The Business Case for Hydrogen-powered Passenger Cars: Competition and solving the Infrastructure Puzzle


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The University of Chicago
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*EPIC = Energy Policy Institute at Chicago
## Overview

### Timeline
- **Start date:** Feb. 2015
- **End date:** Ongoing project

### Budget
- FY14 DOE Funds: 0
- FY15 DOE Funds: $100k
  - Including partners

### Barriers
1. Uncertain future market behavior (viz., fuel costs)
2. Lack of existing market experience for H₂-powered passenger vehicles – and the as-yet unanswered question of market acceptability for H₂-fueled passenger vehicles
3. Inconsistent data, assumptions and guidelines in existing literature
4. Unanticipated technological developments

### Partners/Collaborators

**Funded partners:**
- Univ. of Chicago faculty: Energy Policy Institute at Chicago [EPIC]*, Booth School of Business and Harris School of Public Policy
- Univ. of Chicago students: Ryan Huffman, Itzhak Sigron
- Argonne National Laboratory

**Collaborator:**
- Automotive OEM

* A joint program of the Booth School of Business, the Harris School of Public Policy and the Department of Economics, all at the University of Chicago
Relevance

• A plausible business case for marketing H₂-powered fuel cell passenger vehicles is essential
  – for any manufacturer to proceed producing such cars, and producing/distributing H₂
  – for any VC to consider investing in this market
  – forms the economic justification for the DOE Hydrogen & Fuel Cells Program

• The complete business case analysis requires
  – examination of the competitive posture of such vehicles in the market place
  – study of the business case for a plausible H₂ fuel distribution scheme
    • “plausible” = capital and operating costs, as well as geographic distribution, are consistent with a successful competitive posture vis-à-vis the existing fossil fuel-based vehicle support infrastructure

– Our project’s analyses are aimed at supporting such business case analyses, eventually including the behavioral economic issues
– This document provides a progress report on our 1st two months of study
Approach: 1 – Steps and Status

1. Establish
   Build our team; identify data sets; and and our approach
   (2015, February)

   • Identify and hire collaborating graduate students, and gather information produced by a graduate class exercise on H₂ vehicle industry (car manufacturers, H₂ vendors, ...)
   • Discuss approach with ANL and DOE-FCTO

2. Prototype
   Gather initial cost data sets and build 1st model
   (2015, Feb-March)

   • Collect initial data set for costs for various fuel technologies from industry and lab sources
   • Gather car manufacturer/dealer data
   • Discuss with ANL, Auto OEM, H₂ providers

3. Prototype
   First-cut H₂ production and deployment strategies model
   (2015, April-June)

   • Refine data for H₂ production & distribution technologies costs (viz., H2A)
   • Validate with ANL/NREL/DOE-FCTO fuel cell programs

3. Refine
   Vet data and analyses, consider marketing issues
   (2015, May-September)

   • Validate data and analyses with stakeholders, including commercial vendors
   • Results framed as a business analysis for VC community
   • Sensitivity & uncertainty analyses
Approach: 2 – Program Interconnections and Deliverables

Analysis Framework
- H2A design parameters
- HDSAM design parameters
- OEM capital & O&M costs
- Stakeholder experience/data
- 3rd party car and fuel costs analyses

Models & Tools
- H2A
- HDSAM/HRSAM
- UChicago business analysis tools

Stakeholder Analyses
- Automotive OEM and station manufacturers
- Air Liquide
- Air Products

National Labs
- ANL – HDSAM/HRSAM
- NREL – H2A

3rd Party Studies & Analyses
- Energy Independence Now (EIN 2012)
- McKinsey (2012)
- National Petroleum Council (NPC 2012)
- NRC (2013) analyses

Outputs & Deliverables
- Independent assessment of costs and their uncertainties
- Business case statement for VC community

Stakeholders, FCTO & External Reviews
Accomplishments and Progress: 1 - Background

• Our project entails examination of two distinct business cases
  a. Competitive analysis for H₂-powered fuel cell passenger vehicles
     • Analysis of extant data – including identification of provenance and uncertainties – and modeling of the overall competitive cost structures
  b. Comparative analysis of various means of producing and delivering H₂ to the ultimate customer
     • Analysis of extant data – including provenance, uncertainties, and technological readiness
     • Analysis of extant proposed models for infrastructure development
• Project started 1 February 2015; we report progress as of early April 2015
  • We have finished the ‘first-cut’ competitive analysis for H₂-powered fuel cell passenger vehicles, based on the net present value (NPV) of the vehicles, etc.
  • We have completed a 0th-order cost analysis of H₂ infrastructure development
• An example of one of the variety of cases we have examined in detail is on the next slide ...
Accomplishments and Progress: 2 - Results

KEY ASSUMPTIONS:

