Hydrogen Production Storage and Fuel Cells

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HYDROGEN, 4 MAIN LEADER COUNTRIES

- United-States
- Japan
- South Korea
- Germany

Example
Hydrogen refueling stations
HYDROGEN PRODUCTION

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>309,1</td>
<td>39,0</td>
</tr>
<tr>
<td>Oil</td>
<td>182,9</td>
<td>39,0</td>
</tr>
<tr>
<td>Coal</td>
<td>113,6</td>
<td>3,7</td>
</tr>
<tr>
<td>Electrolysis</td>
<td>25,2</td>
<td>11,1</td>
</tr>
<tr>
<td>Total</td>
<td>630,8</td>
<td>92,8</td>
</tr>
</tbody>
</table>

France (2008)
Annual production about 920 000 t:
About 40% « voluntary »,
60% « involuntary » - By-product – but useful: mainly burn

Three main types of electrolysers

<table>
<thead>
<tr>
<th>Technology</th>
<th>Working temperature</th>
<th>Technological maturity</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline Electrolysis</td>
<td>70 – 100 °C</td>
<td>Commercially available</td>
<td>Suitable for base load production</td>
</tr>
<tr>
<td>PEM Electrolysis</td>
<td>80 °C</td>
<td>Commercially available</td>
<td>Very suitable for intermittent production (PV, Wind)</td>
</tr>
<tr>
<td>High Temperature Electrolysis (SOEC)</td>
<td>700 – 1000 °C</td>
<td>Under development</td>
<td>Needs heat source (CSP, Nuclear plant, waste management plant...)</td>
</tr>
</tbody>
</table>

Source: ALPHEA
Source: CEA
HYDROGEN AS A WAY TO STORE RENEWABLE ENERGIES

Example: MYRTE project (Corsica)

Key facts and figures

<table>
<thead>
<tr>
<th>Partners</th>
<th>Corsica University, CEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>University of Ajaccio</td>
</tr>
<tr>
<td>Power output</td>
<td>100 kWe (1st phase) / 150 kWe (2nd phase)</td>
</tr>
<tr>
<td>Delivery schedule</td>
<td>Dec. 2011 (1st phase) / Sept. 2013 (2nd phase)</td>
</tr>
<tr>
<td>Contract signature</td>
<td>2009</td>
</tr>
</tbody>
</table>

Project highlights

- MYRTE platform demonstrates a hydrogen energy management and storage chain coupled to 500 kWp solar panels
- AREVA Energy Storage systems delivered in May 2011
- Grid connection completed in December 2011
- Inaugurated in January 2012
- Phase 2 expected to enter in operation in September 2013
HYDROGEN AS A WAY TO LINK RENEWABLE ENERGIES AND MOBILITY

Example: California Hydrogen Highway

- 250 light duty vehicles (ICE and fuel cells)
  > 3,200,000 km driven
- 16 buses in operation
  > 265,000 km driven
- 1,300 km
- 37 hydrogen refuelling stations (some of them coupled with PV for in situ H₂ production)
HYDROGEN AS A WAY TO PRODUCE DOMESTIC ENERGY

Example: Domestic Micro Combined Heat and Power (Micro CHP)

**Today**
- Partial hydrogen energy chain (hydrogen produced in situ by reforming)
- Primary energy: Natural gas or biogas

**Tomorrow**
- Full hydrogen energy chain (hydrogen produced locally by electrolysis from renewable energy)
- Primary energy: renewable energy
HYDROGEN AND FUEL CELL MARKET, A REALITY TODAY

- > 4,000 fuel cell forklifts in operation or ordered (USA)
- > 40,000 fuel cell µCHP unit in operation (Japan)
- > 50 fuel cell buses in operation (WW)
- > 300 fuel cell light duty vehicles in operation (WW)
- > 200 HRS in operation (WW)
- > 2,000 fuel cell telecoms backup systems (WW)
HYDROGEN AND FUEL CELL MARKET, KEY CHALLENGES FOR 2030-2050

- **Hydrogen production**
  - Increase “low CO₂ footprint” production (bio H₂, “renewable” electrolysis)
  - Reduce hydrogen production cost < 2 €/kg (especially from electrolysis)

- **Hydrogen storage and delivery**
  - Demonstrate long term safety for nominal and accidental operating modes for HRS and on-board storage for mobility
  - Decrease the cost of hydrogen tanks (especially for automotive applications)
  - Harmonize normalization and standards for HRS deployment
  - Reduce hydrogen delivery cost < 4 €/kg

- **Fuel cells**
  - Increase performances
  - Reduce system production costs
    - Heavy duty vehicles 3 000 €/kW
    - Stationary 750 to 1 500 €/kW
    - Buses 150 to 300 €/kW
    - Light duty vehicles 30 to 50 €/kW
  - Increase durability
    - Stationary 40 000 h
    - Transportation 5 000 h
Thank you for your attention

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