

Fuel Cell Seminar 2008

Transportation and Stationary Power Integration Workshop

“An Automaker’s Views on the Transition to
Hydrogen and Fuel Cell Vehicles”

Phoenix, AZ

27 October 2008

Britta Gross

General Motors – Hydrogen and Electrical Infrastructure



Gas-Friendly to Gas-Free



FUEL EFFICIENCY



E85 ETHANOL



HYBRID



ELECTRIC



FUEL CELL

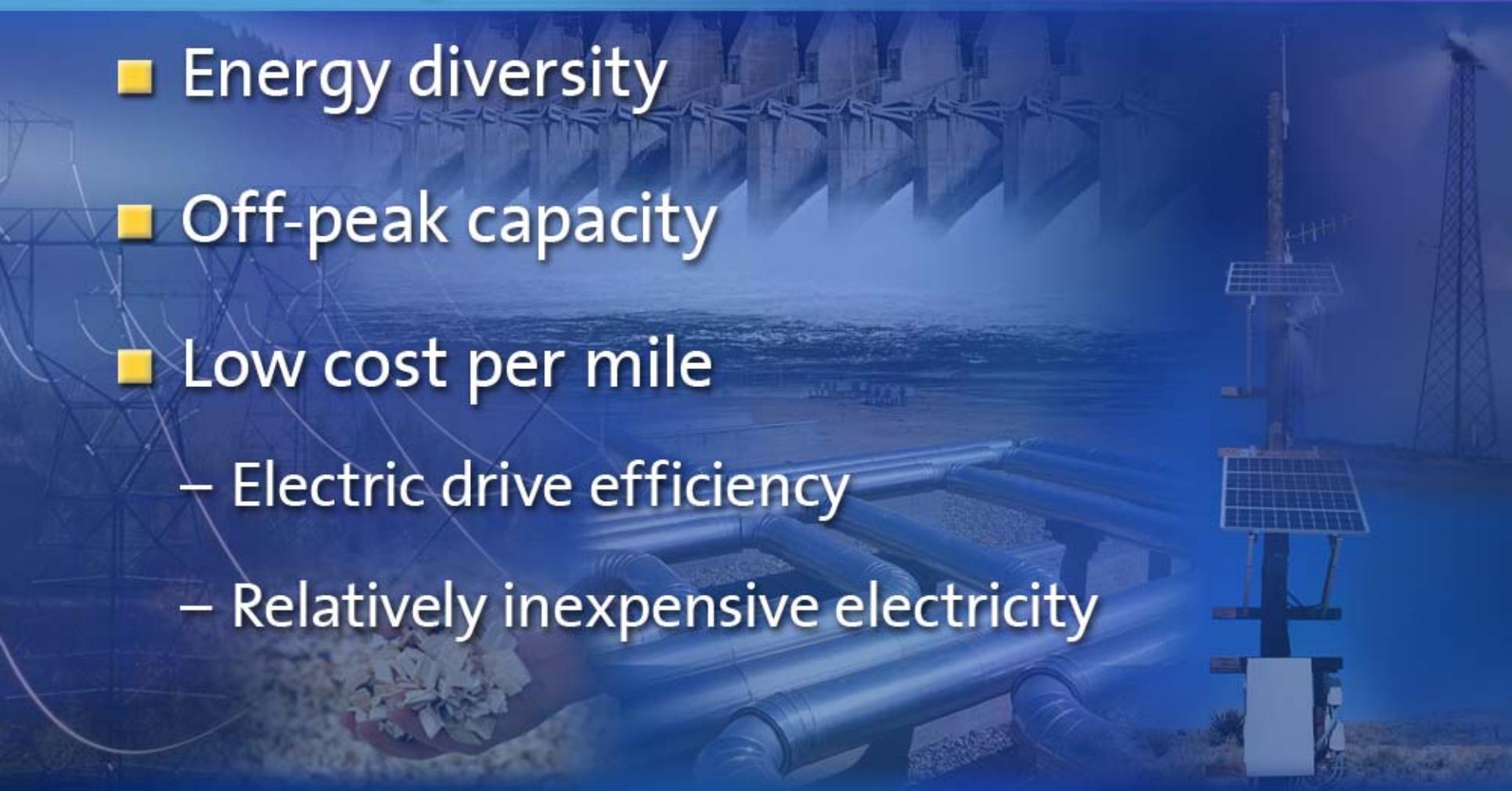


Electrically Driven Vehicles



Electricity

- Energy diversity
- Off-peak capacity
- Low cost per mile
 - Electric drive efficiency
 - Relatively inexpensive electricity



