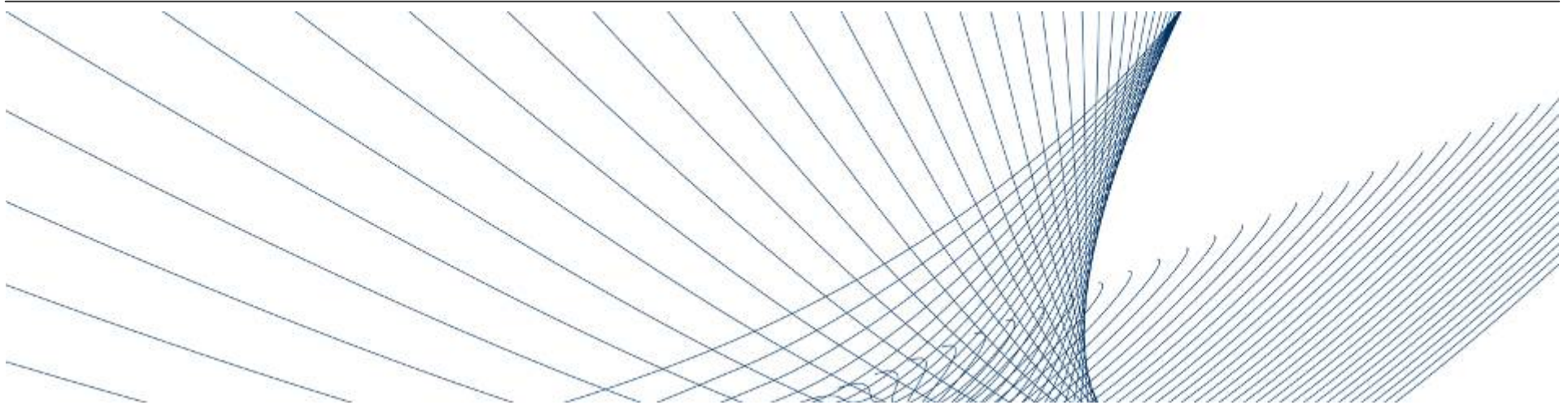


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Volkswagen Group of America

Virginia Energy Conference

Session 30: Fossil Fuels – Diesel Developments

Presented by Stuart Johnson, Engineering and Environmental Office

