

Meeting Future Light-Duty Emission Standards

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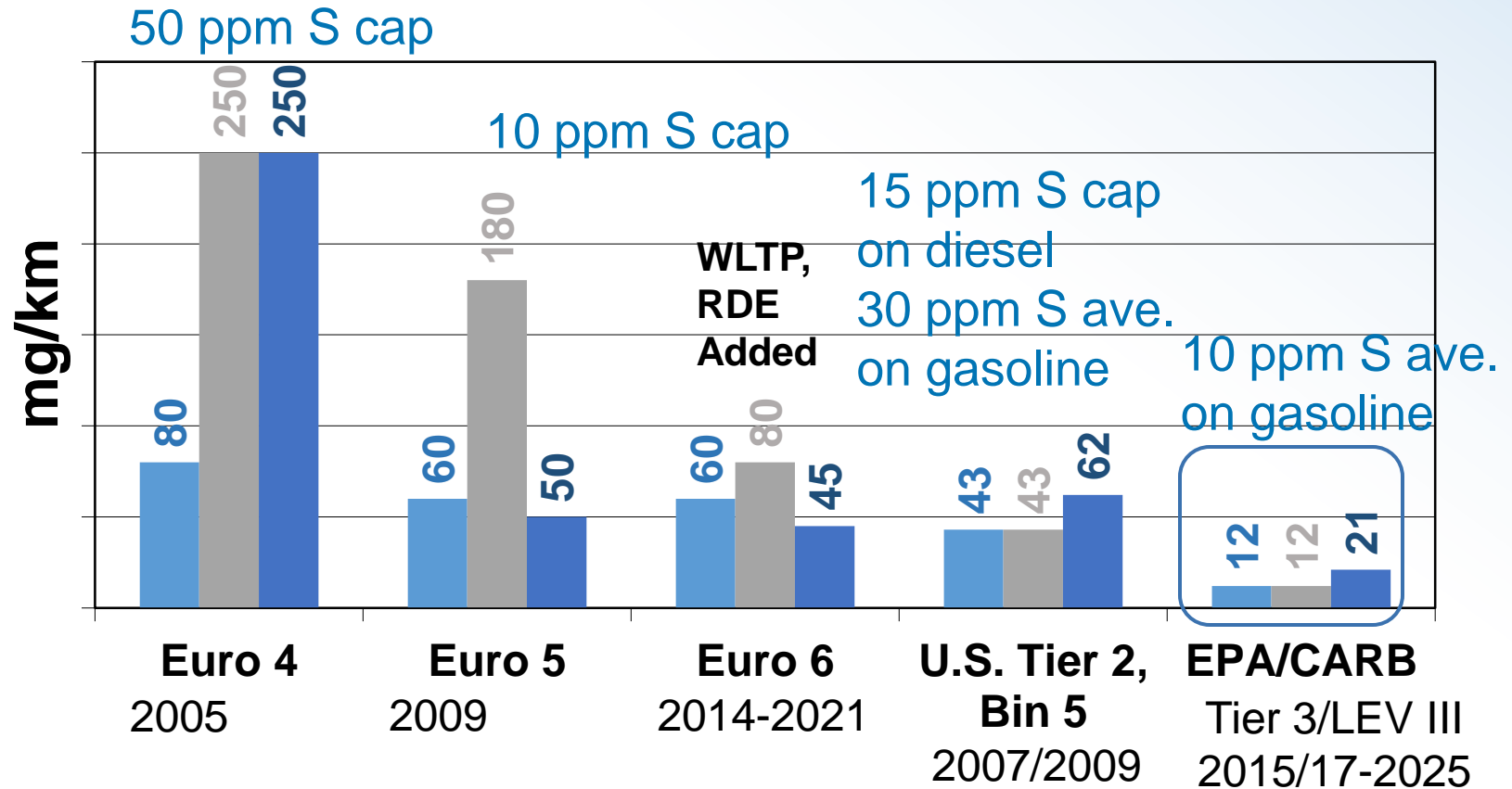
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U.S. vs. Euro Light-Duty Vehicle Emission Standards

