U.S. Vehicle Emission Standards and Emission Control Experience

ECT-2016

November 2016

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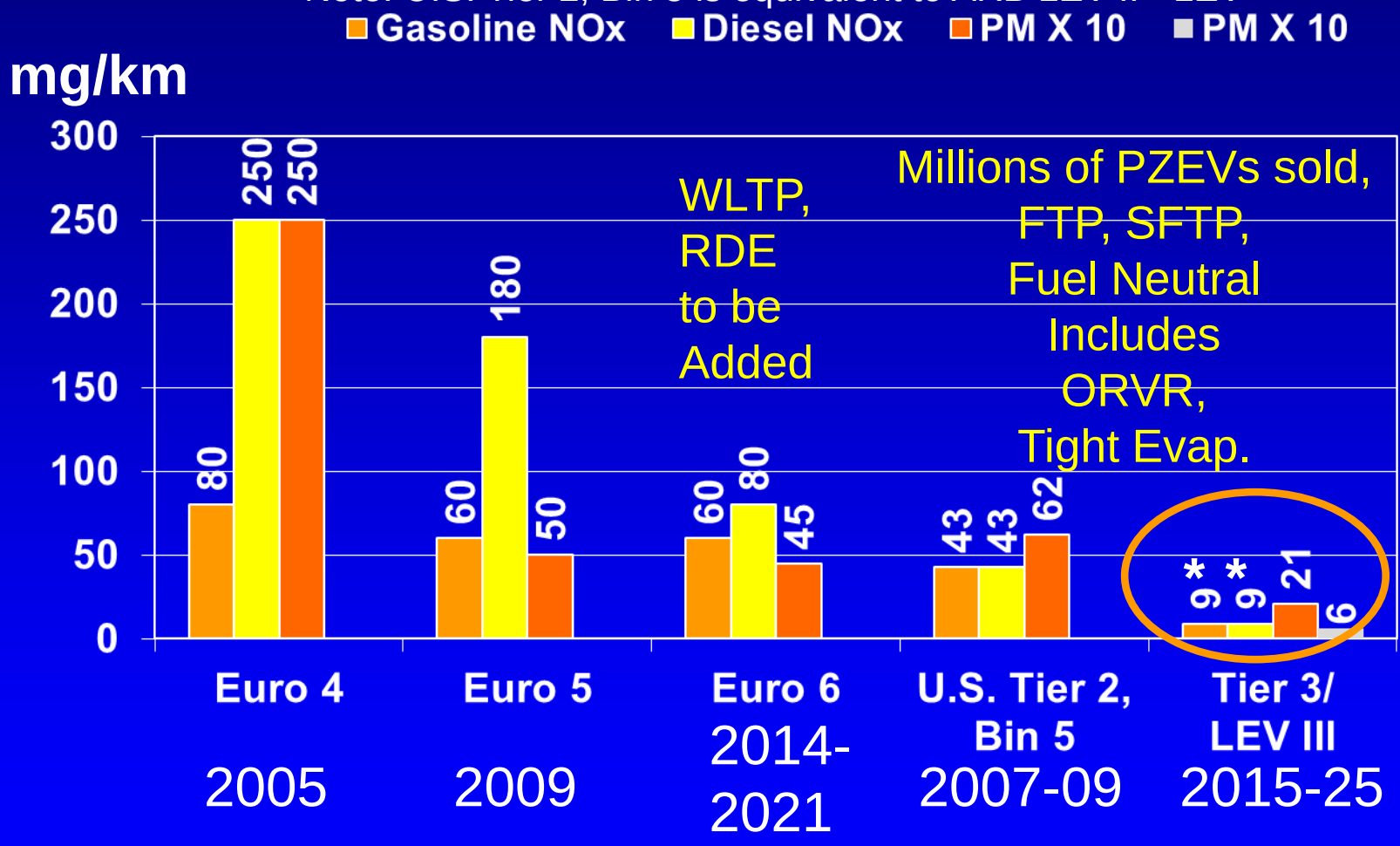
Manufacturers of Emission Controls Association

