

# Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State

A California Roadmap

January 27, 2014



# The cars are coming (buses, too)





# Hydrogen Stations in California



## Open Today:

- Burbank
- Emeryville
- Fountain Valley
- Harbor City
- Irvine #1
- Newport Beach
- Thousand Palms
- Torrance
- West LA #1



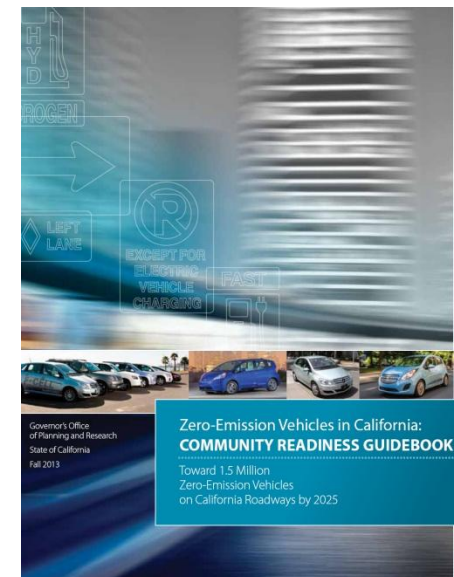
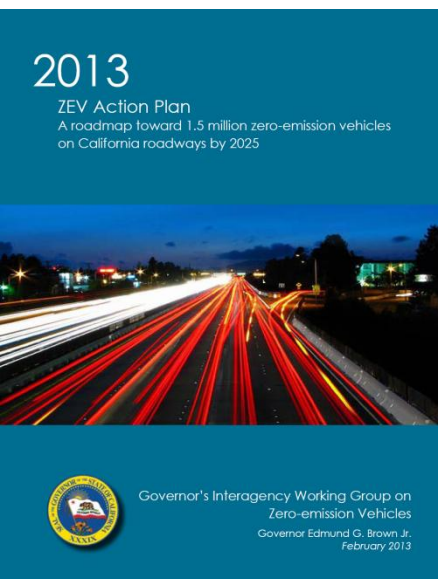
## In Development:

- Beverly Hills
- Diamond Bar (upgrade)
- Hawthorne
- Hermosa Beach
- Irvine #2
- Los Angeles - CSULA
- San Juan Capistrano
- Santa Monica
- West LA #2
- West Sacramento
- Westwood – UCLA
- Anaheim
- Chino
- Cupertino
- Foster City
- Mission Viejo
- Mountain View
- Woodland Hills (LA)

# California ZEV Action Plan



- By 2015: California major metropolitan areas “ZEV-ready” with infrastructure and streamlined permitting
- By 2020: California ZEV infrastructure can support up to 1 million vehicles
  - » Including widespread use of ZEVs for freight and public transit
- By 2025: Over 1.5 million ZEVs in California

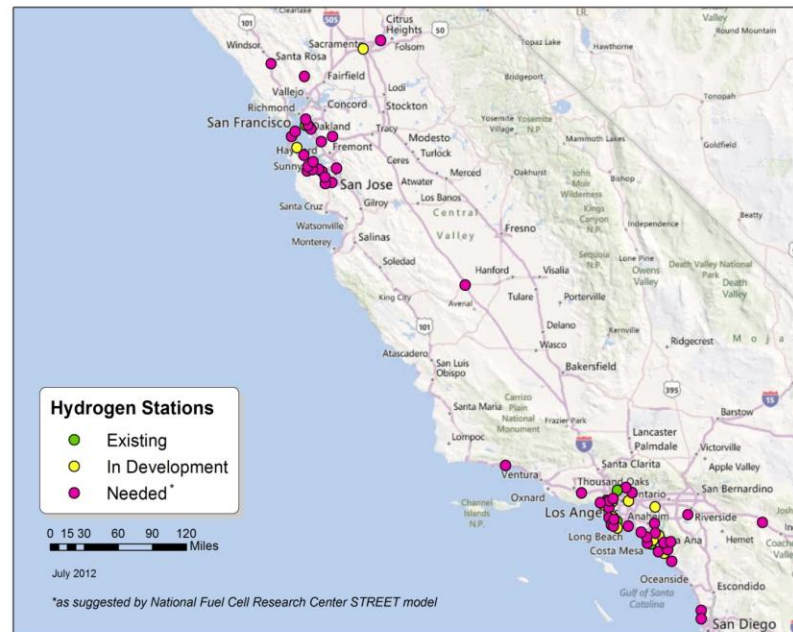


# Stations must come first

- 68 stations provide coverage to enable market launch
  - » Supports customer convenient fueling in early markets
  - » Enables travel throughout early market regions and state



**Map of 68 Hydrogen  
Fueling Stations:  
Existing, In Development  
and Needed**



# Five clusters to launch market



- Santa Monica and West Los Angeles
- Torrance and nearby coastal cities
- Southern coastal area of Orange County
- Berkeley
- South San Francisco Bay area

## Locations based on:

- Demographic information
- Individual OEM market assessments
- California Energy Commission/Air Resources Board Vehicle Survey
- Hybrid and alt fuel vehicles registrations
- Geographic distribution of Clean Vehicle Rebate Program