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

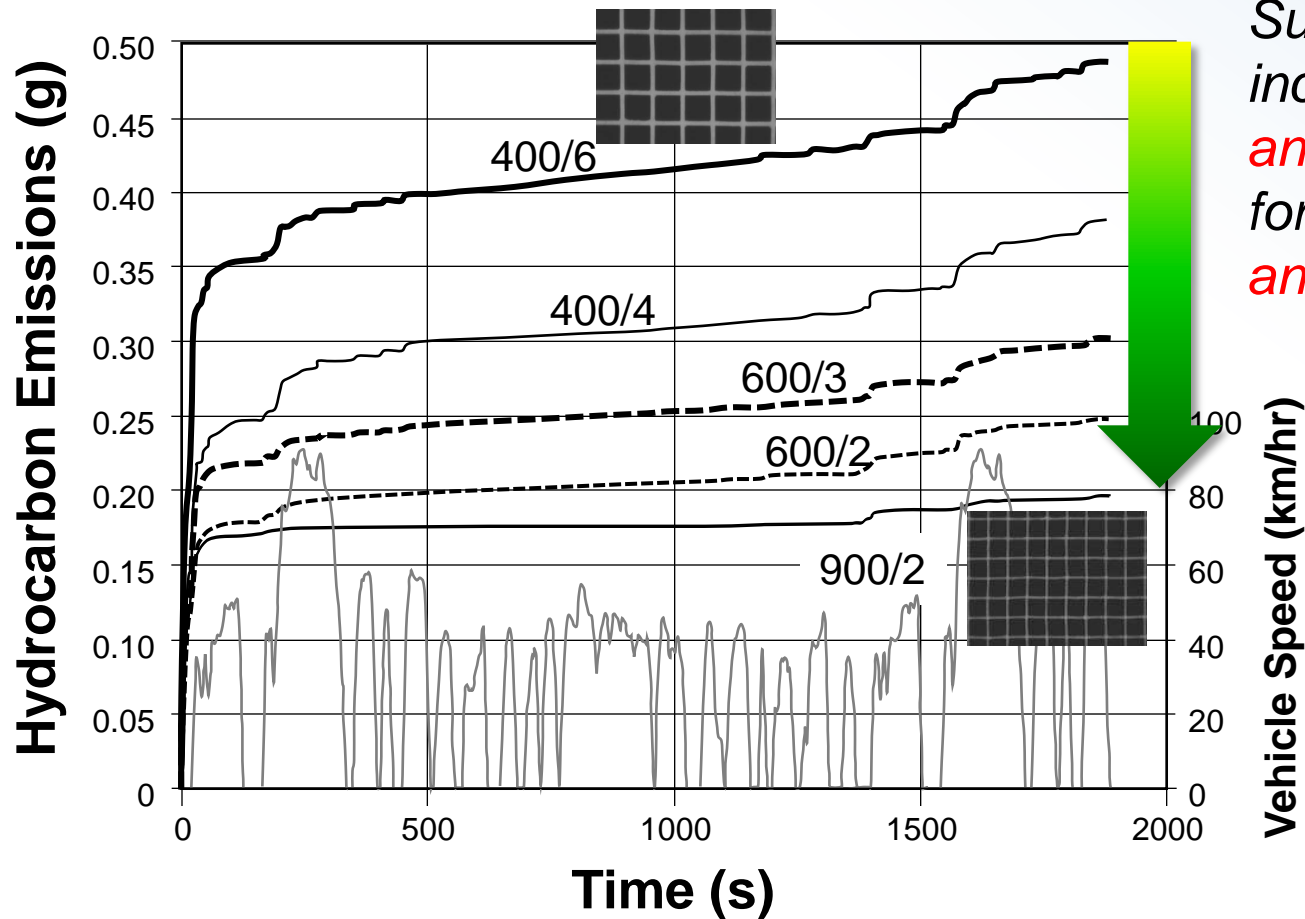
■ Gasoline NOx ■ Diesel NOx ■ Diesel PM X 10



Euro 5+ (2011) and 6 include $6 \times 10^{11}/\text{km}$ diesel particle number limit;
Euro 6c includes PN limit for GDI