www.meca.org

U.S. vs. Europe Light-Duty Vehicle Emission Standards

Note: U.S. Tier 2, Bin 5 is equivalent to ARB LEV II - LEV

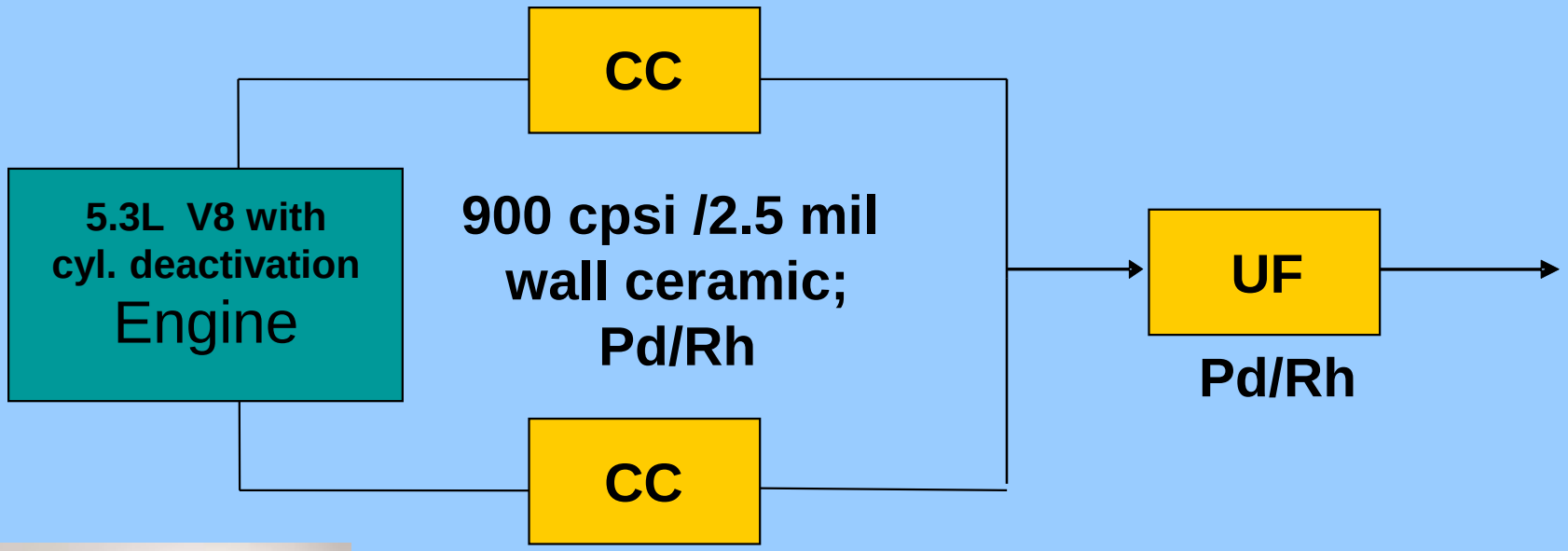


Euro 5+ (2011) and 6 include 6 X 10^{11}/km PN limit for diesels; Euro 6c includes same PN limit for GDI (with 3 year delay);Euro 6 PM mass limit uses revised PMP mass protocol;

* LEV III has a 30 mg/mi (19 mg/km) NMOG+NOx fleet ave. in 2025

2011 5.3 L Chevy Silverado Full Size Pick-up: 150K mi Aged Advanced TWC System ➡ Tier 3 Bin 30

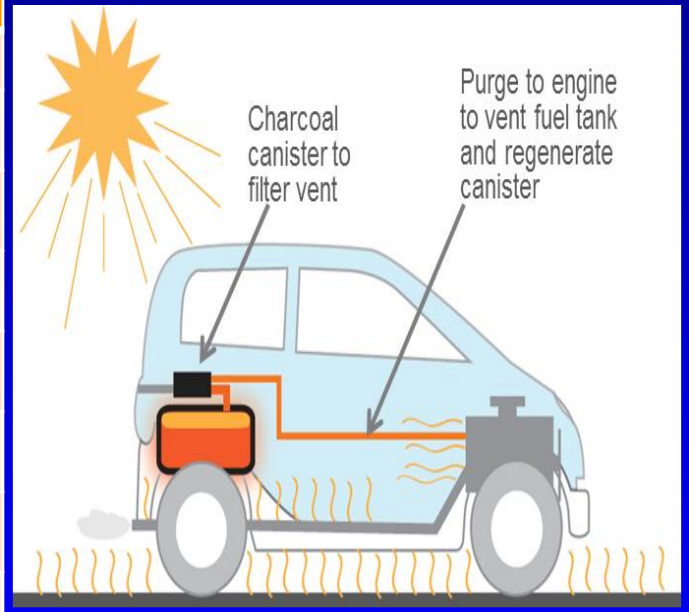
FTP Emissions with *9* ppm S E10: **18 mg/mi** NMOG+NOx
with *29* ppm S E10: **29 mg/mi** NMOG+NOx



TWC System Bench Aged to 150K miles;
Total TWC Catalyst Volume: 1.90 L (0.36 SVR)
Pd/Rh = 16/1; 125 g/cu.ft. (8.4 g PGM total)

