An Auto Manufacturer's Perspective on Alternative Fuels

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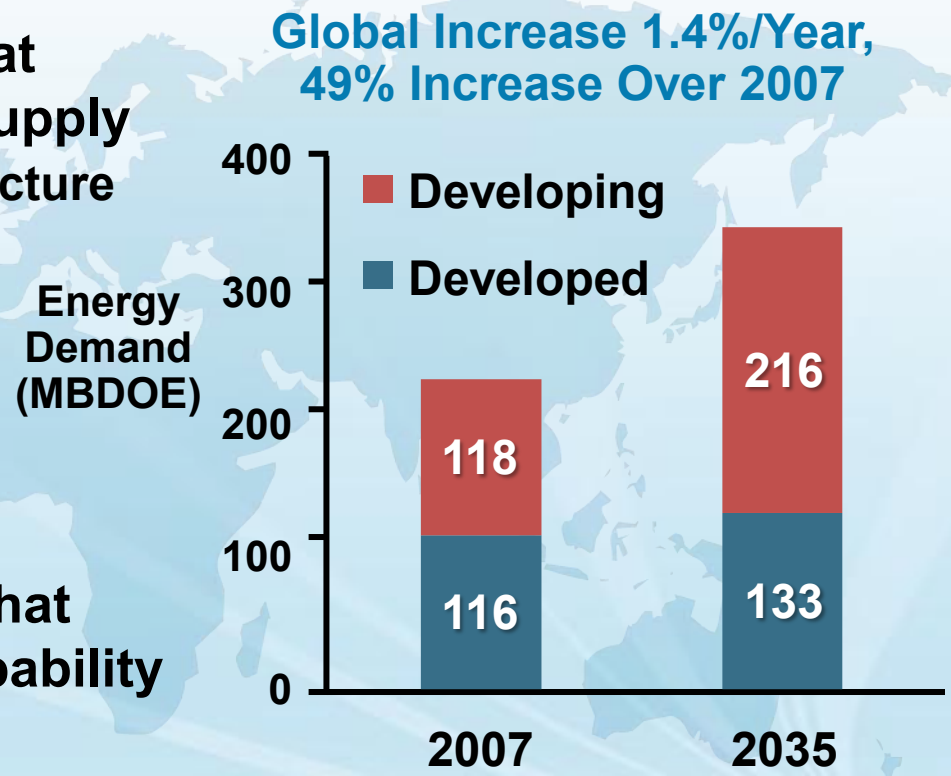
The Challenge

- Global energy demand exceeds our current glide path for supply
- There are several risks that can disrupt the existing supply
  - Above ground infrastructure
  - Natural disasters
  - Wars
  - Hostile regimes
- Growing concern about global climate due to CO_2
- Potential for regulations that exceed both technical capability and business feasibility



MBDOE: Millions of barrels per day oil equivalent

Source: DOE Energy Information Agency

Alternative Fuel Options

Diversify conventional engine fuel sources away from petroleum

Liquid

- Ethanol, Methanol, Bio-Diesel, “Drop-ins”

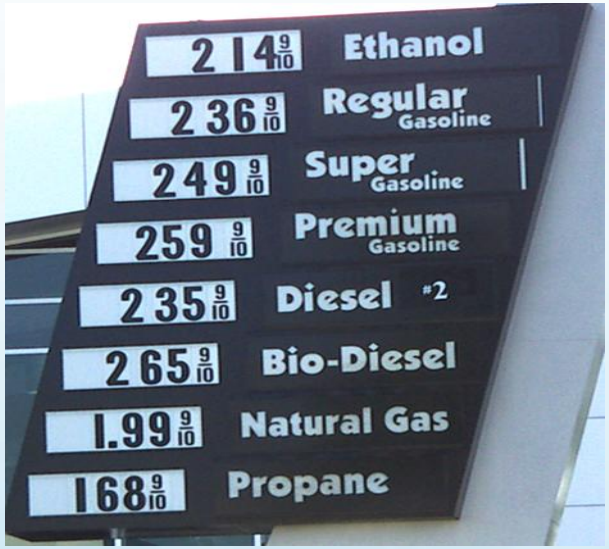
Gaseous

- Compressed Natural Gas (CNG – methane) and Liquefied Petroleum Gas (LPG – propane / butane)

