Policy Background and Future Directions in the US and Europe

HEI Workshop on Effects of Fuel Composition on PM

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International Council on Clean Transportation
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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Overview

- Light-Duty efficiency requirements worldwide
- Biofuel policies and particulate impacts
- Compliance challenges and CO_2/fuel consumption shortfall
- Gasoline engine efficiency improvements (why GDI)
- Summary

Fuel Economy/CO_2 Standards State of the World 2016

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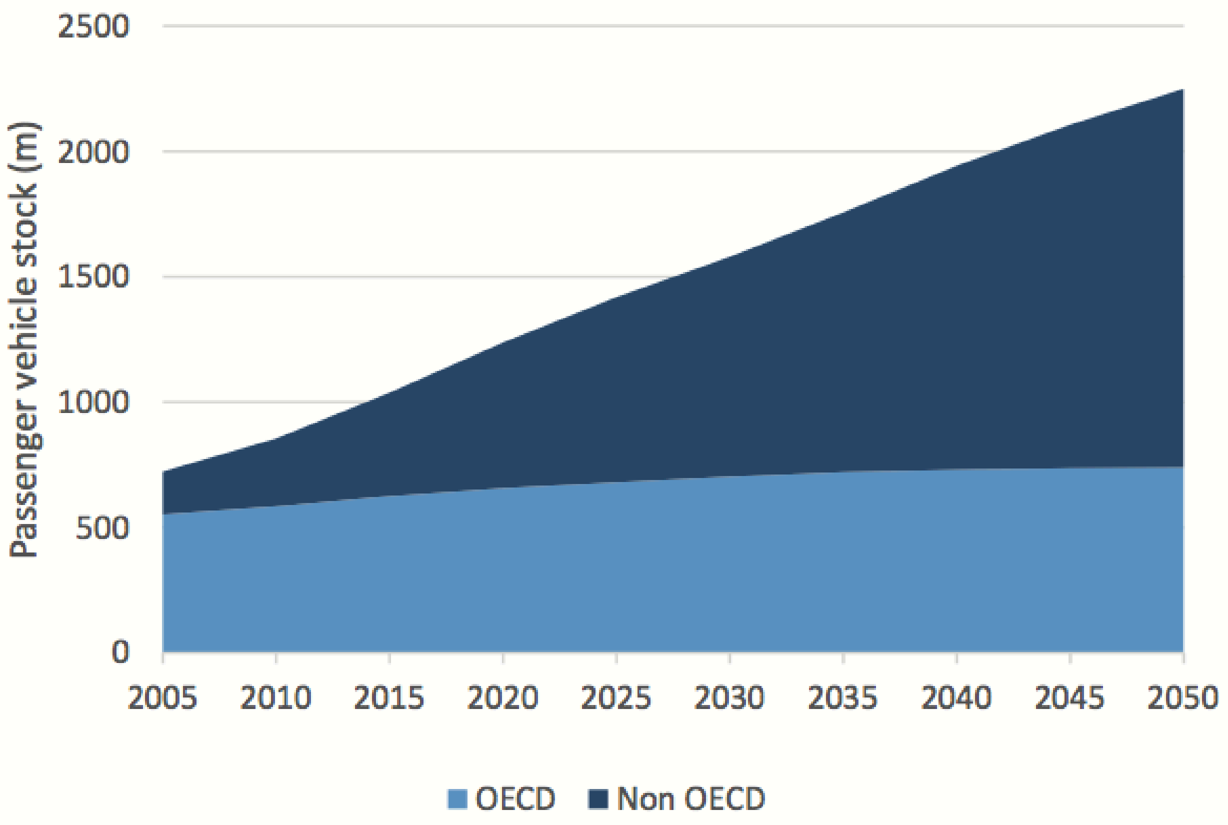
Global car stock to 2050

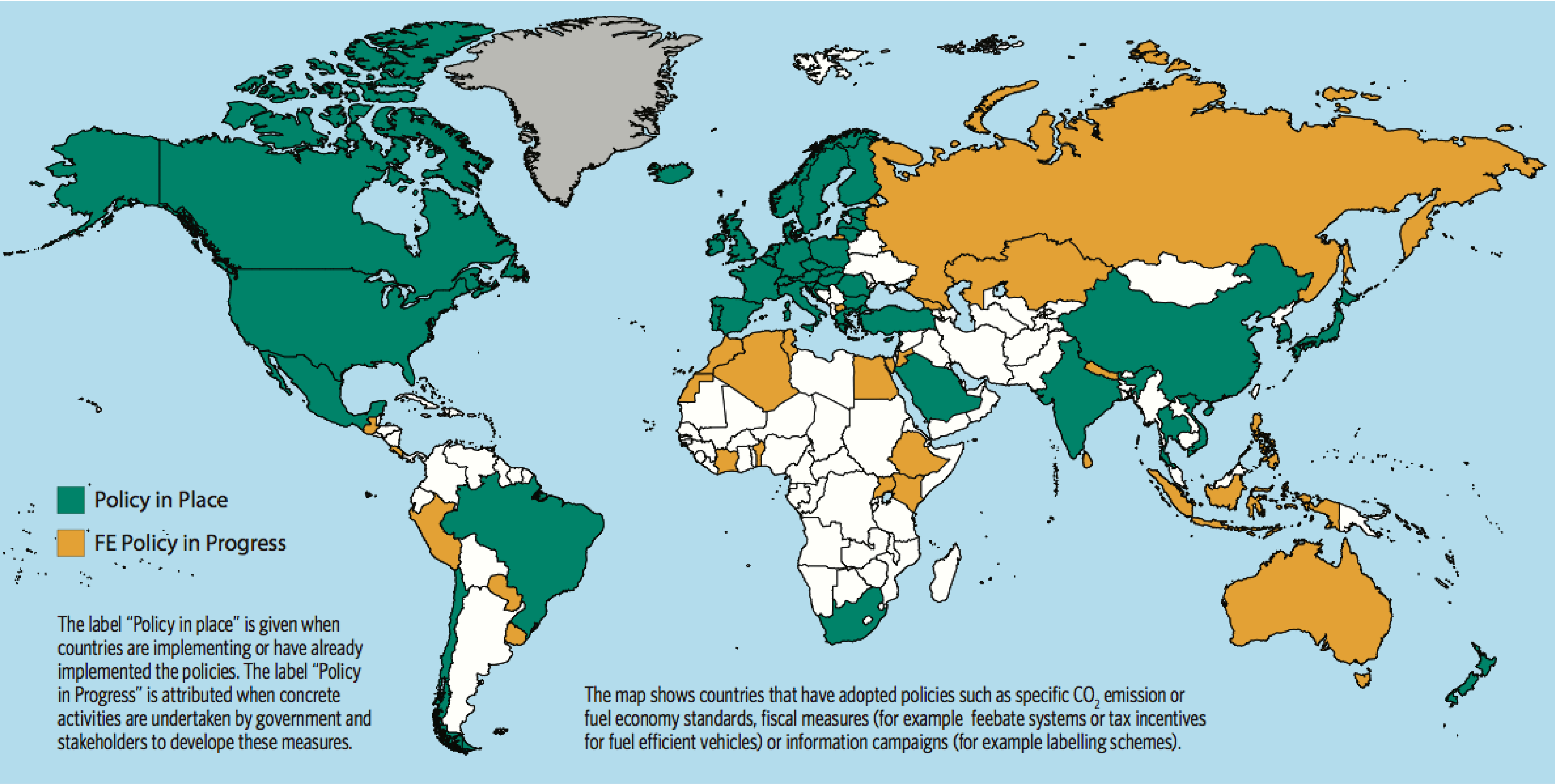
FIGURE 1 Global passenger light duty vehicle stock out to 2050



Source: IEA ETP 2015 (IEA 2015)

KEY MESSAGE ▪ THE GLOBAL PASSENGER LIGHT DUTY VEHICLE STOCK IS EXPECTED TO ALMOST TRIPLE BETWEEN NOW AND 2050.