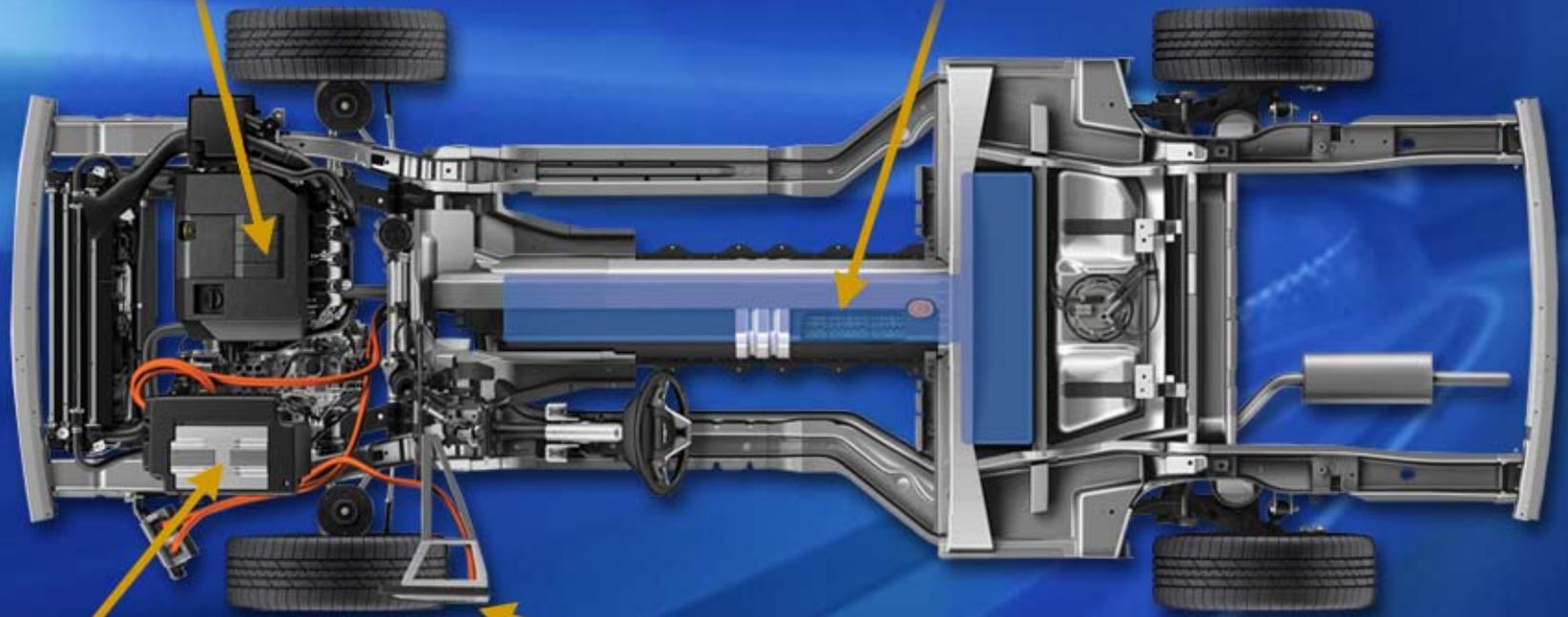
VOLVO





Engine Generator

Lithium-Ion Battery Pack



Electric Drive Unit

Charge Port

Fuel Cell-Electric Vehicles

- Family-sized vehicles
- Long-driving range
- Fast refueling
- Zero petroleum
- Zero emissions



The background of the slide features a vertical sequence of water droplets falling into a pool of water, creating concentric ripples. The color palette is various shades of blue, from a deep navy blue at the bottom to a lighter, almost white blue at the top. A dark blue horizontal band is positioned across the middle of the image, serving as a backdrop for the text.

Hydrogen **represents** an
uncompromising solution



HydroGen3



AUTOonomy



Hy-wire

GM Fuel Cell- Electric Vehicles



Chevrolet Equinox Fuel Cell/HydroGen4



Sequel



FUEL CELL
MARATHON
POWERED BY GM



300-MILE SEQUEL DRIVE

Emissions-Free, Petroleum-Free

GM 300-MILE
ZERO EMISSIONS FUEL CELL DRIVE
FINISH



Equinox Fuel Cell Validation in Arizona





Project Driveway: 100 Fuel Cell Vehicles in LA, NYC, WDC



Get the cost down, and fuel-cell Equinox rocks

“Get busy on hydrogen stations, energy companies. Judging by the (Chevy) Equinox fuel-cell vehicle, reducing the cost seems the only serious challenge. **Its smoother, mostly quieter and generally nicer to drive than a gasoline-electric hybrid vehicle.**”

— Test Drive, James R. Healey
USA Today

EQUINOX



FUEL CELL

AUTOLINE

“The highlight (of the LA Auto show) was getting to drive a fuel cell-powered Chevrolet Equinox. If I didn't know this thing was powered by a fuel cell, I might never have noticed. It drives just like a normal vehicle.”
— John McElroy



