TOYOTA

Benefits & Challenges of Fuel Cell & Plug-in Vehicles

Senate Hydrogen & Fuel Cell Caucus Briefing

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Issues that Influence Automobile Business

Issues	***Action***	***Potential Solution***
Petroleum Supply	Energy & Fuel Diversification	Hydrogen, Biofuels Electricity Natural Gas
Climate Change	Life Cycle CO_2 Reduction	Improved Efficiency Cellulosic Biofuels Green Hydrogen
Balance of Trade	Reduce Imported Fuel	Greater Use of Domestic Feedstocks
Energy Security	Reduce Imports from Unfriendly Countries	Greater Use of Domestic Feedstocks


Hybrid is First Step in Addressing Issues

TOYOTA MODELS

Prius
Midsize 5 Door

Camry Hybrid
Midsize 4 Door

Highlander Hybrid
Midsize SUV

Averaging over 20,000 hybrids sold per month in 2008

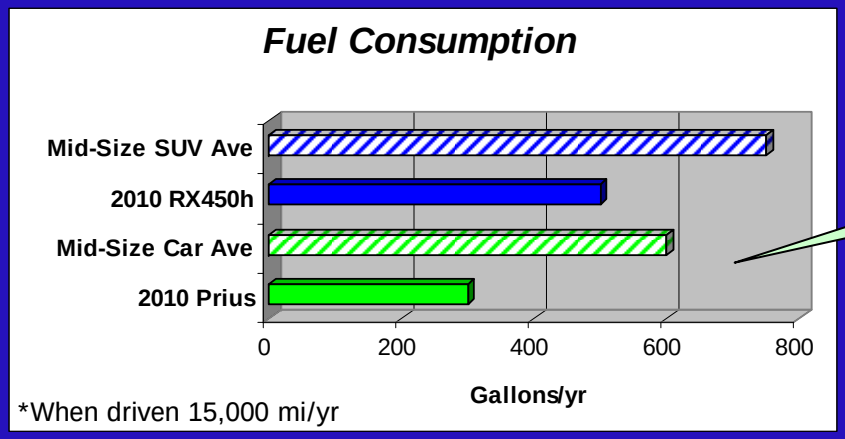
LEXUS MODELS

RX450h
Luxury SUV

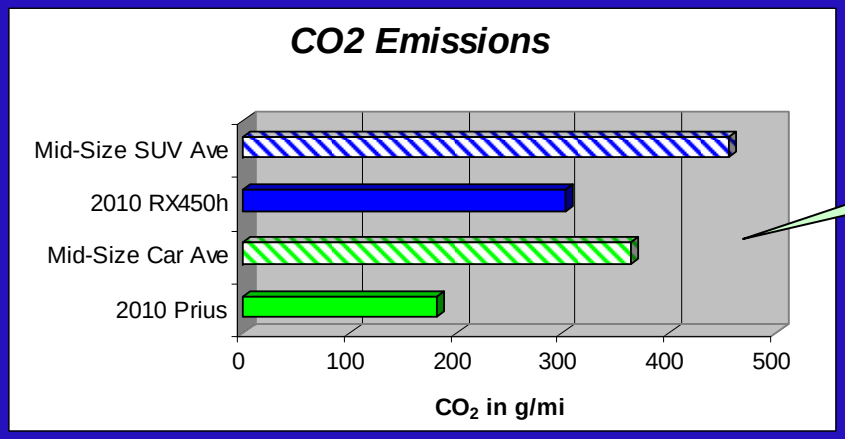
GS450h
Premium Sport Sedan

LS600h
Flagship


Savings with Hybrid Technology



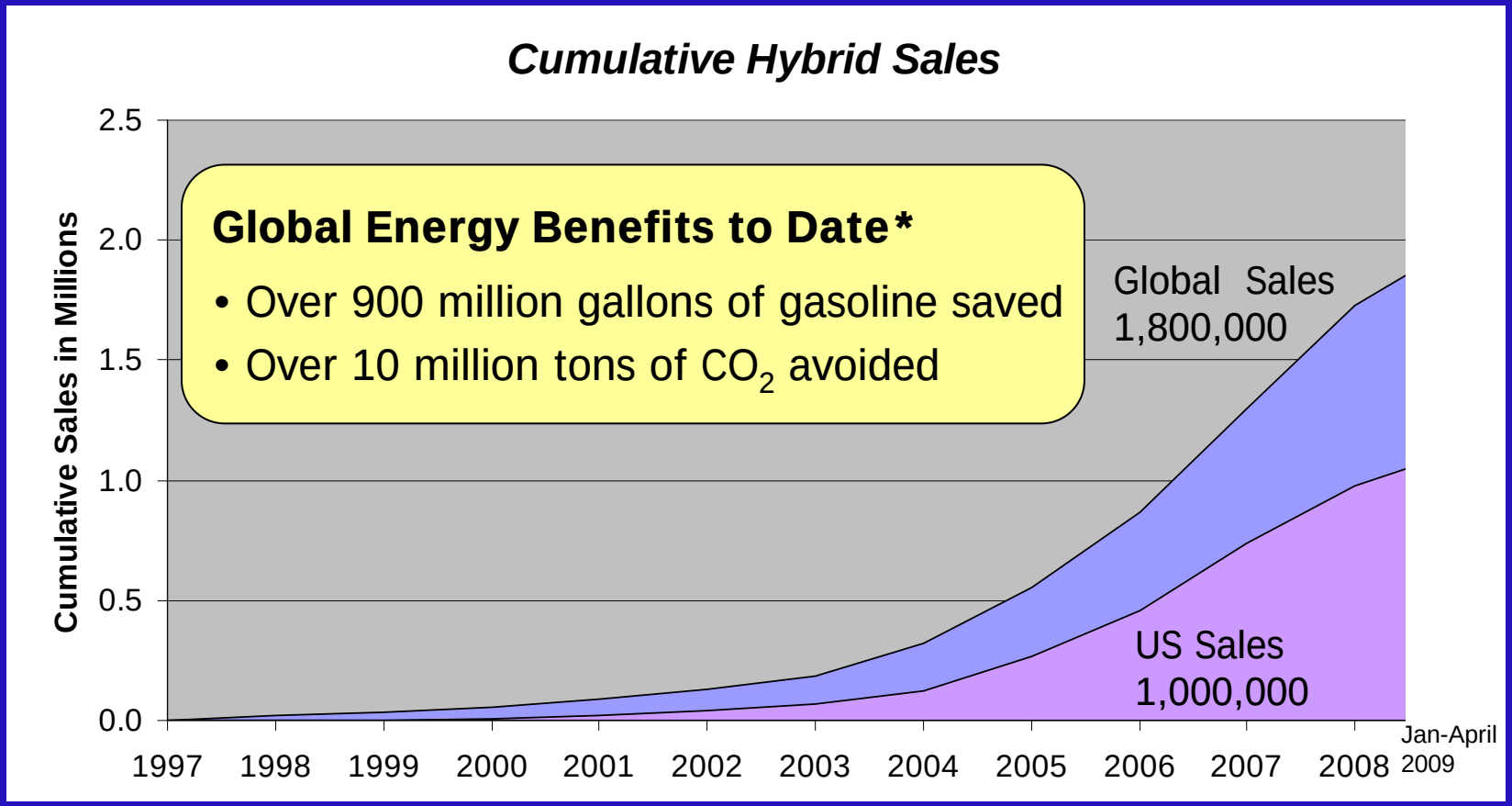
Yearly Fuel Savings
Prius – 300 Gal
RX450h – 250 Gal



