

Conferencia Internacional  
Revision Tecnica Vehicular: Herramienta Fundamental para la Gestion Ambiental y la Seguridad Via  
Febrero 4 y 5, 2009, Quito, ECUADOR

# **Reduccion de emisiones vehiculares: *programas y tecnologias de transicion y perspectivas futuras***

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# Generalidades: *California... El Estado-Nación*

- ~37 millones de habitantes
- 400,000 Km<sup>2</sup> de superficie
- El 5º/6º consumidor de energía mundial
- ~25 millones de vehículos a gasolina
- ~1+ motores a diesel
- 2º/3º consumidor de gasolina y diesel (los EEUU son 1º)
- Promedio de millas viajadas por vehiculos (*Vehicle Miles Traveled*):
  - 389 millones de VMT por dia (1980)
  - 840 millones de VMT por dia (2003)



# Elementos de Programa Comprensivo de Control de Contaminacion Vehicular



Certificacion de  
vehiculos/motores  
nuevos



Auditoria de vehiculos  
nuevos/*in-use*  
*compliance*



Inspeccion de  
*dealership*

Pruebas  
*In-use*  
(Recall)



Retiro (Scrap)

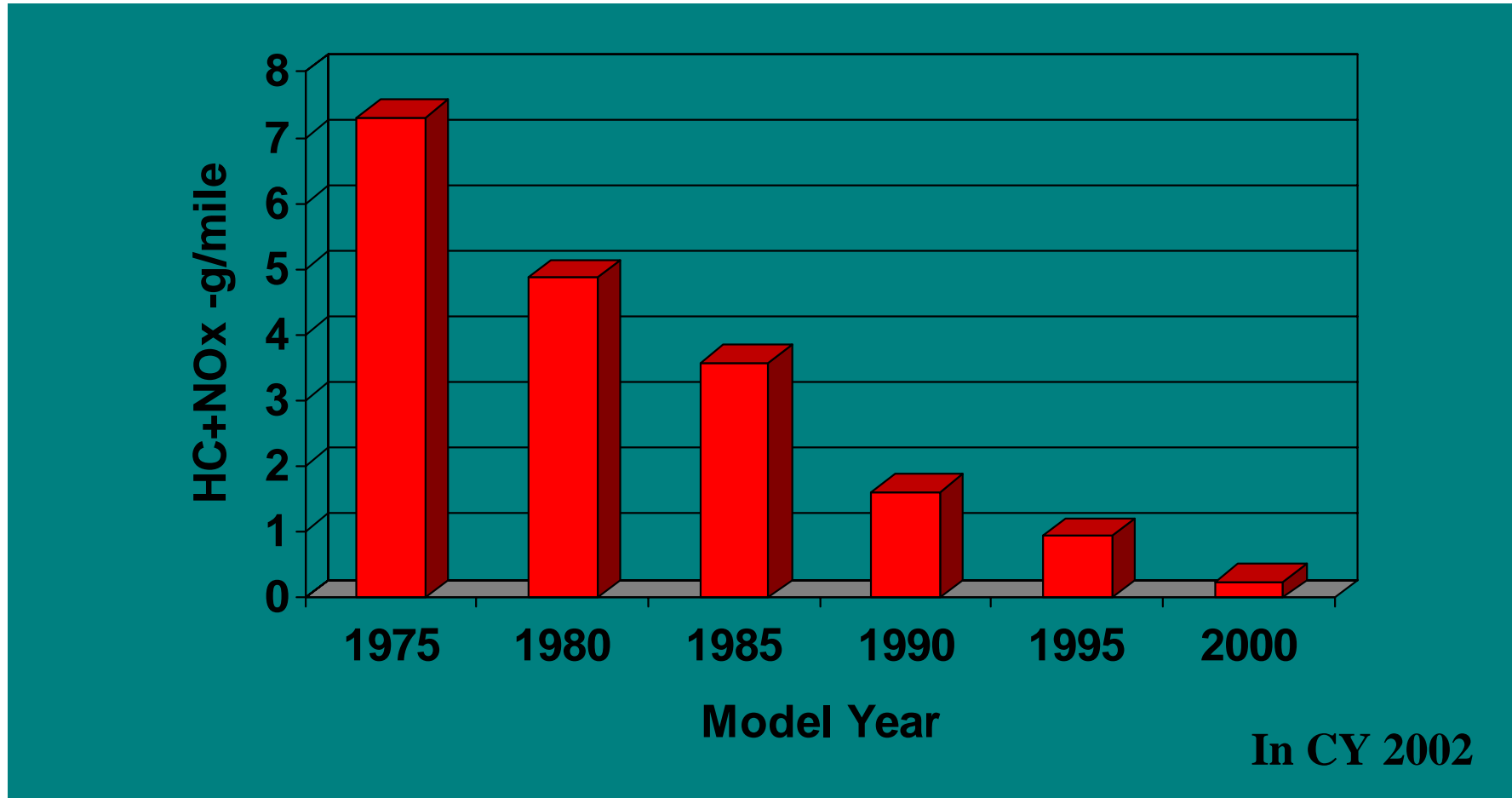


Inspeccion &  
Mantenimiento



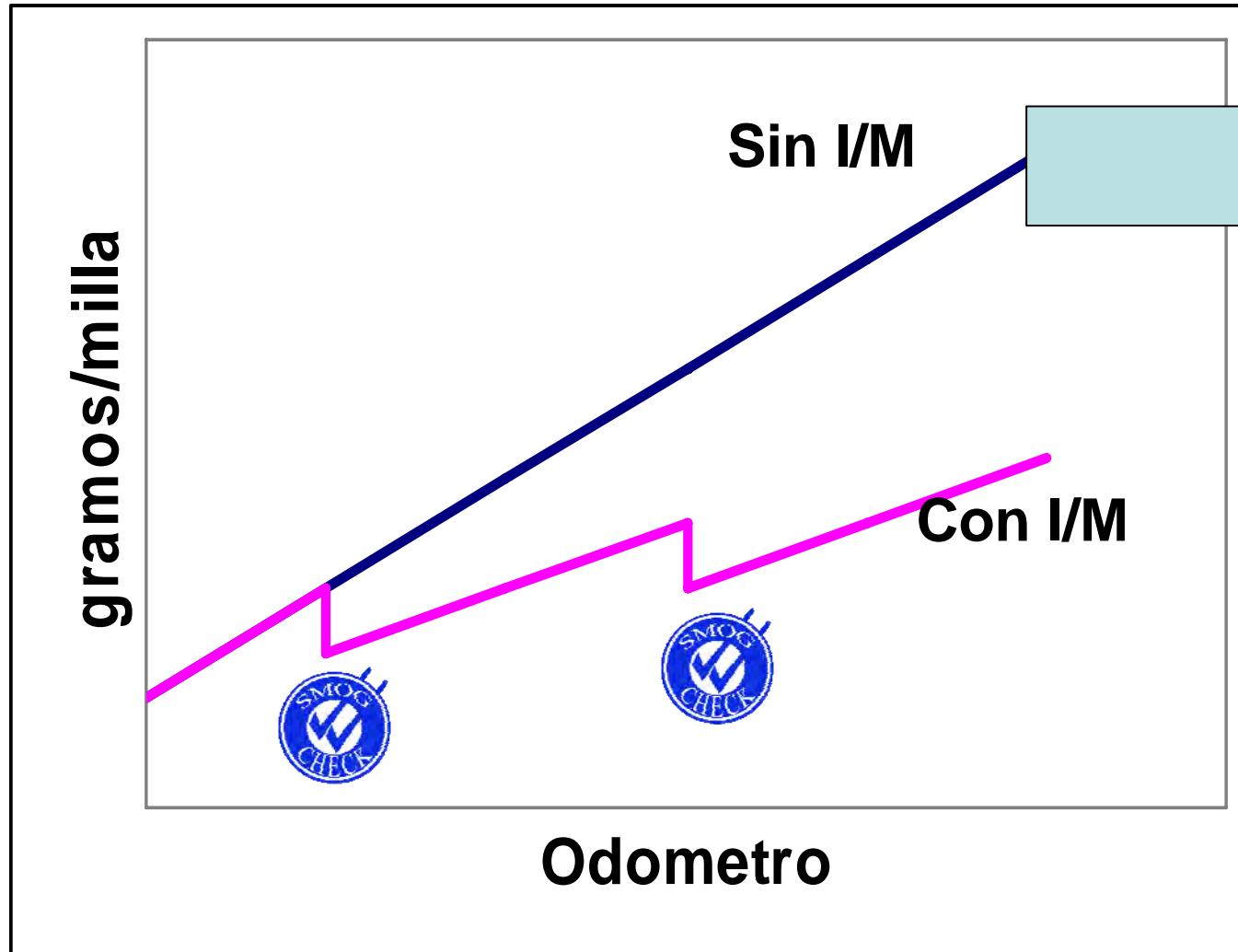
**Programa de  
Inspeccion/  
Mantenimiento de  
Vehiculos**

# Las Emisiones y la Edad del Vehículo



Source: Evaluation of California's Smog Check Program, Presentation by California Environmental Protection Agency/Air Resources Board and Department of Consumer Affairs/Bureau of Automotive Repair, January 27, 2004

# El Modelo del Programa I/M



*La tendencia de incremento baja con el mejoramiento de la tecnología*

# Program Inspeccion & Mantenimiento en California



- Smog Check empezo en 1984
- El presente Programa I/M = *Smog Check II (1996)* >>>>*OBDII*
- Smog Check se aplica a vehiculos a gasolina ligeros y pesados < 14,000 libras de peso grueso neto
- Se modifica para incluir a un futuro vehiculo a diesel
- Vehiculos de mas de seis anos de edad son sujetos a Smog Check
- Pruebas de emisiones bi-anales
- Smog Check se requiere para el registro del auto
- Red de estaciones centralizadas y de-centralizadas y operadas como entidades privadas
- ~9,000 licencias para estaciones de prueba en el Estado
- El enfoque es en las emisiones de NO<sub>x</sub>, HC, CO, recientemente PM
- ~16 millones de vehiculos sujetos a prueba I&M
- ~70% de vehiculos se sejute a prueba ASM

<http://www.arb.ca.gov/msprog/smogcheck/smogcheck.htm>

<http://www.smogcheck.ca.gov/stdhome.asp>

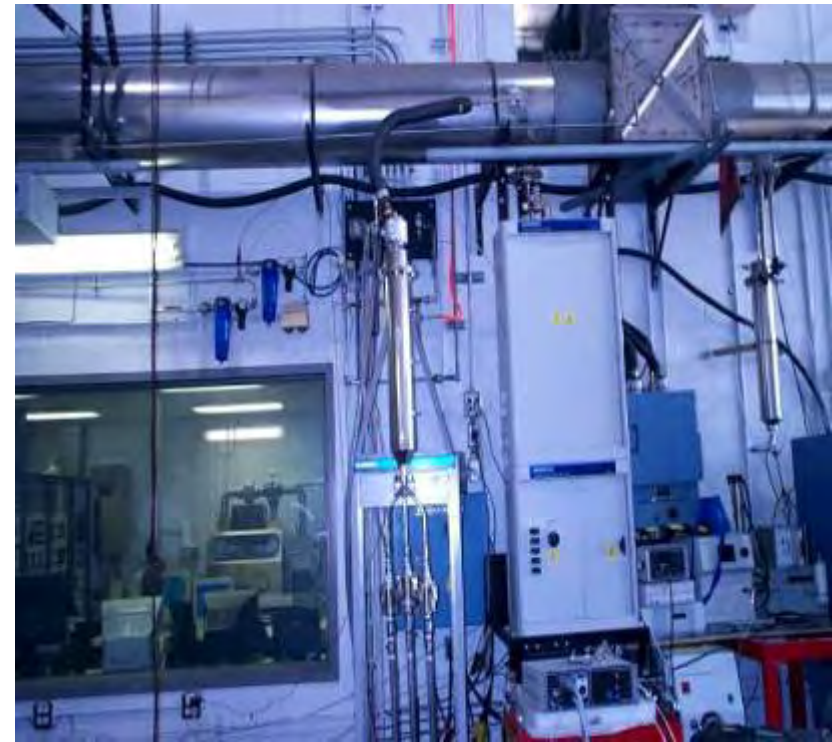
# La Prueba de Aceleracion Simulada ASM

*(acceleration simulation mode)*

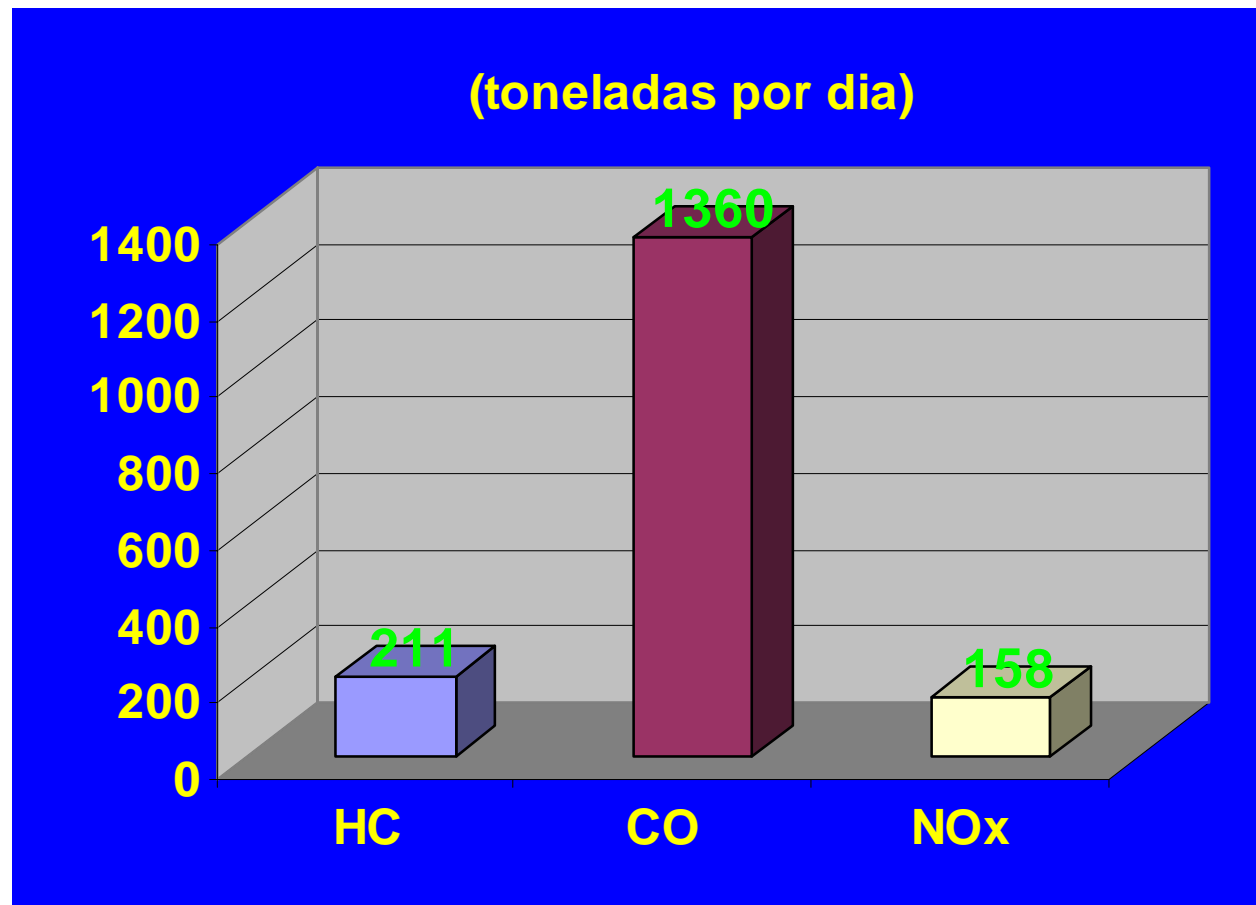


- IM240 requiere carga a motor variante, que requiere equipo con CVS [Constant Volume Sampling system] para medir masa de emisiones por distancia viajada [gramos/milla]
- Prueba ASM mas facil de implementar
- Capacidad comprobada del ASM relativo al IM240
- Pruebas en el dinamometro para vehiculos necesarias para identificar vehiculos con emisiones NOx elevadas
- Inspeccion visual del equipo completo de emisiones
- Se interroga electronicamente a al computado (OBDII – On-board Diagnostics)
- Pruebas de emisions por vaporizacion de combustible: inspeccion de presion, fugas, y sello de la tapa del tanque de combustible
- ASM5015 (15 mph, 50% de la carga maxima del FTP)
  - HC - 54ppm, CO - 0.5%, NO - 430ppm
- ASM2525 (25 mph, 25% de la carga maxima del FTP)
  - HC - 37ppm, CO - 0.47%, NO - 717ppm

