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 H_2 initiatives - - Germany & Japan

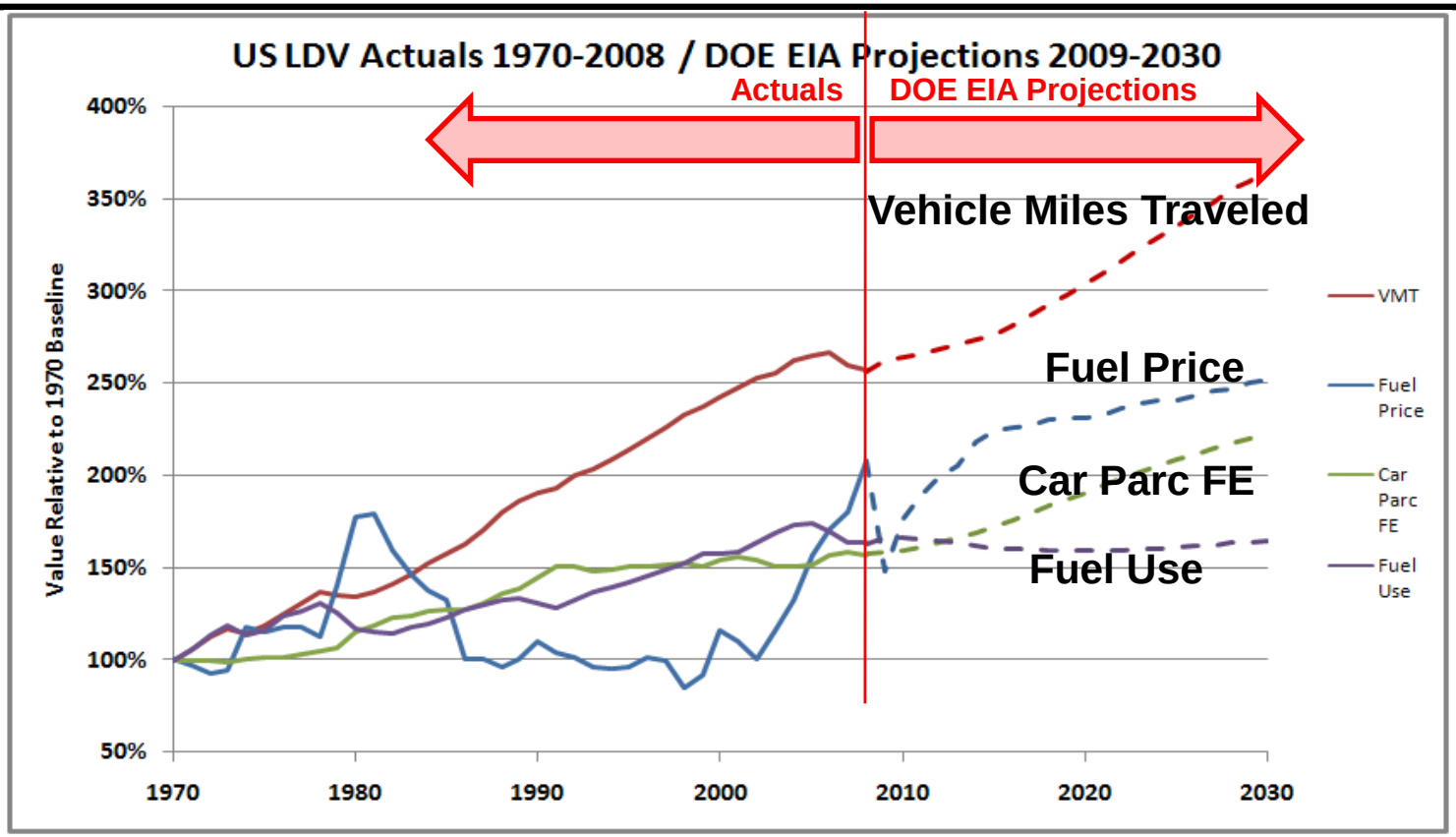
- National Plan
- Hydrogen infrastructure
- Automotive offerings

Conclusions and Implications

Automotive Industry Challenges (Energy and Environment)