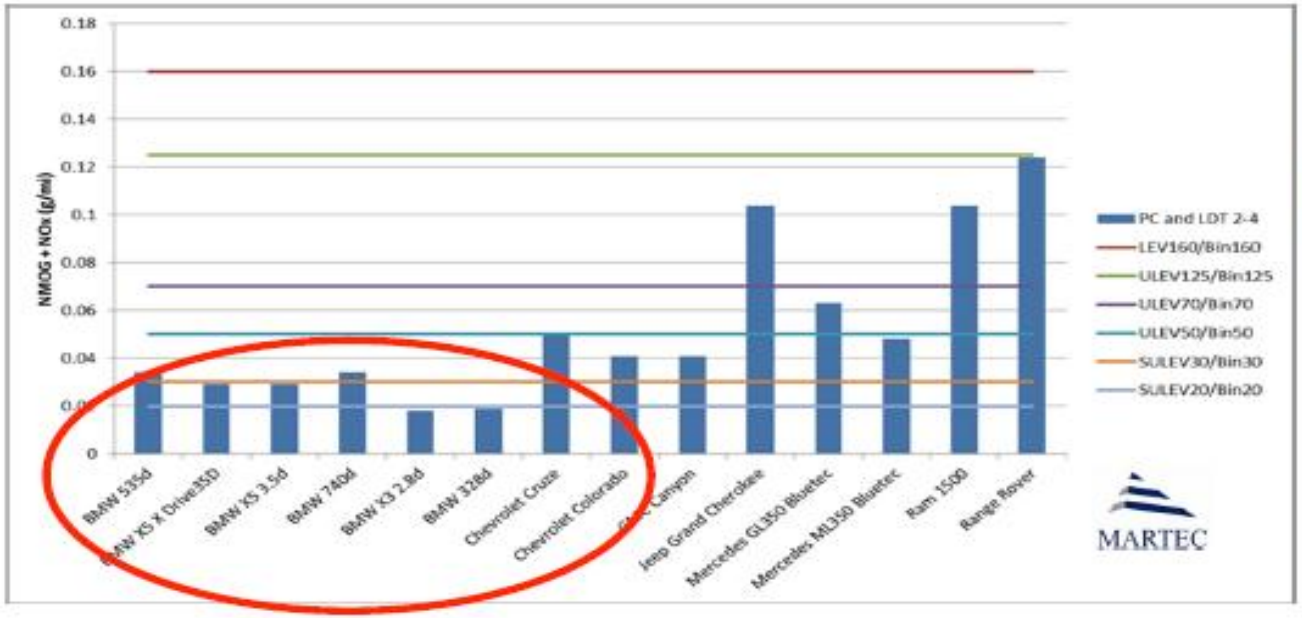
U.S. Evaporative Emission Standards Provide Comprehensive VOC Controls for Gasoline Vehicles; ORVR Included in China 6

Standard	US ≤ 1995 and Euro Evap. Stds.	US ≥ 1996-2004
ORVR		✓
24-hr Diurnal	✓	
48-hr Diurnal		✓
72-hr Diurnal		✓
Evap Standard = 2 g/day	✓	
Evap Standard < 0.5-1.2 g/day		✓
Hot Soak	✓	✓
Running Loss		✓
In-use standards and monitoring		✓
OBD		✓



Since 1996, the US progressively added ORVR, extended diurnals, short drive cycles, running loss, low certification and in-use emissions standards, and OBD to improve air quality.