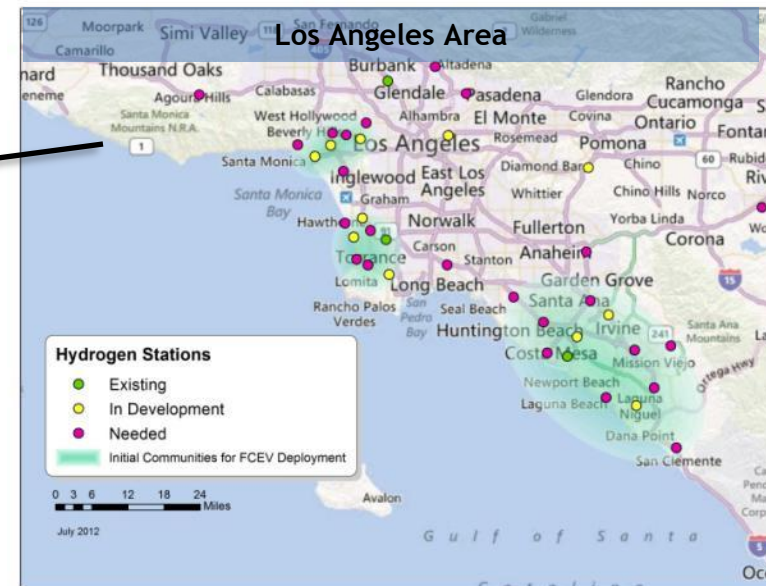
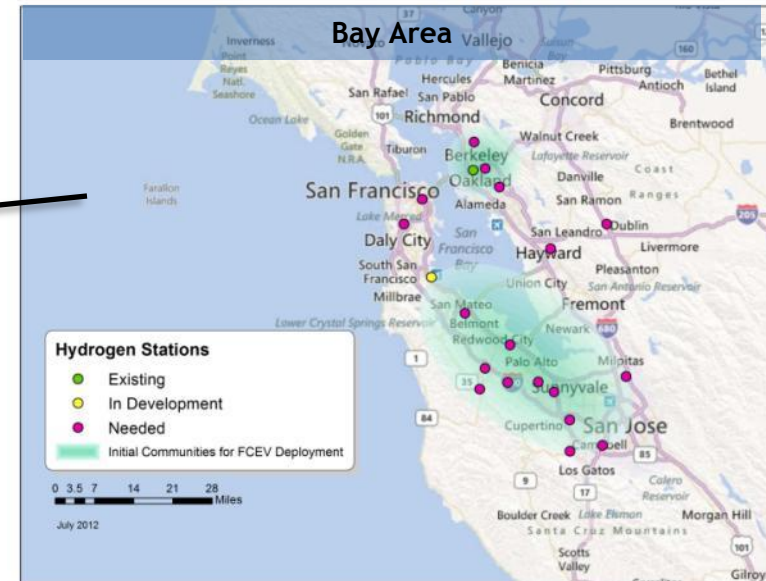
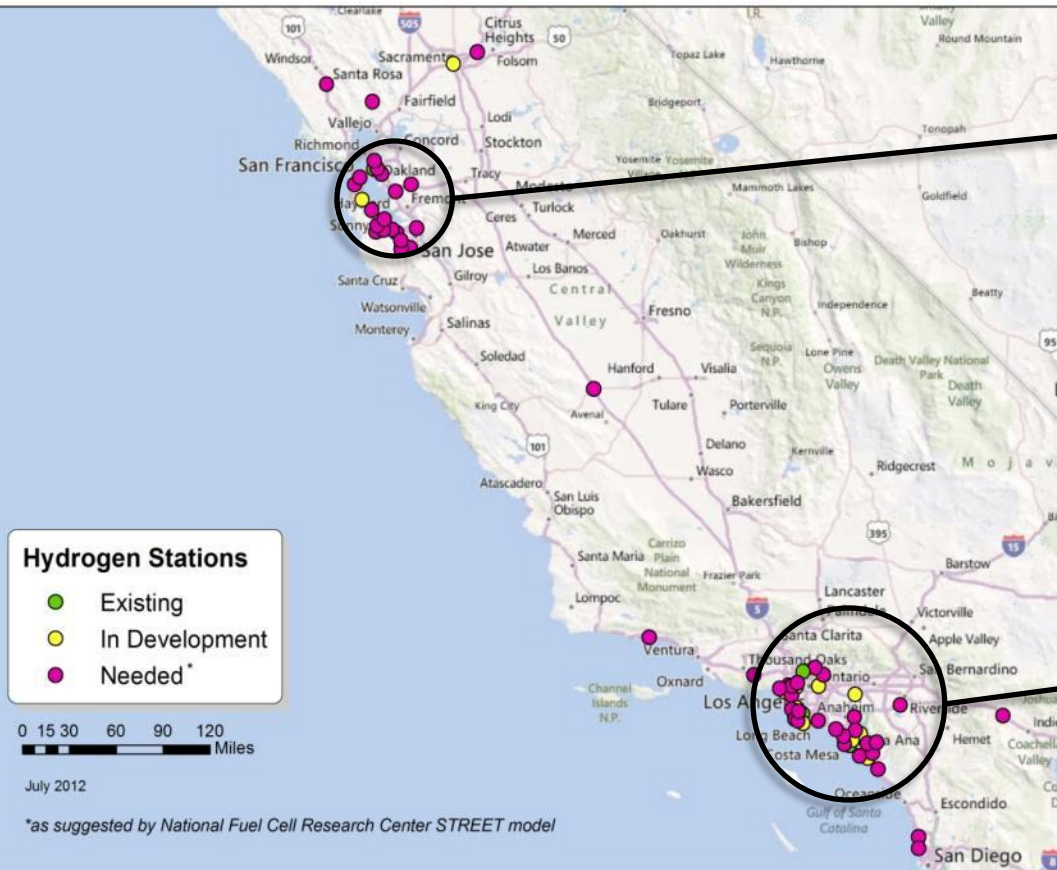
1.6 Million HH in CA with income > \$150,000/year  
50% are within 6 minutes of 70 stations



