Project ID # SA052

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

2015 U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Office
Annual Merit Review and Peer Evaluation Meeting

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The University of Chicago

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*EPIC = Energy Policy Institute at Chicago

THE UNIVERSITY OF CHICAGO | EPIC Energy Policy Institute at Chicago

Argonne NATIONAL LABORATORY

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 H_2-powered passenger vehicles – and the as-yet unanswered question of market acceptability for H_2-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 H_2-powered fuel cell passenger vehicles is essential
  - for any manufacturer to proceed producing such cars, and producing/distributing H_2
  - 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 H_2 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 H_2 vehicle industry (car manufacturers, H_2 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, H_2 providers

3. Prototype
   First-cut H2 production and deployment strategies model

(2015, April-June)

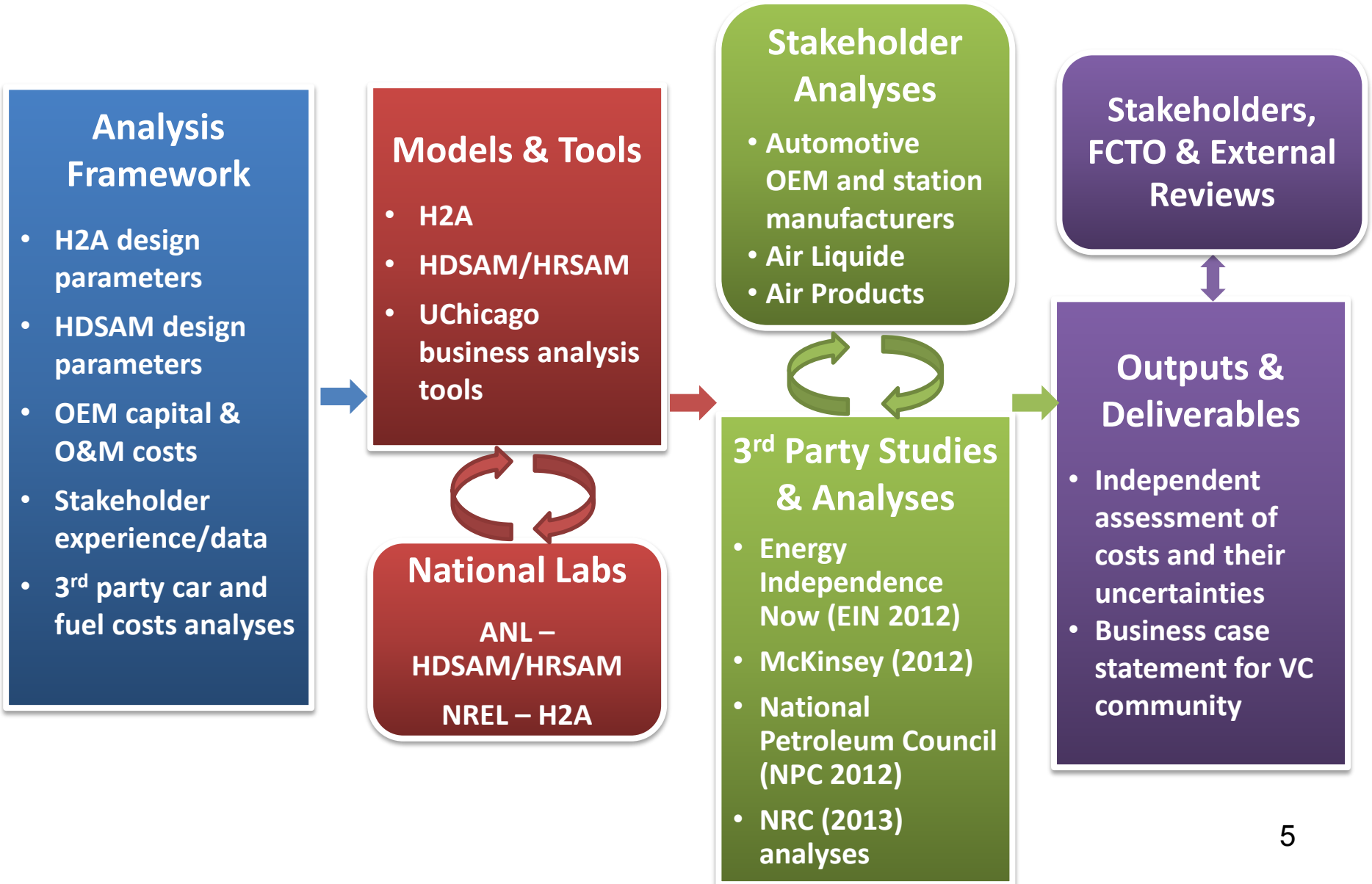
- Refine data for H2 production & distribution technologies costs (viz., H2A)
- Validate with ANL/NREL/DOE-FCTO fuel cell programs