Tier 2/Tier 3 Pathways Available for Light-duty Diesel



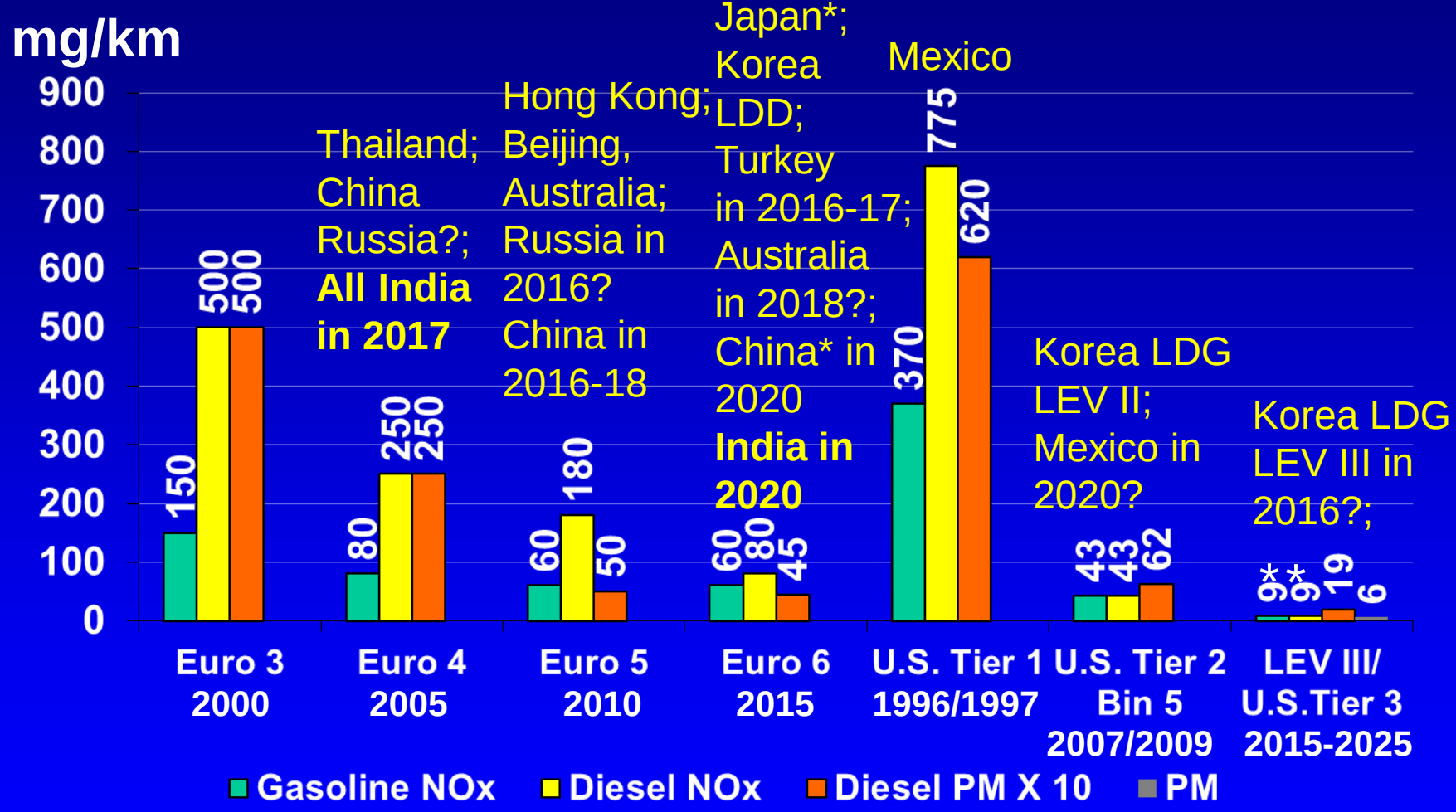
Next generation technology will assist to achieve Tier 3 certification targets

NOx storage catalyst	Selective Catalytic Reduction (SCR)	Advanced SCR on Filter
Stores NOx for increased low temp performance	Optimized from current diesel systems	Combines SCR and DPF to optimize NOx and PM control