UNEP Policy Progress Map



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Fuel economy standards around the world

Table 1. Comparison of the latest adopted regulations for light- and heavy-duty efficiency in selected regions

		Light-duty vehicles			Heavy-duty vehicles		
Region[a]	Percent of world vehicle sales, 2013	Baseline model year[b]	Implementation period (model year)	Reduction in average CO_2 rate (grams/vehicle-km)	Baseline model year	Implementation period (model year)	Reduction in average CO_2 rate (grams/vehicle-km)
China[c]	25%	2011	2012-2015	9%	2012	2014-2015	11%
EU	19%	2015	2020-2021	27%			0%
US	17%	2017	2017-2025	35%	2011	2014-2018	14%
Japan	6%	2015	2020	16%	2006	2015	12%
Brazil[d]	4%	2013	2013-2017	12%			0%
India	4%	2012	2017-2021	17%			0%
Russia	3%			0%			0%
Canada[e]	2%	2011	2011-2016	20%	2011	2014-2018	14%
South Korea	2%	2011	2012-2015	9%			0%
Australia	1%			0%			0%
Mexico	1%	2012	2014-2016	13%			0%

Adopted or newly implemented between Jan. 2013 and Aug. 2014 | Adopted or implemented prior to Jan. 2013

[a] Includes eleven major vehicle markets

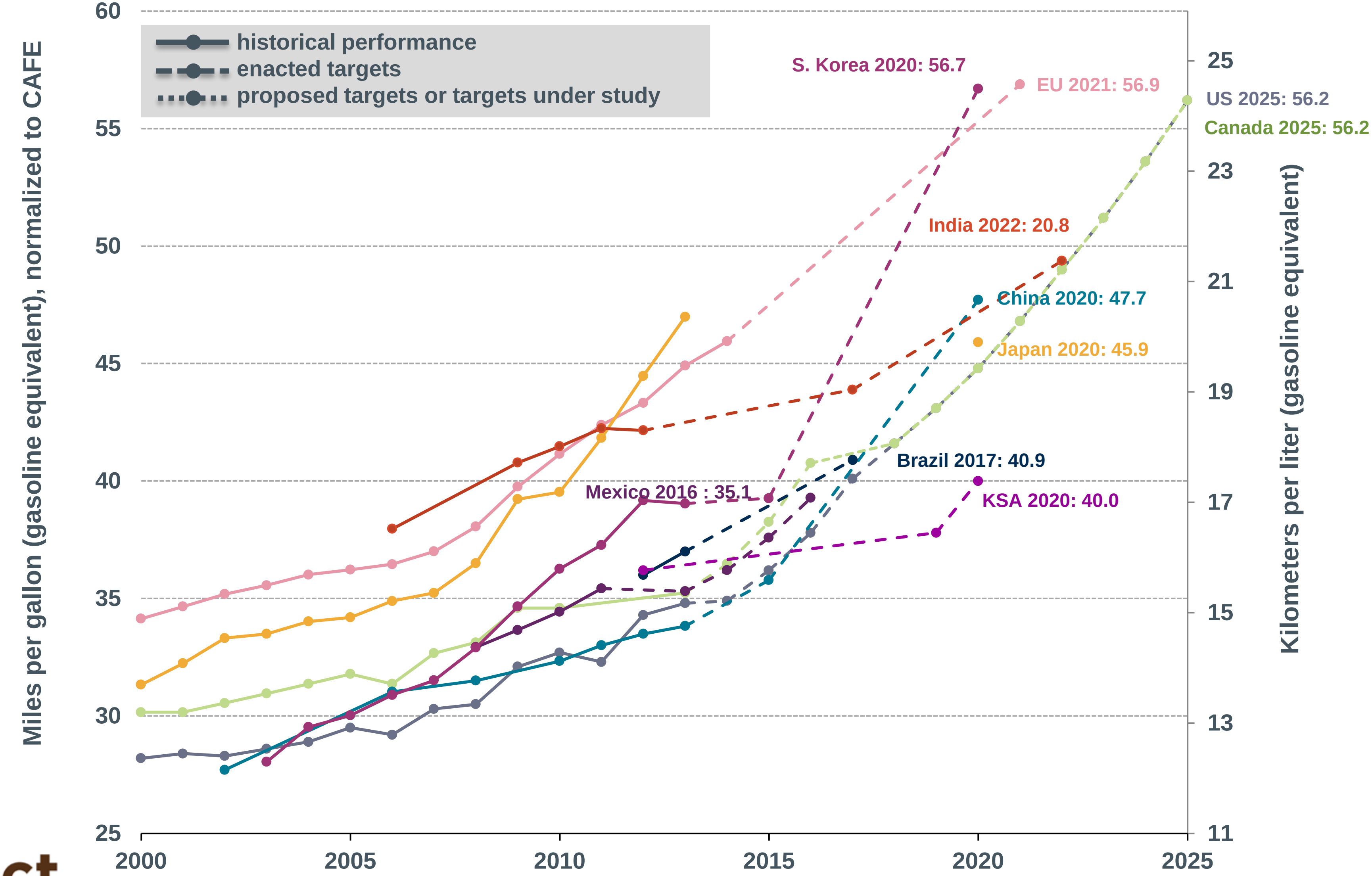
[b] Percent reduction in new fleet fuel consumption estimated from a baseline year (determined by expert judgment rather than regulatory requirement) to the final model year covered by the regulation. Reductions for HDVs are activity-weighted by vehicle type.

[c] China has adopted separate standards for passenger cars and light commercial vehicles. The latest adopted standard for passenger cars (Phase 3) is summarized here.

[d] Brazil's Inovar-Auto program requires a 12.1% improvement for manufacturers to qualify for a 30% reduction in vehicle sales tax.

[e] Canada has announced intention to harmonize with the US 2017-2025 GHG standards; however formal adoption has not occurred as of August 2014.

Status of LDV (car) fuel economy standards, normalized to U.S. CAFE



Source: http://www.theicct.org/global-pv-standards-chart-library

Fuel Economy Standards
Consumer cost and payback

Rule	Per-Vehicle Cost	Payback Period
US LDV 2017–2025	$1,800 (avg. 2025)	3.5 years
US LDV 2012–2016	$950 (avg. 2016)	3 years
Canada LDV 2017-2025	$707 (2021); $2,095 (2025)	2 to 5 years
Canada LDV 2011-2016	$89 (2011); $1,195 (2016)	1.5 years
European 95g CO2/km Standard 2020	€1,300	4-5 years
India LDV 2020	$478 to $637	2–3 years

