HTAC Review
Automotive Fuel Cell Competitive Intelligence

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Today’s Purpose

**Global Automotive Industry Challenges - Energy & Environment**
- Portfolio of technologies needed

**Global Automotive Fuel Cell and H₂ initiatives - Germany & Japan**
- National Plan
- Hydrogen infrastructure
- Automotive offerings

**Conclusions and Implications**
Automotive Industry Challenges (Energy and Environment)

– Portfolio of technologies needed
**DOE EIA 2030 Outlook – Reference Case**

- Continued steady growth in vehicle miles traveled (VMT)
- Upward fuel price trend (highly uncertain)
- Fuel economy improvements offset growth in VMT
- Fuel use remains relatively flat (this is a break from past 40 year trend)
U.S. LDV Transportation – 2050 GHG Reduction Goal

U.S. goal is 80% reduction from 1990 levels by 2050

• Assuming light duty transportation must reduce its GHG footprint in equal proportion to other contributing sectors of economy:

1990 fuel use: 105 billion gallons
1990 GHG: 1,220 million tons CO₂ equivalent

80% reduction

2050 GHG goal: 244 million tons CO₂ equivalent (or less)

LDV 2050 GHG Goal is 244 million tons CO₂ equivalent
All Options in Play – The Power of “AND”

Petroleum Consumption

- Cellulosic biomass ramps to high volume; BEVs / EREVs make 40% of VMT electric; FCEVs penetrate to 40% of parc by 2050
  - Petroleum out of picture by 2032
  - LDV parc mostly transitioned to electric drive and ZEV solutions
  - US grid GHG modeled at 80% lower than 2008 levels
  - Hydrogen from cellulosic biomass or clean electricity

Start soon with early options; finish with strongest long-term solution
Advanced Propulsion Technology Strategy

- Improved Vehicle Fuel Economy & Emissions
- Displace Petroleum
- IC Engine and Transmission Improvements
- Hybrid Electric Vehicles (including Plug-In HEV)
- Battery Electric Vehicles (EREV)
- Hydrogen Fuel Cell
- Hydrogen
- Electricity (Conventional & Alternative Sources)
- Alternative Fuels (Ethanol, Bio-diesel, CNG, LPG)
- Petroleum (Conventional & Alternative Sources)

Energy Diversity

Time
Vehicle Electrification
Hybrid & Electric Drive Types & Benefits

ICE Power
- Internal Combustion Engine (ICE)
  - SIDI
  - 2-step valve
  - HCCI
  - Turbo boost
  - 6 speed transmissions
  - Active Fuel Management

Hybrid
- Functionality
  - Engine off on deceleration and at idle
  - Mild regenerative braking
  - Electric power assist

2-Mode Hybrid
- Functionality
  - Full regenerative braking
  - Engine cycle optimization
  - Electric launch
  - Limited pure electric drive
  - Engine downsize

2-Mode Plug-in Hybrid
- Functionality
  - Plug-in rechargeable
  - More electric drive during charge-depletion
  - Reduced refueling

Extended Range Electric Vehicle
- Functionality
  - Full-function electric drive
  - Initial pure electric range
  - Significantly reduced refueling
  - 100% pure electric range
  - Energy storage in a battery or hydrogen tank
  - No exhaust emissions

Electric with Mechanical Assist
- Functionality
  - Mechanical with Electric Assist

Battery Electric Vehicle & Fuel Cell
- All Electric

Increasing Level of Efficiency & Reduced Emissions
Global Automotive Fuel Cell and H₂ initiatives - - Germany & Japan

- National Plan
- Hydrogen infrastructure
- Automotive offerings
National Hydrogen Plans

**National Research Council Report**
- 2015 competitiveness established
- $1.8B project budget

**Nat. development plan**
- 2015 target start commercialization
- Infrastructure leads vehicles

**METI / Japan Inc.**
Global Hydrogen Infrastructure Development
(Station Locations - Main areas)
Global Competitors
### Competitive Landscape - Summary

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<th>Demonstration Entry</th>
<th>Commercial Entry</th>
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**OEM plans - vehicle demonstration and commercialization**

**Plans for H₂ infrastructure development**
Germany Initiatives
Main Goal: Develop and implement a strategy for a long term, nationwide market introduction of hydrogen as a fuel for transport in Germany

Launched by automotive industry and energy companies in 1999

Supported by the Federal Government (Federal Ministry for Transport, Building and Urban Development BMVBS)

Initiated CEP in 2002

Delivers transportation related input for National Hydrogen and Fuel Cell Technology Innovation Program (NIP)
Main Goal: Substantially foster hydrogen and fuel cell technology

Duration: 2007 to 2016
Funding volume: € 500M

Execution of the National Development Plan

Planning and execution of Lighthouse Projects

The right program at the right time
Clean Energy Partnership (CEP)
The European Lighthouse Project for Hydrogen Vehicles