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



Accomplishments and Progress: 1 - Background

- Our project entails examination of two distinct business cases
  - *a. Competitive analysis for H_2-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 H_2 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 H_2-powered fuel cell passenger vehicles, based on the net present value (NPV) of the vehicles, etc.
  - **We have completed** a 0^{th}-order cost analysis of H_2 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

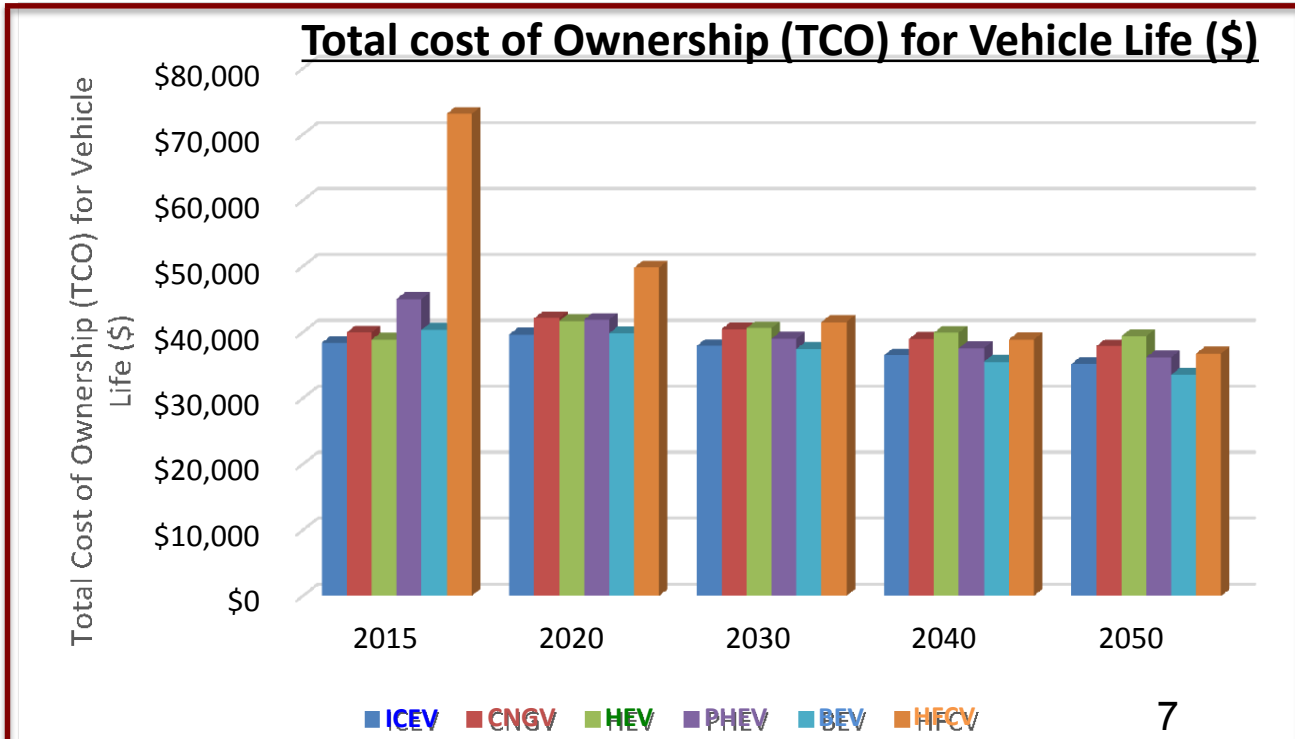
KEY ASSUMPTIONS:

- Learn-by-doing ongoing for H_2, esp. for distribution
- All other technologies have effectively 'learned' …
- H_2 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

	Camry	Honda Civic	Camry HEV	Volt Plug-In	Focus BEV	Mirai HFCV
Cost Categories	ICEV	CNGV	HEV	PHEV	BEV	HFCV
Vehicle Cost	Medium	Medium	Medium	Medium	Medium	High
Fuel Price	Medium	Medium	Medium		Medium	Medium
Efficiency Gain	Medium	Medium	Medium	Medium	Medium	Medium
Maintenance Costs	Medium	Medium	Medium	Medium	Medium	Medium
Low GHG				No		No
Carbon Tax	None					
Vehicle Lifetime	12	years				
Miles Per Year	10088	miles				
Discount Rate	5%					

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-CO_2 emission regime



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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 H_2 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 H_2 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: H_2 production/distribution challenges
  - Optimal H_2 production technology not yet established
    - For example: Centralized vs. distributed H_2 generation?
  - Learning curve ("learn by doing") is highly uncertain, and will depend on the nature of the H_2 production and distribution path chosen

Proposed Future Work

- FY 15: Completion of business case analyses
  - Completion of competitive analysis for H_2-fueled fuel cell-driven passenger vehicles
  - Completion of first-cut competitive analysis for H_2 distribution infrastructure
- FY 16: Validation of business case analyses
  - Market analysis of roll-out of first-generation H_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_2 vehicle technology for passenger cars), and marketing issues
  - Market analysis of first round of installation of H_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

Summary Slide: Progress and Accomplishments

1. **In the 1st two months** (2-3/2015) of our project, **we have completed** a "first cut" analysis of the competitive posture of H_2-fueled passenger cars in the market place
   - **Main results:**
     - Fuel cell-driven H_2-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 H_2 production and delivery technologies
   - The 0^{th}-order version of this analysis has already been used in our life-cycle cost analysis for H_2-fueled vehicles, see above point 1.

Technical Back-up Slides

Data Sources

AAA – *Your Driving Costs 2014*, American Automobile Association. 2014.

EIA - *Annual Energy Outlook 2014,* U.S. Energy Information Administration. 2014.

EIN – *Incentivizing Hydrogen Infrastructure Investment: Phase 1: An Analysis of Cash Flow Support To Incentivize Early Stage Hydrogen Station Investment*, Energy Independence Now. 2012.

GreenCarReports - *Ford Plug-In Drivers Do 60% Of Miles On Electricity (Just Like Volt)*, GreenCarReports.com. 2013.

H2A - *The Hydrogen Analysis (H2A) Project*, U.S. Department of Energy. 2012.

McKinsey – *A portfolio of power-trains for Europe: a fact-based analysis*, McKinsey & Company. 2010.

NPC – *Advancing Technology for America's transportation future,* The National Petroleum Council. 2012.

NRC - *Transitions to Alternative Fuels and Vehicles,* National Research Council. 2013.

NREL - *Hydrogen Pathways: Updated Cost, Well-to-Wheels Energy Use, and Emissions for the Current Technology Status of Ten Hydrogen Production, Delivery, and Distribution Scenarios*, National Renewable Energy Laboratory. 2013.

Acronyms

ANL	Argonne National Laboratory
EPIC	Energy Policy Institute at Chicago
BEV	Battery-powered Electric Vehicle
CNGV	Compressed Natural Gas-fueled Vehicle
FCTO	Fuel Cell Technology Office
H_2	Hydrogen (more usually written as H_2, since hydrogen is a diatomic molecule in its usual gaseous phase)
H2A, HDSAM, HRSAM	FCTO program analysis tools
HEV	Hybrid Electric Vehicle
HFCV	Hydrogen Fuel Cell Vehicle
ICEV	Internal Combustion Engine Vehicle
NPV	Net present value
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
O&M (costs)	Operation and Maintenance (costs)
PHEV	Plug-in Hybrid Vehicle
UChicago	The University of Chicago
VC	Venture Capitalist