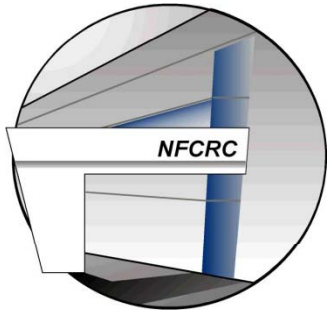
Hydrogen Fuel Cell Vehicles

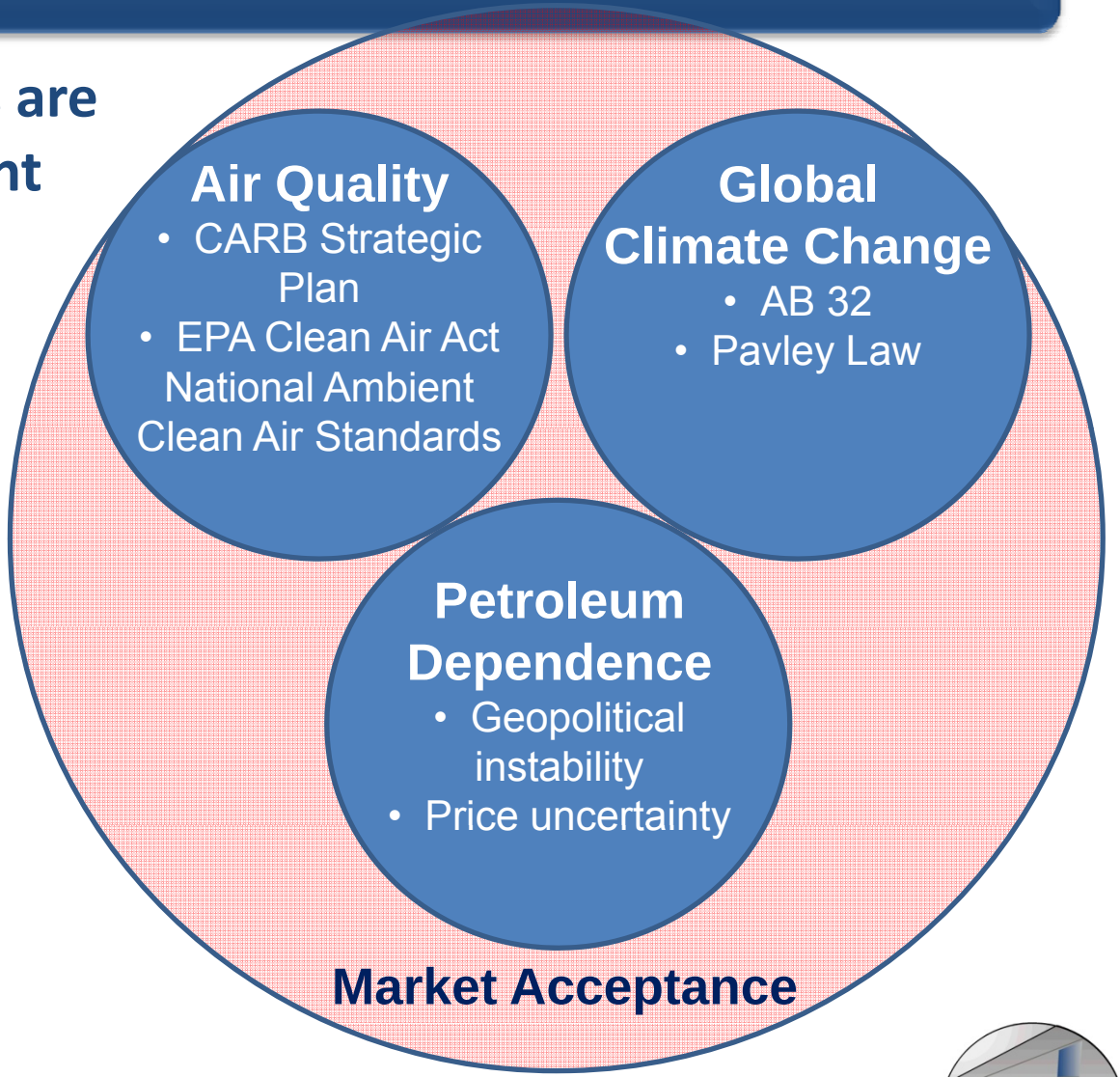
Tim Brown, Ph.D.
Technology Manager Sustainable Transportation
National Fuel Cell Research Center
University of California
Irvine, California 92697-3550
http://www.apep.uci.edu



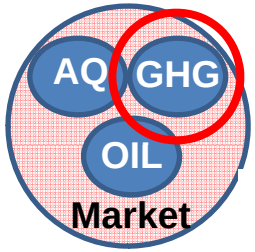
Transportation Problem

Three forcing functions are driving the development of alternative transportation options

