



***“Driving NGV’s Into the Hydrogen
Transportation Future”***

Presented to:

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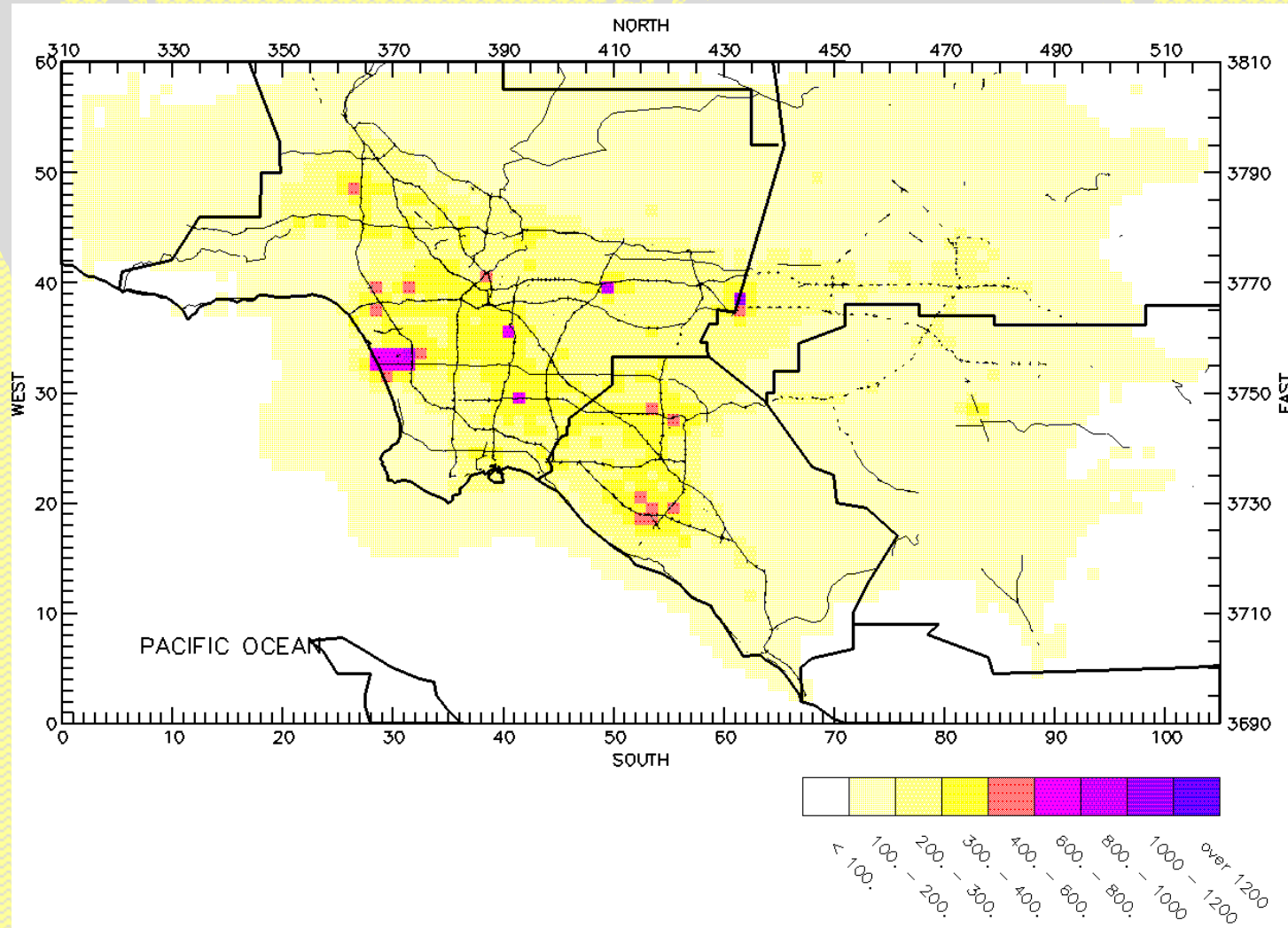
Outline:

- ◆ Why H2 & NGV's?
- ◆ Current Barriers to H2 Commercialization
- ◆ Transition Fundamentals
- ◆ The Transition: NG to H2
- ◆ Conclusions & Actions Needed Today!