Yearly Carbon Reduction
Prius – 3 tons
RX450h – 2.5 tons

* Prius & RX450h Fuel Economy (50 mpg & 30 mpg) - EPA Combined Rating
Class Average Fuel Economy (25 mpg for mid-size cars & 20mpg for mid-size SUV) - 2008 EPA LDV Trends Report


The Big Picture



*Toyota Estimate


Hybrid is a Foundation for Future Technology

- Toyota's Hybrid Synergy Drive is the basis for all next generation electric technologies





Potential of Fuel Cell Vehicles

- Hydrogen-fueled fuel cells have the potential to significantly reduce the environmental impact of the automobile
  - High on-board energy efficiency
  - Zero tailpipe emissions
  - Non-petroleum, diversified fuel sources
  - Potential for low / zero carbon hydrogen



TOYOTA

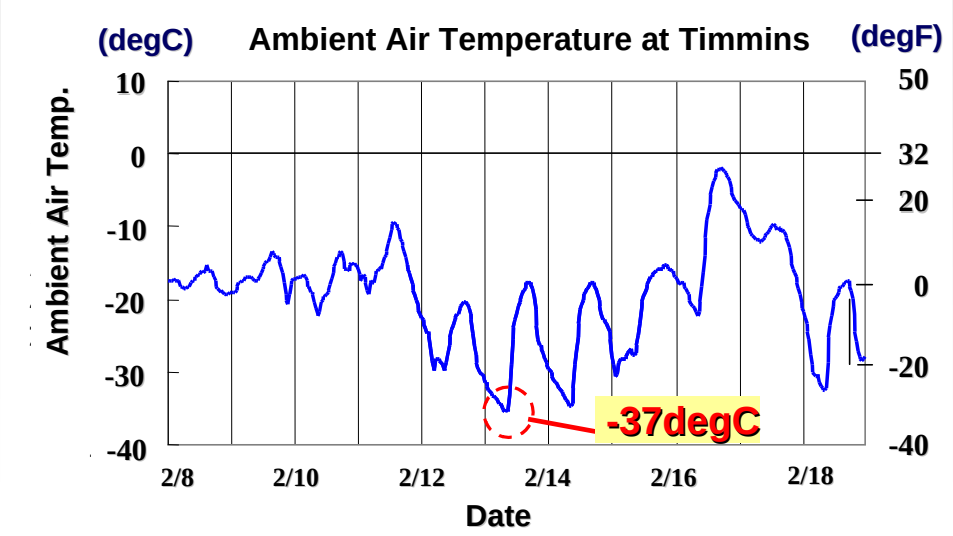

Toyota FCHV Progress

			Present	2015
Vehicle	 Dec. 2002 ~	 Jul. 2005 ~		**FCCJ* / DOE Target** * Fuel Cell Commercialization Conference of Japan
	'02 FCHV (lease model)	**'05 FCHV (lease model)**	**'08 FCHV-adv (lease model)**	Commercial Introduction → Mass Production
Technical Challenges				
1. Cold Start / Driving Capability	0degC ~	0degC~	-30degC	
2. Actual Cruising Range	210km	230km	500km or more	
3. FC Stack Durability				15 years or more
4. Cost reduction				1/10 or less (design / materials)

Toyota continues its efforts on FC stack durability and FC system cost reduction, targeting commercialization in 2015.


Demonstrated Cold Start Capability

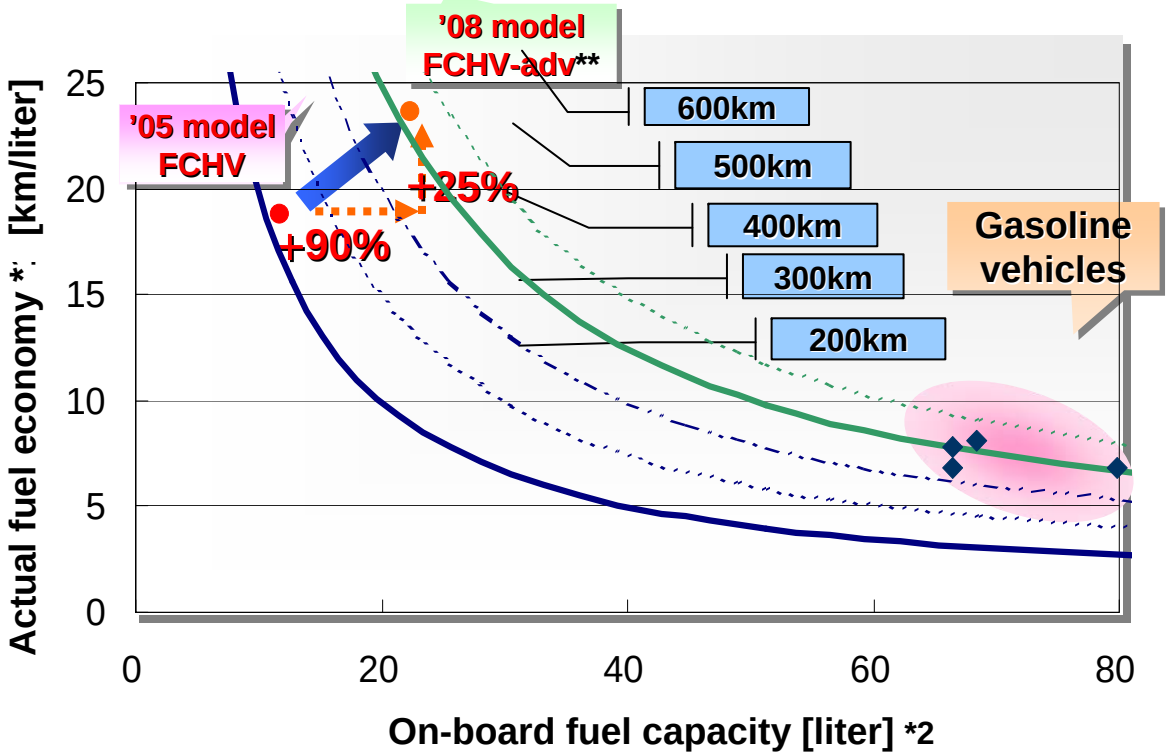
Timmins, Canada



Yellowknife, Canada

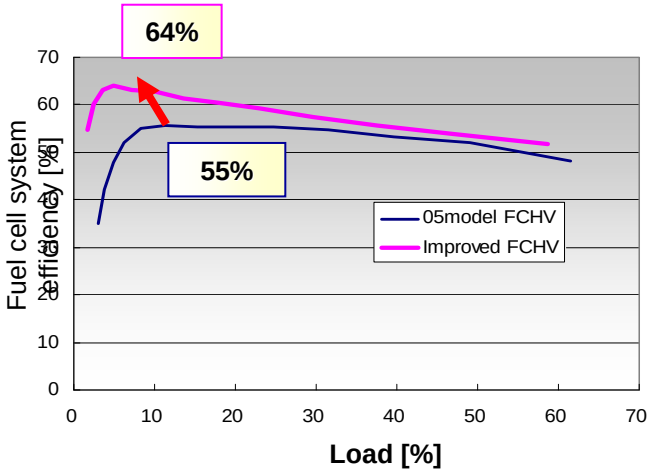
➔ Cold weather performance similar to conventional gasoline vehicles


Increased Efficiency & Range



Actual driving	> 400 mi
10-15 Japanese test cycle	> 500 mi
LA#4 test cycle	475 mi