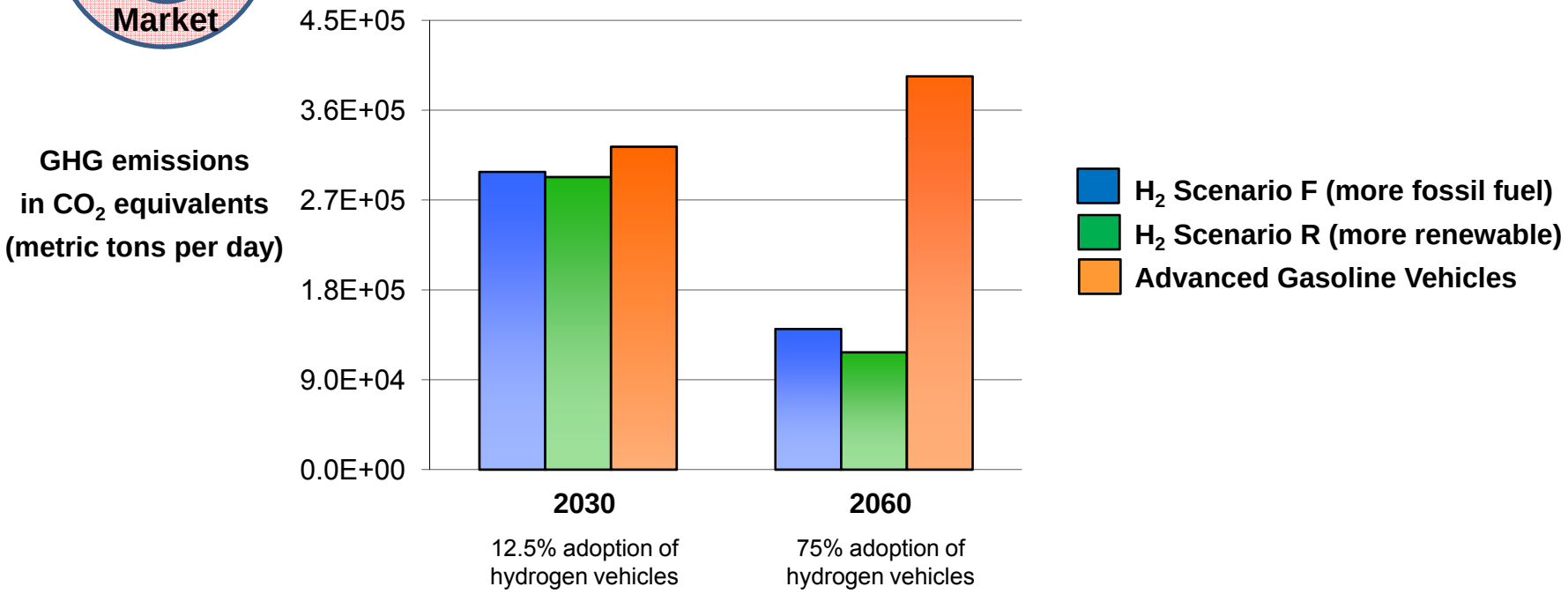
The only successful alternative is one that will meet the needs of consumers and the economy



Hydrogen Reduces GHG Emissions



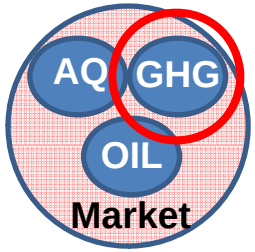
Well-to-wheel GHG emissions are drastically reduced for a realistic *mix of H_2 generation technologies*



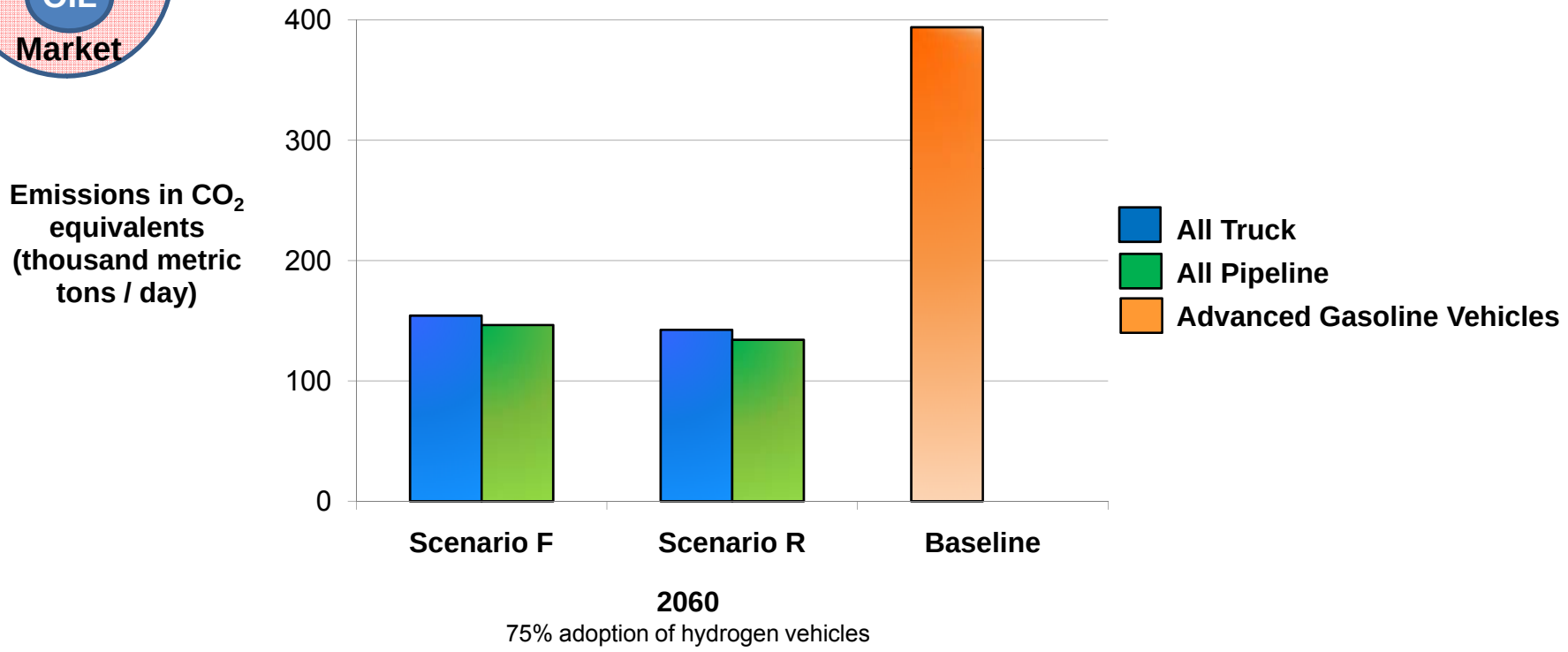
Results from NFCRC STREET modeling tool as published in:

Stephens-Romero, Samuelsen. Demonstration of a novel assessment methodology for hydrogen infrastructure deployment *International Journal of Hydrogen Energy*, *Volume 34, Issue 2*, *January 2009*, *Pages 628-641*

Hydrogen Reduces GHG Emissions



Well-to-wheel GHG emissions are drastically reduced *regardless of H_2 delivery method*



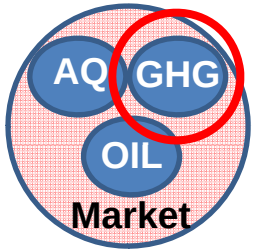
2060

75% adoption of hydrogen vehicles

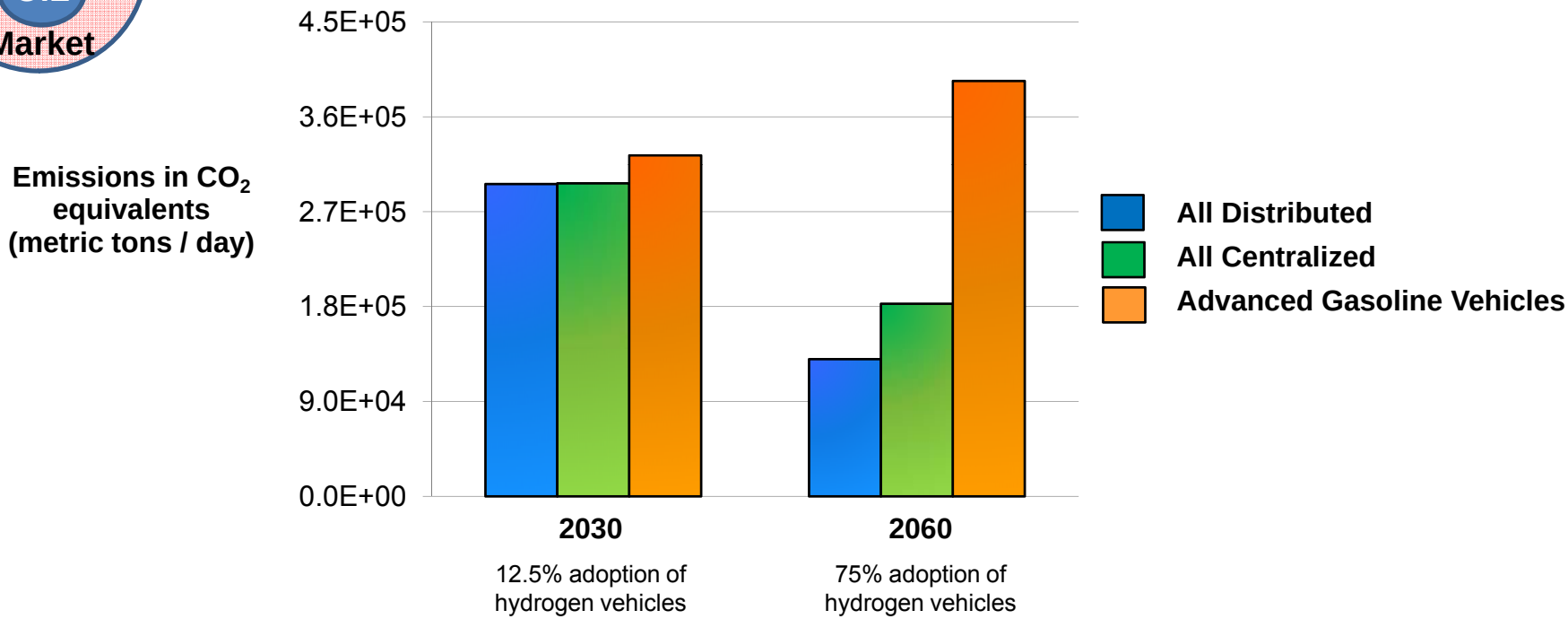
Results from NFCRC STREET modeling tool as published in:

Stephens-Romero, Samuelsen. Demonstration of a novel assessment methodology for hydrogen infrastructure deployment *International Journal of Hydrogen Energy*, *Volume 34, Issue 2*, *January 2009*, *Pages 628-641*

Hydrogen Reduces GHG Emissions



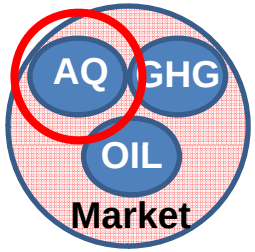
Well-to-wheel GHG emissions are drastically reduced *regardless of H_2 generation location*



Results from NFCRC STREET modeling tool as published in:

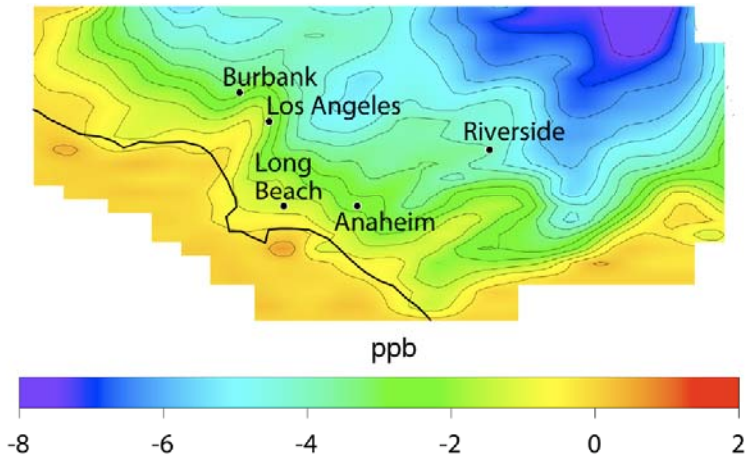
Stephens-Romero, Samuelsen. Demonstration of a novel assessment methodology for hydrogen infrastructure deployment *International Journal of Hydrogen Energy*, *Volume 34, Issue 2*, *January 2009*, *Pages 628-641*

Hydrogen Improves Air Quality

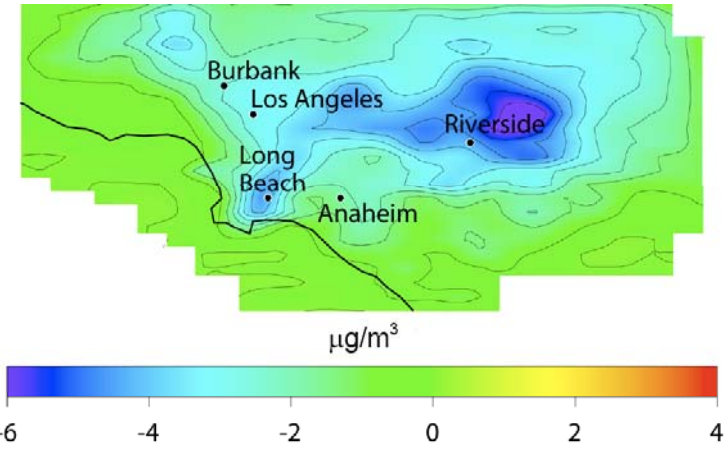


FCVs emit zero criteria pollutants resulting in dramatic air quality improvements even when H_2 is generated in urban areas

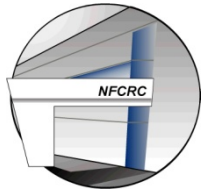
8-hr Ozone, 75% FCV Penetration
(Δ with respect to the baseline)



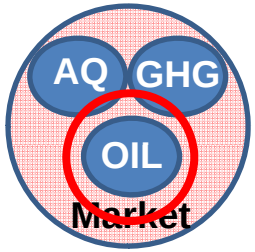
Particulate Matter, 75% FCV Penetration
(Δ with respect to the baseline)



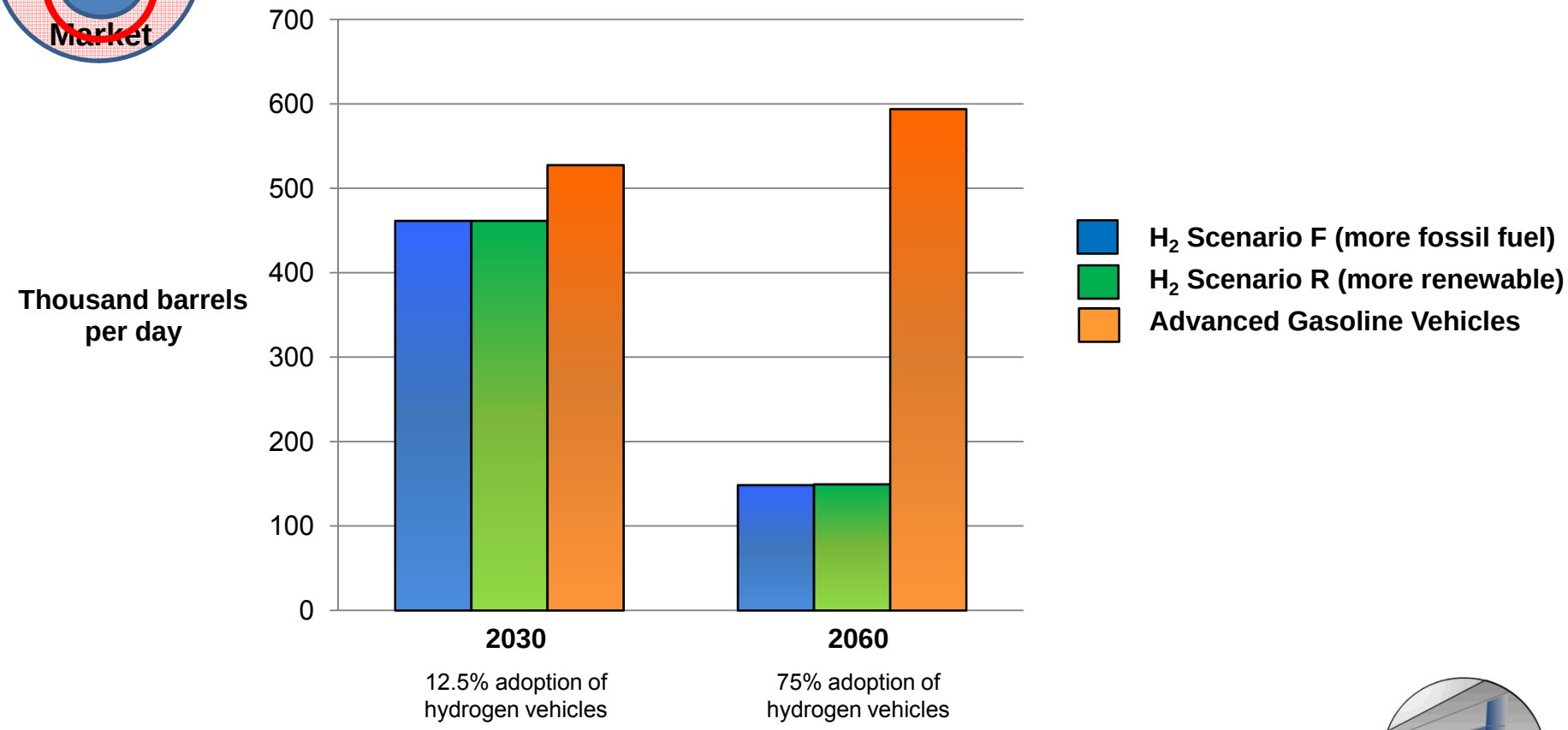
Results from NFCRC STREET modeling tool as published in:
Stephens-Romero, Carreras-Sospedra, Brouwer, Dabdub , Samuelsen. Determining Air Quality and Greenhouse Gas Impacts of Hydrogen Infrastructure and Fuel Cell Vehicles
Environmental Science & Technology, *In Press*



