California ARB and ITS-Davis GHG Symposium

"Advanced Technologies"

Sacramento, CA
April 21, 2008

Britta K. Gross
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General Motors Corporation

Gas-Friendly to Gas-Free

FUEL EFFICIENCY

E85 ETHANOL

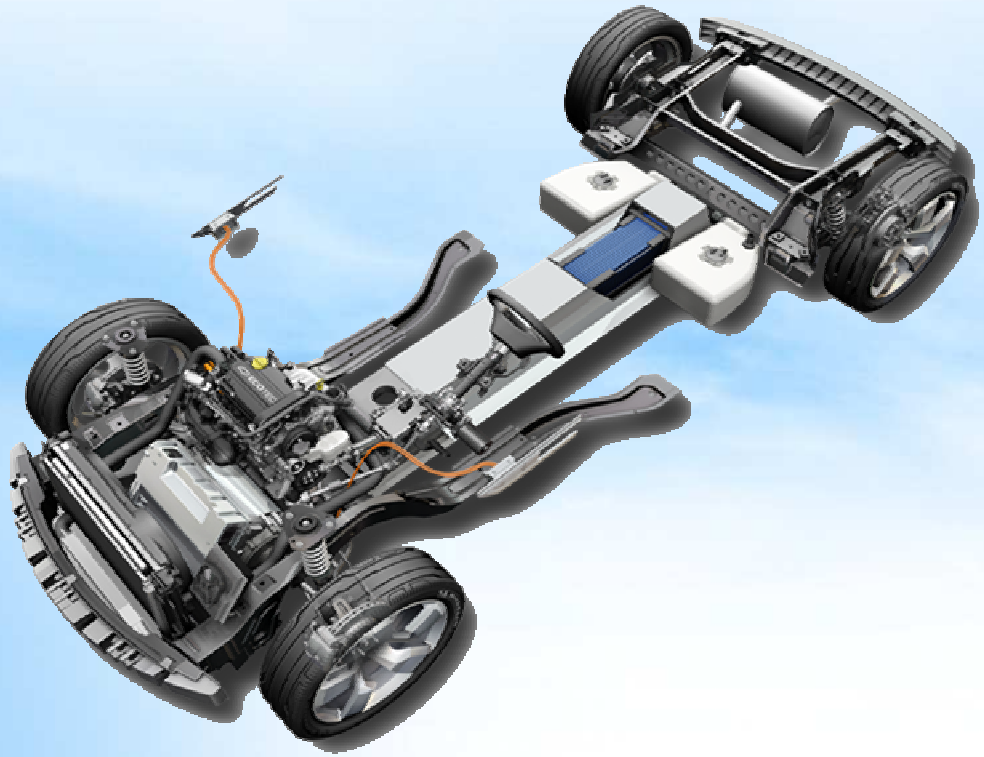
HYBRID

ELECTRIC

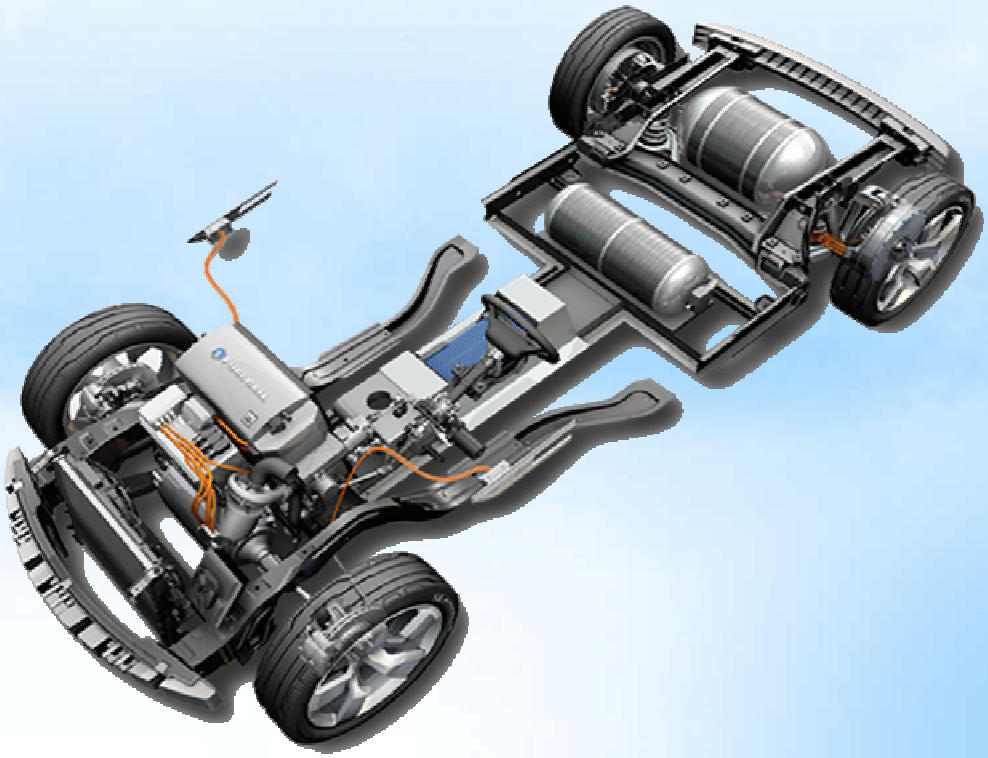
FUEL CELL

Why Hydrogen Fuel Cells AND Battery Electric Vehicles?

