Particulate Control Experience with GDI and GPFs

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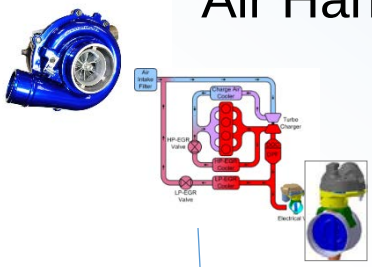
Manufacturers of Emission Controls Association
www.meca.org

September 28, 2016
South Coast AQMD
Diamond Bar, CA

MECA Technologies Control Criteria and GHG Emission

Fuel Combustion Controls

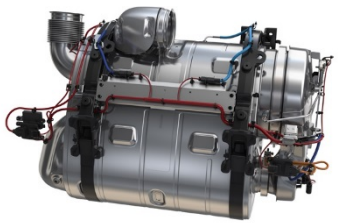
Air Handling



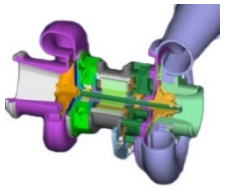
Filters & Substrates

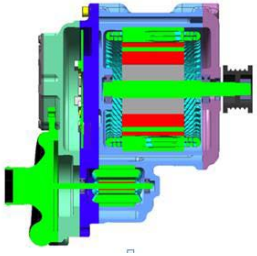
Evaporative Controls

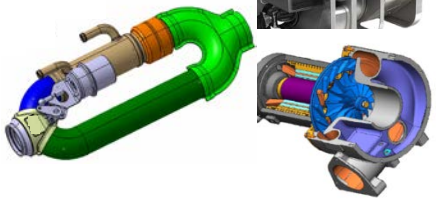
Exhaust System Integration

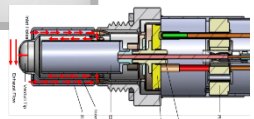


Powertrain Electrification





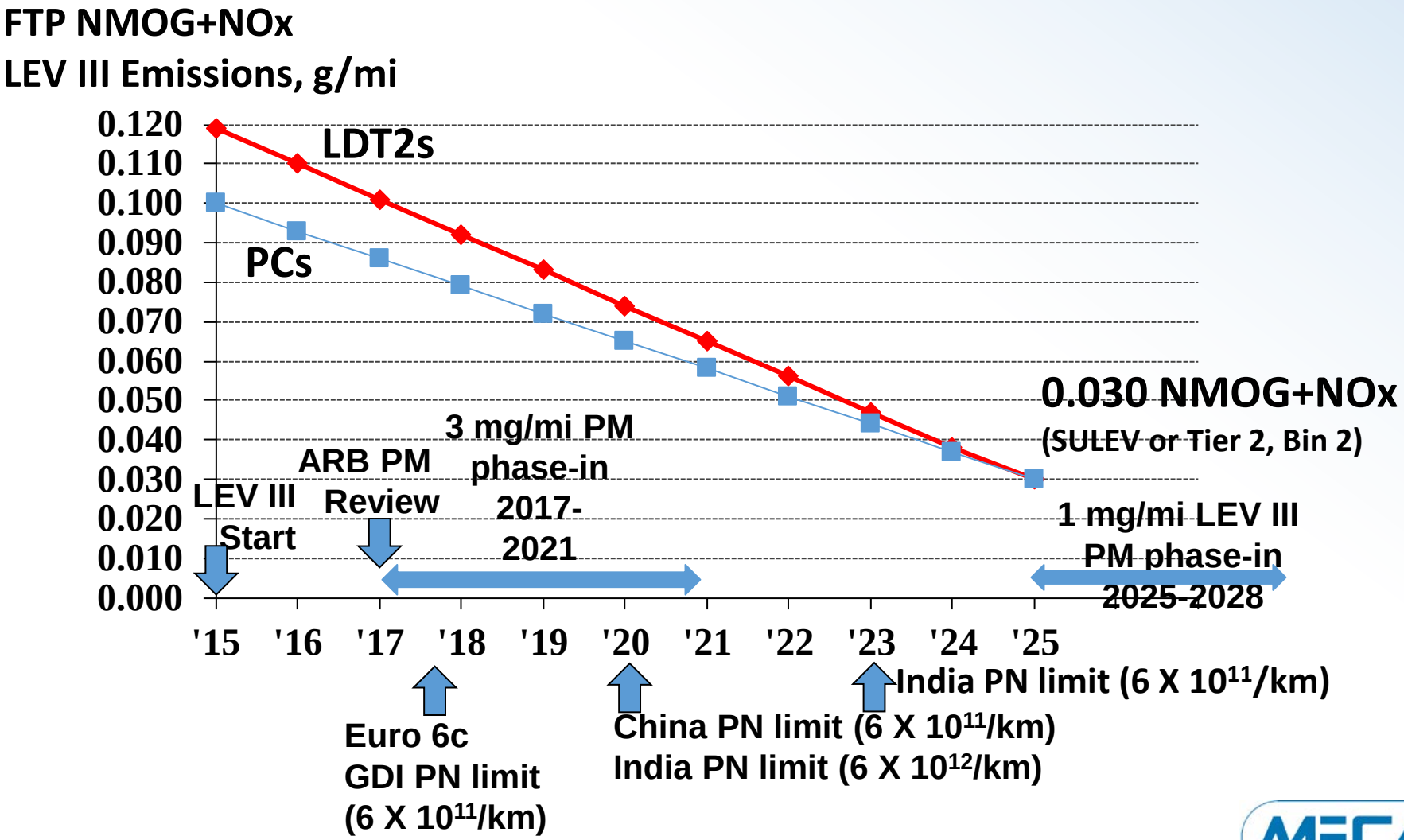




OBD Sensors

Waste Heat Recovery

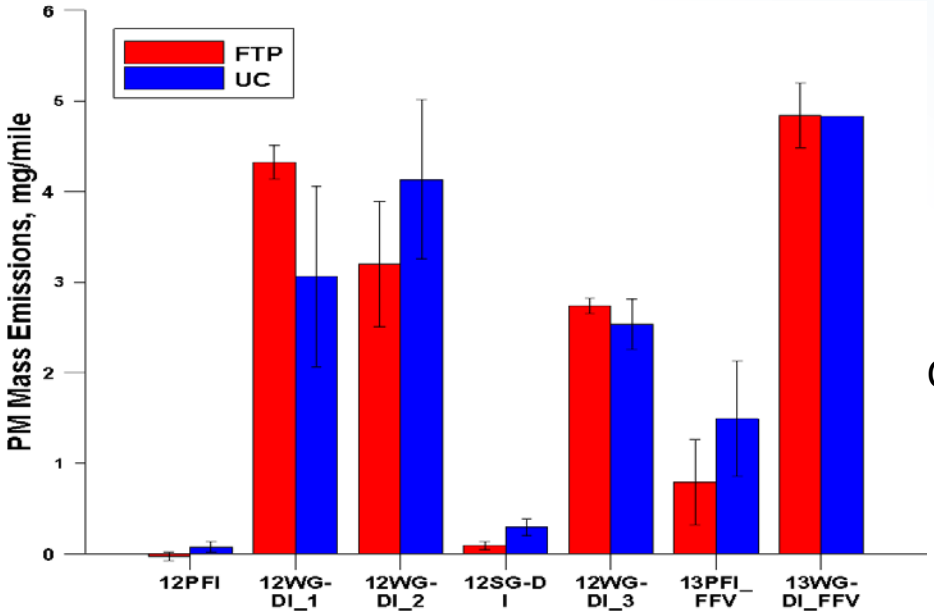
LEV III/Tier 3 Phase-In
PN Implemented Soon for GDI Vehicles