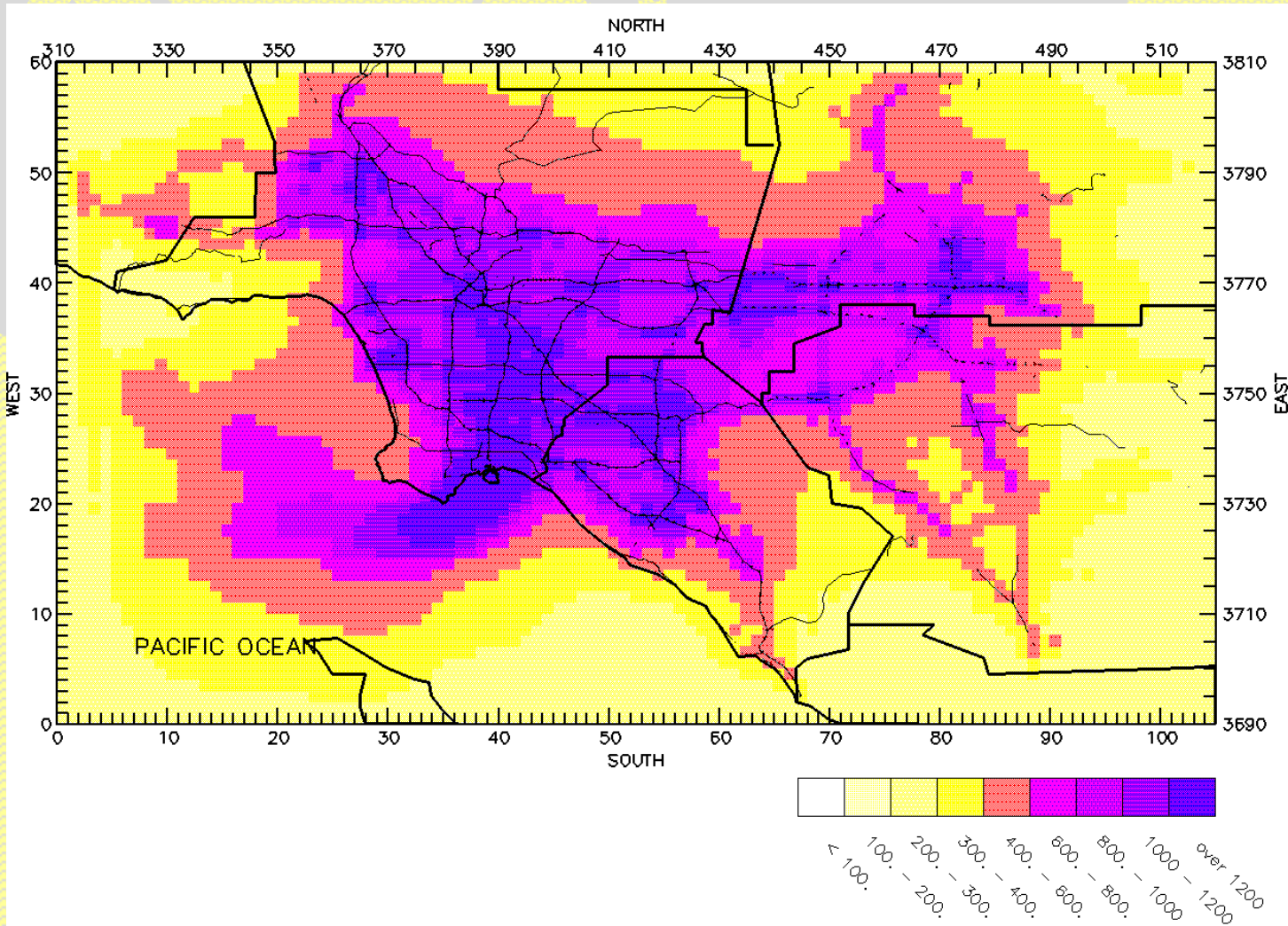
Fundamental Premises

- ◆ Managing our carbon cycle represents the single greatest challenge to the next 3 generations
- ◆ The pace of oil and natural gas resource depletion and climate change are accelerating faster than the rate of viable sustainable strategies
- ◆ There is an unprecedented need to help develop technologies and incentive strategies to address air quality, climate change & resource depletion issues...

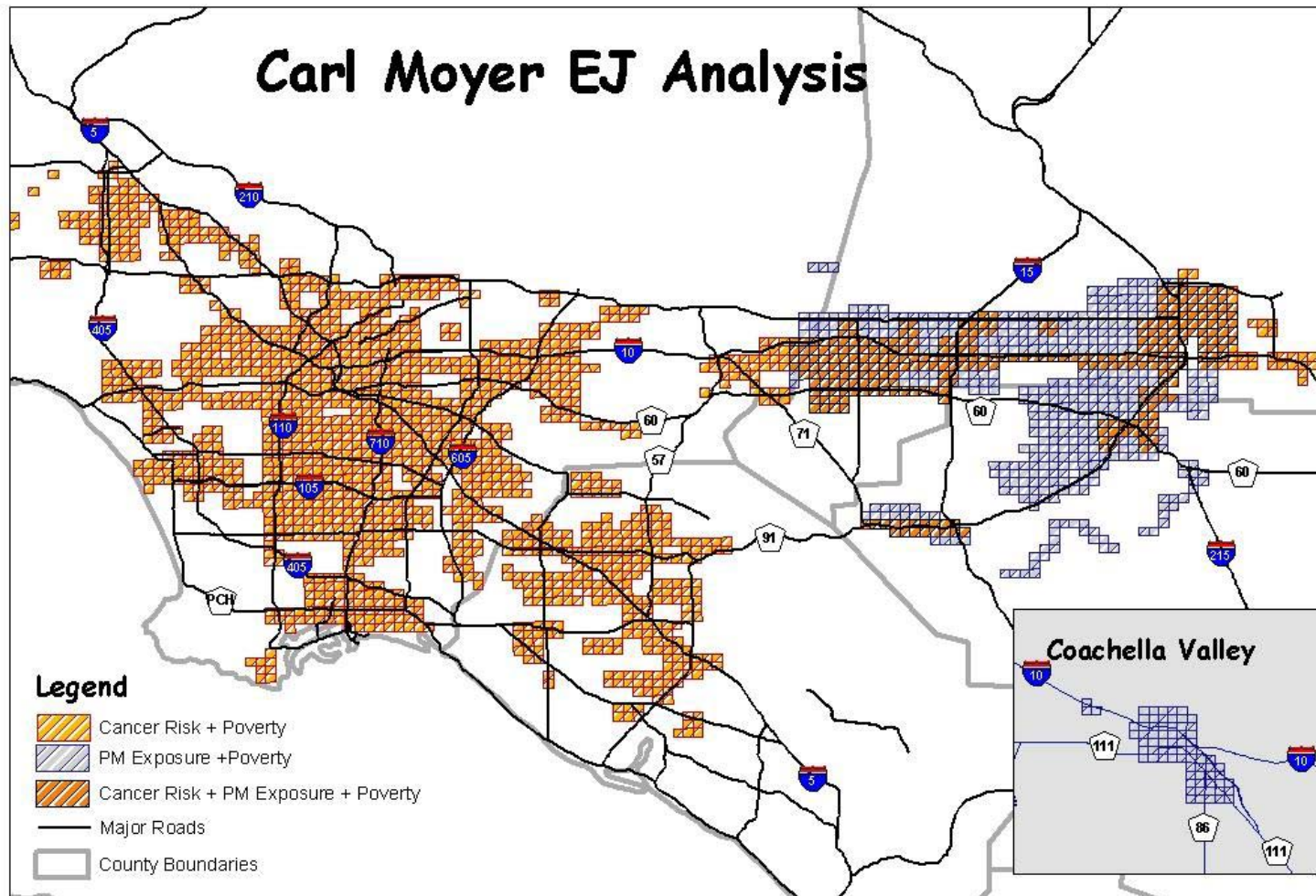
Model Estimated Risk Excluding Diesel Sources