International LDV Emission Standards

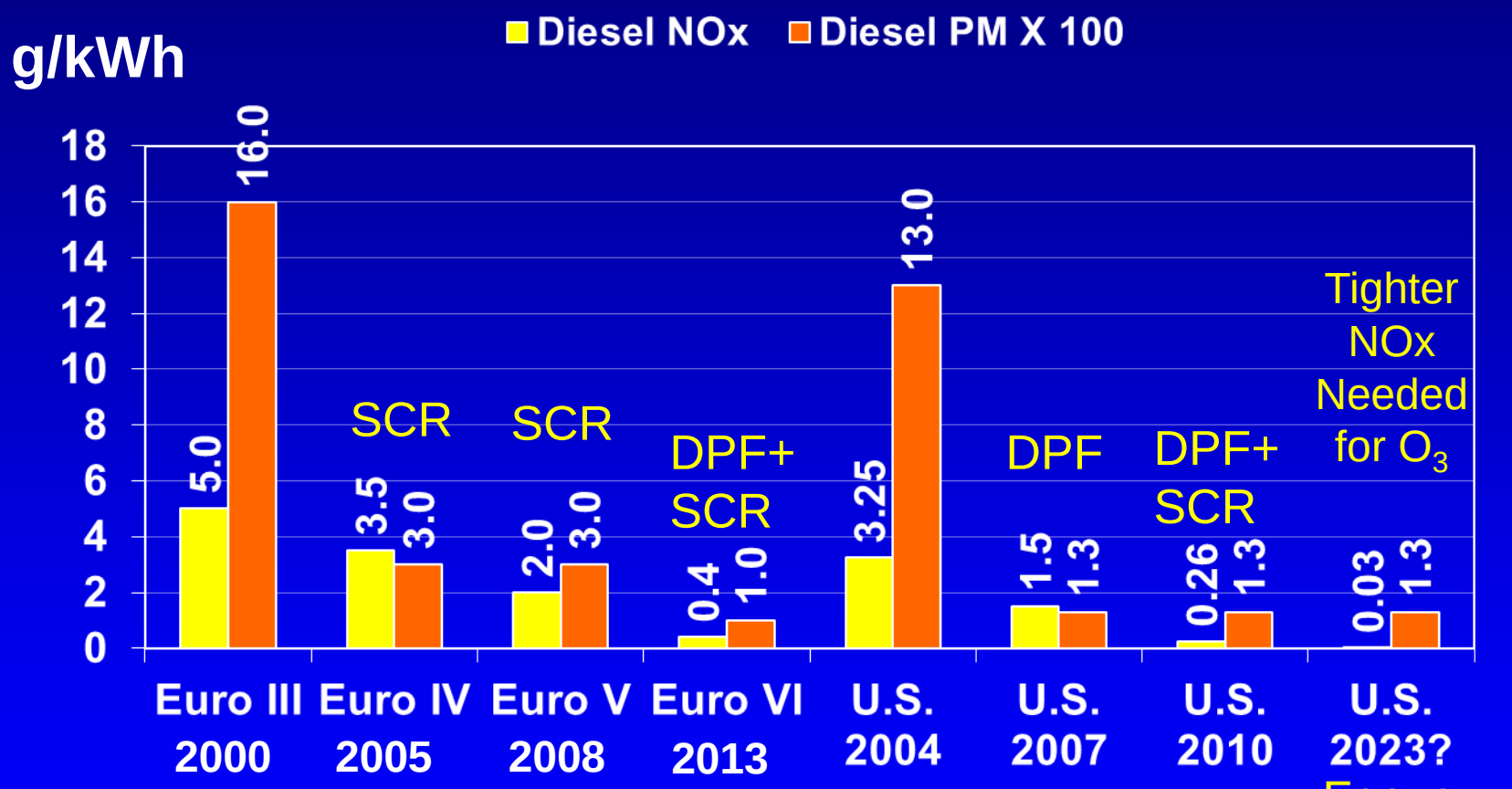
(U.S. Tier 2, Bin 5 is equivalent to CARB LEV II-LEV;
* LEV III has a 30 mg/mi (19 mg/km) NMOG+NOx fleet ave. in 2025)

Standards shown are for lowest vehicle weight class



Euro 5+ (2011) and 6 include 6 X 10^{11}/km particle number limit for diesels; Euro 6c starting late 2017 includes same PN limit for gasoline direct injection engines, WLTC, & start of RDE;
Brazil currently at Proconve 6 (LDG only for PC):
80 mg/km NOx @ 80K km using the FTP

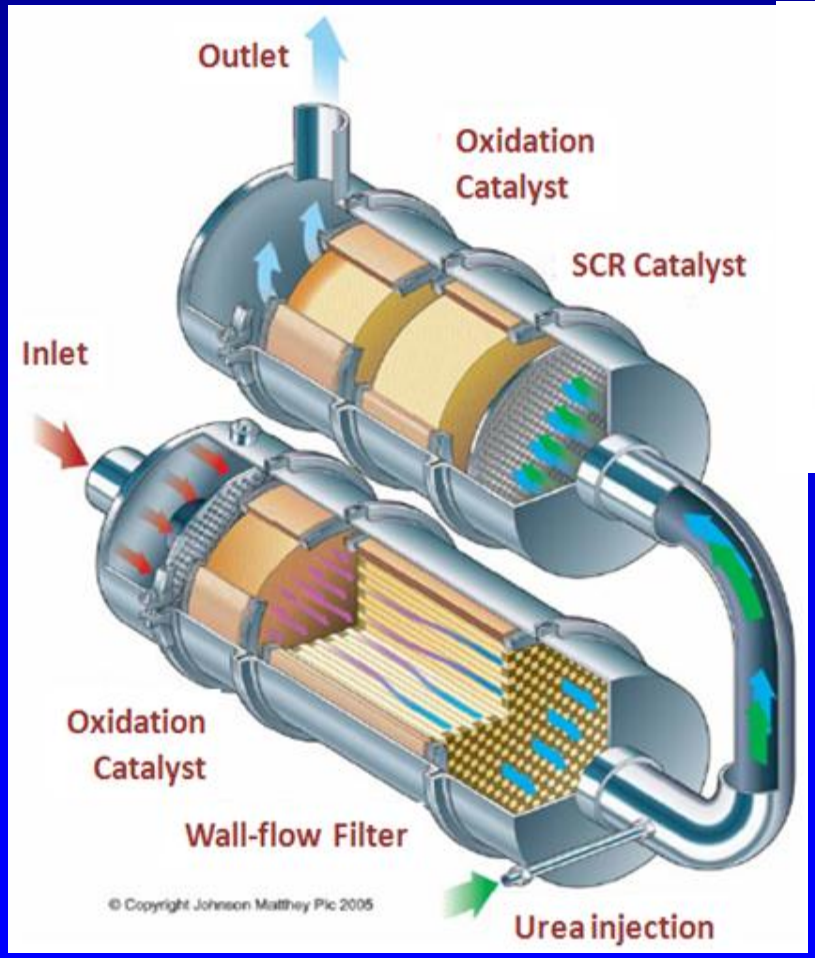
U.S. vs. Europe Heavy-Duty Engine Transient Cycle Emission Standards