# Building a statewide network



Map of 68 Hydrogen Fueling Stations: Existing, In Development and Needed



# Access to stations

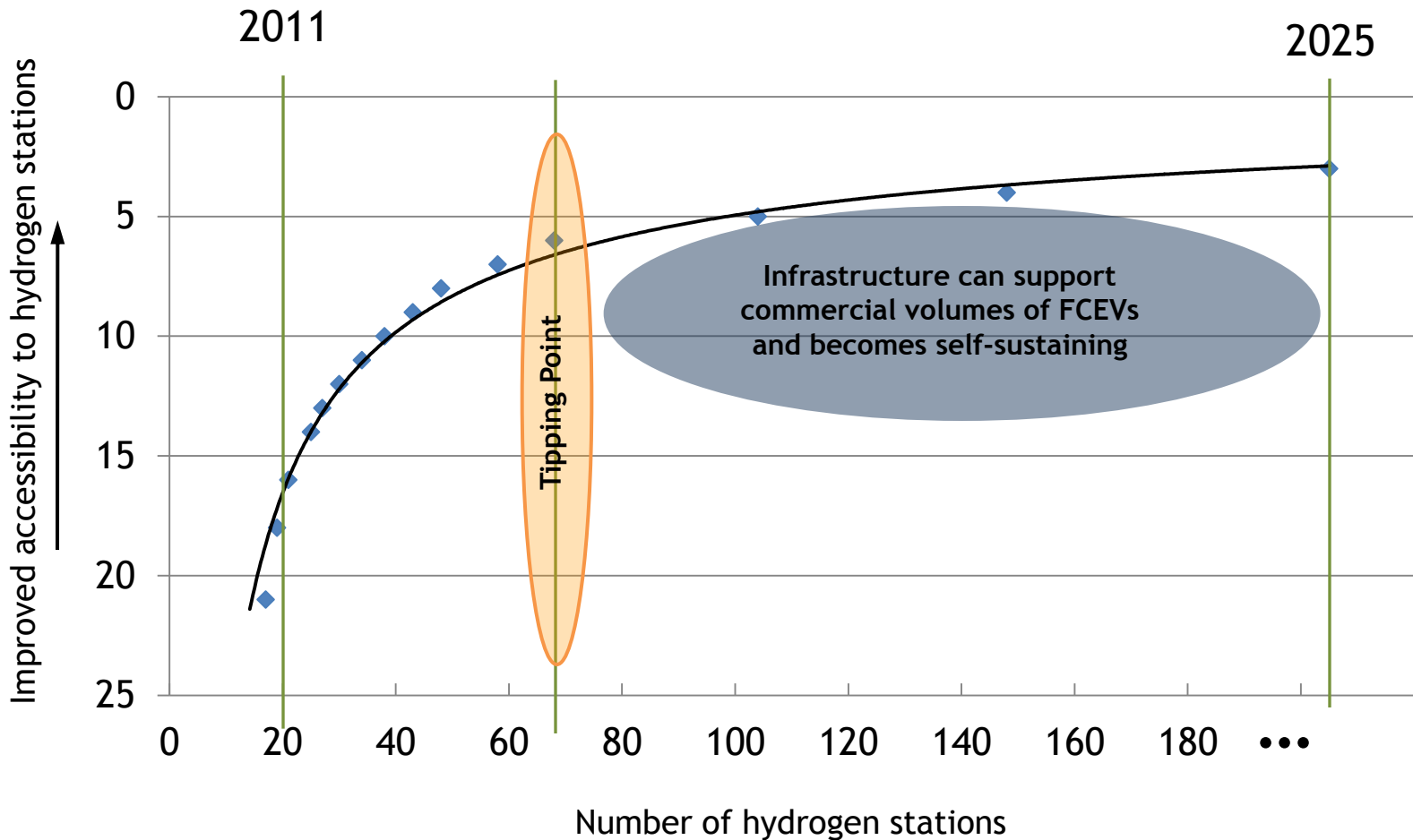


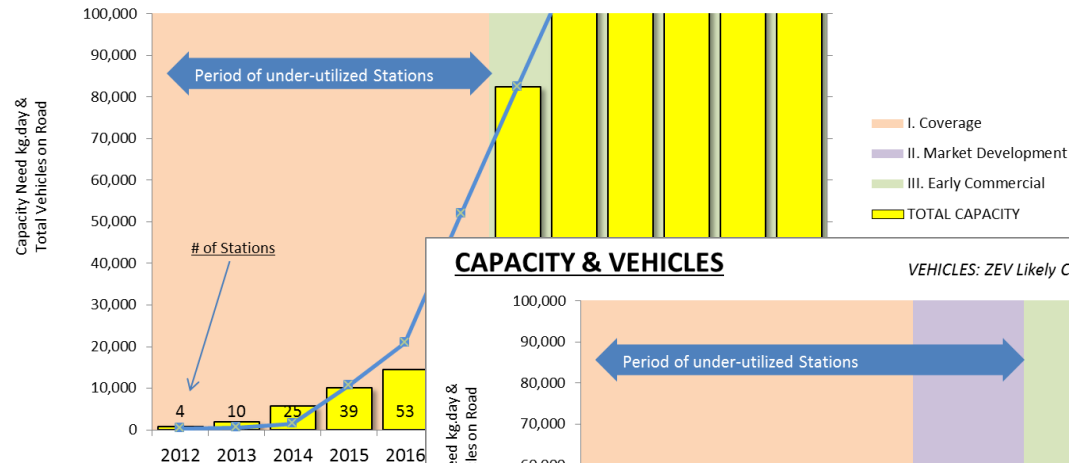
Chart courtesy of National Fuel Cell Research Center at UC Irvine