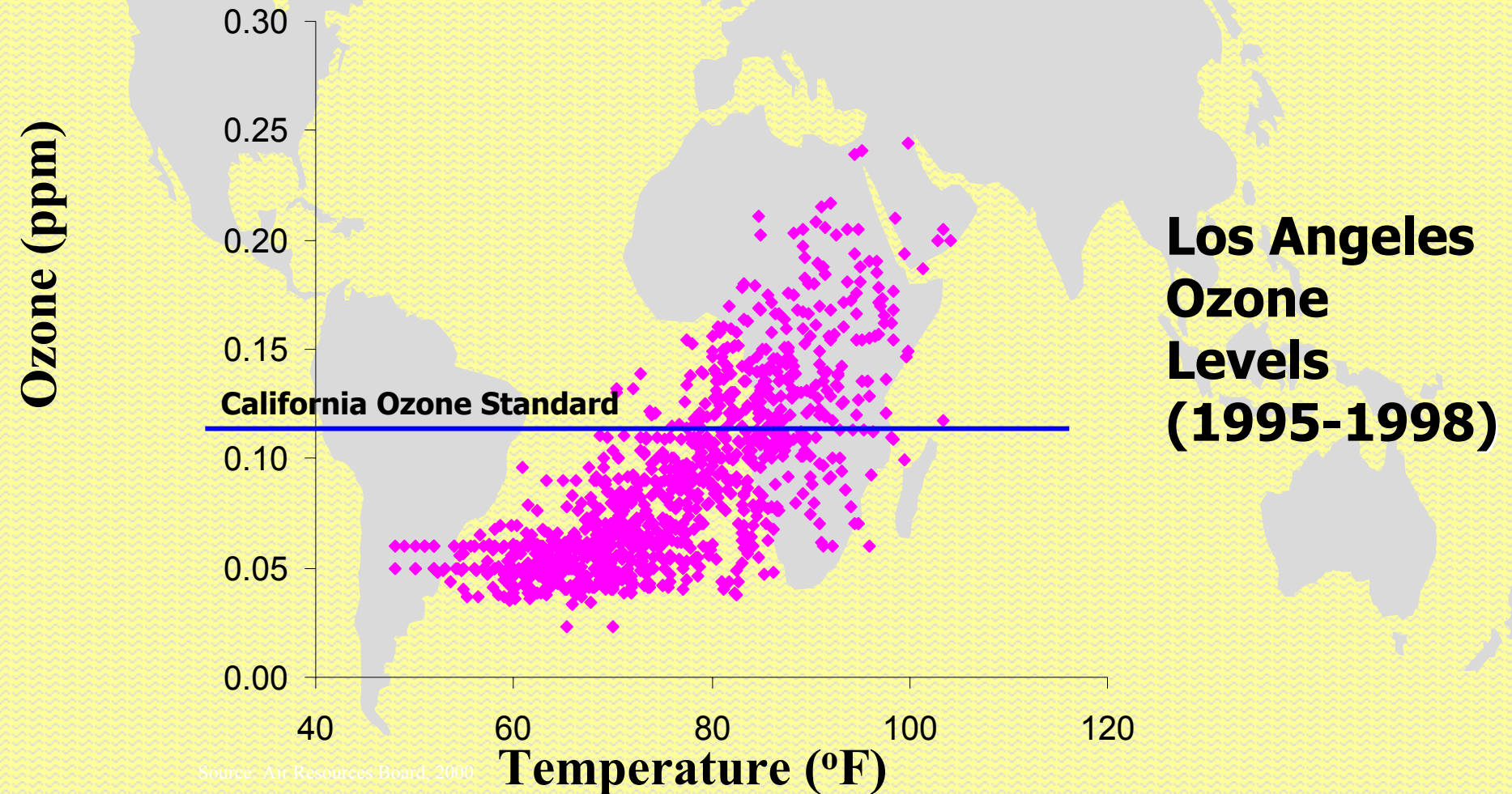
Model Estimated Risk From All Emission Sources



Diesel Exposure Also Tracks Cancer Risk & Poverty...