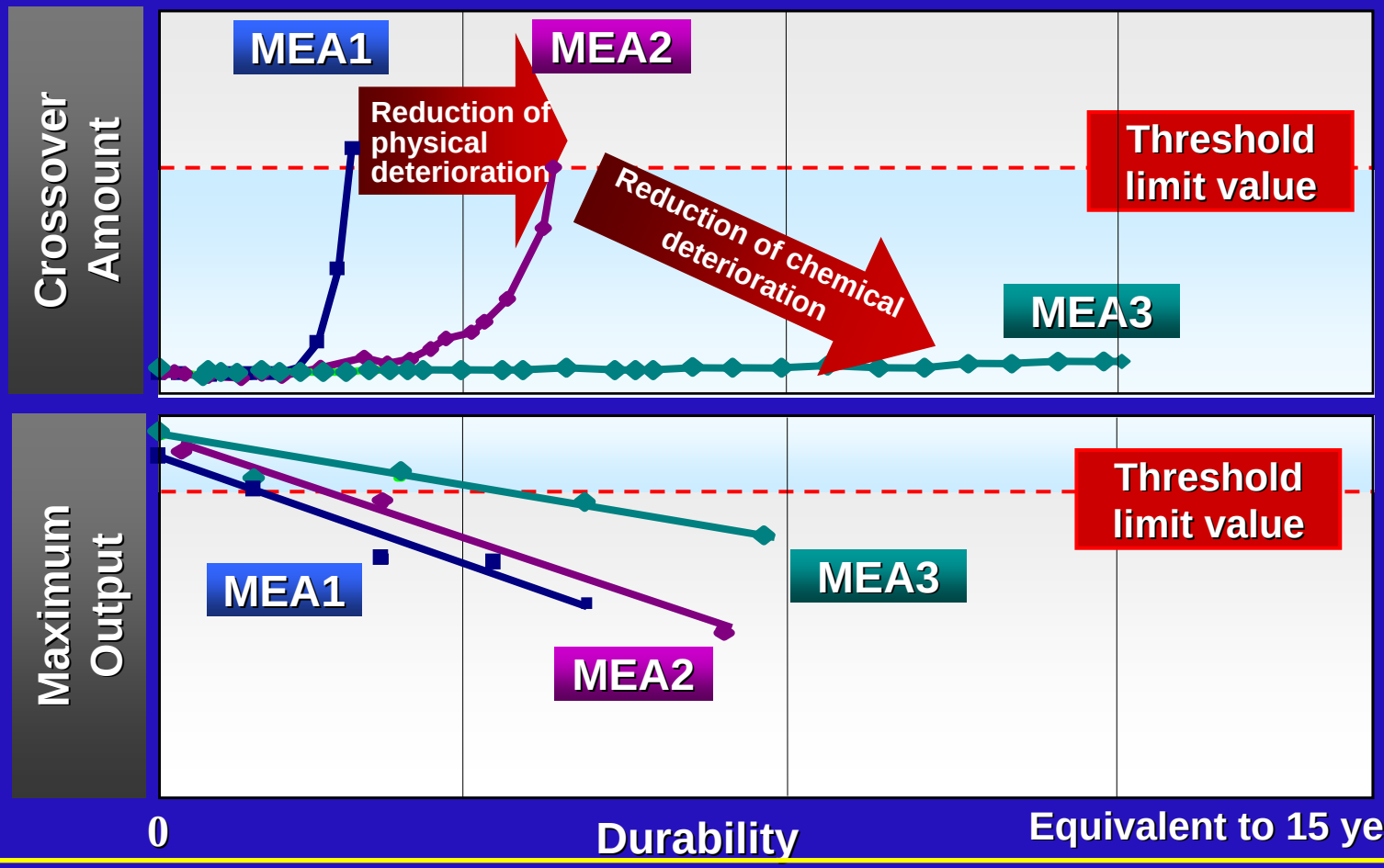
In-house test



*: measured by internal test cycle
**: Gasoline equivalent

➔ Demonstrated over 400 mile real-world driving range

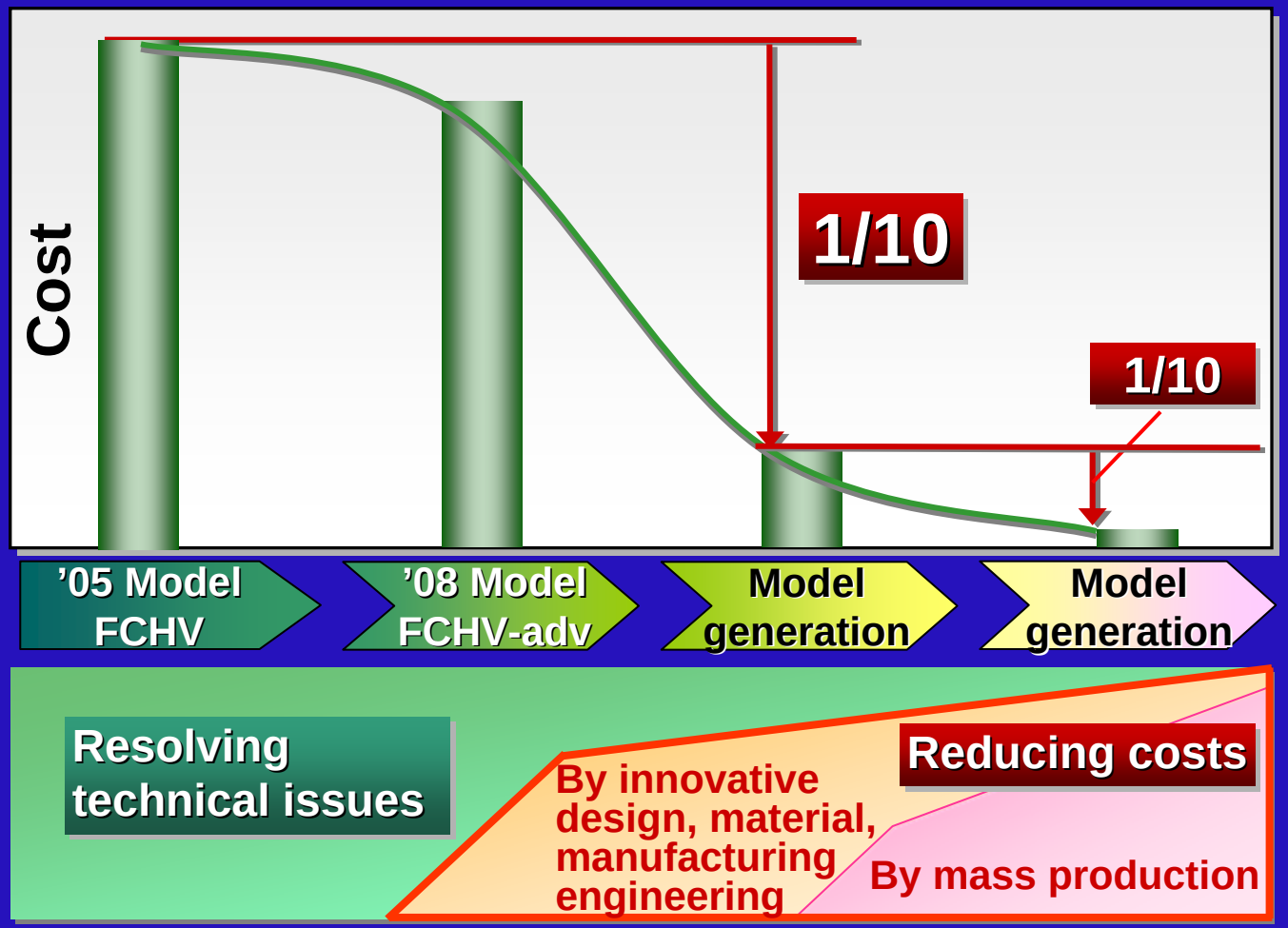
Stack Durability



Efforts continue to reduce MEA deterioration under real-world conditions

➔ Durability has been improved by more than three times

FCHV Cost Reduction




Commercialization Challenges

Production

- Solar / biomass
- Coal
- Petroleum
- Natural Gas
- Electricity

Hydrogenated compounds

Delivery, Supply

Hydrogen

Vehicle

Issues

- Production
- Storage method
- CO_2 Stabilization
- Cost

Issues

- Transportation Method
- Infrastructure Development
- Codes & Standards
- Hydrogen Delivery Cost