# Sistema CVS – tunnel de dilucion del flujo completo de emision vehicular



# El Beneficio del Program Smog Check

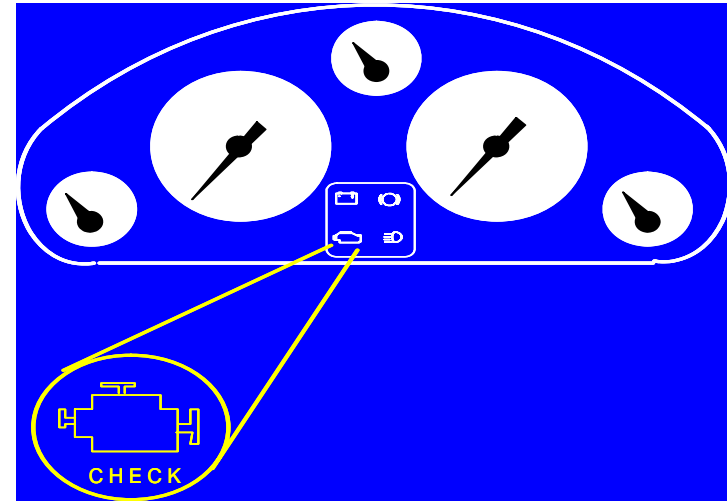


Basado en  
EMFAC2002

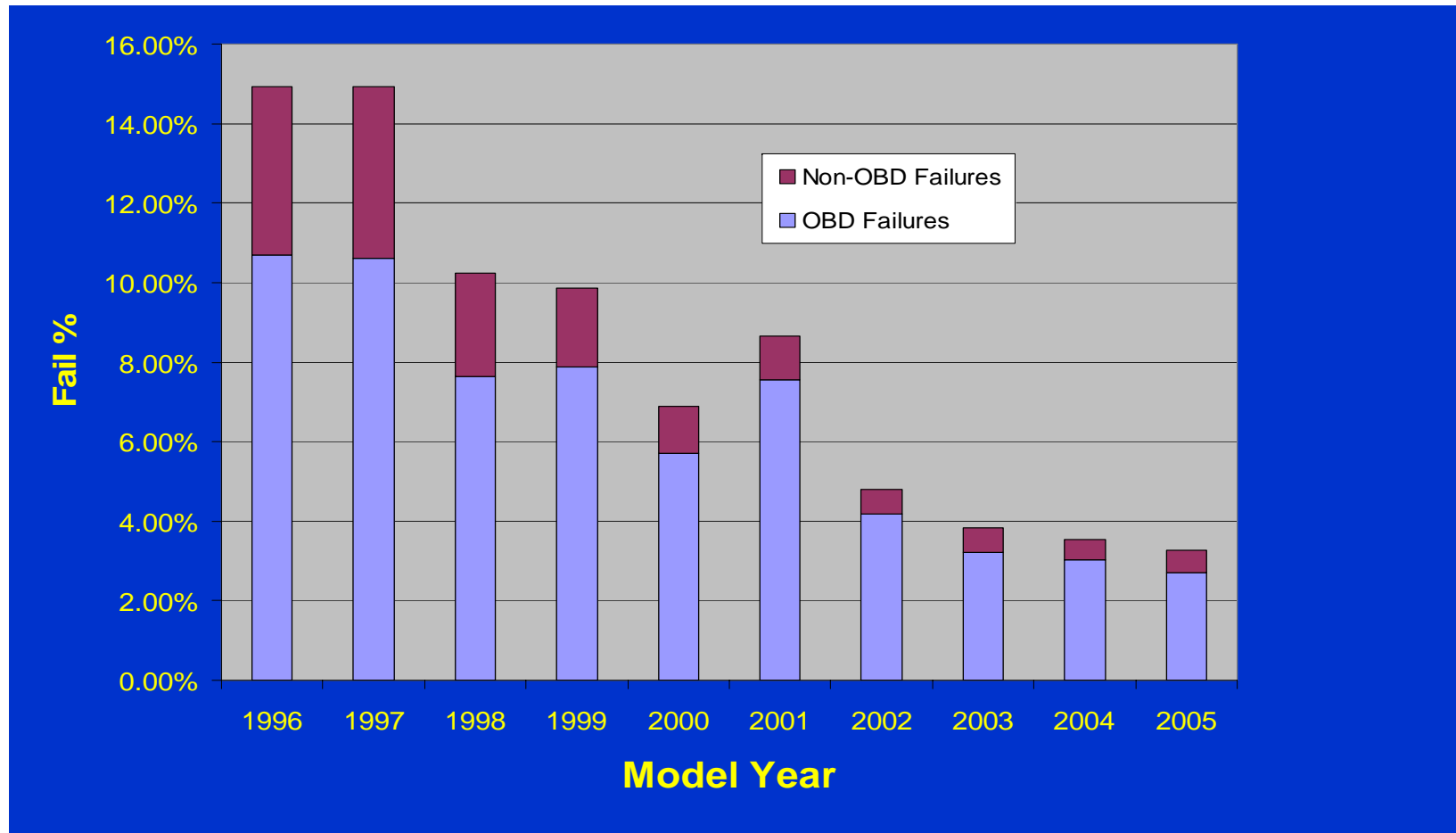
Source: Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program, Draft Report to the Inspection and Maintenance Review Committee, California Air Resources Board and Bureau of Automotive Repair, April 2004.

# On-Board Diagnostics (OBD)

- Monitoreo computarizado de la operacion de virtualmente todo y cada componente relacionado al equipo de control de emisiones del vehiculo
- Principalment software en la computadora del vehiculo que conduce rutinas de diagnostico en el *background* mientras el vehiculo esta en uso
- OBDII sistema en todo ligero, medium-duty vehiculo desde modelo 1996
- Mas de 140 millones de vehiculos equipados con OBDII en el pais
- OBDII usado en I/M en 32 estados
- Mecanismo principal para identificar el mantenimiento requerido
- Cuando falla, un indicador aparece en el *dashboard*
- MIL (malfunction indicator light) – indicador de malfuncion
- La computadora guarda la informacion de la falla
- El mecanico puede acceder la informacion de la falla atravez de una herramienta *scan tool*



# Rechazos en el Programa SmogCheck



Fuente: M.McCarthy/CARB, California Emerging Clean Air Technology Forum, Univ. of CA, Merced, July 9, 2008

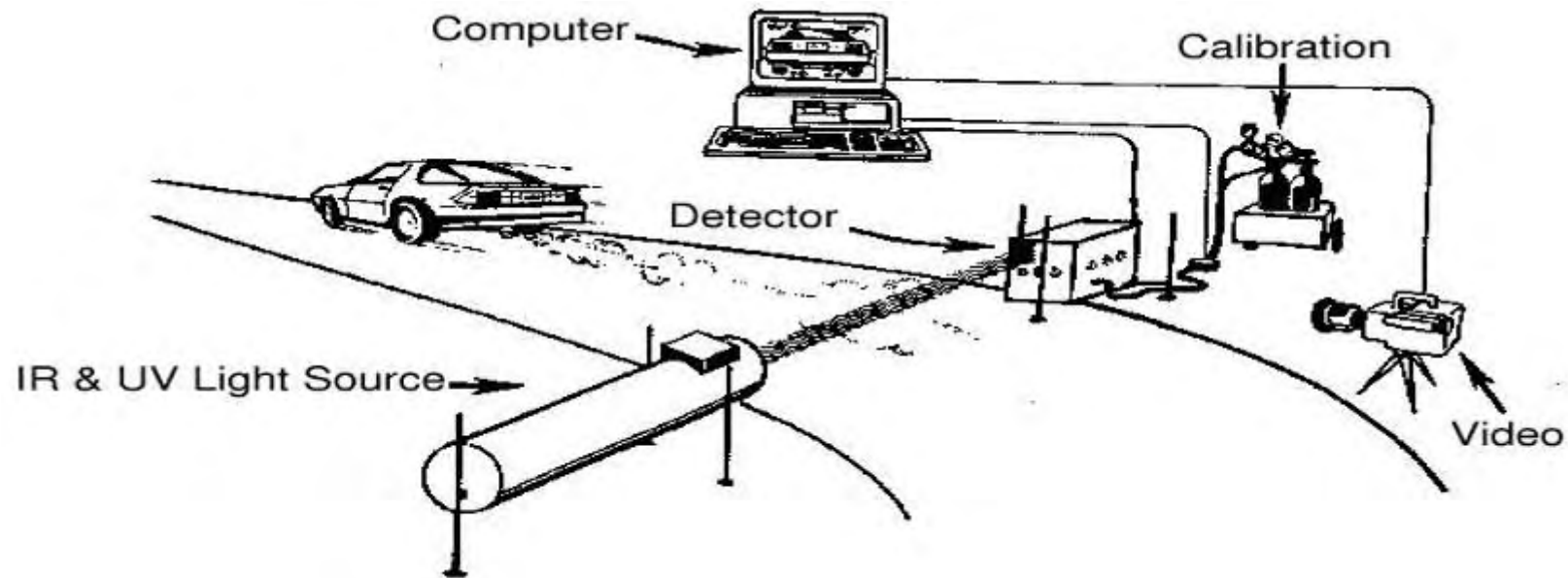
# Informando el Posible Futuro del Programa de Control de Emisiones Vehiculares:

## ***Estudios de investigacion actuales***

- Remote sensing (Sensores remotos) y Medicion de emision de material particulado (PM)
- OBD + (programa para vehiculos ligeros y pesados)

# Motivacion para el estudio de Remote sensing (Sensores remotos)

- Vehiculos de California LEV II estandar tienen ultra baja emision de material particulado
- Pero, un numero pequeno de vehiculos de mal funcion (gross emitters) pueden contribuir un fraccion muy grande de las emisiones totales de la flota
- RSD tienen potencial para identificar dichos vehiculos de alta emision

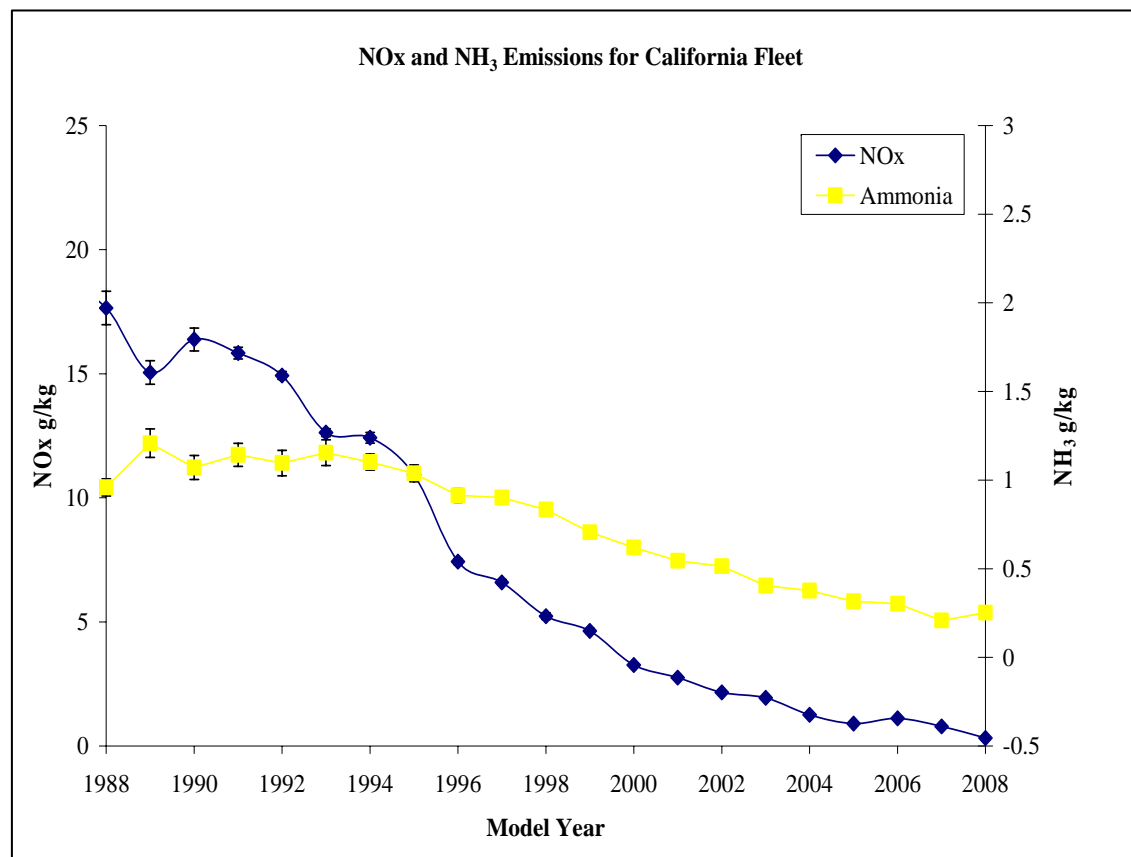


## On-road Light-duty Vehicle Remote Sensing of CO, HC and NO, as well as NH<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub>



Fuentes: Studio de CARB por D. Stedman/Univ. of Denver

# Ejemplo de Resultados Preliminares

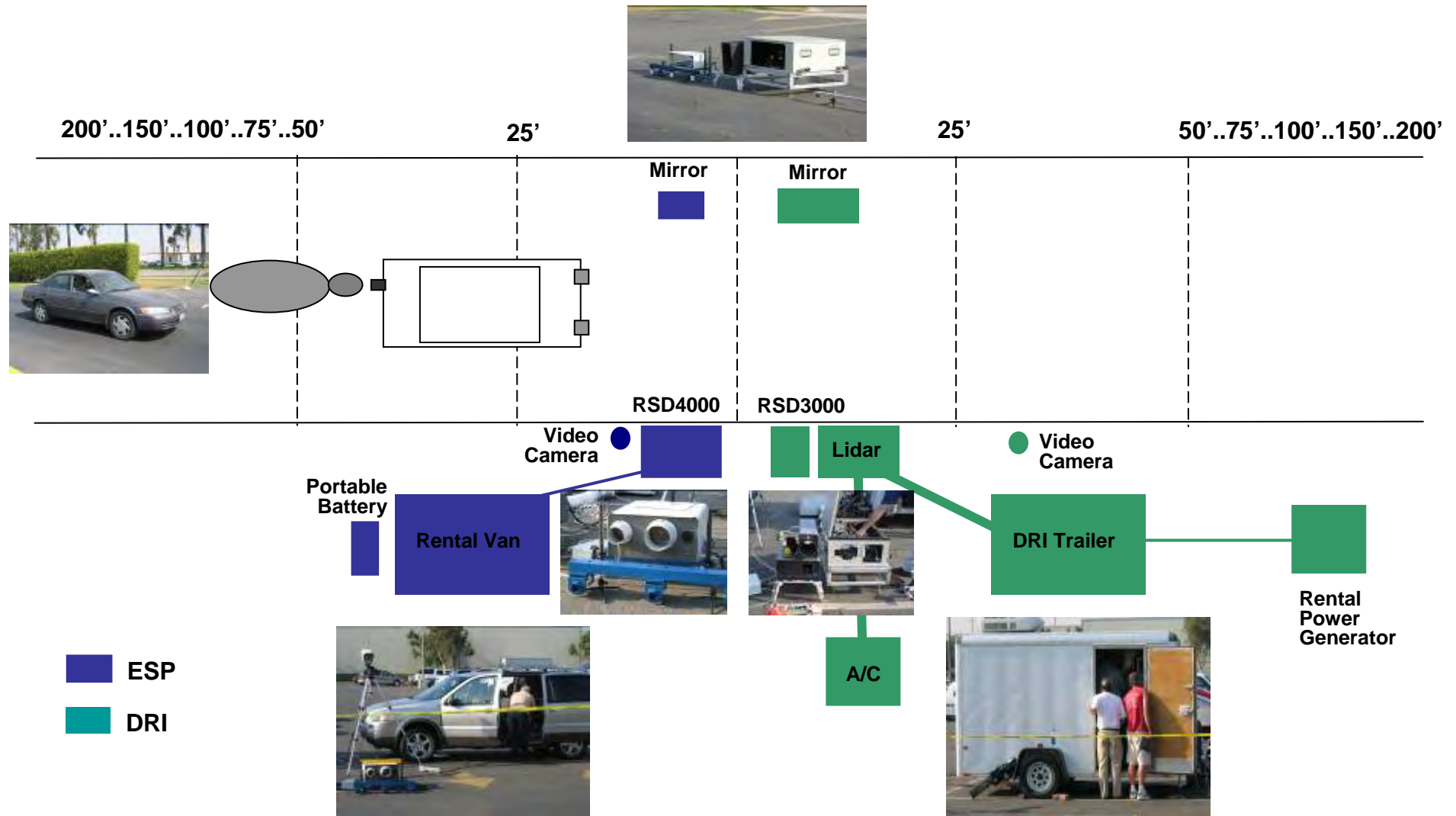


Note the scale of the  $\text{NO}_x$  g/kg axis is 8 times larger than the  $\text{NH}_3$  g/kg axis for viewing convenience.