Considerations

- Ethanol, biodiesel, CNG & LPG are domestically produced vehicle fuel alternatives to gasoline and diesel fuels in many markets
- Re-engineered vehicles and retail facilities are required
- Vehicle and retail changes are easiest for ethanol and biodiesel
- Gaseous fuels have the highest vehicle material costs and infrastructure challenges

California (2004)



France

Thailand

Sweden

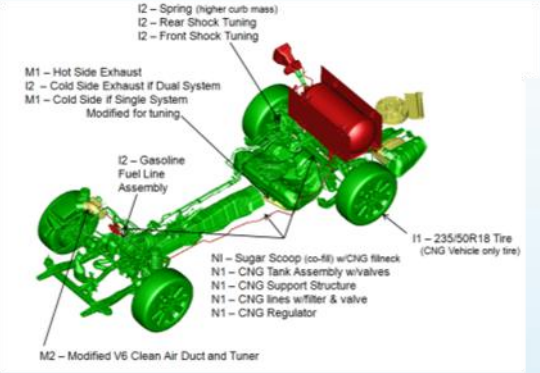
Missouri

Gaseous Alternative Fuels

Attractive U.S. natural gas supply and price, but with high vehicle material cost and infrastructure challenges

Compressed Natural Gas (CNG)

- **U.S. is currently the world's largest natural gas producer (but not the largest source of "proven" natural gas resources)**
  - **64 bcf/day (billion cubic feet / day) (IEA)**
  - **A fleet of 10 million CNG cars and trucks would consume only ~3% of current U.S. natural gas production**
- **CNG can be used in re-engineered conventional vehicles**
- **Vehicles can be built as dedicated gaseous fuel or bi-fuel (two complete fuel storage and fuel injection systems) to enable transition**



Bi-Fuel CNG Sedan

CNG Fuel Fill

Gasoline Fuel Fill

CNG Fuel Injectors

Gasoline Fuel Injectors

Bi-Fuel CNG Opel Zafira

Liquid Alternative Fuels

Biodiesel

- Limited feedstock potential
- GM U.S. Diesel currently B20 (20% Bio, 80% Petroleum) capable, European B7 capable

"Drop-in" Bio-hydrocarbons (Gasoline, Diesel)

- Currently at research or limited pilot phase
- Planned to be indistinguishable from petroleum
- Intended for blended use with petroleum
- Variety of biochemical and thermochemical pathways are competing for viability

Methanol

- Behind in technical development, domestic production, customer awareness, education and infrastructure
- 80% of U.S. methanol is imported and derived from natural gas via conversion to Syngas (mixture of CO and H_2) and subsequent catalysis
- No vehicle manufacturer has approved use in the U.S. today, limited use in China
- Toxicity and storage concerns

Liquid Alternative Fuels (Continued)

Ethanol is the highest short term lever to reduce dependency on foreign oil

- **Currently displaces more petroleum in the U.S. than all other options**
- **Today it displaces over 9% of U.S. gasoline consumption by volume and is mandated to replace 25% of U.S. gasoline by volume by 2022**
- **GM is industry leader of Ethanol (E85) FlexFuel capable vehicles, followed by Ford, Chrysler and Nissan (GM > 5.5M U.S. and Canada Fleet)**
- **GM is producing FlexFuel vehicles at over 40% of U.S. production**
  MY 2011
- **The additional piece cost of a FlexFuel Vehicle ranges from $50-$100 (Federal Emissions Pre-MY2014)**
- **Cost increases as emission standards tighten disproportionally for alcohol blend fuels**

Five Important FACTS About Gasoline Ethanol Blend Fuels for the Automobile

- Biofuels are in competition with other energy alternatives
- Fuel economy follows fuel energy density
- Today's E85 FFVs are energy efficient
- The biofuel industry needs a 2nd generation success story
- FFVs must not be taken for granted

