Advanced Technologies at Toyota

Clean Air Act Advisory Committee

September 18, 2008

Tom Stricker
Toyota Motor North America

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Topics

- Market Overview and Factors
- Deploying New Technology
- Hybrid
- Plug-In Hybrid
- Fuel Cell
- Conclusions

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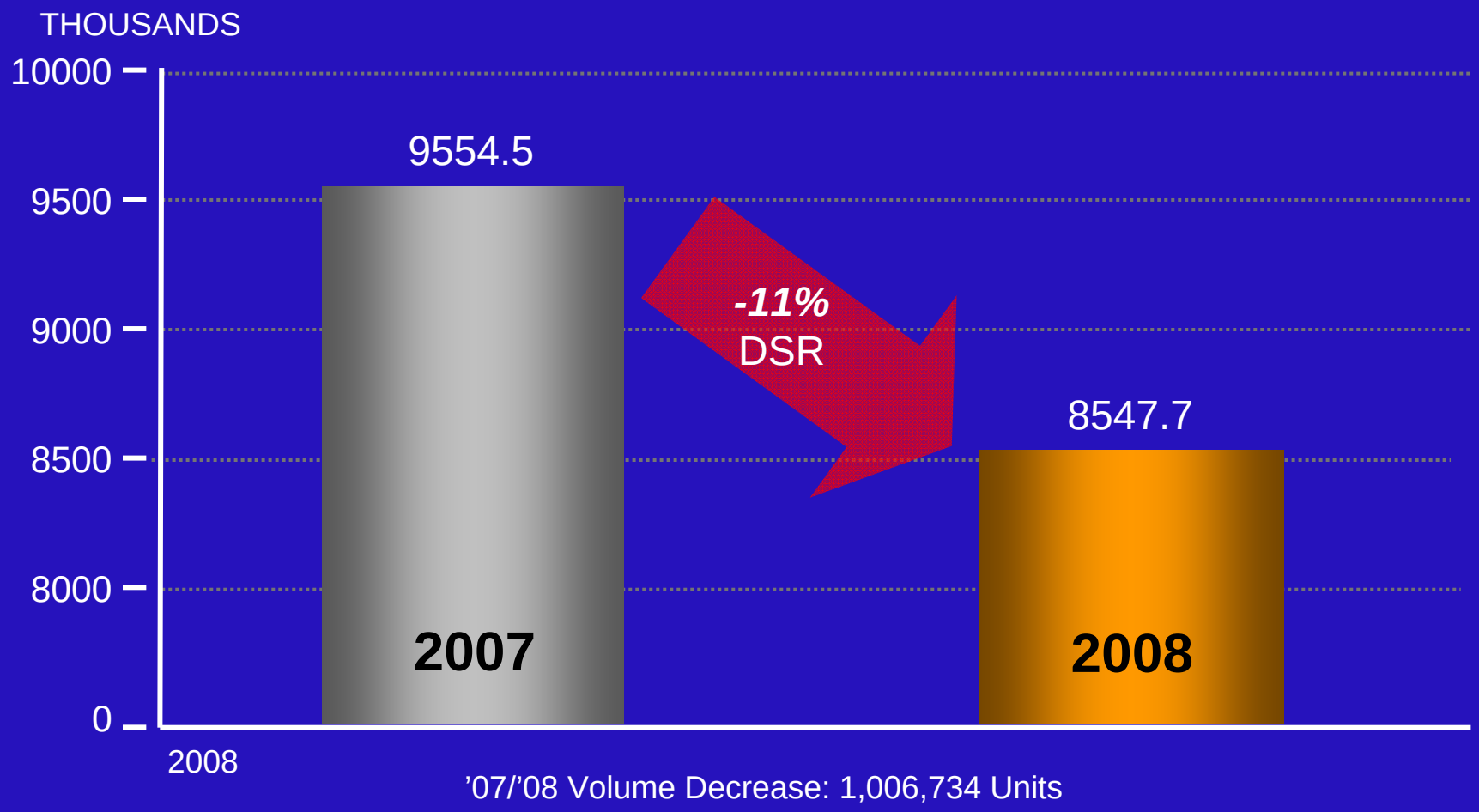
US Industry January-July Sales



'07/'08 Volume Decrease: 1,006,734 Units

Source: July Industry Report, (combined sales, include Hawaii)

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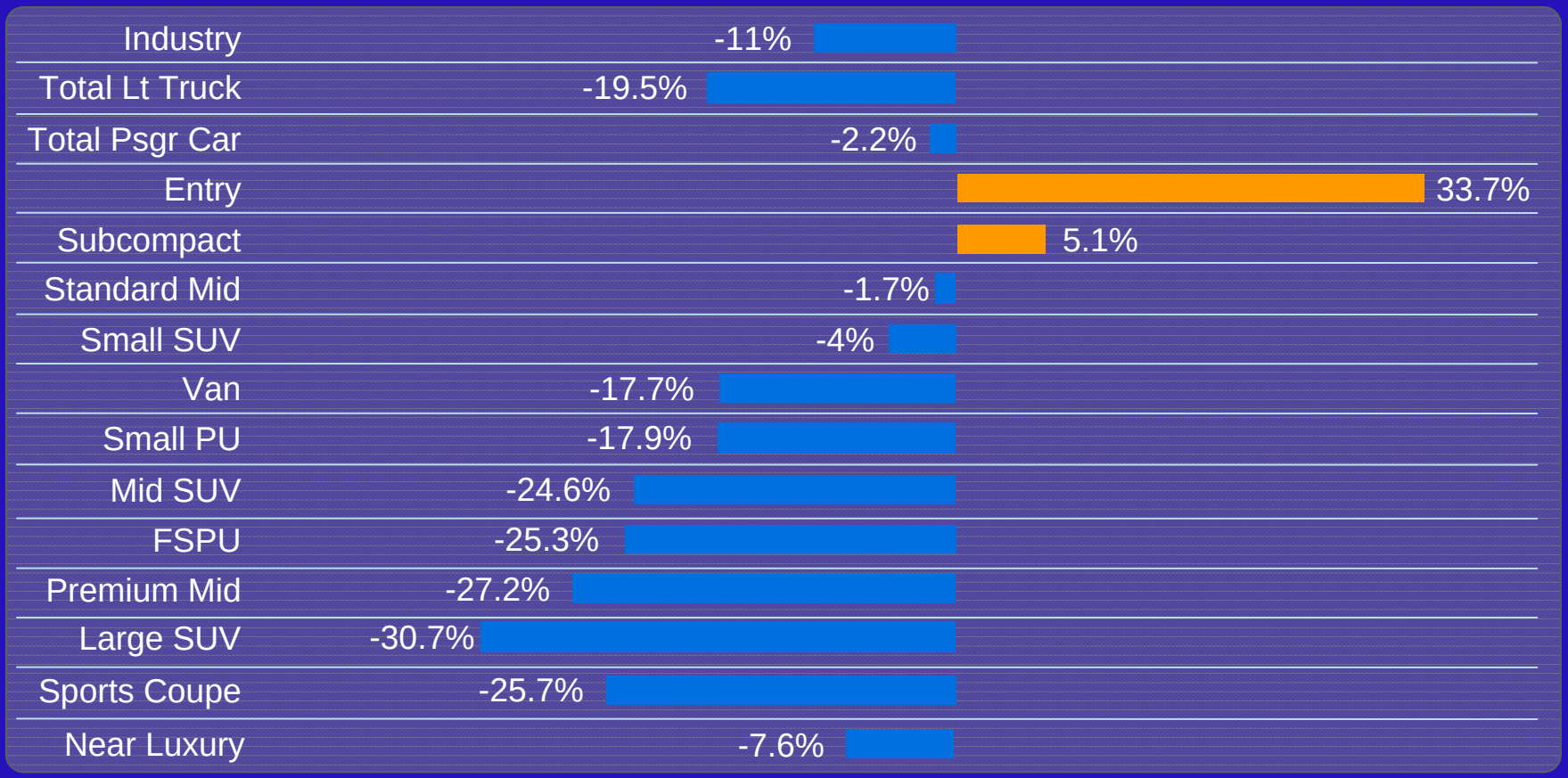
New Vehicle Segment Shifts