- Public-private partnership
- Aim to prove everyday suitability of hydrogen for transport
- Project duration until 2016
- Phase I: 2002 – 04/2008
  - 17 hydrogen vehicles
  - 2 fully integrated hydrogen refueling stations
    - Total: Heerstraße (opened 03/2006)
- Different methods of hydrogen production demonstrated
- CEP service station specialized for hydrogen propulsion
Clean Energy Partnership (CEP)
The European Lighthouse Project for Hydrogen Vehicles

- **Phase I ➔ Phase II**
  - Hamburg 2nd location
  - Aral/BP resigned ➔ Messedamm decommissioned
  - Shell + Hamburger Hochbahn joined

- **Phase II: 05/2008 – 2010**
  - More than 40 hydrogen vehicles
  - 3 fully integrated hydrogen refueling stations:
    ➔ Total: Heerstraße
    ➔ Total/StatoilHydro/Linde: Holzmarktstraße
    ➔ Shell: Sachsendamm
Funding for 25 Pilot H$_2$ Stations included in 2009 Germany Stimulus

- Support a relative oversupply of stations during the early years
Dr. Zetsche, Auto Motor Sport (#1 German Car magazine)

• Fuel Cell Production will begin this summer
  – Ramped up to 100,000 units within the next years
  – FCPS cost competitive to bluetec hybrid within the next 4-5 years at 100,000 units (not anticipated before)

• Hydrogen infrastructure
  – Partnered with Linde
  – Analyzed network of 1000 H₂ stations (max distance 35 km)
  – Investment ~1.7 billion EUR ($2.2B) for Germany

• The end of the fossil fuel age has begun - - Chance for the German Auto Industry to win with better solutions

Key recent media statements:
• Zetsche- - production readiness by 2015
• Wolfgang Tiefensee, German minister of Transportation
  – “We support research, development, and market preparation with 500 mio Euro”
  – “Hydrogen is the fuel of the future: efficient, emission-free, ecological”
Wind-Hydrogen-Plant Construction is Underway (21APR09)
Northeastern Germany (6 MW System)

German Chancellor Angela Merkel @ construction site

Minister President Matthias Platzeck (State of Brandenburg)
Rationale for investment in H₂ and fuel cell
Germany and Daimler

- High consumer and government awareness of environmental issues
- Industry / Governmental focused on gaining competitive advantage
  - Increase energy efficiency
  - Reducing CO₂
  - Diversify primary energy portfolio (given high dependence on imported energy)
- Daimler focused on protecting core profit base (e.g. larger cars) while meeting or exceeding regulations
- H₂ plays a key role in integrated energy system for storage of renewable energy
- Export driven industrialized country - - high technology finished goods and equipment

Source: Now-gmbh
Japan Initiatives
Government / Industry Fuel Cell and H2 Initiatives

• 1992 onwards: METI has funded H2 and fuel cell development “New Sunshine Project”

• In 1997, CO$_2$ was put on high priority due to COP3 (“Kyoto Protocol”)
  – Past initiatives had been driven mainly by energy conversation

• “Millennium Project” 2000-2005 (3 major areas addressed: Information, Aging, Environment), was launched - fuel cells and H2 were picked as key to reduce CO$_2$ emissions

• In 2001, METI facilitated Study Group consisting of representatives of industry, academia, media, national labs, semi-government organizations

• Fuel cells are relevant for vehicular an stationary application
  – Efficient energy use, Less environmental impact, Energy diversification, Distributed generation
  – **Strengthen the industrial competitiveness of a wide range industries**
    • 21$^{st}$ century will be driven by energy efficient and environmentally friendly technologies

• It was agreed that fuel cells are a “key technology” which need to be accelerated towards realization
  – Fuel Cell Commercialization Conference of Japan (FCCJ) was established

Source: Japan Fuel Cell and Demonstration Project Report March 2008 and March 2009

Date: 27Jan09
Government / Industry Fuel Cell and H2 Initiatives

- FCCJ committee has committed to 2015 as the target for FCV commercialization
- Infrastructure should lead vehicle deployment
- Four phases defined
  - Technology Demonstration
  - Technology & Market Demonstration
  - Initial Diffusion
  - Full Commercialization
- Government sponsored program to understand various processes and feed stream sources for H₂
  - 11 different H2 refueling facilities with H₂ from 11 different feedstocks
  - Understand most economical process
  - Develop refueling equipment
Council on Competitiveness-Nippon Interim Report on Fiscal 2008 Project Theme

H₂ Supply Infrastructure Deployment Project

2015

100 stations

2020

1,000 stations

2030

5,000 stations

Fukuoka hydrogen energy strategy conference

Tokyo renewable energy strategy
Energy front runner Chiba

Aichi hydrogen energy industry council
Aichi FCV spread promotion council
Fuel cell vehicle model plot of town