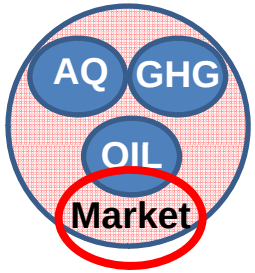
Hydrogen Displaces Petroleum



FCVs use zero petroleum and can significantly lesson our dependence on oil



Hydrogen Vehicles are Marketable



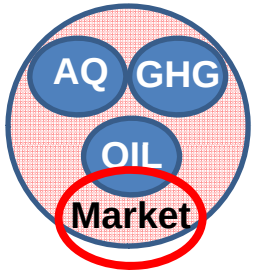
FCVs provide range competitive with current gasoline vehicles

Kia Borrego FCEV:
426 miles

Honda FCX Clarity
240 miles

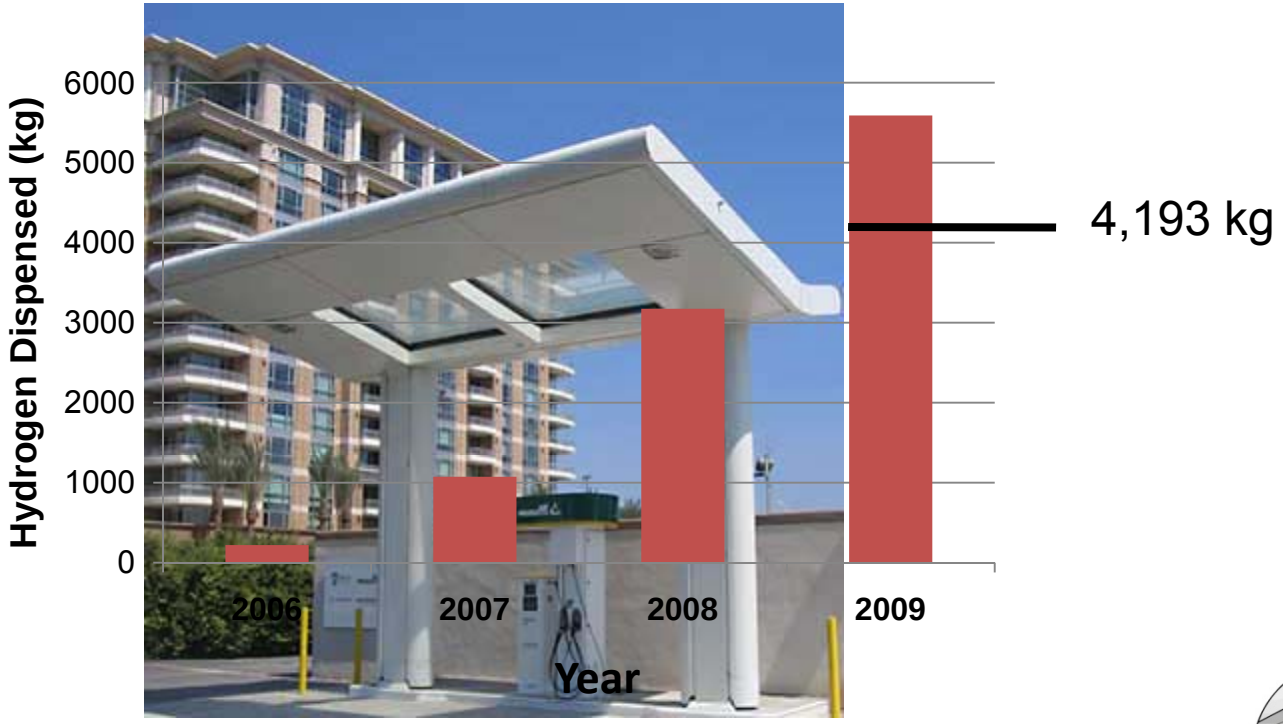
Toyota
FCHV-adv:
431 miles

Hydrogen Infrastructure

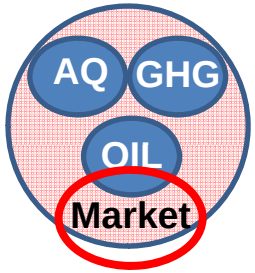


UC Irvine station usage is continually increasing

- Station was established as research facility for vehicles and fueling
- We are currently operating near our design limit of 25 kg/day
- Not uncommon to find 2 or 3 cars in a line waiting for fuel