- Portfolio of technologies needed

U.S. LDV Transportation – DOE EIA 2030 Outlook



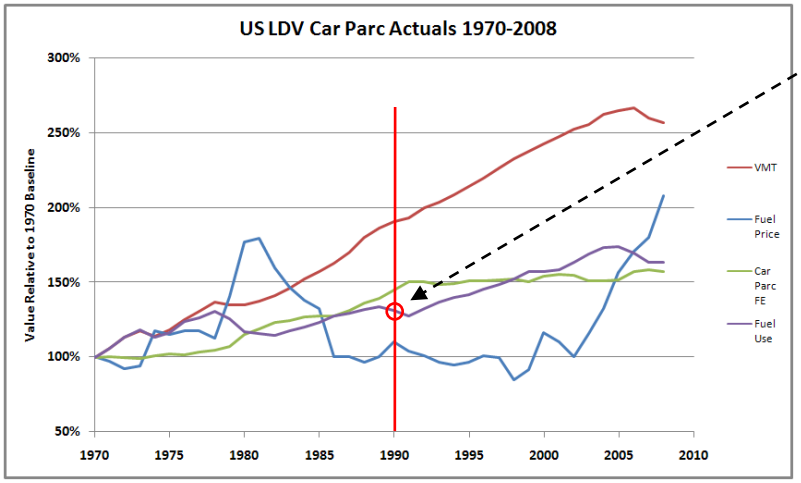
DOE EIA 2030 Outlook – Reference Case

- 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 ➡ **1990 GHG**

105 billion gallons

1,220 million tons CO_2 equivalent

80% reduction

2050 GHG goal

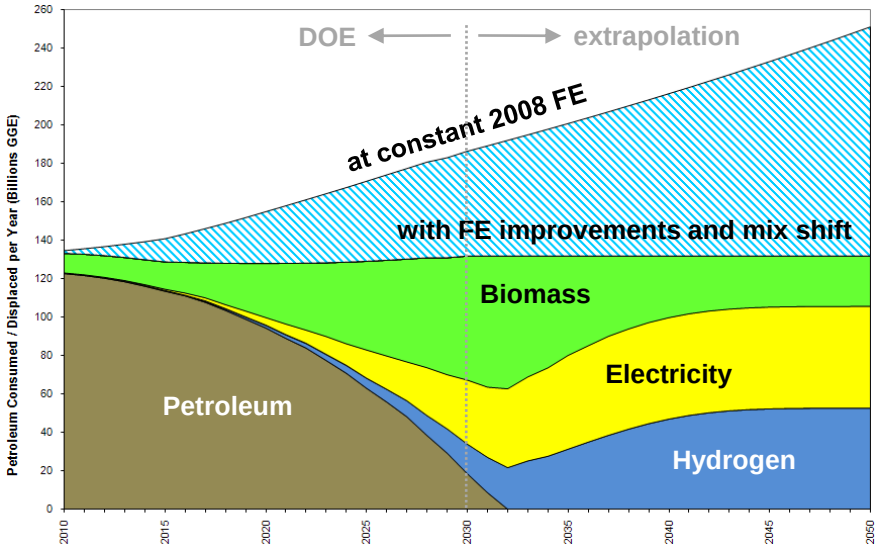
244 million tons CO_2 equivalent (or less)

LDV 2050 GHG Goal is 244 million tons CO_2 equivalent

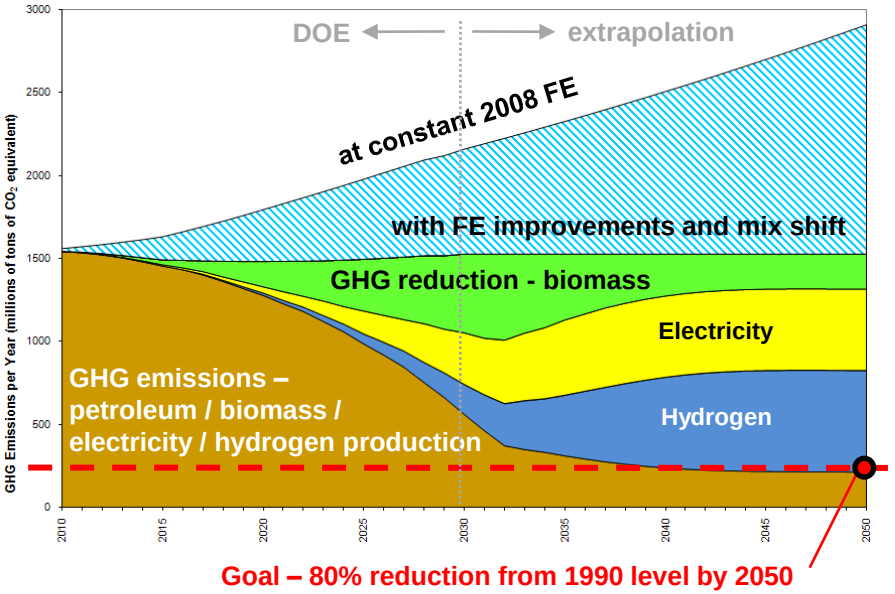
5

All Options in Play – The Power of "AND"