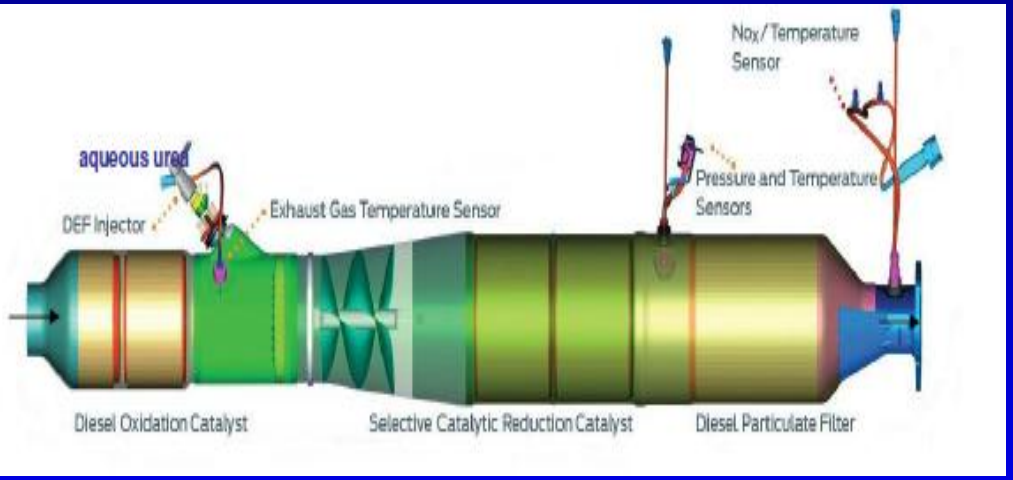
Note: Euro VI NOx limit is 0.46 g/kWh on the WHTC
Euro VI includes 6.0 X 10^{11}/kWh particle number limit for diesels on WHTC

U.S. 2010 Compliant Heavy-duty Systems:
> 4 Million OEM DPFs; > 2 Million OEM DPF+SCR Trucks