July CYTD Sales versus Year Ago



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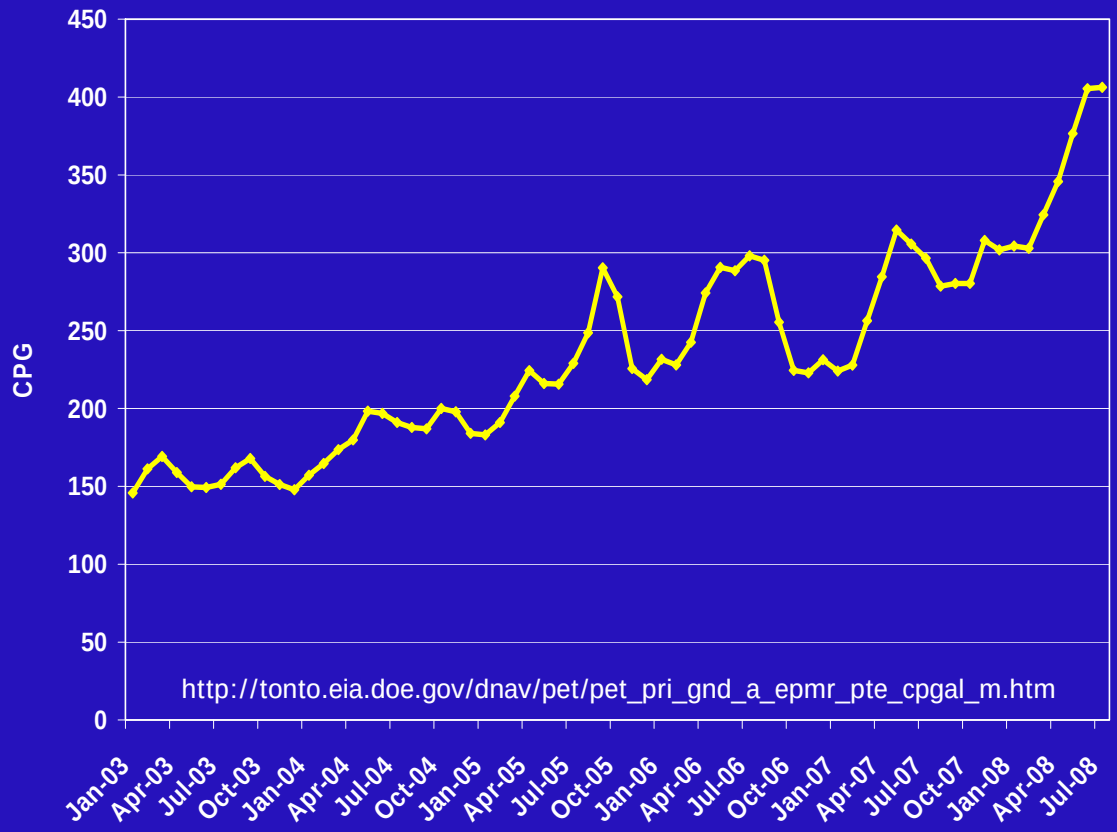
Short-Term Factors



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Longer-Term Issues Driving Change in Business

All affect Auto Industry

Global development of industry and technology in the 21st century

Population growth

Growing number of motor vehicles

Accelerated consumption of fossil fuels

1. **Energy & Fuel Diversification**
2. **CO_2 Reduction**
3. **Air Quality**
4. **Urban Congestion**

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The Automobile Challenge

1. Balance reduction of environmental impact with meeting <u>consumer wants</u>
   - ***It doesn't matter how "green" a product is if no one will buy it***
2. Mass market appeal
   - ***Must sell millions to make real impact***
3. Life Cycle Assessment
   - ***Must look beyond "tailpipe" for true environmental impact***

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Toyota's Multi-Path Approach

Issues

- CO_2 Reduction
- Energy Diversification
- Reduced Emissions
- Urban Congestion

Sustainable Products

Hybrid Technology

- Alternative fuel HV
- Diesel HV
- HSD
- Plug-in HV
- FCHV

- Biofuels
- Synthetic fuels
- CNG
- DPNR
- Common rail DI
- D-4
- Lean burn
- VVT-i
- EV

Alternative fuel engines | **Diesel engines** | **Gasoline engines** | **Electrical energy**

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Product Cycles Are A Reality

	Gen 1 **Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	***Gen 2*** **Year 6**
Typical Cycle	Base FE	→ Minor mods.			→	Gen 1 + △%
4% CAFE Scenario	Base FE	⇢ Major mods.?			⇢	Gen 1 **+ 22%**

Cost and product cycles cannot be separated. NAS costs (and others) assume normal product cycles.

22% improvement at each generation requires major modifications in mid-cycle (substantially higher cost) and/or multiple technologies at each new redesign

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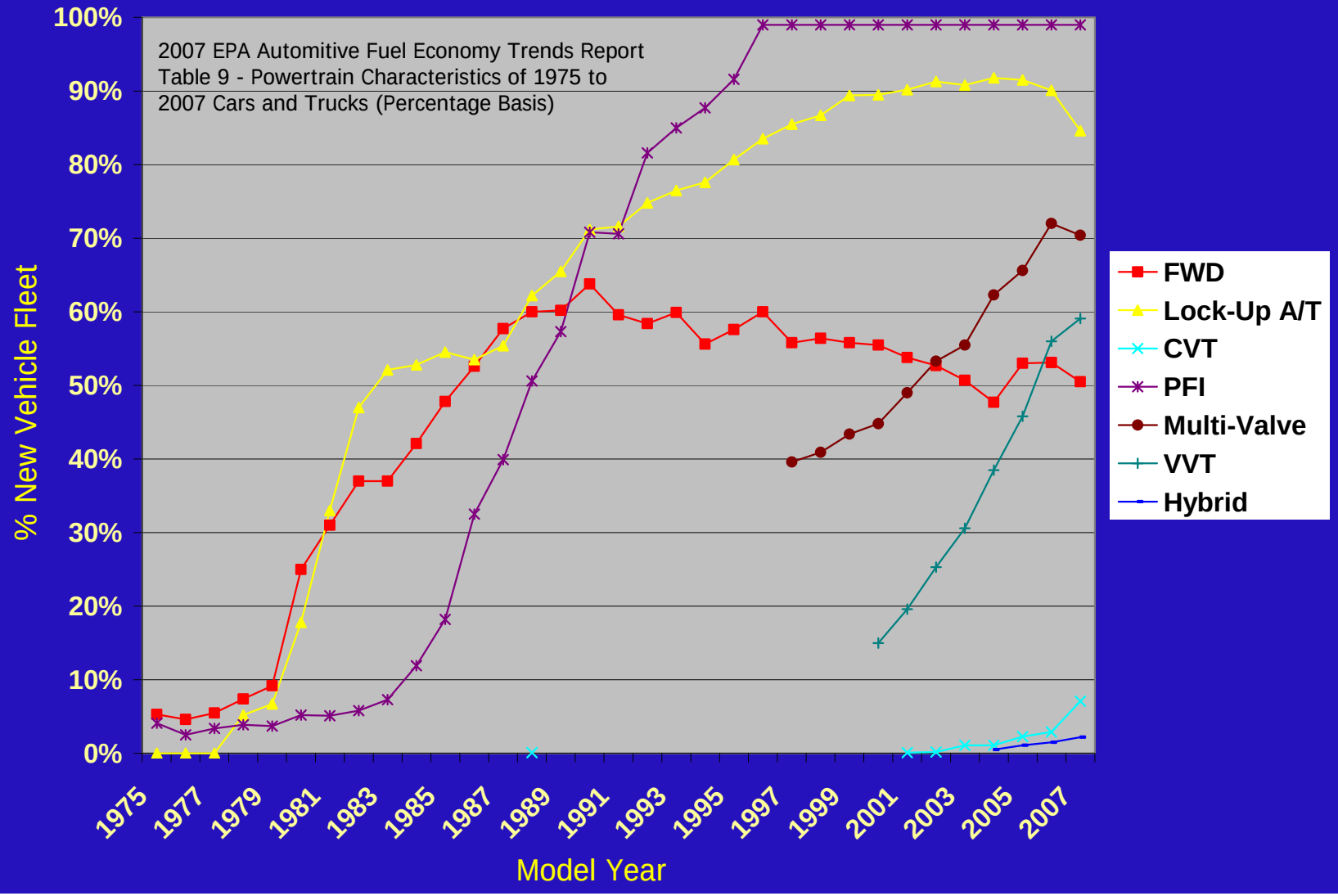
Technology Takes Time to Penetrate



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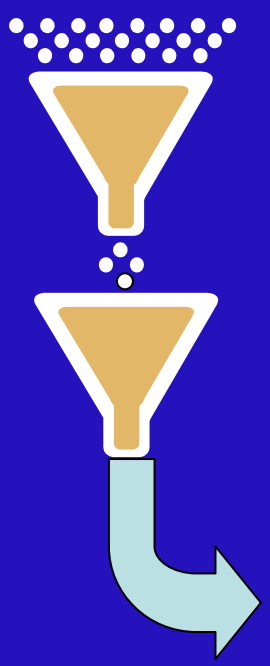
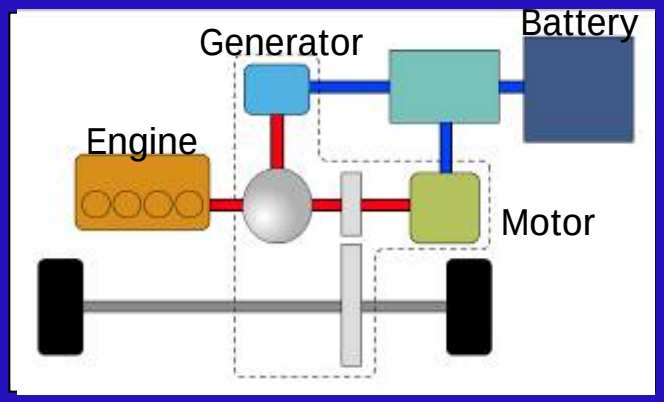
Toyota Hybrid Development



80 Hybrid Designs

- Fuel Economy
- Emissions

- Technical Feasibility
- Cost



Hybrid Synergy Drive

1998 Prius

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Toyota's Line of Hybrids in America