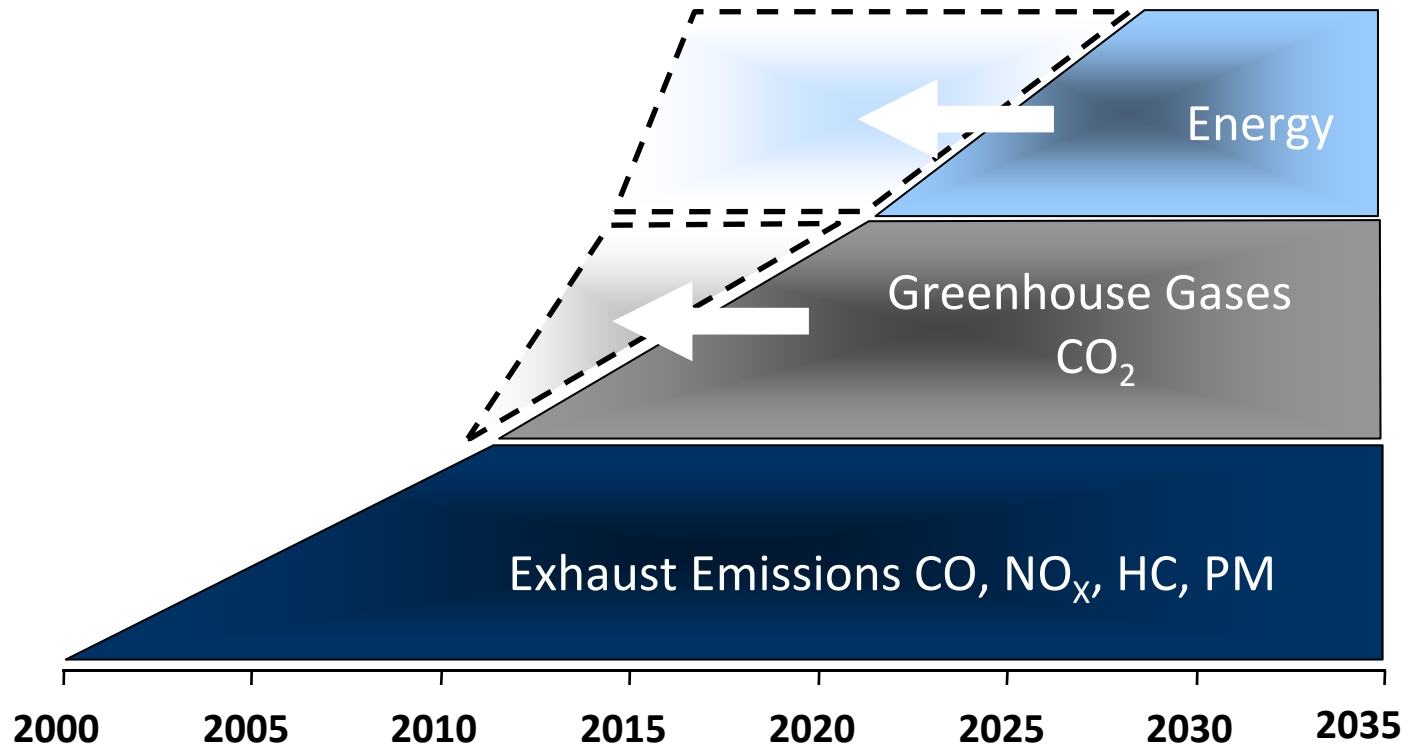
October 14, 2010

Future Developments in Engines and Fuels Agenda

- **Introduction**
- **Industry Challenges**
- **Engine Technologies**
 - **Gasoline/Diesel**
- **Diesel Developments in Detail**
- **Conclusions**