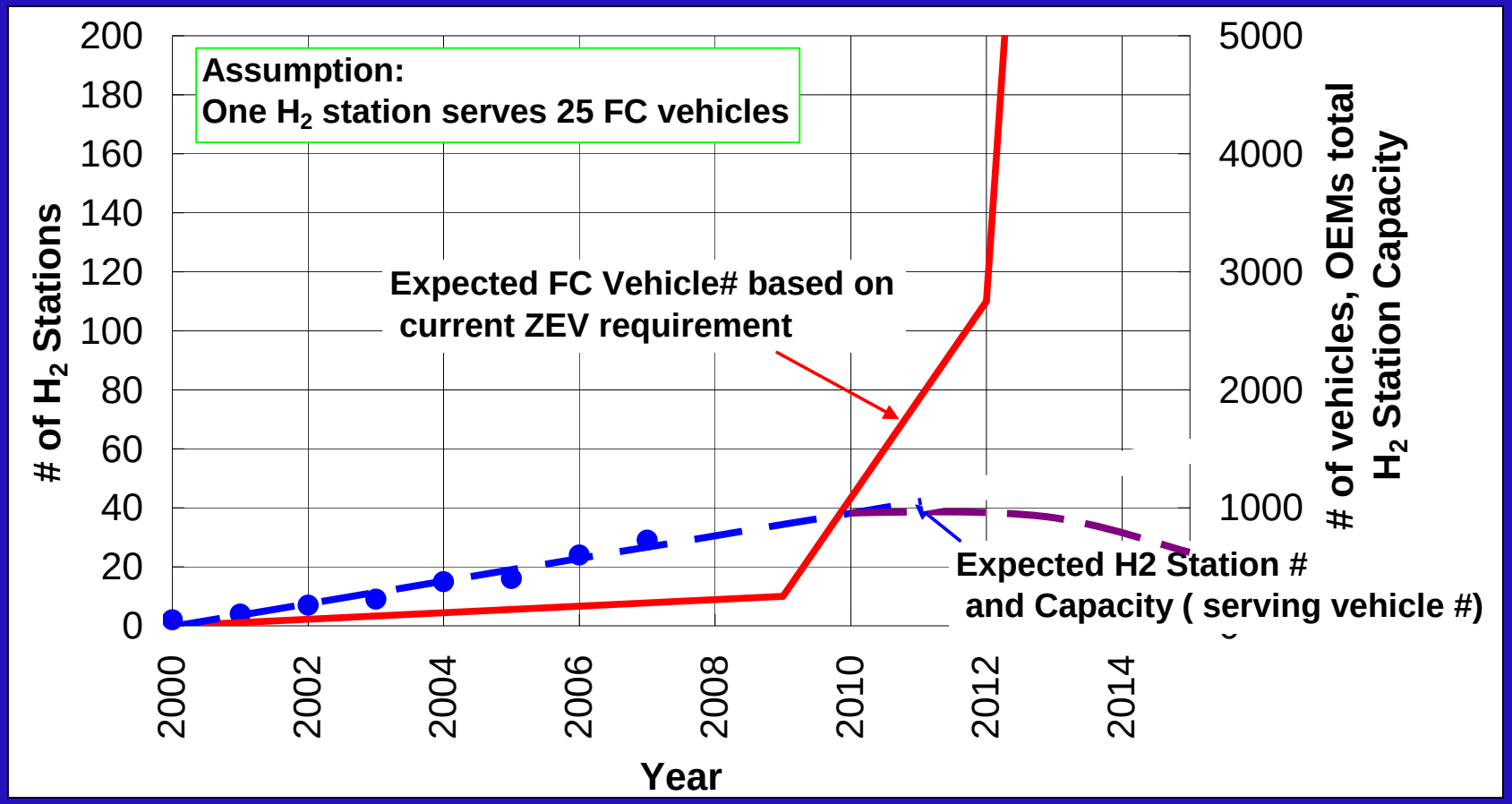
Issues

- Stack Durability
- Power Density
- Freeze Start Capability
- Driving Range
- Vehicle Cost

Government, Energy Suppliers

Car makers

California Infrastructure Concern

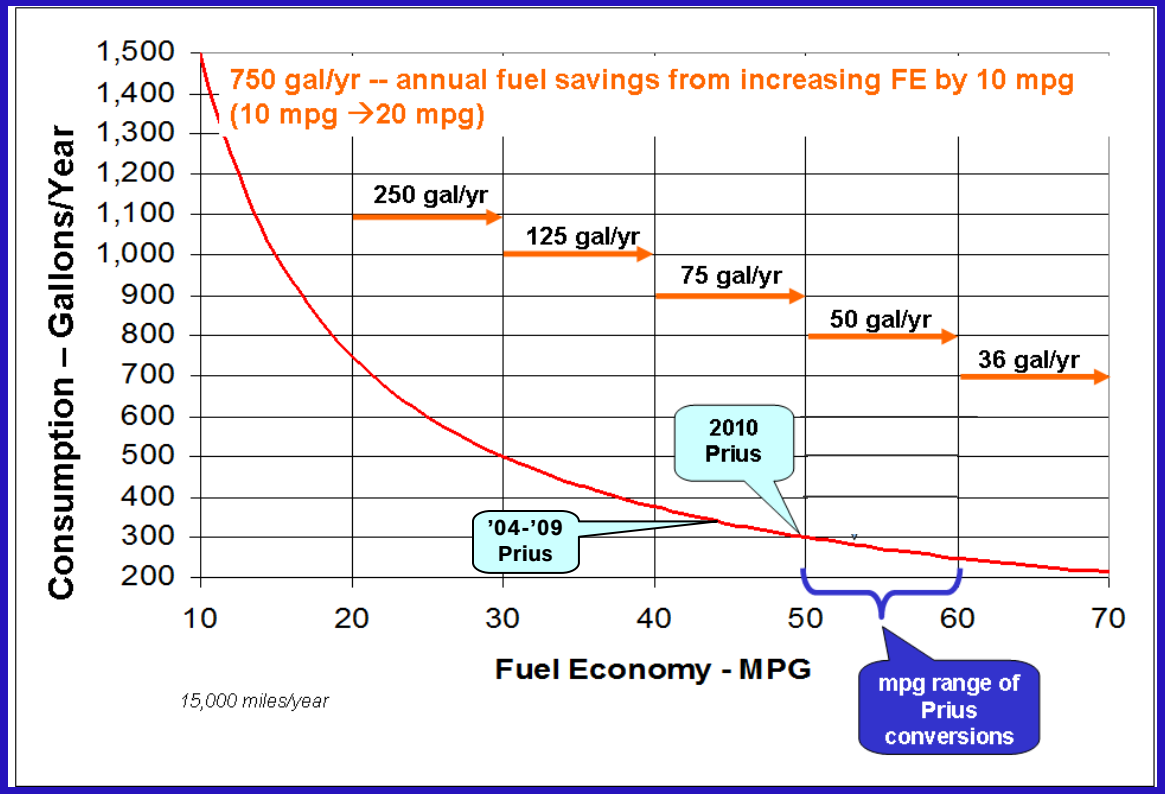


➔ By the 2012, the demand for H_2 stations will far exceed supply if station deployment is not accelerated