Hotter Days Lead To Higher Emissions And More Smog

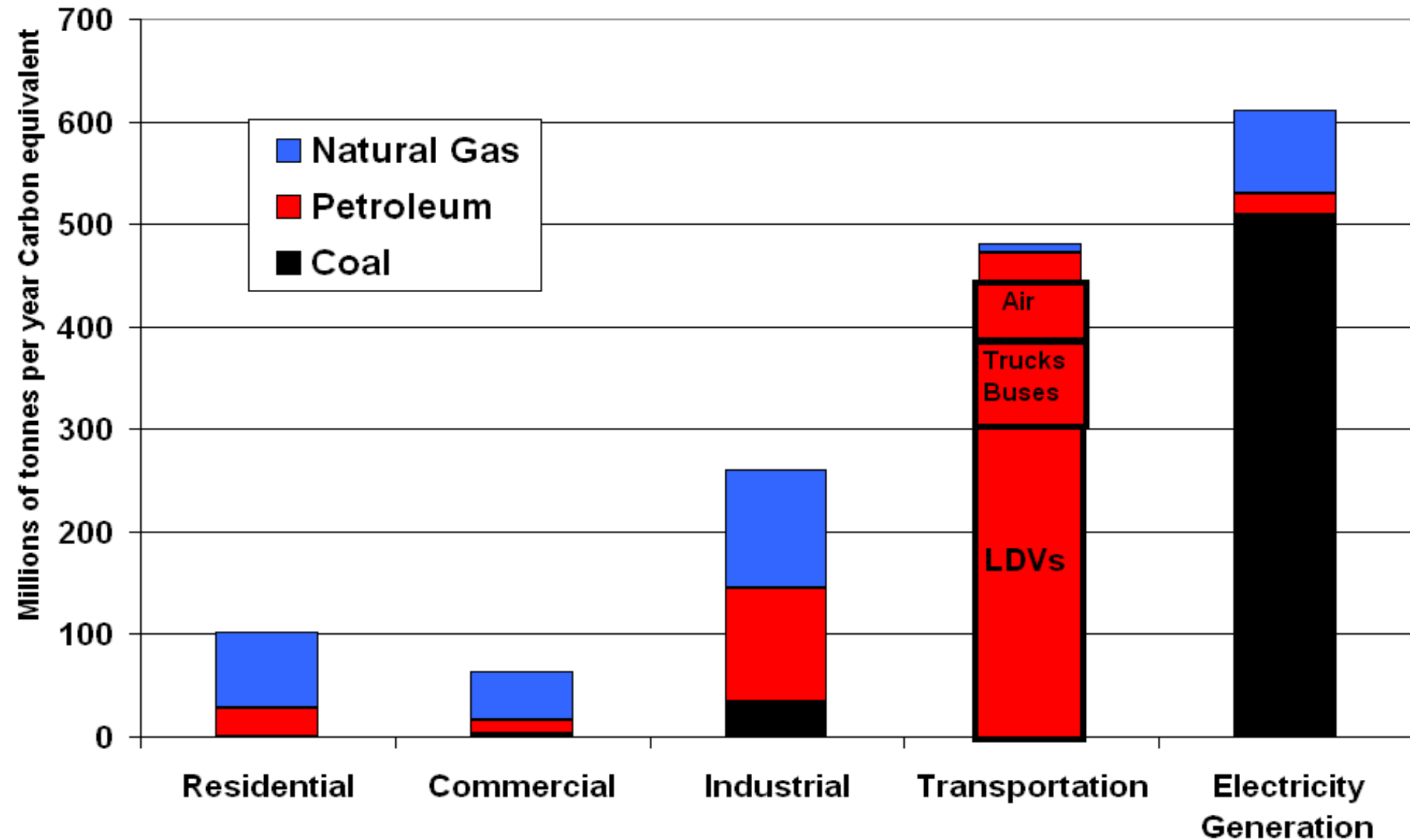


**Los Angeles
Ozone
Levels
(1995-1998)**

Source: Air Resources Board, 2000

Source: California Environmental Protection Agency

United States Carbon Emissions: 2002



The Need to Diversify our Energy Economy Stems from Several Long Term Challenges:

- ◆ **Attain & Maintain Air Quality Standards**
- ◆ **Abrupt or Profound Climate Change**
- ◆ **Oil resource depletion**
- ◆ **Toxic air pollution concerns (*especially diesel*)**
- ◆ **Growth in fuel use**
- ◆ **Population, VMT & economic growth**
- ◆ **Oil & Auto “Supra-national” Corp. R & D priorities**
- ◆ **Growing geopolitical instability**