TOYOTA MODELS

Prius
Midsize 5 Door

Camry Hybrid
Midsize 5 Door

Highlander Hybrid
Midsize SUV

LEXUS MODELS

RX400h
Luxury SUV

GS450h
Premium Sport Sedan

LS600h
Flagship

Combined US sales averaging over 23,000 / month in 2008

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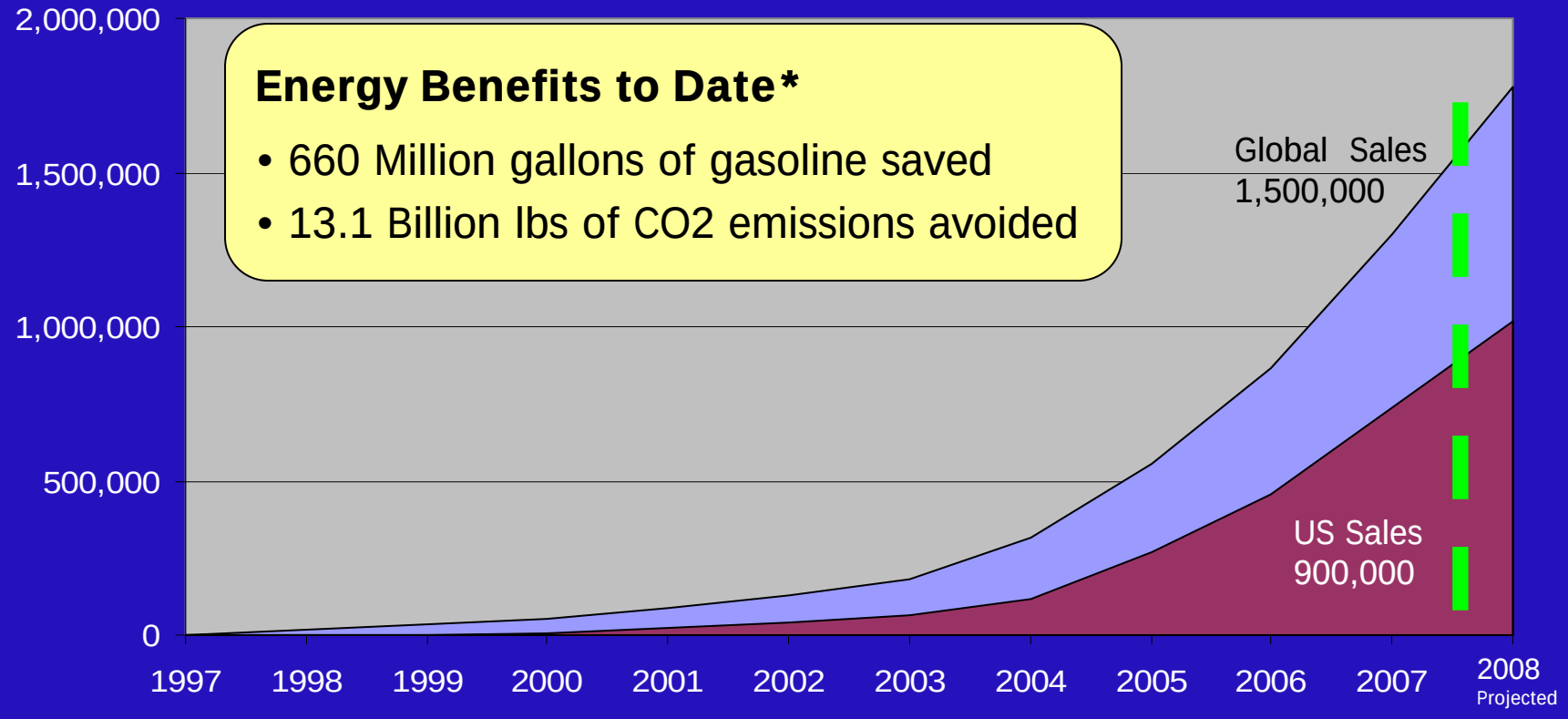
A Million & Half Hybrids Sold & Growing

Cumalative Hybrid Sales thru July 2008



Energy Benefits to Date*

- 660 Million gallons of gasoline saved
- 13.1 Billion lbs of CO2 emissions avoided

*Toyota Estimate

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Hybrid as a Foundation

- Toyota's Hybrid Synergy Drive is the powertrain foundation for next generation technologies
  - Flexibility
  - Reduced development time & cost
  - Lower cost higher volume potential

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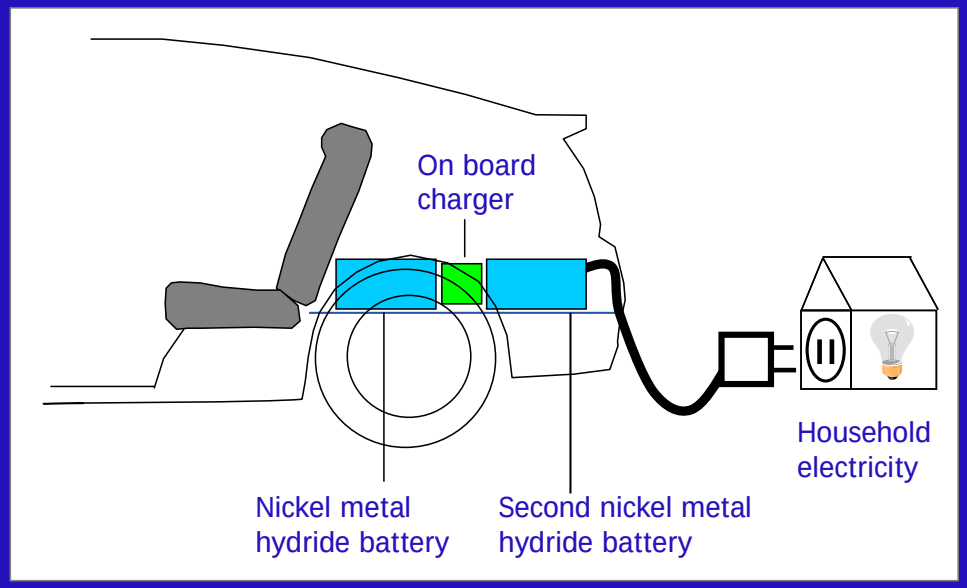
Toyota's Current PHEV Prototype



VEHICLE BENEFITS

- Fuel diversification (energy security)
- Potential greenhouse gas reduction
- Reduced fuel cost

PROTOTYPE OBJECTIVES

- Study consumer behavior (US)
- Study public charging (Europe)
- Demonstrate system, not battery capability

CHALLENGES

- Battery cost & life – key for commercial introduction
- Packaging
- Need for cleaner electricity

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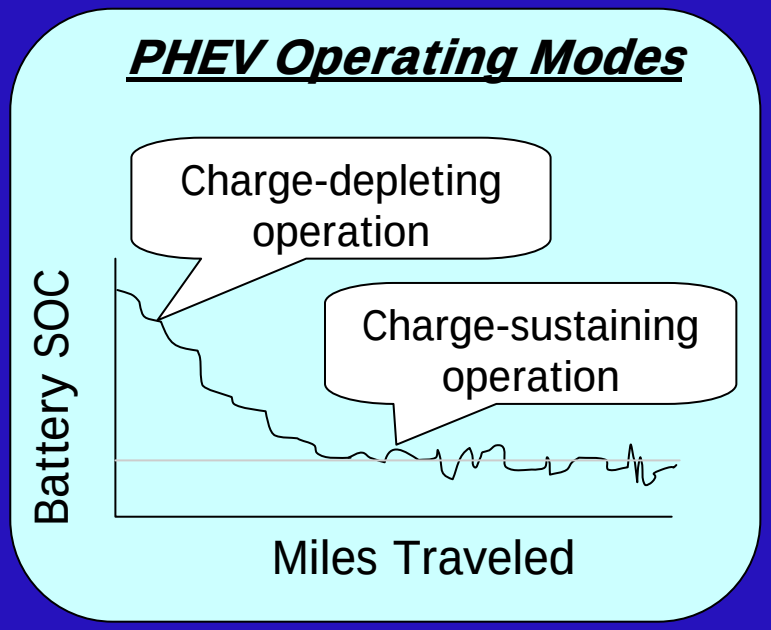
Toyota PHEV Performance Specifications

- EV Performance (Charge-depleting)
  - Top speed in EV mode – 62 mph
  - Max EV power ~ 40 kW
  - EV range ~ 7 miles
- Battery (2 x NiMH)
  - 2 x 6.5 Ah (13Ah / 2.6kW-hr)
  - 202 V
- Charging Time
  - 1-1.5 hr on 220V
  - 3-4 hr on 120V
- Max system power 100kW (20kw more than Prius)



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2010 – The Next Step

- Toyota has announced our next generation PHEV:
  - Significant numbers beginning in 2010 model year
  - Global program
  - Commercial fleets
  - Li-Ion batteries
    - Manufactured by Panasonic EV (Joint venture with Toyota)
  - Results to help determine suitability for consumer market
- Re-evaluate suitability of battery electric vehicles for consumer market