Biofuels are in Competition with Other Energy Alternatives

Renewable Electricity

Electricity from Coal

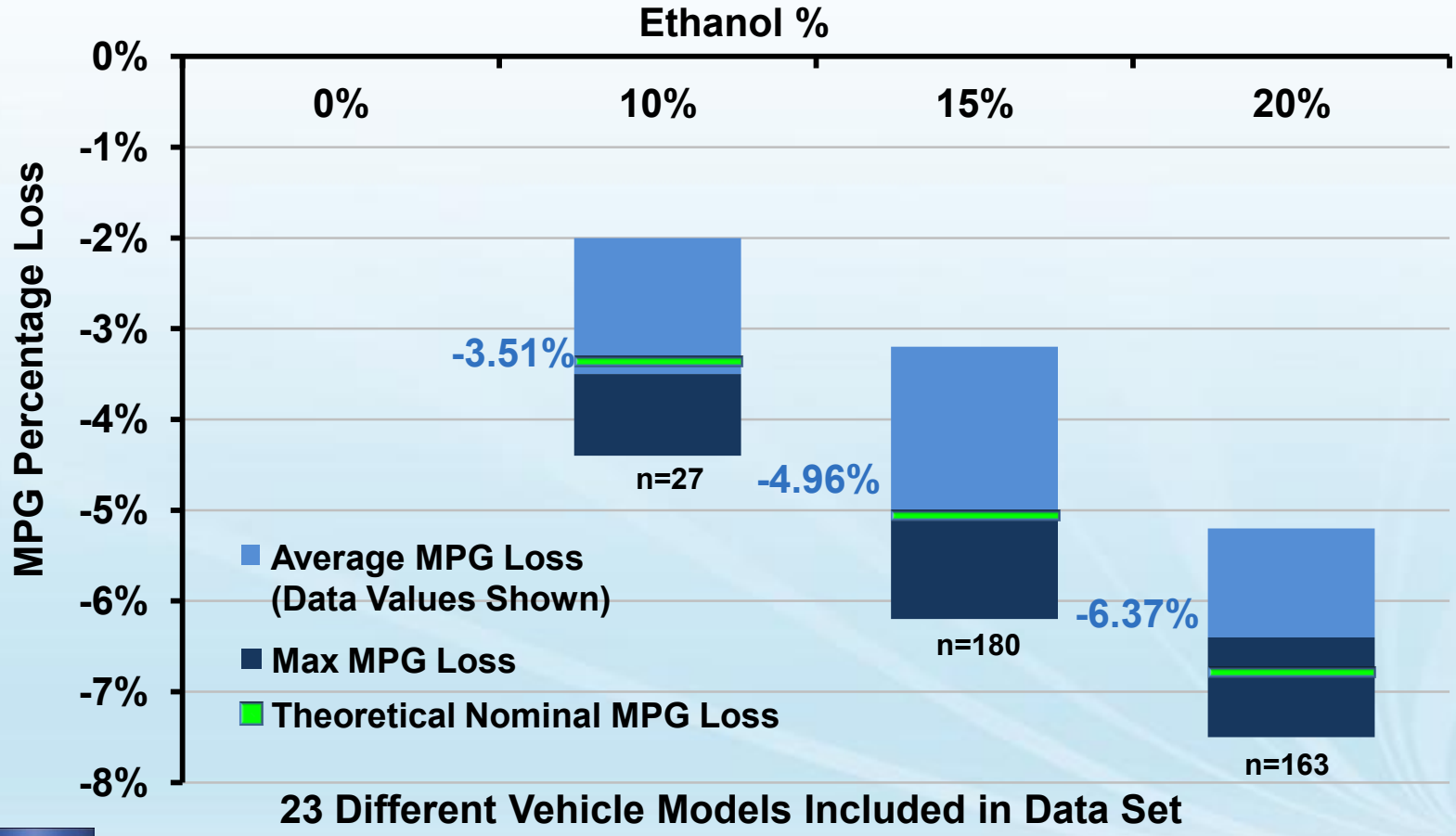
Compressed Natural Gas

Propane