Osaka FCV promotion conference

Example of efforts of local government

Hydrogen highway:
Build hydrogen station at rest area

Environment model and candidate environment model

Hydrogen town:
Deployment of hydrogen station

Less→Station density→High

Source: November 18, 2008
Council on Competitiveness-Nippon (COCN)
Toyota Motor Corp. is counting on a huge reduction in the cost of fuel-cell stacks as it makes a bid to market a fuel-cell vehicle in 2015 -- Goal to retail an FCV in 2015

- 90% cut in cost over the next six years
- Reduced platinum use to 10% of current levels
- Reduce tank costs - Thinner carbon-fiber layer with simplifying valve and regulator design
- 50%-100% increase in power density and stack durability
- Wide operating temperature band from -22°F to 221°F
- Technology may be applied to long-haul trucks and buses

Toyota began leasing FCVs in 2002

- > 60 in operation in Japan (US starting 2009) Highlander FCHV-adv, including eight buses.
- 840k JPY ($9,300) per month (for 30 months = $279,000) lease rate to Japanese Government
- Exceeded its planned 400-mile driving range by more than 100 miles in Japanese Drive Cycle
- Almost doubling of fuel-tank capacity achieved in part by raising pressure levels to 700 bar
- Fuel economy improved 25% by reducing auxiliary system loss and increasing regenerative energy
- Automated fuel cell stack assembly line

Source: Toyota, Ward’s Auto World, TMC
Honda starts producing next-gen fuel cell car

- Honda continues fuel cell development and has led “retail” deployment of FCEVs
- Introduced Honda Clarity in 2008
  - World's first dedicated fuel cell vehicle platform
  - 4 Passenger sedan, 100kW Stack, 4.1 kg H₂, 280 miles range
- Deployment
  - “Retail” (lease-only) FCEV - $600/mo. for 36 months
  - 12 vehicles leased in Year 1
  - Total of 200 units over the next 3 years, starting in California & Japan

Source: Honda.com, NHK
Date: 16Jun08
Rationale for investment in H$_2$ and fuel cell
Japan and Toyota / Honda / Nissan

- Very limited natural resources - “conservation” is part of culture
- Export driven economy - global viewpoint
- Focused on strengthening industrial competitiveness of a wide range industries
- Joint industry / government agreement - energy efficient and environmentally friendly technologies will drive 21$^{st}$ century
- Technology focus
  - Increasing energy efficiency
  - Reducing environmental impact
  - Diversifying energy sources
- Example: Toyota Presentation at Nagoya University, March09
  - Expect oil prices to rise significantly - negatively affect Japanese economy
  - Unrealistic assumption that electricity replaces crude oil for transportation, thus H$_2$ substitution
  - HEVs will reduce CO$_2$ by 30-40% max - Won't solve CO$_2$ and oil issue
  - Fuel cell vehicles are moving towards realization with viable cost models
  - Fuel cell vehicle industry will create value domestically for both vehicle and hydrogen production/distribution

Source: Mr.Hirose, Strategic Planning and Administration Department, Toyota Motor Corporation
Other competitors: Hyundai / Kia

- Hyundai-Kia also plans to commercialize fuel cell electric vehicles by 2012
  - 1,000 units in 2012
  - 30,000 units by 2018
  - Long-term plans for 1M units/year by 2030

- Hyundai-Kia very bullish on the prospect of FCEVs for the South Korean home market
  - Almost half the population lives in very condensed Seoul metropolitan area
  - Nearly all energy sources are imported
  - Only 100 H₂ stations needed to serve Seoul area
GM Gen2 goal is to be "among the few Fuel Cell Leaders" - - Great Product Execution on track to Automotive competitive fuel cell vehicle offering
Fuel Cell Technology: Government & Competitive Landscape Summary

Germany & Japan:
- Long term government / industry collaborations (Auto, Energy) to improve domestic competitiveness & energy security
- High volume H₂ fuel cell vehicle introductions by 2015
  - Addressing CO₂ & energy independence challenges
  - Developing infrastructure to support fuel cell growth
- Daimler, Toyota and Honda are executing aggressive plans for fuel cell technology
  - Leverage learning cycles to mature technology

China & Korea
- Chinese companies are developing internal fuel cell capability
- Korean government & Hyundai are working together to ensure competitiveness by 2015

Other U.S. OEMs:
- Ford scaled back to an R&D project (Technology was from Daimler)
- Chrysler not an active player
GM Competitive Position in Fuel Cell Technology
GM is the only domestic OEM with in-house automotive experience

- GM developed a leadership position
  - GM has over 20 years experience & invested >$1B
  - GM is operating world’s largest fuel cell vehicle fleet (Project Driveway)
  - GM established technology strength in electrochemistry, materials, systems engineering, modeling and packaging
- In total, U.S. Government & Companies invested over $3B
- Given co-dependence of high volume vehicle introduction & refueling infrastructure, GM has invested to remain among the fuel cell leaders
  - Need consistent and long term government policy supporting fuel cell and hydrogen commercialization
  - Need funding initiatives (Fuel cell and H₂ infrastructure development) in light of significant economic challenges
Thank You