Future Developments in Engines and Fuels

Introductory Slide



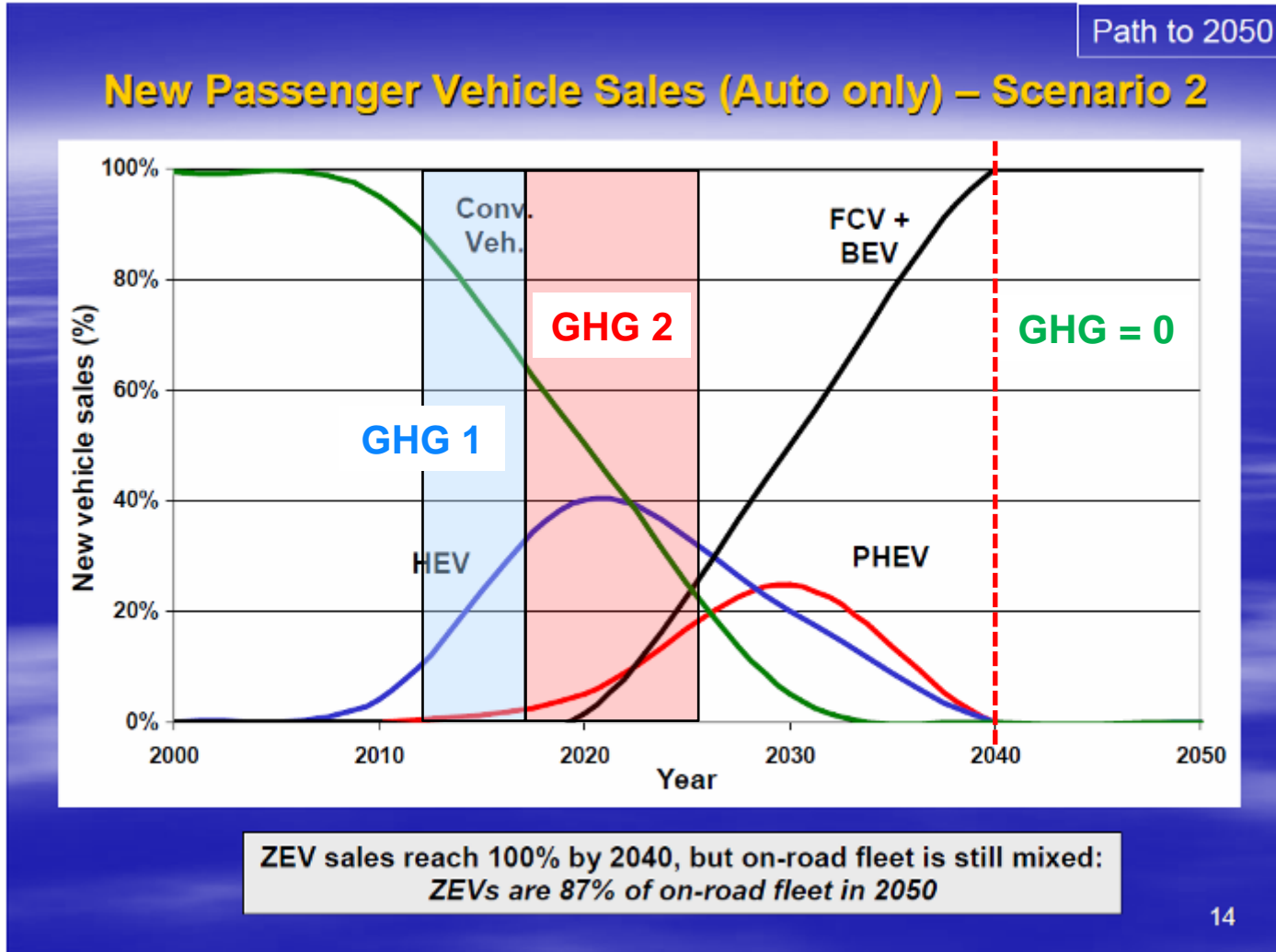
Future Developments in Engines and Fuels Mobility Industry Challenges – Criteria Emissions

- **Agencies (EPA, CARB) expected to significantly lower emission standards**
 - **California: LEV III**
 - **SULEV (Tier 2, Bin 2) fleet average**
 - **Reduces HC, CO NOx, PM levels**
 - **Zero evaporative emissions**
 - **Lower full useful life off-cycle standards (SFTP)**
 - **EPA expected to set a similar regulation**
 - **Tier 3**
 - **Future advanced combustion engines expect to comply**
 - **Both diesel and gasoline concepts**
 - **LEV III, Tier 3 could be the last set of traditional emission standards**

- **Future regulatory focus has shifted away from criteria pollutants towards energy issues (policy, security, climate change)**