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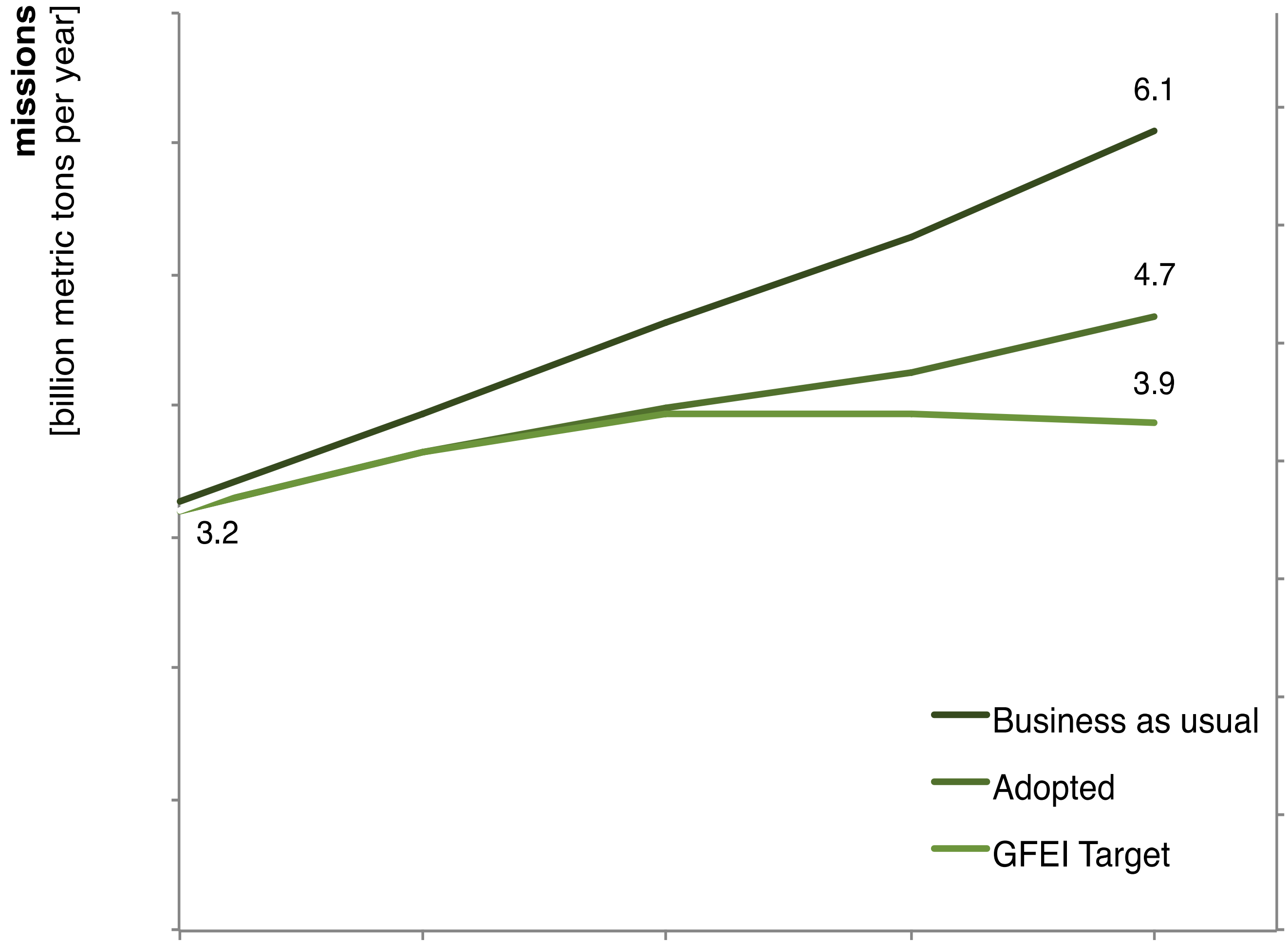
Meeting GFEI target will stabilize global CO_2 emissions

GFEI Target
Standards reduce average fuel consumption of new vehicles to 50% below 2005 levels by 2030



*Estimated using ICCT's [Global Transportation Roadmap model] (Facanha, et al., 2012). **Business as usual** = vehicle efficiency remains at 2005 levels. **Adopted** = currently adopted policies.*

Biofuel Policies and PM Impacts

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US Renewable Fuel Standard (RFS)

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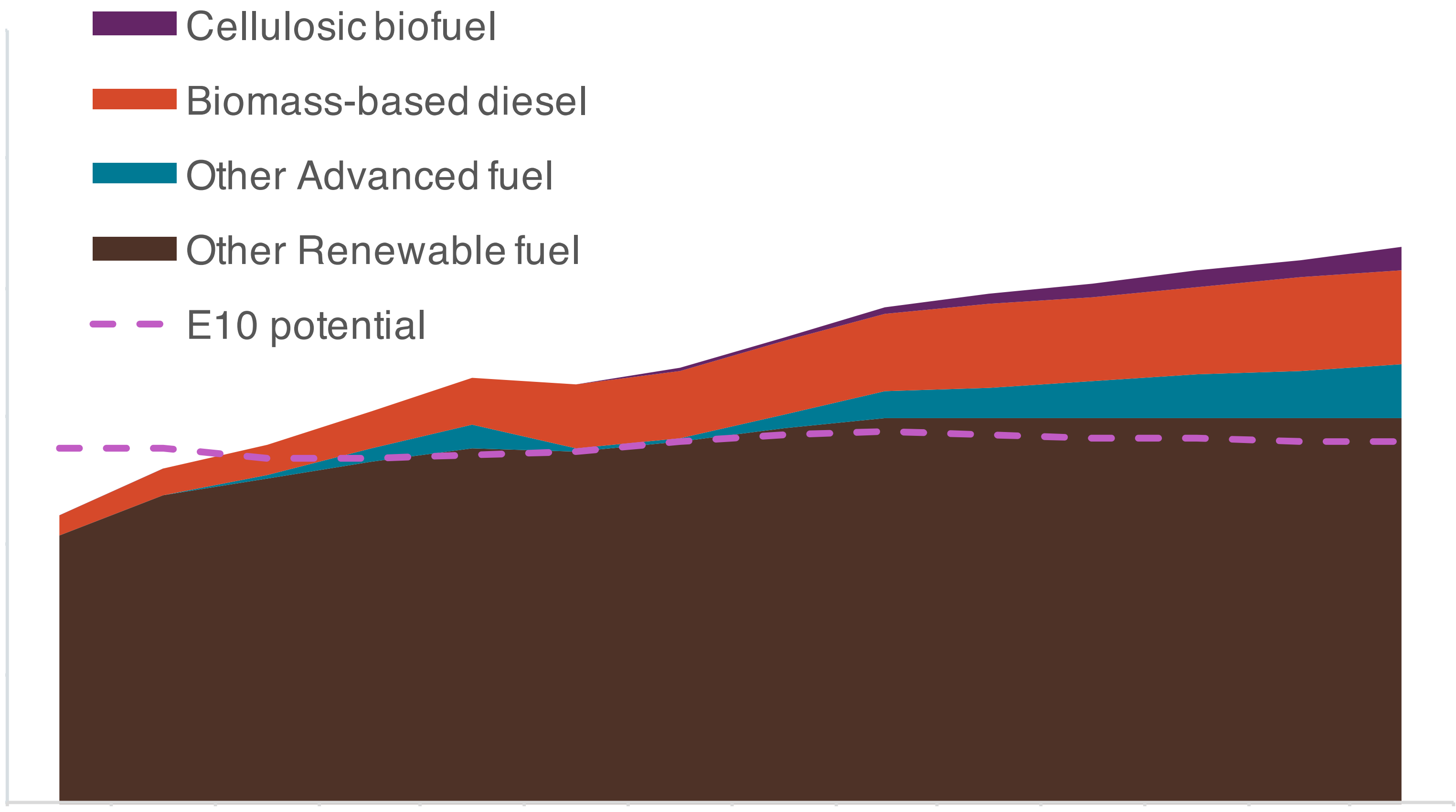
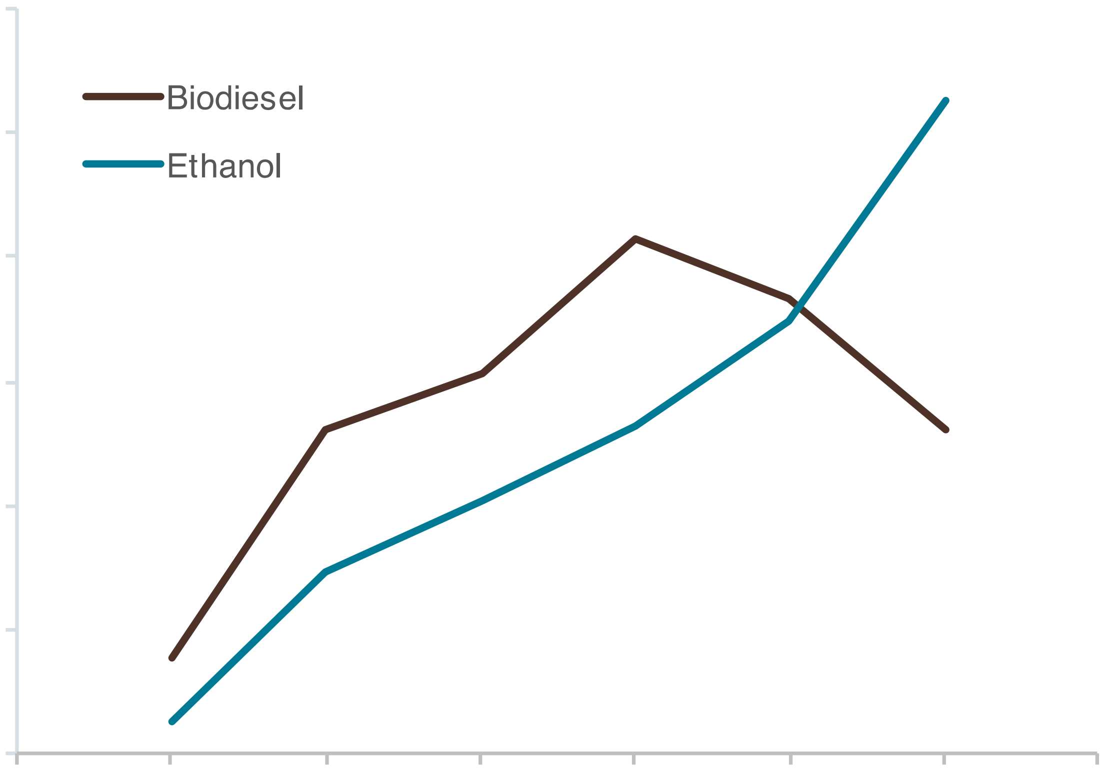