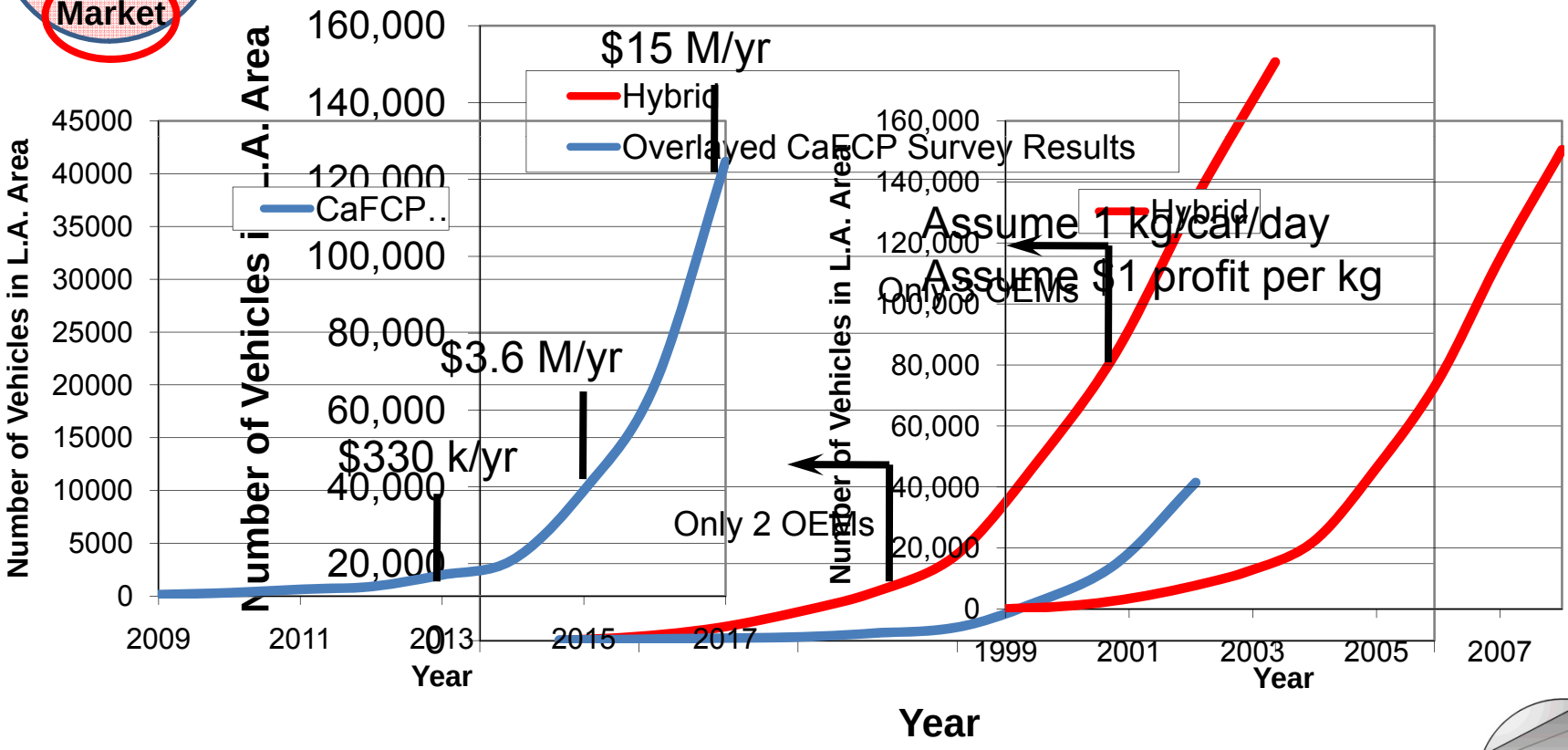


Hydrogen Infrastructure



CA Fuel Cell Partnership survey results show 40,000 FCVs in southern California by 2017

- Projections are very modest in comparison to historic HEV sales



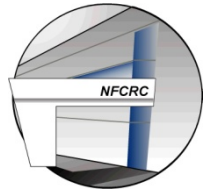
Bridge Between 2009 and ~2017

Infrastructure needs to reach threshold for vehicle commercialization

- **OEMs can only sell vehicles if fueling is sufficient enough for normal day-to-day requirements**
- **H_2 station "cluster" concept addresses this problem for localized areas**