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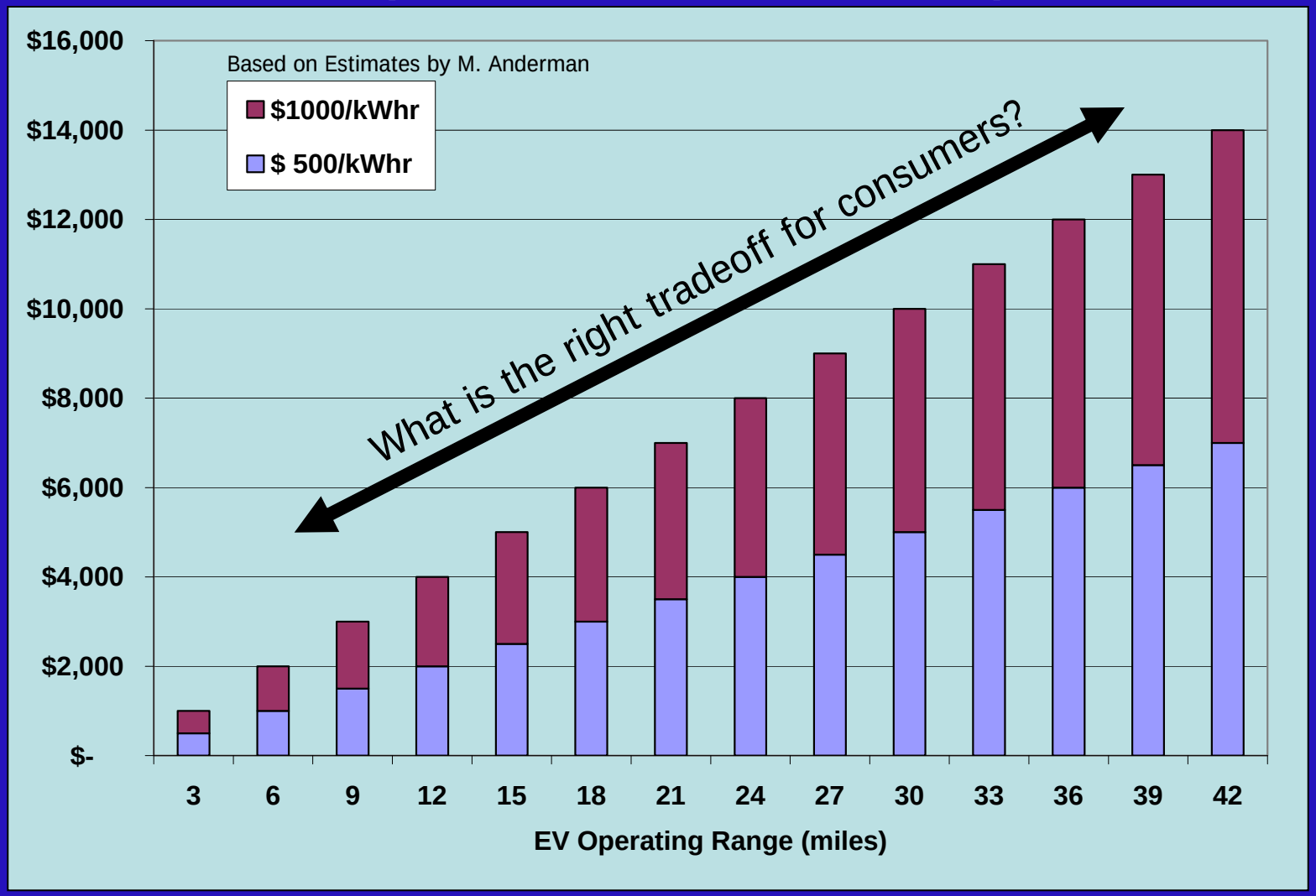
External Expert Cost Estimate per kWhr



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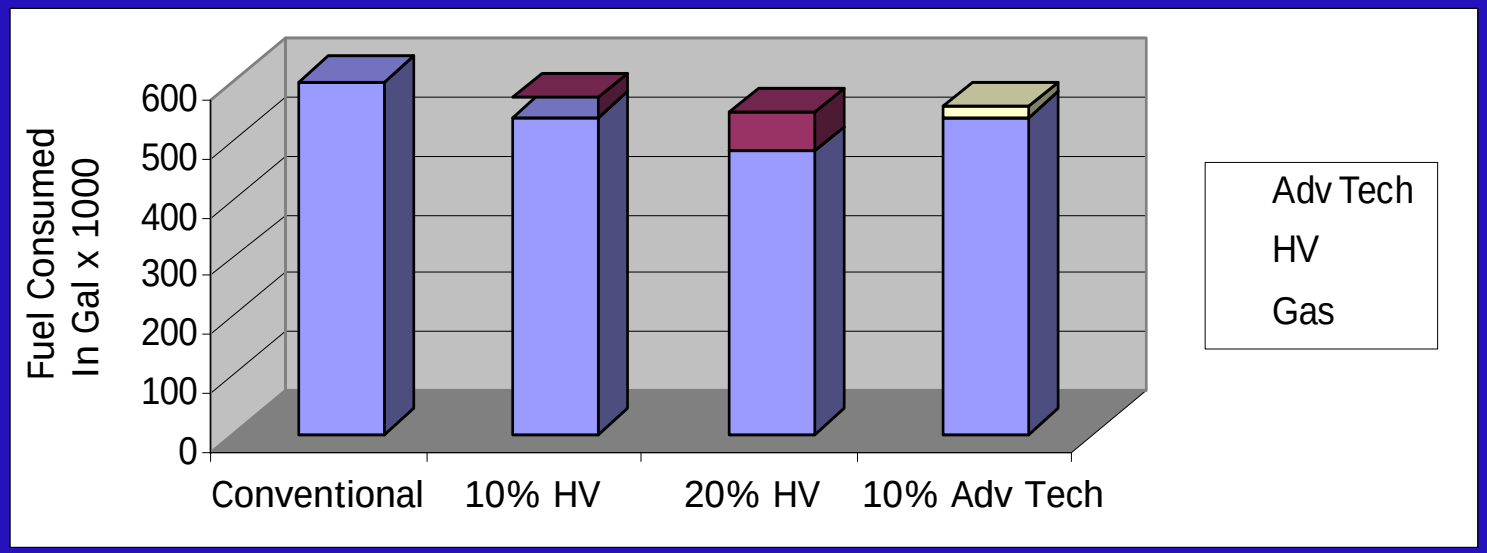
The Benefit of High Volume Sales

		Vehicle Number			
		Baseline	10% HV	20% HV	10% Adv Tech
Conventional gas	(25 mpg)	1000	900	800	900
HV	(45 mpg)		100	200	
Adv Tech	(90 mpg)				100
Gallons Saved		N/A	26,667	53,333	43,333



Assumes all vehicles travel 15,000 mi/yr

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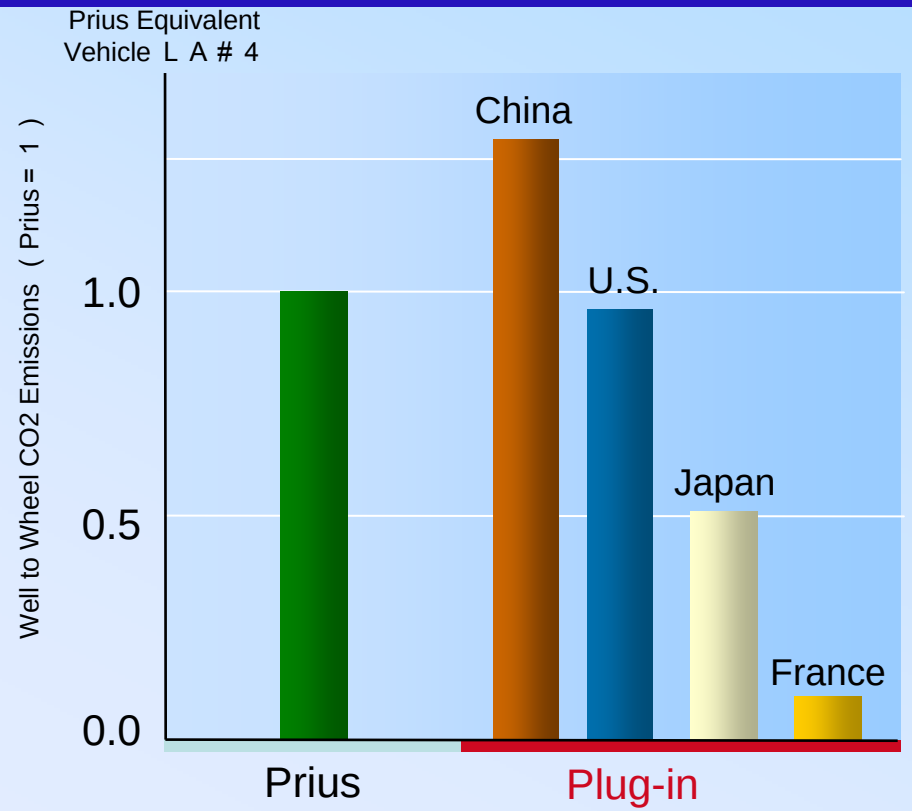
Clean Power is Essential



The advantage is big in France where nuclear power generation is common. There is no advantage in China, which mainly uses coal-fired power plants.

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Toyota's Current Fuel Cell Prototype

VEHICLE BENEFITS	PROTOTYPE OBJECTIVES	CHALLENGES
• Zero tailpipe emissions	• Public education on hydrogen	• Fuel cell system cost
• Potential non-petroleum, diversified fuel sources	• Demonstrate technology	• Fuel cell stack life
• Low / zero carbon fuel	• Identify infrastructure issues	• Lack of infrastructure

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Key System Components

Power control unit (PCU)
Controls precisely the distribution of electric power of the fuel cell and secondary battery.

Secondary battery
Stores the regenerative electric power and assists output of the fuel cell at acceleration.

Toyota FC Stack
Unit (fuel cell) that generates electric power from the hydrogen and oxygen in the air.

High-pressure hydrogen tank
Stores the hydrogen supplied to the Toyota FC Stack.

Motor
Generates the driving force of the vehicle.