Critical H₂ Deployment Barriers

- ◆ FC vehicle costs
- ◆ H₂ transport, storage and distribution costs
- ◆ Very low volume fuel demand
- ◆ No commercial engine products
- ◆ Lack of harmonized codes and standards
- ◆ Very low energy density
- ◆ Lack of infrastructure
- ◆ Public hesitation due to safety perceptions

Specific Issues For Current Hydrogen Storage Options

Compressed H₂

- Bulky

Liquid H₂

- Low temperature (-253°C)
- High liquefaction energy

Solid H₂

- Uncertainty as Ultimate solution
- Heavy
- Some kinetics are not reversible

H₂ Fuel Vehicle Issues:

- ◆ Opportunities are great
- ◆ Barriers are formidable
- ◆ Transition times will be decades
- ◆ Fundamental R&D is crucial
- ◆ NGV's provide essential lessons & deployment options

Science Breakthroughs Needed for **Hydrogen FCV Retail Commercialization:**

- ◆ **150,000 + mile durable PEM membranes**
- ◆ **H₂ handling equivalent to retail liquid fuels:**
 - **Bulk & On-Board Storage**
 - **Transport**
 - **Hybrid-equivalent range [*300 – 500 Miles ?*]**
- ◆ **5-10 x improvement in electrolyzer efficiencies**
- ◆ **Competitive first cost**

**ALL OF THESE NEEDED
SIMULTANEOUSLY !**

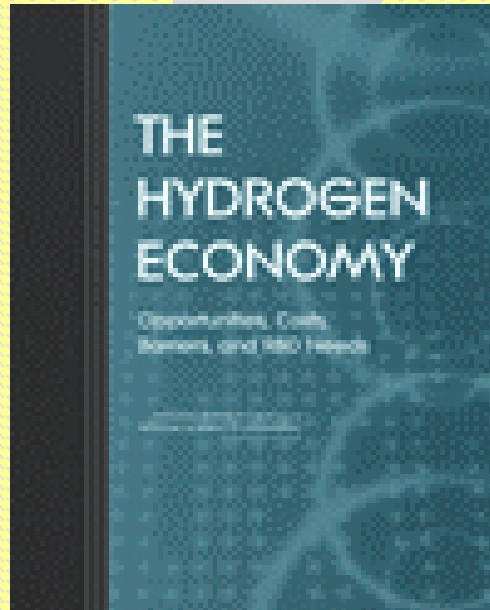
“The Hydrogen Economy:

Opportunities, Costs, Barriers, and R&D Needs”

***“Committee on Alternatives and Strategies for Future
Hydrogen Production and Use”***

National Research Council, June 2004

Basic Finding: “Transition Issues Are Critical”



Hydrogen / Natural Gas Synergies:

- ◆ Both are gaseous fuels
- ◆ NG with mixtures of H₂ significantly reduce NO_x emissions
- ◆ 95% of H₂ currently produced from NG
- ◆ Mixtures of H₂ + NG can be carried in existing NG pipelines (*up to 20 -30%*)
- ◆ NG can provide a means of reducing the barriers to H₂ utilization:
 - Common infrastructure elements (e.g., compression)
 - Lessons learned from gaseous fuels permitting
 - Large fleet customer experience
 - Major OEM gaseous fueled engine commercialization expertise
- ◆ H₂ commercialization requires a economically viable transition path currently being pioneered by NG vehicles.

Daimler Chrysler's CUTE Program

Hydrogen Vehicle Refueling:



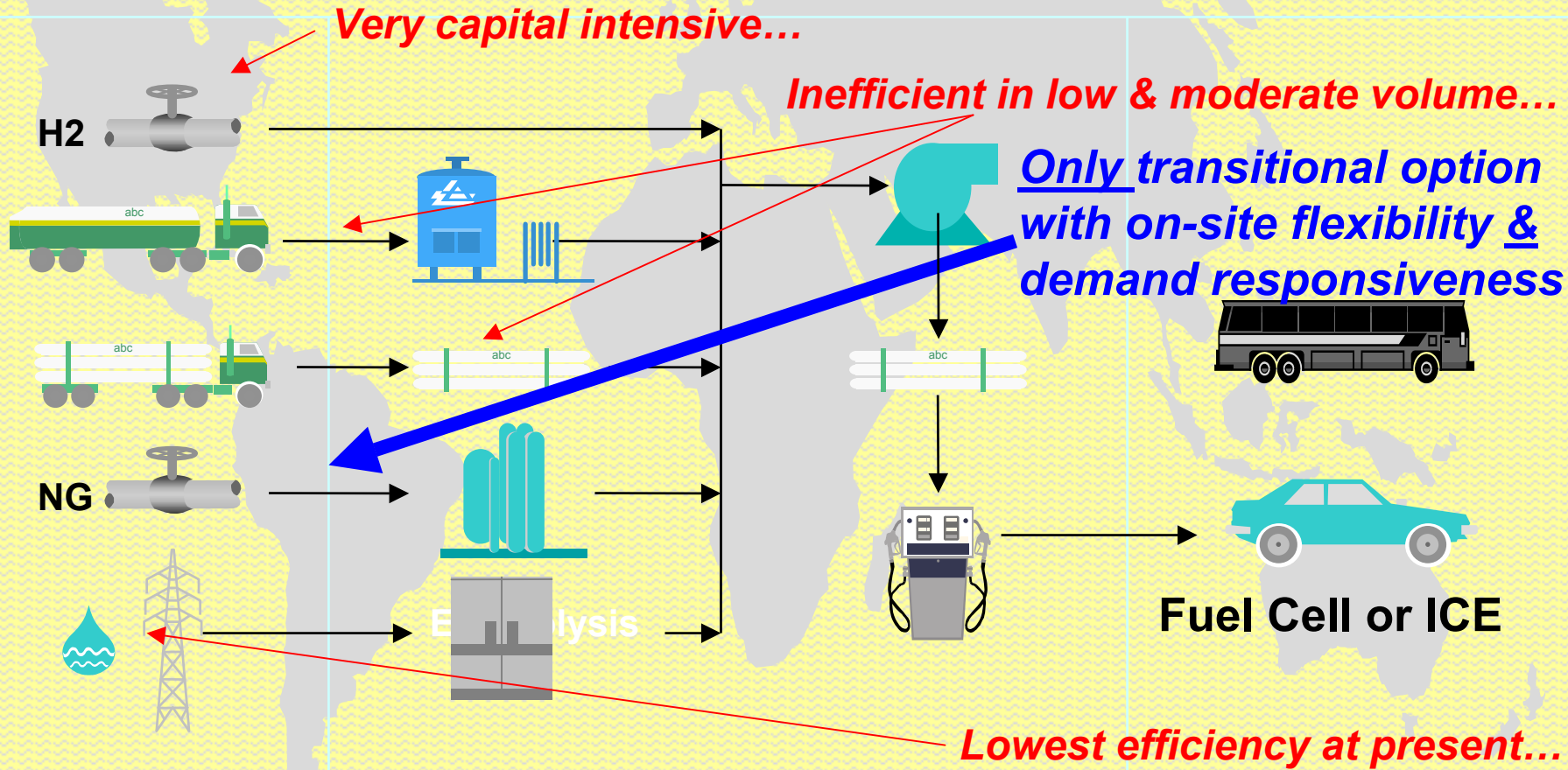
- **Safe handling**
- **User-friendly filling operation**
- **Coupling based on CNG standard**

