Electrolysis Development and Hydrogen Infrastructure

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Why are we here?

Can we produce hydrogen using electrolysis on a large scale to support hydrogen fuel cell transportation and other markets?

Outline

Present US Department of Energy and National Laboratory concepts on hydrogen production from electrolysis

- General electrolysis fueling overview
- Near term hydrogen electricity integration
- Grid based renewable hydrogen integration

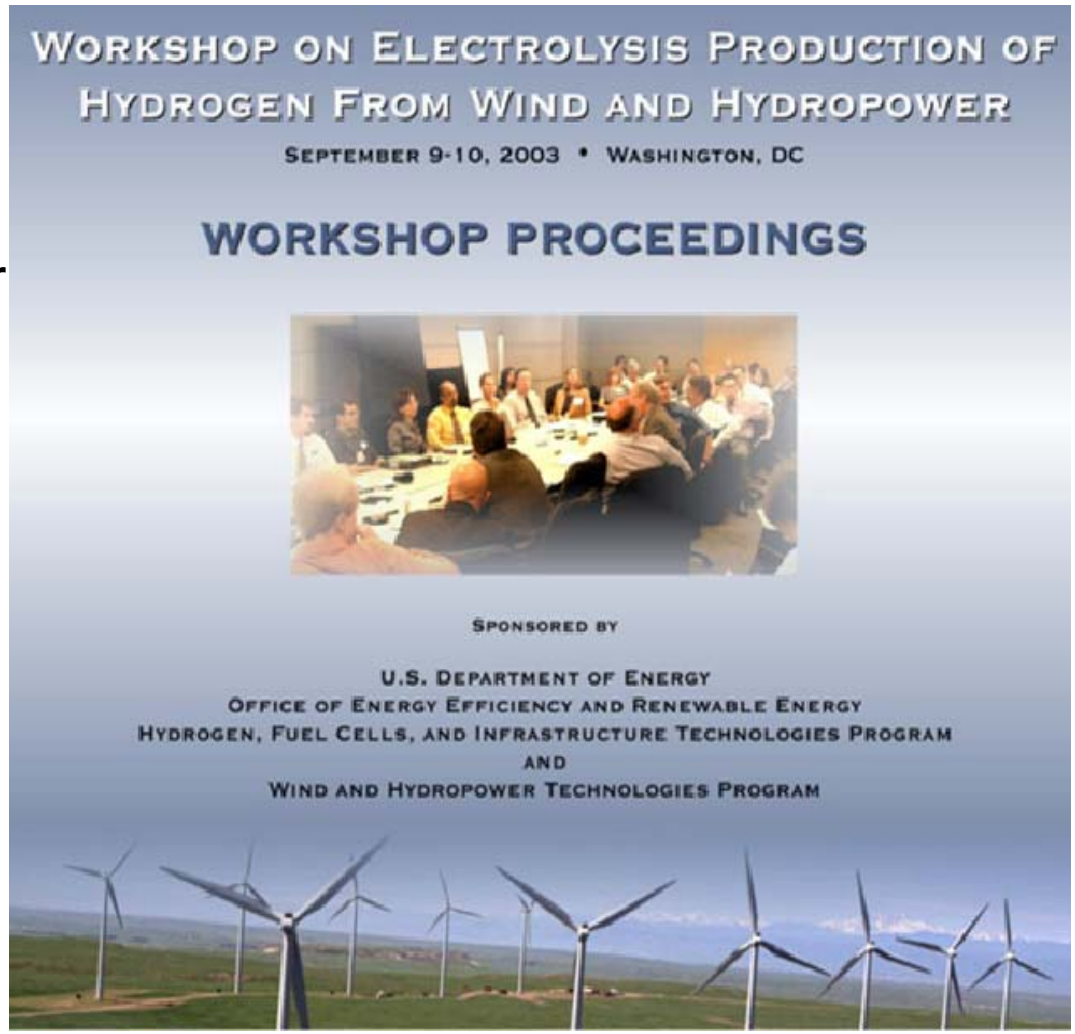
Receive feedback from industry on viability of concepts