Future Developments in Engines and Fuels

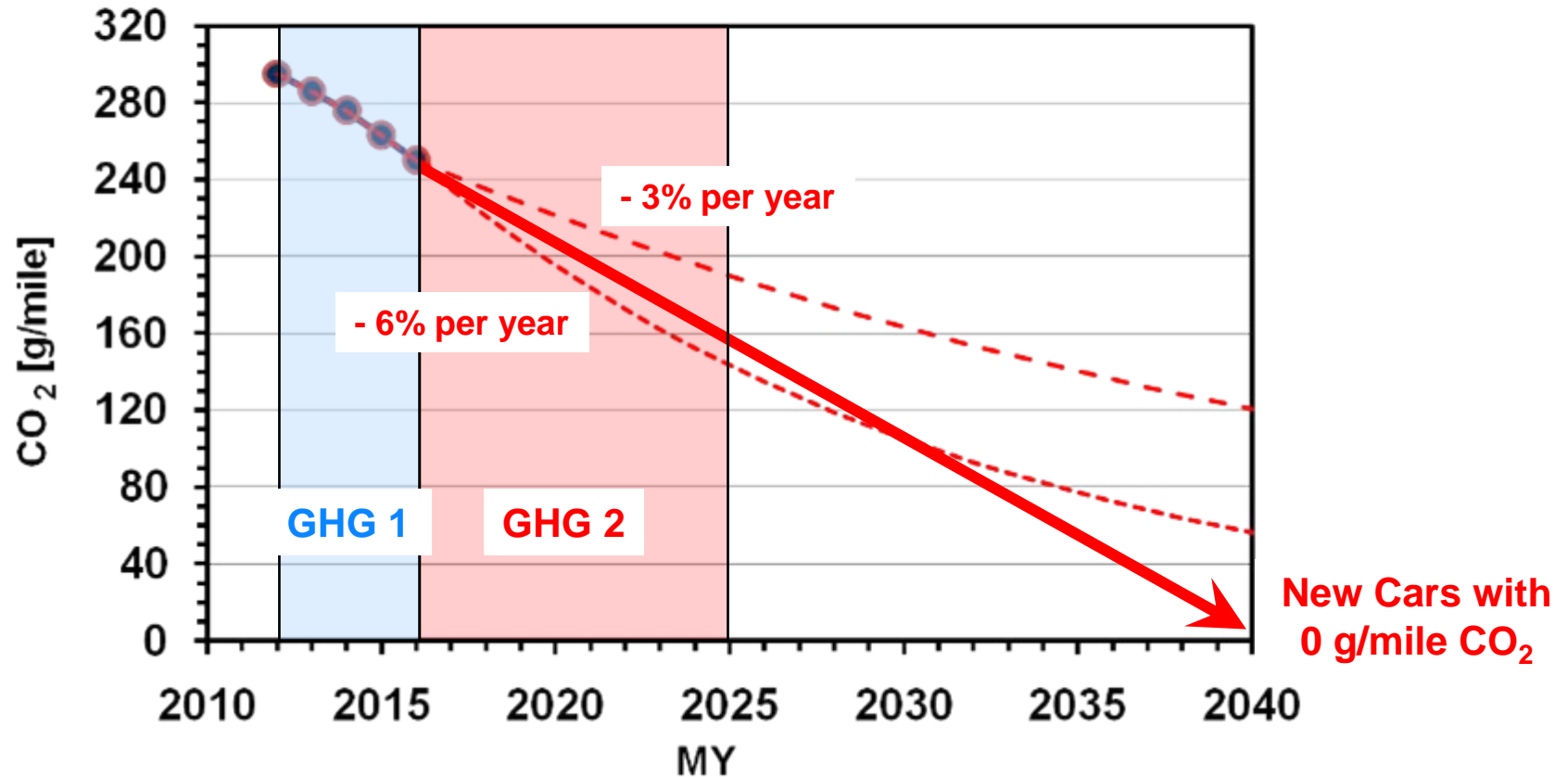
Mobility industry Challenges – CARB GHG Scenario



CARB Board hearing
Dec. 2009

Future Developments in Engines and Fuels

Mobility Industry Challenges – Potential California GHG CO₂ Targets



Future Developments in Engines and Fuels Industry Mobility Challenges – NGO Press Campaign NRDC Supports 60 mpg Fuel Efficiency Standard by 2025

WASHINGTON (September 2, 2010) -- The Consumer Federation of America released a report today recommending the Obama administration establish a 60 miles-per-gallon fuel efficiency standard for cars by 2025. (...)