Petroleum Consumption



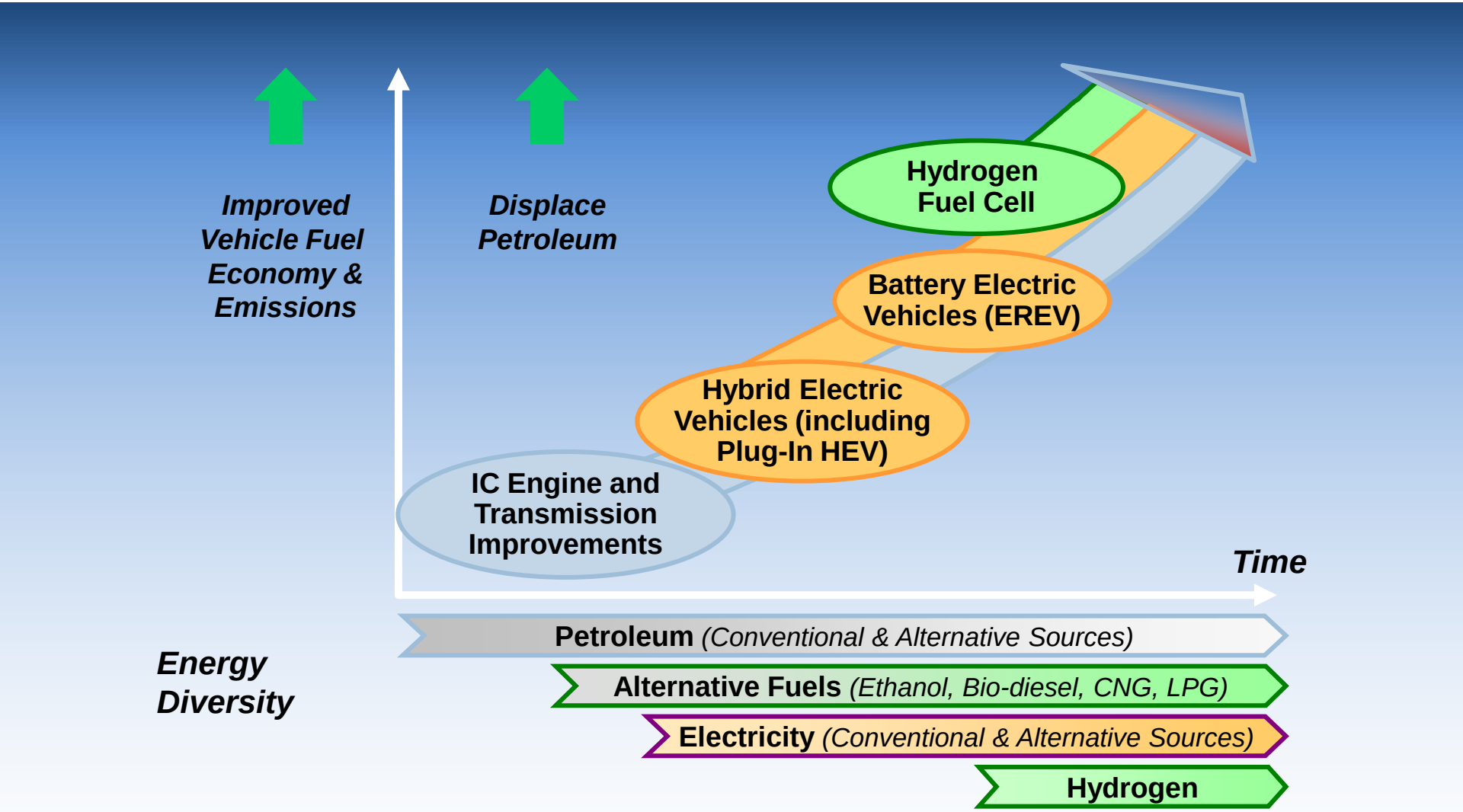
GHG Emissions



- 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



Vehicle Electrification

Hybrid & Electric Drive Types & Benefits

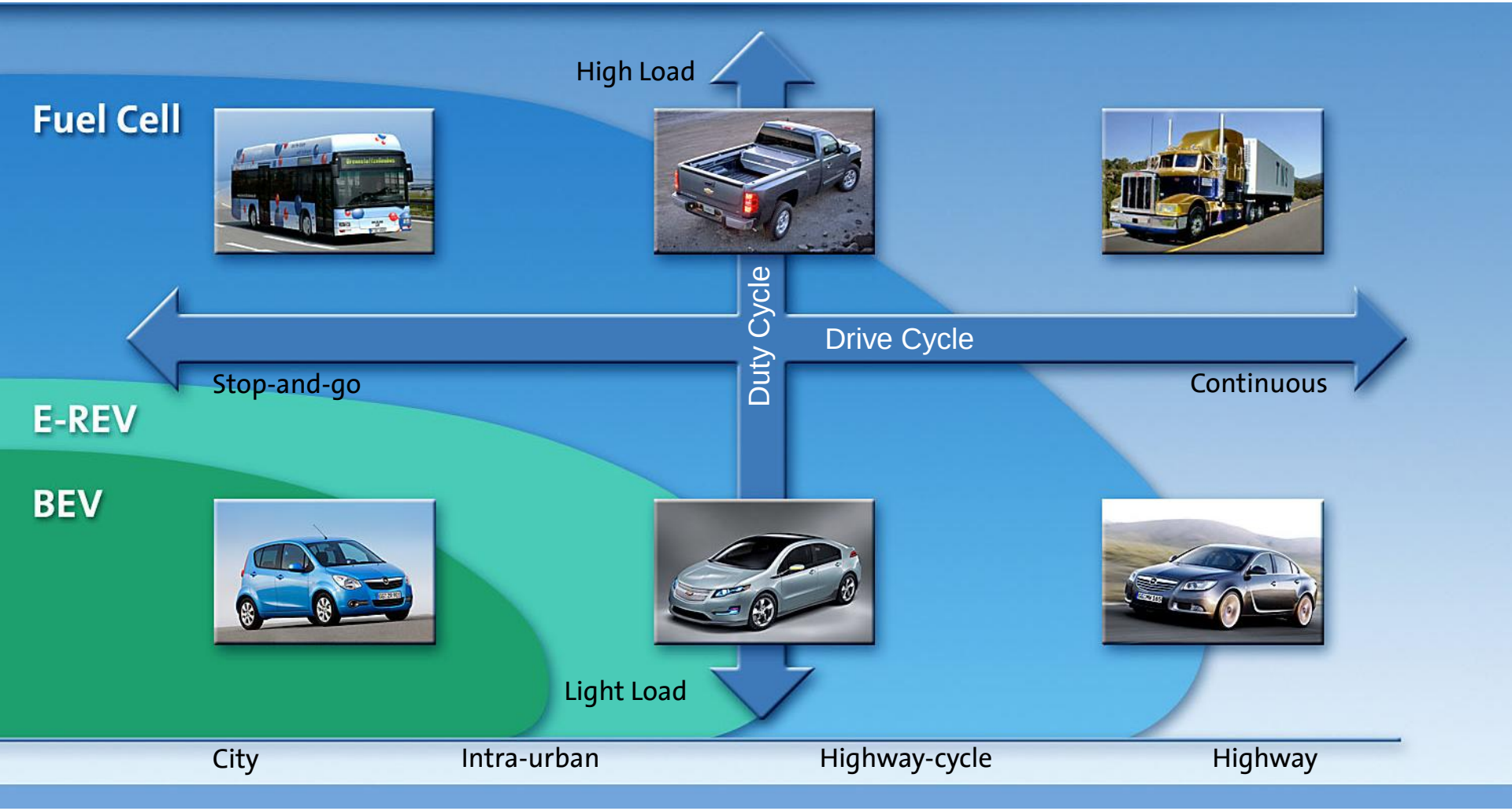
FUNCTIONALITY

DRIVE SYSTEM

Internal Combustion Engine (ICE)	Hybrid	2-Mode Hybrid	2-Mode Plug-in Hybrid	Extended Range Electric Vehicle	Battery Electric Vehicle & Fuel Cell
• SIDI • 2-step valve • HCCI • Turbo boost • 6 speed transmissions • Active Fuel Management	• Engine off on deceleration and at idle • Mild regenerative braking • Electric power assist	• Full regenerative braking • Engine cycle optimization • Electric launch • Limited pure electric drive • Engine downsize	• Plug-in rechargeable • More electric drive during charge-depletion • Reduced refueling	• 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
			Mechanical with Electric Assist	Electric with Mechanical Assist	All Electric