# H<sub>2</sub>NIP: FCEV deployment scenarios

## CAPACITY & VEHICLES

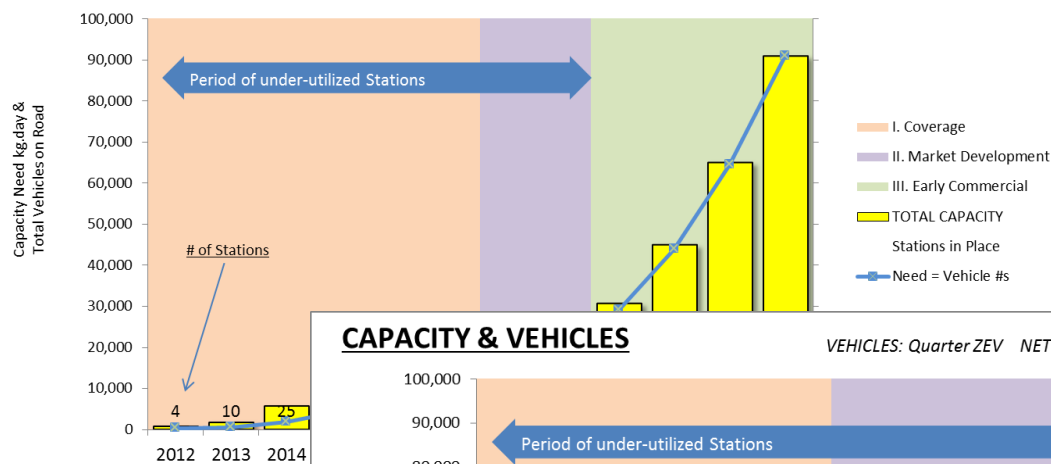
VEHICLES: CaFCP 2010 NETWORK: Current



2010 OEM surveys

## CAPACITY & VEHICLES

VEHICLES: ZEV Likely Compliance NETWORK: Current

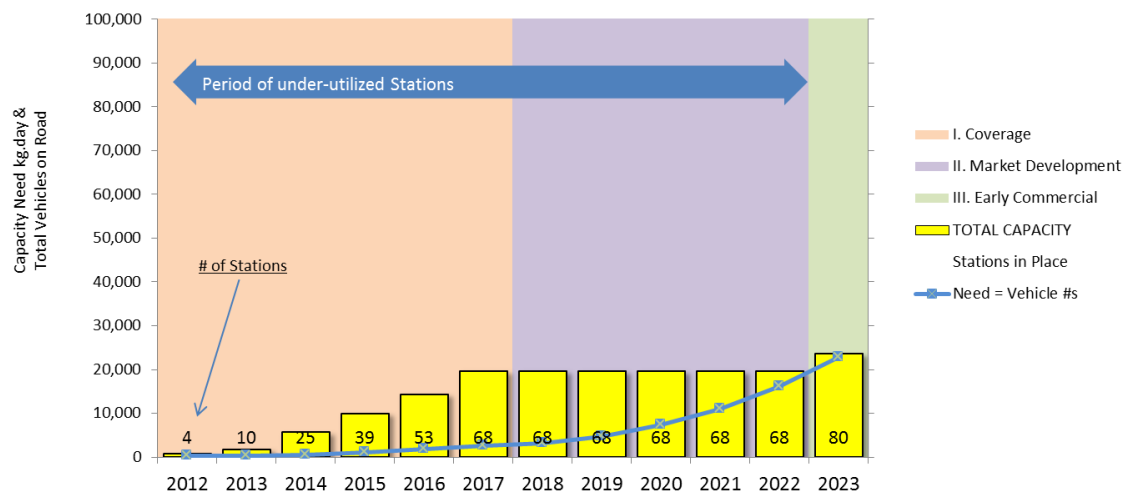


CARB ZEV likely compliance

1/4 ZEV likely compliance

## CAPACITY & VEHICLES

VEHICLES: Quarter ZEV NETWORK: Current