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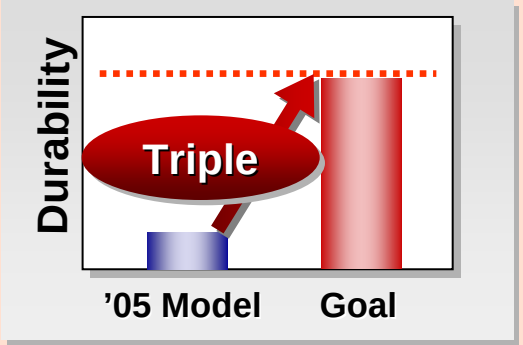
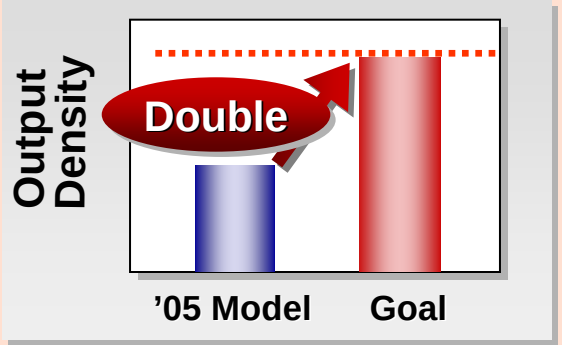
Challenges Remain

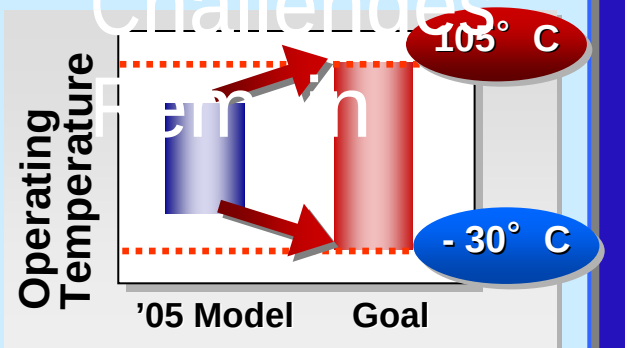
Stack Durability



Compactness / High Power Density



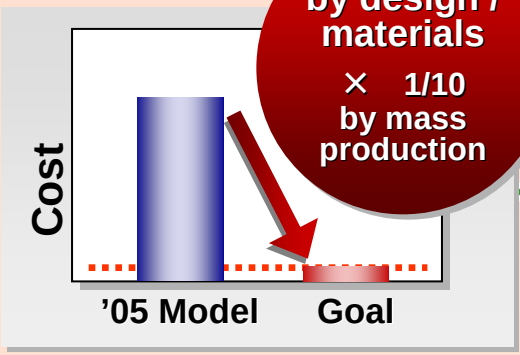
High & Low Temperature



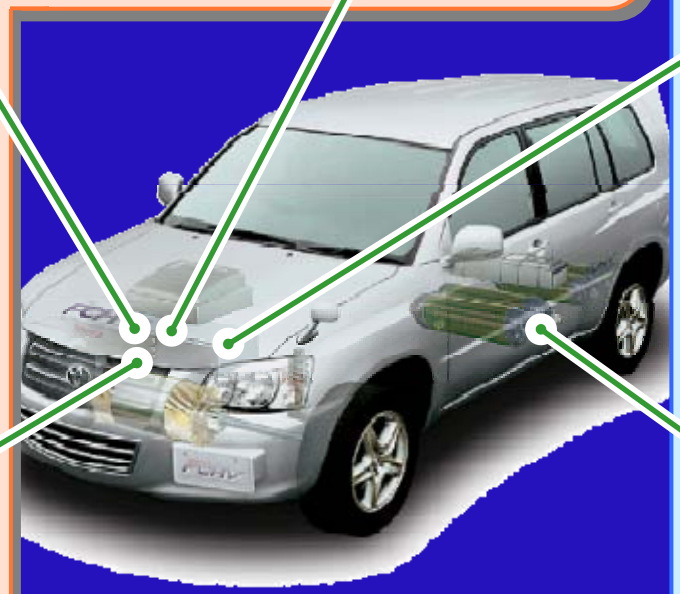
Next targets

Significant Progress

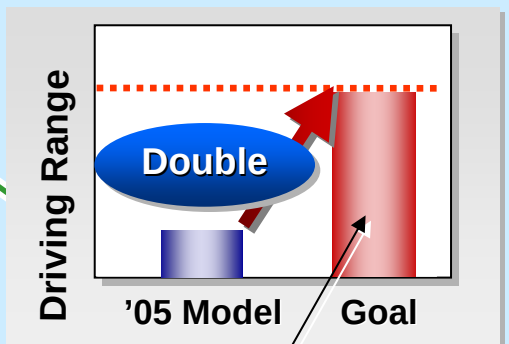
Cost



1/10 by design / materials × 1/10 by mass production



Driving Range



Over 500 miles demonstrated

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Conclusions

- Toyota recognizes we must adapt to multiple energy and environmental issues and regulations
- Deploying technology takes time
- Hybrid is the foundation for future vehicle technologies at Toyota – PHEVs & FCs are evolutions
- PHEVs & FCs show environmental & energy security promise, but only if produced in large volumes
- Durability, cost and infrastructure challenges remain for PHEVs and FCs
- Without “green” fuels, the environmental benefit (GHG reduction) of these technologies will be modest at best

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Thank You!

Questions?

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Corporate Average Fuel Economy (CAFE)

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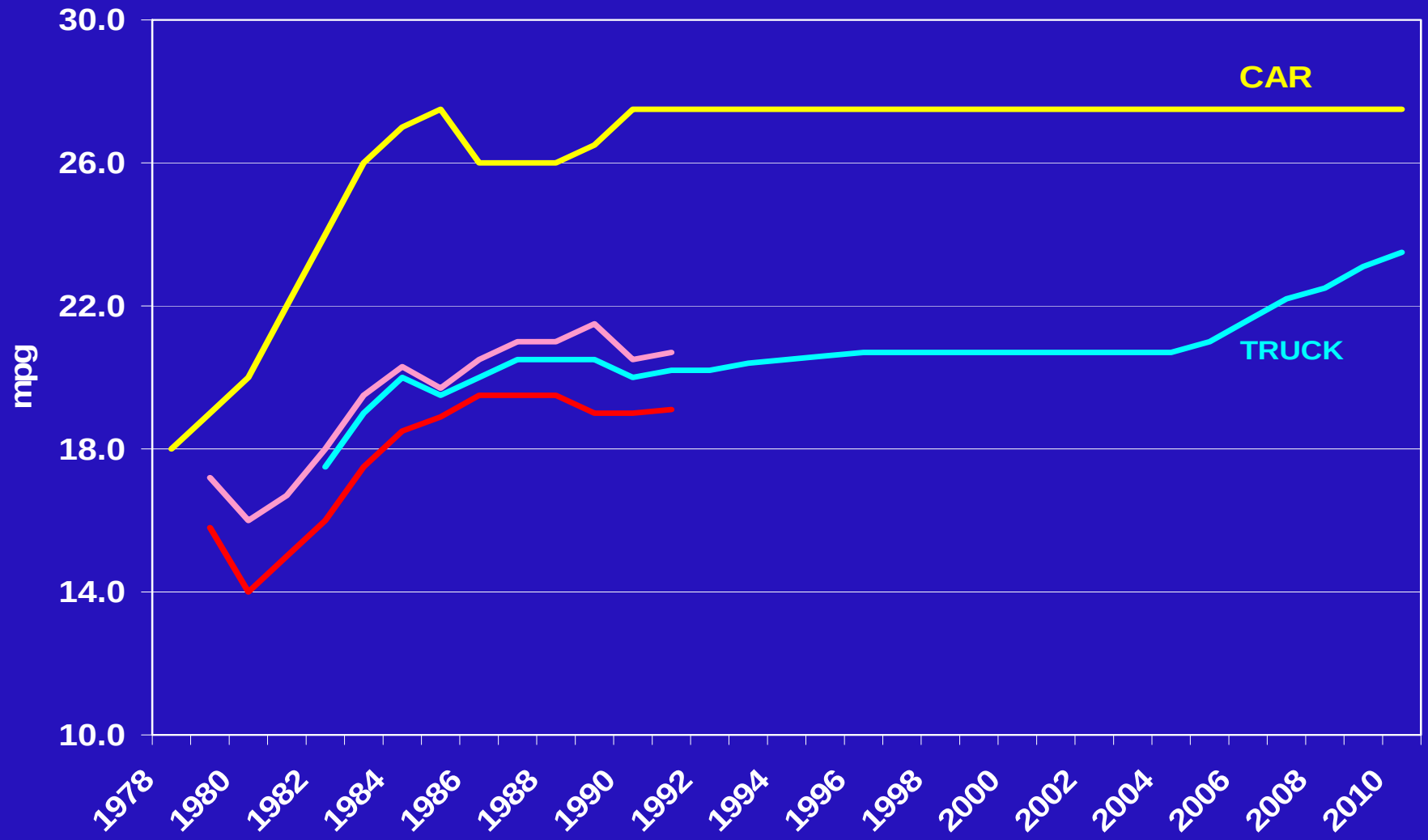
Historical CAFE Standards