Envision path forward on electrolysis technology

Background

September 9-10, 2003 meeting on electrolysis hydrogen production from wind & hydropower

- Potential for low-cost electricity
- Utility-scale, efficient electrolyzers
- Need to involve more electricity stakeholders to address requirements for hydrogen production



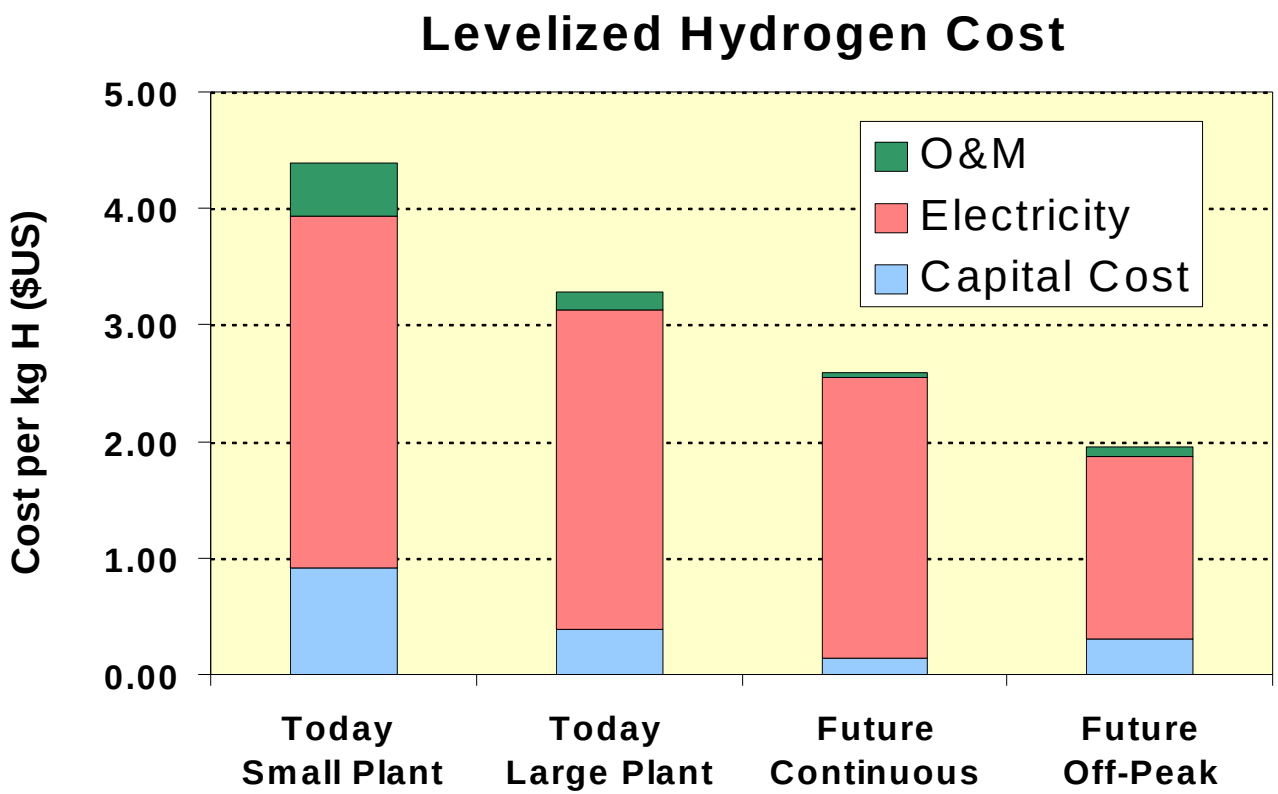
Electrolysis Goals

- Produce Hydrogen for 10 – 30% US Light Duty Vehicle Fleet
- Improve GHG emissions on well to wheels basis versus conventional gasoline vehicles
- Economically competitive with conventional fuels
- Produced using domestically-available resources