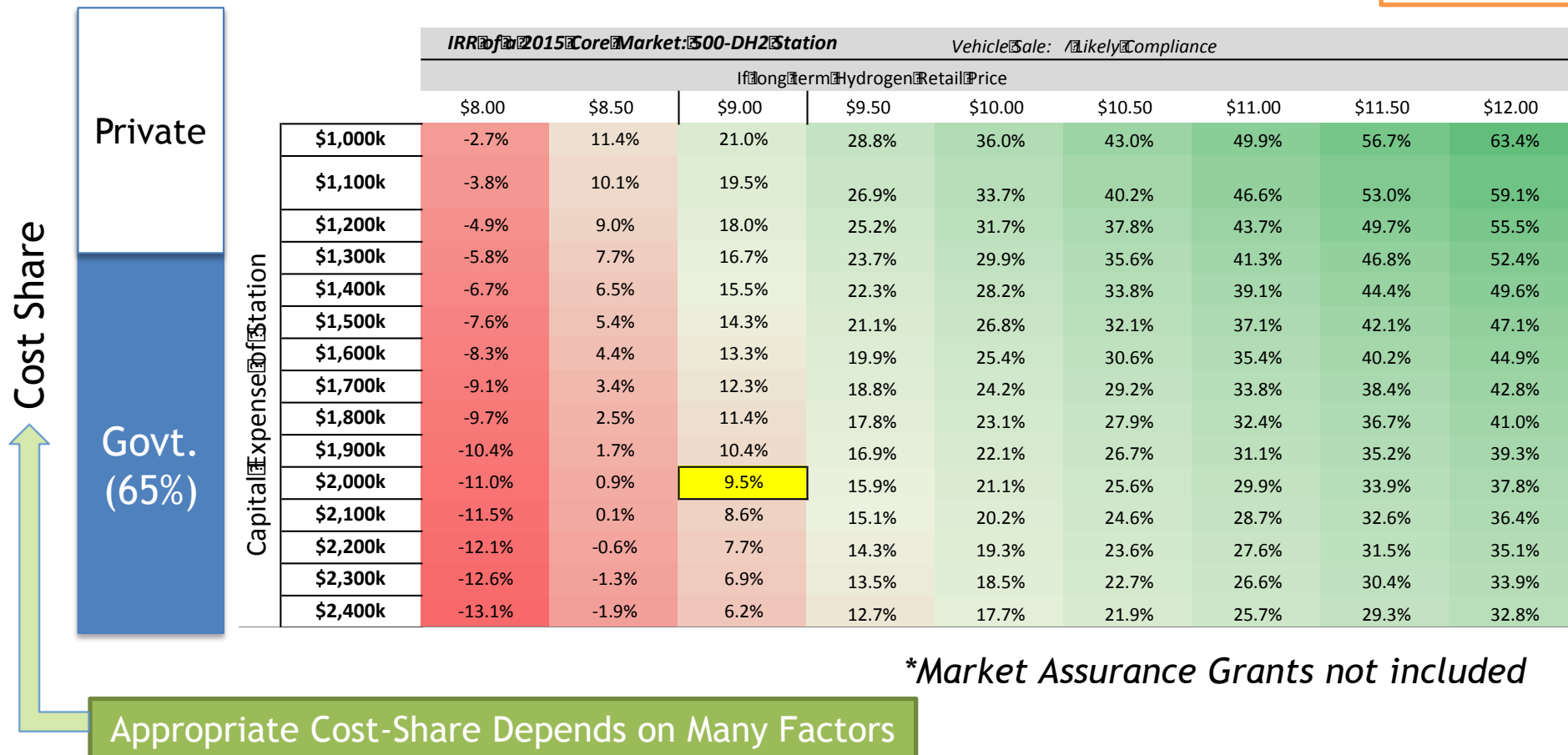


# H<sub>2</sub> NIP: Capital cost share essential

Core Market, ZEV Likely Compliance, \$2m 500kg/day Delivered Gas Station, Built in 2015:

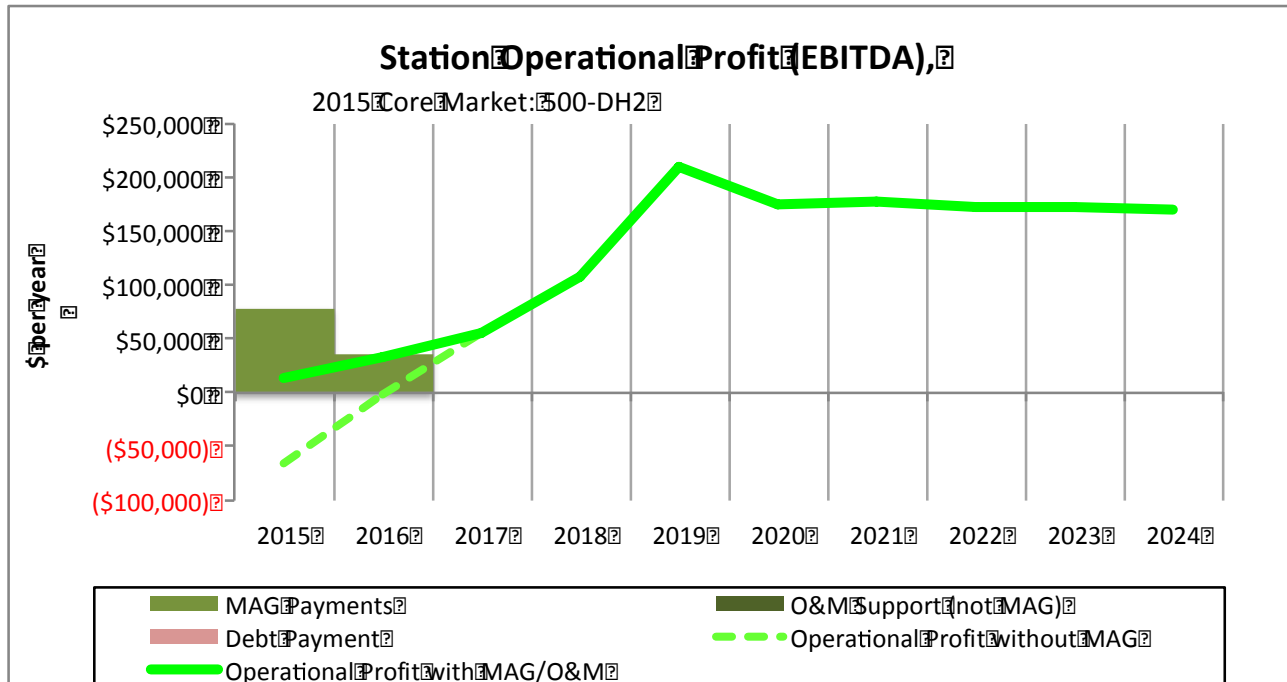
Better for  
Consumer

Better for  
Station  
Provider



# H<sub>2</sub>NIP: Important to cover O&M

ZEV likely compliance (10,500 FCEVs by 2017):