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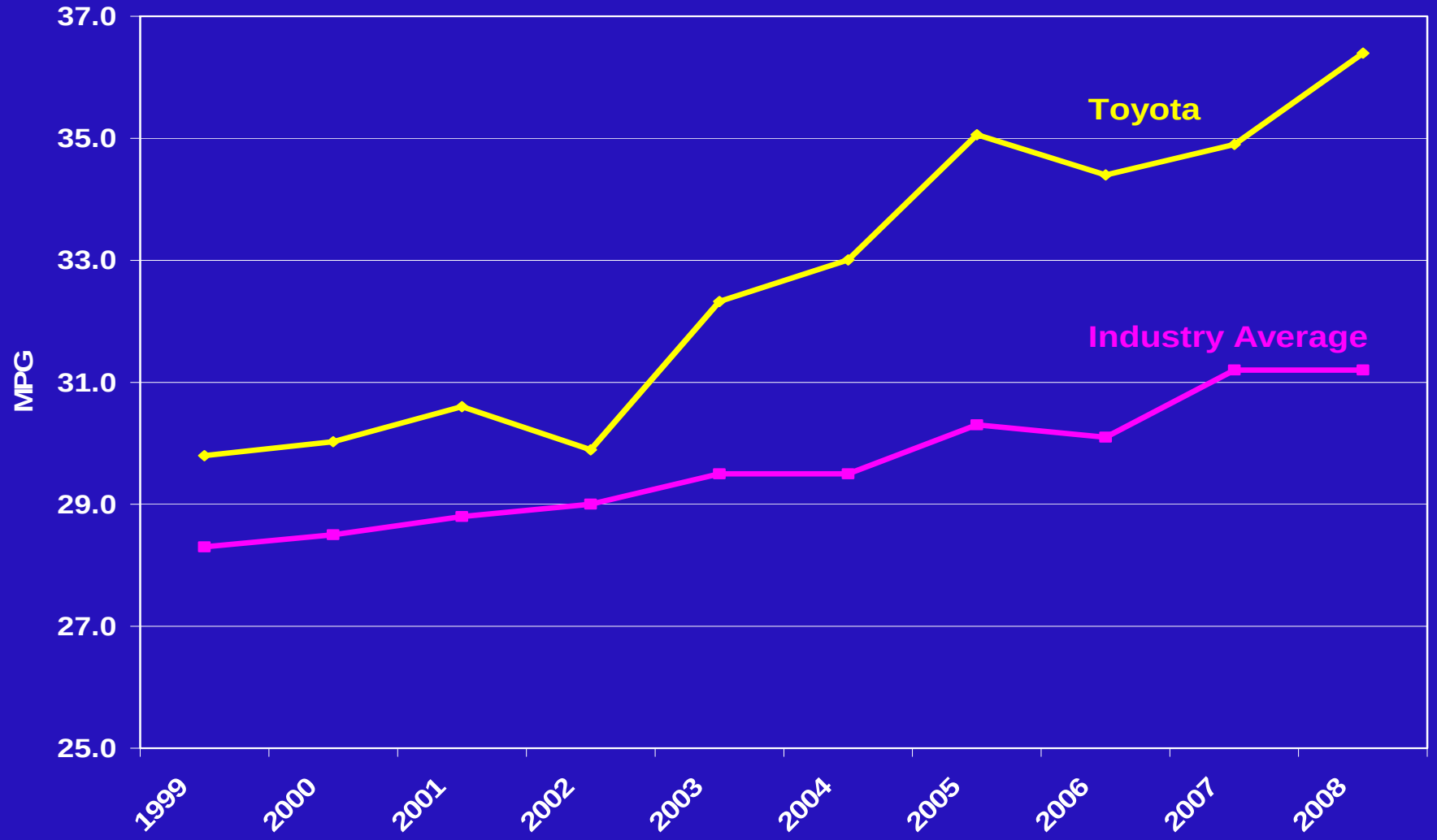
Car CAFE Performance



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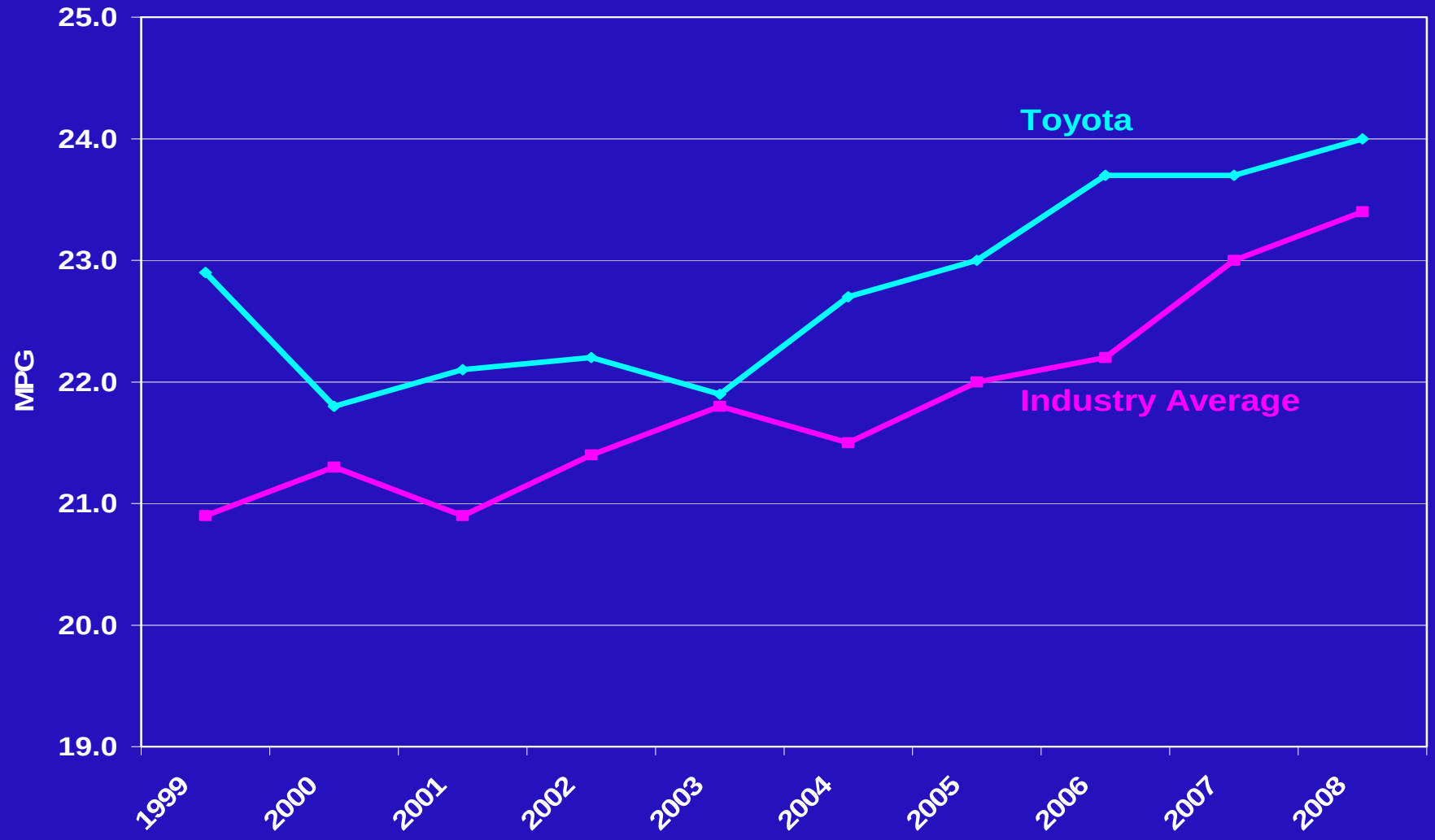
Truck CAFE Performance



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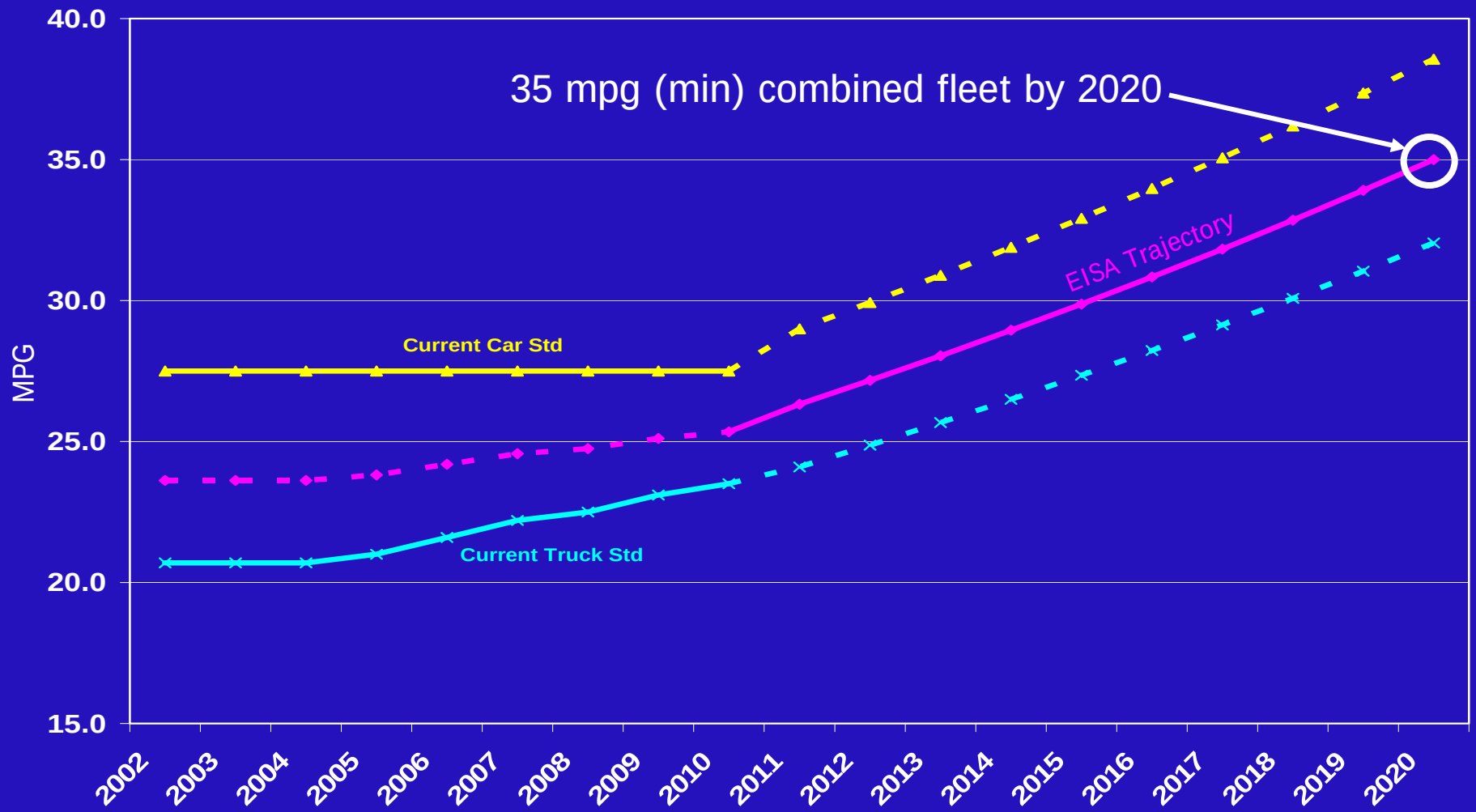
Energy Bill (EISA) Requirement