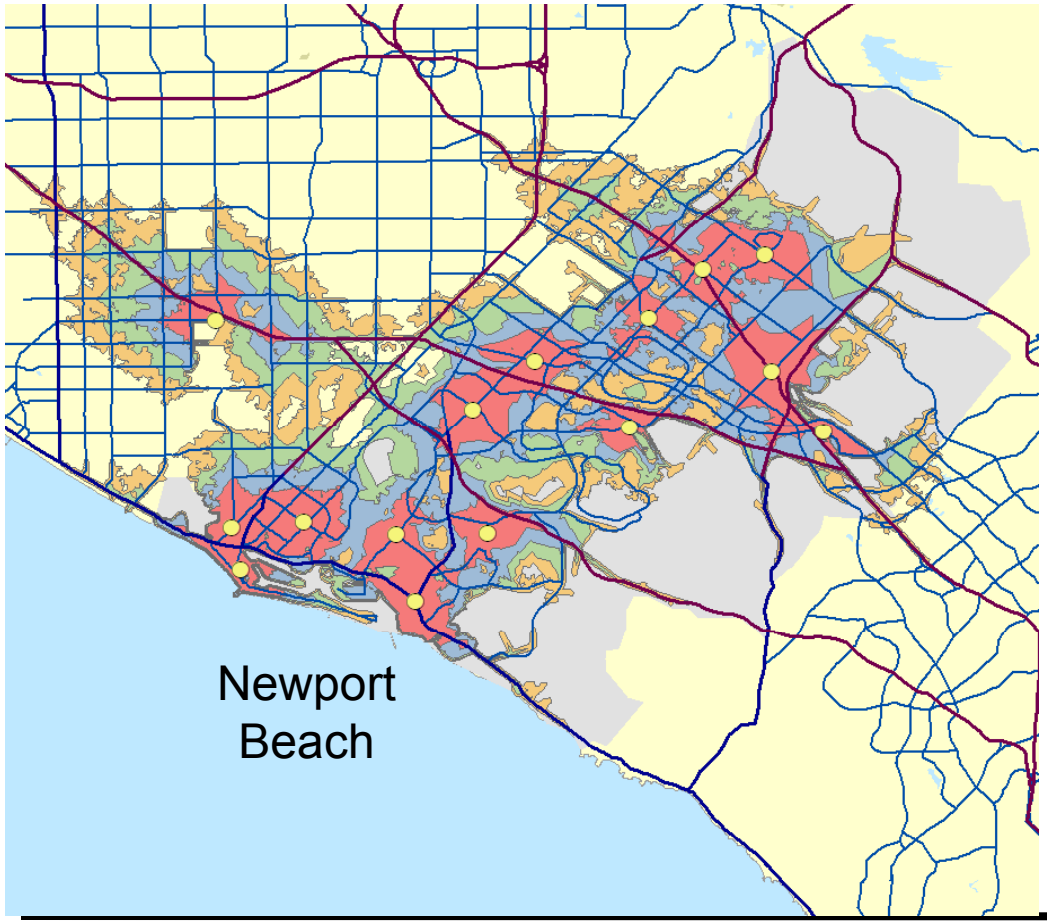
UC Irvine STREET modeling tool optimizes station location in near term to overcome *activation energy* necessary for commercialization

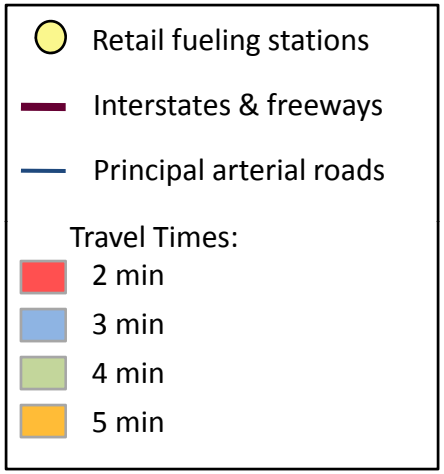
- **Roadway network optimization algorithm**
- **Land use**
- **Travel density**
- **Population centers**
- **Stakeholder input**
- **OEM customer data**



Blueprint for Hydrogen Station Clusters

Irvine case study: 8 well-placed H_2 stations can guarantee a basic city-wide level of service comparable to 34 gasoline stations.





Travel Time (min)	*Gas Stations (34)*	*H_2 Stations (8)*
5	73.5%	66.4%
4	67.3%	58.2%
3	54.0%	45.1%
2	42.8%	24.3%

Hydrogen Station Rollout Plan

Station rollout is also essential in early years

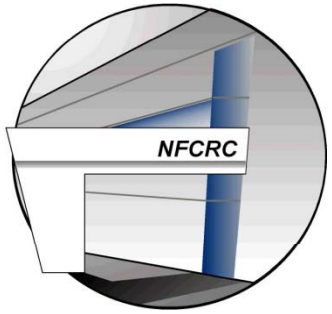
118 Investment Recommendations

NFCRC recommendations:

- **Infrastructure**
- **Infrastructure planning**
- **Renewable H_2 generation technology**
- **Technologies to reduce the fueling pressure (e.g., increased FC stack efficiency, on board fuel storage technology, plug-in capability)**
- **FC specialty vehicle deployment**
- **Consumer vehicle use behavior to inform station design and operation**
- **HTFC-H_2 tri-generation (NG, DG, LFG, biogas)**
- **H_2 compressor technology (increase efficiency)**
- **H_2 leak control (fuel transfer, vehicle storage and injection, pipeline, storage,…)**
- **Consumer safety (enclosed space: ordorant? Sensors? …)**
- **Weights and Measures**