Increasing Level of Efficiency & Reduced Emissions

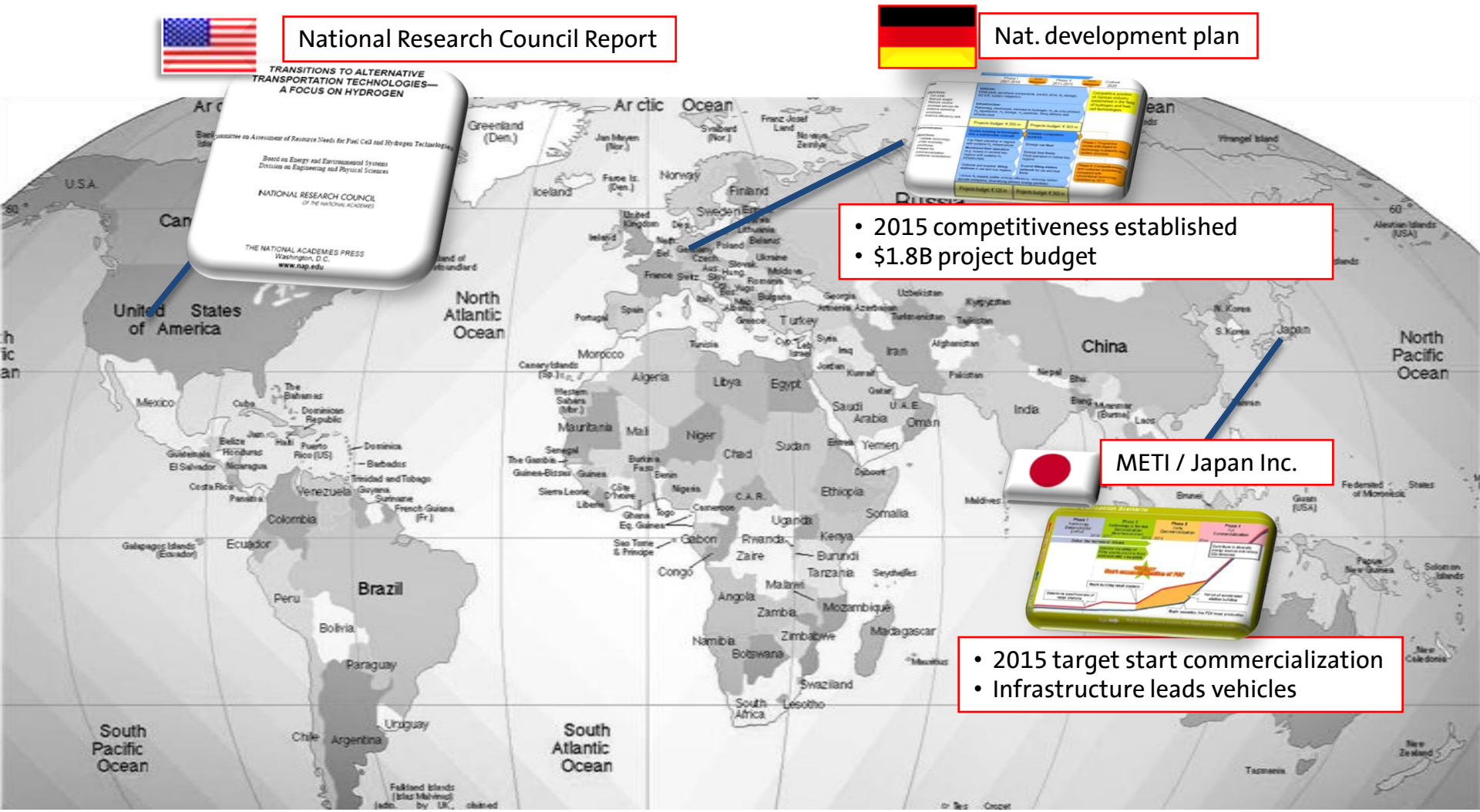
Application Map



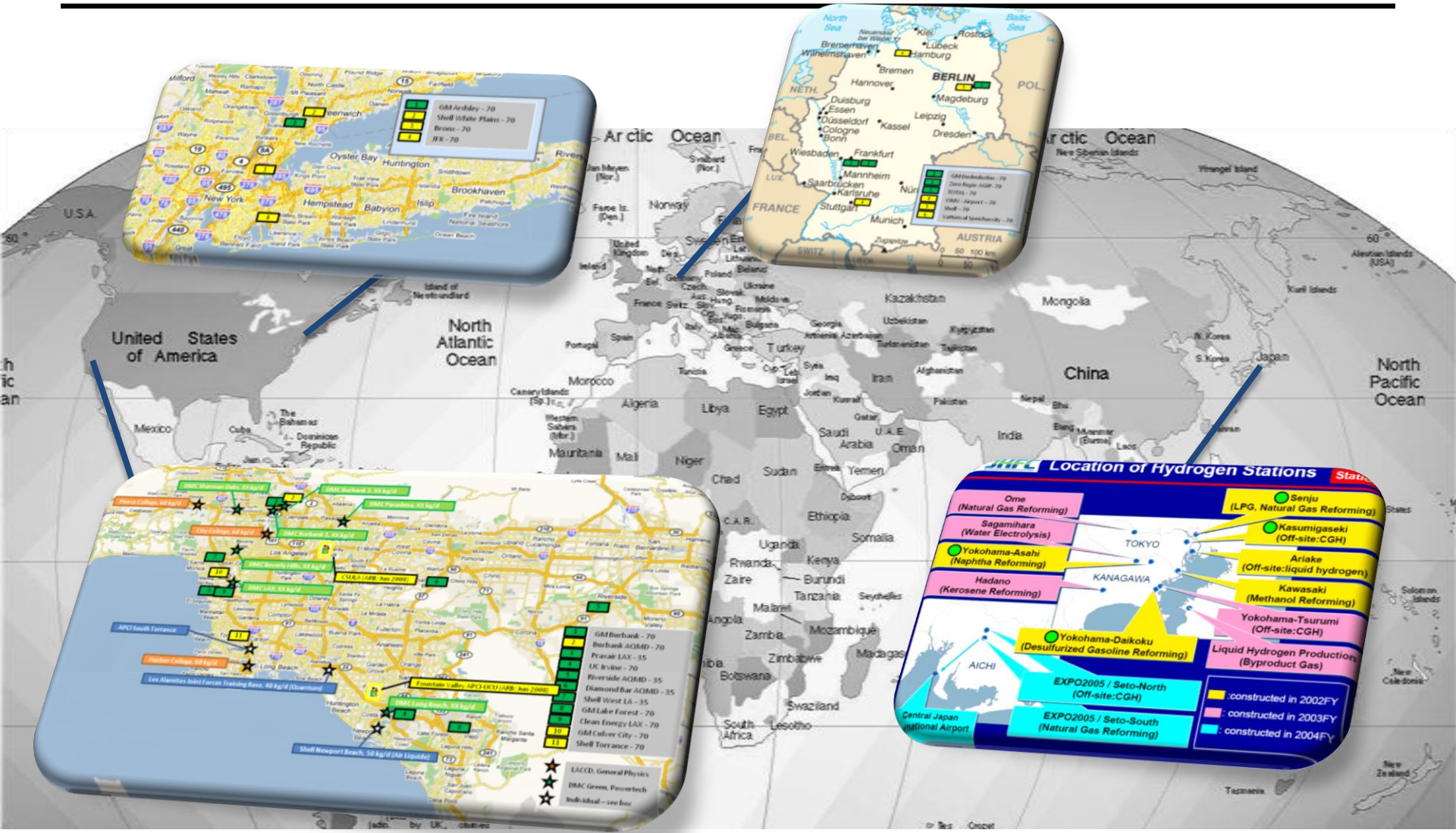
Global Automotive Fuel Cell and H_2 initiatives - - Germany & Japan