The standard error of the mean for both  $\text{NH}_3$  and  $\text{NO}_x$  are shown.

Ambos  $\text{NO}_x$  and  $\text{NH}_3$  presentan tendencia a bajar en vehiculos de menor edad

# Pruebas RSD en un estacionamiento para la medición de emisión PM



Fuente: Collins et al./CARB, CRC On-road Emissions Workshop, San Diego, March 2007

# Categorías de Nivel de Emission PM

Baseline	No Smoke	
Light (Invisible):	Blue	Black
Medium:	Blue	Black
Heavy:	Blue	Black
Medium:	Gray	

# Vehicle Identification

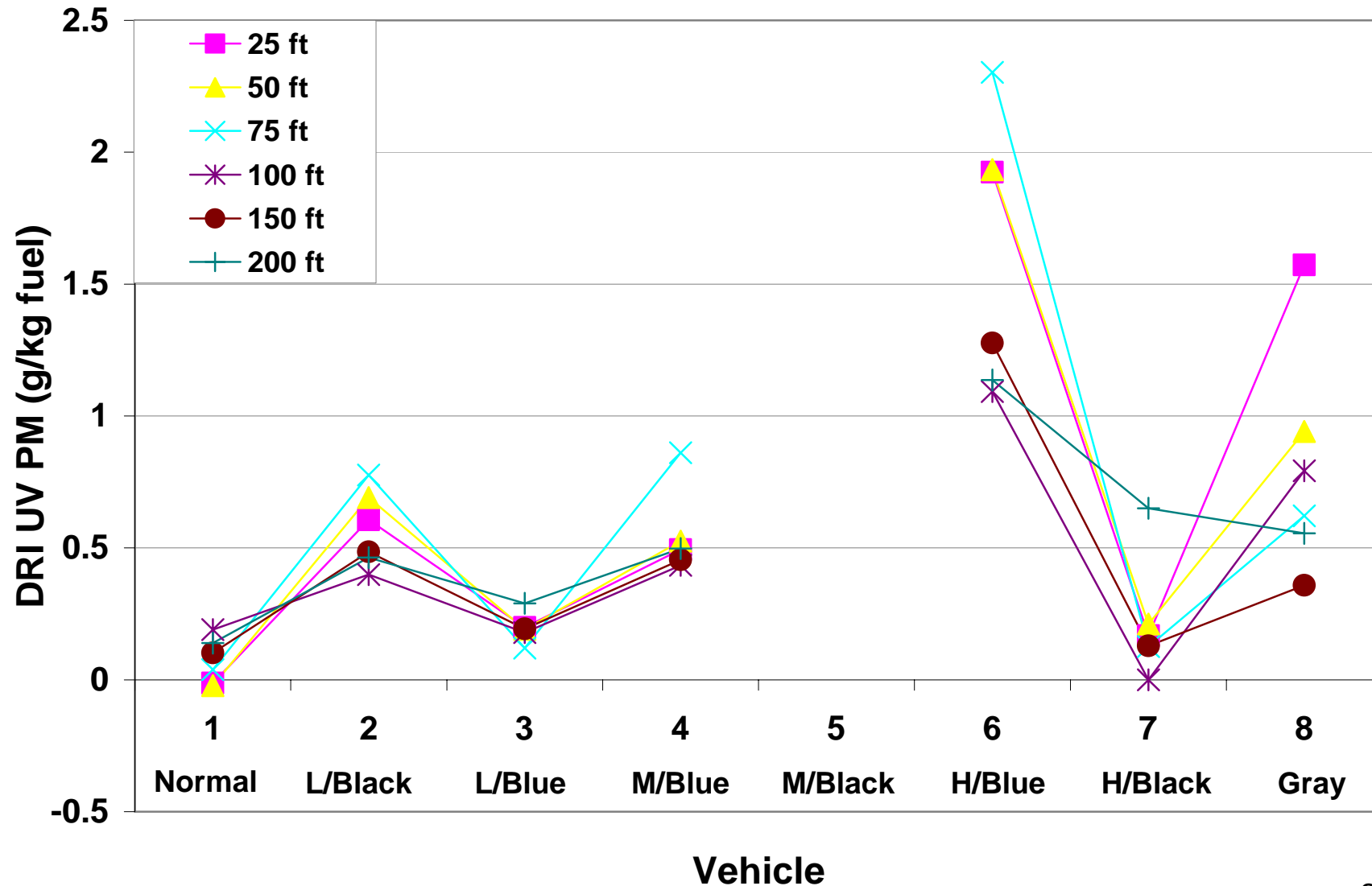
#	MY	OEM	Model	Type	Disp.(L)	Mileage	Target Smoke Type	Target PM (mg/mi)
1	1997	Ford	Escort	PC	2.0	25,598	Normal emitter (no smoke)	< 5
2	1985	Toyota	Camry	PC	2.0	268,423	Light Black (invisible)	25 to 75
3	1991	GMC	Sonoma	LDT	4.3	171,487	Light Blue (invisible)	25 to 75
4	1981	Toyota	Pickup	LDT	2.4	119,728	Moderate Blue	50 to 500
5	1995	Dodge	Dakota	LDT	2.5	123,974	Moderate Black	50 to 500
6	1963	Studebaker	Avanti	PC	4.6	high	Heavy Blue	50 to 500
7	1998	Toyota	Camry	PC	3.0	82,704	Heavy Black	50 to 500
8	1986	Mitsubishi	Max	LDT	2.0	163,913	Gray	50 to 500

PC = Passenger Car; LDT = Light-Duty Truck.

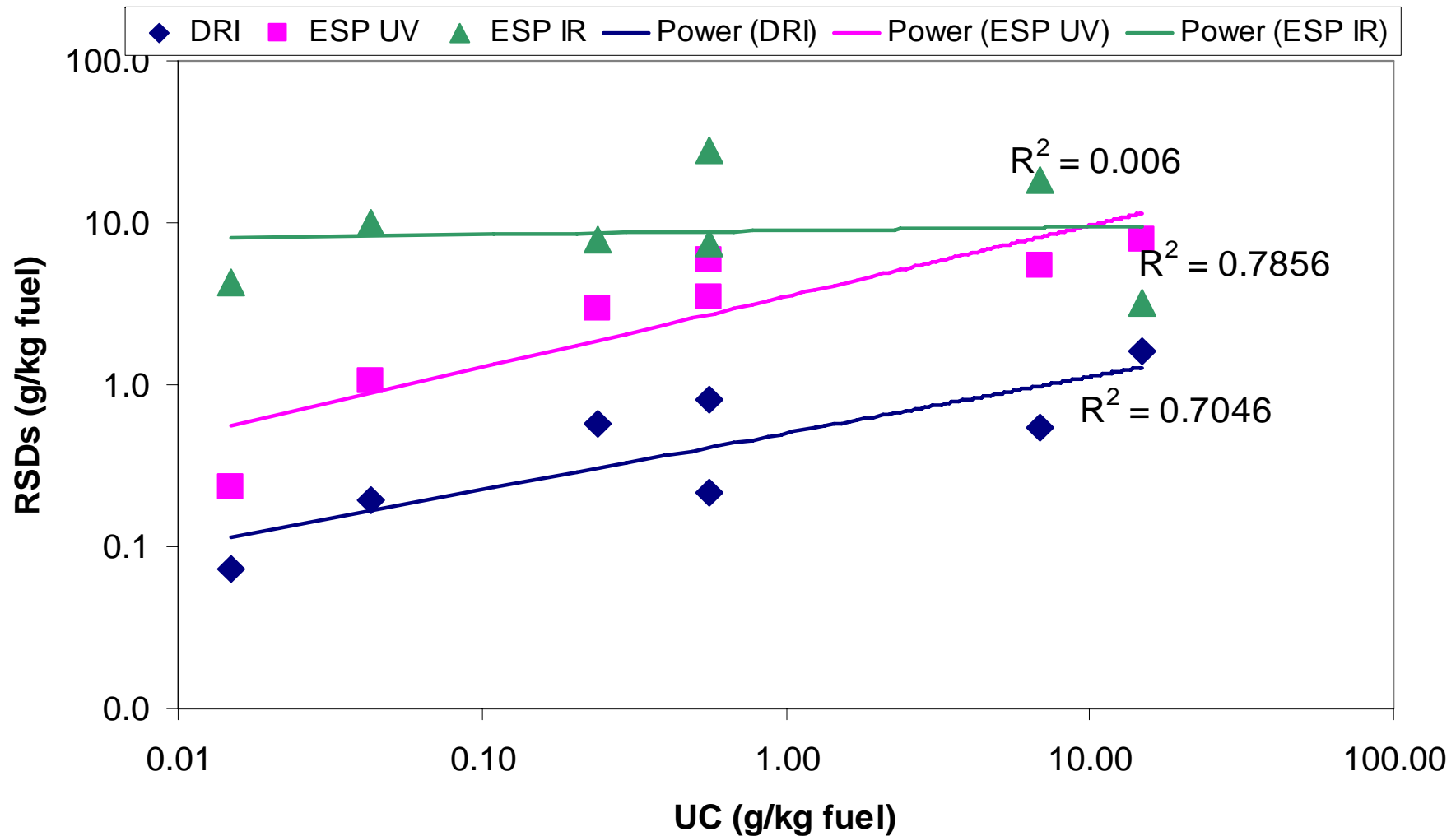
# New Remote Sensing Systems for PM measurement

- ESP RSD 4000
  - Gaseous measurements
  - PM measurements: two channels
    - UV Transmissometer
    - IR Transmissometer
  - Commercial system
- DRI Custom System
  - Gaseous measurements: ESP/RSD 3000
  - PM measurements:
    - UV backscatter light detection and ranging (LIDAR)
  - Research system

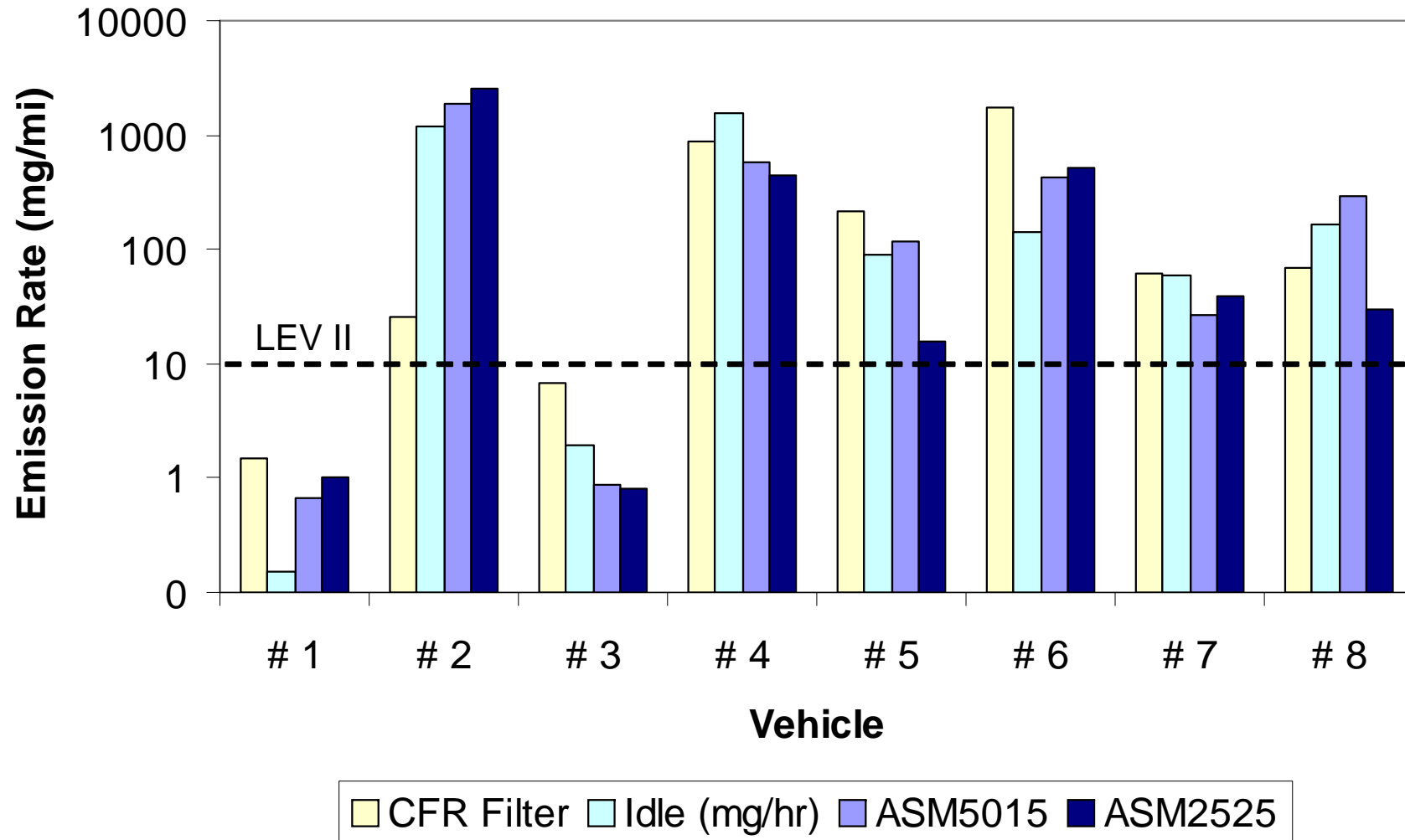
# Ejemplo de Resultados: RSD DRI UV LIDAR