E-Flex: Gasoline or E85
Extended-Range Electric Vehicle



E-Flex:
Fuel Cell Electric Vehicle



- **40mile all-Electric range** ⟷ **300mile all-Electric range**
- **4-6 hour recharge** ⟷ **3-5 minute refuel**
- **Zero emissions for 40miles** ⟷ **Zero emissions for 300 miles**

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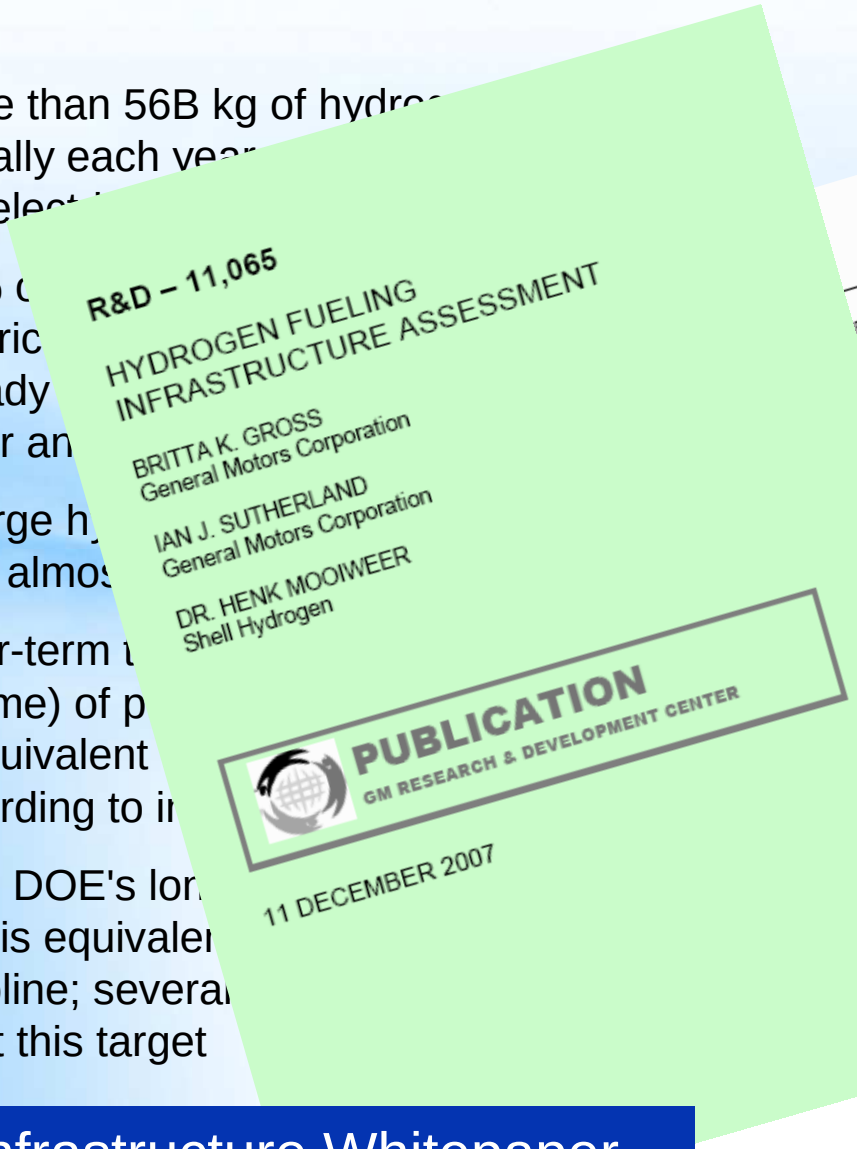
R&D – 11,065

HYDROGEN FUELING INFRASTRUCTURE ASSESSMENT

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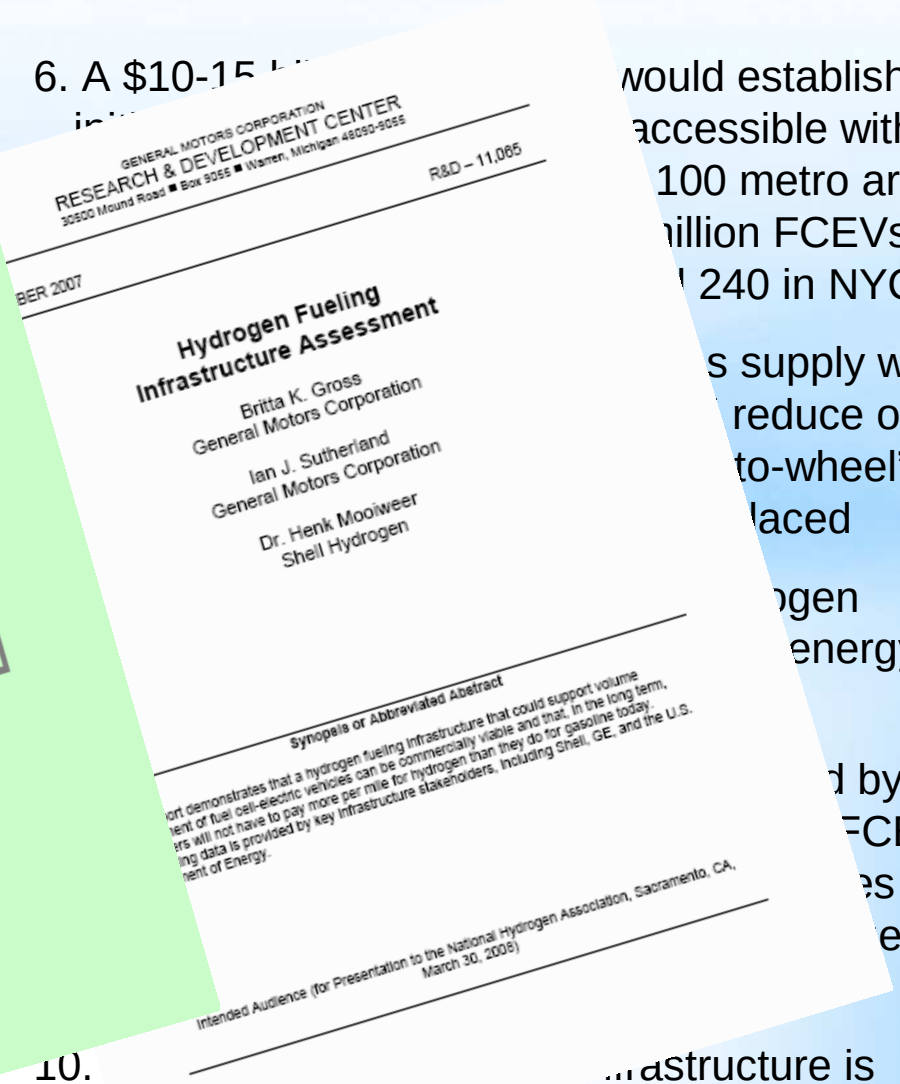
Shell Hydrogen