Toyota's PHEV

- Based on the 2010 Prius
- 500 to be leased to commercial fleets beginning late 2009
- Global program (~150 coming to the US)
  - Study customer use patterns in different markets (US, EU, Japan)
  - Explore public charging infrastructure options (Europe)
- Li-Ion batteries
    - Manufactured by Panasonic EV (Joint venture with Toyota)
- Key Objectives:
  - Confirm battery durability in real-world operation
  - Evaluate suitability of PHEVs in various markets


Fuel Savings 101

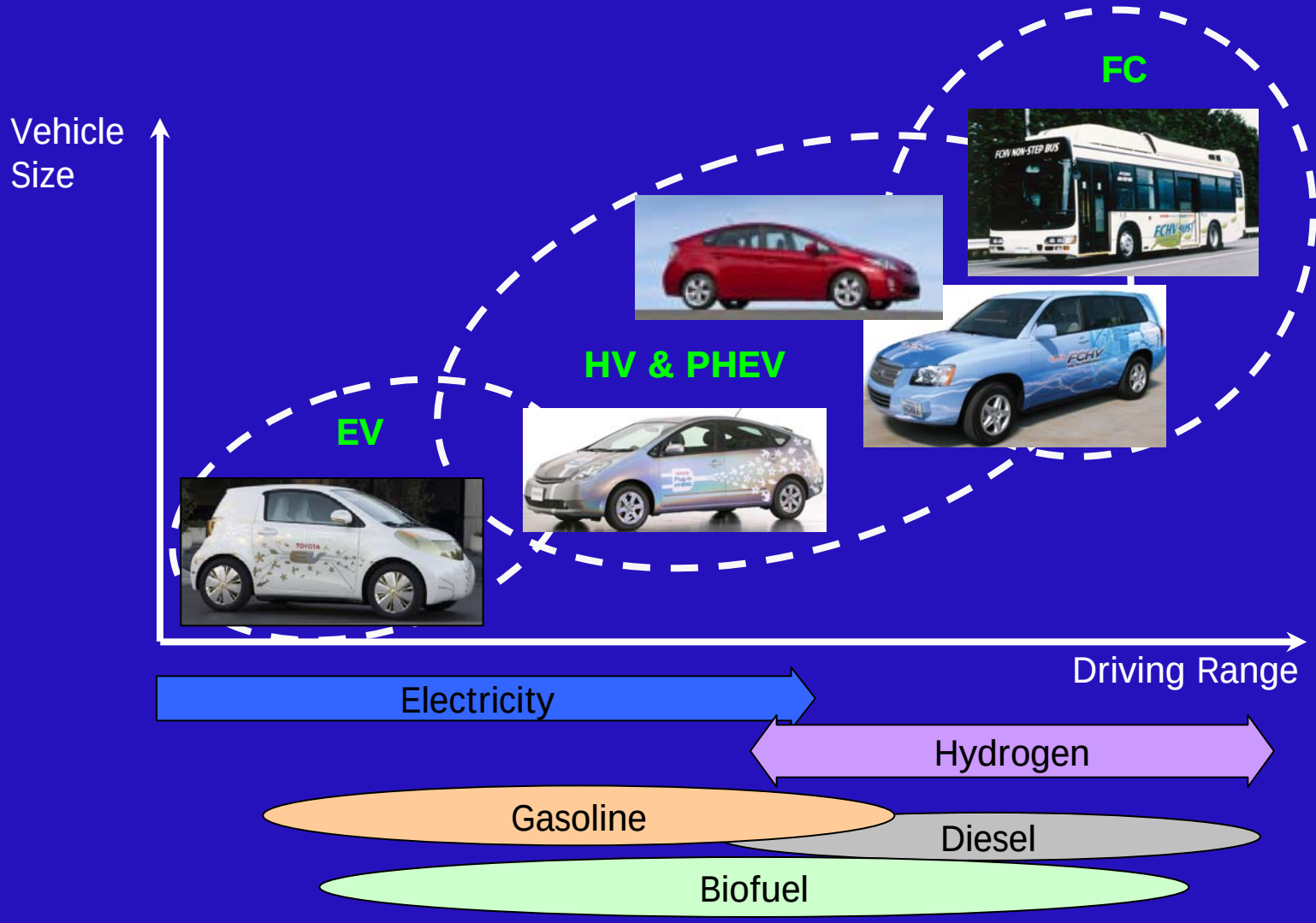


DOE's Adv Vehicle Testing Activity
PHEV Conversion Results

- 120 PHEVs under test
- 480,000 total miles
- 46-49 mpg (cumulative)

- Law of diminishing returns for fuel savings
- Real world FE of OEM PHEVs likely 20 - 25% better than hybrid


Market Segments for Each Technologies




Status & Challenges

Fuel Cell

- Cost – high, but on track to reach commercial introduction targets
- Durability – improving with path to reaching targets understood
- Range & cold start – resolved
- Power density – close with path to targets understood
- Infrastructure – technology understood, business case unclear, third party must initially subsidize

PHEV / BEV

- Battery cost – high on a usable kW-hr basis. Significant reductions are challenging with Li-Ion
- Durability – not proven when meeting cost & size targets
- Power/energy density – poor. Limited improvements possible
- Cold temp performance – poor. Limited improvements possible
- Charging - Residential (~50%) and few public stations

Conclusions

- Hybrid is the cornerstone for future Toyota vehicles
- Toyota sees a clear path to commercial introduction of a fuel cell vehicle by 2015
  - **Infrastructure is our primary concern**
- Initial sales will be modest for all new technologies
- ***Too early to select a winning technology***
  - ***All require additional development***
  - ***Timing for commercialization is similar***
  - ***All will be needed in the market of the future***

Thank You!