- National Plan
- Hydrogen infrastructure
- Automotive offerings

National Hydrogen Plans

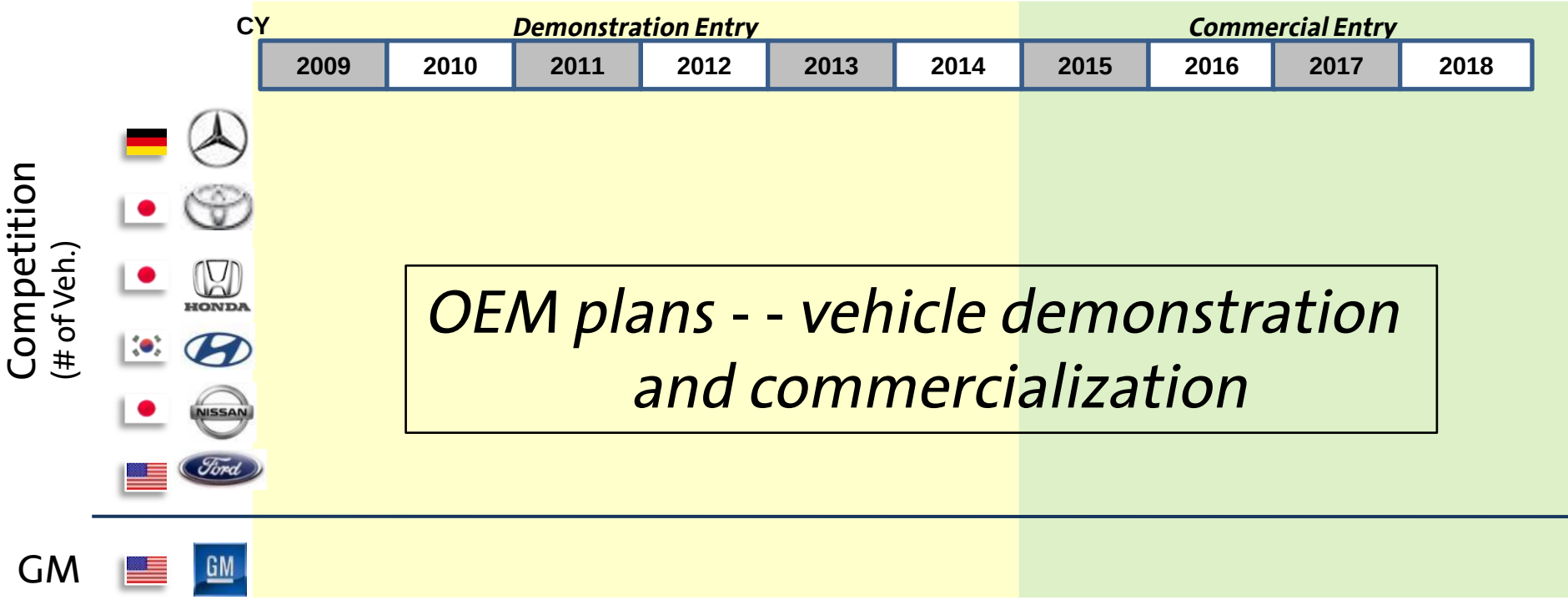


Global Hydrogen Infrastructure Development
(Station Locations - Main areas)



Global Competitors

Competitive Landscape - Summary



Hydrogen Stations (cumulative)

Plans for H_2 infrastructure development

Germany Initiatives

It Didn't Happen Over Night

Verkehrswirtschaftliche Energiestrategie (VES) – [Transport Energy Strategy]

- 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)

German 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

Die Bundesregierung · ARAL · bp · BMW Group · BVG · DAIMLER · Ford · GM · OPEL · Linde · StatoilHydro · TOTAL · VATTENFALL · VOLKSWAGEN

- **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
    - ➔ Aral/BP: Messedamm (opened 11/2004)
    - ➔ Total: Heerstraße (opened 03/2006)
  - Different methods of hydrogen production demonstrated
  - **CEP service station specialized for hydrogen propulsion**

Clean Energy Partnership (CEP)
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- **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**