PUBLICATION
GM RESEARCH & DEVELOPMENT CENTER

11 DECEMBER 2007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BER 2007

Hydrogen Fueling Infrastructure Assessment

Britta K. Gross
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Shell Hydrogen

Synopsis or Abbreviated Abstract

ort demonstrates that a hydrogen fueling infrastructure that could support volume
ent of fuel cell-electric vehicles can be commercially viable and that, in the long term,
ers will not have to pay more per mile for hydrogen than they do for gasoline today.
ing data is provided by key infrastructure stakeholders, including Shell, GE, and the U.S.
ent of Energy.

Intended Audience (for Presentation to the National Hydrogen Association, Sacramento, CA, March 30, 2006)

Infrastructure Whitepaper available

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Ten things you should know about a hydrogen fueling infrastructure for automobiles

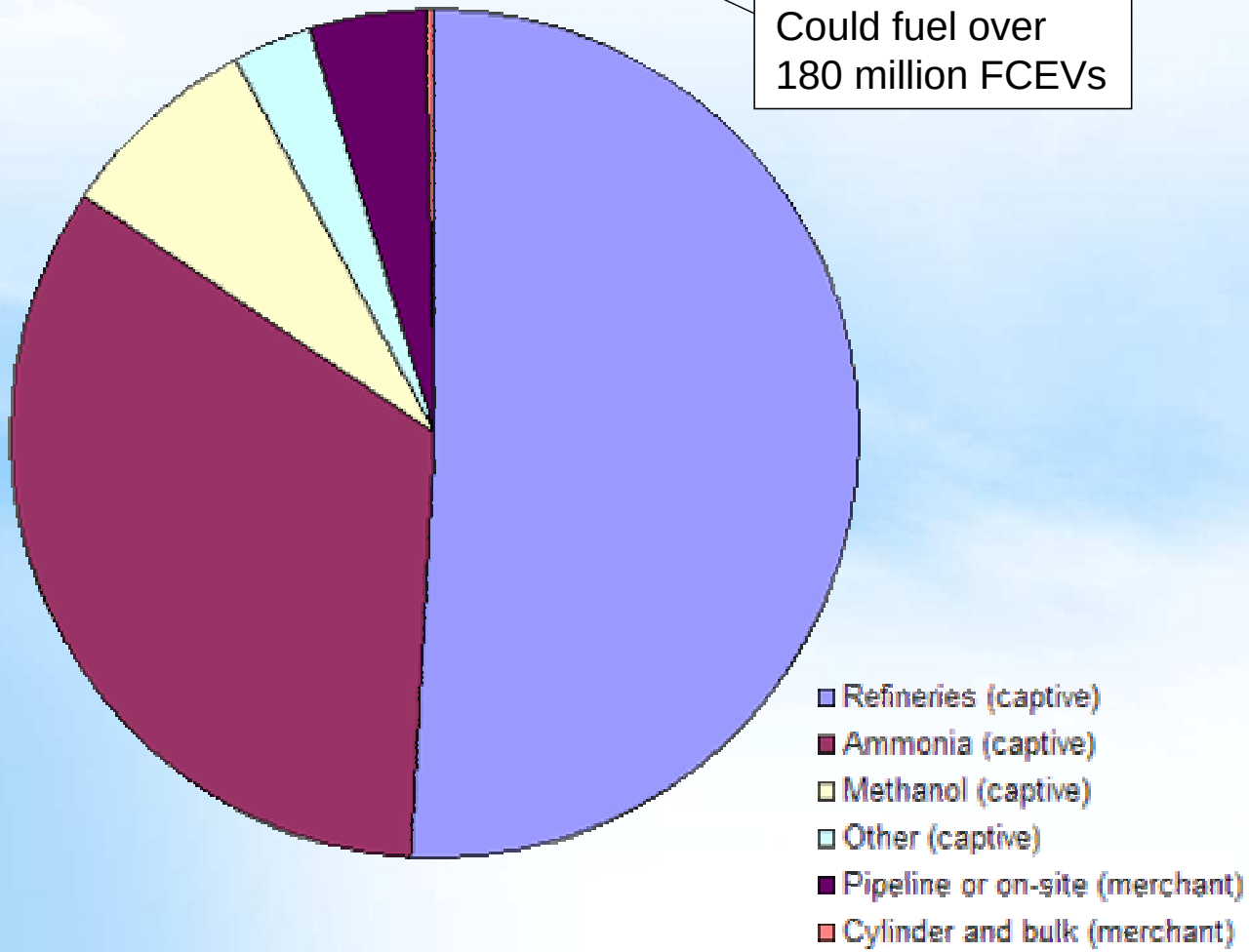
1. More than 56B kg of hydrogen are produced globally each year – enough to fuel 180M fuel cell-electric vehicles (FCEVs) annually
2. 60% of the hydrogen produced in North America (enough to fuel 21mil FCEVs) is already dedicated to transportation - removing sulfur and “sweetening” petroleum at refineries
3. A large hydrogen production site exists today near almost every major U.S. and European city
4. Near-term total cost (i.e. today's technology, at volume) of producing and dispensing hydrogen is equivalent to $2-3/gallon of gasoline according to industry studies
5. U.S. DOE's long-term target for total hydrogen cost is equivalent to $1.00-1.50/gallon of gasoline; several pathways have potential to meet this target
6. A $10-15 billion investment would establish an initial refueling infrastructure accessible within two miles anywhere in the top 100 metro areas - sufficient to support the first 1million FCEVs - assumes 240 stations in LA and 240 in NYC
7. A 2% increase in U.S. natural gas supply would support 10M FCEVs annually and reduce overall CO2 emissions by 50% on a “well-to-wheel” basis for every gasoline vehicle replaced
8. A fuel cell vehicle operating on hydrogen produced from renewable sources of energy eliminates all exhaust emissions
9. Early capitalization risk will be managed by balancing infrastructure availability with FCEV sales growth and concentrating initial sales in specific geographic regions (e.g., Los Angeles, New York, or Shanghai)
10. Bottom line: A hydrogen infrastructure is economically viable and doable - it requires the collective will of automakers AND energy suppliers AND governments