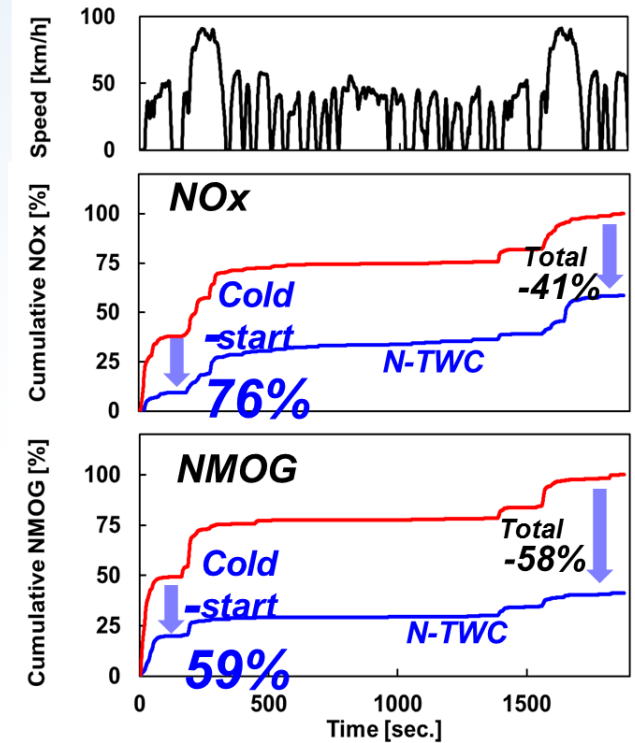
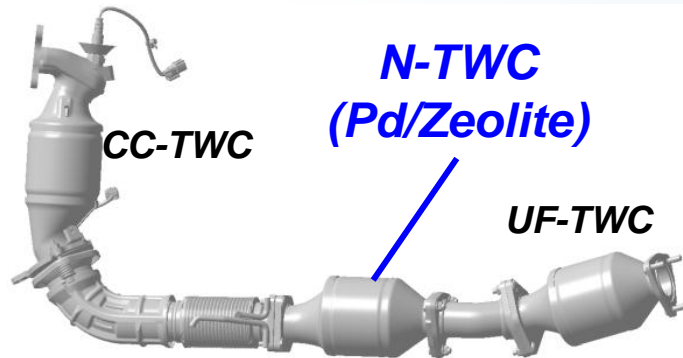
Advanced Substrates have been developed to decrease tailpipe emissions



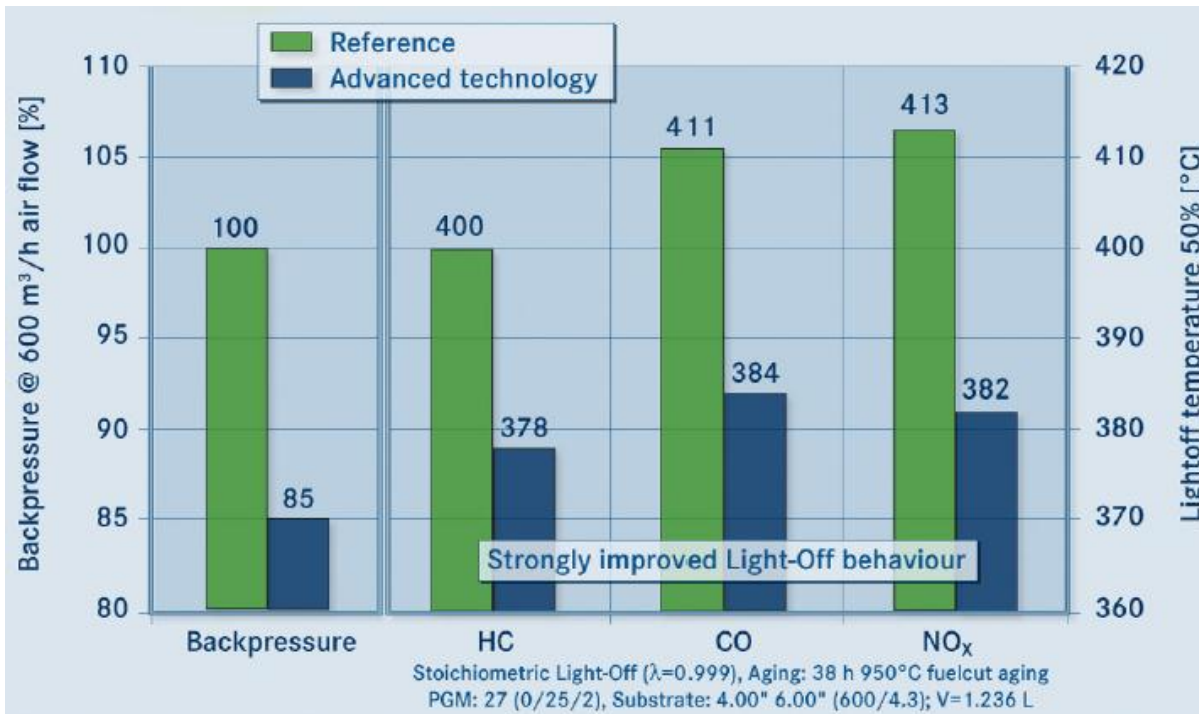
Substrates with increasing surface area and low thermal mass for high catalyst activity and rapid warm-up