Hydrogen

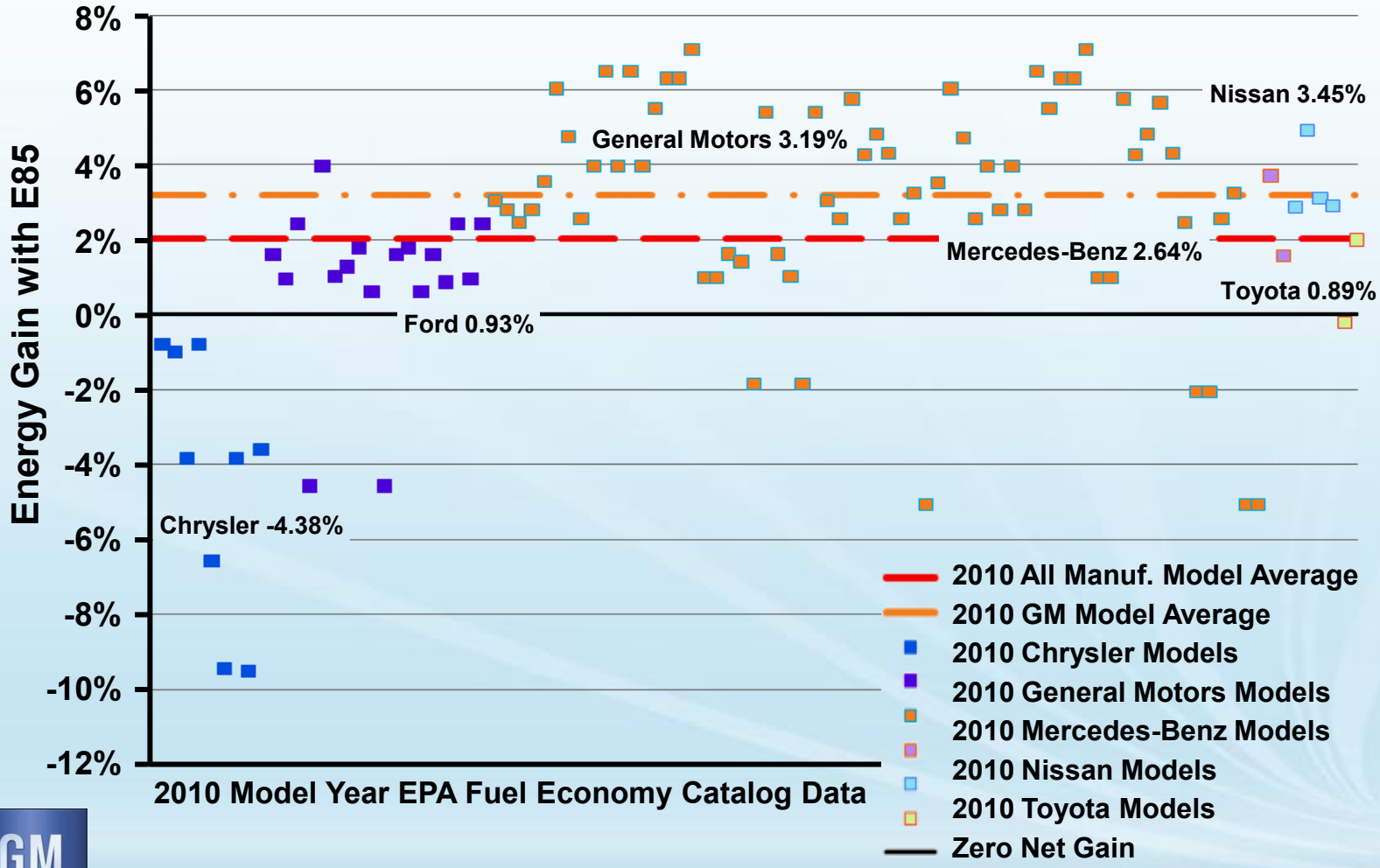
Fuel Economy Follows Fuel Energy Density

Fuel Economy Percent Loss vs. Ethanol Content (DOE Midlevel Blend Test Data)