# Conclusion: Ciertos sistemas RSD dan promesa para la medición de emisión PM

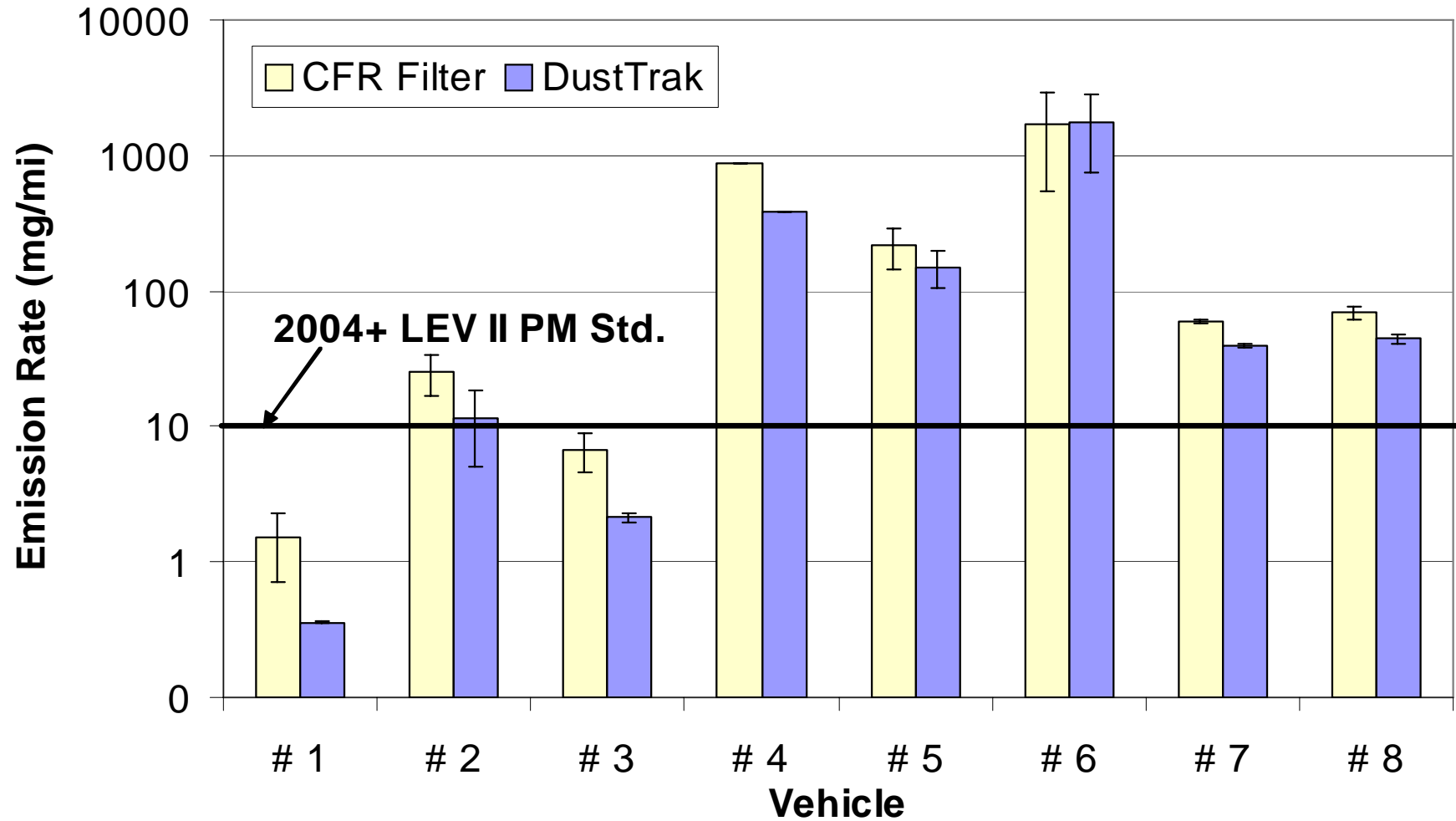


# Ciclo UC (referencia), Prueba Estatica (ralenti), and Prueba Dinamica ASM



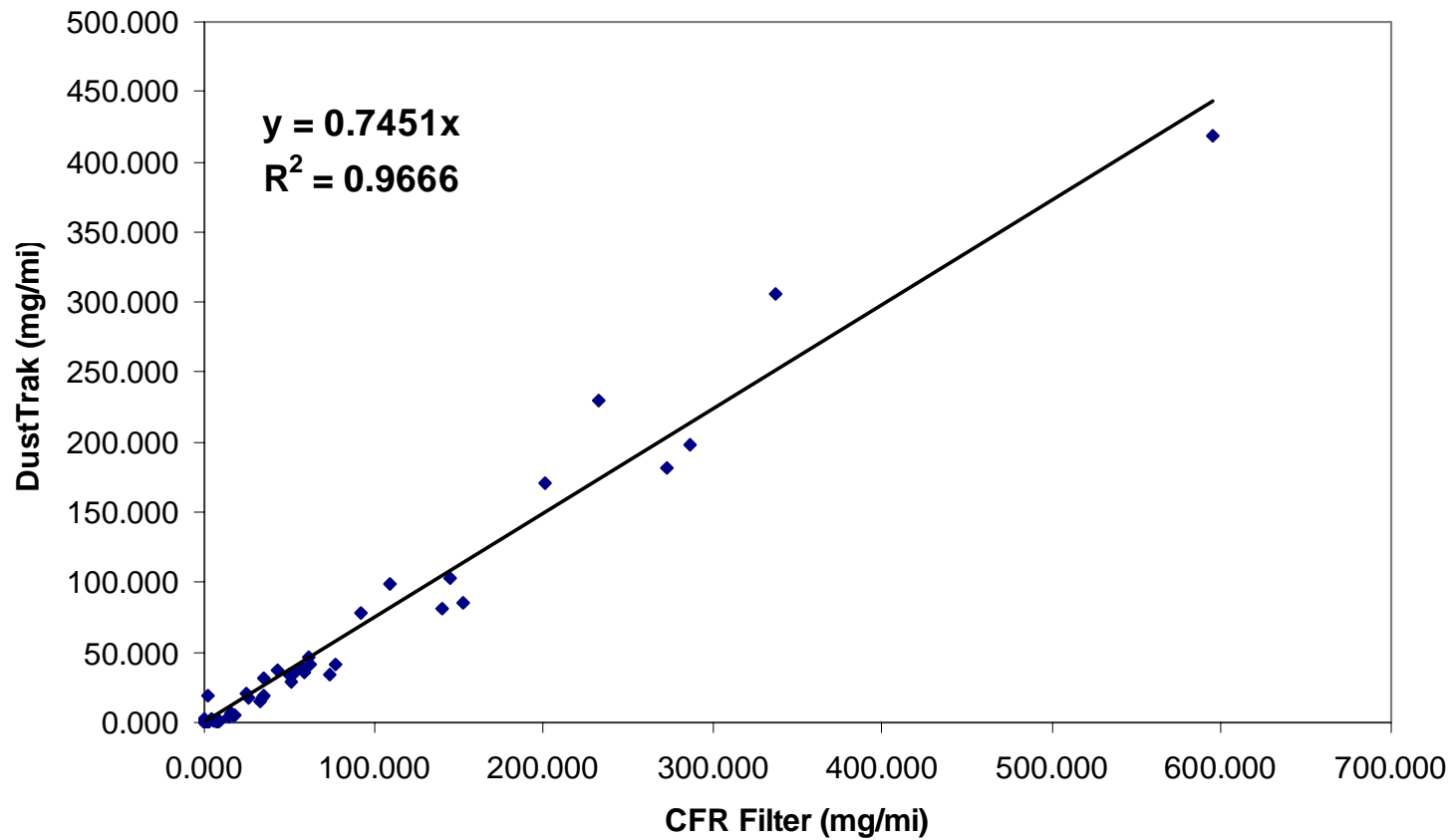
# CVS Mass / Unified Cycle

## Sistema de Medicion de PM DustTrak vs. Metodo de Referencia

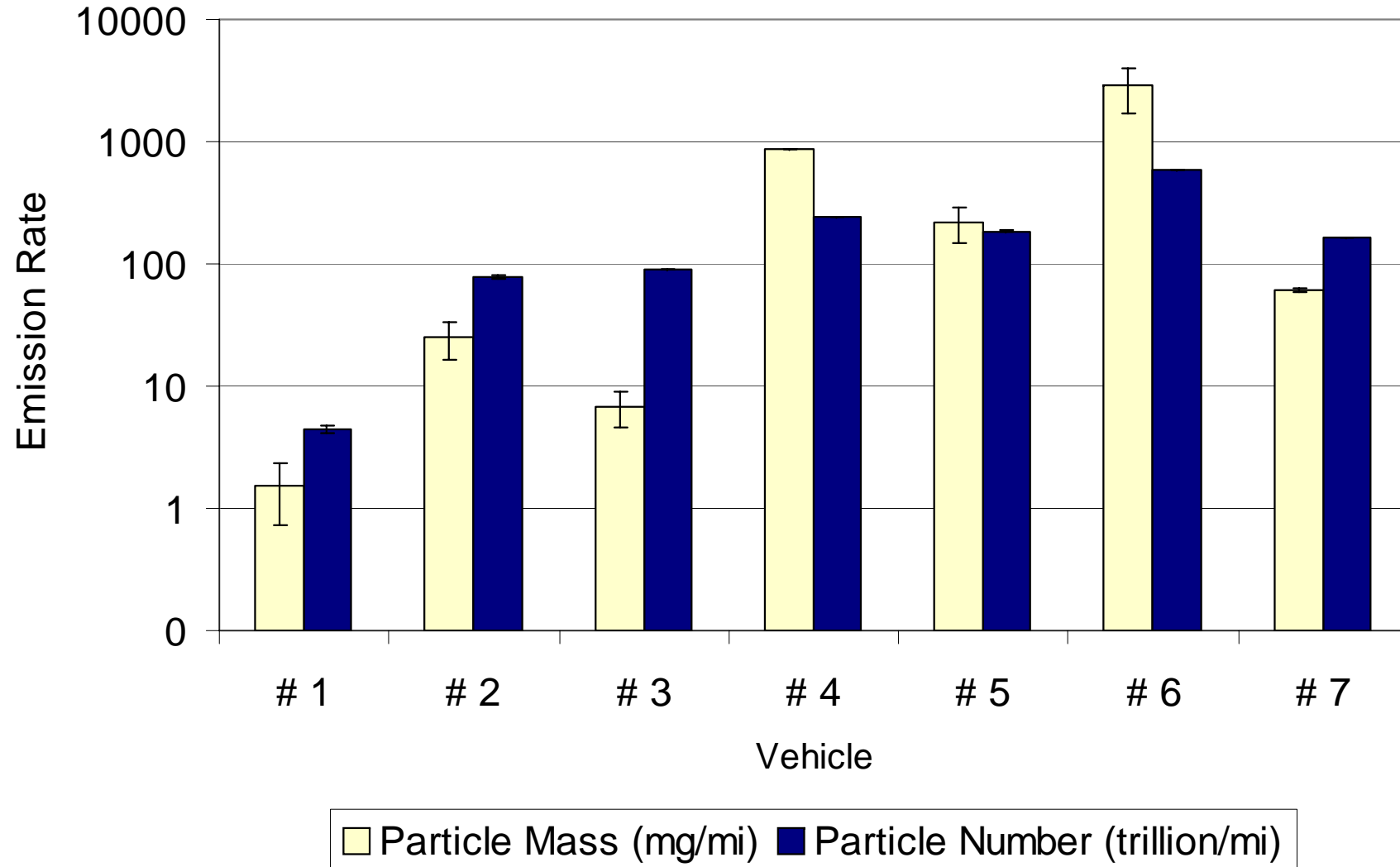


NOTA: TSI, Inc. DustTrak, [www.tsi.com](http://www.tsi.com)

# DustTrak Correlation (excluding blue smokers)



# La Emision de Numero de Particulas sobre Ciclo UC



# References

## Journal Papers

- Wei Li et al., (2007). Detection of Gasoline Vehicles with Gross PM Emissions. SAE Technical Paper.

## Conference Presentations

### **18th CRC On-Road Emissions Workshop, March 31 - April 2, 2008, San Diego, CA**

John F. Collins et al., Evaluation of High PM Emitting Light-Duty Gasoline Vehicles Using RSD, ASM, and Laboratory Dynamometer Testing.

### **17th CRC On-Road Emissions Workshop, March 26-28, 2007, San Diego, CA**

Tao Huai et al., Comparison of Remote Sensing Devices (RSD) with Gravimetric Measurements of Light-Duty Gasoline PM Emissions.

John F. Collins, Real-Time Measurement Methods to Detect High PM Emissions from Light-Duty Gasoline Vehicles.

## ARB Project Report

Thomas D. Durbin et al., (2007). Light Duty Gasoline PM: Characterization of High Emitters and Valuation of Repairs for Emission Reduction. ARB Contract No. 05-323.

## Web Link

<http://www.arb.ca.gov/research/veh-emissions/ldgv-highpm/ldgv-highpm.htm>

# Hacia donde puede ir Programa de Inspeccion SmogCheck?

- Inspecciones de solo OBDII (OBDII-only)
  - Simple, rapido, reduccion de costos de inspeccion
  - Ya en uso por 31 estados
- Enfoque: el beneficio de la reduccion de emision esta en la reparacion de los vehiculos que lo necesitan
  - Necesidad de minimizar el tiempo perdido inspeccionando vehiculos limpios (de baja emision)

# “Self-serve” OBD Inspecciones en prueba hoy en dia

- Kioskos como los de cajero automatico
- Abierto 24horas/7dias
- Maximizar tiempo reparando autos que lo necesitan
- Minimizar evaluacion de autos de baja emision



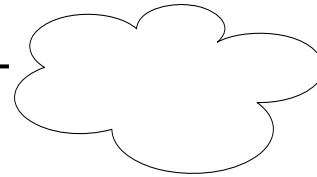
# OBD Remoto (OBD III)

- Concepto investigado por varios estados
  - Coleccion de la misma informacion que hoy se colecta en Programa SmogCheck
  - Comucacion automatica de datos
  - Requisito estricto de reparacion del vehiculo dentro de un marco de tiempo especificado
- Beneficios:
  - Virtualmente elimina las inspecciones en centro vehicular
  - Solo mandar vehiculo a taller mecanico cuando se necesita la reparacion
  - Inspeccion continua en vez de a tiempo (bi-annual)
- Tecnologia en el mercado hoy

# NetworkCar System



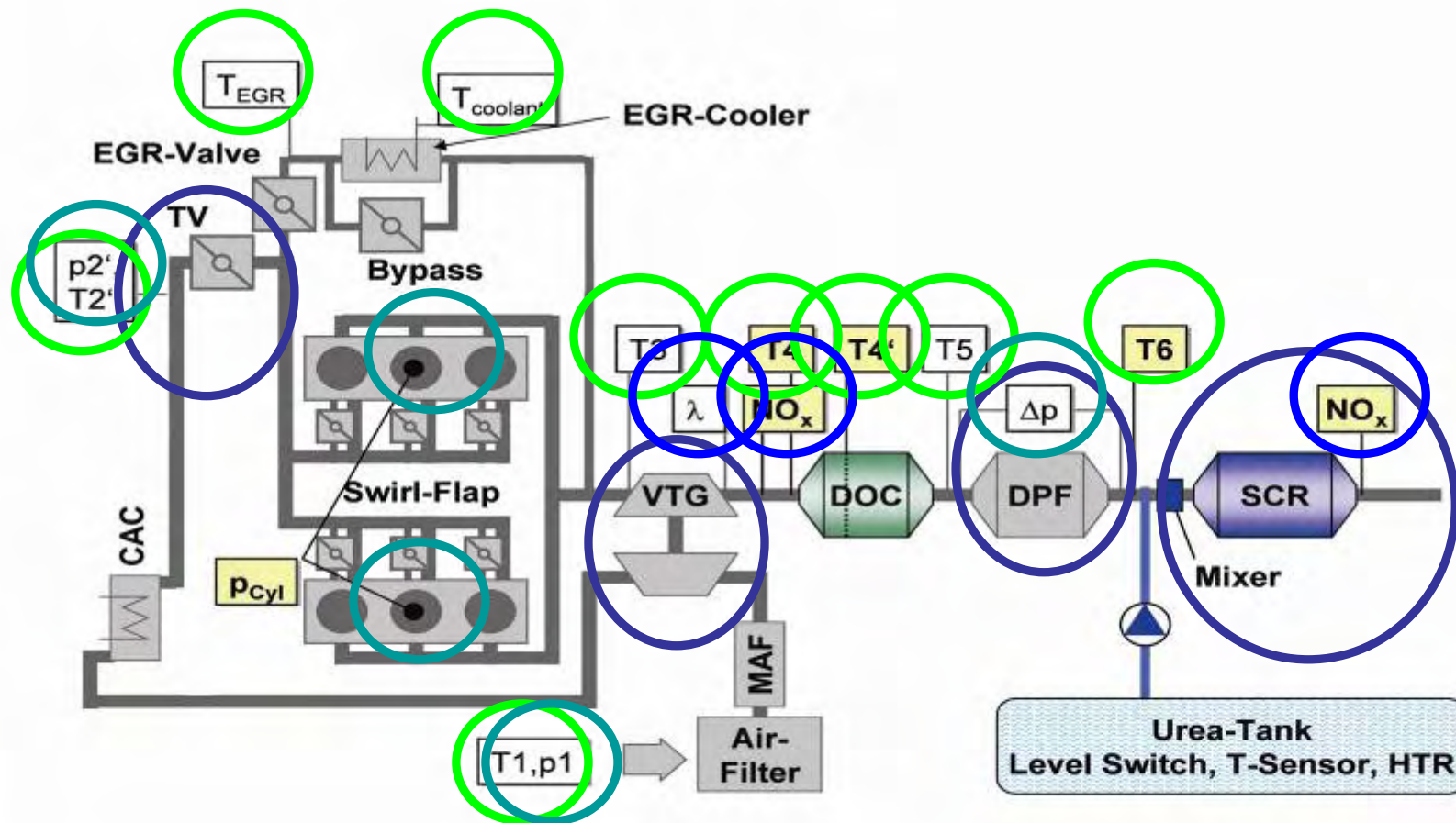
Vehicle owner notified via e-mail of vehicle problem.