Hydrogen Fuel Cell Vehicles

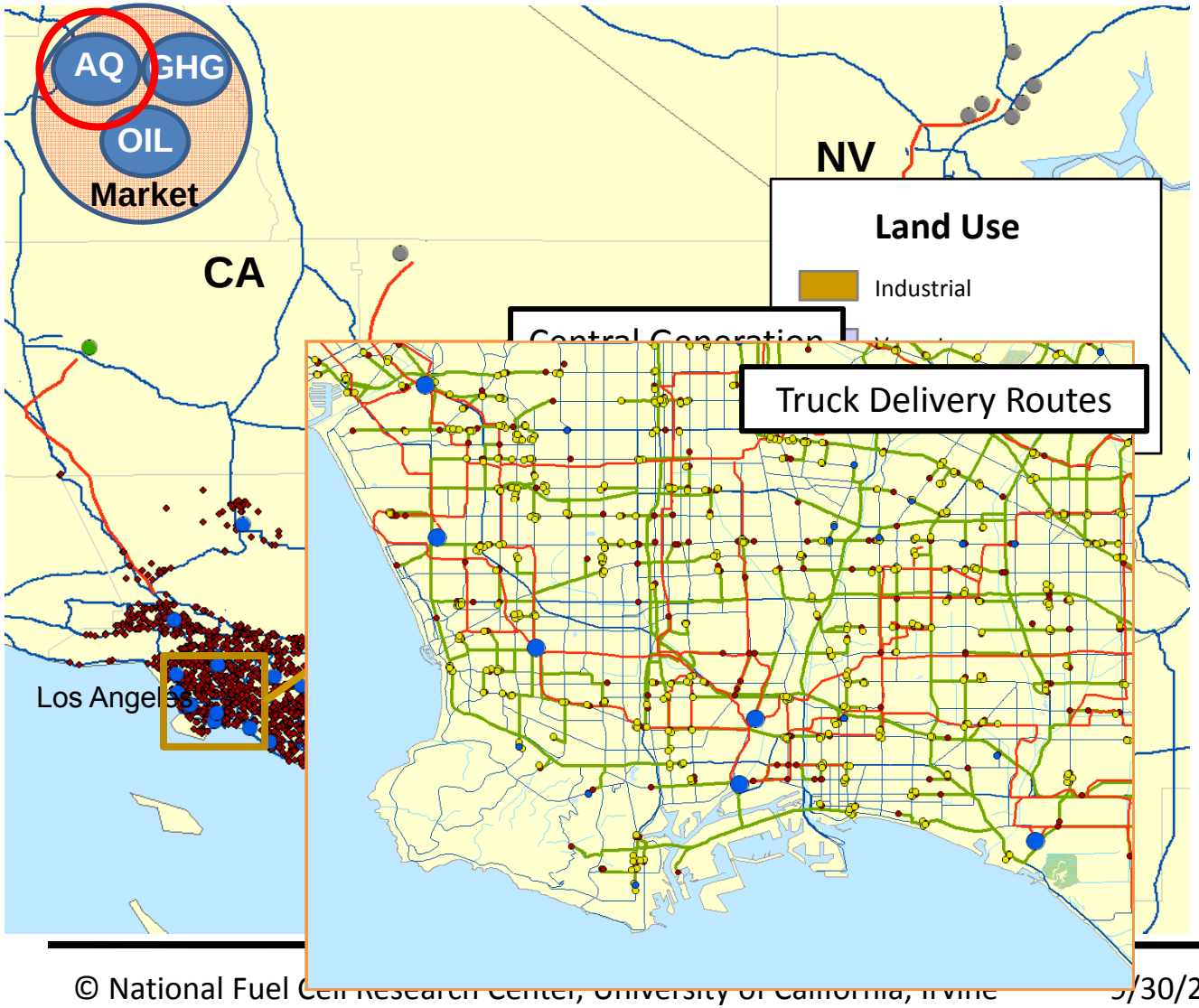
Tim Brown, Ph.D.
Technology Manager Sustainable Transportation
National Fuel Cell Research Center
University of California
Irvine, California 92697-3550
http://www.apep.uci.edu



Back up Slides

	Scenario-R: H_2 generated from more renewable sources				Scenario-F: H_2 generated from more fossil fuel sources			
Population of HFCV				10,162,500				10,162,500
Hydrogen demand (kg/day)				5,943,730				5,943,730
VMT/day by HFCV				573,807,694				573,807,694
Hydrogen Generation	Number of facilities	H_2 output (kg/day)	Percent contribution	Location relative to the SoCAB	Number of facilities	H_2 output (kg/day)	Percent contribution	Location relative to the SoCAB
Centralized								
Steam Methane Reforming	15	2,022,285	34.0%	Inside	16	2,157,104	36.3%	Inside
Coal IGCC	5	641,560	10.8%	Outside	12	1,539,744	25.9%	Outside
Petroleum Coke IGCC	0	0	0.0%	Inside	2	247,466	4.2%	Inside
Electrolysis	7	1,905,133	32.1%	Outside	7	429,196	7.2%	Outside
Distributed								
Steam Methane Reforming	155	135,700	2.3%	Inside	155	135,700	2.3%	Inside
Stationary Fuel Cell	2,023	736,372	12.4%	Inside	2,560	931,840	15.7%	Inside
Electrolysis	950	305,942	5.1%	Inside	950	305,942	5.1%	Inside
Home or Office Fueling	39,348	196,738	3.3%	Inside	39,348	196,738	3.3%	Inside
Hydrogen Distribution	Distance (km/kg H_2)	H_2 throughput (kg/day)			Distance (km/kg H_2)	H_2 throughput (kg/day)		
Remote pipelines	50	2,546,693			50	1,968,940		
Urban pipelines	15	3,064,615			15	3,064,615		
Liquid tanker	30	1,504,363			30	1,308,895		
Hydrogen Refueling		H_2 delivered (kg/day)	Percent contribution			H_2 delivered (kg/day)	Percent contribution	
140 bar gaseous fueling		4,108,125	70%			4,108,125	70%	
350 bar gaseous fueling		1,760,625	30%			1,760,625	30%	

Hydrogen Improves Air Quality



Southern California
Year: 2050

- H2 Fueling Stations
- Regional SMR
- Regional Petroleum Coke
- Central Coal/Biomass
- Central Renewable /Nuclear
- Local High-Temp Fuel Cells
- Distributed SMR
- Interstates & Freeways
- H2 Pipelines
- H2 Truck Deliver Routes