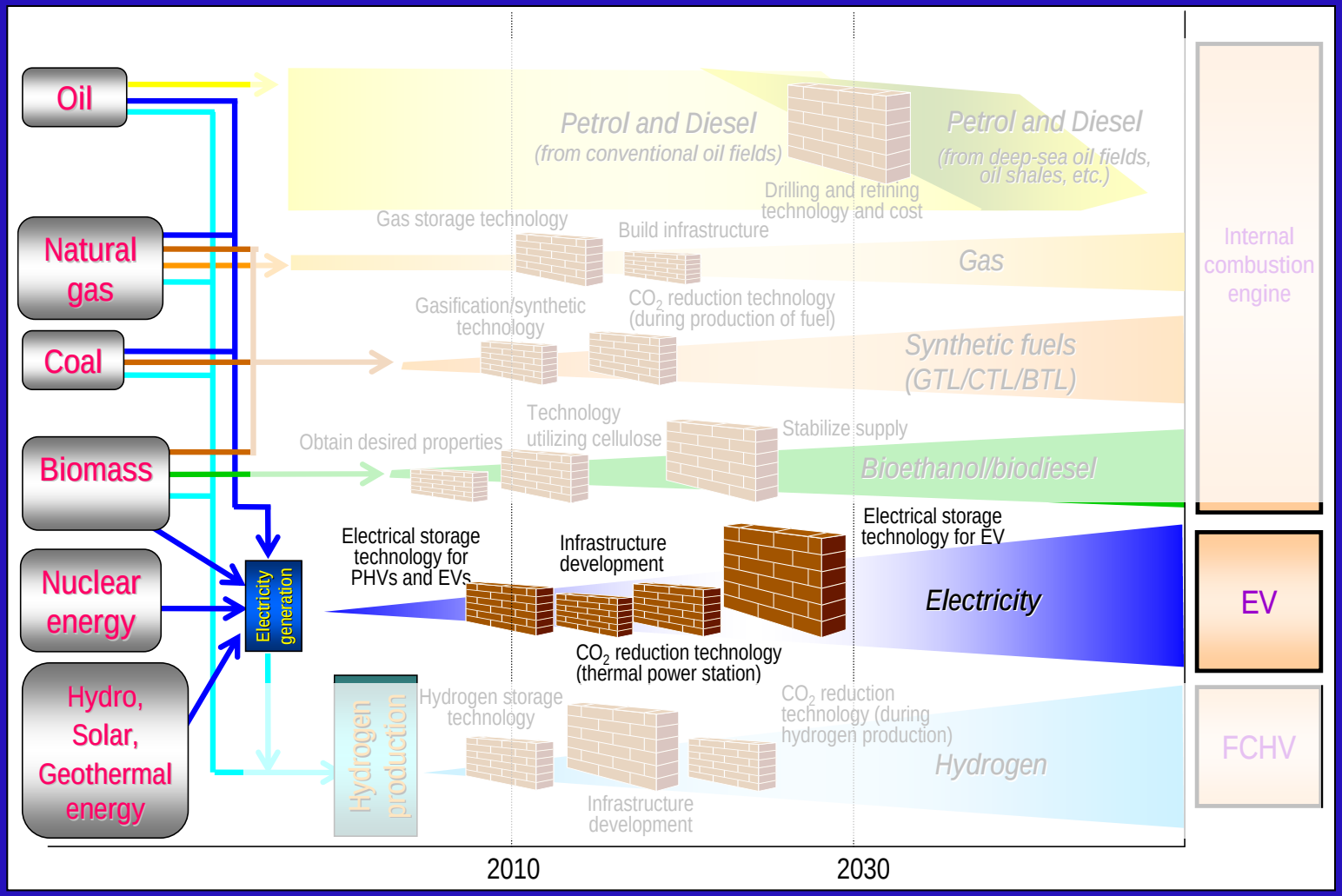

Outline

- Issues and fuels
- Hybrids – the cornerstone of our strategy
- Evolution of hybrid technology
  - Fuel Cell
  - PHEV
- Benefits and challenges
- Market size
- Conclusions

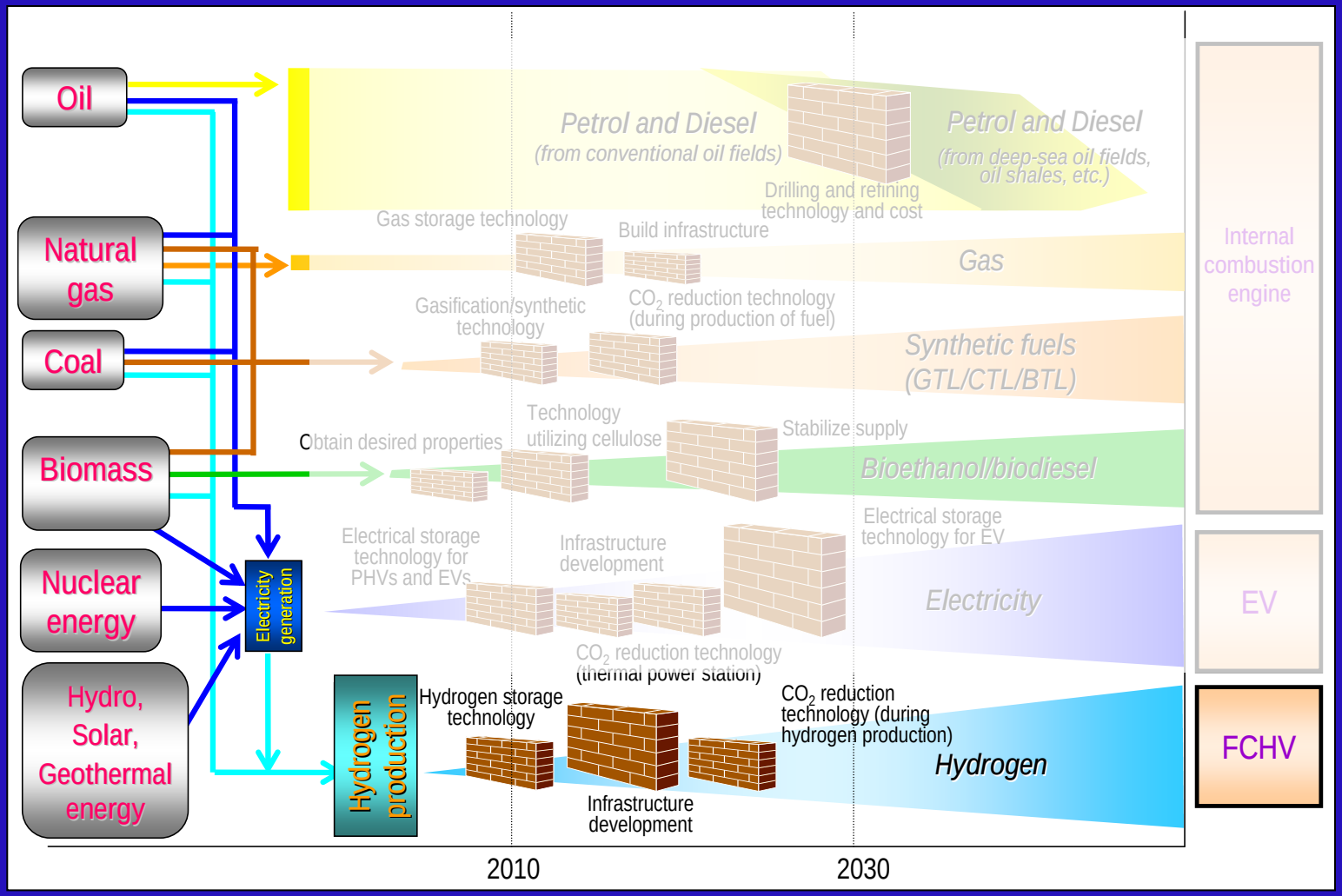
Fuel Options - ICE

Oil
Natural gas
Coal
Biomass
Nuclear energy
Hydro, Solar, Geothermal energy
Electricity generation
Hydrogen production
Petrol and Diesel (from conventional oil fields)
Petrol and Diesel (from deep-sea oil fields, oil shales, etc.)
Drilling and refining technology and cost
Gas storage technology
Build infrastructure
Gas
Gasification/synthetic technology
CO_2 reduction technology (during production of fuel)
Synthetic fuels (GTL/CTL/BTL)
Obtain desired properties
Technology utilizing cellulose
Stabilize supply
Bioethanol/biodiesel
Electrical storage technology for PHVs and EVs
Infrastructure development
Electrical storage technology for EV
Electricity
CO_2 reduction technology (thermal power station)
Hydrogen storage technology
CO_2 reduction technology (during hydrogen production)
Hydrogen
Infrastructure development
Internal combustion engine
EV
FCHV
2010
2030