EU Renewable Energy Directive (RED) and Fuel Quality Directive (FQD)



RED: 10% renewable energy blending in transport fuels in 2020; 7% cap on support for food-based biofuels

FQD: 6% GHG reduction target in 2020

RED II: proposal for advanced biofuels in 2030 including cellulosic ethanol and some waste-based biodiesel; 3.8% cap on support for food-based biofuels

Biofuel blend levels

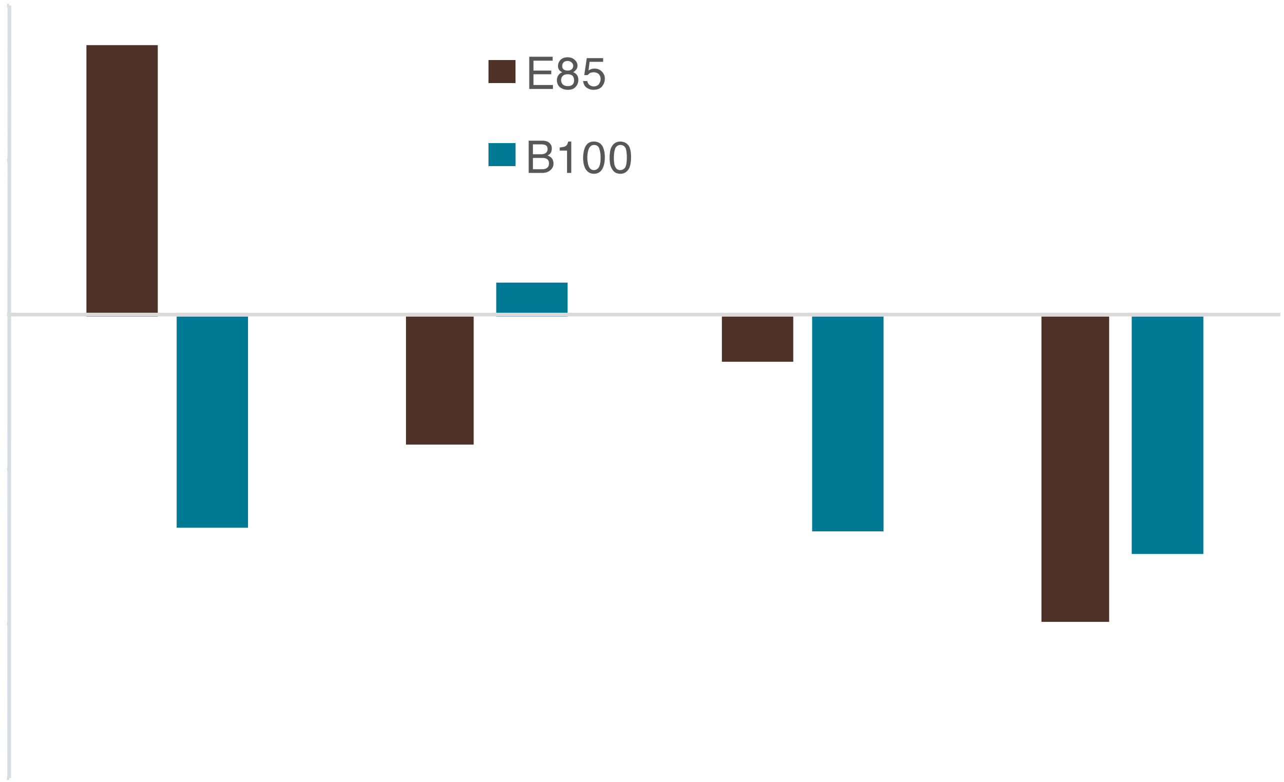
Ethanol

- US: RFS ensures all gasoline is E10, but not a very strong driver for higher ethanol blends
- EU: Cellulosic ethanol support will likely raise ethanol blends to E10, with some E85
- Some interest in higher octane value of ethanol blends
  - But enormous financial and practical barriers to expanding compatible infrastructure for E15-E85, even with government support for E85 pumps

Biodiesel

- US: RFS not major driver beyond B5 in most places
- California: LCFS likely expands B5 and B20
- EU: B7 common but biodiesel support will likely decline after 2020 as most biodiesel is food-based

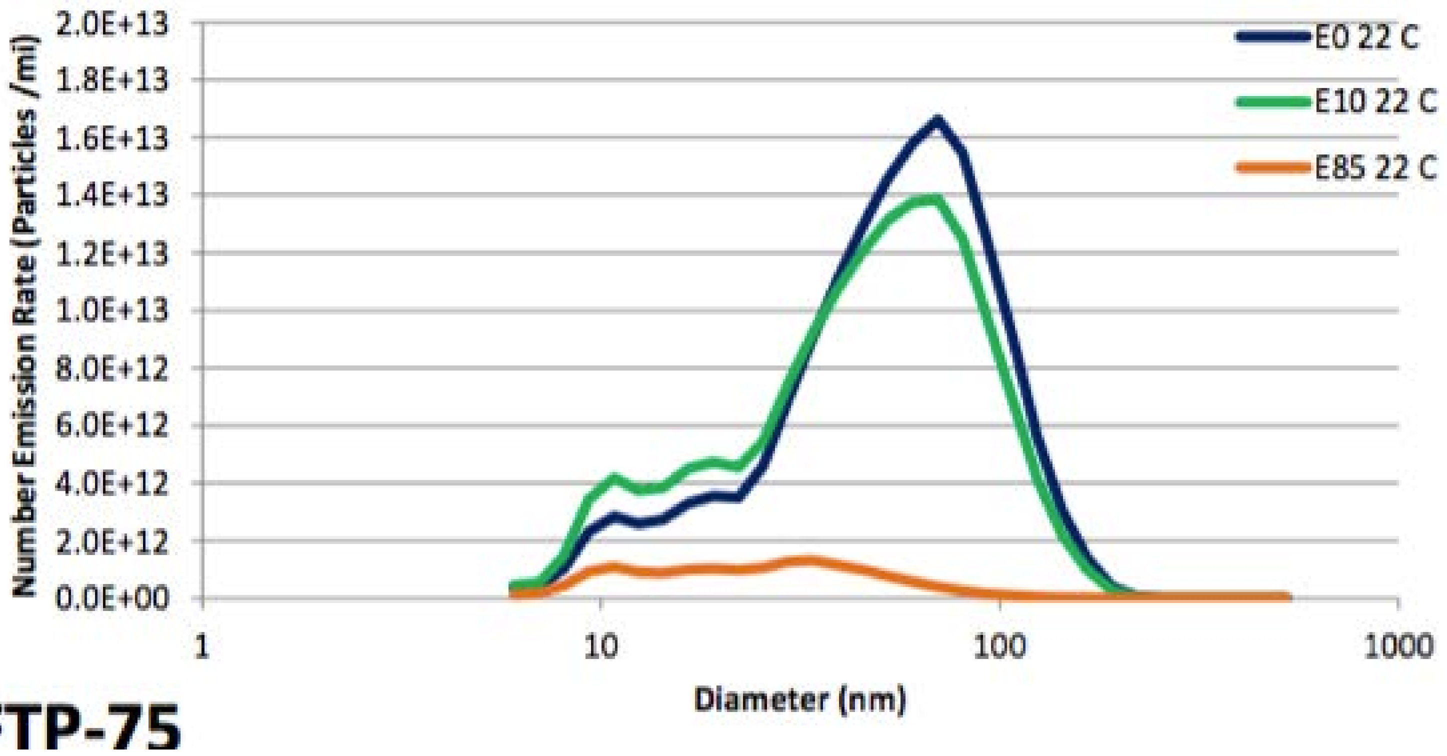
High biofuel blends have large reductions in particulate mass emissions