USA TODAY

Get the cost down, and fuel-cell Equinox rocks — “Driving automakers' ever-improving hydrogen fuel-cell vehicles is a setup for a letdown. They are getting to be so good, so ordinary, so much like any other vehicles in the way they drive, that you start thinking you ought to just go get one. After all, they issue no pollutants, and they go about twice as far as gasoline vehicles do on the same amount of energy.”
— John Healy

WARDS AUTO

“Known as ‘Project Driveway,’ ...making good on a promise GM made in September, 2006 to deliver the industry's largest fuel-cell test fleet yet. And while the project is geared to furthering research in the quest to produce marketable fuel-cell vehicles in volume, it also appears designed to position GM at the forefront in the image race for ‘green’ leadership.”

leftlane

“Overall, the hydrogen fuel-cell Equinox has an impressive package where most people would expect a lack of a fuel cell.”

The bottom line on a nifty, green driving machine

► Quick. At least thanks to the instant start.
► Quiet and no roar from the battery.

www.usatoday.com

USA TODAY

Money

SECTION B



Test Drive

Fuel-cell Equinox: It's like buttah

Too bad the hydrogen fuel-cell Chevrolet Equinox



**High Volume
Is Key!**

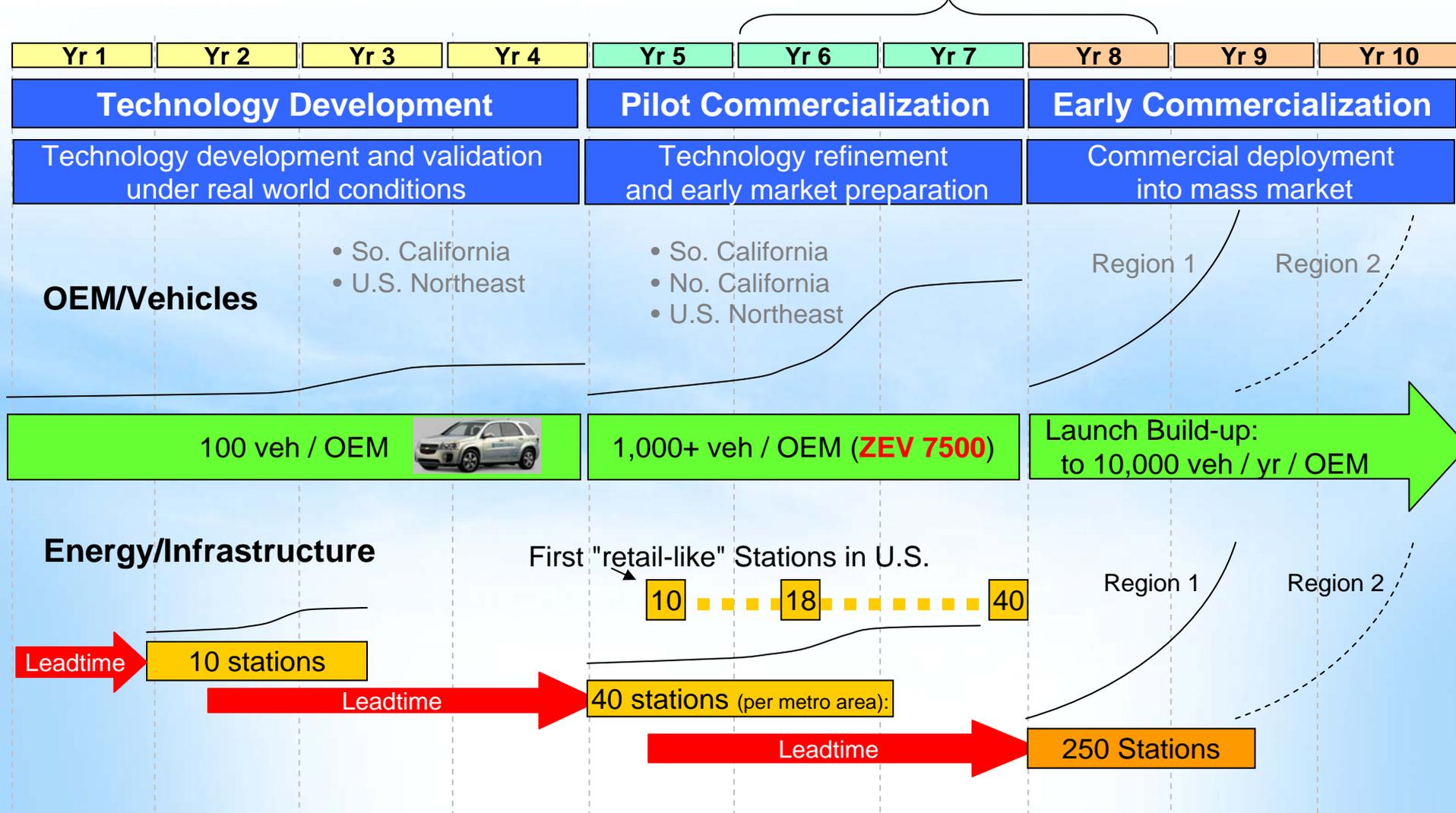
Commercialization by 2015

100 → 1,000 → 10,000



Fuel Cell Commercialization Overview (Conceptual)

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



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

Hydrogen Infrastructure – Where are We?