Fuel Options - EV



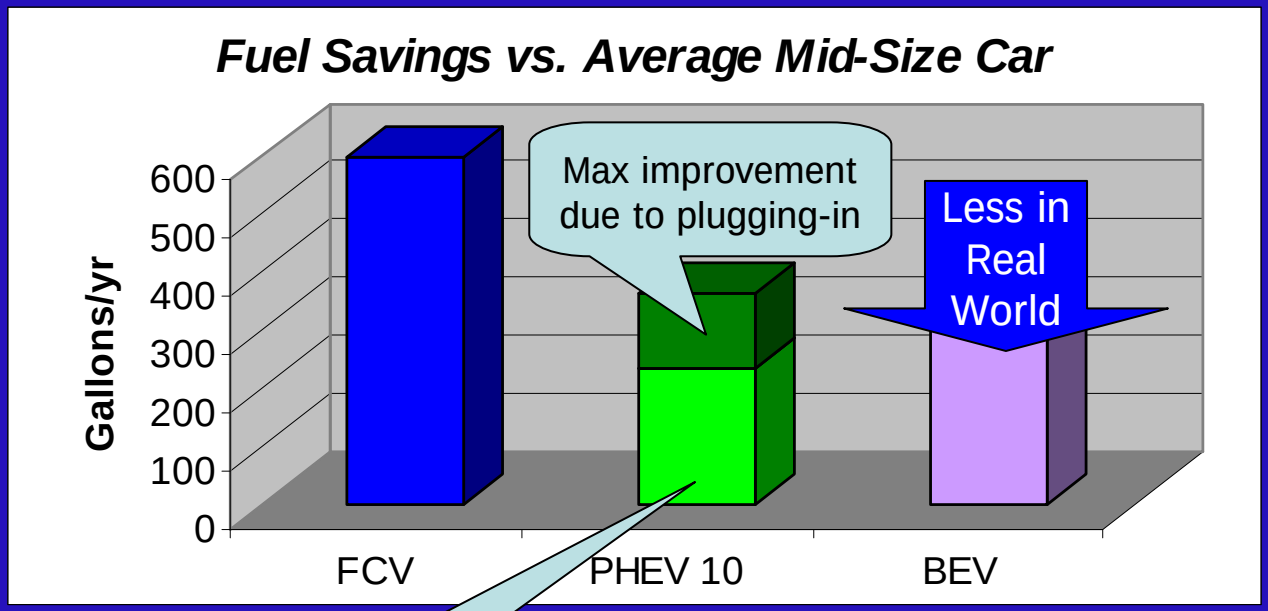
Fuel Options - Hydrogen




FT-EV Concept

- Urban commuter battery electric vehicle
- Based on Toyota iQ that is on sale in Japan and EU
- Designed to meet the needs of an urban commuter
- 2012 launch
- Over-night charging on 110 volt household power


Benefit Comparison – Petroleum Savings



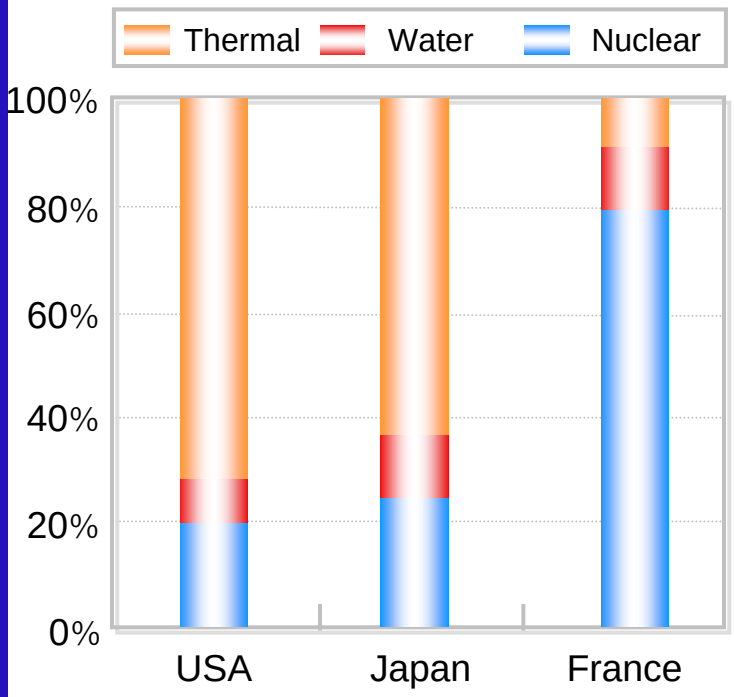
A fuel cell vehicle's greater flexibility (long range and rapid refueling) will result in greater use and fuel savings

Assumptions

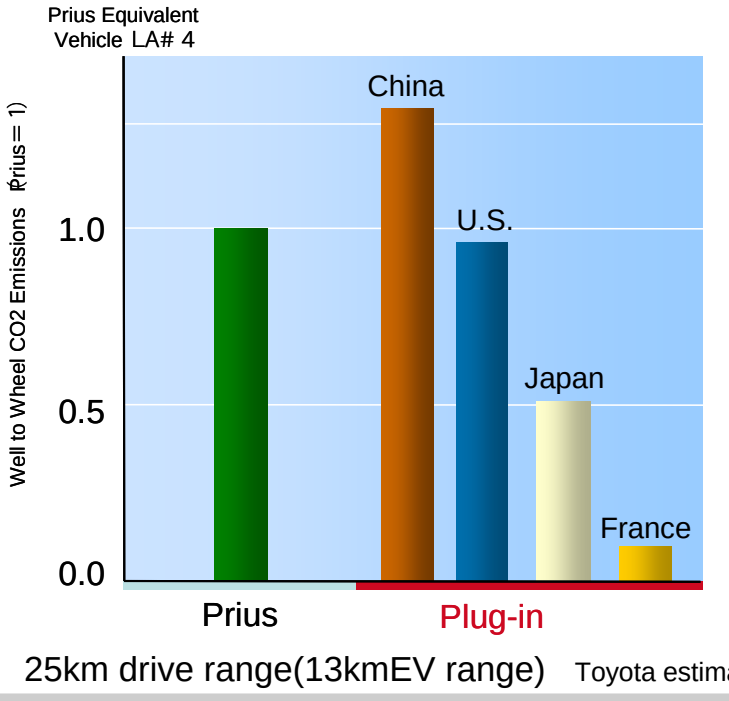
- Fuel Economy
  - Conventional Vehicle - 25 mpg
  - PHEV on gasoline – 50 mpg
- PHEV & BEV recharged nightly
  - Full electric range used 6 days/wk, 52wk/yr
- FCV & PHEV driven - 15,000 mi/yr
- BEV driven – 12,480 mi/yr (40 miles/charge)