Source: EPA 2010 (RFS impact analysis)
Estimated from: EPA 2002 (Biodiesel impacts on exhaust emissions report)

Average particle number size distributions for a GDI engine using E0, E10 and E85 fuels over FTP-75

E85 may reduce PM emissions in the range of 70-90% between E85 and E0



Source: Rosenblatt, Morgan, McConnell, Nuottimaki, 2015

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Implications of biofuel policy on PM

- Policies in US and EU have not been major drivers of biofuel blends beyond 5-10%
  - These policies may result in modest volumes of E85 consumed with much lower PM compared to gasoline
- High biodiesel blends not likely to be common in either US or EU
  - Small quantities of B20 and B100 with lower PM
- Drop-in gasoline and diesel biofuel production may increase, especially with the EU's proposed 2030 targets
  - Little impact on PM

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Compliance Challenges

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US and EU Light-Duty Particulate Standards

	US Tier 2 (diesel only)	US Tier 3 (diesel and gasoline)		California 2025-28 Phase-in	Euro 6c (diesel and GDI)	
		FTP	US06		NEDC	RDE (proposed)
PM mass (mg/km)	6.2	1.9	3.7	0.6	4.5	**X**
PN (#/km)	**X**	**X**	**X**	**X**	6.0×10^{11}	9.0×10^{11}

GDI PN on NEDC: 6.0×10^{12}/km within first three years of Euro 6 effective dates

US06: High speed/acceleration cycle

RDE: Real-driving emissions

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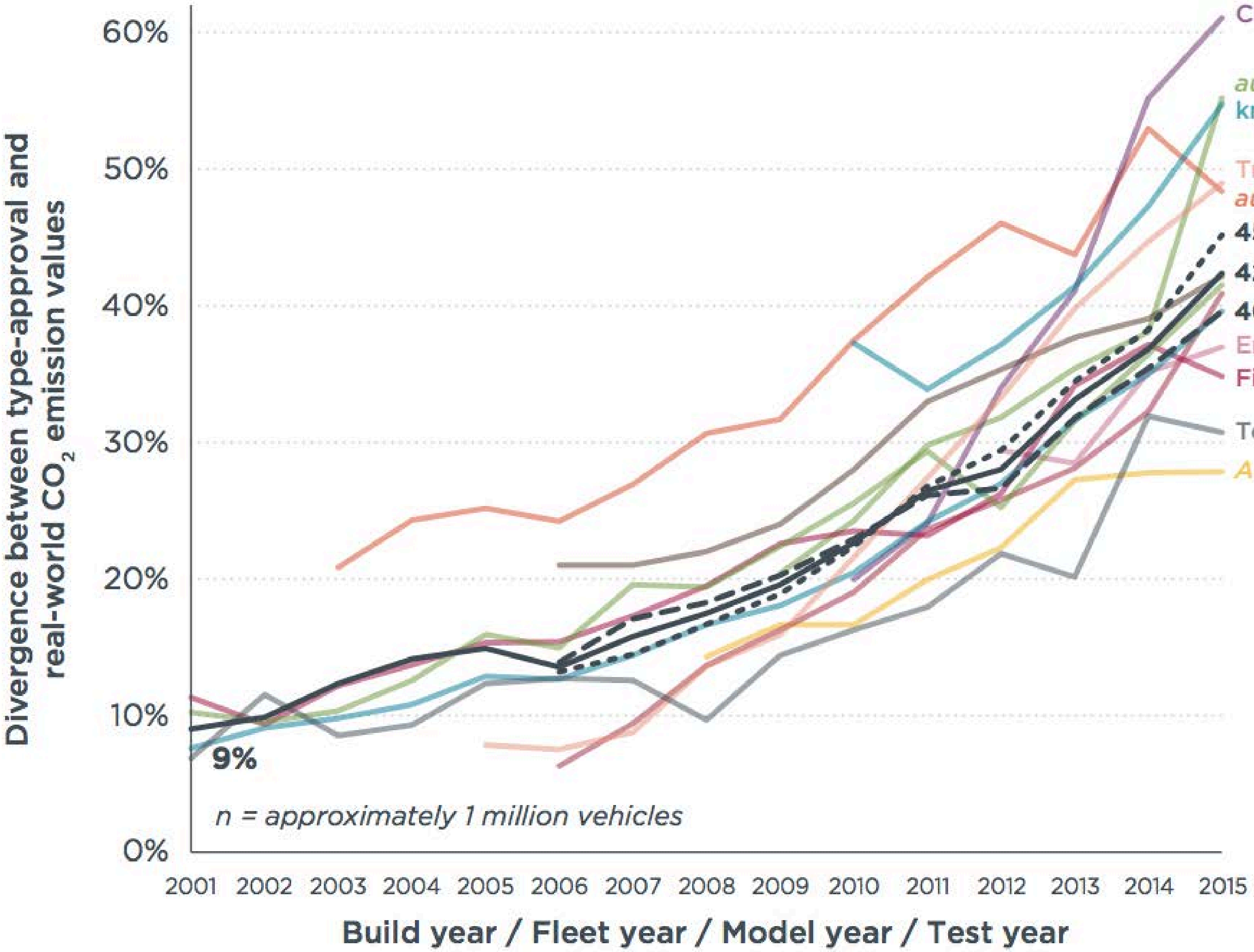
Rising concern: real world emissions diverging from standards