2006 Global and N. American Hydrogen Markets

Global

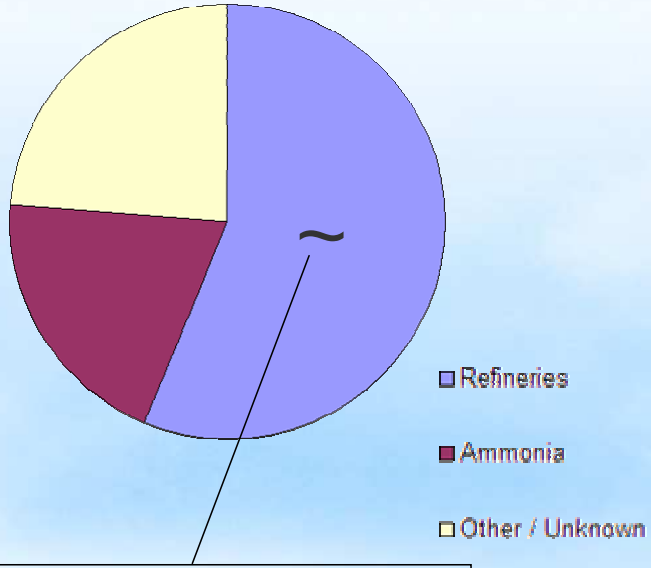
(more than 56 billion kg/yr)

Could fuel over
180 million FCEVs



North America

(more than 11 billion kg/yr)



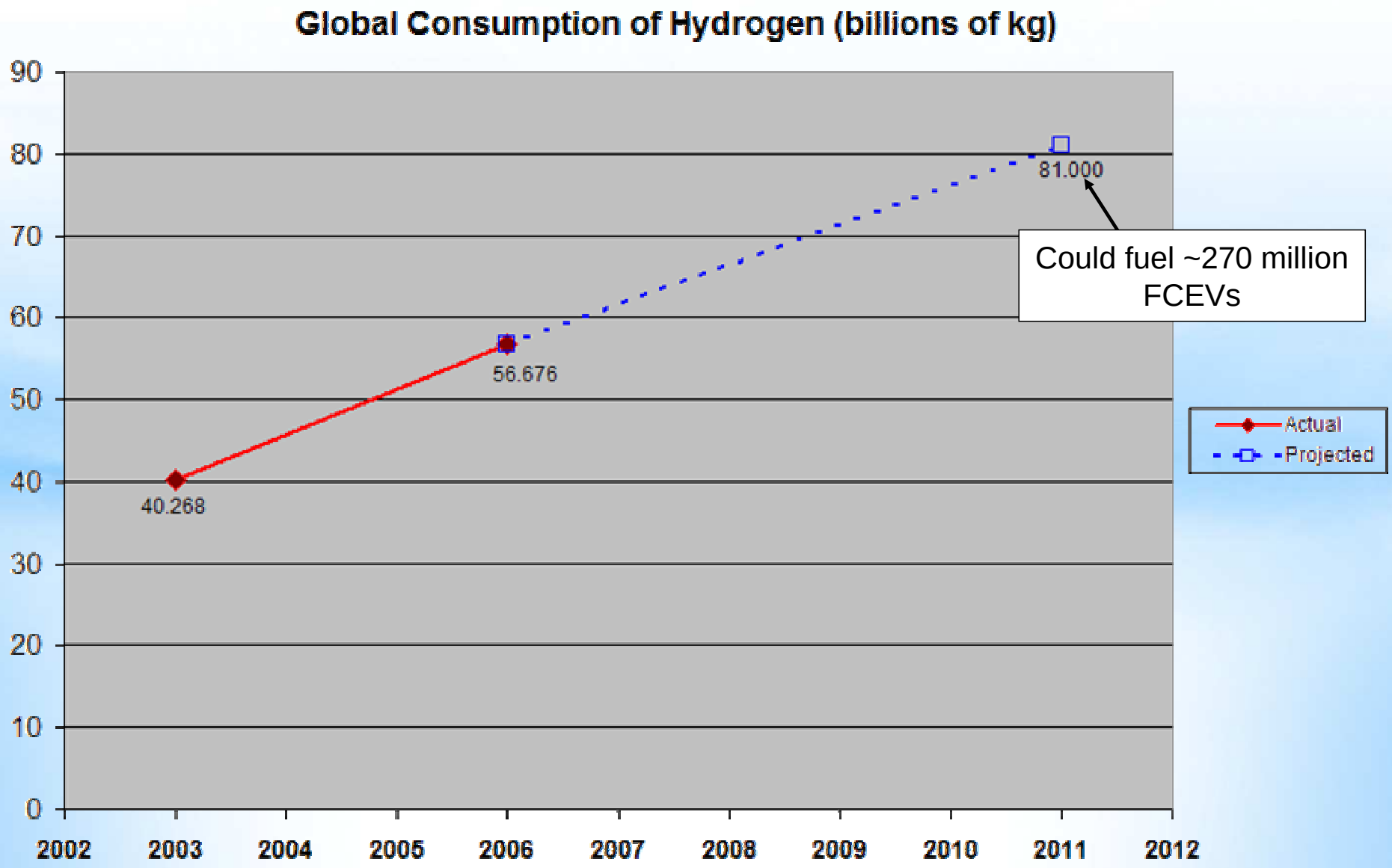
North American refinery hydrogen could fuel over 21 million FCEVs