- Heavy-duty trucks: DOC+DPF+SCR configurations

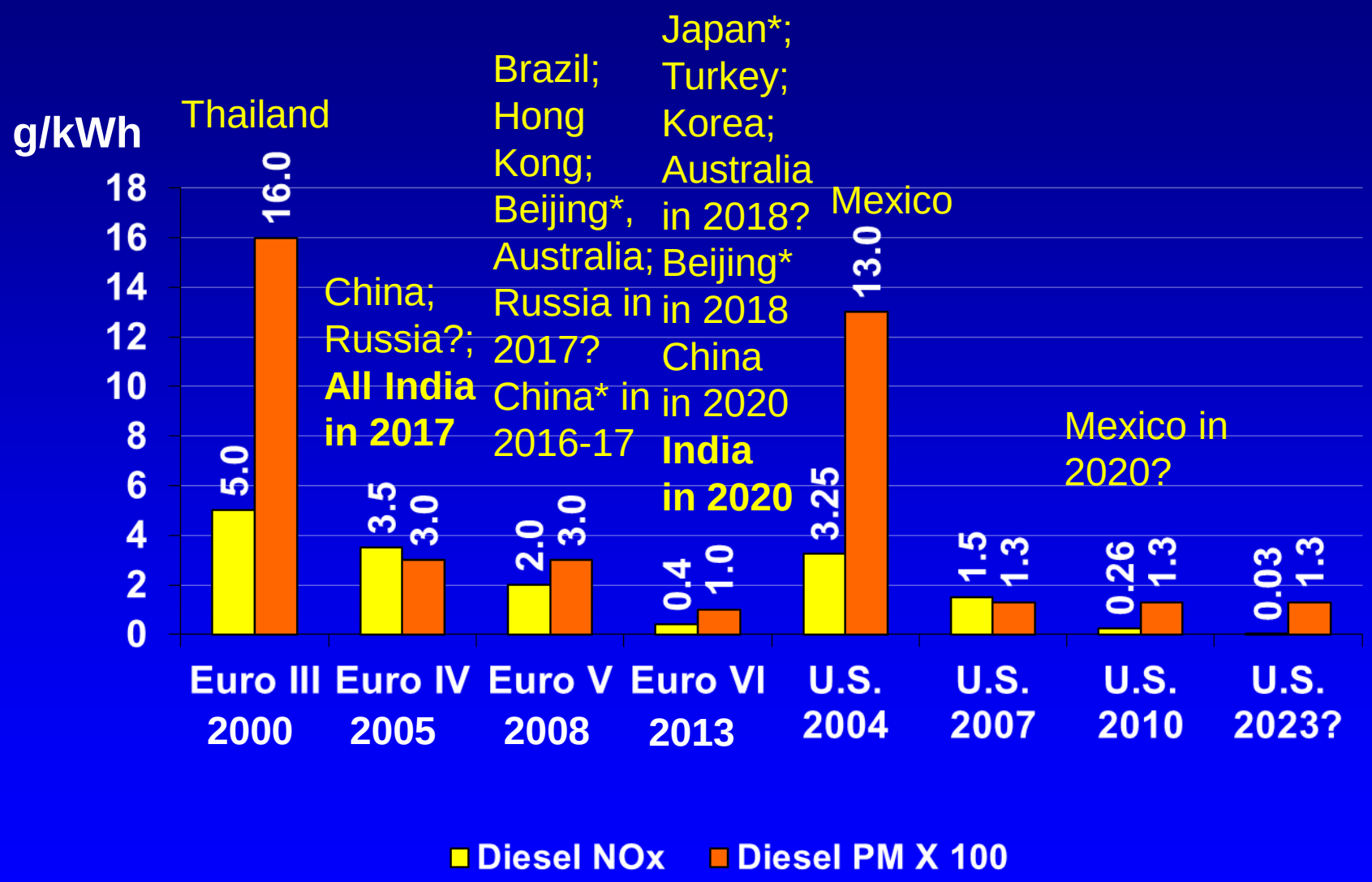


- Medium-duty trucks: DOC+SCR+DPF designs for cold-start NOx control



- 32.5% urea/water meets defined standards (API run quality program)
- Post-SCR oxidation function for minimal ammonia slip
- Other features include reductant mixers, thermocouples, NOx sensors
- Stoichiometric natural gas engines use proven three-way catalysts

International HDV Emission Standards



Note: Euro VI NOx limit is 0.46 g/kWh on the WHTC
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Advanced Emission Technology Driven By U.S. Mobile Source Emission Regulations including Comprehensive Compliance and Enforcement Programs

Tier 3 Light-Duty
final rule 2014
fully phased in 2025
Diesels held to same standards as gasoline vehicles
Diesel sulfur now < 15 ppm;
Gasoline sulfur at ca. 10 ppm in 2017

Ocean-going Vessels
final rule 2009; IMO ECA in 2010
ECA: 1000 ppm Sulfur in 2015;
80% lower NOx in 2016
(new OGVs)

