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The Hydrogen Transition

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The Hydrogen Energy Transition

Edited by Daniel Sperling & James Cannon

Asilomar Biennial Conference on Transportation and Energy

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- Includes presentations by the world's leaders in government, industry and academia
- Provides real-world solutions for the world's current fuel crisis
- Endorsed by the University of California, Davis Institute of Transportation Studies

The focus of ***The Hydrogen Energy Transition*** is to address key questions with regard to the transition to hydrogen fuel to satisfy the world's rapidly growing need for alternative fuel options. The initiatives set forth in this book will mold the research, development and education efforts that will change the practice of fuel consumption in the near future.

With contributions from researchers and policy makers at the US Department of Energy, Toyota Motor Corporation, University of California, DaimlerChrysler, Proton Energy and others, this book discusses key questions with regard to the transition to hydrogen fuel as a means to satisfy the world's rapidly growing energy needs. The initiatives set forth in this book will mold the research, development and education efforts that changing the practice of fuel consumption around the world.

Contents: Ch. 1: Introduction and Overview, by Daniel Sperling and James S. Cannon: Ch. 2: Back from the Future: To Build Strategies Taking Us to a Hydrogen Age by David Sanborn Scott; Ch. 3: Prospecting the Future for Hydrogen Fuel Cell Vehicle Markets by Kenneth S. Kurani, Thomas S. Turrentine, Reid R. Heffner, and Christopher Congleton; Ch. 4: Fuel Cell Hybrid Vehicles: The Challenge for the Future by Taiyo Kawai; Ch. 5: Where Will the Hydrogen Come From? System Considerations and Hydrogen Supply by Joan Ogden; Ch. 6: Clean Hydrogen from Coal with CO2 Capture and Sequestration by Richard D. Doctor and John C. Molburg; Ch. 7: Doing Good by Doing Well: Entrepreneurship in the Hydrogen Transition by David L. Bodde; Ch. 8: Hydrogen from Electrolysis by Chip Schroeder; Ch. 9: The President's U.S. Hydrogen Initiative by Steve Chalk and Lauren Inouye; Ch. 10: The Hydrogen Transition: A California Perspective by James D. Boyd; Ch. 11: U.S. Hydrogen Activities-A Reflection from the European Perspective by Barend van Engelenburg; Ch. 12: Lessons Learned from 15 years of Alternative Fuels Experience 1988 to 2003 by Barry McNutt and David Rodgers; Ch. 13: Lessons Learned in the Deployment of Alternative Fueled Vehicles by Bernard I. Robertson and Loren K. Beard; Ch. 14: Understanding the Transition to New Fuels and Vehicles: Lessons Learned from Analysis and Experience of Alternative Fuel and Hybrid Vehicles by Paul Leiby and Jonathan Rubin; Ch. 15: The "Chicken or Egg" Problem Writ Large: Why a Hydrogen Fuel Cell Focus is Premature by John M. DeCicco; Ch. 16: The Case for Battery Electric Vehicles by Paul B. MacCready; Epilogue: Hydrogen Hope or Hype by Daniel Sperling and James Cannon

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SESSION I: Keynote Session

Untangling Politics, Business, and Public Interest

- Business, political, and societal goals for pursuing a transportation "hydrogen transition"?
- Short term opportunities and policy needs, and how do they relate to long term plans and goals?
- Roadmaps, strategies, and other organizing frameworks to use in thinking about this transition?
- How are international experiences relevant to U.S. H2 debates?

Chair: Dan Sperling, University of California, Davis

David Garman, Assistant Secretary, U.S. Dept of Energy

Larry Burns, Vice President, General Motors

Taiyou Kawai, General Manager, Fuel Cell System Development Center, Toyota Motor Corporation

Roy Wilson, Vice Chair, South Coast AQMD

Policy Drivers

	Primary Pollutant Reduction	Energy Efficiency Petroleum Independence
Federal	NAAQS O_3	H_2 Energy Roadmap
State	SIP ZEV	AB 1493 (CO_2) AB 2076 (Petroleum)
Local	NO_x and VOC Emissions	

Why Hydrogen Fuel Cells?

- Emit only water
- Twice as efficient as other powertrains
- Enable energy feedstock diversity
- Can substantially reduce greenhouse gases
- Potential source of electrical power
- Enable innovative, compelling, affordable new designs

GM

Three Essential Factors for Successful Dissemination of FCV (Toyota)