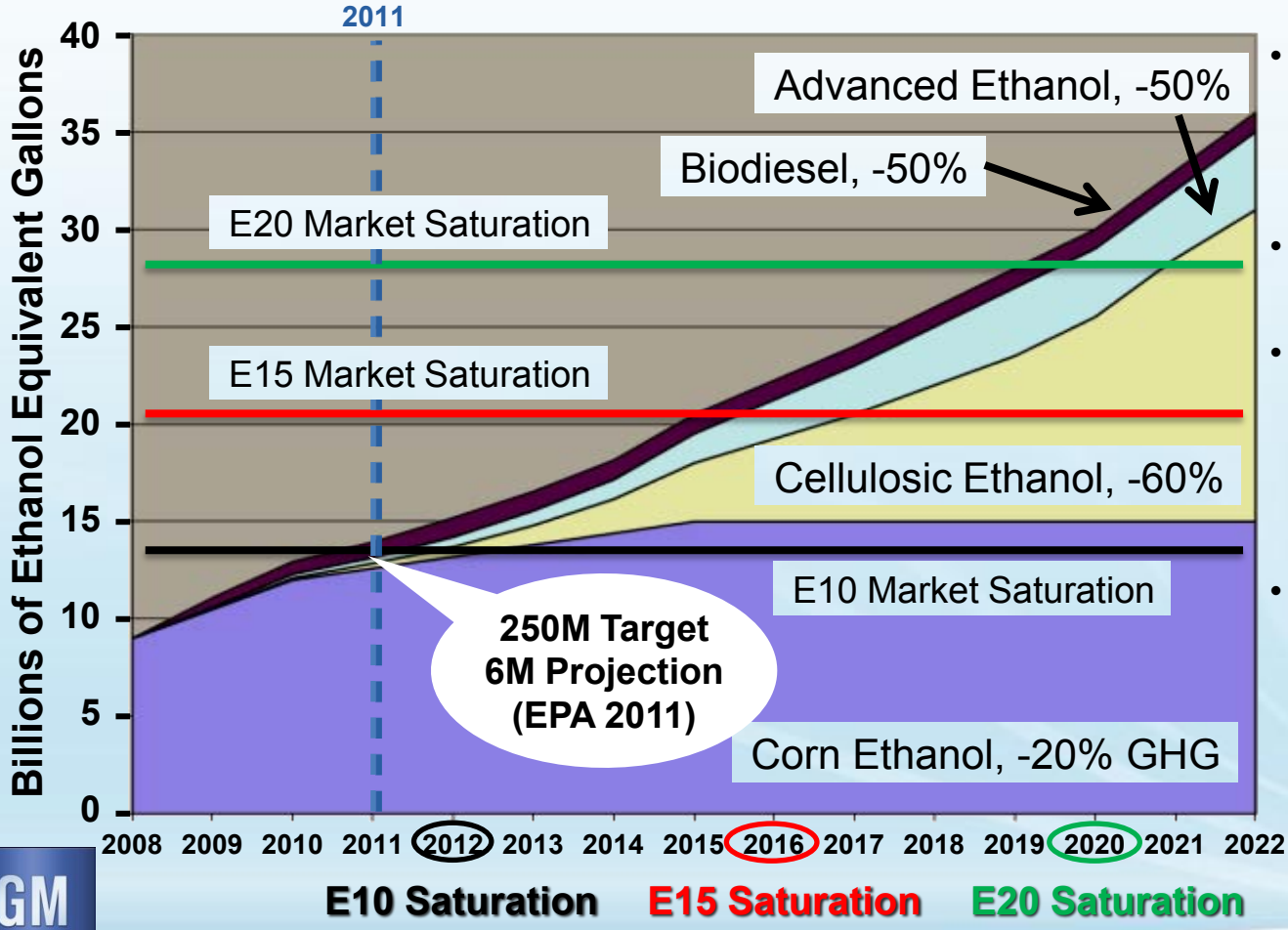
Today's E85 FFVs are Energy Efficient

Energy Efficiency of FFVs Running on E85 vs. Gasoline



The Biofuel Industry Needs a 2nd Generation Success Story