# Nuevo OBD para vehiculos pesados de motor a diesel

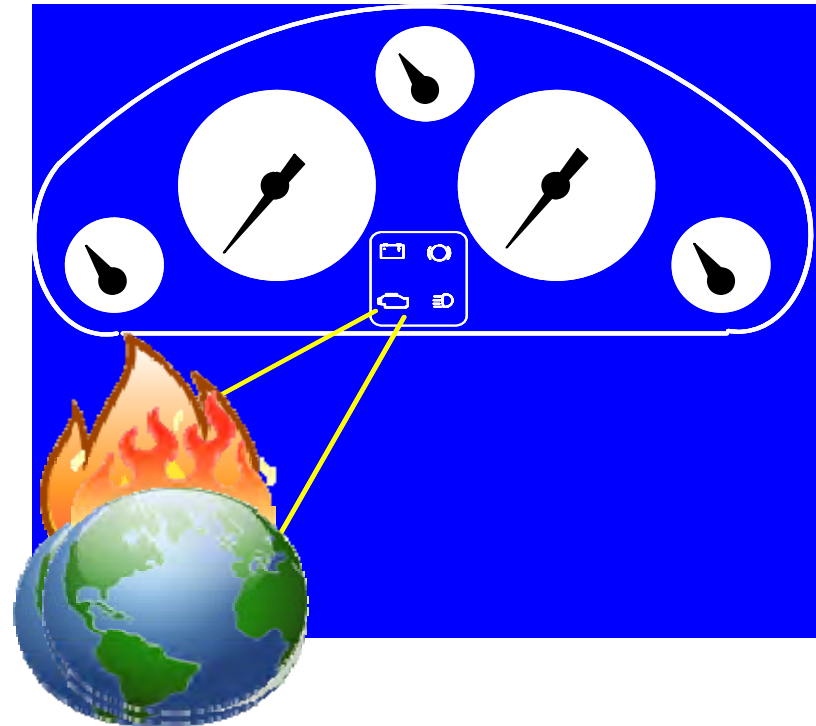
- Vehiculos pesados (>14,000lbs GVWR)
  - Fuentes importantes de emisiones de NOx y PM
- Requerimiento OBD empieza con el modelo 2010 para los vehiculos pesado (HD on-road vehicles)
  - Fase de introduccion en 2010
  - Todos los productos por 2013

# Los controles de emisiones crecen en complejidad!!!



# OBD y las Emisiones de Gases de Efecto de Invernadero y Calentamiento Global

- OBD enfocado en emisiones de criterio
- En general, reparacion y buen mantenimiento baja la emision CO2
- Posible area de expansion para OBD
- En hecho, ya se pasa la informacion al conductor sobre el consumo de combustible a tiempo real
- Eco-driving



# ***Cuenta Regresiva a Cero***

**Controles y Reconversión**

**Reformulación y Tecnología**

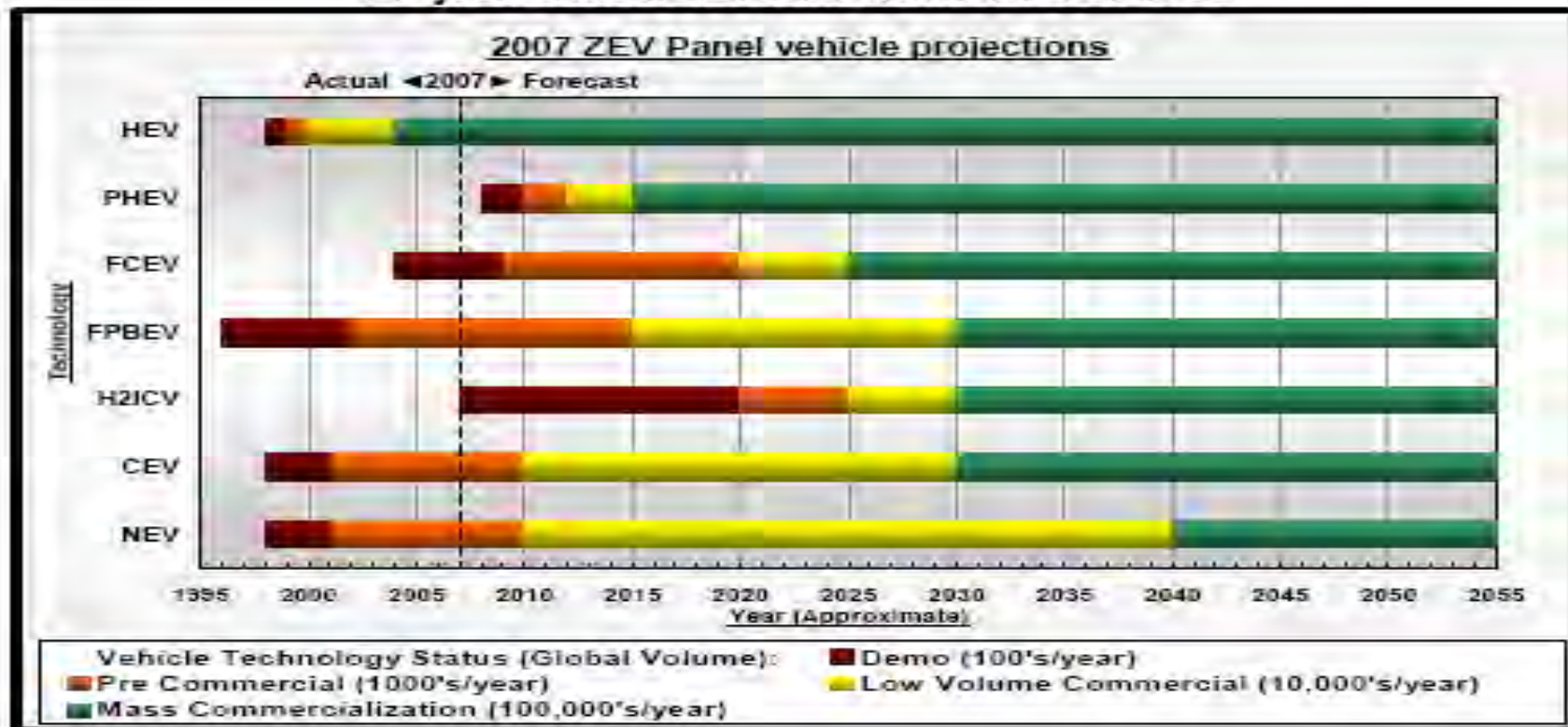
**EL FUTURO**

**Emisiones Cero**



# La Bola de Cristal para la Futura Tecnología Automotriz en California

Figure 3.1  
Projected Achievement of Global Volumes



1. "HEV" means hybrid electric vehicle; "PHEV" means plug-in hybrid vehicle; "FCEV" means fuel cell electric vehicle; "FPBEV" means full performance battery electric vehicle; "H2ICV" means hydrogen internal combustion vehicle; "CEV" means city battery electric vehicle; "NEV" means neighborhood battery electric vehicle.

# La Odisea del Vehiculo Hibrido\*

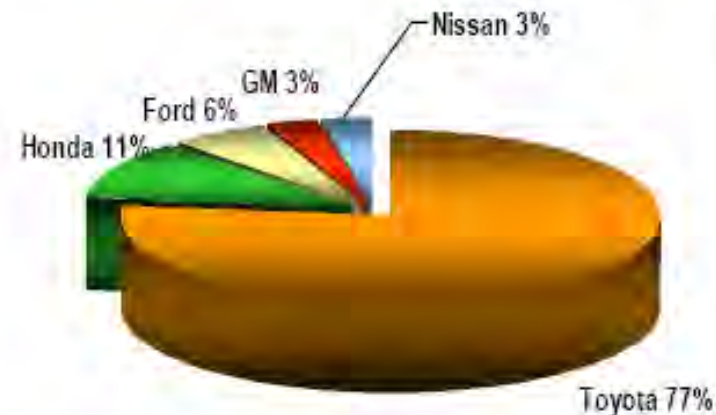
- El exito mas grande
- El motor electrico es complementado con el motor a combustion interna (gasolina, diesel, etc)
- Concepto principal es el de CORTAR la coneccion entre las llantas y el motor
- Facilitar la operacion del motor de combustion interna a carga constante y cerca del punto de mayor efficiency



	<b>Gen. 1</b>	<b>Gen. 2</b>	<b>Gen. 3</b>
First Sales	1997	2000	2003
Battery weight (kg)	57	50	45
Battery capacity (Watt-hrs)	1,728	1,778	1,310
Electric Motor Power (kW)	30	33	50
Electric Motor Voltage	299	273	500
IC Engine Power (kW)	43	52	57
U.S. Sales	N/A	~40k	~290k

## YTD Hybrid Sales January-September 2008

- YTD hybrid sales: 280,000
- 4.5% lower than YTD 2007
- 2.45% share of LV sales
- Shortage of Prius models due to strong global demand
- But Prius still accounts for 50% of all hybrid sales
- Hybrid battery shortages
- Recessionary environment makes fewer people able to justify hybrid price premium
- Phase out of federal tax breaks indirectly raises price of hybrids
- Competition from compacts and sub-compacts

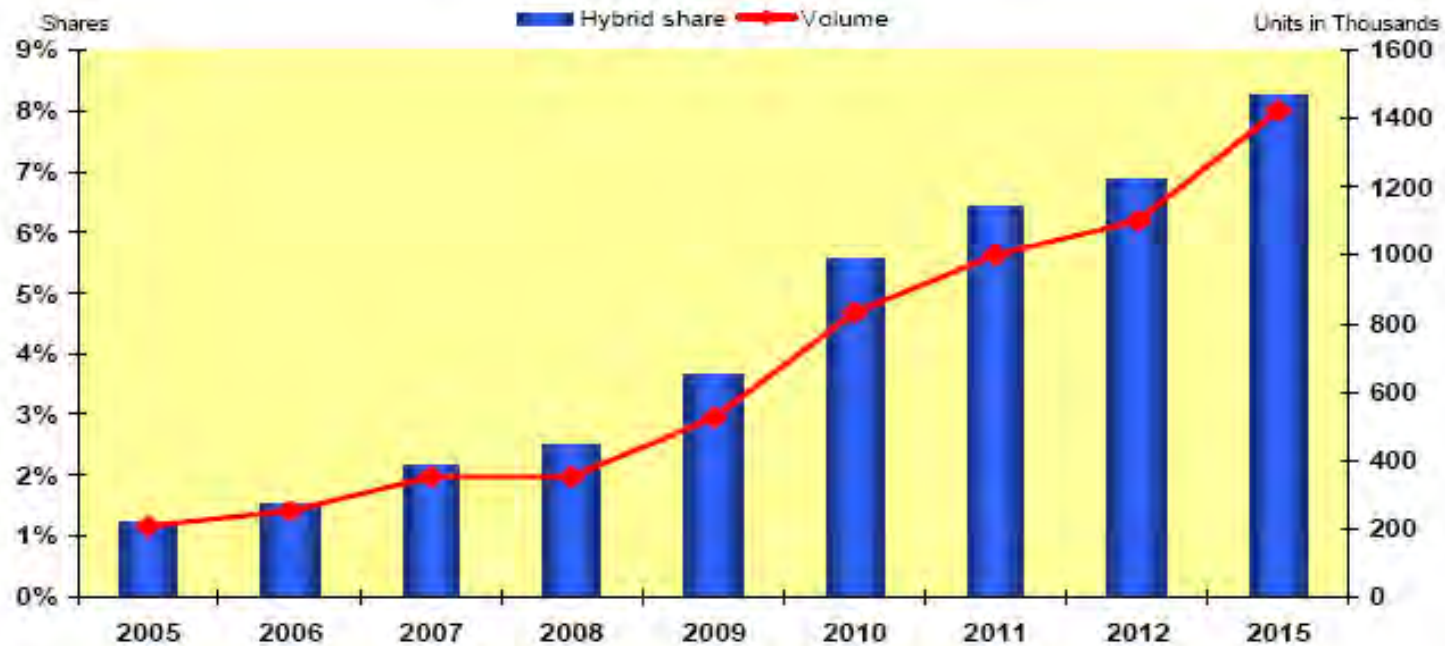


- Honda Fit: Up 52% YTD October 08 VS. 07
- Ford Focus: Up 20.5% YTD
- Toyota Yaris: Up 26% YTD
- Smart ForTwo: up 26% from Sep to Oct 08

# Hybrid Vehicle Forecast

## Hybrid Share of U.S. Light Vehicle Sales

### Q3 2008 Hybrid Forecast Update



Source: J.D. Power Automotive Forecasting U.S. Hybrid-Electric Vehicle Sales Forecast Q3 2008

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J.D. POWER  
HYB ASSOCIATES  
Automotive Forecasting

Fuente: M. Omotoso, J.D.Power, SAE Webminar, Meeting the Fuel Economy Challenge, Nov. 2008

**Figure 32: Product availability: Most major OEMs plan to introduce a full or mild hybrid into the US market by 2010**

	Stop-Start / Micro Hybrid	Mild Hybrid	Full Hybrid	
Current Product	<ul style="list-style-type: none"> <li>GM: Chevrolet Silverado, GMC Sierra</li> </ul>	<ul style="list-style-type: none"> <li>Honda: Accord, Civic</li> <li>GM: Saturn Vue Greenline</li> </ul>	<ul style="list-style-type: none"> <li>Toyota: Prius, Highlander, Camry</li> <li>Lexus: RX400h, GS450h</li> </ul>	<ul style="list-style-type: none"> <li>Ford: Escape, Mercury Mariner, Mazda Tribute</li> <li>Nissan: Altima</li> </ul>
2007/08		<ul style="list-style-type: none"> <li>GM: Chevrolet Equinox, Malibu</li> <li>Honda: Fit, CR-V</li> <li>Mercedes S-Class</li> </ul>	<ul style="list-style-type: none"> <li>GM: Chevrolet Tahoe, GMC Yukon, Dodge Durango, Saturn Vue Greenline</li> <li>Lexus: LS600h</li> <li>Toyota: Sienna</li> </ul>	<ul style="list-style-type: none"> <li>Ford: Fusion, Mercury Milan</li> <li>VW: Touareg</li> <li>Audi: Q7</li> </ul>
2009/10		<ul style="list-style-type: none"> <li>Hyundai Accent / Kia Rio</li> <li>Honda: 'Global Small Hybrid'</li> </ul>	<ul style="list-style-type: none"> <li>Toyota: Prius</li> <li>Ford: 500, Edge, Montego</li> </ul>	<ul style="list-style-type: none"> <li>Ford: Lincoln MKX</li> <li>VW: Tiguan</li> <li>Porsche: Cayenne, Panamera</li> </ul>

Source: Press searches, OEM websites.