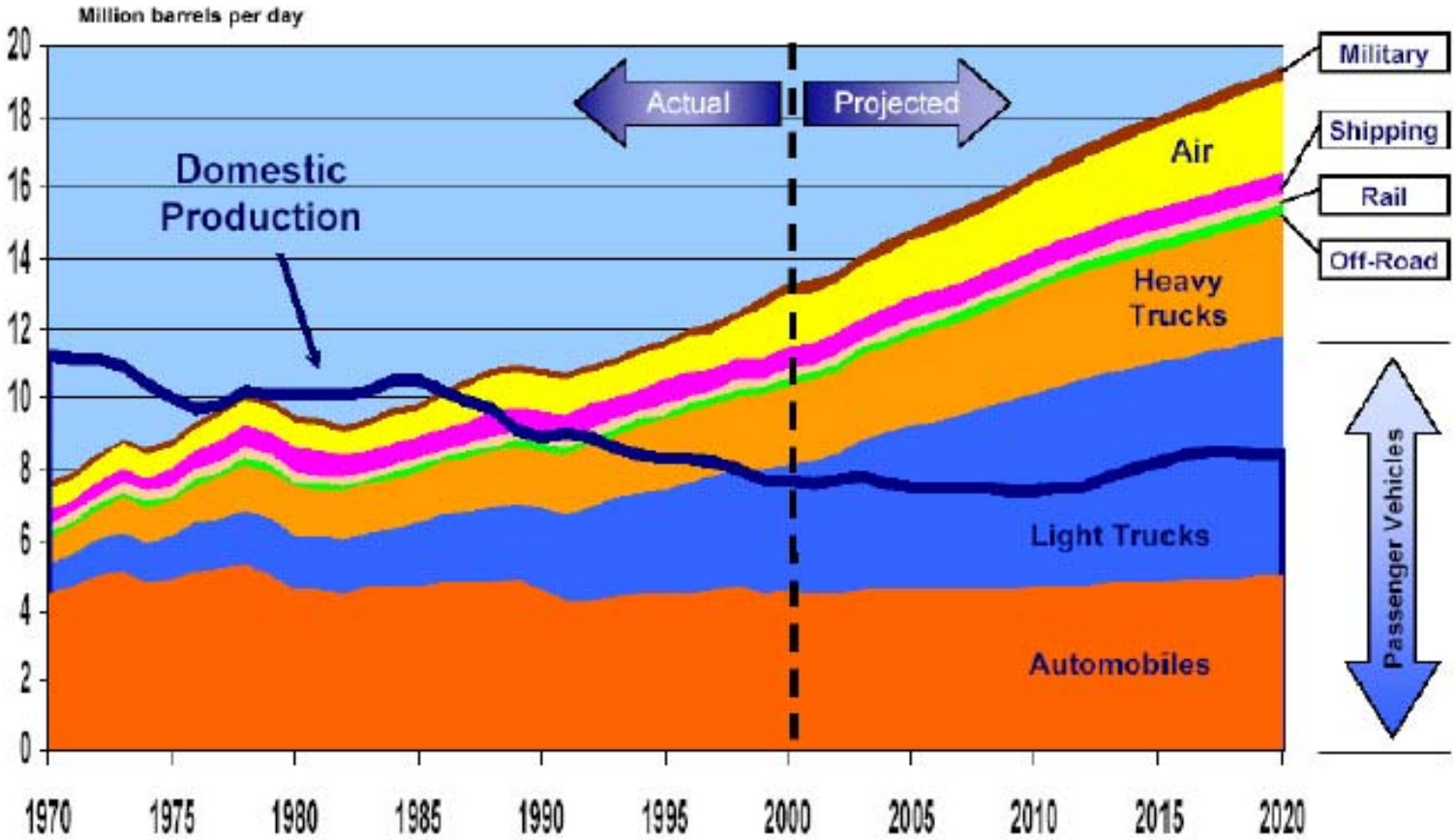
1.Vehicle marketability

Resolve technical challenges, reduce costs, increase vehicle attractiveness

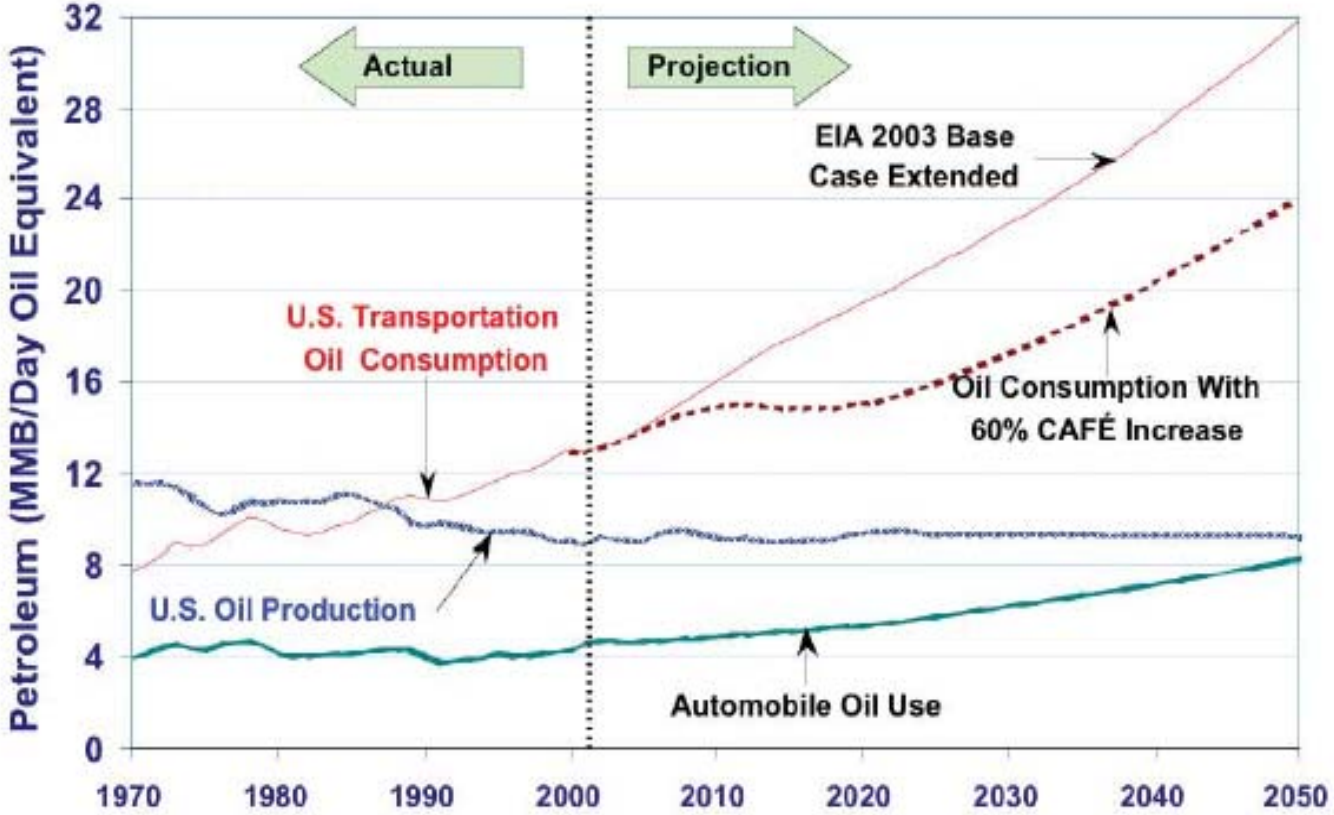
2. Preparation for hydrogen society

3. Social needs to de-fossil fuels

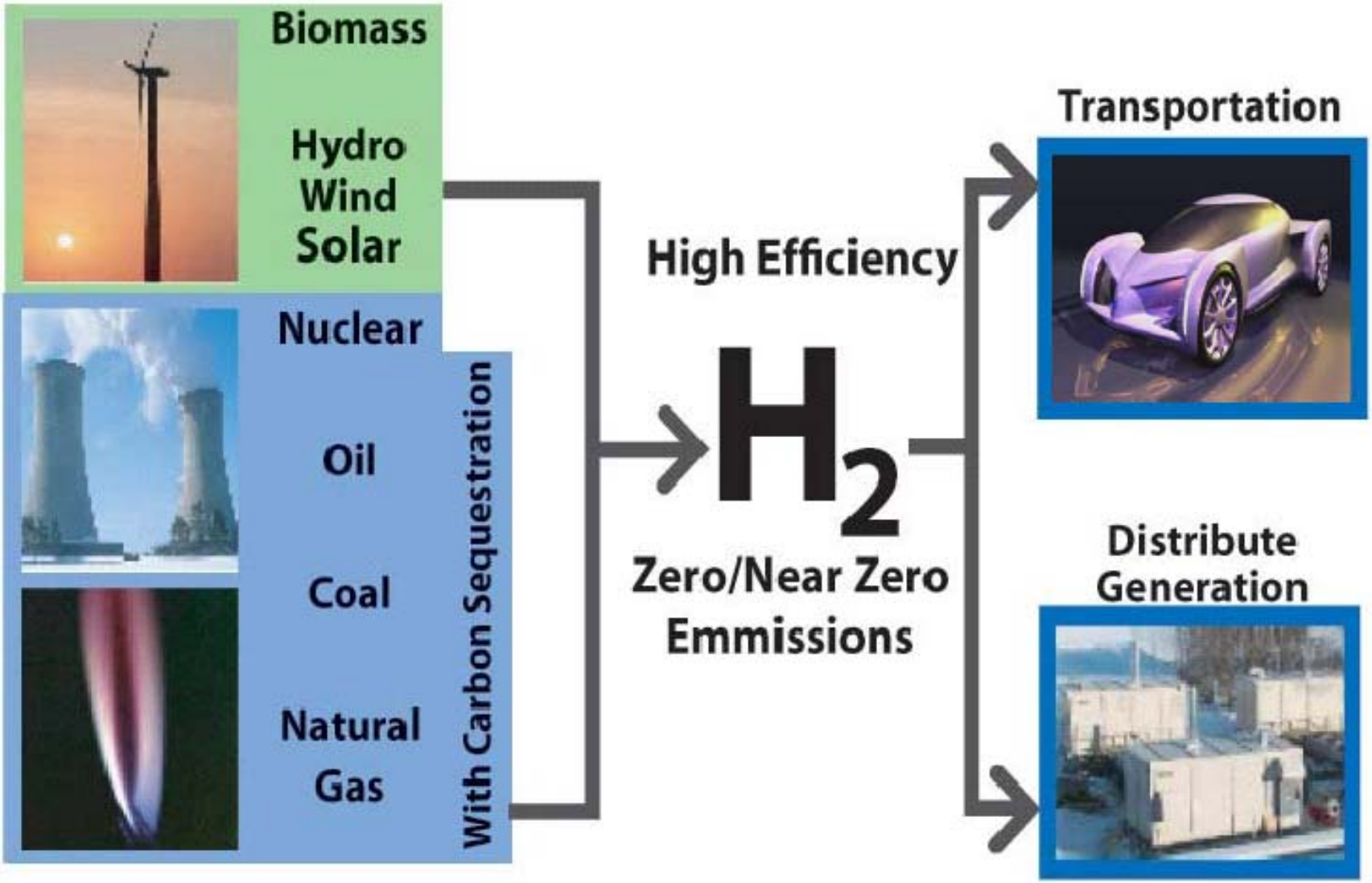
Troubling Trend



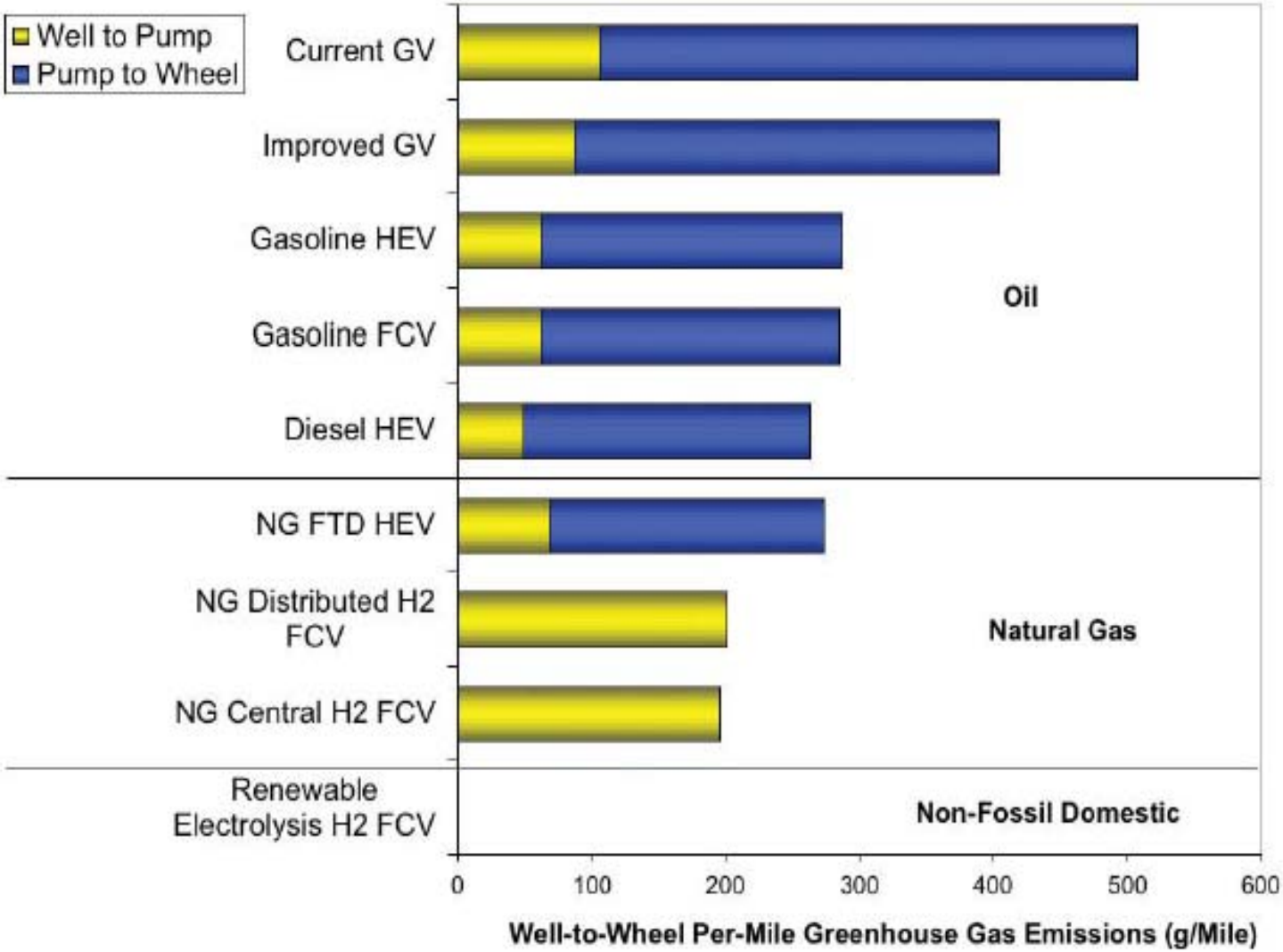
CAFE Can't Close Gap



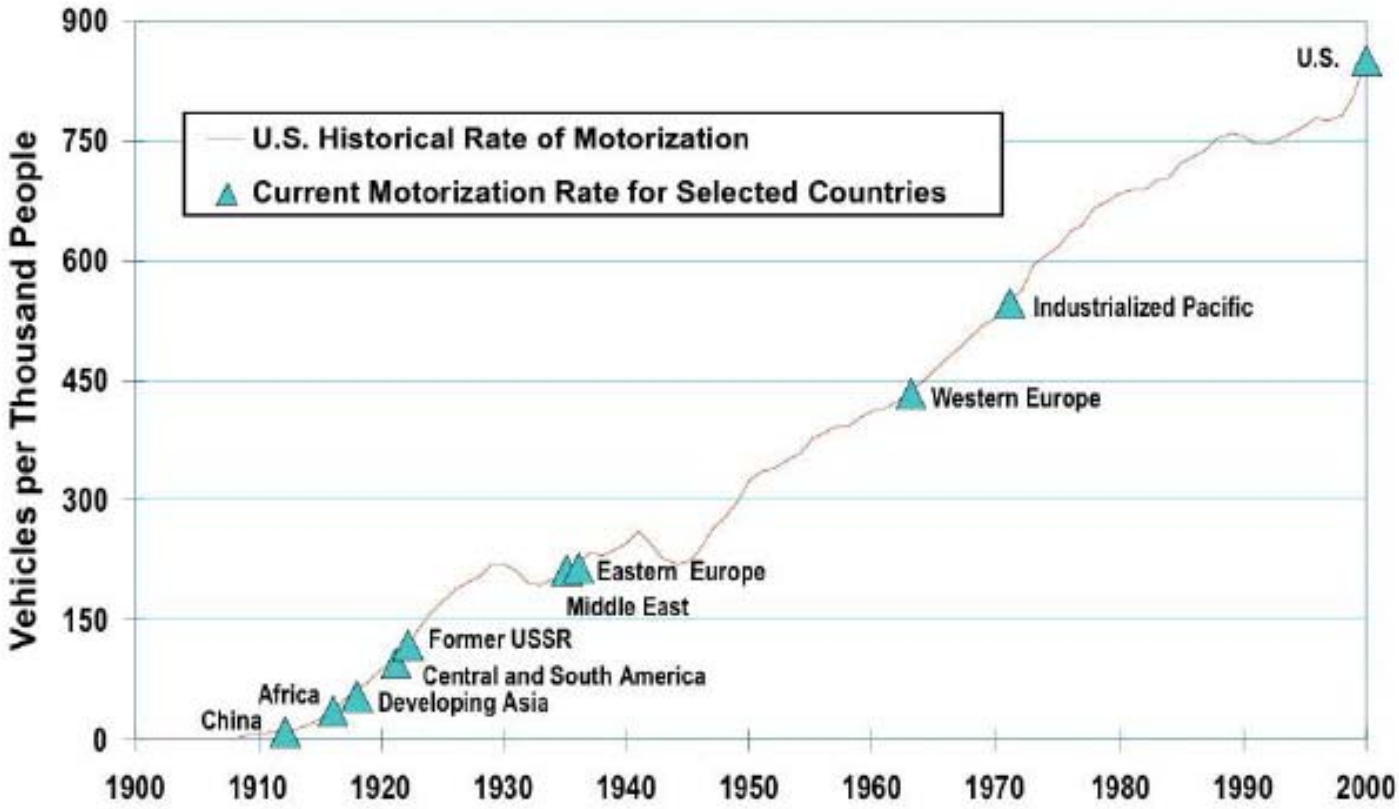
H_2: Primary Energy Diversity



H_2: GHG Impact



Global Implications

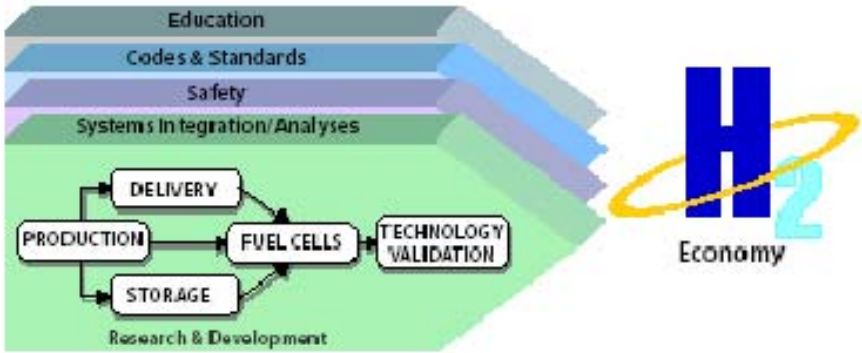