Low Temperature Catalysts and Adsorbers for Cold Start Performance



SAE 2015-01-1002

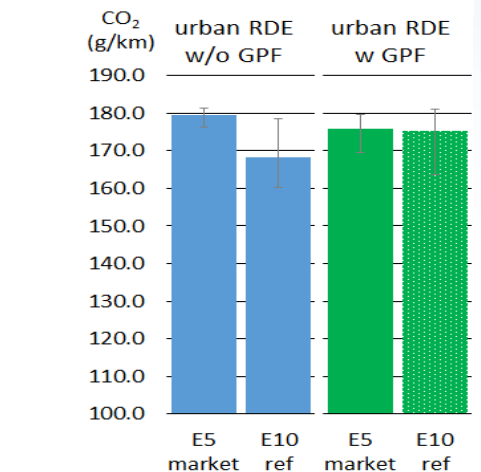
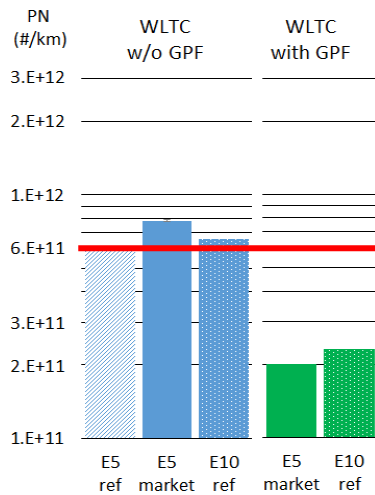
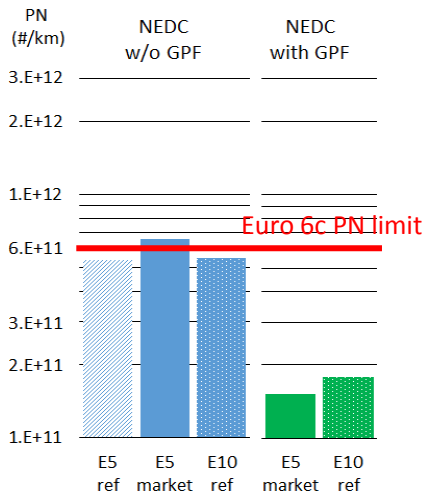
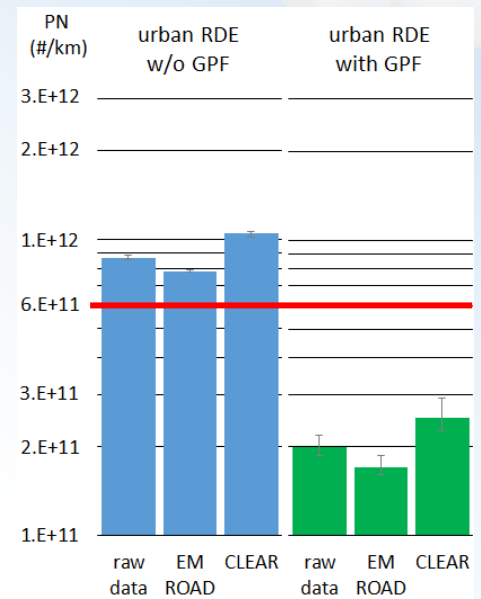
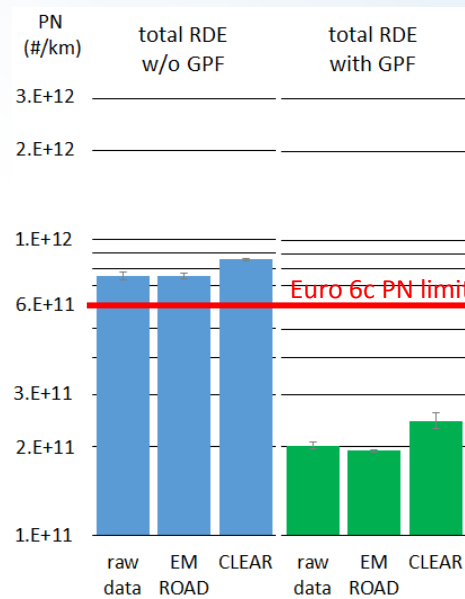
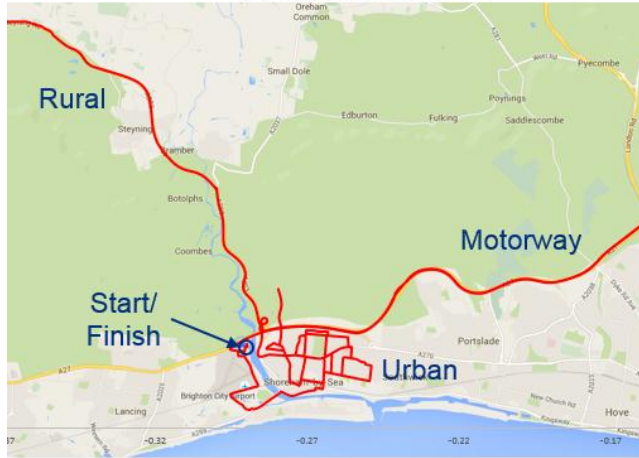