Washington D.C.



Germany



Berlin (Total)



UC Irvine



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

1. More than 56B kg of hydrogen is produced globally each year. Cell-electricity is the most efficient way to produce hydrogen.

2. 60% of hydrogen in America is already produced from sulfur and natural gas.

3. A large hydrogen pipeline near almost every city.

4. Near-term technology (small volume) of production is equivalent to gasoline according to infrastructure.

5. U.S. DOE's long-term goal is that hydrogen cost is equivalent to gasoline; several technologies can meet this target.

Infrastructure Whitepaper available

R&D - 11,065

HYDROGEN FUELING INFRASTRUCTURE ASSESSMENT

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Shell Hydrogen



PUBLICATION
GM RESEARCH & DEVELOPMENT CENTER

11 DECEMBER 2007

6. A \$10-15 billion investment would establish an accessible within 100 metro areas and 240 in NYC.

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R&D - 11,065

DECEMBER 2007

Hydrogen Fueling Infrastructure Assessment

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Synopsis or Abbreviated Abstract

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

Intended Audience (for Presentation to the National Hydrogen Association, Sacramento, CA, March 30, 2008)

10.

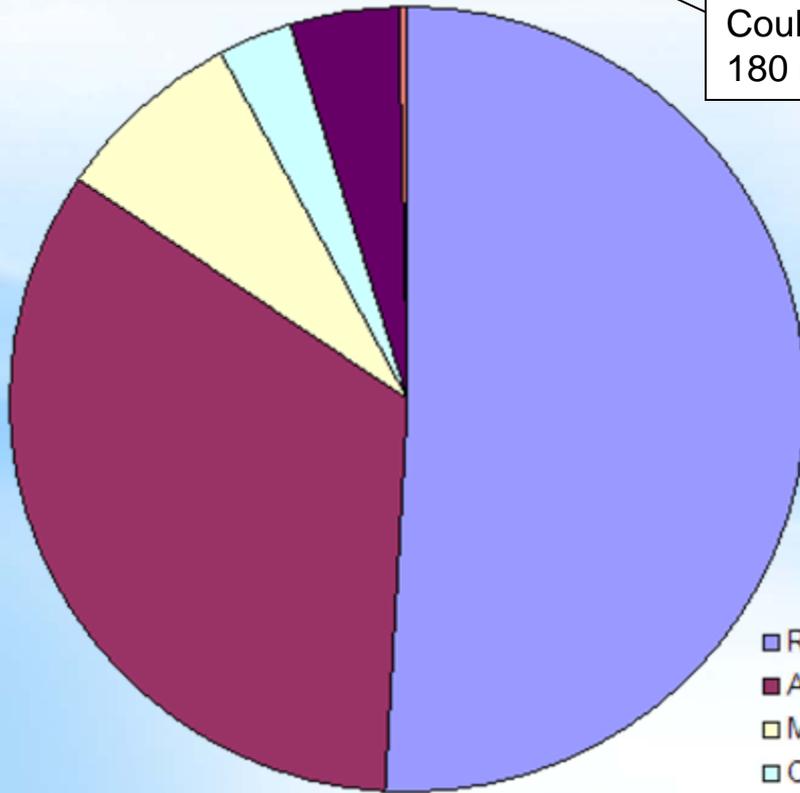
Infrastructure is economic and achievable and doable - it requires the collaborative will of automakers AND energy suppliers AND governments

2006 Global and N. American Hydrogen Markets

Global

(more than 56 billion kg/yr)

Could fuel over
180 million FCEVs

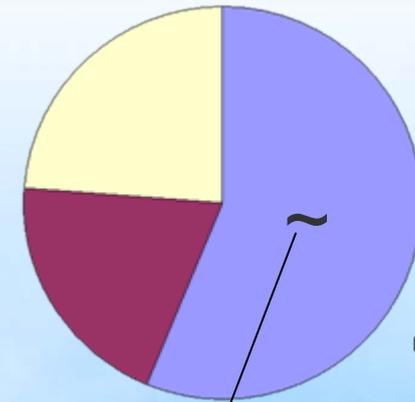


- Refineries (captive)
- Ammonia (captive)
- Methanol (captive)
- Other (captive)
- Pipeline or on-site (merchant)
- Cylinder and bulk (merchant)