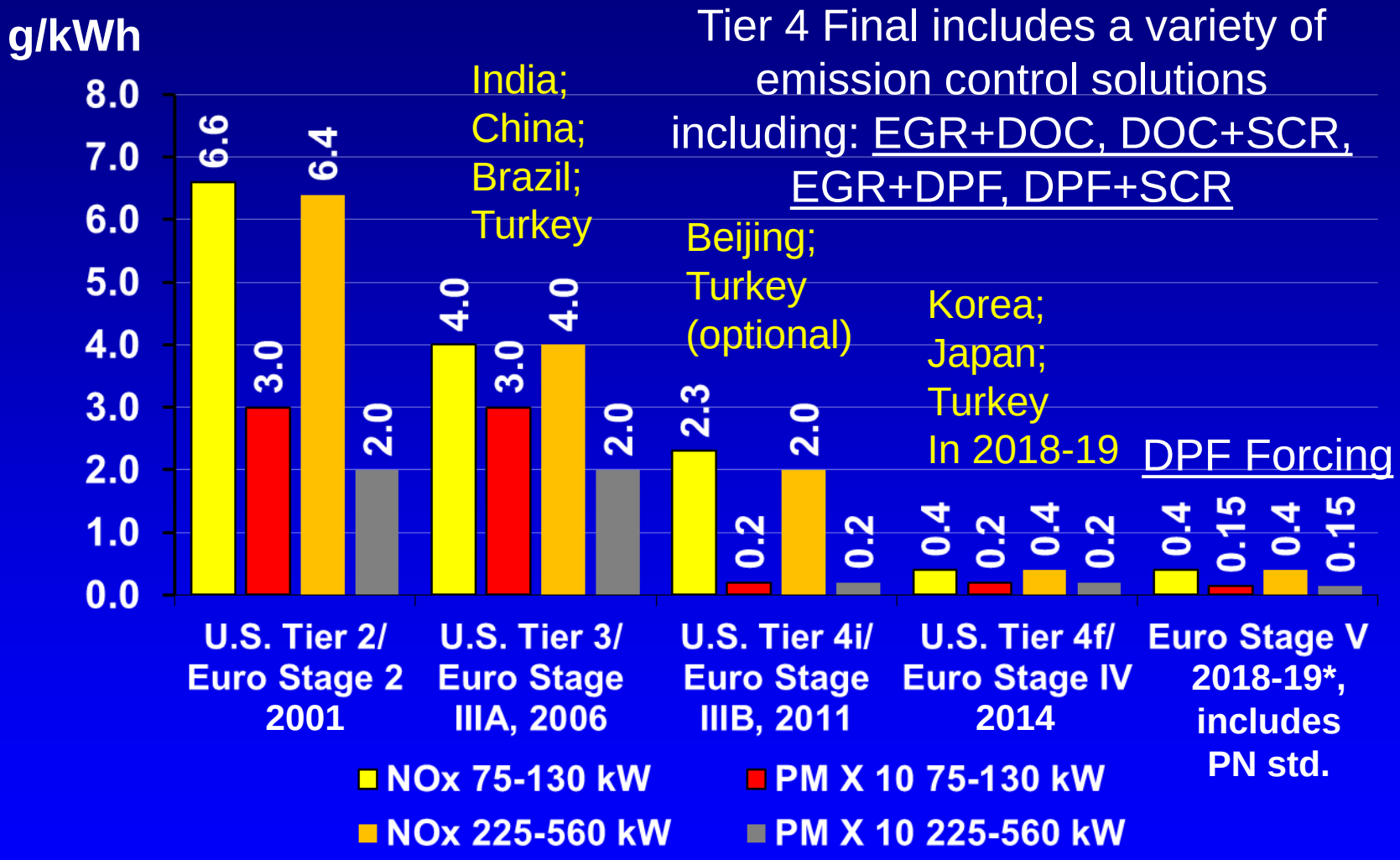
Heavy-Duty Highway
final rule 2000
Sulfur now < 15 ppm
fully phased in 2010

Locomotive / Marine Tier 4
final rule 2008
Sulfur now < 15 ppm
fully phased in 2017

Nonroad Diesel Tier 4
final rule 2004
Sulfur now < 15 ppm
fully phased in 2015;
basis for new stationary engines

International Nonroad Diesel Emission Standards

(representative standards only shown for select engine power ratings)



Tier 4 Final includes a variety of emission control solutions including: EGR+DOC, DOC+SCR, EGR+DPF, DPF+SCR

Notes: Change from steady-state cycle to NRTC starting with U.S. Tier 4i/Euro Stage IIIB (5% cold transient weighting in U.S.; 10% in EU & Japan)

Critical Challenges/Opportunities for India

- Deliver on the Fuel Road Map for 50 and 10 ppm fuels by 2017 and 2019 (establish a pan-India AdBlue infrastructure and AdBlue quality program)
- Significant U.S. experience to draw on for BS VI (and beyond) - implement BS VI on schedule
- Establish effective compliance programs to ensure vehicles deliver needed emission reductions (U.S. EPA/CARB Model)
- Add the resources required to manage an effective vehicle control program
- Significant VOC reductions available through U.S. style evap. regulations
- Opportunity for significant reductions in the off-road diesel sector by leap-frogging to Stage V standards as soon as possible
- India needs to clean-up its fast growing population of diesel gen-sets through retrofits and tighter emission standards that require DPFs and SCR
- Establish ECA requirements along India's coast line

MECA/AECC Involvement in Asia for 20 Years

- CATEC 1997 Beijing [MECA only]
- Diesel Technology & Motorcycle Workshop 1999 Hong Kong [MECA only]
- AVECC 2001 Bangkok, Thailand
- AVECC 2004 Beijing (delayed from 2003 due to SARS outbreak)
- **AVECC 2006 Jaipur, India**
- **ECT 2007, 2009, 2011, 2013, 2015, 2016 Delhi**
- AVECC 2007, 2011, 2015 Beijing