Hydrogen Production from Nuclear Energy

By
Leon Walters and Dave Wade
November 12, 2002
Hydrogen.....The Vision

• Energy Security

• Environmental Compatibility

if...
Two Questions are Addressed

- Is the hydrogen generation process of sufficient scale to meet the needs?
- Does the full cycle, from mining, to production, to distribution, to use, to cleanup, meet our environmental standards?
Energy Utilization

- Process Heat: 34%
- Nuclear Electricity: 7%
- Fossil Electricity: 26%
- Transportation: 33%

Hydrogen Production from Nuclear Energy
Hydrogen Technologies

- Steam Reforming
- Advanced Steam Reforming
- Electrolysis
- Thermo Chemical Processes
Hydrogen Generation

- Steam reforming of methane accounts for nearly all the 50 million tons of hydrogen used world-wide for ammonia based fertilizers and oil product enhancement.

- Electrolysis also is a mature technology and is used primarily for the production of high purity oxygen and hydrogen.

- Hydrogen produced by high temperature thermo-chemical processes has not been demonstrated on a commercial scale but promises high efficiency production in the future.
Relative Costs

- H2 produced by electrolysis — $3.00/kg @ $0.06/kwh
- H2 produced by methane reforming — $0.80/kg
- H2 expectations for nuclear & thermo chemical — $1.30/kg
Cost of Hydrogen by Electrolysis

- 3 kg H2 to drive 250 miles
- 12.5 gal gasoline to drive 250 miles at 20 miles /gal
- 152 kwh to generate 3 kg H2
- 152 kwh @ $0.06/kwh = $9.00 + service and equipment
- 12.5 gal of gasoline @ $1.50/gal = $18.75

Conclusion: Electrolysis H2 is competitive

BP executive: “At the refinery gate, hydrogen’s cost-mile driven is actually substantially less than conventional fuel because of the outstanding efficiency of the fuel-cell engine. Hydrogen’s current high cost can be attributed to the expense of transporting and dispersing it.”
# Transportation: Annual Hydrogen/Energy Requirement

<table>
<thead>
<tr>
<th>Fuel used</th>
<th>0.013 kg H₂/mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>From electrolysis</td>
<td>0.66 kWh/mile</td>
</tr>
<tr>
<td>Miles driven in U.S. in 1997</td>
<td>2.6 x 10¹² miles</td>
</tr>
<tr>
<td>Requirements</td>
<td>3.4 x 10⁷ T H₂ and 241 GWe</td>
</tr>
</tbody>
</table>

- To provide the needed electricity:
  - 241 1,000 MWe electrical generating plants
  - OR
  - 640,000 — 1.5MW windmills — 71,000 square miles
EXTERN-E External Costs

\( \text{€/kWh} \)

- Coal \( 3-10 \) €/kWh
- Gas \( 1-4 \) €/kWh
- Nuclear \( 0.2-0.5 \) €/kWh
Deployment of Nuclear-Generated Hydrogen

Hydrogen Production from Nuclear Energy
Nuclear as a Link in the Energy Supply Chain

Generation 4 Goals for Nuclear Energy Supply

Sustainability Goals

Safety-Reliability Goals

Economic Goals

Hydrogen Production from Nuclear Energy
Hydrogen Distribution

• Extraction of hydrogen from fossil fuels by stationary or on board reformers is a near-term option for transportation or stationary uses.

• Distribution of hydrogen with personal and large central electrolyzers is a near term option.

• Use of existing methane pipelines to concurrently distribute hydrogen, with large centrally located generation plants is a longer-range option.
Transition to Nuclear/Hydrogen Now

- Off-peak nuclear power
- Distributed Electrolyzers
- Ubiquitous distribution - the electrical grid
Chicken and Egg Problem

- Large numbers of fuel-cell vehicles, without adequate fuel availability, are not possible. However, the required infrastructure will not be created unless there are significant numbers of fuel-cell vehicles.

- Stuart—The first path-distributed electrolytic hydrogen at fleet sites or at the vehicle by “Hydrogen Fuel Appliances”. These use the existing electrical grid to transmit energy.

- Key issues that must be addressed include subsidy funding, incentives for developing refueling stations, creation of uniform standards, and general education about the topic.
Nuclear Reactors of the World
Energy for Tomorrow

Hydrogen Production from Nuclear Energy
Sustainability

- Optimistic growth rate for nuclear power without hydrogen generation is 2.5% per year

- The growth rate could double or triple should the market for hydrogen production from nuclear energy materialize

- The sustainability of the nuclear/hydrogen option would be questioned

- Fast breeder reactors would receive renewed attention
Global Energy Outlook

Total known and undiscovered conventional resources = 15.5 million tonnes U

Hydrogen Production from Nuclear Energy

Pioneering Science and Technology
Conclusions

• Hydrogen, when produced from fossil fuels, is no solution for energy independence or environmental compatibility.

• Wind, solar, and geothermal do not possess the energy density to generate sufficient hydrogen.

• The transition to a nuclear/hydrogen economy can begin today with electrolysis.

• Should the nuclear/hydrogen vision materialize then uranium resource depletion becomes important.