Lessons and Challenges for Early Hydrogen Refueling Infrastructure

Marc W. Melaina
Hydrogen Technologies and Systems Center, NREL

Presented at the Lessons Learned for Hydrogen Workshop
Presentation Overview

• Learning from Past Alternative Fuel Vehicle Experiences
  • Lessons from the previous NREL Workshop (July 2006)
• Lessons and Challenges for Hydrogen Infrastructure
  – How many stations?
  – How many vehicles per station?
  – Early gasoline faced no chicken-and-egg problem
• Timing, Geography and Risks
Introduction: Learning from the Past

The learning process involves interpreting feedback to improve decision making.

- **Past Experience**
- **Outcome**
- **Forecasts & Scenarios**
- **Decision Making**

Reference + Assumptions

- **Feedback**

**New context today**
- Technology has improved
- Oil is above $100 a barrel
- Peak Oil and Climate Change drivers overshadow Air Quality
- Regulatory agencies are taking on greenhouse gas emissions
AFVs have an Extensive History

- Alternative Fuel Vehicle Policy Initiatives
  - Nixon (1973) Domestic Oil & Nuclear: Zero imports in a decade
  - Carter (1977) Efficiency & Synfuels: Cut imports in half by 1985
  - Bush (2007) Alt fuels & CAFE: 20% gasoline reduction in 10 years
- Various policy strategies have been pursued
  - Mandates, tax credits, grants, renewable fuel content, etc.
- Waves of Enthusiasm
  - Ethanol
  - Methanol
  - Natural Gas
  - Electric Vehicles
  - Hydrogen
  - Biofuels
  - Plug-in Hybrids
Recommendations from NREL’s previous Lessons Learned Workshop (July 20th, 2006)

1) Set realistic deployment goals. Don’t let deployment get out ahead of research and development.

2) Educate policy makers, OEMS, vehicle dealers, fleets and consumers.

3) Address both vehicle and infrastructure costs.

4) Create and maintain a cohesive, consistent national policy.

5) Use local efforts for deployment.

6) Use fleets for initial deployment, but create a strategy to leap to the individual consumer market.

Focus of this workshop:
• Adequate refueling infrastructure is fundamental to near-term vehicle commercialization
Lessons from the “Fleets” Strategy

• In theory, fleets are an ideal niche market
• In reality, fleets are troublesome as ideal early adopters
  – Many fleet vehicles refuel at public refueling infrastructure
  – Fleet facilities are not always appropriate locations for public refueling stations
  – Fleet operators are relatively conservative in terms of accepting technological risks
  – Many fleets require a diverse set of specialized vehicles
Lessons for Hydrogen Infrastructure
Significant Refueling Infrastructure must Precede Vehicle Mass Production

- Refueling availability at 10% of existing stations satisfied most early diesel and natural gas vehicle adopters
  - Surveys: New Zealand (CNG), Southern CA (diesel)
  - But 10% of what? 25% station reduction from 1991 to 2006

Station densities vary significantly among cities

Melaina, Energy Policy 2008
CNG Success stories have achieved a ratio of about 1000 - 1300 vehicles per Station

\[ \text{VRI} = \text{Vehicle-to-Refueling Station Index (1000s vehicles/station)} \]

Yeh, Energy Policy 2007
Early “Non-Station” Refueling Methods

- Gasoline had limited markets in urban and rural areas before gasoline vehicles (cans)
- “Non-station” methods preceded stations around 1900-1920
- 10s of thousands of non-station outlets were in place ~1910

Barrels

Hand Carts

Home pumps
Timing and Geography
Geography is Key

ORNL Scenarios Study
Developed through DOE Workshops (Sig Gronich)

Phase I (2012-2015)
Phase II (2016-2019)
Phase III (2020-2025)
Timing is Key

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<th>Growth Phase</th>
<th>Phase I</th>
<th>Phase II</th>
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<td>10 stations</td>
<td>X stations</td>
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<td>(Los Angeles + New York City)</td>
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<td>emergent capability for cross-country travel</td>
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Beyond Transition: Market Sustainability

ORNL Scenarios Study 2008
The Early Transition Period: Managing Risk

- Underutilization of stations
- Economies of scale (1500 kg/d?)
- Competition among stations
- Number of stations

Cost H₂
[$/kg]

Hard Part?

ROI RISK!

Number Vehicles

~2015  2025?  2035?
Thank You!
Backup slides
Metro cost penalties are relatively high

At 10% of existing stations, cost penalty is $3000 - $4000
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