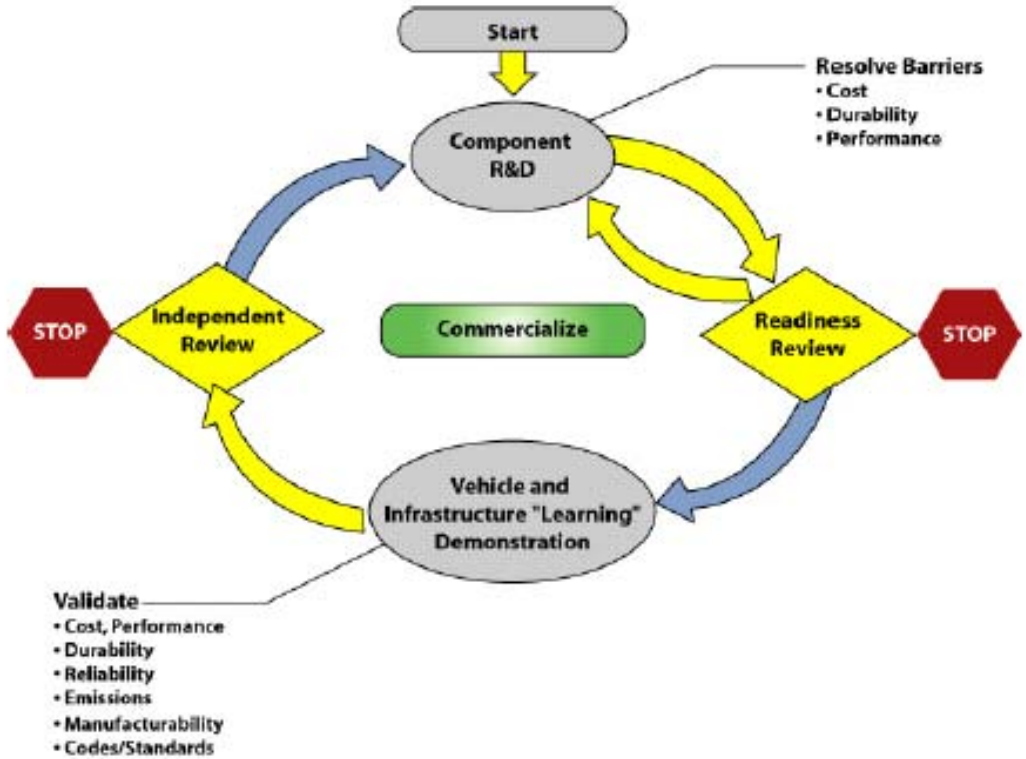
Collaboration Is Essential

- With most stringent stationary source controls in U.S., South Coast is in need of greater balance in emissions management of mobile sources and transportation-related emissions.
- Sources under federal jurisdiction need to achieve a fair share of emissions from air and sea ports and related shipping traffic, trains, and planes.
- Huge port and rail expansion is an unparalleled opportunity to kickstart clean fuel infrastructure.