Understanding GDI PM Emissions

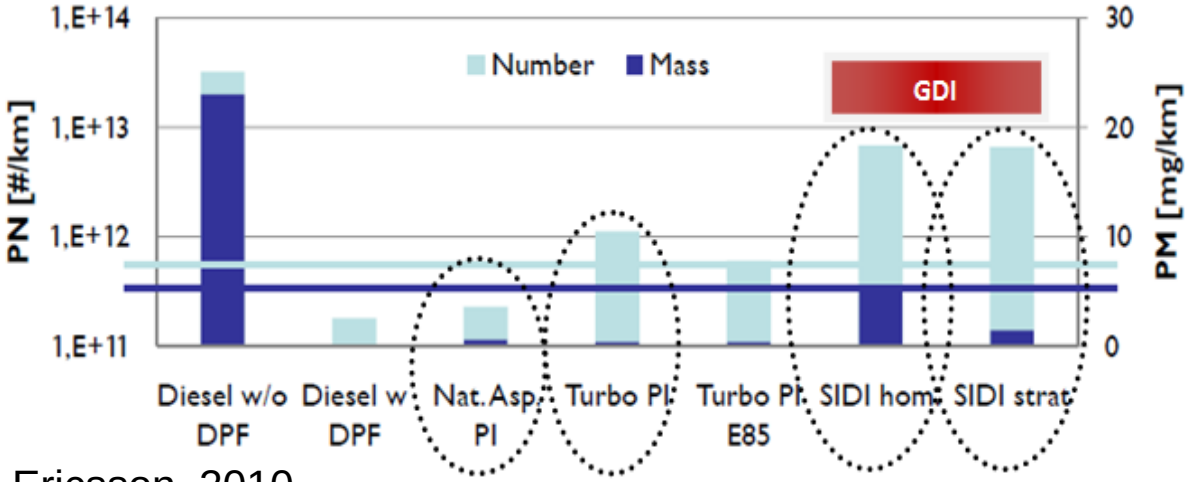
- GDI fleet is growing; expected to reach 7 million per year by 2020 in U.S.
- MECA has been studying GDI PM characteristics and GPF performance for past 5 years.
  - PM/PN emissions are highest during cold start, transient and sub-ambient temps
  - Vehicle cold-start strategy introduces PM variability
  - Fuel chemistry can affect GDI PM through PM Index
  - Lean GDI combustion exhibits range of EC and OC
  - Secondary organic aerosol emissions from GDI engines
- GPFs reduce variability in PM emissions caused by fuel, temperature and driving effects to lowest possible levels.
- Advanced fuel injection systems are delivering PM levels well below 1 mg/mile

Engine and Injection Technology Impacts Particulate Emissions



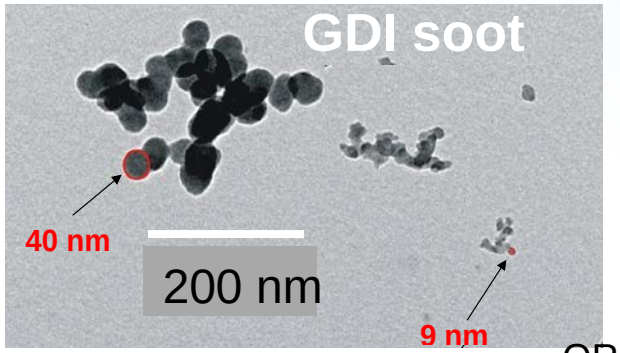
WG-DI	Wall guided direct injection
SG-DI	Spay guided direct injection
PFI	Port fuel injected
FFV	Flex fuel vehicle
FTP	Federal Test Procedure
UC	Unified Cycle