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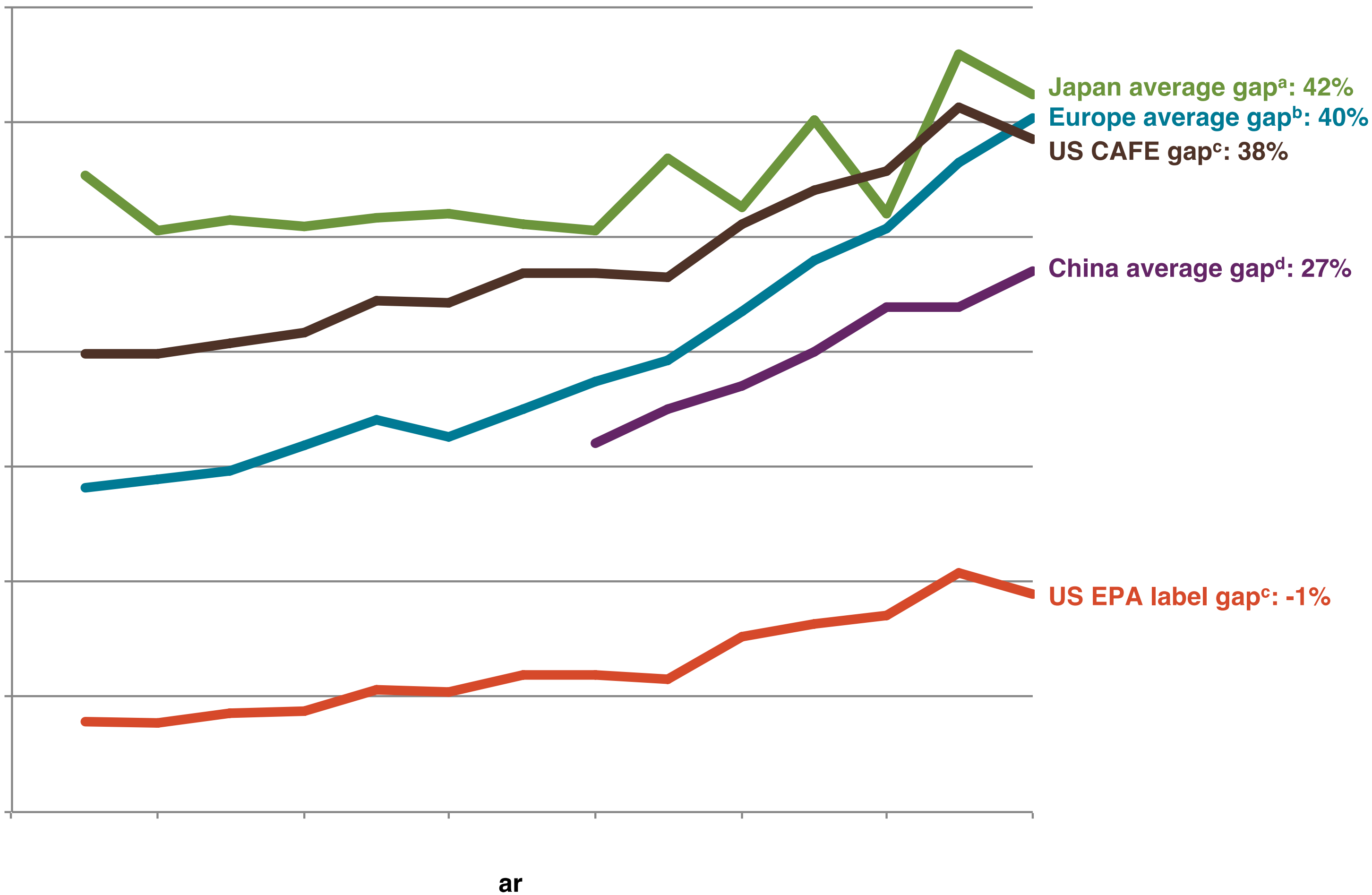
http://www.theicct.org/laboratory-road-2014-update

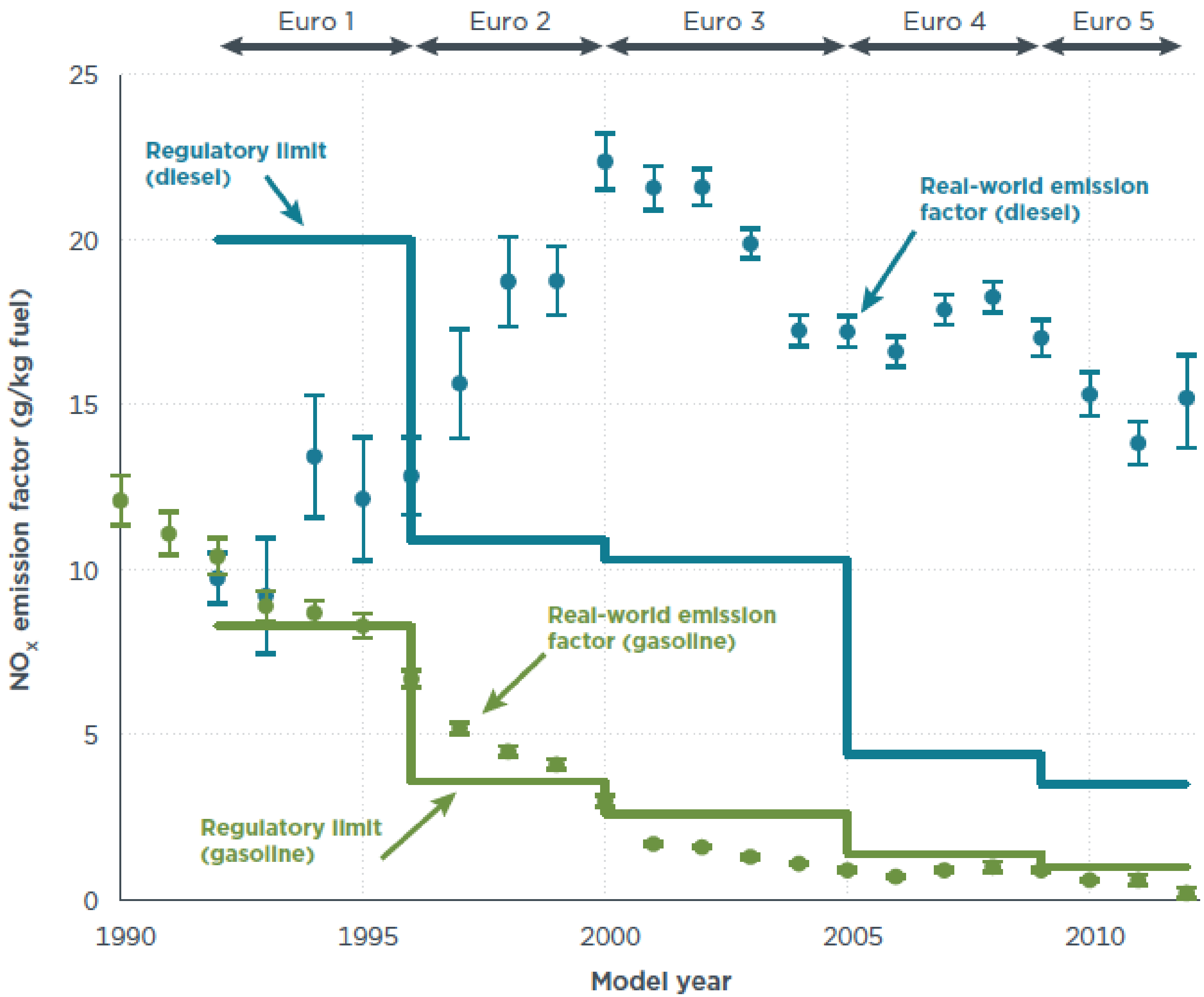
…and this is not just a European issue



Data sources
[a] www.e-nenpi.com
[b] www.theicct.org/laboratory-road-2015-update
[c] www.fueleconomy.gov
[d] http://www.icet.org.cn/english/admin/upload/2015071073476825.pdf