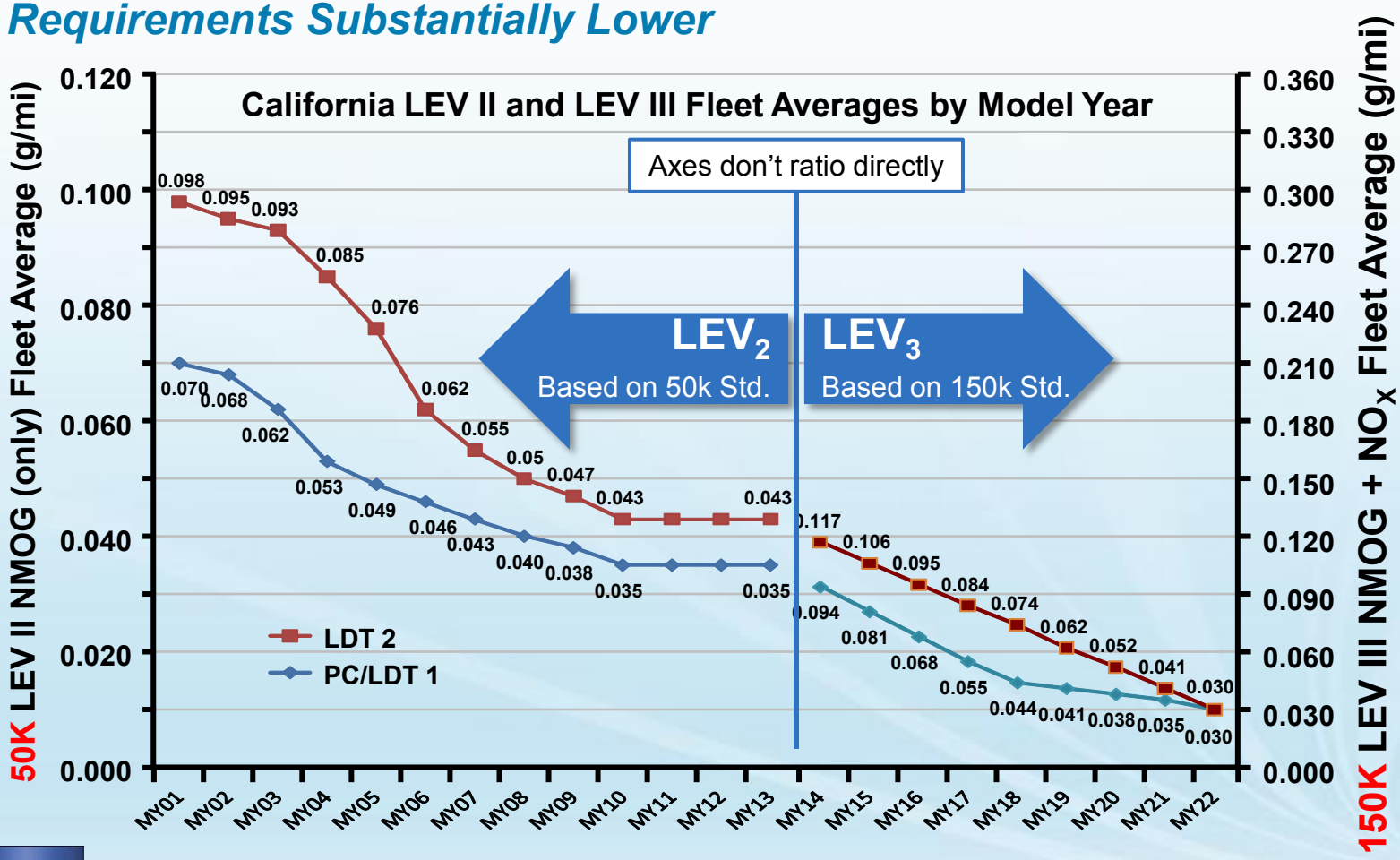
RFS Advanced Biofuel Growth Assumptions



- Assumes constant gasoline market
- 140 billion G
- Falling sales will bring saturation forward
- E85 usage will push saturation back