Catalyzed GPF tested on RDE



Association for Emissions Control by Catalyst AISBL

RDE Cycle Route from GPS



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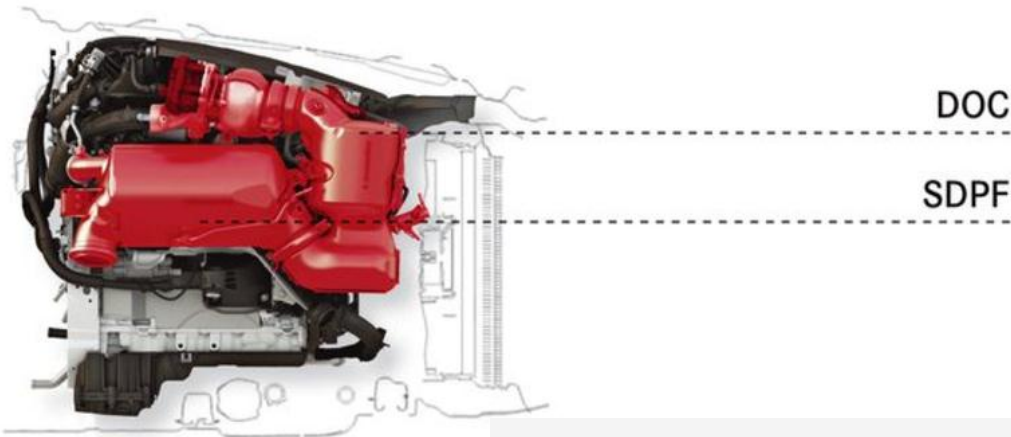