North America

(more than 11 billion kg/yr)

North American refinery
hydrogen could fuel over
21 million FCEVs



- Refineries
- Ammonia
- Other / Unknown

Extensive hydrogen production capacity in place

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

Viability of Early Hydrogen Infrastructure

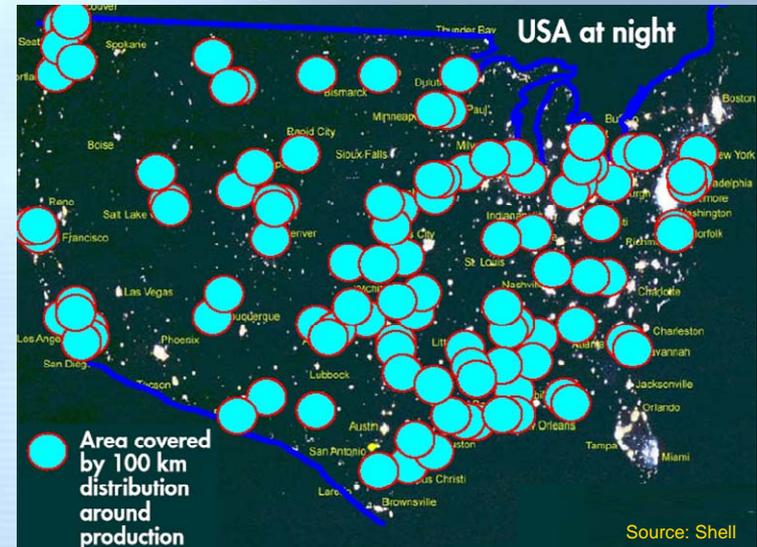
Early hydrogen refueling infrastructure can be commercially viable by:

- Leveraging existing hydrogen production/distribution infrastructure
- Geographically concentrating deployment & reflecting consumer driving patterns
- Coordinating vehicle/infrastructure deployment

Existing U.S. H2 Infrastructure



Existing U.S. H2 Infrastructure



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

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

Station always within
2 miles in urban areas



Top 100 U.S.
metro areas



1 highway station
every 25 miles



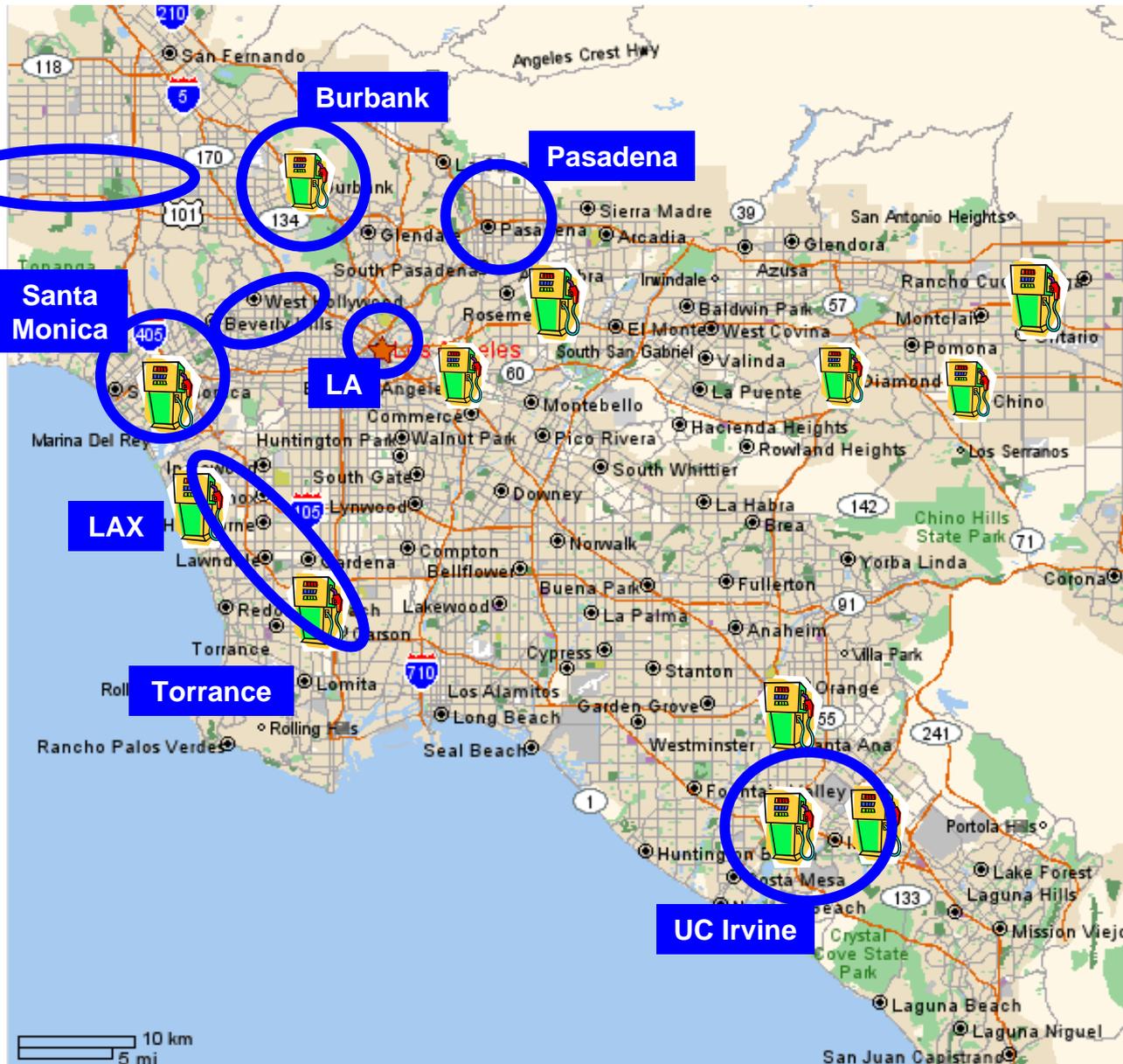
Ten things you should know about a hydrogen fueling infrastructure for automobiles