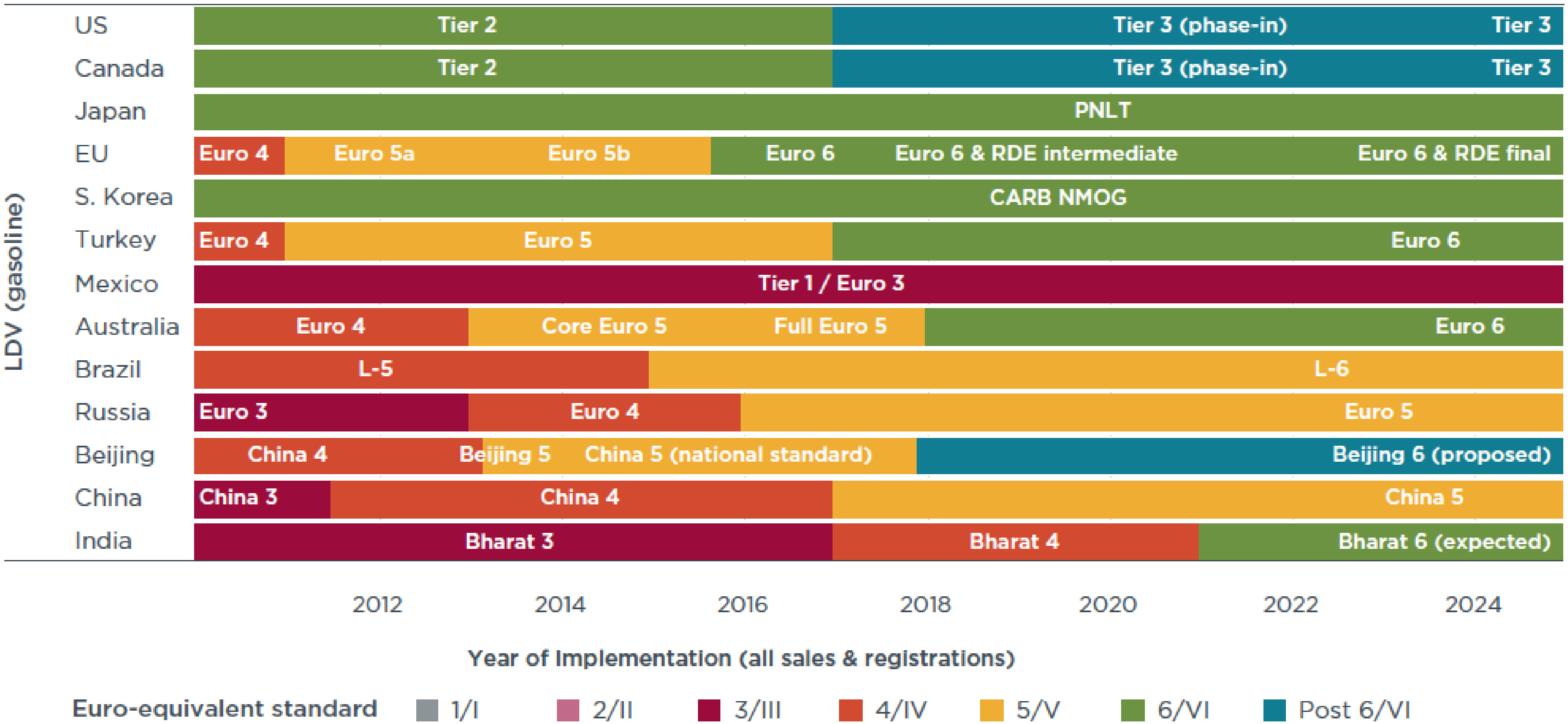
Preliminary data: Additional US data still under analysis

While emission standards were tightened, real-world NO_x from diesel cars remained high



Source: http://www.theicct.org/environmental-risks-diesel-passenger-vehicles-brazil-2016, based on Chen and Borken-Kleefeld (2014)

Historically, many regions follow the EU emissions regulations – will "Dieselgate" be a turning point?



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Source: http://theicct.org/automotive-sector-turkey-baseline-analysis

Pace of Technology Improvement is Quickening

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All conventional technology forecasts are conservative

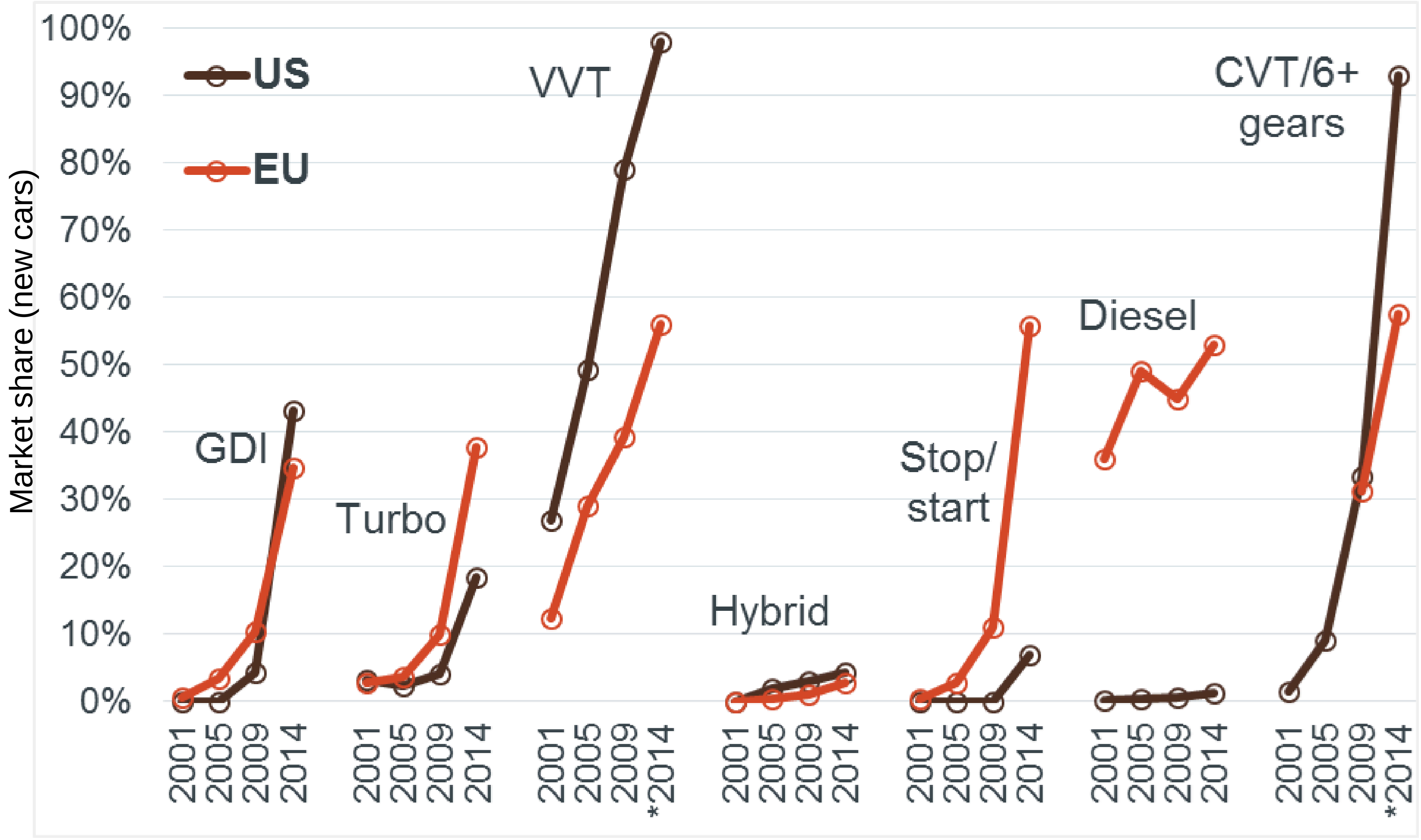
- Donald Rumsfeld hit the nail on the head, although in a different context:
- "there are known knowns; there are things that we know that we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know."

The Real Technology Breakthrough

Computers

- Computer design, computer simulations, and on-vehicle computer controls are revolutionizing vehicles and powertrains
- The high losses in the internal combustion engine are an opportunity for improvement
- Transmissions are improving rapidly
- Reducing size and cost of hybrid system
- Especially important for lightweight materials
  - Optimize hundreds of parts – size and material
  - Capture secondary weight – and cost – reductions

CO_2 regulations are driving new technologies into the market, both in the EU and U.S.



still work in progress!