The following is a statement from NRDC's Transportation Director Roland Hwang:

“CFA’s analysis clearly shows that raising fuel efficiency standards to 60 miles per gallon is good for consumers’ pocketbooks. Making cars and trucks go farther on a gallon is the cleanest, cheapest and fastest way to meet our energy needs and will help break the country’s addiction to oil.

Without stronger standards, American automakers could fall behind in the global race for the clean car market, putting even more manufacturing jobs at risk. Achieving 60 mpg by 2025 can be done using and improving technologies that already exist, such as hybrid electric cars and electric vehicles. We have learned from cell phones, microwaves, and computers that higher volumes can lead to dramatic improvement in innovation and driving down costs. Raising standards to 60 mpg is good for consumers, good for the environment and good for jobs.”

The Natural Resources Defense Council is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has **1.3 million members** and online activists, served from offices in New York, Washington, Chicago, Los Angeles, San Francisco and Beijing.

Future Developments in Engines and Fuels Focus on Efficiency/GHG – Engine/Fuel Technology

- **Advanced combustion concepts will focus on efficiency**
 - **Significant CO2 reductions are still possible**
 - **Diesel and GDI (Gasoline Direct Injection)**
 - **Downsized displacement**
 - **Fewer cylinders**
 - **Optimized charging**
 - **Reduced friction**
 - **Improved fuel Injection**
 - **Variable valve timing**
 - **Variable valve lift**
- **Low carbon fuels will also play an important role**
 - **Liquid fuels make the most sense for a light-duty vehicle**
 - **Energy density, range**
 - **Increased use of ethanol and biodiesel is certain**



Future Developments in Engines and Fuels

Diesel Developments in Detail

- **The diesel engine currently has**
 - **A 30% advantage in fuel economy over gasoline engines**
 - **A 20% advantage in CO2 reduction over gasoline engines**
 - **From the VW perspective this advantage will continue**
- **From the emissions standpoint diesel aftertreatment continue to develop**
 - **Improved conversion efficiency**
 - **Improved durability**
 - **Lower cost**
 - **Reduced CO2 penalty**
- **From an efficiency standpoint the diesel is also improving**
 - **2200 bar (33,000 psi), multi-hole injectors**
 - **Up to 7 discrete injection events per combustion cycle (rate shaping)**
 - **Sophisticated high and low pressure EGR systems**
 - **In cylinder pressure sensors (reduced cylinder to cylinder variations)**
 - **VVT and VVL added to diesels**

Future Developments in Engines and Fuels

First 25 Years of Diesel Development at the Volkswagen Group

First Diesel Golf I 1976



| | |
|-------------------------|--------------------|
| Cylinder number | 4 |
| Displacement | 1.5L |
| Power | 50 HP |
| Rotational speed | 5000 rpm |
| Maximum torque | 84 Nm |
| Maximum speed | 140 km/h |
| 0-100 km/h | 18 sec |
| Consumption | 6.5 l/100km |
| Curb weight | 780 kg |

Diesel Golf V 2003



| | |
|-------------------------|--------------------|
| Cylinder number | 4 |
| Displacement | 2.0L |
| Power | 140 HP |
| Rotational speed | 4200 rpm |
| Maximum torque | 320 Nm |
| Maximum speed | 203 km/h |
| 0-100 km/h | 9.3 sec |
| Consumption | 5.5 l/100km |
| Curb weight | 1400 kg |

Future Developments in Engines and Fuels Conclusions

- **Criteria pollutants essentially zero after LEV III, Tier 3 finalized and phased-in**
- **Future focus in on CO2 reduction, energy security**
- **Still significant CO2 reduction possible from combustion engines**
- **Diesel engines will maintain a MPG and CO2 reduction advantage over gasoline engines**
- **Increased use of liquid biofuels should not be an issue for advanced combustion engines**
- **Government policy can greatly influence the introduction and the use of biofuels (treatment in future GHG regulations, for example)**

Future Developments in Engines and Fuels

Volkswagen Powertrain and Fuel Strategy