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 new technologies available 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



Southern California (2010-2012)

High-profile market areas and 70MPa Refueling Priorities

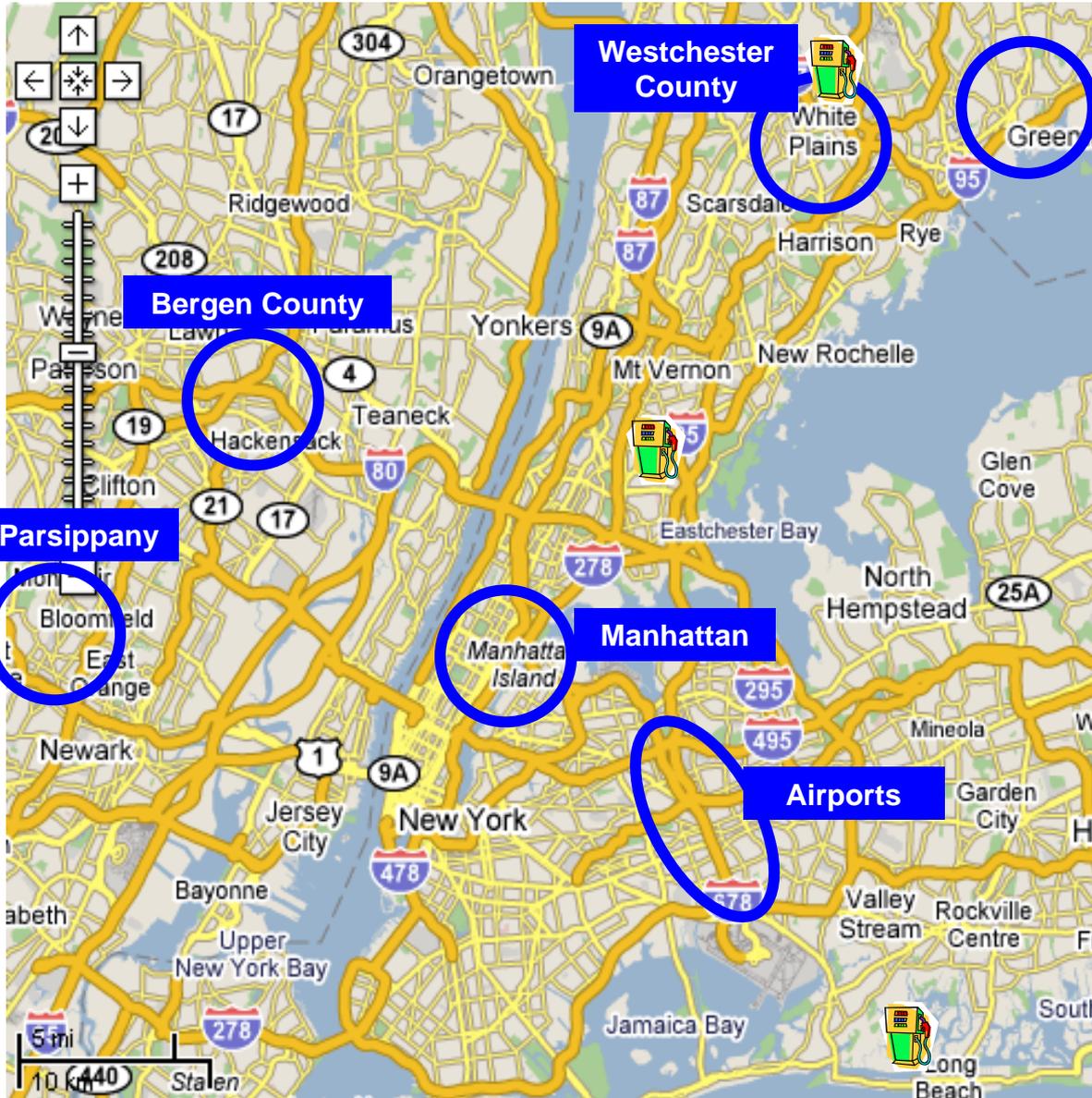


Current/planned refueling sites:

- almost exclusively 350bar
- expedient, not targeted, sites
- "behind-the-fence"
- call-ahead
- OEM access limitations
- limited capacity
- varying fueling procedures

New York (2010-2012)

High-profile market areas and 70MPa Refueling Priorities

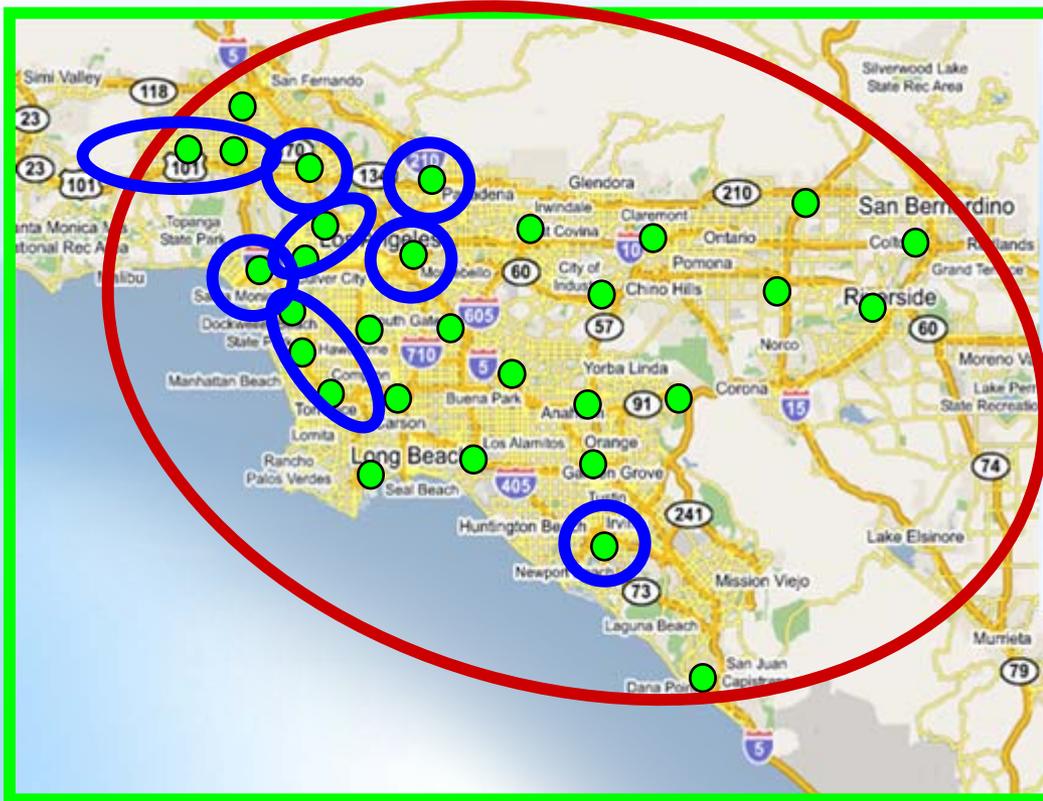


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40 Stations: LA Metro Area 2010-2015

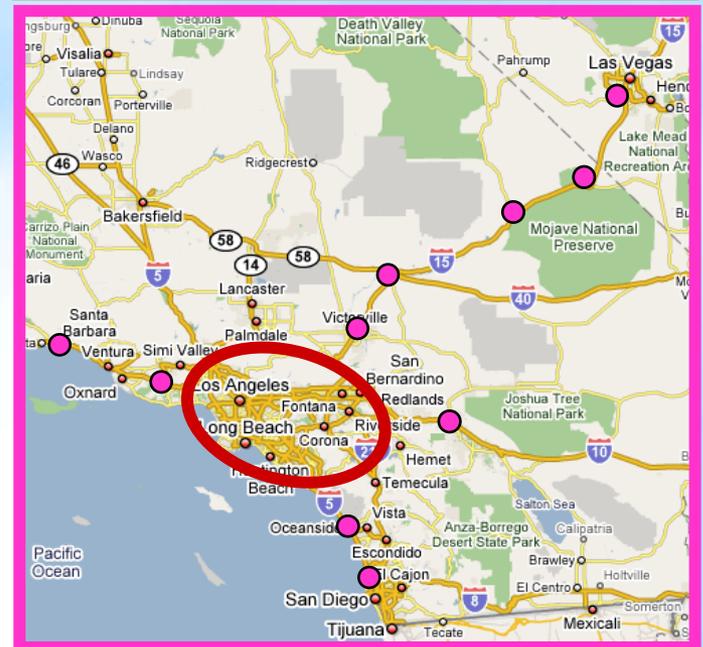
Refueling Priorities: High-profile market areas and key destinations