Forthcoming ICCT Working Paper

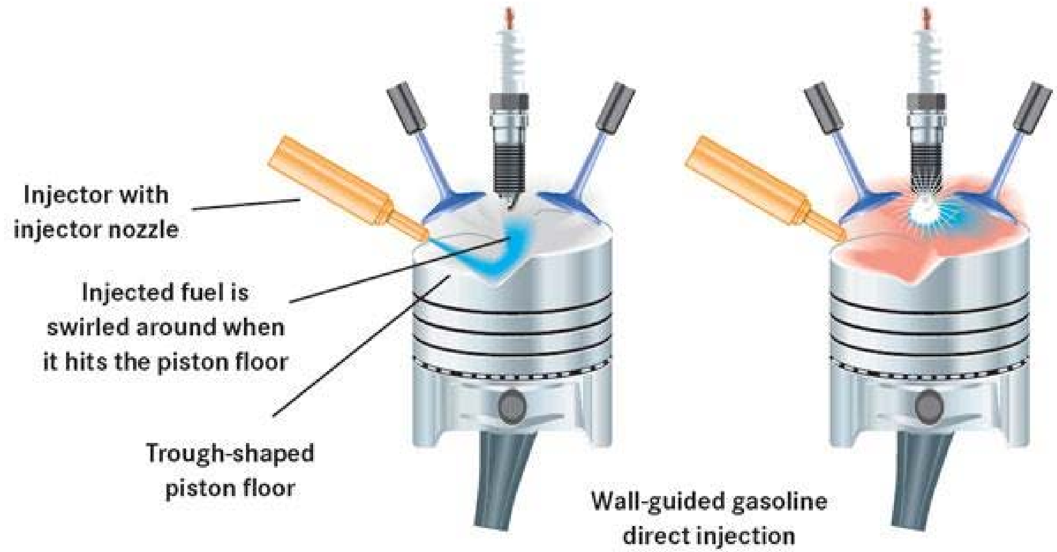
GDI is part of the Future

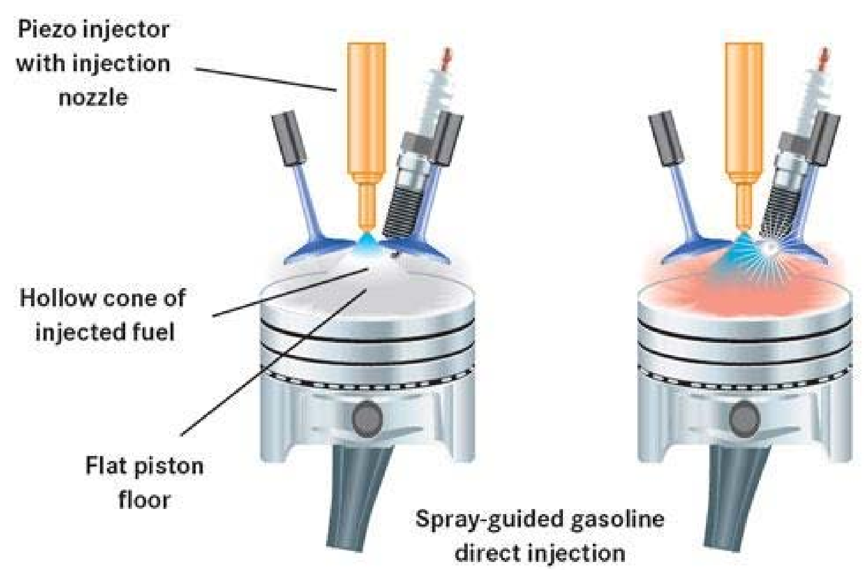
Injects fuel directly into the cylinder

- Evaporation of the injected fuel creates a “charge cooling” effect
- Reduces compression temperatures and knock onset
- Enables higher compression ratios, boost pressures, and optimized spark timing

Only air flows through the intake valves

- Allows valve timings that promote scavenging of the cylinder during high-load operation
- Increases power by increasing trapped air mass
- Further reduces charge temperatures





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High-Ethanol Fuel Blends (e.g. E30)

- Ethanol has an especially high heat of vaporization
- Provides a larger charge cooling effect
- Significant synergy with GDI

But

- Large power loss if E30 is not used
- Lower energy density
- EGR and Miller cycle provide similar benefits

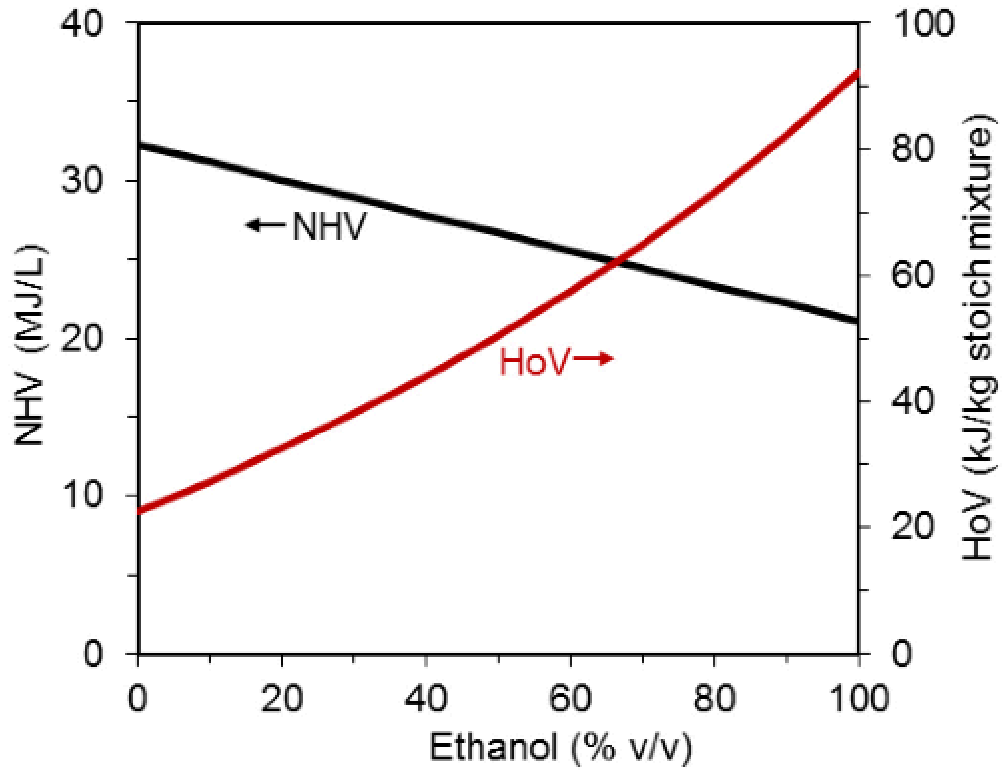

Figure 2. NHV and estimated HoV of ethanol-gasoline blends for a typical gasoline blendstock.

An Overview of the Effects of Ethanol-Gasoline Blends on SI Engine Performance, Fuel Efficiency, and Emissions SAE 2013-01-1635

Summary

- Most new vehicles are subject to CO_2 standards and more – and more stringent - standards are coming all the time
- Computers are transforming technology – and the pace is accelerating
- GDI will be on almost every vehicle within 5-10 years
- High blend biofuels dramatically reduce PM – but aren't likely to penetrate the market in any significant amount
- Will countries move to US emission standards?

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Thank You

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Country by country progress on fuel economy

Status	Region	Projected share of global LDV sales in 2030	Reduction in new LDV CO_2 rates with adopted standards 2005-2030
Adopted LDV efficiency standards	China	29%	34%
	India	16%	26%
	US	13%	52%
	EU	12%	39%
	Brazil	3%	13%
	Japan	2%	27%
	Mexico	2%	14%
	Canada	1%	49%
	South Korea	1%	48%
	Saudi Arabia	1%	15%
	Total	**80%**	**38%**
No efficiency standards	**Total**	**20%**	**4%**
Global sales-weighted average		**100%**	**27%**

Source: Fuel Economy State of the World 2016, GFEI