NG Can Enhance H2 Vehicle Deployment

Distribution

Fuel Station

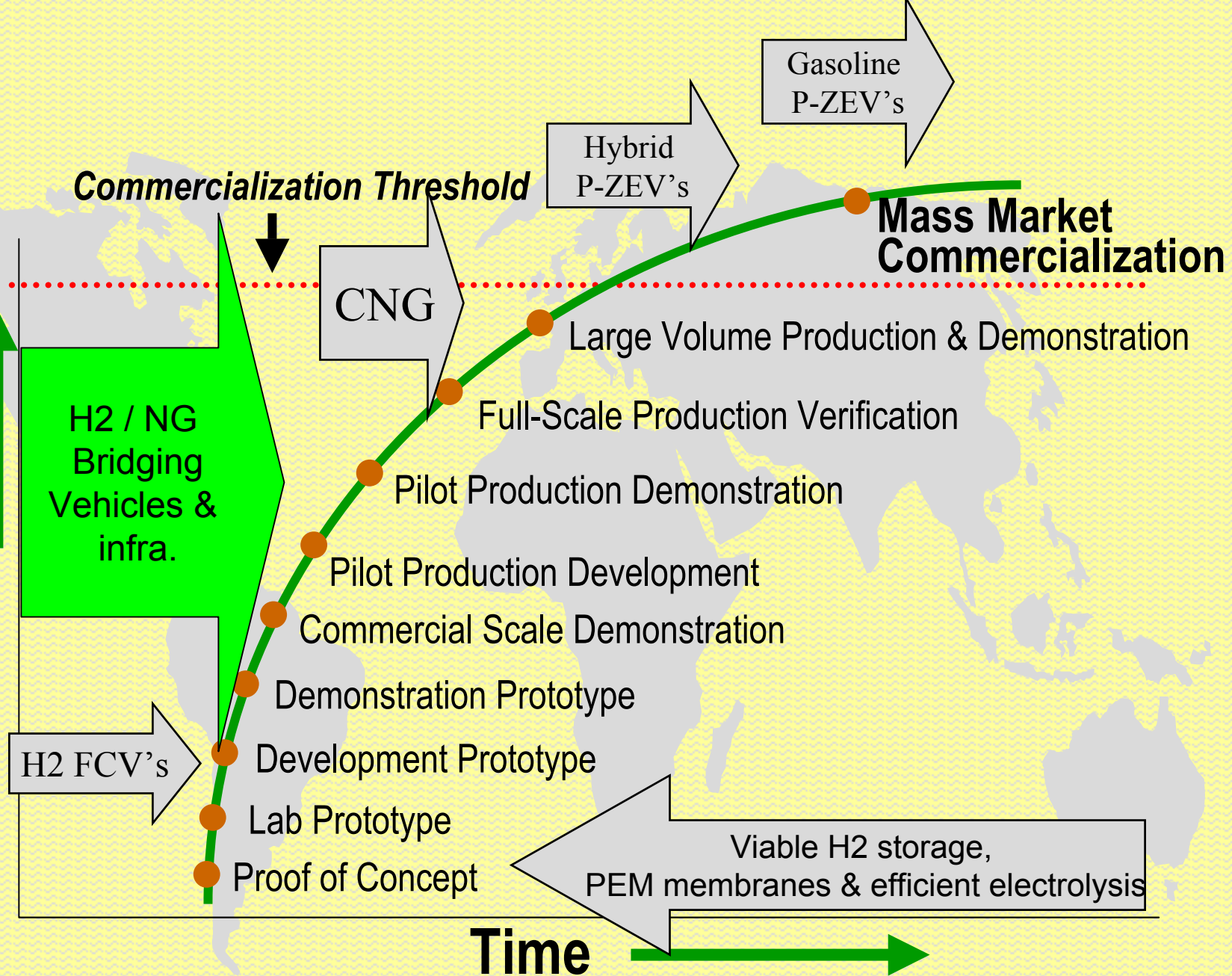
Vehicle



H₂ Hwy at SCAQMD – *Adjacent to our NG Refueling!*



Commercialization Risk and Technological Maturity



Natural gas as a bridge fuel to Hydrogen...

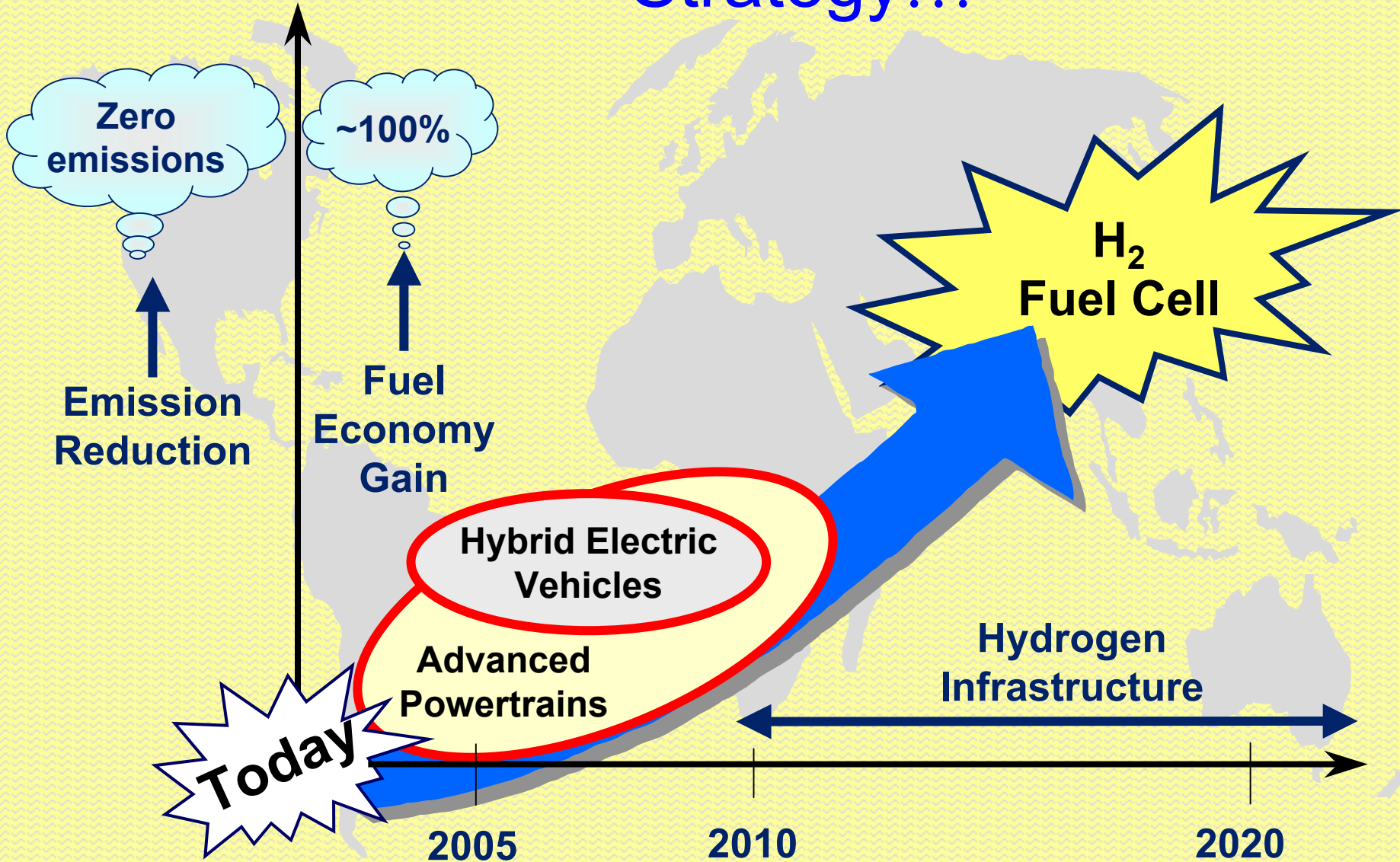


The Transition: Natural Gas to H2

- ◆ NG is ready today and is a driver for H2 tomorrow
- ◆ 3,317,036 natural gas vehicles
- ◆ 6,629 refueling stations
- ◆ 8,055 NG vehicle refueling appliances
- ◆ 16,200 CNG buses in Beijing alone by 2007
- ◆ Less than 100 hydrogen vehicles worldwide