CEP Refueling Station Situation

Funding for 25 Pilot H_2 Stations included in 2009 Germany Stimulus

- Support a relative oversupply of stations during the early years

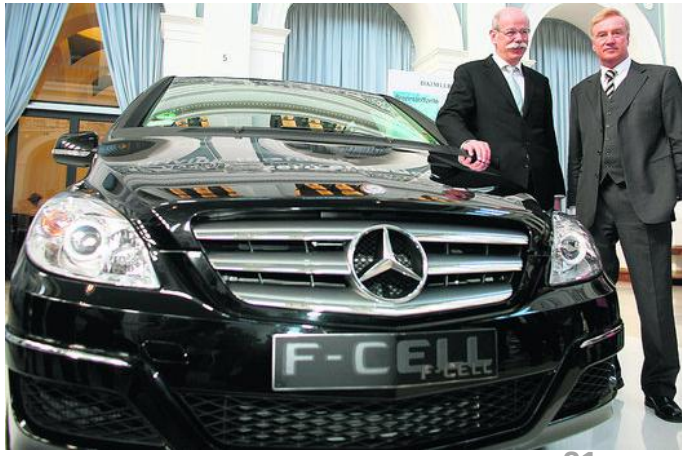
Recent Media Articles

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 H_2 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:

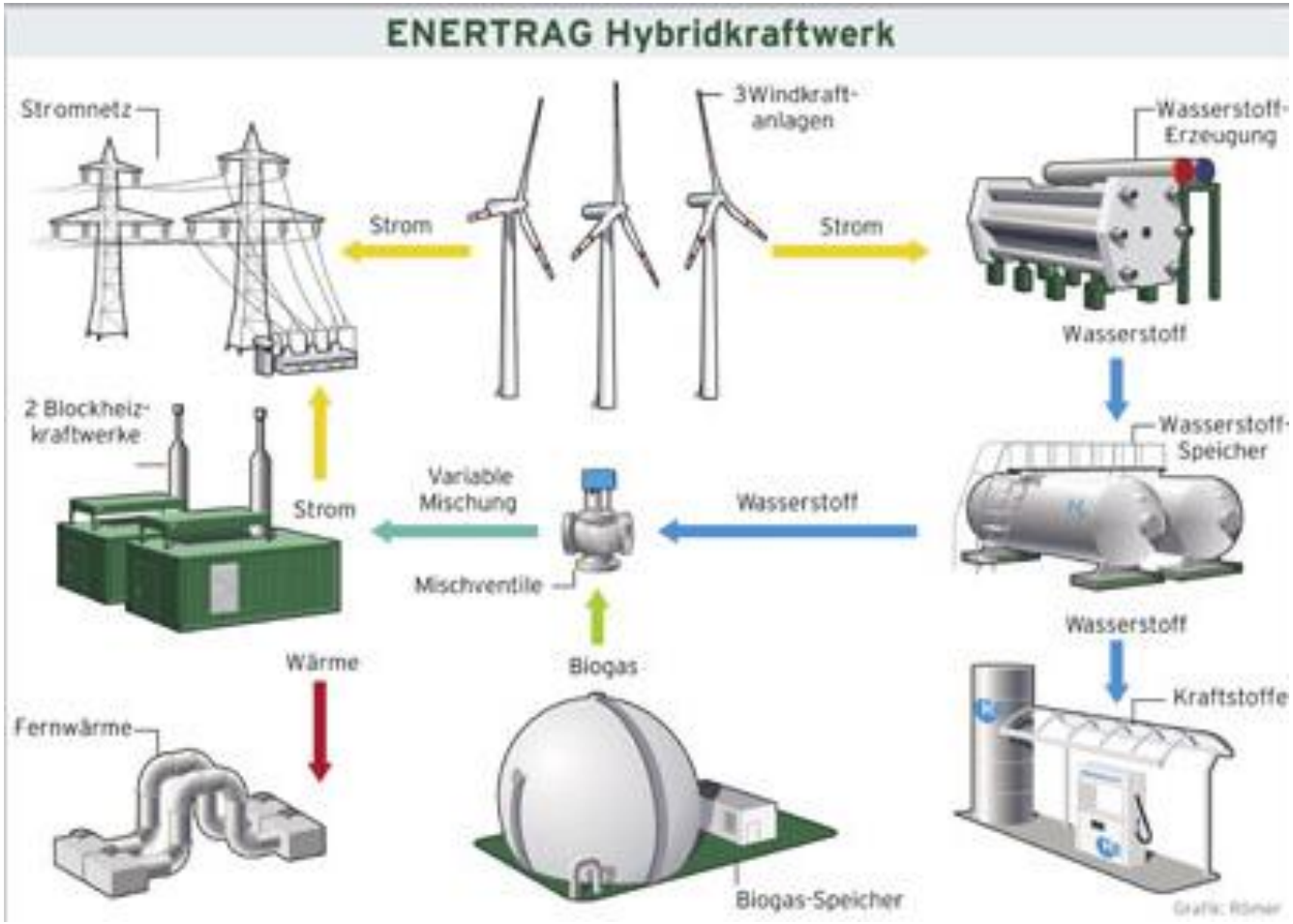
- Zetsche- - production readiness by 2015
- Wolfgang Tiefensee, German minister of Transportation
  - “We support research, development, and market preparation with 500 mio Euro”
  - “Hydrogen is the fuel of the future: efficient, emission-free, ecological”



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 H_2 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 CO_2
  - 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
- H_2 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**
    - **21st 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

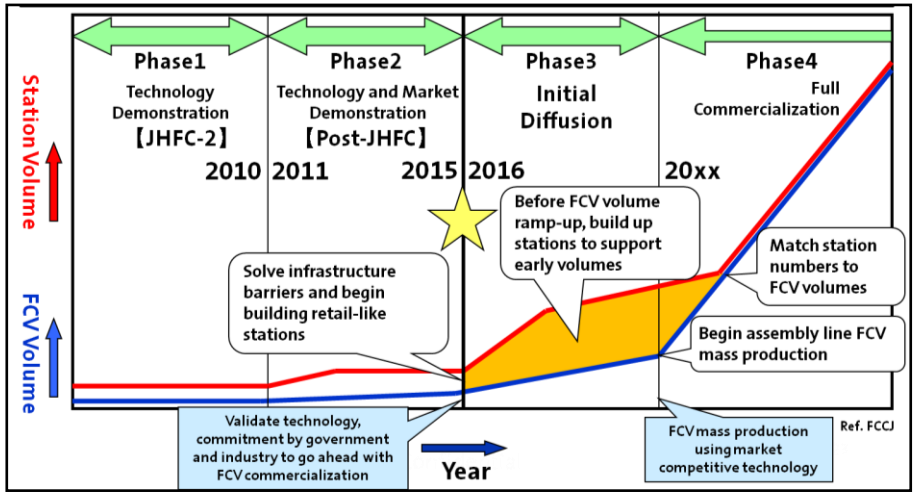
Source: Japan Fuel Cell and Demonstration Project Report March 2008 and March 2009