**Figure 11: The configuration of hybrid powertrains varies significantly, as do the costs and customer benefits**  
 Comparison of three types of hybrid

			Attributes							US Market Interest
			# of hybrid features	MPG	CO <sub>2</sub> Reduction	Reliability	Packaging	Piece Cost	Investment Required	
• Stop / start & micro hybrid	<ul style="list-style-type: none"> <li>• <b>Front of powertrain</b></li> <li>• Low cost, fuel economy improver</li> </ul>	<ul style="list-style-type: none"> <li>• Saturn: Vue</li> <li>• Citroen: C3</li> </ul>	+	+	+	++	++	\$	\$	Low
• Mild hybrid	<ul style="list-style-type: none"> <li>• <b>Mid powertrain</b></li> <li>• More hybrid features</li> </ul>	<ul style="list-style-type: none"> <li>• Honda: Accord, Civic</li> </ul>	++	++	++	++	+	\$\$	\$\$	Medium - High
• Full hybrid	<ul style="list-style-type: none"> <li>• <b>Mid powertrain</b></li> <li>• Full set of hybrid features</li> <li>• High-tech image vehicle</li> </ul>	<ul style="list-style-type: none"> <li>• Toyota: Prius, Camry, Highlander</li> <li>• Lexus: RX400h, GS650h</li> <li>• Ford: Escape</li> </ul>	+++	+++	+++	++	++	\$\$\$	\$\$\$	High

Source: Ricardo

# Configuraciones Basicas del motor para vehiculo hibrido

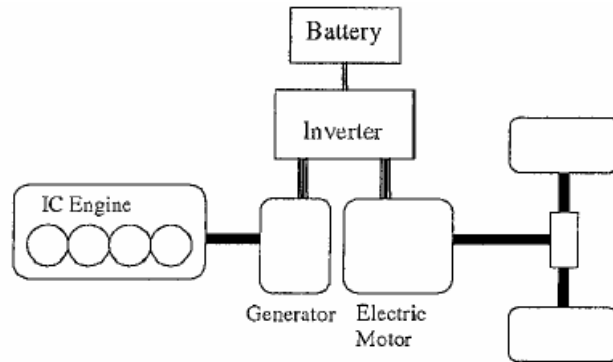


Figure 3a. Series Configuration HEV

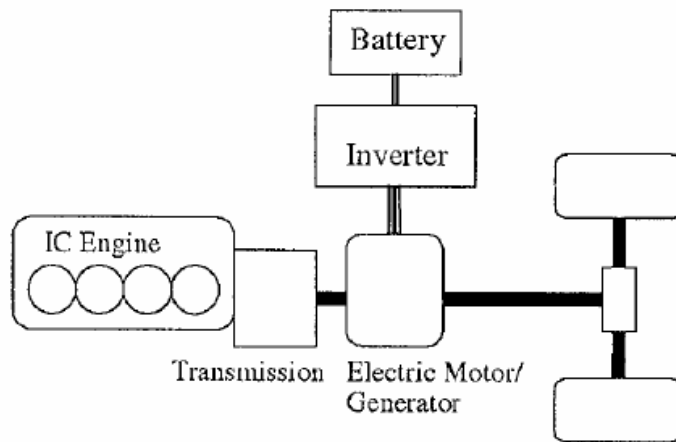


Figure 3b. Parallel Configuration HEV

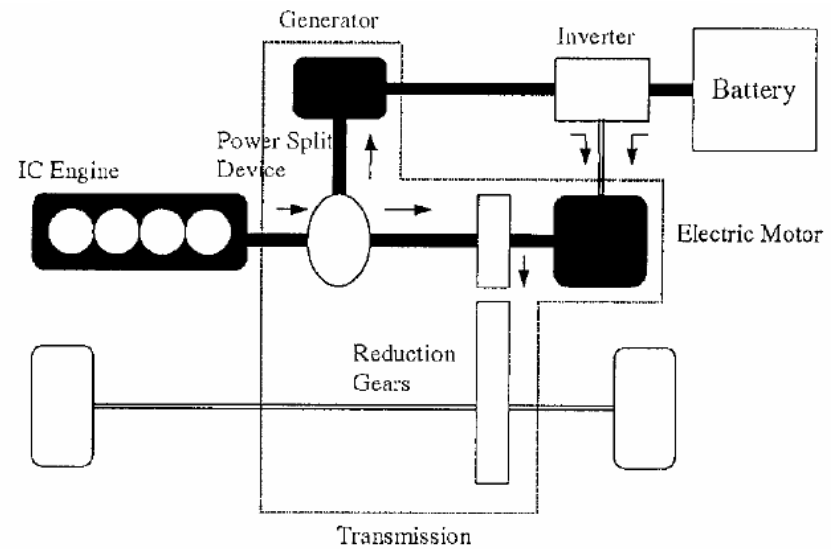


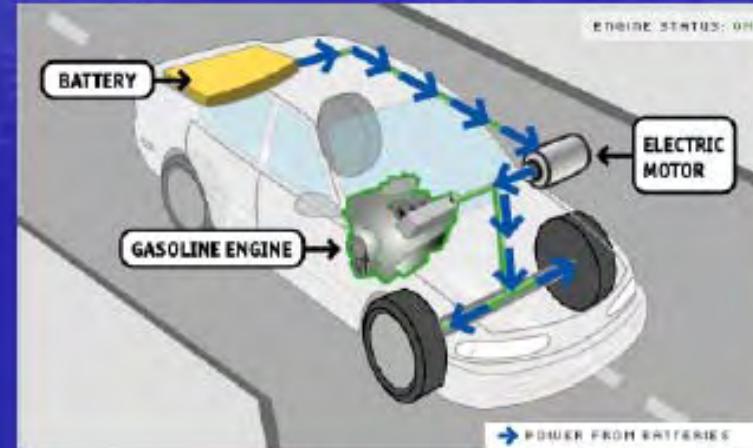
Figure 3c. Power-Split Configuration HEV

# Hybrid-Electric Vehicles (HEVs)

- Literature suggests \$4000 incremental capital cost for a 40% fuel consumption reduction
- Possible penetration in 2020: 75% (for supply curves)



2007 Ford Escape Hybrid



## Plug in hybrid:

- **“*genial*”**
- **40 millas usando solo motor electrico**
- **La mayoria de Americanos viajan un promedio de 30 millas por dia**
- **\$10K costo incremental**
- **“Powered by the sun”**

## *Home Runs*



- **Hybrid technologies: Integrated starter-generator w/idle-off; integrated motor assist; 2-mode hybrids; power split hybrid**
- **Plug-in hybrids**
- **Lightweighting technologies**
- **Lean-burn GDI tech**
- **Homogeneous charge compression engine**
- **Synergistic combinations**

# Batteries



GM Volt

- Biggest remaining challenges:
  - Cost
  - Calendar life
    - (But PHEV 20 → PHEV 16 isn't so bad)

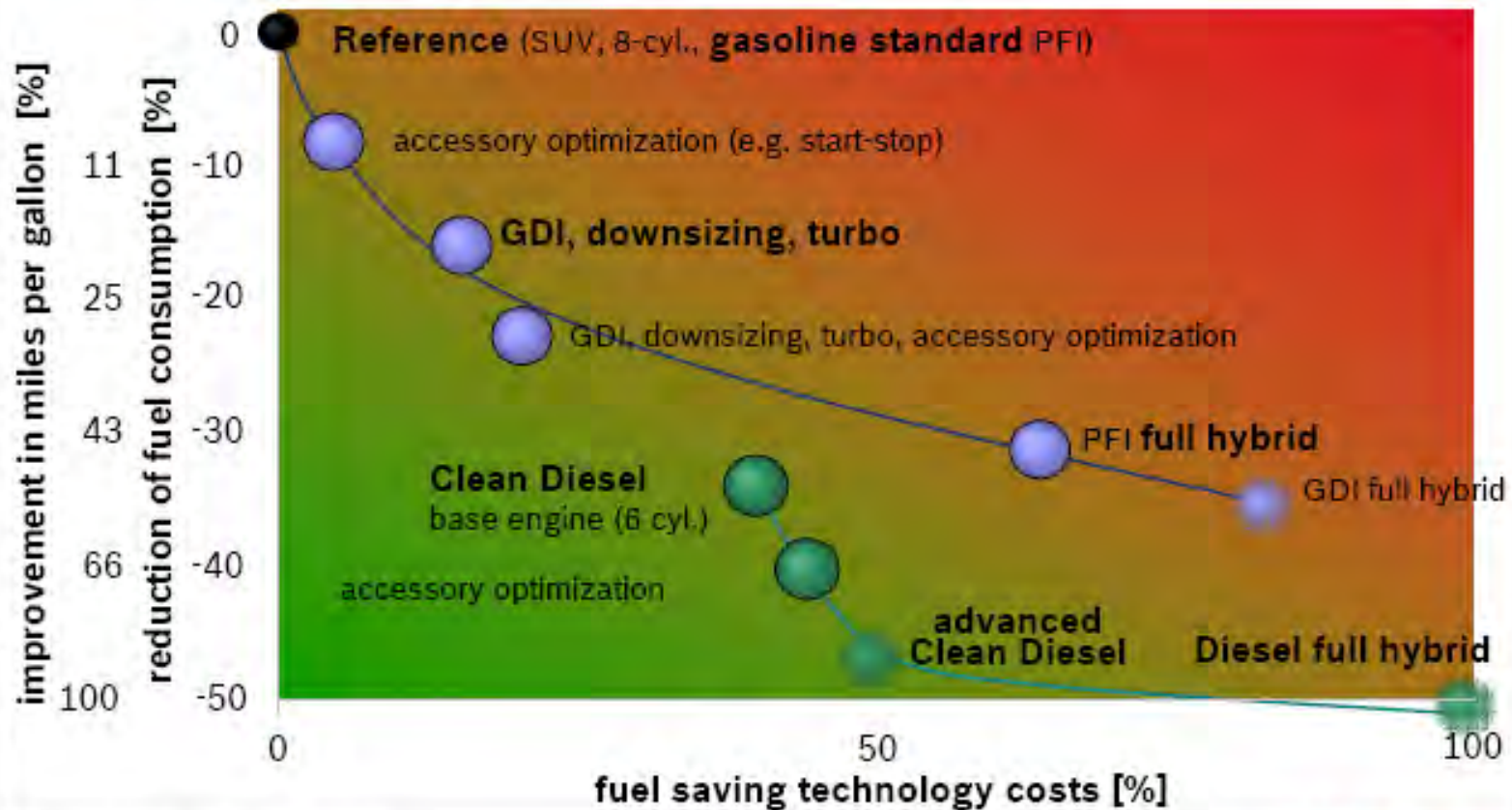


# Battery Comparison Chart

Chemistry	Energy	Power	Cost	Life	Stab. / Safety	Development
LiCoO <sub>2</sub>	+		X		X	+
Li(Ni-Co-Al)O <sub>2</sub> (NCA)	+					
Li(Ni-Co-Mn)O <sub>2</sub> (NCM)	+					
LiMnO <sub>2</sub> (LMS)		+	+	X*		
LiFePO <sub>4</sub>		+	X*	+	+	
Li-Polymer	+	+	+	+	+	X
NiMH	X	X	X	+	+	+
*Potential for improvement						

## Fuel Economy – Clean Diesel with Superior Real-World Performance

### Fuel Economy vs. Costs



Automotive Technology

16

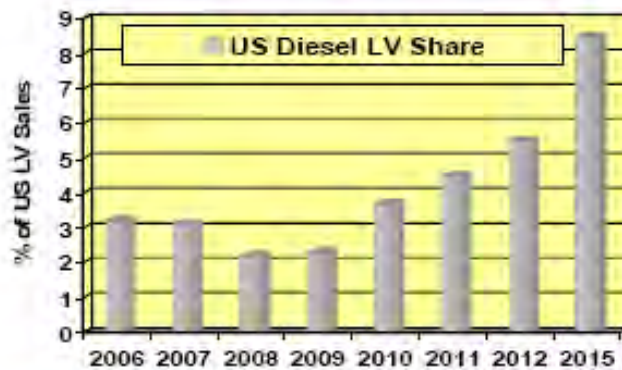
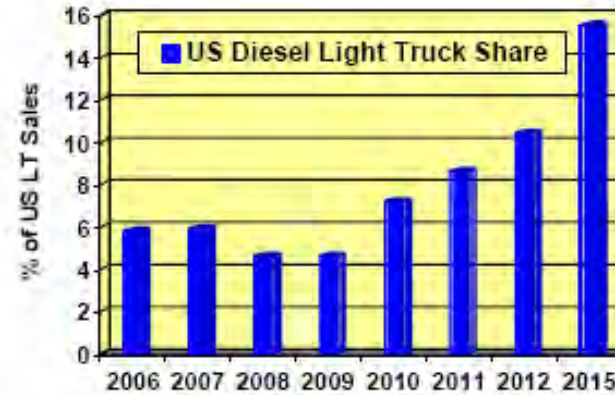
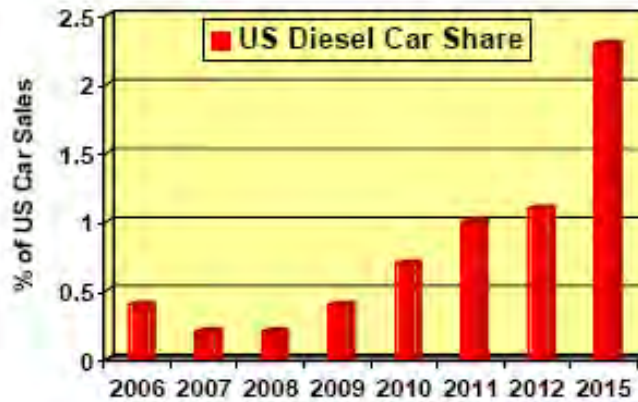
09/VE-NA | November 15, 2008 | 591\_065 | © Robert Bosch GmbH reserves all rights even in the event of industrial property rights. We reserve all rights of disposal such as copying and passing on to third parties.



**BOSCH**

Fuente: J. Rueger, Robert Bosch LLC, SAE Webminar, Meeting the Fuel Economy Challenge, Nov. 2008

# U.S. Diesel Outlook



- Light Truck share is significantly higher than car share; volumes 3-6x higher
- Light duty pickups will be largest diesel segment, followed by SUV/CUVs
- Diesel-gas pump price gap needs to shrink for diesel sales growth to continue
- DPF and urea add to upfront costs
- Our forecast is less optimistic than a year ago, but still bullish

# Vectrix Electric Scooters



[www.vectrix.com](http://www.vectrix.com)

# Hybrids - Hydraulic

- Combines IC engines with pressurized tank & hydraulic motors
- Dual drive system
- Biggest challenges are capacity, weight & cost
- Recovers energy from braking
- Better suited for city driving & large vehicles
- Complex system requirements





# *El futuro de la movilidad personal*

## California Fuel Cell Partnership



**21 vehiculos**



**105,000+ millas**



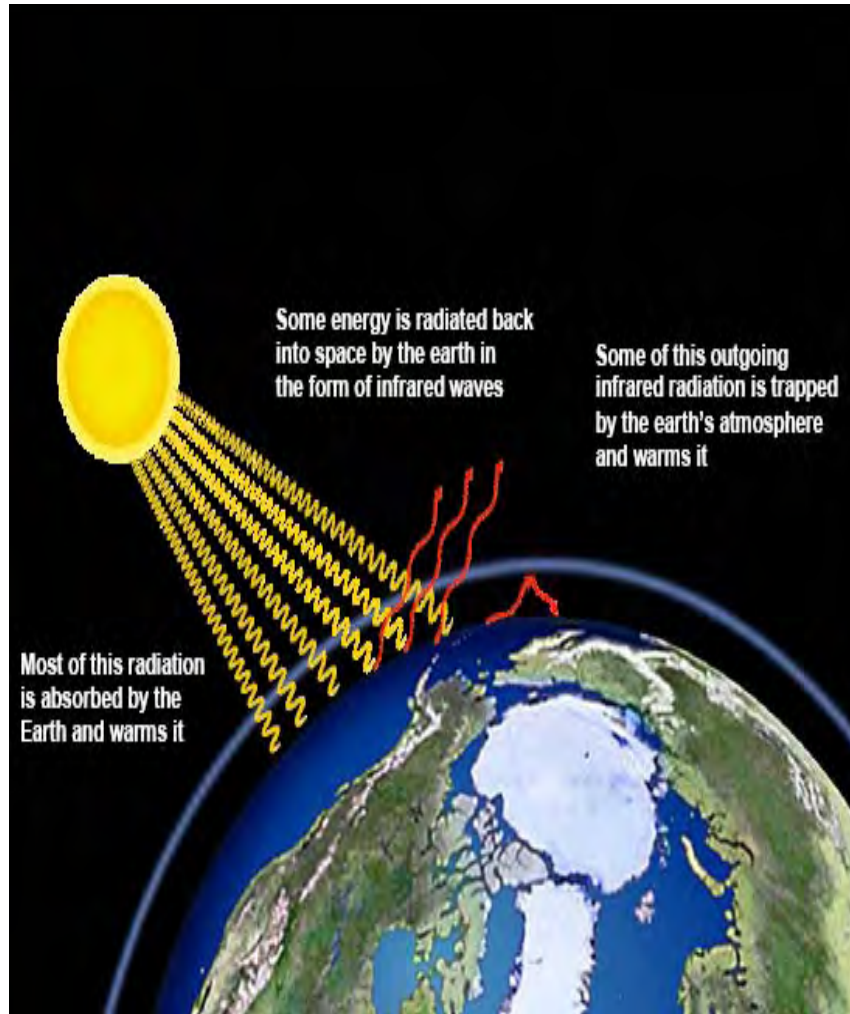
**7,000+ usuarios**

# *Promocion del combustible hidrogeno en California*

Hydrogenhighway.ca.gov



# El Efecto de Invernadero y el Cambio Climático



# El Tema del Cambio Climatico Global en Ecuador

Miércoles 28 enero Medio Ambiente

## Cambios climáticos irreversibles en próximos 1.000 años

AP | WASHINGTON

- Fotos

<http://www.eluniverso.com/2009/01/28/1/1430/BB219543FABE472C900F1CD2ED0DC4...> 2/1/2009

Cambios climáticos irreversibles en próximos 1.000 años - ENE. 28, 2009 - Medio Ambie... Page 2 of 4



[Ampliar imagen](#)

Los daños por el cambio climático son irreversibles, según un estudio.