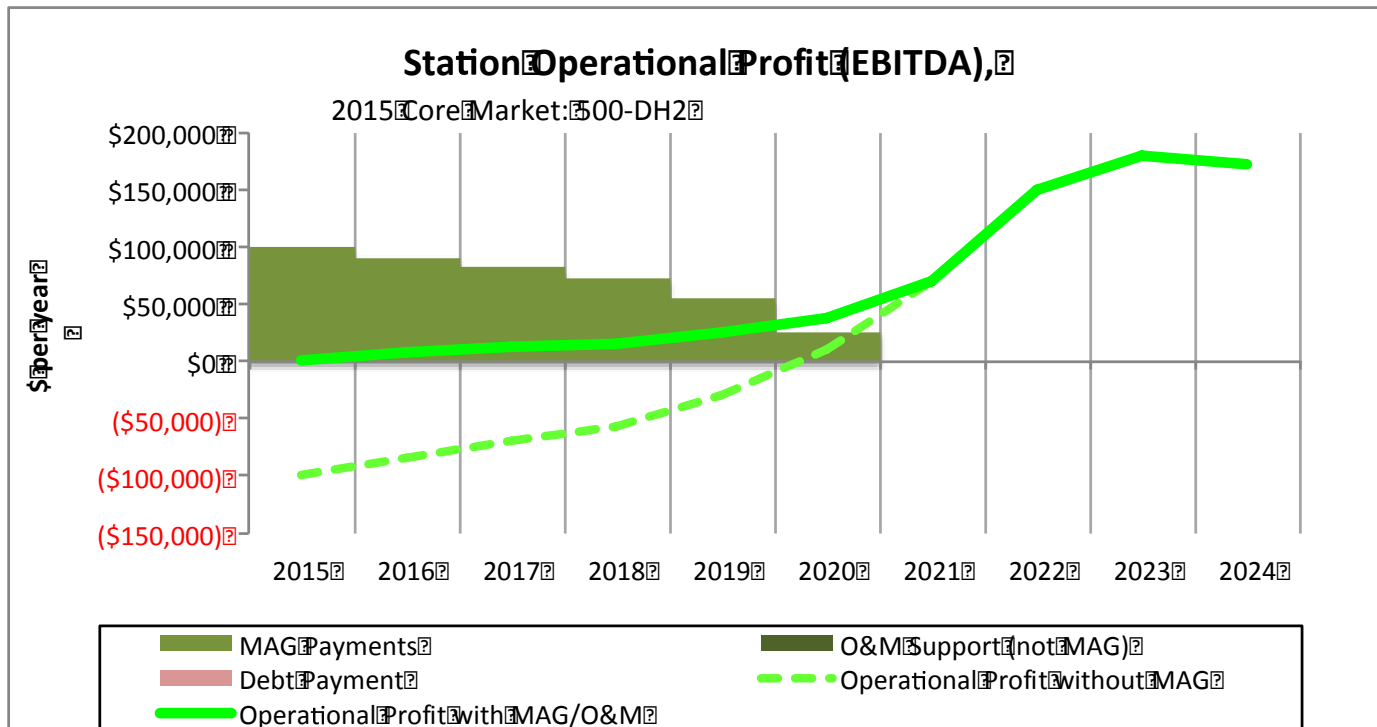
	IRR	Public Funds				Private Capex	TOTAL COST
		Capex Grant	MAG Grant	O&M Grant	Total Grant		
No Incentive	-7.9%	0	0	0	-	\$2,000k	\$2,000k
Capital Grant	9.5%	\$1,300k	-	-	\$1,300k	\$700k	\$2,000k
Capital Grant + MAG for O&M	12.8%	\$1,300k	\$114k	-	\$1,414k	\$700k	\$2,114k

Core market, 500 kg/day station, \$2M station (65% cost share), \$9/kg H<sub>2</sub> (\$5.50 wholesale) - \$2.18 net margin



# H<sub>2</sub>NIP: Market assurance grants

¼ ZEV Likely Compliance (2,625 FCEVs by 2017):

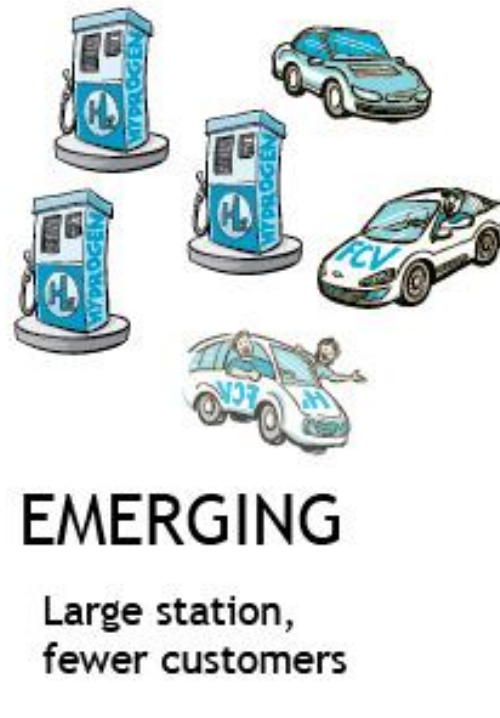
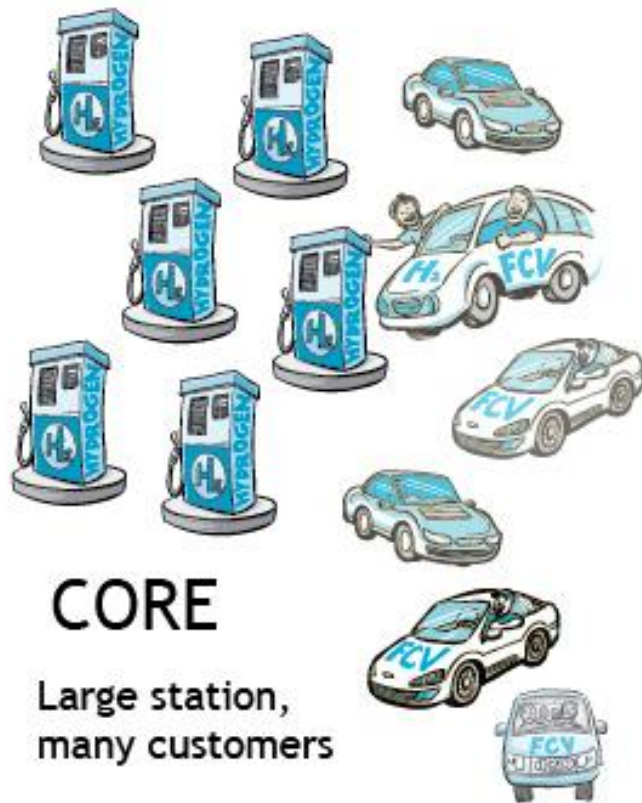