AQMD

Systems Approach





Preparation for Hydrogen Society (Toyota)

- Energy-mix strategy
- Codes and standards
- Hydrogen production / distribution / storage technologies
- Hydrogen stations
- Human resource development
- Understanding towards the hydrogen society

- Government
- Fuel industry
- Auto manufactures
- R&D organizations
- Universities & Technical schools
- General public

Need for International Cooperation (Toyota)

- **FC Technology is still underdeveloped.**
  Many technical challenges remain and need to achieve technical breakthroughs

- **In order to improve the technical level of FCV as the existing ICEs and ICEs/HVs,**

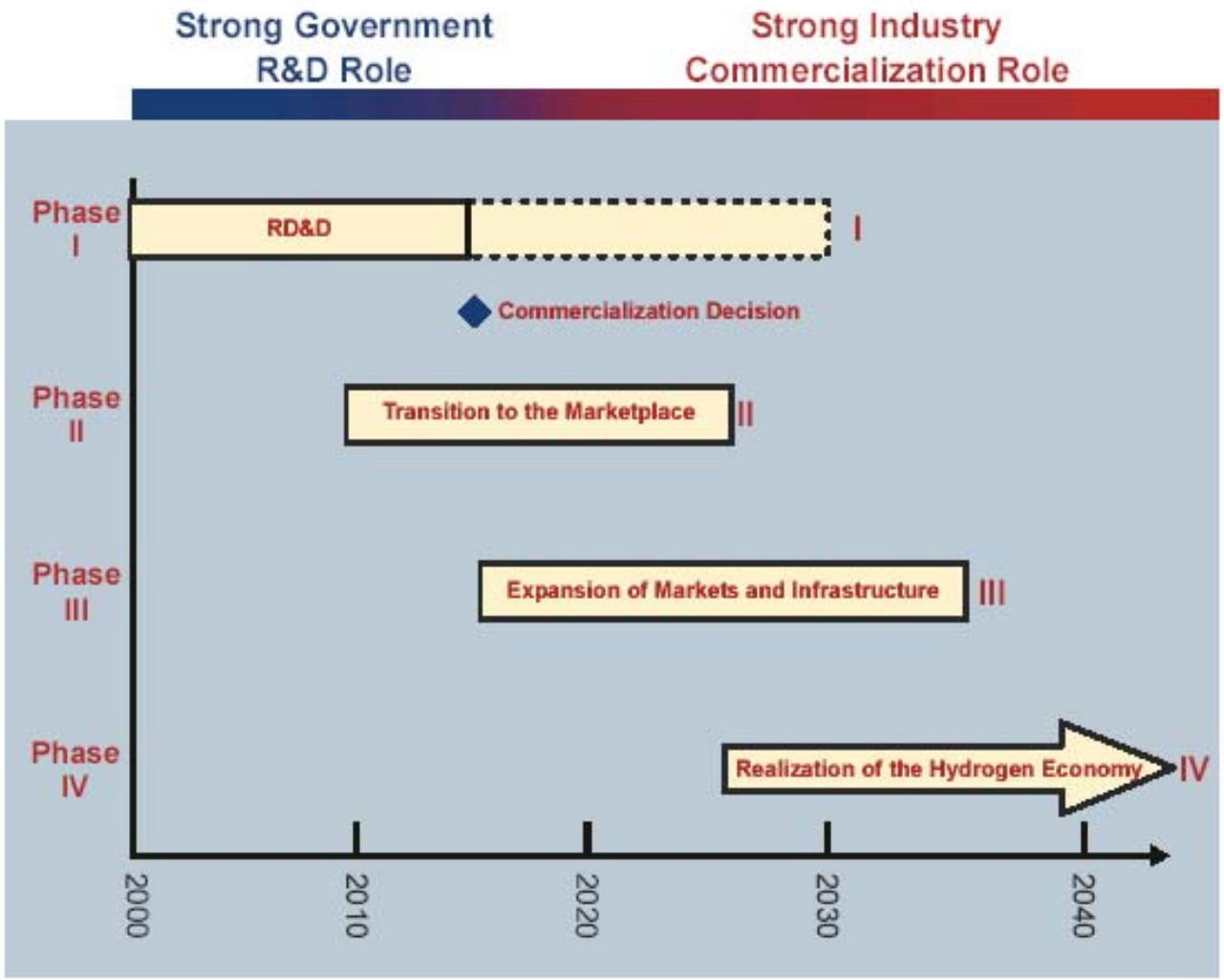
➡ **At the level of basic research, formulation of international cooperation and framework for exchanging research outcomes are necessary.**

➡ **Competition among automotive manufacturers helps stimulate activities in the phase of production and commercialization.**