Extensive hydrogen production capacity in place

- More than 56 billion kg consumed in 2006 (could fuel over 180M fuel cell electric vehicles)

Global Hydrogen Production

Continued use of petroleum-based fuels requires increased use of hydrogen

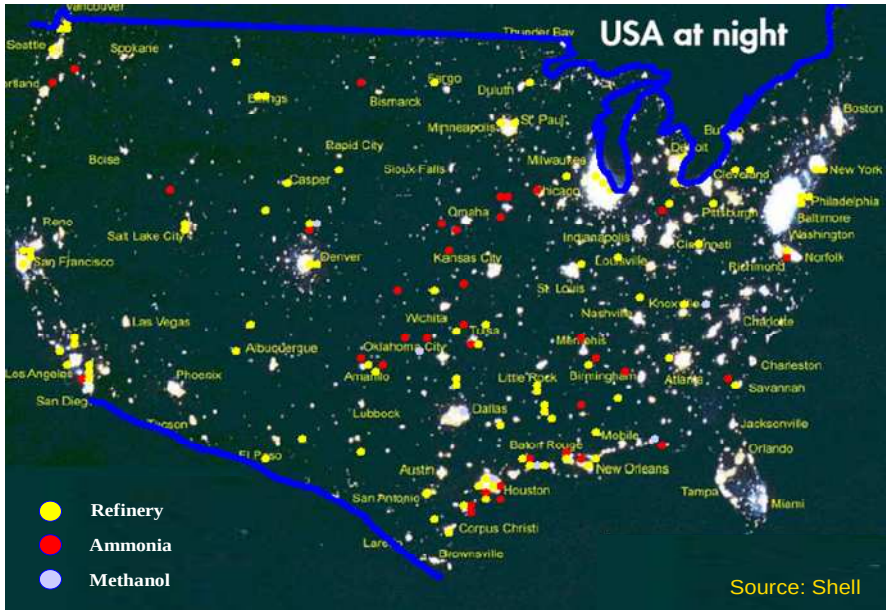


A hydrogen transition is already happening

- Strong growth in hydrogen market is forecast to continue
- Growth driven partly by processing needs for heavier and non-conventional petroleum

Leveraging Existing Hydrogen Production Sites

Existing U.S. H2 Production



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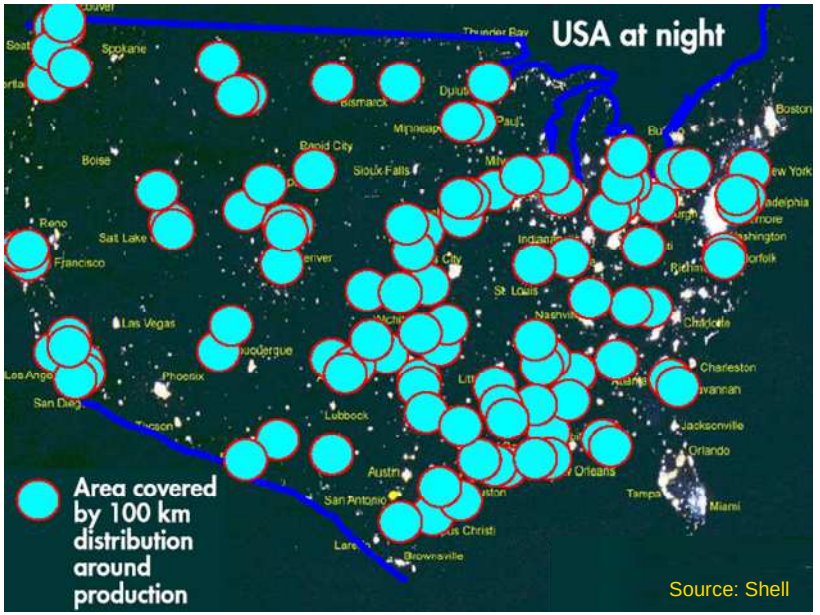

Large hydrogen production sites are already within reach of most major U.S. metropolitan areas (roughly 70% of the U.S. population)

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U.S. Infrastructure Development For First Million Fuel Cell Vehicles