	IRR	Public Funds				Private Capex	TOTAL COST
		Capex Grant	MAG Grant	O&M Grant	Total Grant		
No Incentive	-16.6%	0	0	0	-	\$2,000k	\$2,000k
Capital Grant	-7.2%	\$1,300k	-	-	\$1,300k	\$700k	\$2,000k
Capital Grant + MAG for O&M	0.1%	\$1,300k	\$427k	-	\$1,727k	\$700k	\$2,427k

Core market, 500 kg/day station, \$2M station (65% cost share), \$9/kg H<sub>2</sub> (\$5.50 wholesale) - \$2.18 net margin

# H<sub>2</sub>NIP: Incentives vary by market

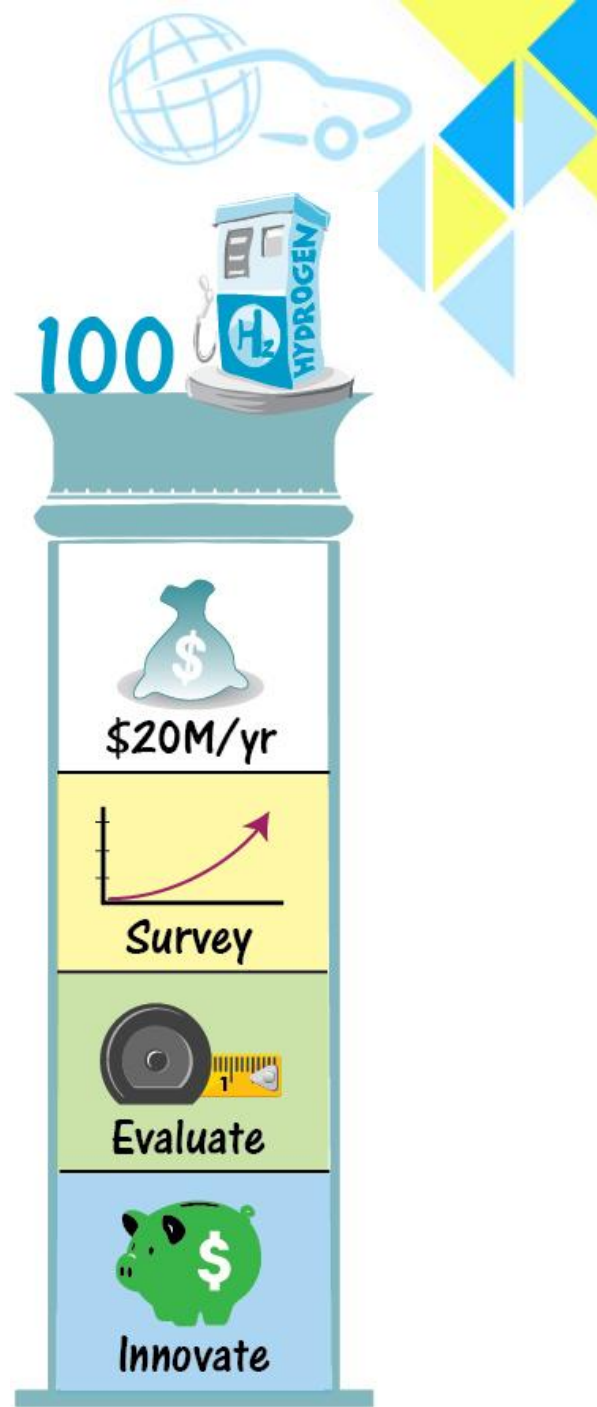
Increasing incentive required per station →



→ Decreasing number of stations

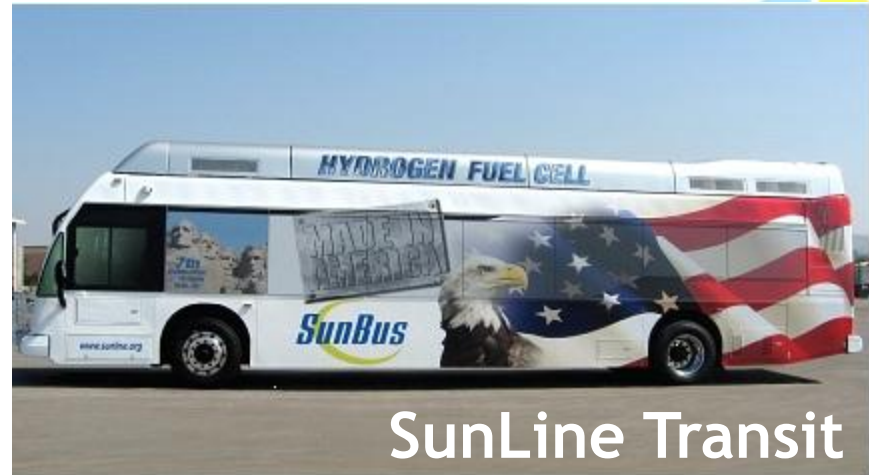
# H2 station funding

- AB 8 signed into law by Gov. Brown
  - » Extends funding for important air quality and alternative fuel programs
  - » Guarantees \$20M annually through 2023 to achieve 100 hydrogen stations in California
  - » Annual survey, evaluation and reporting
  - » Removes Clean Fuels Outlet regulation
- H<sub>2</sub> funding provision increases certainty that stations will be in place to support early market FCEVs
- Diverse stakeholder groups supported the bill