- Learn-by-doing ongoing for H₂, esp. for distribution
- All other technologies have effectively ‘learned’ ...
- H₂ distribution infrastructure utilization at ~80%
- No technological surprises ...
- State or federal incentives not accounted for; no carbon tax
- No residual value at end of life

REPRESENTATIVE RESULTS:

- HFCVs become highly competitive w/ BEVs within 15 years, and at comparable costs will have substantially larger range
- At the 2015 $57.5K (US) price point and feature package, Mirai currently has no effective competitor in the low-CO₂ emission regime
Responses to Previous Year Reviewers’ Comments

• This project was not reviewed last year
Collaborations

• Argonne National Laboratory
  – Prime contractor for UChicago activities and primary collaborator, inside the DOE Hydrogen and Fuel Cells Program
  – Is serving as our main technical support for fuel cell, automotive and H₂ production technology information
  – We work directly with the key ANL staff (including M. Mintz and M. Wang)

• Related collaboration
  – Some of our assumptions have been gathered from a related research project, which included inputs from an automotive OEM
Remaining Challenges and Barriers

• Business Case: Competitive analysis challenges
  – **Learning curve for passenger car-scale fuel cell technology remains uncertain** – effects of high volume production not yet established
  – **Competitive postures depend on**
    – regional and seasonal variations in fuel and distribution costs
    – market segment, e.g., the retail price point at which the H₂ vehicle is marketed
  – **Future fossil fuel costs highly uncertain**
  – **Market acceptance remains to be established, and may well vary considerably country-to-country**

• Business Case: H₂ production/distribution challenges
  – **Optimal H₂ production technology not yet established**
    – For example: Centralized vs. distributed H₂ generation?
  – **Learning curve (“learn by doing”) is highly uncertain, and will depend on the nature of the H₂ production and distribution path chosen**
Proposed Future Work

• FY 15: Completion of business case analyses
  – Completion of competitive analysis for H\textsubscript{2}-fueled fuel cell-driven passenger vehicles
  – Completion of first-cut competitive analysis for H\textsubscript{2} distribution infrastructure

• FY 16: Validation of business case analyses
  – Market analysis of roll-out of first-generation H\textsubscript{2}-fueled fuel cell-driven passenger cars during FY 15/16
    • Examine early evidence for “learn-by-doing”
    • Analysis of competitive environment, including consumer preferences and attitudes (such as public acceptance of H\textsubscript{2} vehicle technology for passenger cars), and marketing issues
  – Market analysis of first round of installation of H\textsubscript{2} distribution infrastructure
Technology Transfer Activities

• Our approach to business case analyses has been motivated by our detailed discussions with the automotive industry – a case of industry motivating work in academia …

• Our business case results are also being shared with the automotive industry … here our academic results are informing the automotive industry
1. **In the 1st two months** (2-3/2015) of our project, *we have completed* a “first cut” analysis of the competitive posture of H₂-fueled passenger cars in the market place
   - **Main results:**
     - Fuel cell-driven H₂-powered vehicles can be cost-competitive with passenger vehicles using other fuels in ~10-15 years
     - Such cars have operating costs and driving ranges comparable to gasoline-powered passenger cars
     - Such cars have substantially larger driving ranges than their battery-powered vehicle competition

2. **We have initiated** the “first cut” analysis of the extant H₂ production and delivery technologies
   - The 0th-order version of this analysis has already been used in our life-cycle cost analysis for H₂-fueled vehicles, see above point 1.
Technical Back-up Slides
Data Sources


# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANL</td>
<td>Argonne National Laboratory</td>
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<td>EPIC</td>
<td>Energy Policy Institute at Chicago</td>
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<tr>
<td>BEV</td>
<td>Battery-powered Electric Vehicle</td>
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<td>CNGV</td>
<td>Compressed Natural Gas-fueled Vehicle</td>
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<td>FCTO</td>
<td>Fuel Cell Technology Office</td>
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<td>H₂</td>
<td>Hydrogen (more usually written as H₂, since hydrogen is a diatomic molecule in its usual gaseous phase)</td>
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<td>H₂A, HDSAM, HRSAM</td>
<td>FCTO program analysis tools</td>
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<td>HEV</td>
<td>Hybrid Electric Vehicle</td>
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<td>HFCV</td>
<td>Hydrogen Fuel Cell Vehicle</td>
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<tr>
<td>ICEV</td>
<td>Internal Combustion Engine Vehicle</td>
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<td>NPV</td>
<td>Net present value</td>
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<td>NREL</td>
<td>National Renewable Energy Laboratory</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>O&amp;M (costs)</td>
<td>Operation and Maintenance (costs)</td>
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<td>PHEV</td>
<td>Plug-in Hybrid Vehicle</td>
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<tr>
<td>UChicago</td>
<td>The University of Chicago</td>
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<tr>
<td>VC</td>
<td>Venture Capitalist</td>
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