Key Commercialization Challenges

- Hydrogen storage
- Cost
- Fueling infrastructure

Timing



Transitional Phases

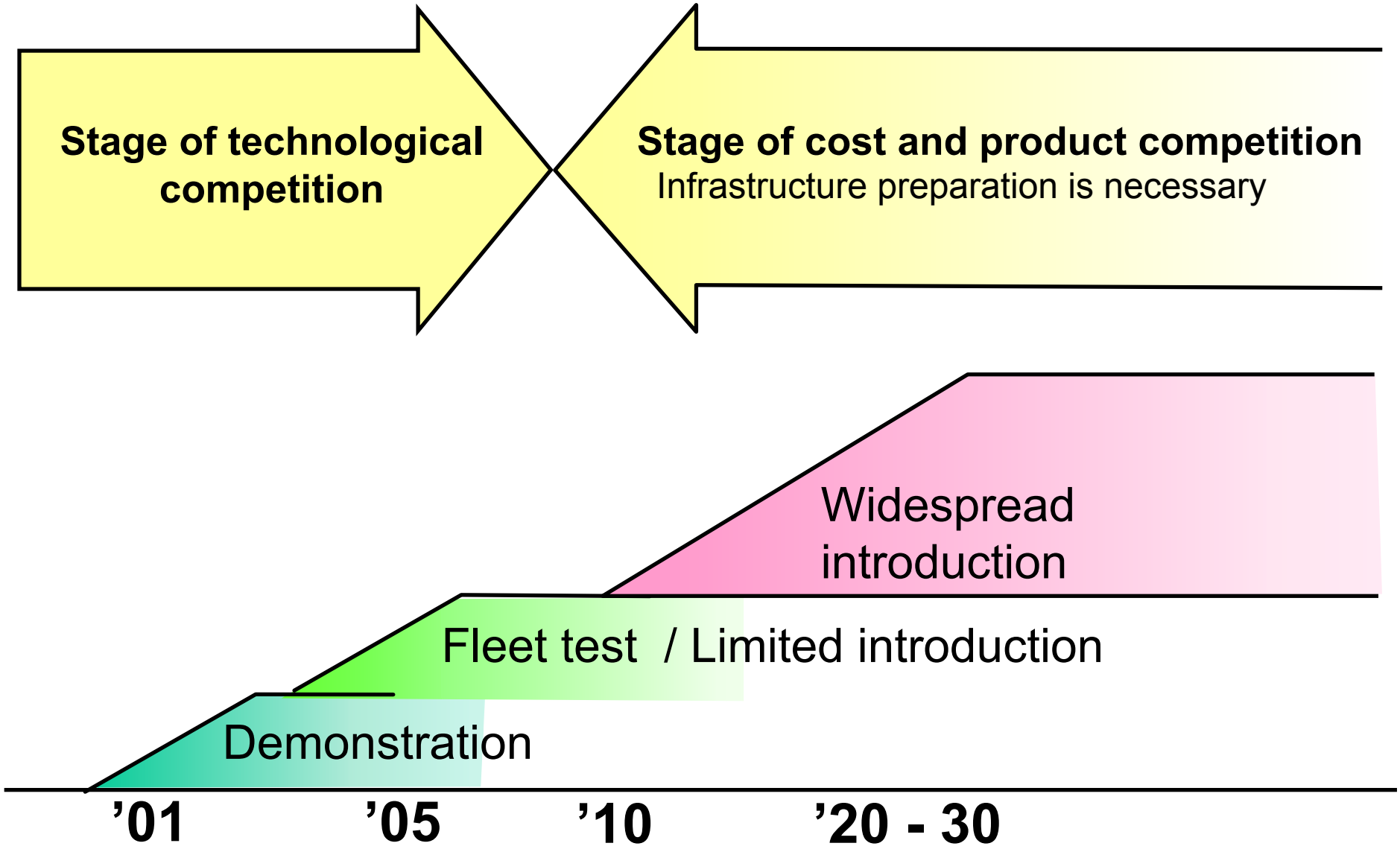
I. Technology Development Phase

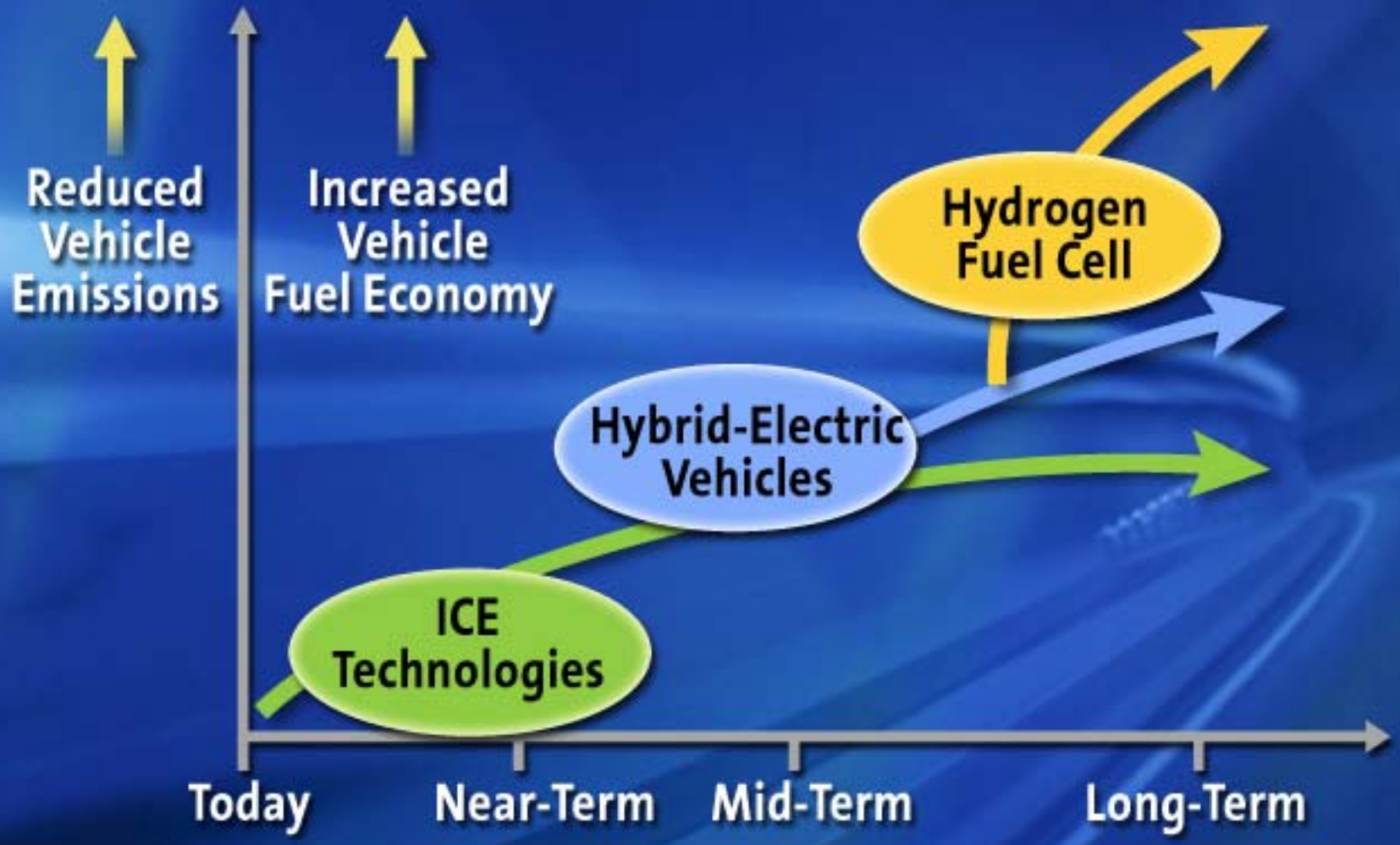
II. Initial Market Penetration Phase

III. Infrastructure Investment Phase

IV. Fully Developed Market and Infrastructure Phase

Forecast of FCV Market Introduction (Toyota)



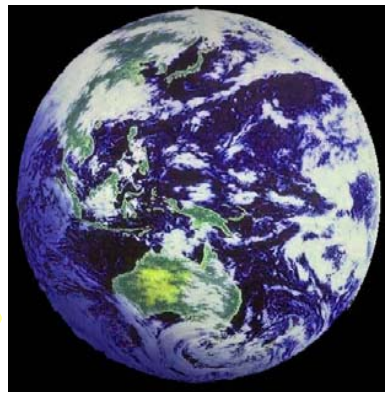

Reduced Vehicle Emissions
Increased Vehicle Fuel Economy
Hydrogen Fuel Cell
Hybrid-Electric Vehicles
ICE Technologies
Today
Near-Term
Mid-Term
Long-Term

TOYOTA's Concept for Ultimate ECO Car

The Ultimate ECO Car

Exhaust Emission Reduction

CO2 Reduction



Energy Security

Hybrid Technology

FCHV

THS

D-4

CNG

Diesel DI

Lean Burn

EV

VVT-i

Alternative Fuel

Diesel Engine

Gasoline Engine

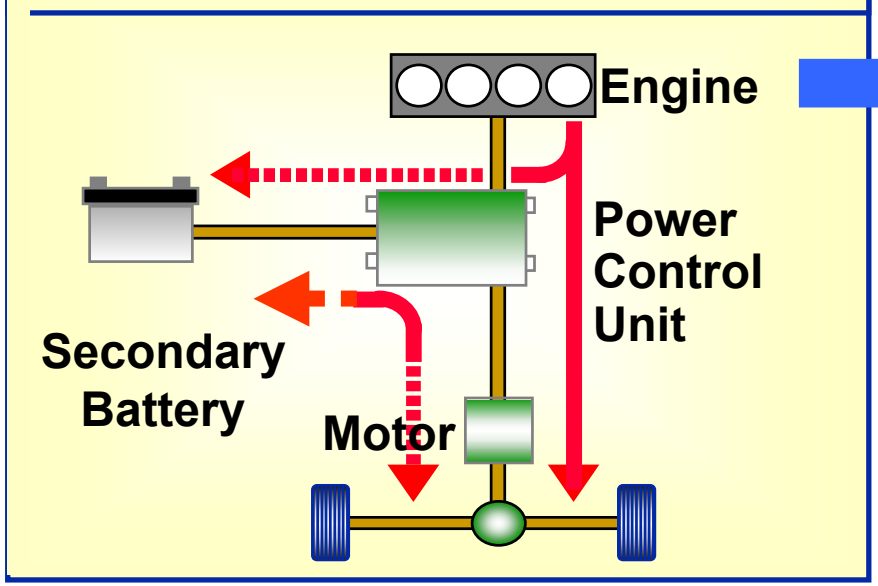
Electric Vehicle

Fuel Cell Vehicle with Hybrid Technology

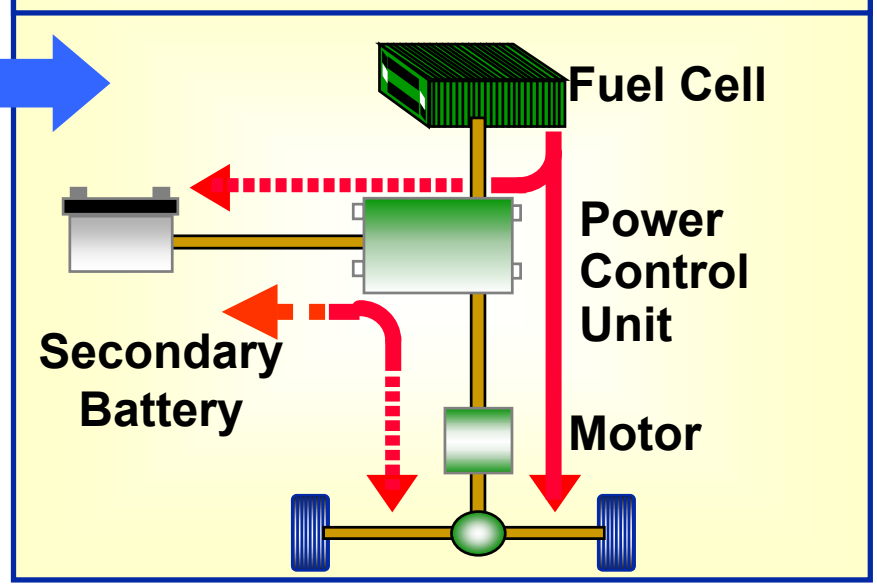
Prius

TOYOTA-FCHV

ICE Hybrid Vehicle (Prius)