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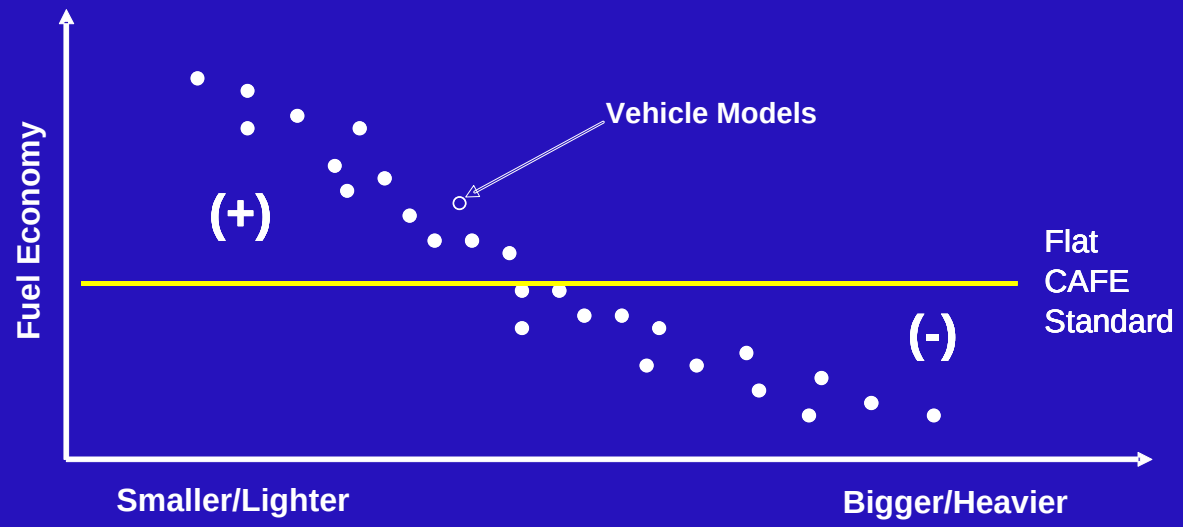
Old CAFE System



<u>Old CAFE System</u>

-Smaller vehicles provided a benefit
-Concern about small vehicle safety
-Concern about manufacturers with greater number of larger vehicles

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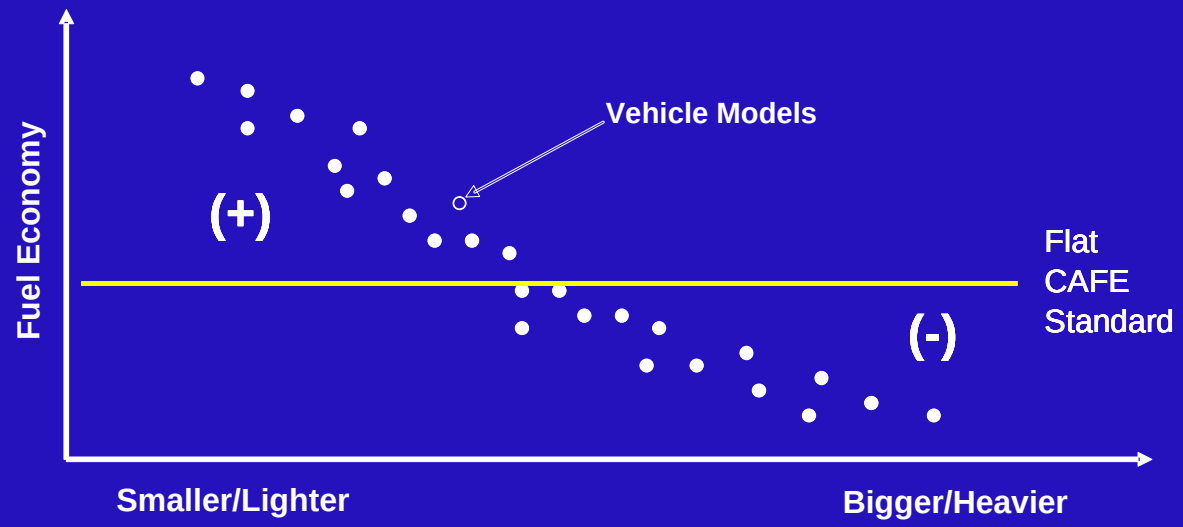
Old CAFE System



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New CAFE System

- Target based on size of vehicle
- Head-to-head fuel economy within each class is more important
- Particular challenge for light trucks
- Technology needed on all size classes

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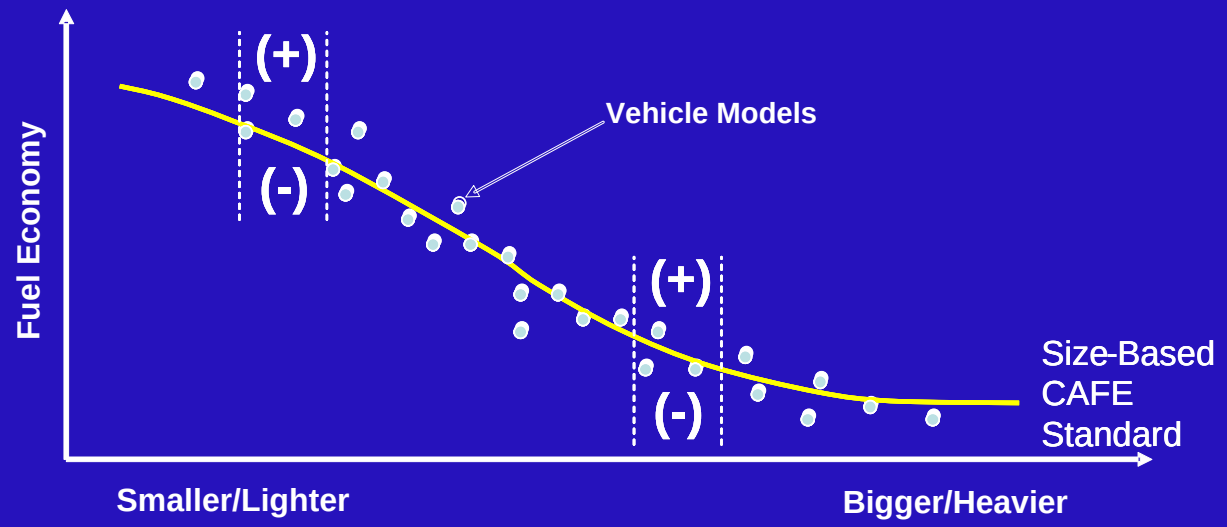
New CAFE System (2011 model year)



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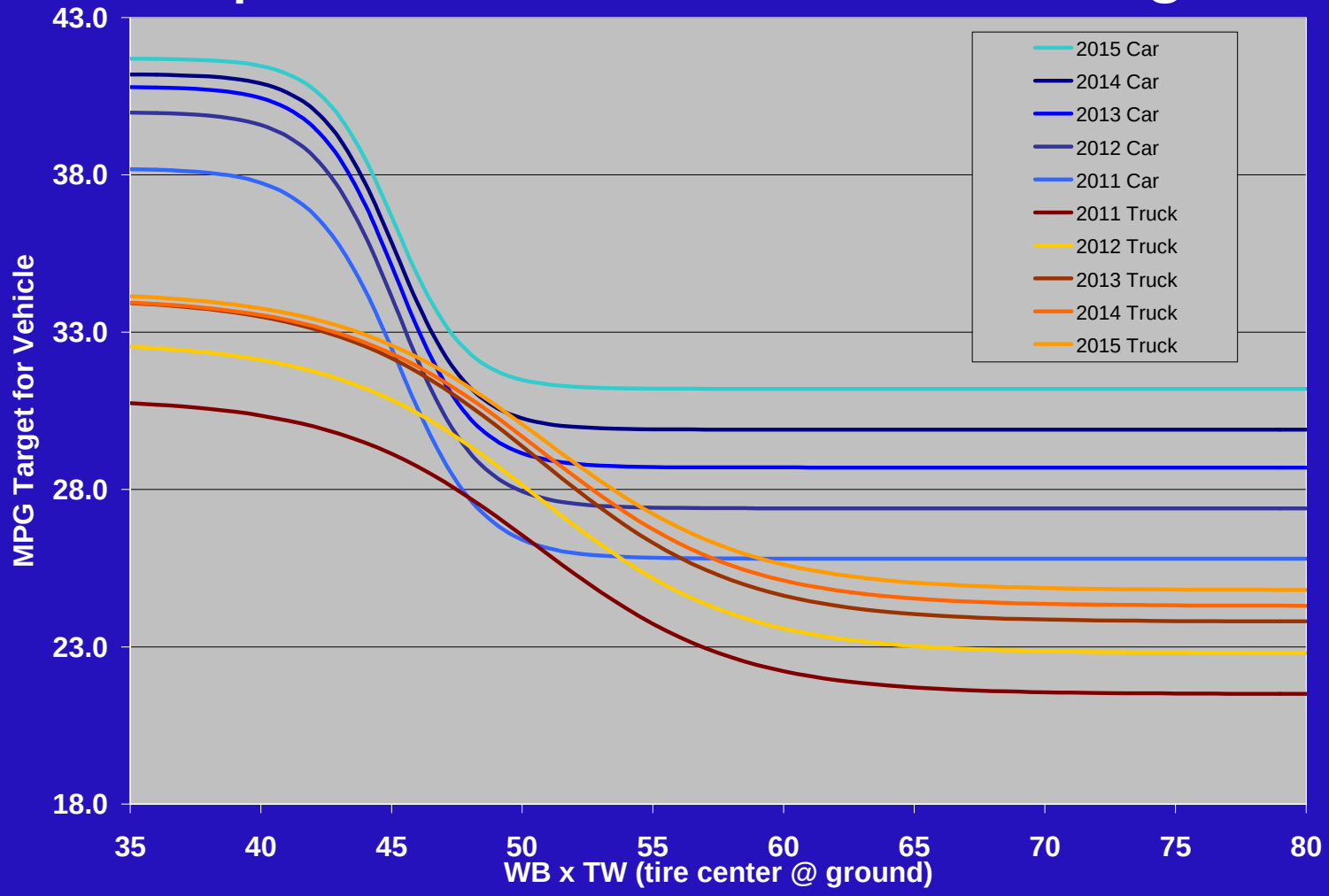
Proposed Size-Based CAFE Targets