$10-15 Billion investment would establish network of 11,700 stations

- Top 100 urban areas (i.e. 70% of U.S. population)
- 130,000 miles of highway

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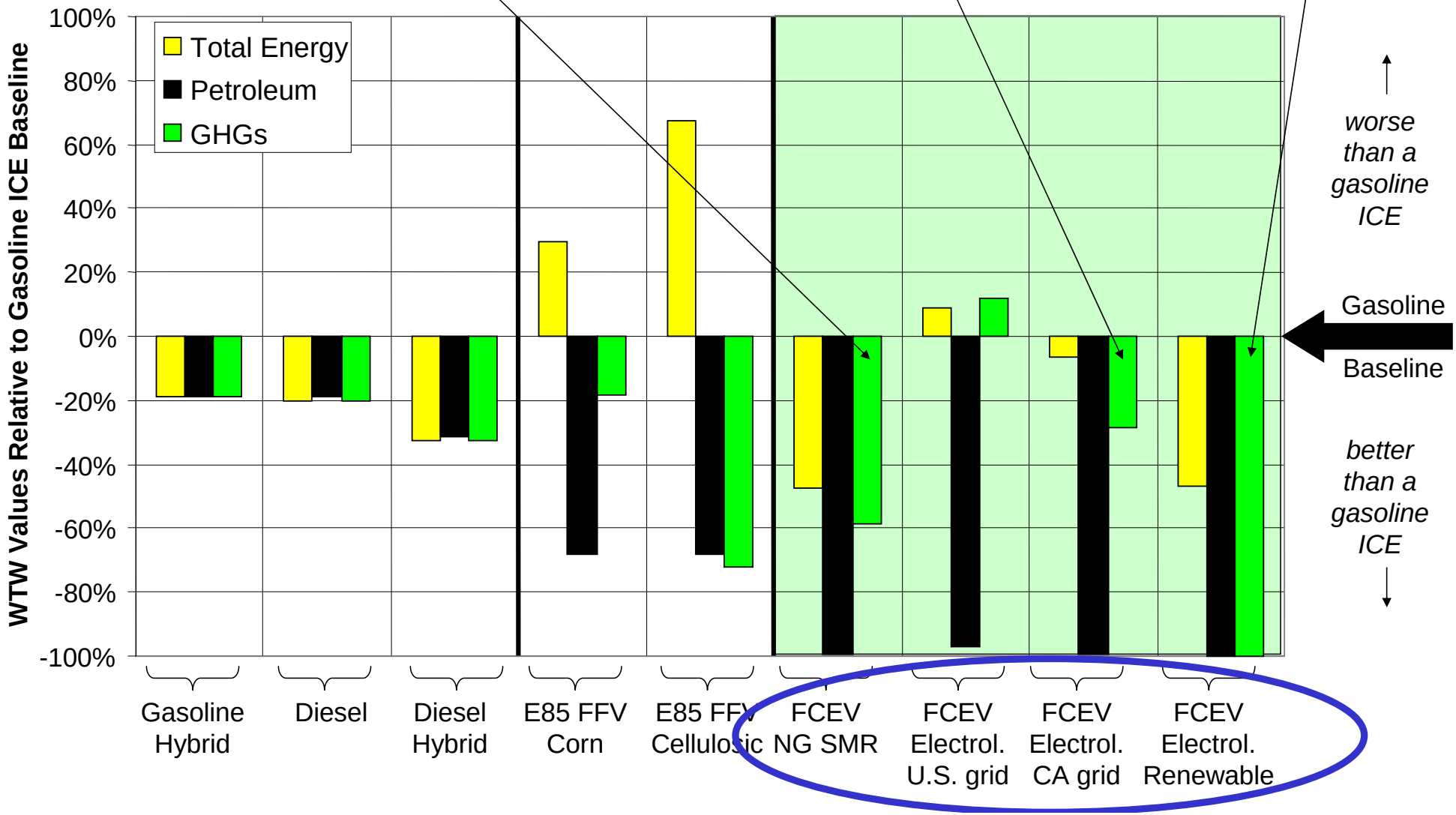
Overall "Well-to-Wheels" Energy and Emission Results

The most cost-effective pathway for producing hydrogen today (i.e. NG SMR), reduces overall GHG emissions almost 60%.

Hydrogen from CA grid (or comparable) electrolysis reduces GHG almost 30%.

Hydrogen from renewables-based electrolysis results in 0 emissions WTW.



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Fuel Cell Commercialization Overview (Conceptual)

New Calif ZEV Ruling: 2012-2014 → 7,500 FCEV

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10
Technology Development				**Pilot Commercialization**			**Early Commercialization**		
Technology development and validation under real world conditions				Technology refinement and early market preparation			Commercial deployment into mass market		

OEM/Vehicles

- So. California
- U.S. Northeast

- So. California
- No. California
- U.S. Northeast

Region 1 Region 2

100 veh / OEM 

1,000+ veh / OEM (**ZEV 7500**)

Launch Build-up: to 10,000 veh / yr / OEM

Energy/Infrastructure

First "retail-like" Stations in U.S.

10 18 40

Region 1 Region 2

Leadtime → 10 stations

Leadtime → 40 stations (per metro area):

Leadtime → 250 Stations

- Planning and execution of next phase infrastructure must begin now
- Early deployment of fueling infrastructure will influence vehicle deployments

EQUINOX FUEL CELL

Project Driveway (chevy.com)

- Largest fuel cell vehicle market test
- More than 100 vehicles in the hands of customers
- Deployed in Los Angeles, New York City, and Washington D.C.
- Learnings to guide future vehicle development, marketing, outreach, and infrastructure development
- Fully freeze durable
  - Start from -15C; Operate to -25C
- All safety features of the 5-star production Equinox (designed to meet or exceed all applicable Federal Motor Vehicle Safety Standards)
- Final certification test was run with an operating fuel cell and hydrogen on board
  - Witnessed by NHTSA and Transport Canada