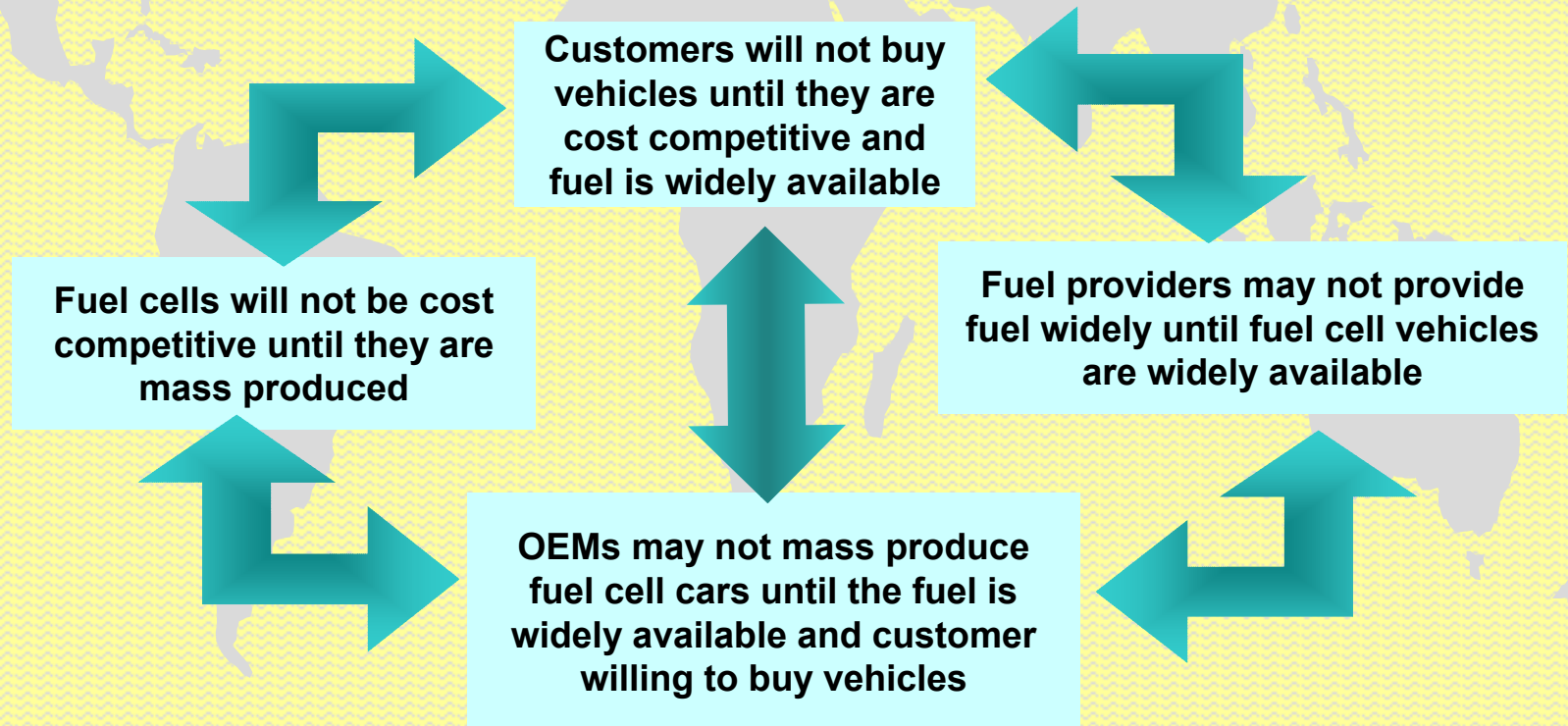
Source: International Natural Gas Vehicle Coalition

An OEM's FreedomCAR Technology Strategy...



This is a complex transition...

- **Competing new technologies– Radical change and market disruption.**
- **Long wavelength and uncertain end-state hamper investment.**
- **Government and Industry alliances will be critical to delivery.**





Suggested Future Efforts...

Recommended Near Term R & D Priorities Related to H2 / NG

- ◆ **Project #1:** *ENGINE DEVELOPMENT AND DEMONSTRATION*
- ◆ Development and Integration of a HD Direct In-cylinder Injection Fuel System for H2 ICE
- ◆ Development and Certification of a H2 / NG Transit & Heavy Duty Engines
- ◆ **Project #2:** *INFRASTRUCTURE DEVEL. & DEMONSTRATION*
- ◆ CNG / H2 Heavy Duty Bus and Infrastructure Evaluation
- ◆ Analysis of Manufacturing and Lifecycle Costs of NG-based H2 Production
- ◆ H2 Production and Utilization Laboratory / NG Reforming Technology Development
- ◆ Opportunities for H2 Integration with Existing NGV Stations
- ◆ Design / Analysis of H2, CNG and HCNG fueling station, including NG - based H2 Energy Station

Conclusions

- ◆ **Concerns over oil use and climate promoting interest in “paradigm shift”**
- ◆ **Many options, but now only 0.3% of new sales**
- ◆ **Hybrids & NGV’s are building credible momentum**
- ◆ **Heavy duty & Light duty market segments offer opportunities for H2 and NG synergistically**
- ◆ **Advocates searching for policy drivers; large federal tax credits appear likely, with constituent support...**
- ◆ **No guarantees--should pursue multiple paths**

Thank you from the SCAQMD!

Questions?

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