Toyota Fuel Cell Hybrid Vehicle



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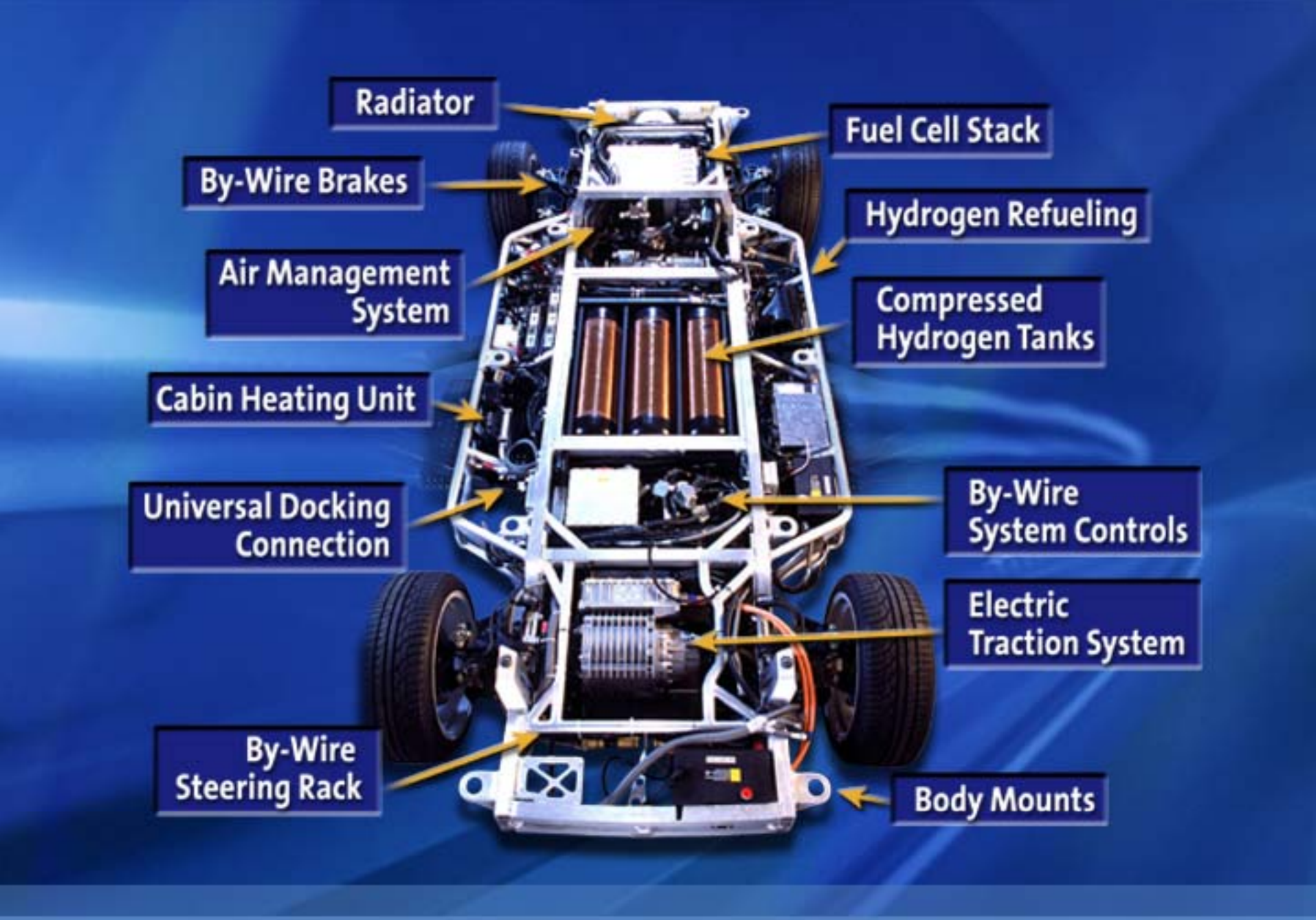
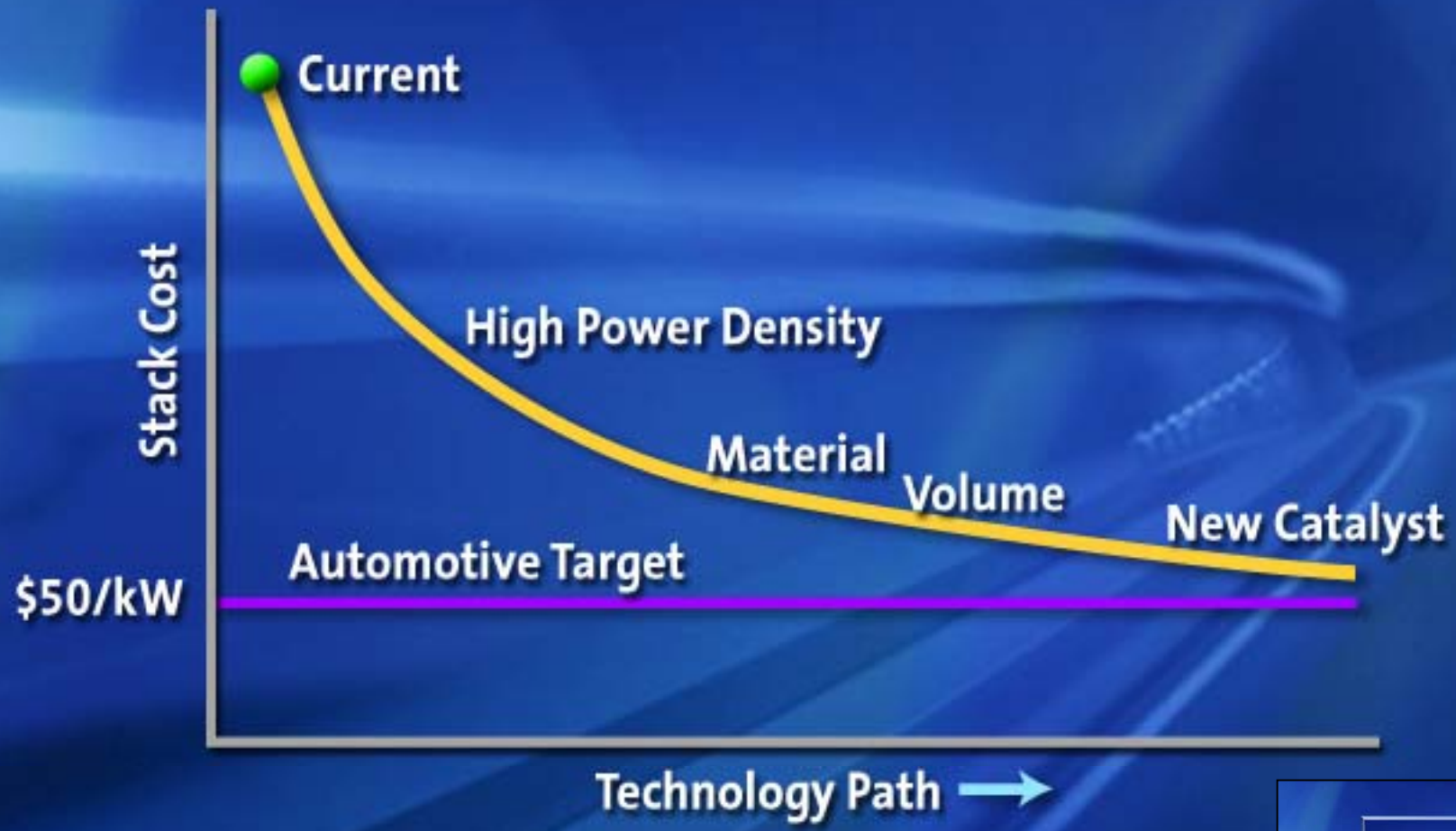
AUTONOMY
Reinventing the Automobile


Radiator
Fuel Cell Stack
By-Wire Brakes
Hydrogen Refueling
Air Management System
Compressed Hydrogen Tanks
Cabin Heating Unit
Universal Docking Connection
By-Wire System Controls
Electric Traction System
By-Wire Steering Rack
Body Mounts

Business Challenge: Cost



Fuel Cell Vehicles Must Be:

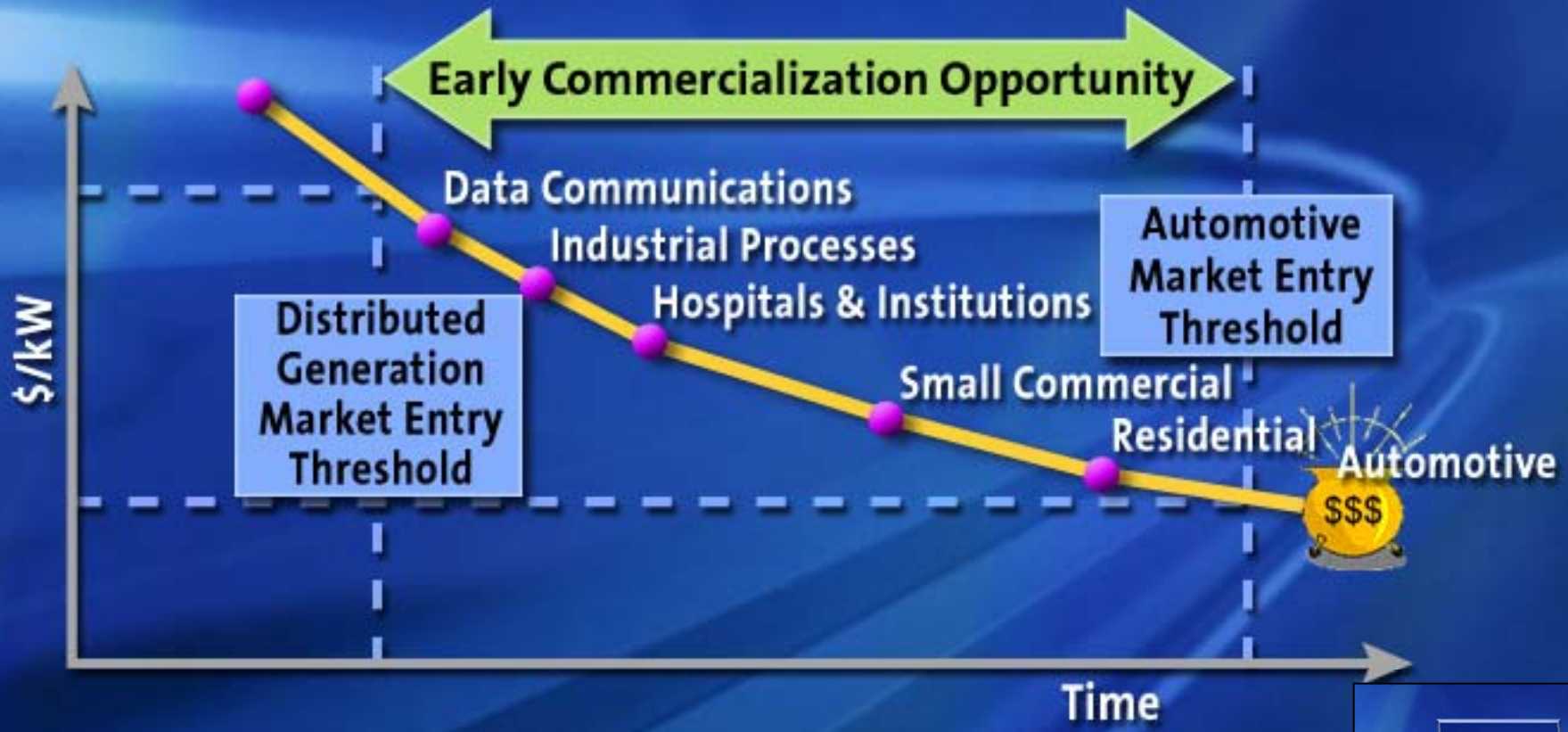
Compelling

Affordable

Sustainable

Distributed Generation Business Opportunities

Interim Market Opportunities on GM's Roadmap



TOYOTA Fuel Cell Technology

TOYOTA-FCHV

Fuel: Hydrogen(Gaseous)

FCHV-3

Fuel: Hydrogen(Metal hydride)

FCHV-5 (Fuel reforming)

Fuel: CHF (Clean gasoline)

TOYOTA FC Stack

MOVE FCV-K-II

Fuel: Hydrogen(Gaseous)

FCHV-BUS2

Fuel: Hydrogen (Gaseous)

Fuel Cell Co-generation System

Fuel: Natural gas

Hydrogen Infrastructure

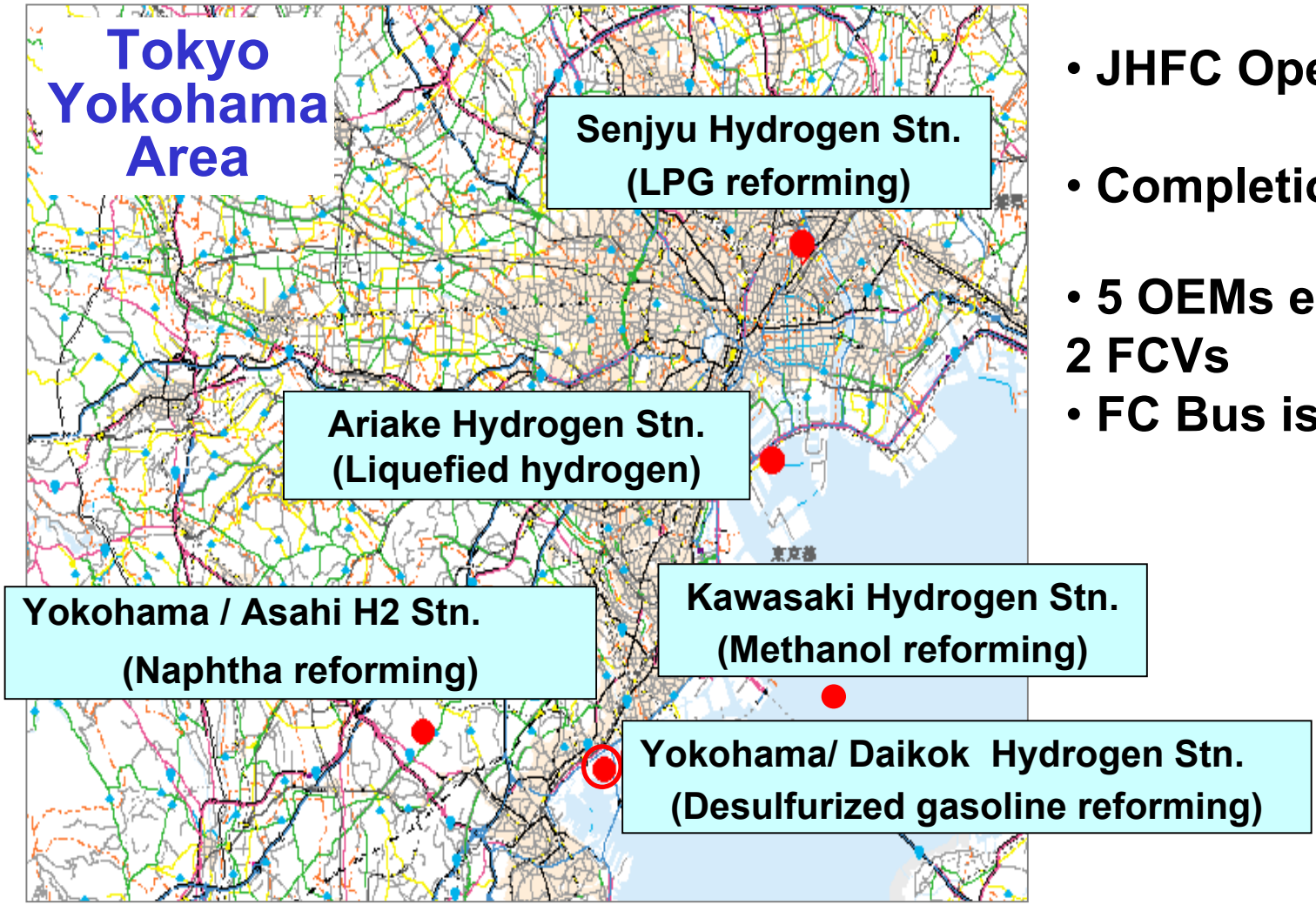
AQMD Strategy

- Co-deployment of both vehicles and fueling in controlled fleet demonstrations
- Allows fleet operators (end-users) and manufacturers to gain/share experience for product evolution
- Opportunities for outreach, education, and public acquaintance
- Partner with DOE and other agencies

Hydrogen Infrastructure
FREEWAYS

... and now Governor Schwarzenegger's "Hydrogen Highway"!!

Japan Hydrogen & Fuel Cell Demonstration Project (JHFC)



- JHFC Opening (March 12 / ’03)
- Completion of 6 stations (August / ’03)
- 5 OEMs each run 1 or 2 FCVs
- FC Bus is run by Toyota (April / ’03-)

Hydrogen Economics

- Hydrogen not inherently expensive
- Expense comes from distribution costs
- Lots of experience worldwide generating hydrogen and transporting it via trucks and pipeline
- Using today's technology, within a factor of 1.3 of where we need to be on cost
- With on-site appliances, cost challenge is 2-3 times today's technology