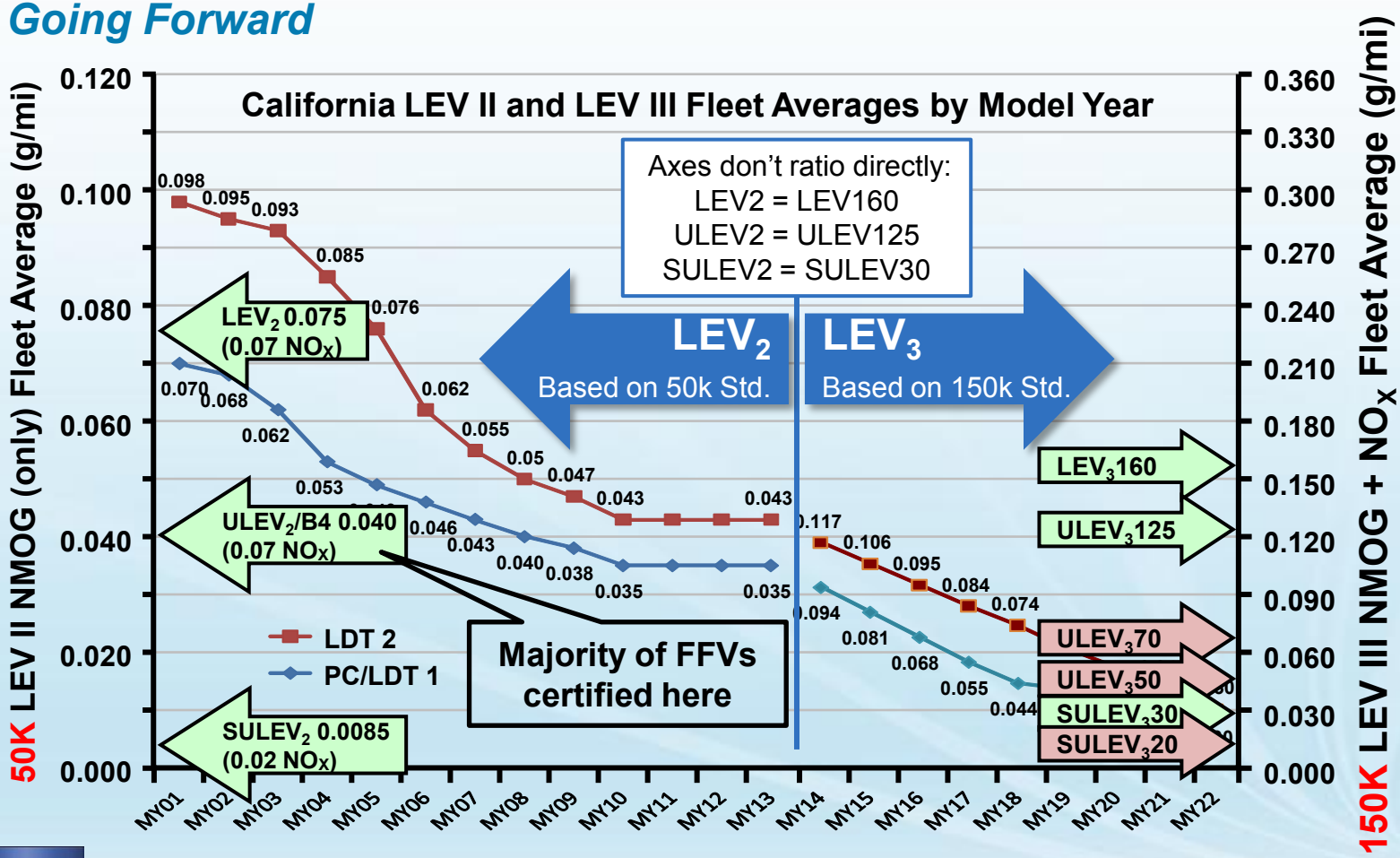
FFVs Must Not be Taken for Granted

Pending LEV 3 Rules Will Drive Manufacturer Fleet NMOG Requirements Substantially Lower