Inclusive si las emisiones de carbón pueden de alguna manera ser frenadas, las temperaturas alrededor del globo seguirán altas al menos hasta el año 3.000.

"Muchas personas habían imaginado que si cesáramos de emitir anhídrido carbónico el clima retornaría a la normalidad en 100, 200 años. Eso no es cierto", dijo la investigadora de climas Susan Solomon, quien pronosticó problemas cada vez mayores en la atmósfera en los 10 siglos próximos.

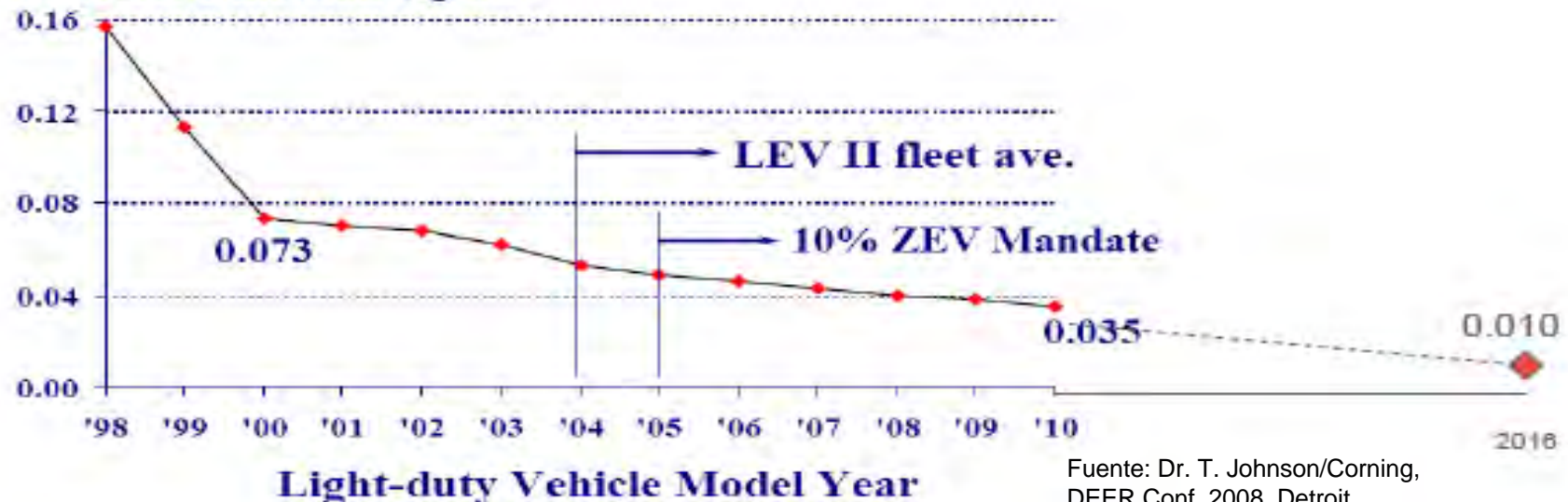
Solomon, del Laboratorio de Investigaciones de la Administración Nacional del Océano y de la Atmósfera en Boulder (Colorado), lideró un equipo de investigadores internacionales que informó de daños irreversibles como resultado del cambio climático. El trabajo fue publicado en la revista especializada Proceedings of the National Academy of Sciences.

La investigadora dijo que define como irreversible un cambio que se mantendrá durante 1.000 años, inclusive si los seres humanos cesan de añadir carbón a la atmósfera de manera inmediata.

# Propuesta LEV III de CARB para Emisiones Criterio y de Impacto Climatico Global

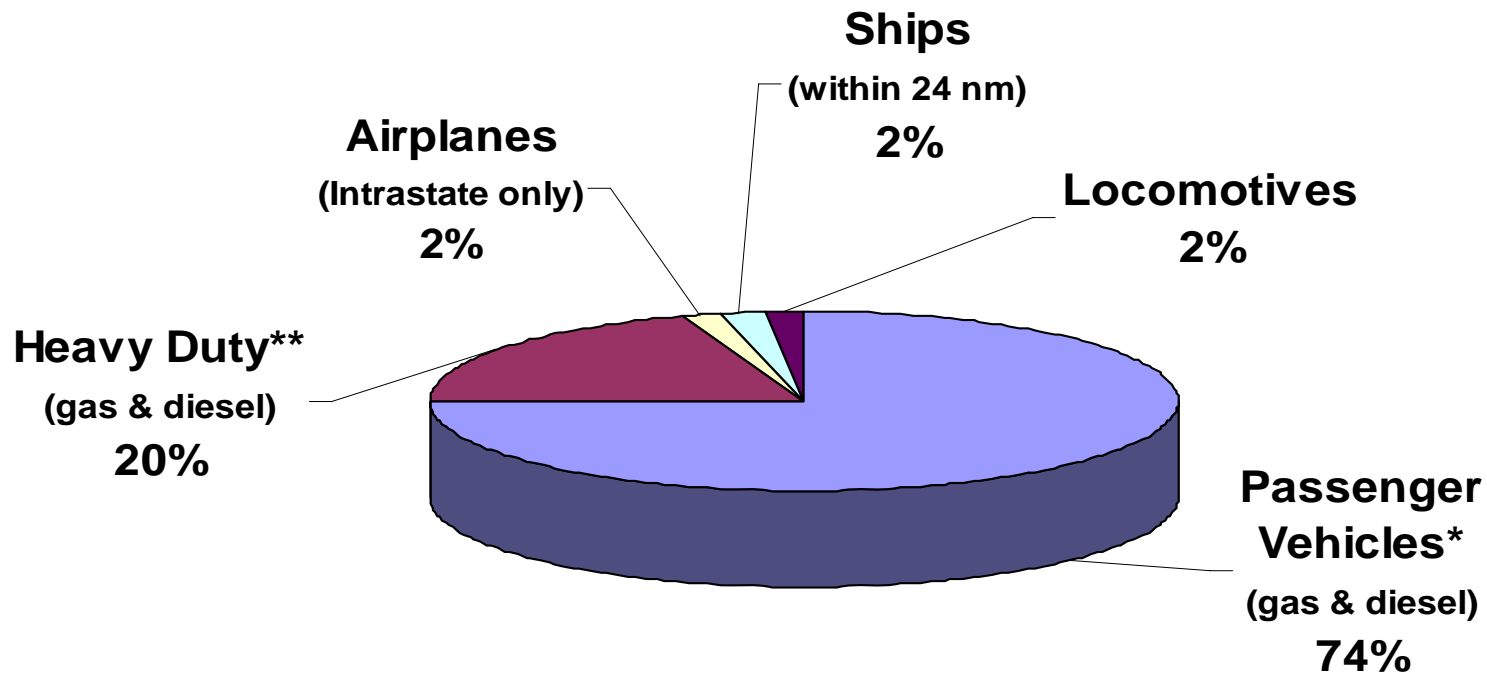
- Limites de emision de efecto invernadero 2009-2016, 2017+
- Aplicacion para emisiones de criterio se expande:
  - PC/LDT1
  - LDT2 (5,751 lbs. LVW – 8,500 lbs. GVW)
  - MDV 8,501 – 14,000 lbs. GVW
- Implementacion
  - 2013 – 2016
- NMOG Fleet Average Equal to SULEV (PC/LDT1 + LDT2)
  - Considering 150,000 mile durability requirement

**FTP NMOG Emissions, g/mi**



Fuente: Dr. T. Johnson/Corning,  
DEER Conf. 2008, Detroit

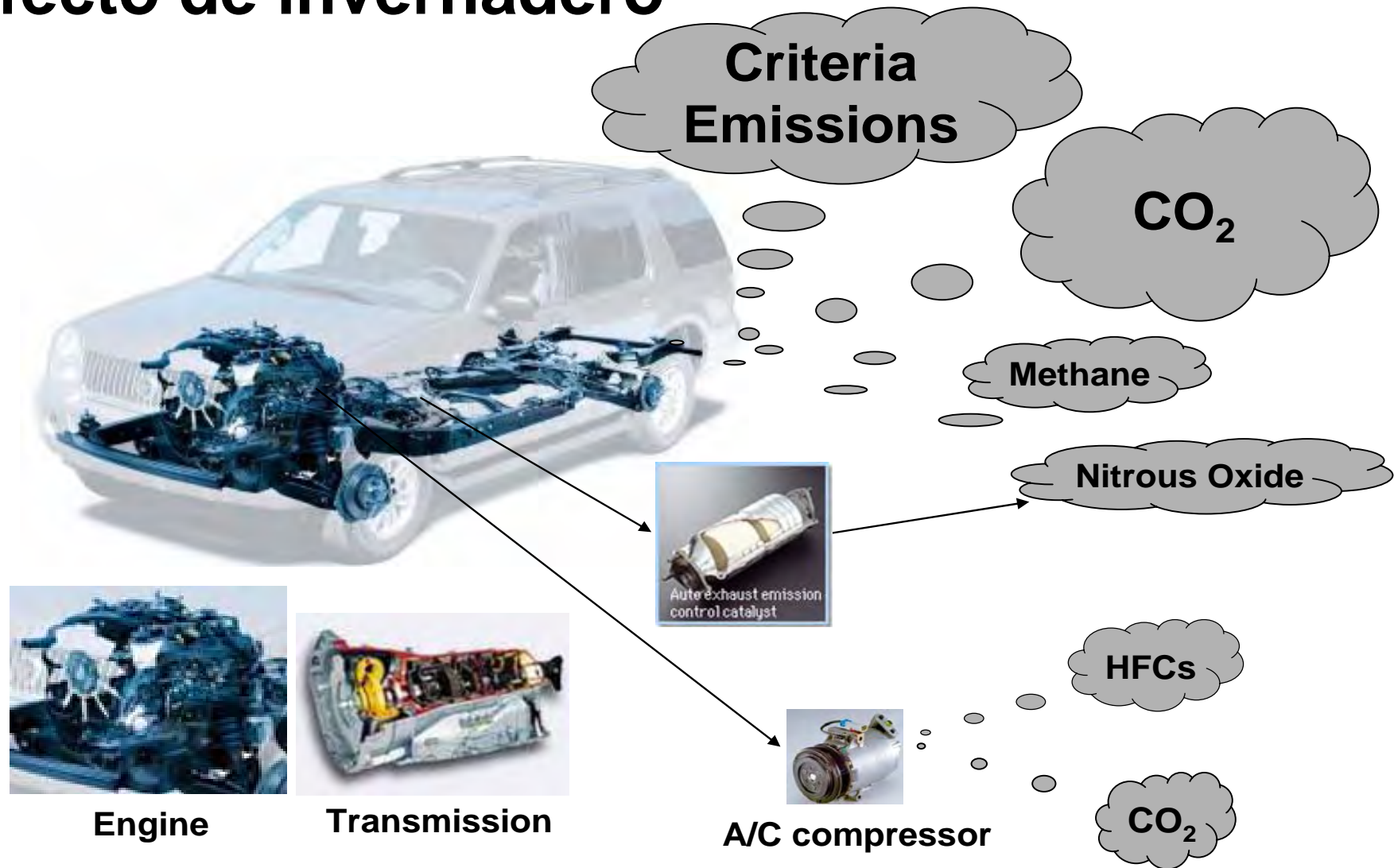
# Transportation Emissions 2004 (182 MMTCO<sub>2</sub>E)

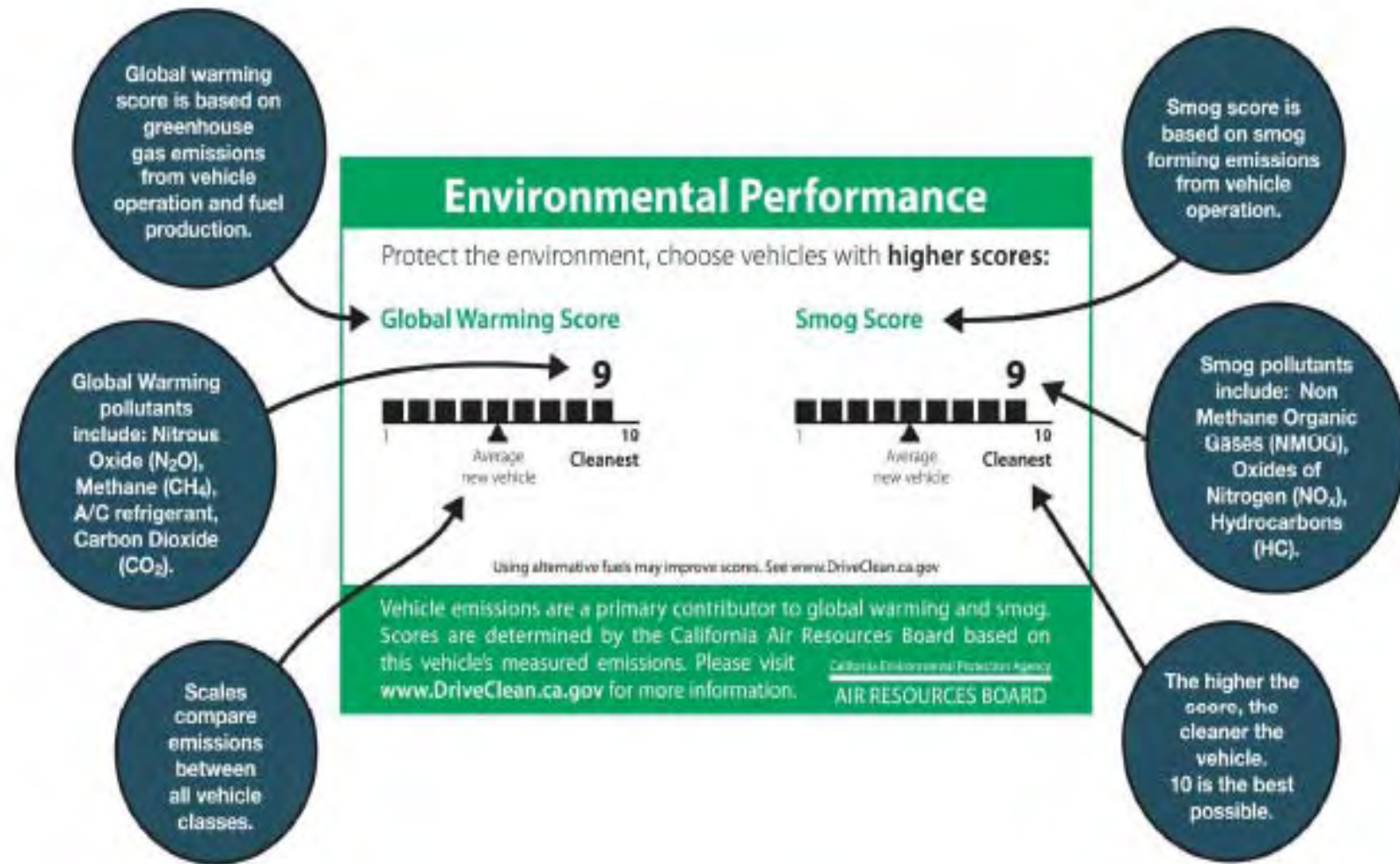


\*Passenger = light duty fleet (passenger cars, motorcycles, light duty trucks & medium duty vehicles with loaded weights of 8500 lbs or less)