Multiple Distribution Scenarios

In the case of the Hydrogen Economy, perhaps infrastructure is

~~Pipeline~~
~~Refineries~~
~~Tankers~~

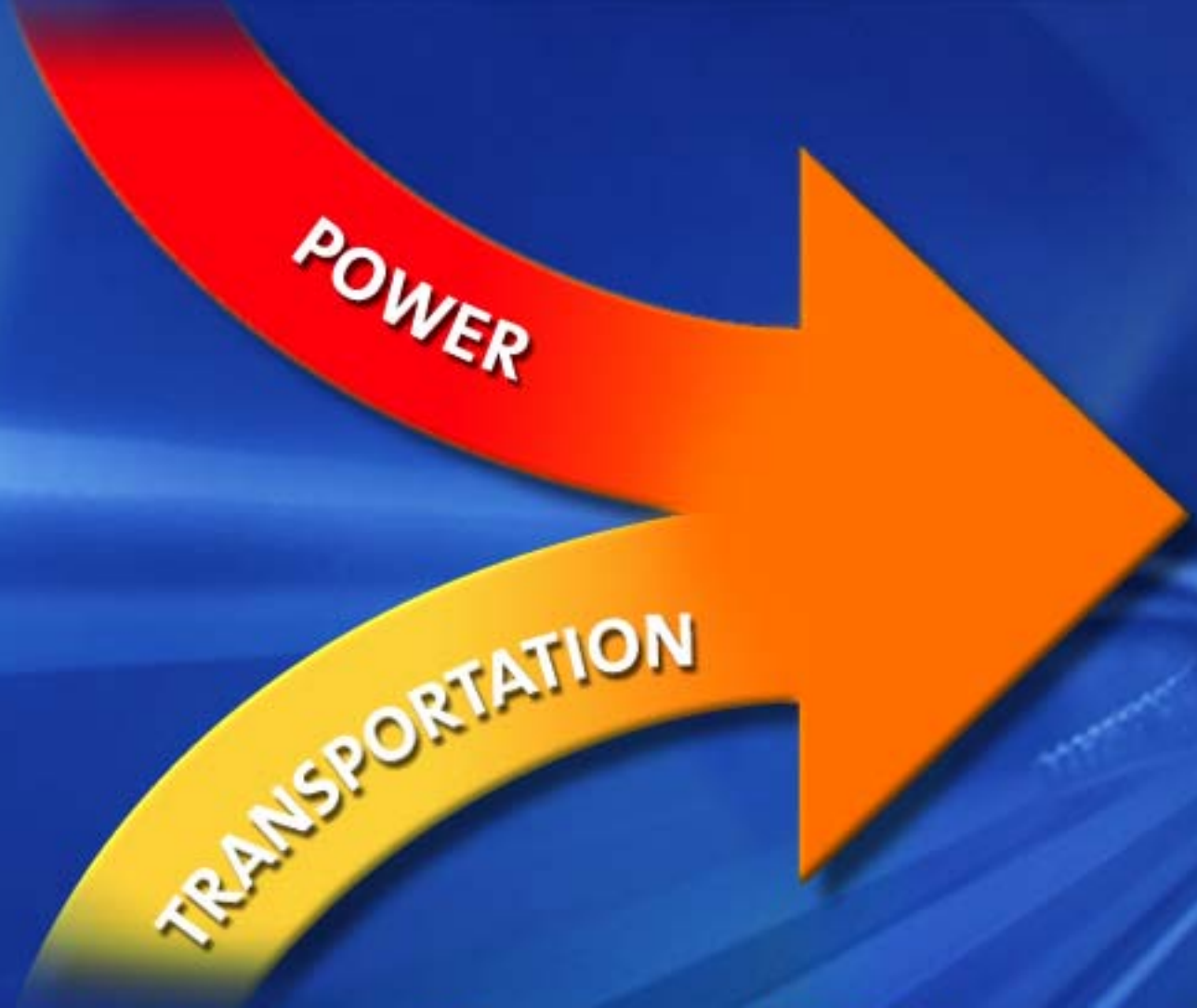
but instead

Appliances
Electrolyzers
Reformers

Today's Home Appliances

Refrigerator	$900	Home Computer	$3,000
Stove	$700	TV(s)	$1,200
Microwave	$300	Sound System	$3,000
Dishwasher	$400	Security System	$2,500
Garbage Disposal	$200	Air Conditioning System	$5,000
Furnace	$5,000		

Home Refueling



45% of Fortune 50 revenues ($1.8T) impacted directly by hydrogen economy and fuel cells

Call to Action

- Establish national initiative on hydrogen storage and production
- Establish aggressive, breakthrough fuel cell materials R&D program
- "Undeclare" hydrogen as a hazardous material and treat it as a fuel
- Direct federal and state agencies to evaluate the use of fuel cell technologies in their operations
- Develop national template for codes and standards

GM

Potential Federal Efforts

- Ensure no barriers in federal research programs by clearly defining roles and deliverables (e.g., intellectual property ownership)
- Provide tax credits for:
  - Taxpayers who purchase a fuel cell vehicle
  - Installation of hydrogen refueling property
  - Production of hydrogen fuel, with additional credit for use of renewable sources
  - Retail sale of hydrogen fuel
  - Business energy tax credit for incremental cost of fuel cell purchases (vehicle and distributed generation)
- Create national legislation that harmonizes state/local codes for hydrogen
- Support programs to educate key audiences
  - Facilitate market acceptance
  - Incorporate hydrogen and fuel cell lessons in K-12 science education

Pathway to the Hydrogen Economy

- ✓ A Strong National Commitment, expressed by the President
- ✓ Diversified Technology Portfolio
- ✓ Public-Private Partnership Approach
- ✓ We must keep the earmarks and "non-learning" demonstrations in check

Potential State Efforts

- Provide tax incentives for fuel cell R&D and fund grants to universities for basic research
- Help identify resources and funding for pilot fleet testing
- Provide tax incentives for purchase of fuel cell vehicles and backup/ peak power-generation units
- Exempt purchase or lease of vehicles and stationary devices from sales tax
- Exempt fuel cell vehicles from parking fees, high-occupancy vehicle restrictions, and wave registration fee for a period of time
- Exclude facilities that run on fuel cells from the state's franchise tax
- Support accelerated depreciation on investment to incentivize manufacturers
- Create matching grant programs to convert fleets/public transport to fuel cell vehicles
- Support the adoption of national codes and and standards
- Support education and safety programs

GM

“Wishlist”

- More coordinated effort between federal, state, and local governments
  - Regulations
  - Training and education
  - Placement of fuel cell vehicles
  - Co-funding partners

Our Vision

- Fuel cell as the long-term power source
- Hydrogen as the long-term fuel
- Fuel cell vehicles cost-competitive by early next decade
- Stationary fuel cells pave way for fuel cell vehicles
- Infrastructure: Think appliances, not just pipeline
- Focus on small demo projects in next 3-5 years
- Beyond 5 years, larger-scale commercial projects involving industry and government

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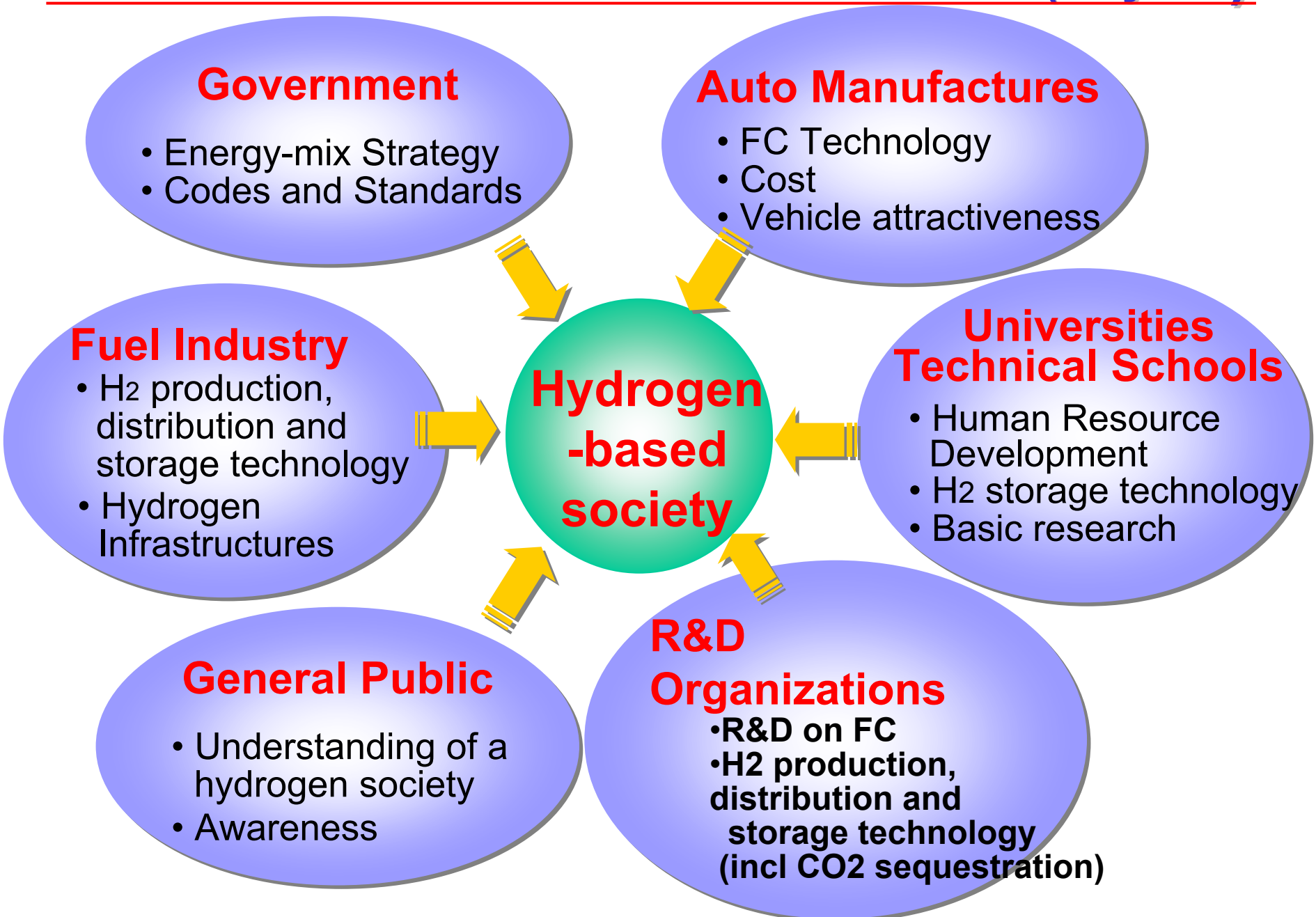
Towards Diffusion of Fuel Cell Vehicles (Toyota)



Thank You