \), \( \downarrow \times 4 \), cost = LH₂
  – Faster filling (HYTRANSFER)
    • CFD and lab testing
    • Reduction of HRS OPEX and CAPEX
H₂ bulk storage

- Underground storage in salt caverns (HYUNDER)
  - Technically feasible, suitable geology, public acceptance
  - Cavern contributes €0.5/kg to cost of H₂
  - Short term: Transport sector only market for commercial operation of H₂ plant (electrolyser and storage)
PROGRAMME TARGETS AND ACHIEVEMENTS

• Studies
  – Energy Storage
  – Green Hydrogen (just launched, 1/12/2014 deadline)
    • http://www.fch-ju.eu/page/vacancies-procurement
Thank you for your attention!