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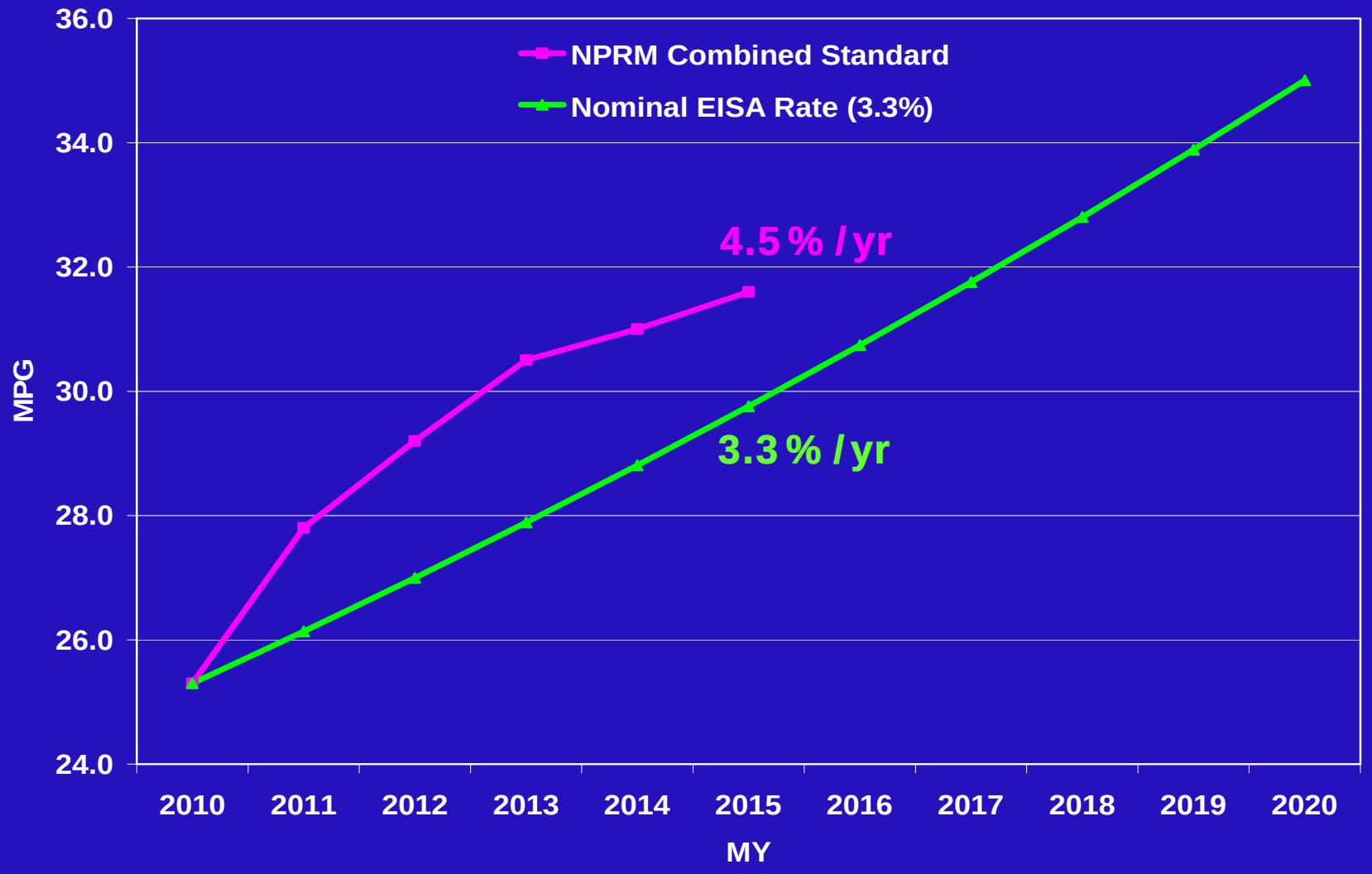
Energy Bill (EISA) and NHTSA Proposal



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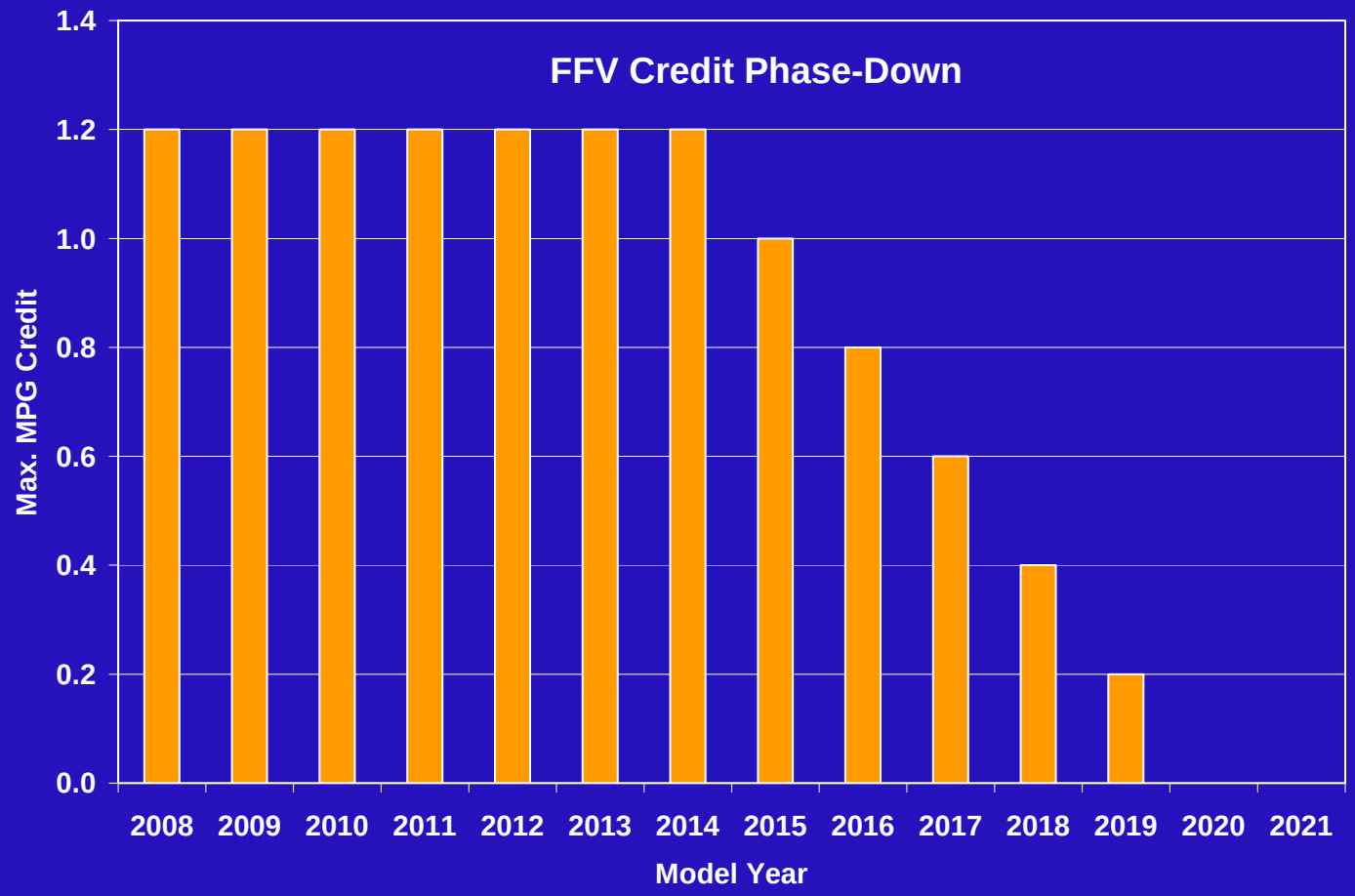
Flex Fuel Vehicle Credit