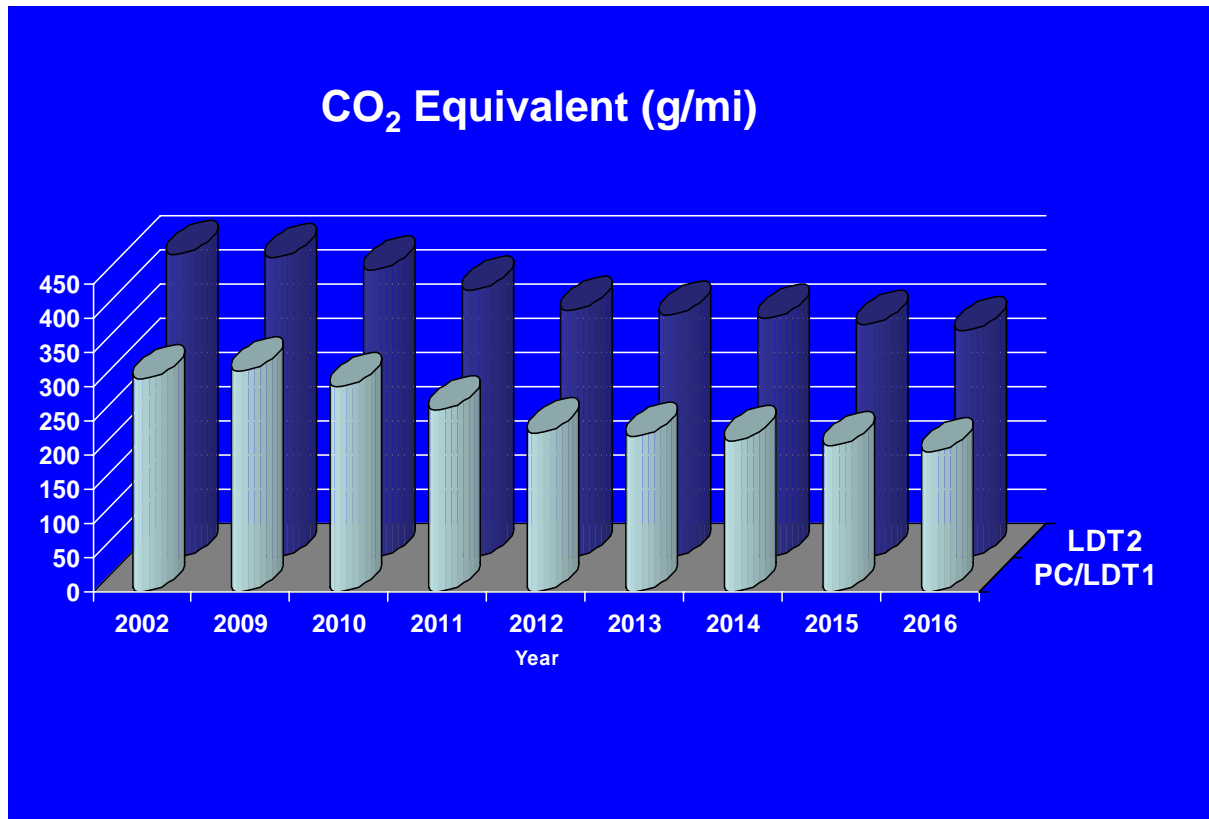
\*\*Heavy duty = heavy duty fleet (light-heavy through heavy-heavy duty trucks, as well as all buses and motorhomes)

# Programa integral de control vehicular de contaminantes del aire y de gases de efecto de invernadero





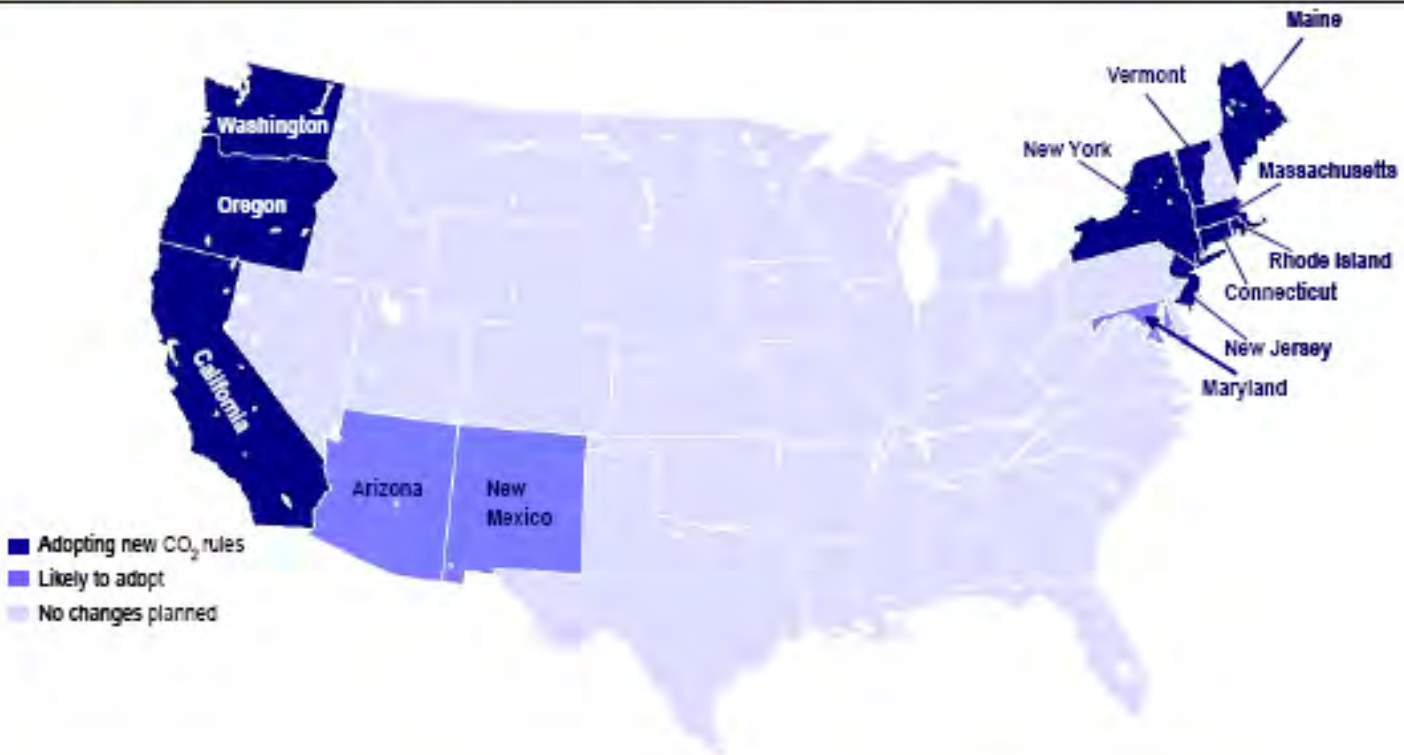
# California GHG Emission Standards



Year	Emission Standard CO <sub>2</sub> e (g/mi)	
	PC/LDT1	LDT2
2009	323	439
2010	301	420
2011	267	390
2012	233	361
2013	227	355
2014	222	350
2015	213	341
2016	205	332

Nuevos limites para modelo 2017+  
en estudio y desarrollo hoy

Figure 1: California and nine other states plan to demand a 30% reduction in vehicle CO<sub>2</sub> output by 2016. These rules will affect more than 30% of vehicles sold in the US. Other states may follow



Source: UBS

# Steady roll-in of existing technologies does the job.



2002 Chevy Impala – 3.4l Overhead Valve Engine



2007 Impala – 3.5l Overhead Valve Engine  
Variable Valve Timing  
310 g/mi CO<sub>2</sub>



By 2016 - Add Continuously Variable Valve Lift  
Integrated Starter/Generator  
~200 g/mi CO<sub>2</sub>



By 2012 - Downsized Turbocharged Engine  
Dual Overhead Cam Engine, Variable Valve Timing,  
Gasoline Direct Injection Improved A/C ~231 g/mi CO<sub>2</sub>

# GHG Technologies Already in Production 2008 Model Year

Technology	Vehicle Model
Variable Valve Timing	Audi: A5, Q5 BMW: 335i, 5 Series, 535i, 535xi, 550, M3, M5 Chrysler: Sebring, Avenger, Caliber, Viper Ferrari: F430 Ford: Taurus, Sable, MKZ GM: Allure, Enclave, CTS, Escalade, SRX, STS, XLR, XLR-V, HHR, Impala, Malibu, Silverado, Suburban, Acadia, Yukon, Hummer H2, G6, Solstice, Vibe, Aura, Outlook, Sky, Vue Honda: Accord, Civic, CR-V, Element, Ridgeline, S2000 Hyundai: Genesis, Sonata, Magentis, Rio, Sedona, Spectra Land Rover: LR2 Maserati: GranTurismo Mitsubishi: Eclipse, Lancer Nissan: EX, FX45, G37, Altima, Versa Porsche: Cayenne Rolls-Royce: 101EX Subaru: Legacy, Tribeca Toyota: LS 600h L, RX 350, Matrix, Scion xB, Scion xD Volvo: C30, XC70
Variable Valve Lift	Audi: A5 BMW: 5 Series, 550 Honda: Civic, CR-V, Element, S2000 Nissan: G37 Subaru: Outback, Legacy, Impreza
GDI	Audi: A3, A4, A5, A6, Q5, Q7 gasoline, R8, RS4, TT BMW: 335ci, 335i, 335xi, 535i, 535xi, 550 GM: CTS, STS, HHR, Solstice, Sky Mazda: CX-7, Speed3 Porsche: 911, Cayenne Toyota: IS-F, LS 600h L Volkswagen: EOS, GTI, Jetta, Passat, Touareg

# GHG Technologies Already in Production 2008 Model Year (cont'd)

Turbocharging/Supercharging	<p>Audi: A3, A4, Q5, Q7 diesel, TT          Bentley: Arnage, Azure          BMW: 335i, 5 Series, 535i, 535xi, 550          Bugatti: Veyron          Chrysler: PT Cruiser, Caliber          Ford: Shelby GT500          GM: SRX, STS, XLR-V, HHR, Solstice, Corvette, Sky          Jaguar: S-Type, Super V8, XJR, XKR          Land Rover: LR2          Mazda: CX-7, Speed3          Mercedes: C Class, CL65 AMG          Mitsubishi: Lancer Evolution X          Porsche: 911, Cayenne Turbo          Saab: 9-3, 9-5          Subaru: Forester, Impreza, Legacy, Outback, WRX          Volkswagen: EOS, GTI, Jetta, Jetta TDI, Passat, Touareg2          Volvo: C30, S80</p>
5-Speed Automatic Transmission	<p>Chrysler: Dakota, Magnum          Ford: Explorer, Taurus          GM: SRX, Equinox, G8, Solstice, Torrent, Sky          Honda: Accord, Civic          Hyundai: Sonata, Amanti, Magentis, Sedona, Sorento          Mazda: B-series pickup          Mercedes: CL65 AMG          Mitsubishi: Eclipse Spyder          Nissan: EX, FX35, FX45, G37, QX56, Armada, Pathfinder, Titan          Saab: 9-3, 9-5          Subaru: Legacy, Tribeca          Toyota: RX 350, Highlander, Highlander hybrid, Sequoia          Volkswagen: Microbus          Volvo: C30</p>

# GHG Technologies Already in Production 2008 Model Year(cont'd)

6-Speed Automatic Transmission	<p>Aston Martin: Rapide  Audi: Q7 (diesel), R8, TT  BMW: 335i, 335xi, 5 series, 550  Chrysler: Sebring, Toun&amp;Country, Avenger, Caravan, Grand Caravan  Ferrari: F430  Ford: Explorer, Five Hundred, Fusion, Taurus, Taurus X, MKS, MKZ, Navigator, Sable  GM: Enclave, CTS, Escalade, SRX, STS, XLR, XLR-V, Equinox Sport, Malibu, Silverado, Suburban, Acadia, Yukon, Hummer H2, G6 GXP, G8, Torrent, Aura XR, Outlook, Vue  Honda: Accord  Hyundai: Genesis  Jaguar: S-Type, Super V8, Vanden PLAS, XJ8, XJR  Land Rover: LR2  Maserati: GranTurismo  Mazda: CX-7, CX-9, Mazda6  Mitsubishi: Lancer Evolution X  Porsche: Cayenne  Saab: 9-3  Rolls-Royce: 101EX, Phantom Drophead  Toyota: Sequoia, Tundra  Volkswagen: R32, Touareg  Volvo: XC70</p>
7-Speed Automatic Transmission	<p>Audi: TT  Mercedes: C Class, CL63 AMG, ML550, S63 AMG</p>
8-Speed Automatic Transmission	<p>Toyota: IS-F</p>
Automated Manual Transmission	<p>Aston Martin: Vantage Roadster  BMW: 550, M3  Mitsubishi: Lancer Evolution X  Porsche: 911  Volkswagen: Jetta TDI</p>
Continuously variable Transmission	<p>Audi: A5  Chrysler: Aspen Hybrid, Durango Hybrid  Ford: Escape Hybrid, Taurus X, Mariner Hybrid  Mitsubishi: Lancer  Nissan: Altima, Rogue, Versa  Toyota: LS 600h L, Corolla, Highlander Hybrid, Prius</p>

# GHG Technologies Already in Production 2008 Model Year (cont'd)

Cylinder Deactivation	<p>Chrysler: Aspen Hybrid, Durango Hybrid, Magnum, Allure, GM: LaCrosse Super, Escalade Hybrid, Avalanche, Impala, Suburban, Tahoe, Tahoe Hybrid, Yukon, Yukon Hybrid, G8, Envoy Denali, Grand Prix</p> <p>Honda: Accord Saab: 9-7</p>
Dual Overhead Cam	<p>Aston Martin: Rapide, Vantage Roadster Audi: A5, A8, R8, TT BMW: 335i, 335xi, 5 Series, 535i, 535xi, 550, M5 Chrysler: Sebring, Avenger Ferrari: F430 Ford: Escape, Escape Hybrid, Fusion, Shelby GT500, Taurus, Taurus X, MKZ, Mariner, Mariner Hybrid, Sable GM: Allure, Enclave, Lucerne, CTS, DTS, SRX, STS, XLR, XLR-V, Aveo, Colorado, HHR, Malibu, Optra, TrailBlazer, Acadia, Canyon, Envoy, Hummer H3, G6, G8, Solstice, Vibe, Wave, Astra, Aura, Outlook, Sky, Vue Honda : CR-V, S2000 Hyundai: Genesis, Sonata, Amanti, Magentis, Rio, Sorento, Spectra Jaguar: S-Type, Super V8, Vanden PLAS, XJ8, XJR Land Rover: LR2 Maserati: GranTurismo Mazda: CX-7, CX-9, Mazda 6, Tribute Mercedes: C-Class, CL63 AMG, ML550, S63 AMG Mitsubishi: Lancer, Lancer Evolution X Nissan: EX, FX35, FX45, G37, QX56, Altima, Armada, Pathfinder, Rogue, Titan, Versa Porsche: Cayenne Rolls-Royce: 101EX Saab: 9-3, 9-5 Subaru: Tribeca Toyota: IS-F, LS 600h L, RX 350, Matrix, Scion xB Volkswagen: Touareg Volvo: C30</p>

# GHG Technologies Already in Production 2008 Model Year (cont'd)

E85 Flex Fuel	<p>Chrysler: Aspen, Sebring, Avenger, Town&amp;Country, Durango, Ram 1500, Dakota, Caravan, Magnum, Grand Cherokee, Commander</p> <p>Ford: Crown Victoria, F150, Grand Marquis, Town Car</p> <p>GM: Terraza, Silverado, Avalanche, Suburban, Tahoe, Express, Impala, Sierra, Yukon, Savana, Montana, Relay</p> <p>Nissan: Armada</p>
Electrohydraulic and Electric Power Steering	<p>Ford: Escape</p> <p>GM: Mariner, Mariner Hybrid, Vue</p> <p>Mazda: Mazda3</p> <p>Nissan: Rogue</p> <p>Toyota: Prius, Highlander Hybrid, Yaris, Scion xB</p>



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