# Fuel cell electric buses in California



SunLine Transit



AC Transit

See [http://www.nrel.gov/hydrogen/proj\\_fc\\_bus\\_eval.html](http://www.nrel.gov/hydrogen/proj_fc_bus_eval.html) for NREL fuel cell bus evaluation reports

# Fuel cell bus roadmap



## Goal

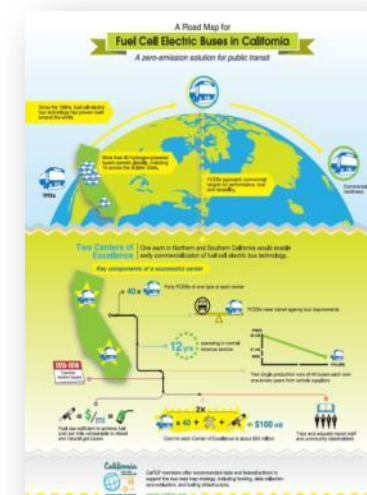
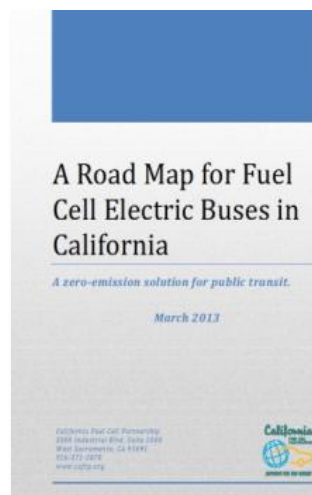
- » Move FCEB deployment and manufacturing from pre-commercial (2012-2015) to early commercial (2016-2017)

## Major objectives

- » Create two Centers of Excellence
  - One in Northern and one in Southern California
- » Achieve DOE/DOT 2016 FCEB targets
- » Provide information to support state and federal decision making




AC Transit fueling station (Photo courtesy of L. Eudy, NREL)



# Fuel cell bus roadmap goal



NREL Technology Readiness Levels for FCEB Commercialization

Technology Readiness Level	Description (abbrev.)
TRL 9	Technology in its final form. Fully commercial products.
 TRL 8	Last step in true system development (50-100 buses/location)
TRL 7	Full-scale demonstration and reliability testing (5-10 buses/location)
TRL 6	First tests of prototype buses in actual transit service (1-2 buses/location)
TRL 1-5	R&D → lab scale testing & early prototype/mule

A step change in the FCEB market from the current pre-commercial phase of deployment and manufacturing to the early commercial phase



# U.S. DOE and U.S. DOT targets



**Table 1.** Performance, cost, and durability targets for fuel cell transit buses.

	Units	2012 Status	2016 Target	Ultimate Target
Bus Lifetime	years/miles	5/100,000 <sup>1</sup>	12/500,000	12/500,000
Power Plant Lifetime <sup>2,3</sup>	hours	12,000	18,000	25,000
Bus Availability	%	60	85	90
Fuel Fills <sup>4</sup>	per day	1	1 (< 10 min)	1 (< 10 min)
Bus Cost <sup>5</sup>	\$	2,000,000	1,000,000	600,000
Power Plant Cost <sup>2,5</sup>	\$	700,000	450,000	200,000
Hydrogen Storage Cost	\$	100,000	75,000	50,000
Road Call Frequency (Bus/Fuel Cell System)	miles between road calls	2,500/10,000	3,500/15,000	4,000/20,000
Operation Time	hours per day/days per week	19/7	20/7	20/7
Scheduled and Unscheduled Maintenance Cost <sup>6</sup>	\$/mile	1.20	0.75	0.40
Range	miles	270	300	300
Fuel Economy	miles per gallon diesel equivalent	7	8	8

TRL 7

TRL 8

TRL 9



Shell  
**Hydrogen**



**HYDROGEN**  
WARNING  
FLAMMABLE, HIGH PRESSURE GAS. NO SMOKING,  
NO OPEN FLAME. USE IN ACCORDANCE WITH  
AIR PRODUCT'S MATERIAL SAFETY DATA SHEET.



CHEVROLET  
**CLARITY**

# Members

Air Liquide  
Air Products  
Alameda-Contra Costa Transit District  
(*AC Transit*)  
Automotive Fuel Cell Cooperation  
Ballard Power Systems  
Bay Area Air Quality Management District  
California Air Resources Board  
California Department of Food  
and Agriculture  
California Energy Commission  
California State University - Los Angeles  
CALSTART  
The Center for Energy Efficiency and  
Renewable Technologies (*CEERT*)  
Center for Transportation and the  
Environment (*CTE*)  
Chrysler  
Daimler  
Energy Independence Now  
General Motors

Honda  
Hydrogenics  
Hyundai  
Institute of Transportation Studies, UC Davis  
Linde North America, Inc.  
National Fuel Cell Research Center, UC Irvine  
National Renewable Energy Laboratory (*NREL*)  
Nissan  
Powertech Labs  
Proton OnSite  
Sandia National Laboratories  
South Coast Air Quality Management District  
Southern California Gas Company  
SunLine Transit Agency  
Toyota  
U.S. Department of Energy  
U.S. Environmental Protection Agency  
US Hybrid  
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