Zero Petroleum **Zero Emissions**

Gap Between Existing and Required H_2 Fueling Experience

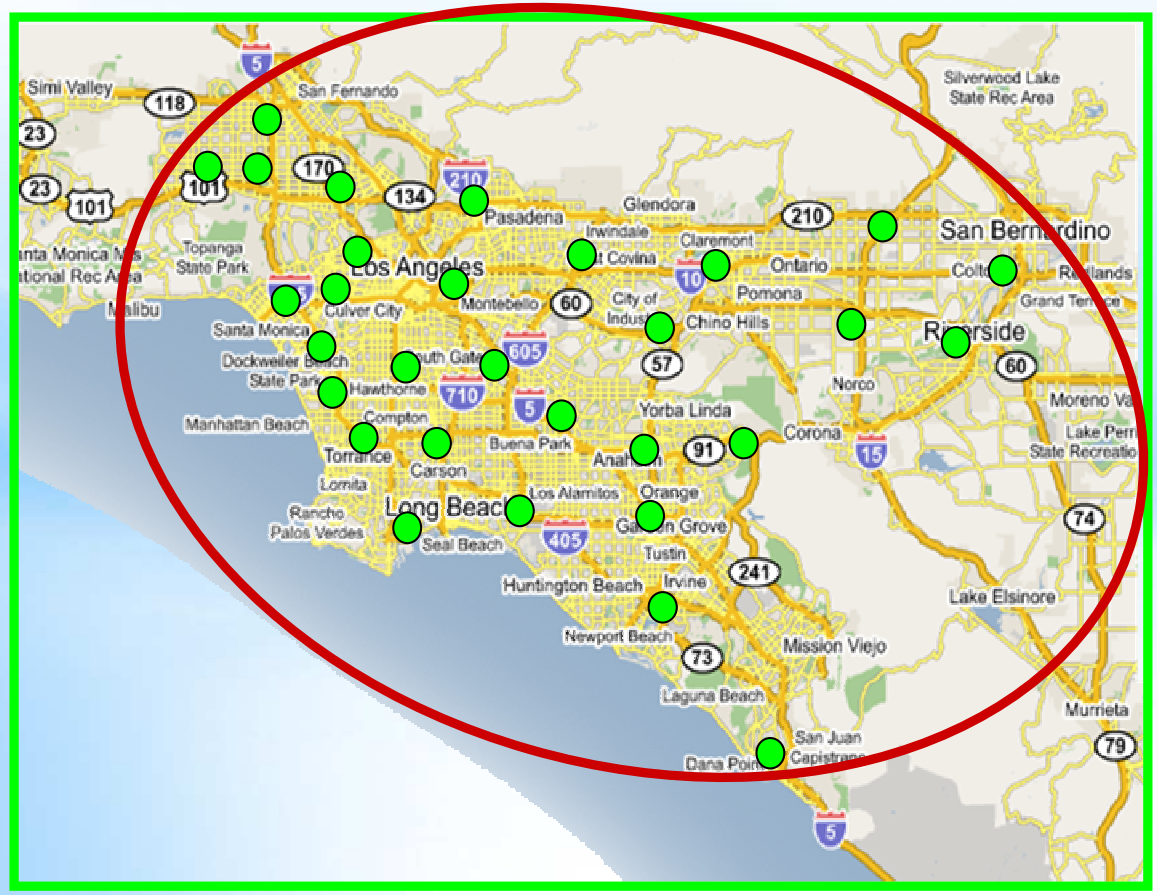
- Very limited access to today's stations
- Very limited availability of 700bar fueling
  - Every major OEM is developing 700bar capability (GM vehicles since 2004)
  - With only two exceptions, 700bar is the baseline
- Current stations are largely behind-the-fence, demo-like, and lagging in technology availability (note: vehicle technology refreshed every 3-4 years)

Additional challenges:

- Infrastructure providers don't necessarily have suitable sites/land – requires complex/time-consuming effort to establish partnerships
- State funding only available if stations meet renewable h2 production requirements, which drives different technology solutions – infrastructure providers most knowledgeable about hydrogen fueling, don't necessarily have the know-how/resources – results in a complex/costly/time-consuming effort (or no bid for state funding)

➔ Build a new generation of hydrogen stations that inspire confidence in hydrogen as a transportation fuel

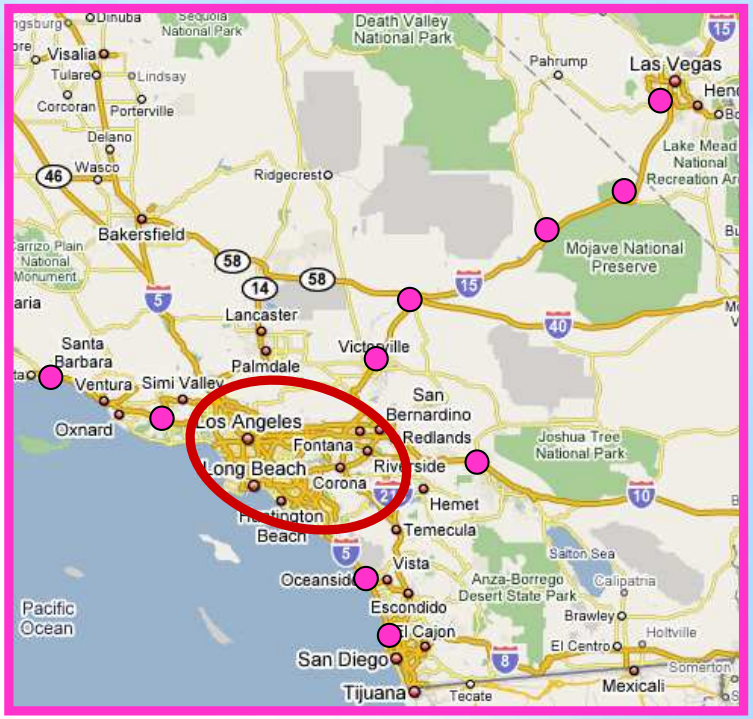
LA Metro Area 2010+
Hydrogen Infrastructure (Conceptual)



30 stations in LA Metro Area
(illustrative placement)