Improved Packaging for Thermal Management

Conventional emission control lay-out



Compact on-engine packaging

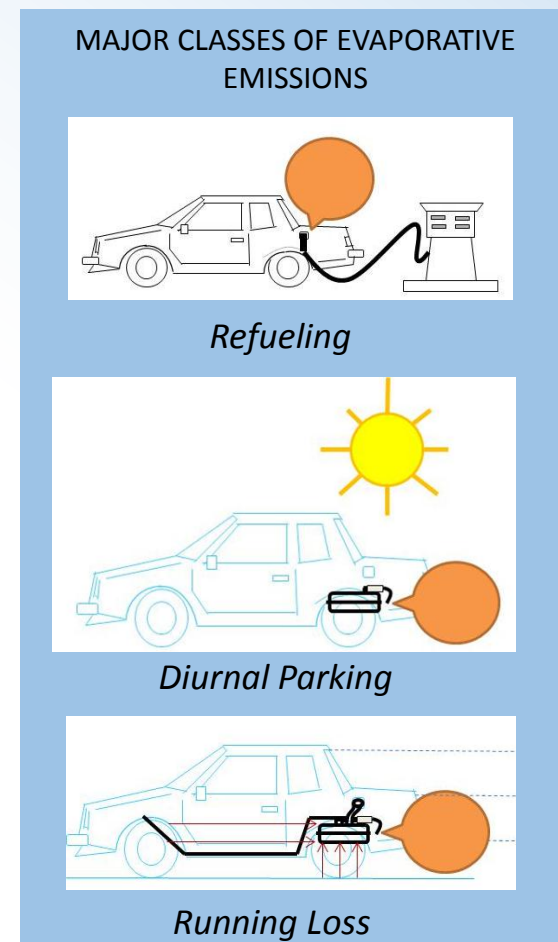


- All aftertreatment components installed directly on engine
- Dual wall packaging and improved catalysts reduces need for active thermal management
- New design results in fuel savings



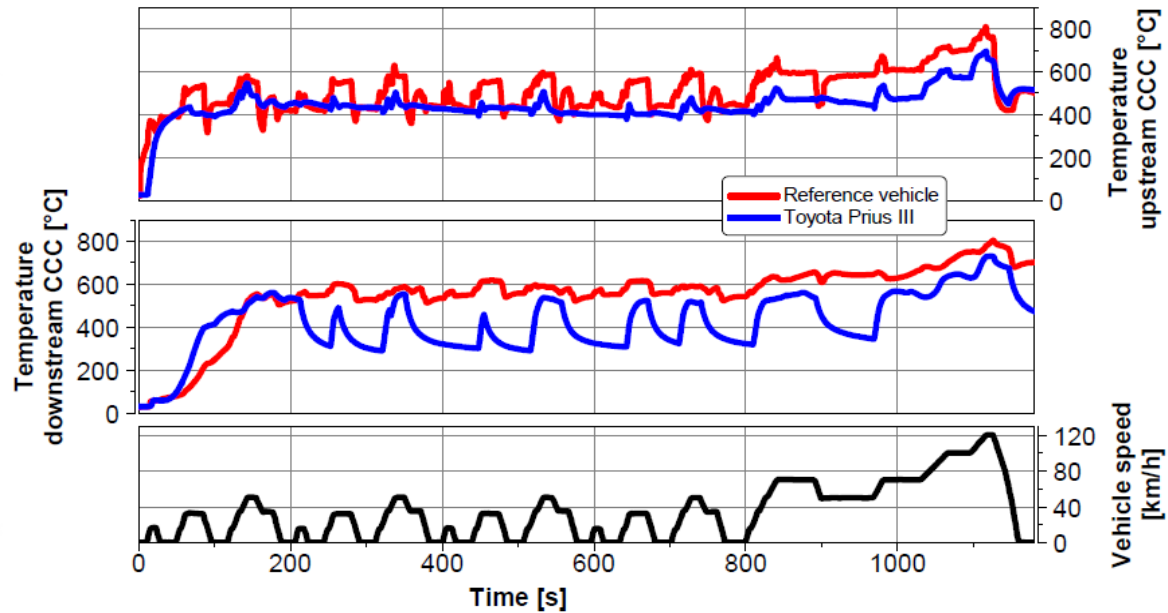
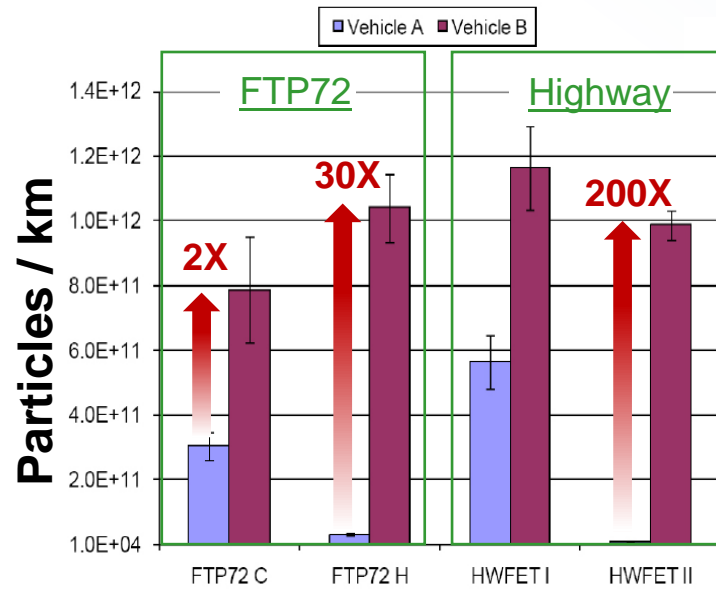
U.S. Evaporative Emission Standards Provide Comprehensive VOC Controls for Gasoline Vehicles