Technology Barriers

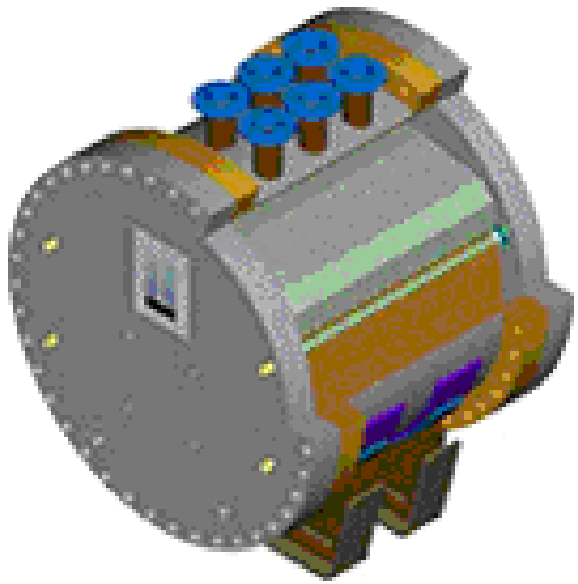
- Electricity cost and emissions
- Delivery (electrons vs hydrogen)
- Capital Cost
- System Efficiency

Electrolysis Costs



Electrolyzer Development Goals

- 250kW to 3MW system designs
  - Transition fueling to large station
  - Larger sizes help to justify industrial rates
- System efficiency 74% LHV at 400+psi
- Capital cost of $300kWe installed large system
- Hydrogen production cost of $2.85 per kilogram hydrogen



Hydrogen Delivery Options

- **Distributed**-utilize electricity infrastructure to reach hydrogen fueling station
- **Centralized**-utilize electricity infrastructure to production facility and then use trucks, pipelines, etc. to deliver the final 10-30 miles to fueling station

Electrolysis Fueling Station

- Located in similar fashion as current gasoline stations
- 1500 kg per day ~ 300 vehicles
- 3 MW electrolyzer uses 68 MWh per day
- Onsite Storage of ~ minimum of 1 day (1500 kg at 6000 psi)
- Electricity required at 4.5 cents per kWh or less to achieve $2.85 per kilogram

Substation Terminal Electrolysis

- 20-100MW city gate hydrogen facility
- Compressed gas truck delivery to stations
- 10,000-50,000 kilograms hydrogen per day serves 5-30 hydrogen fueling stations
- Electricity required at 3.5 cents per kWh or less to approach $2.85 per kilogram
- Delivery charge adds ~70 cents per kilogram for delivered hydrogen to end user

Grid Emissions & Electrolysis

- Typical grid mix electricity increases CO2 emissions using electrolysis for vehicles
- 31% CO2 emissions reduction from grid mix required to equal 27.4 mpg gasoline vehicle
- 65% CO2 emissions reduction required from grid mix to equal distributed steam methane reformed hydrogen
- Electrolysis offers a pathway to carbon free fuel for transportation sector

Electricity Challenges

- Low Price (3.5-4.5 cents per kWh or less)
- Net reduction in CO_2 emissions
- New electricity infrastructure for 250kW to 3MW stations and centralized stations?

Electricity Load Growth

- 20% Light duty vehicle fleet requires 12 million short tons hydrogen
- At 74%LHV requires 450 TWh of electricity annually
- How will the electricity infrastructure cope with this growth?
- Will this growth benefit the utility industry?

Electricity Assumptions

- Will require industrial electricity rates through aggregation or other means
- New low-cost generation technologies such as wind will be utilized
- Creative financial arrangements with off peak generators
- Real time optimization of electricity and hydrogen production on the grid

Electricity Opportunities

- New market opportunity (transportation fuel production)
- Better utilization of off-peak generation and transmission
- Electricity infrastructure could utilize electrolysis to improve grid reliability

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