Average distance to metro station = 3.6 miles

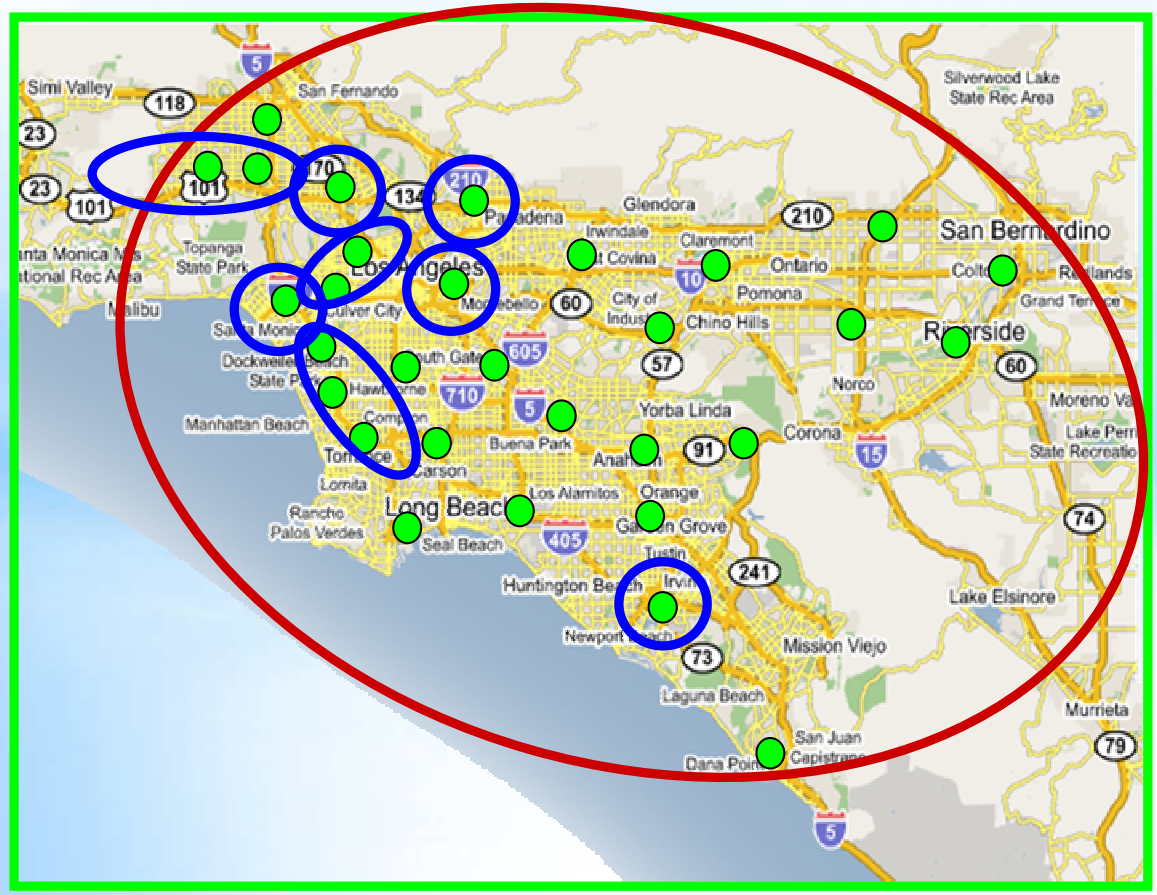
10 stations for
Destination Corridors



To: San Diego, Santa Barbara, Palm Springs & Las Vegas

LA Metro Area 2010+
Hydrogen Infrastructure (Conceptual)

➡ High-profile market areas and 700bar Refueling Priorities



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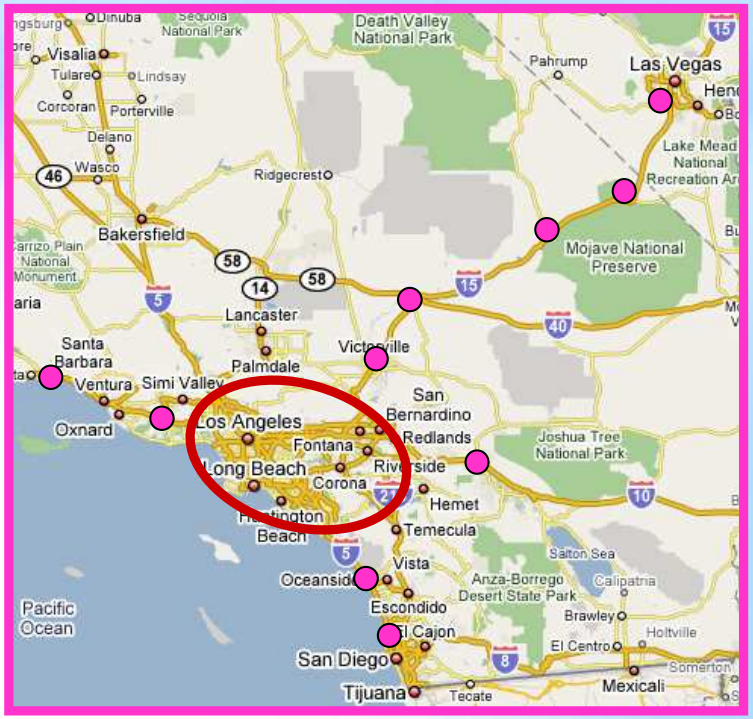

To: San Diego, Santa Barbara, Palm Springs & Las Vegas

Hydrogen Refueling Infrastructure:
Need for Broadened Perspective

Current mindset:

- Provide enough hydrogen for the vehicle miles driven
  (assuming vehicles will travel to a single station or few stations)
- Strive for high station utilization for relevant field experience

Automaker Perspective:

- Consumers move about the coverage region, and therefore, determine their own patterns for where they want to refuel -- efforts to match a station's supply with overall vehicle demand will be inaccurate
- Vehicles are far too costly to leave stranded due to an underbuilt infrastructure
- Early customers are too valuable to hydrogen outreach efforts to risk dissatisfaction

Broadened Perspective:

- Hydrogen stations are a critical element in building market pull for a hydrogen future
  -- which means serving the consumer/driver -- which means focusing on consumer access to fuel rather than fuel availability.

This is about more than just fueling vehicles – this is about building a market!

- Can’t wait to deploy fueling stations once the market signal is clear – these stations have a key roll in making that market signal emerge


GM