30 stations in LA Metro Area
(illustrative placement)



10 stations for Destination
Corridors



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

Average distance to metro station = 3.6 miles

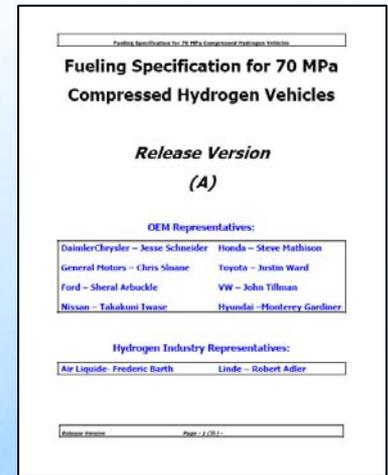
How might FCVs deploy in the U.S.? Project Driveway Locations are LA, NYC, WDC



In order to best coordinate the deployment of refueling infrastructure with fuel cell vehicles a concentrated regional deployment is most logical

Need to Demonstrate Commercial-Scale Specs for 700bar Hydrogen Refueling

- OEMs and Industry published a Fast-fill 70 MPa Fueling Guideline in April 2007 (to be superseded by SAE J2601)
 - Up to 5kg in 3 minutes (implies -40°C fuel delivery temp.)
- All stations do not need to be fast-fill
 - Stations of lesser cost and capability can support today's fuel cell vehicle demo fleet
- Some stations MUST be fast-fill
 - Station technology development needed in advance of commercial phase
 - Enabler for customer experience and market learning
- Germany leads in fast-fill public stations ...



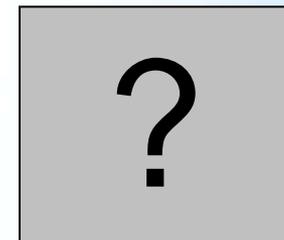
... the US has not kept pace



Berlin #1



Berlin #2



U.S.

Some Observations (I could be wrong)

Energy Companies:

- \$\$\$\$\$
- But, not necessarily from the retail business (and in many cases only ~10% stations are company owned/operated)
- Don't generally do station storage/dispensing technology development (exceptions are e.g. Chevron's onsite reformer work)
- They do have land (retail sites)
- Don't perceive an Early Mover Advantage, so there is no need to enter a business that has no revenue potential

Industrial Gas Companies (and other equipment suppliers):

- Station and fueling technology experts
- \$
- Don't do retail (dealing with general public/liability is new)
- Don't have land (requires complex/time-consuming effort to establish partnerships)
- Don't have renewable expertise (yet) – renewable requirement for state funding drives different technology solutions – no in-house expertise/resources – results in a complex/costly/time-consuming effort (or no bid for state funding)

Infrastructure Next Steps...

- **Retail-like refueling stations**

- Geographically targeted regions where automakers want to put vehicles
- 700bar fast-fill refueling (several demonstrating commercial capability)
- Compelling, comfortable stations
- Operational with (or before) vehicles

- **Access to key existing stations**

- All-OEM accessible
- Access agreements w/ reasonable liability terms (or eliminate altogether)

- **Expedient station approval and permitting process**

- State-wide consistency and local adherence
- Community support

- **Funding Support and Incentives**

- Stations and upgrades
- Liability coverage (funded liability pool, liability cap) or...
Full-service attendants to mitigate liability issues
- Station operating costs/refueling costs

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





Thank you ...

**Shawn Murphy (Environmental Media Association) ,
'Coolfuel' TV Producer / Host, wrote the following:**

Thank you for providing the GM Equinox Fuel Cell vehicle for me to test. I have driven hundreds of vehicles all over the world, have used more fuels than most people would have even heard of, from vegetable oil to biodiesel, hemp oil, geothermal power -- even food scraps and donuts as fuel. I drove 16,000 miles around the USA without using any gas in all types of vehicles --- bus, truck, boat, plane, car. As a constant traveler and also a parent, the GM Equinox Fuel Cell is the first family vehicle that has cracked the code for me. I see it not as a car of the future, but a car for now. For function, no petroleum, speed, comfort and the opportunity to produce a vehicle with zero emissions derived from renewable sources, it's the best I have driven. Well done, it's a great ride and perfect for the family of the coming decade.