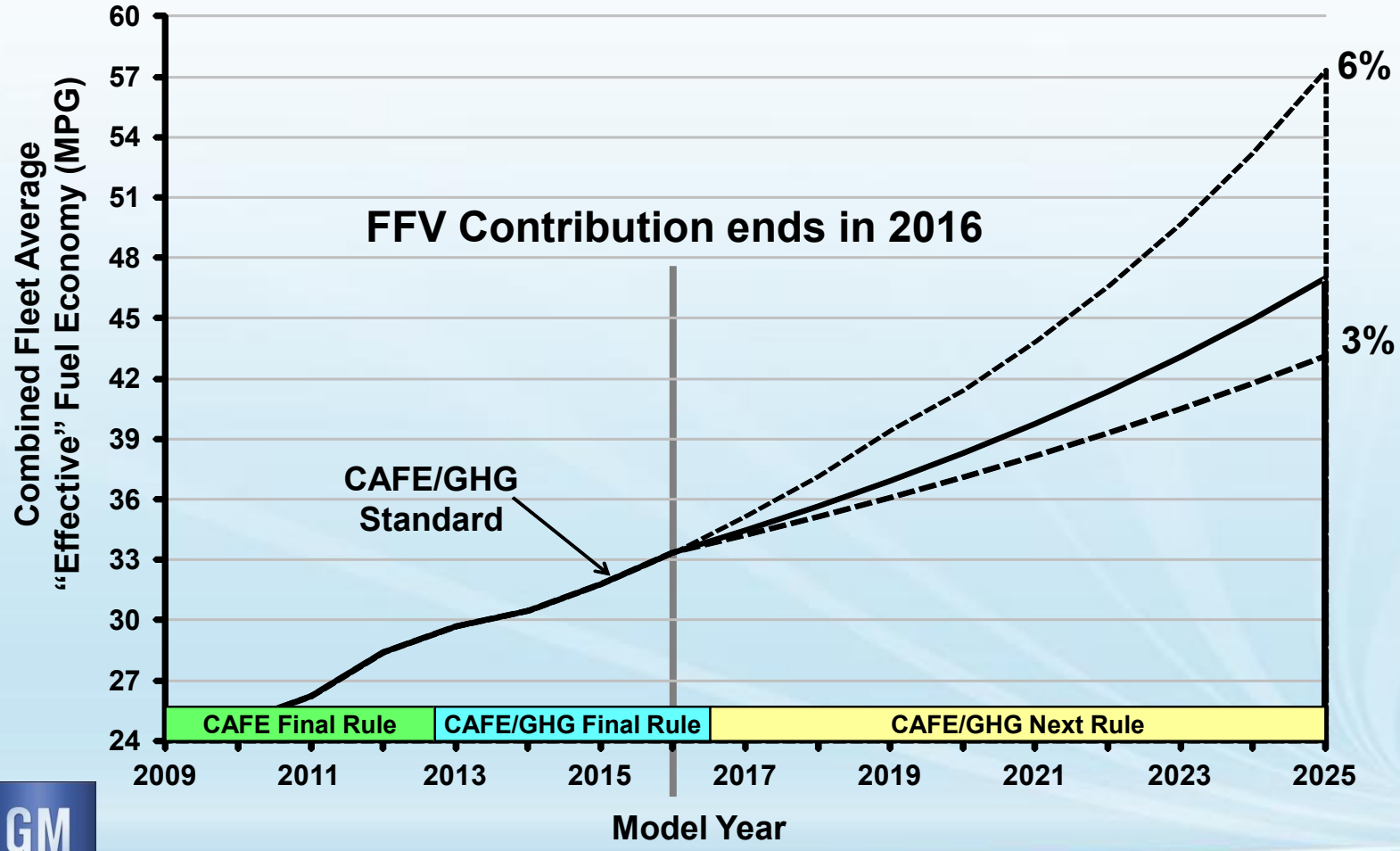
FFVs Must Not be Taken for Granted

LEV 3 Fuel Requirements Challenge the Viability of FFVs Going Forward



FFVs Must Not be Taken for Granted

Future CO_2 Requirements do not Comprehend the Value of E85 FFVs or Other Alternative Fuels with CO_2 Reduction Potential



Comparison of Alternatives

	Gasoline Approx. ~ C_7H_{13}	Ethanol C_2H_5OH	Methanol CH_3OH	CNG (1) CH_4
Octane (R+ M)/2	87	99	99	120
BTU/Gallon	115,000	76,000	56,800	115,000
Price/Volume Gallon (April 2011)	$3.30	$2.63	$1.20	$1.00-$2.50
Price/Gasoline Equivalent	$3.30	$3.97	$2.43	$1.00-$2.50
Vehicle Cost (Federal Emissions Pre-MY2014)	$0	$50-$100	~$350 (4)	$3000-$3500(5)
U.S. Refueling Stations	160,000	2400	0	900
CO_2 Reduction (TTW)	0	5-7% (2)	8-10% (3)	15%
Corrosion	0	+	++	0
Toxicity	+	0	+	0
Water Soluble	-	+	+	-

(1) One Gallon Gasoline equivalent stored at 3600 PSI is ~ 3 Gallon of Volume
(2) Carbon energy density basis only
(3) MIT Estimate
(4) Assumes same thermal efficiency improvement as ethanol, better hydrogen to carbon ratio (4:1 vs. 3:1)
(5) Cost Estimate for mature, fully manufacturing and design integrated mid-size sedan.

GM

Auto Perspective Summary

- We will be consumer driven.
- We are in a very highly and increasingly constrained technology-forcing regulatory environment.
- We need to reduce dependency on imported petroleum.
- Alternative fuels can offer customer value, compliance leverage and energy diversification if included in the policy framework.
- Biofuels are at risk if they are not contained in that policy framework.

We should all be concerned about the future because we will spend the rest of our lives there.

– Charles Kettering