PHEV/BEV CO_2 Reduction Potential

Electric Generation by Country

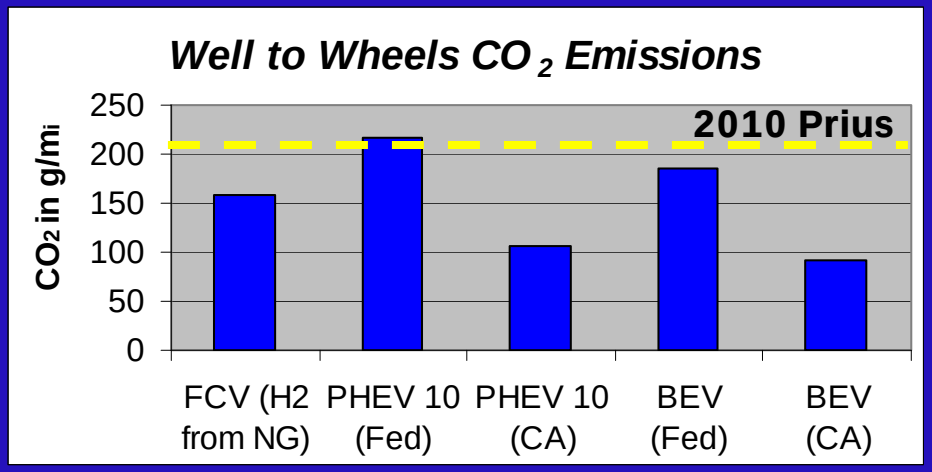


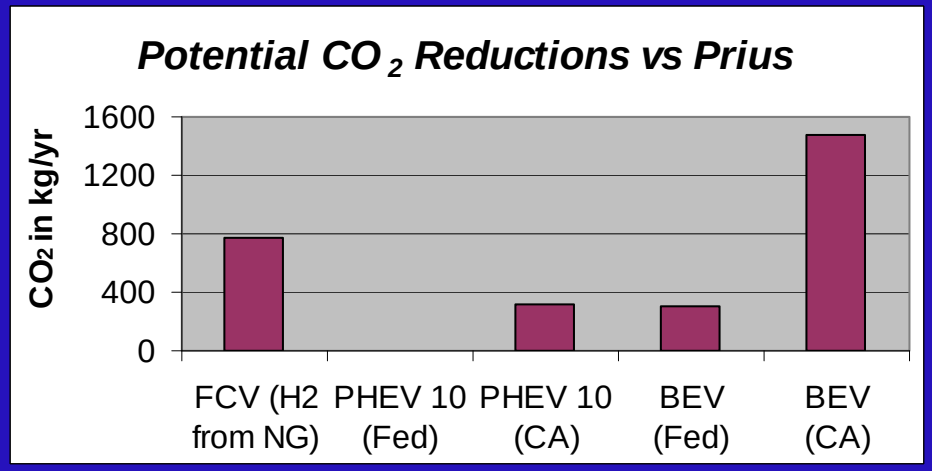
Well-to-Wheel CO_2 Emissions



PEV's ability to reduce CO_2 emissions
depends on carbon-intensity of electricity generation


Benefit Comparison – CO_2 Reduction





* PHEV CO_2 value for electric only operation

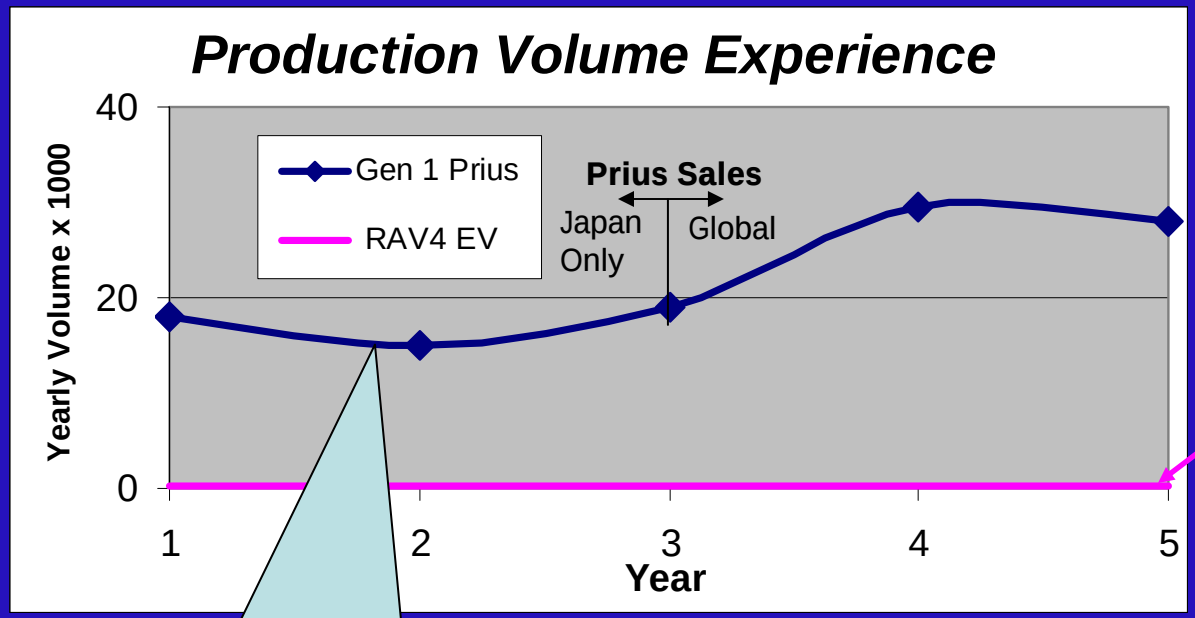
Limited CO_2 benefit for all technologies without:

- Greening of the electrical grid
- Renewable or nuclear hydrogen

Assumptions

- Those on "Petroleum Savings" slide
- 0.605 kg-CO_2/kWh US grid average
- 0.298 kg-CO_2/kWh CA grid average
- 7.2% Transmission losses
- Electric drive efficiency
  - PHEV 3.0 mi/ac-kWh
  - BEV 3.5 mi/ac-kWh
- 2800 g C/kg H2 NG Reforming
- 65 mi/kg H_2


Potential Volumes for New Technologies

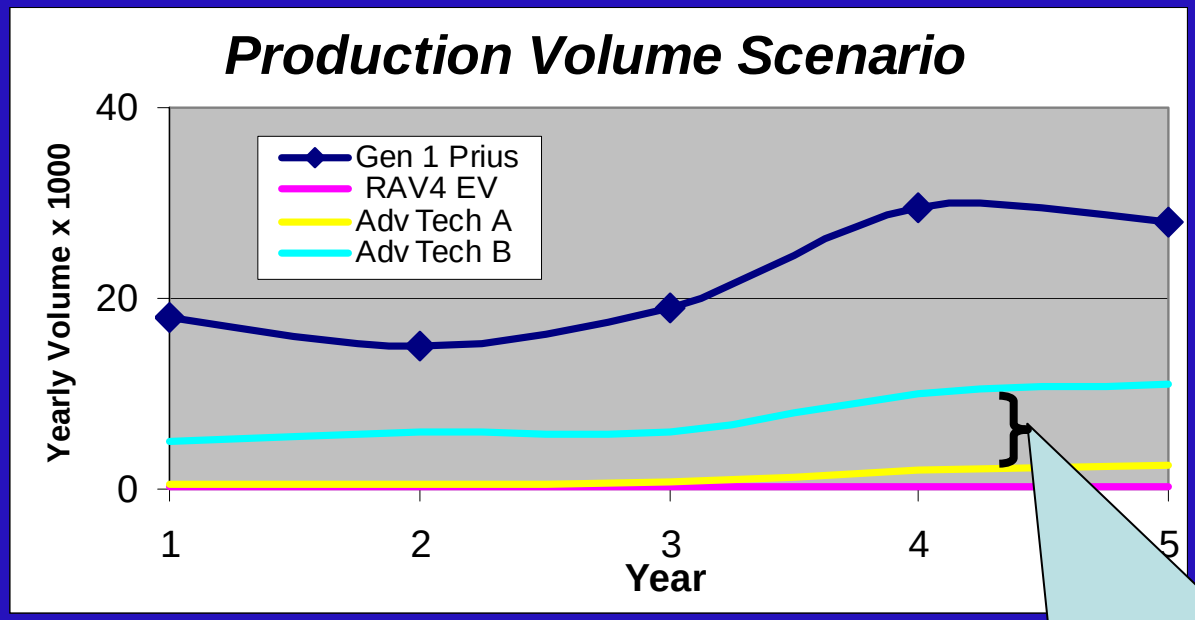


RAV4-EV ~300/yr

Best Case - Prius

- No new customer action required
- No new infrastructure
- No operational limitations
- Quick refuel
- Modest price increase + manufacturer support

Potential Volumes for New Technologies



Adv Technology Case

- Market demand will set volume
- Demand proportional to
  - Utility (range, capacity, performance)
  - Convenience (refueling / recharging)
  - Price (value & image)
  - Real or perceived “range anxiety”


Toyota's PHEV Introduction Scenario

'07 '08 '09 '10

Field Test Phase

Test Car

~25 Vehicles Globally

Field Data

Understand market potential

Small Demo

~500 Vehicles Globally

Accumulate Field Data

? ? ?

Medium Volume

Accumulate Field Data

Mass Production

Battery

NiMH

Li

Li <Revised>

Li <Advanced>

Vehicle deployment dependent on battery development