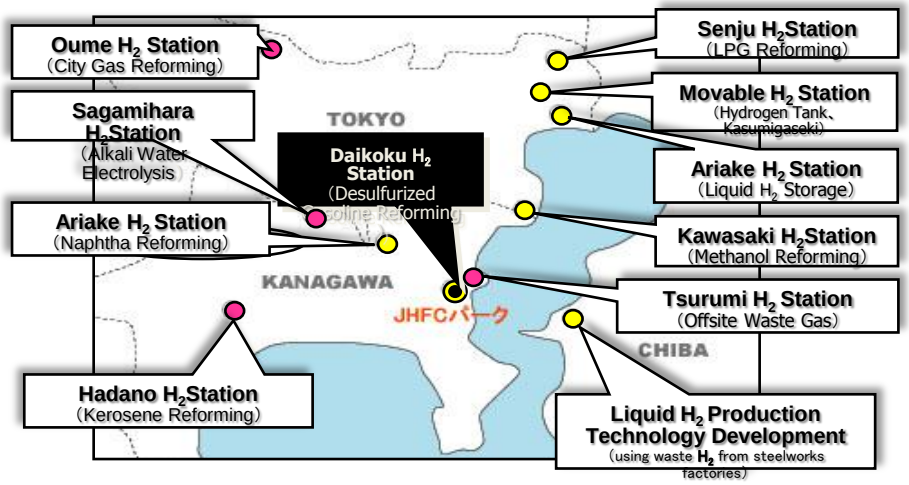
Date: 27Jan09

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 H_2
  - 11 different H2 refueling facilities with H_2 from 11 different feedstocks
  - Understand most economical process
  - Develop refueling equipment





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

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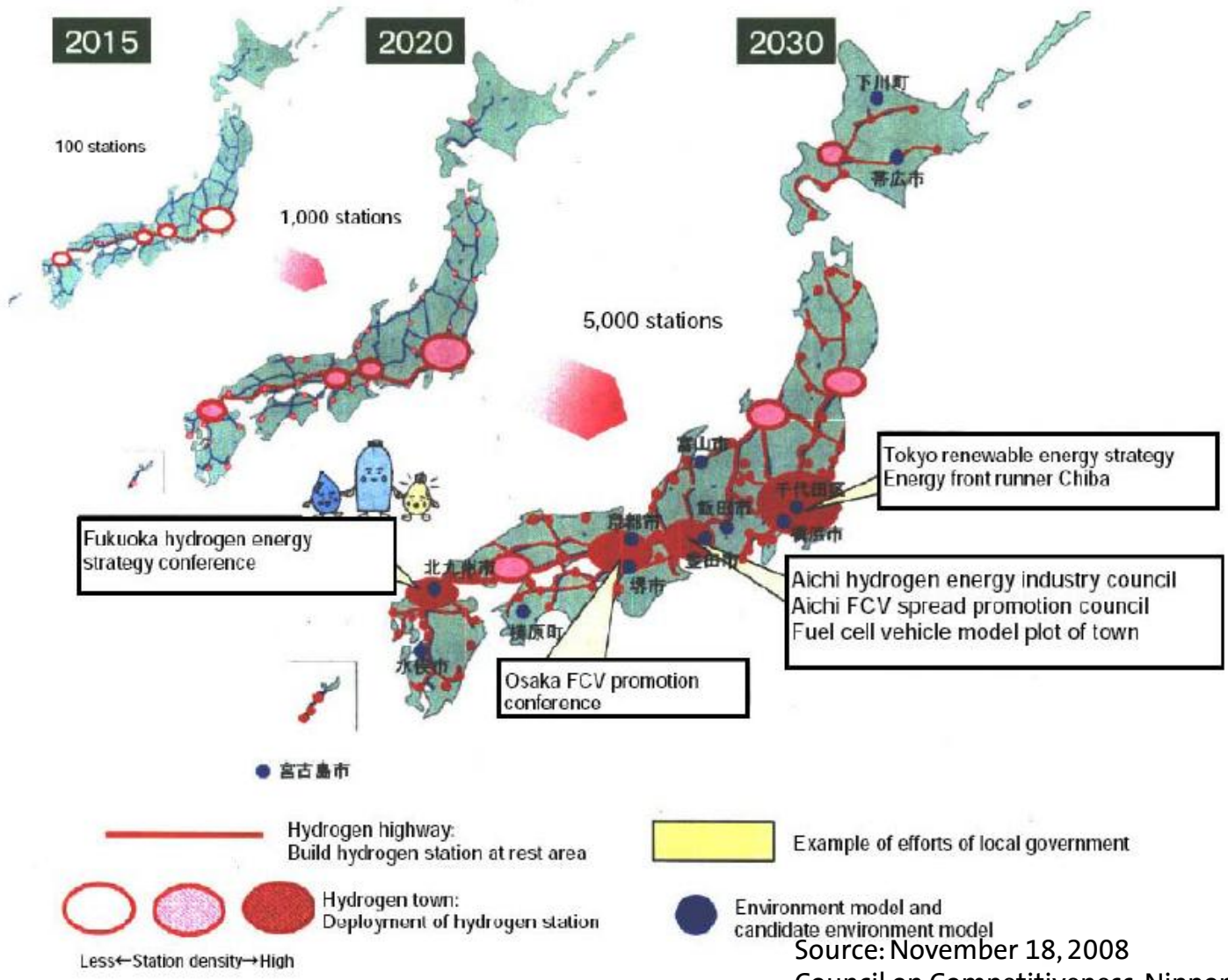
Council on Competitiveness-Nippon Interim Report on Fiscal 2008 Project Theme