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		✓

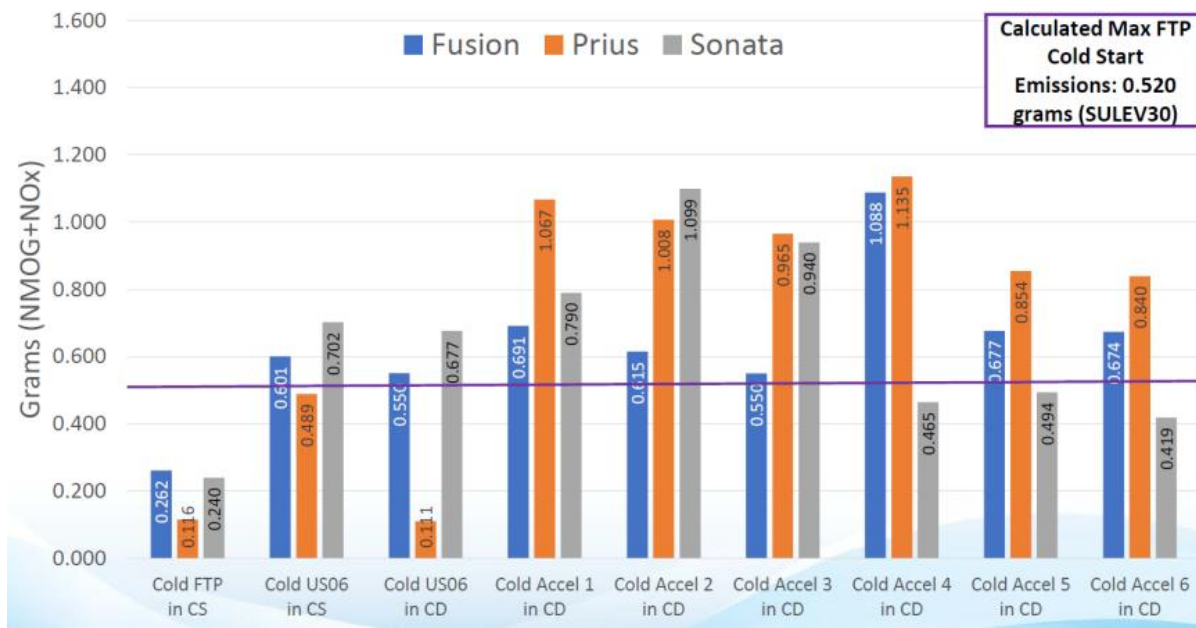


Since 1996, the US progressively added ORVR, extended diurnals, short drive cycles, running loss, low certification and in-use emissions standards, and OBD to improve air quality.

PHEVs Pose Real World Emission Challenges



- PHEV have lower exhaust temperatures
- PHEVs emit particles and NOx during engine restarts with hard accelerations
- Low purge rate increase evap emissions



Opportunities and Challenges for India

- Significant U.S. and EU experience in technology and compliance policy exists for India to draw upon.
- China is the first to combine the best of U.S. and EU policy frameworks.
- Like China, India can establish effective compliance programs to ensure vehicles deliver real world reductions, this will require resources.
- Significant VOC reductions available through U.S. style evap. regulations.