H_2 Supply Infrastructure Deployment Project



Source: November 18, 2008
Council on Competitiveness-Nippon (COCN)

Future Products/Strategies

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 -22º F to 221º 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

Percent Energy Efficiency by Powertrain Type

Powertrain	Well-to-Tank	Tank-to-Wheel	Well-to-Wheel
Fuel Cell	67	59	40
Electric Vehicle	39	85	33
Gas-Electric Hybrid	84	40	34
Gasoline-Vehicle	84	23	19

Source: Toyota

Source: Toyota, Ward's Auto World, TMC

GM Confidential

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 H_2, 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 21st 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

Automobile

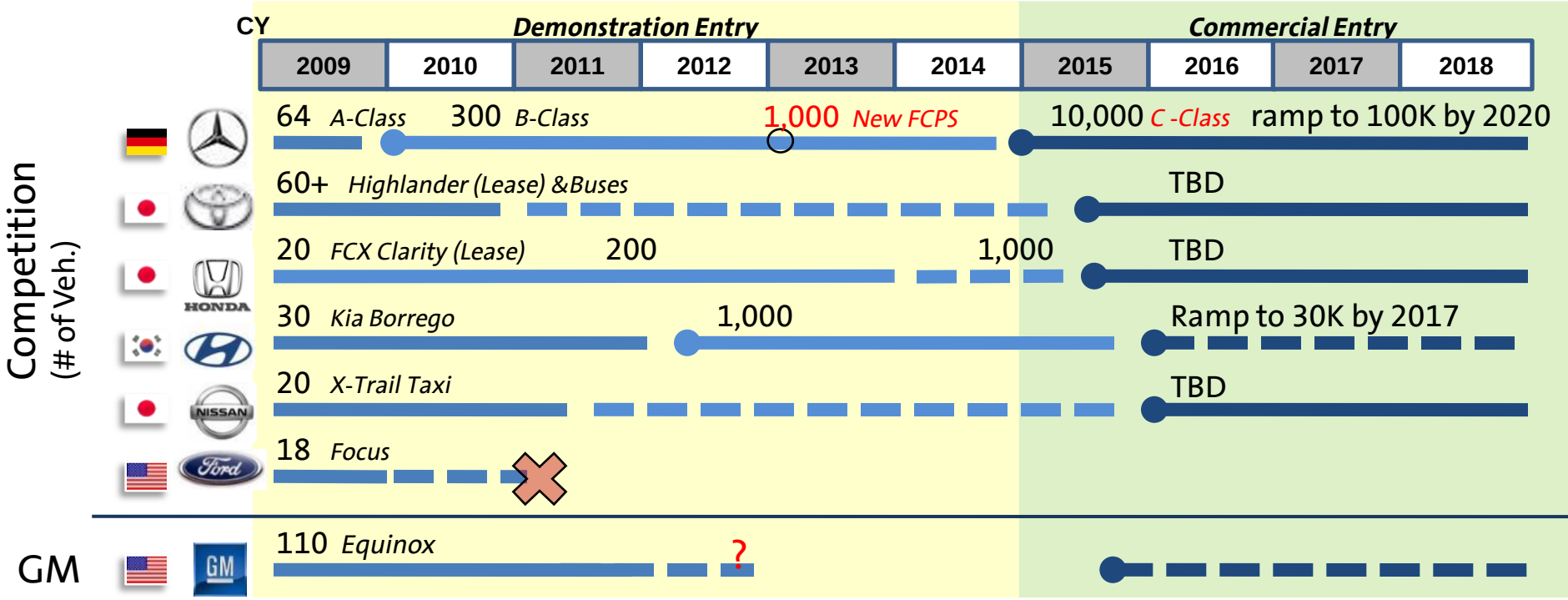
Kia's Big Fuel Cell Plans

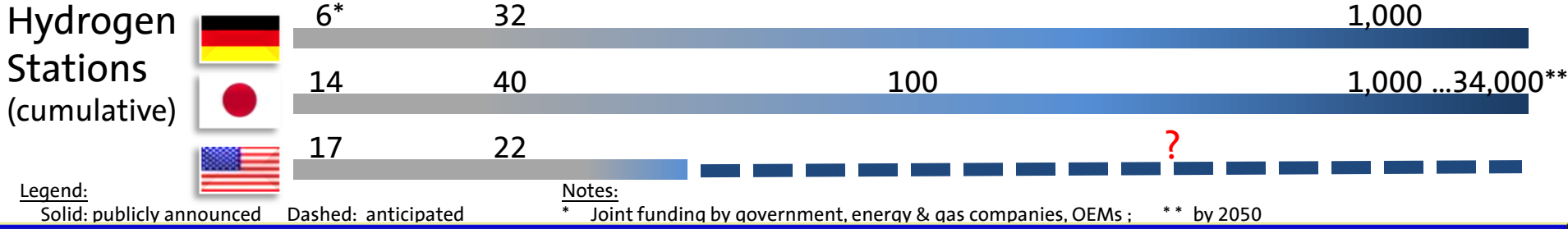
Kia reveals next generation Borrego fuel cell vehicle and production Soul

November 22, 2008
By Le Guide de l'auto

- 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 H_2 stations needed to serve Seoul area

Competitive Landscape - Summary





Legend:
Solid: publicly announced
Dashed: anticipated

Notes:
* Joint funding by government, energy & gas companies, OEMs ;
** by 2050

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 competiveness & energy security
- High volume H_2 fuel cell vehicle introductions by 2015
  - Addressing CO_2 & 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

PLAN REPORTS

Nat. development plan

- 2015 competitiveness established
- $1.8B project budget

METI / Japan Inc.

- 2015 target start commercialization
- Infrastructure leads vehicles

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 H_2 infrastructure development) in light of significant economic challenges

Fuel Cell Technology Competitive Position

Leader

Among the Leaders

Followers

Thank You