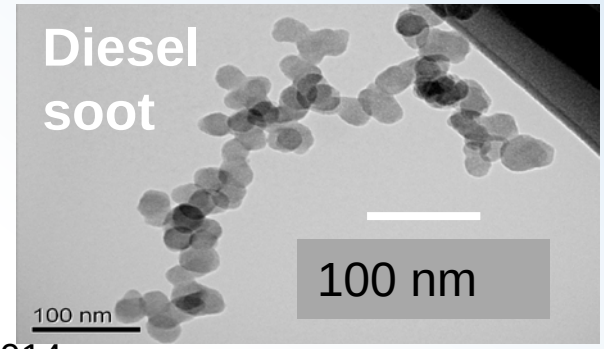
CE-CERT, Karavalakis et al., ES&T, 2014



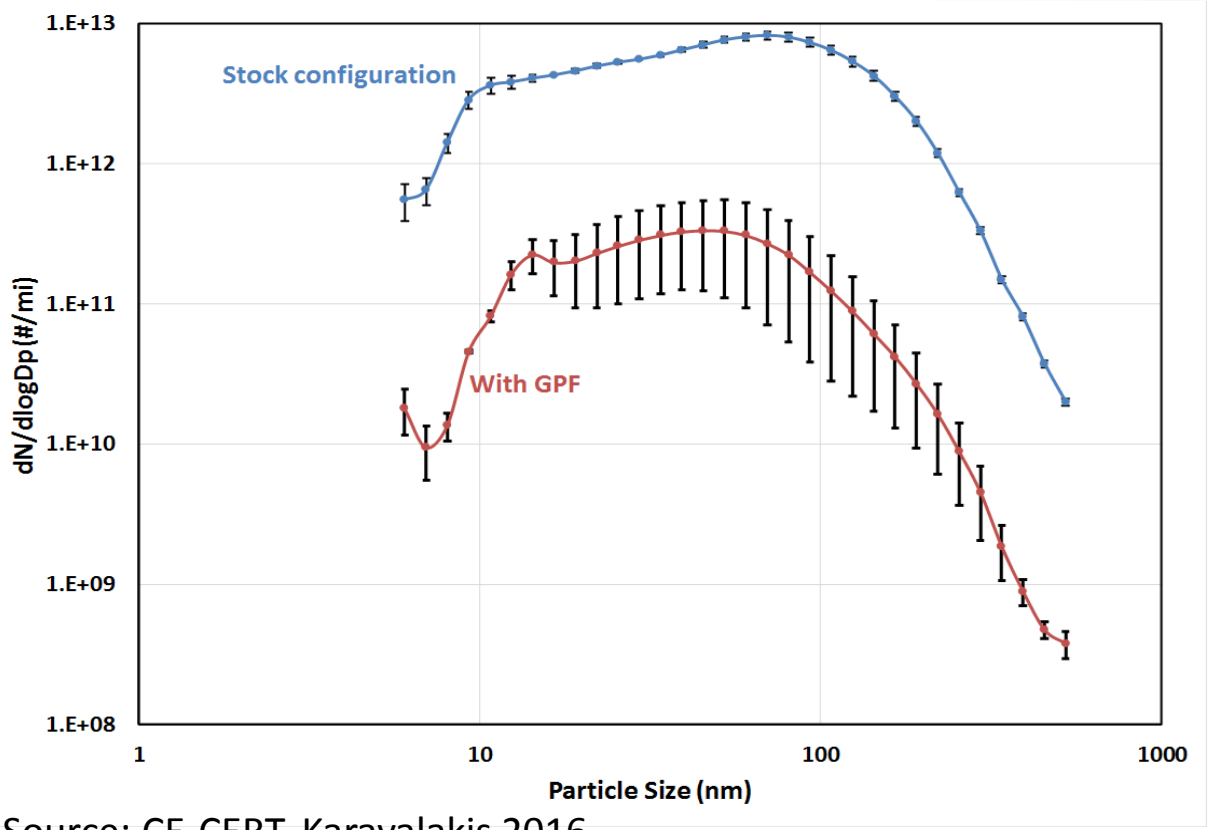
Ericsson, 2010

GDI PM Resembles Diesel PM



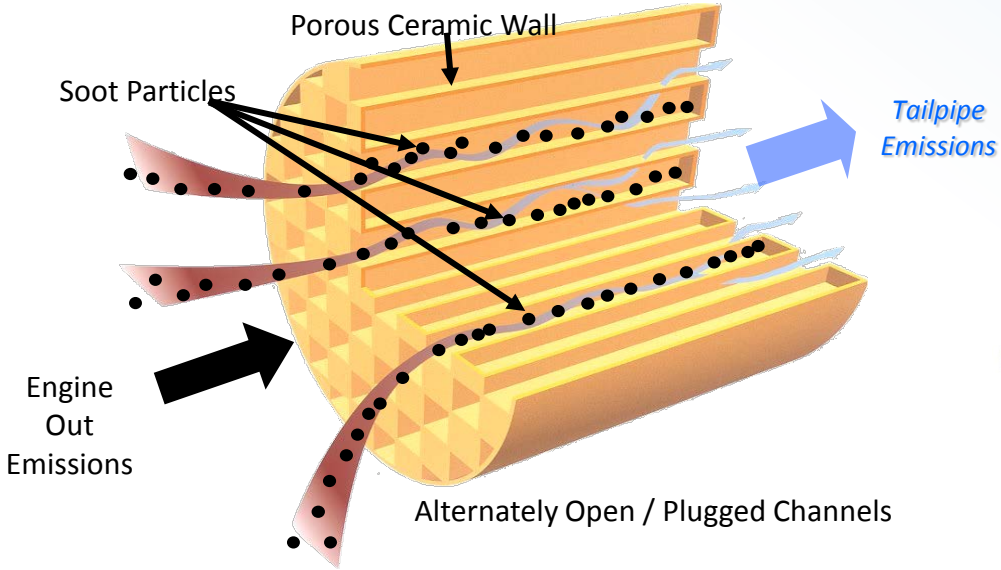


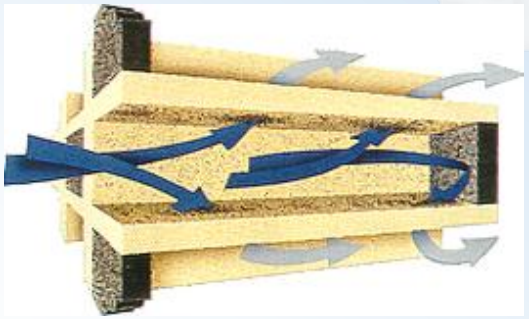
ORNL, 2014

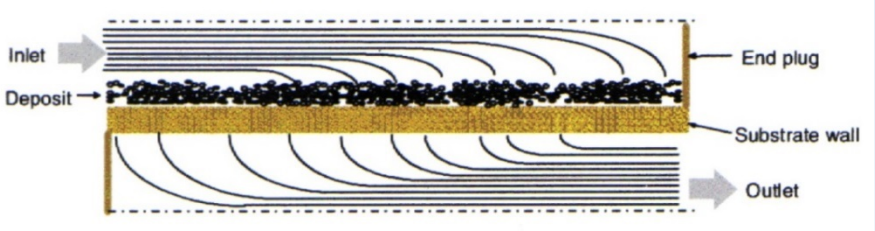


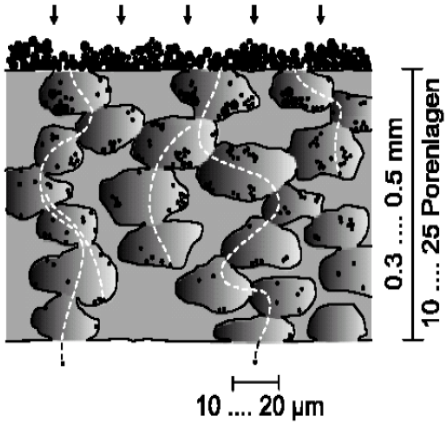
Source: CE-CERT, Karavalakis 2016

Anatomy of a Wall-flow Particulate Filter









Source : Anforderungen an Partikelfiltersysteme für Dieselmotoren, A.Mayer, TTM

- Effectively reduce: >95% PM, >99% UFP reduction
- Catalyzed filters capture and incinerate soot and associated toxics
- Experience with tens of millions of OE applications

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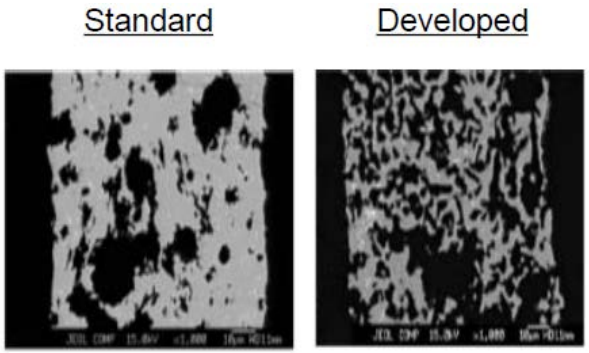
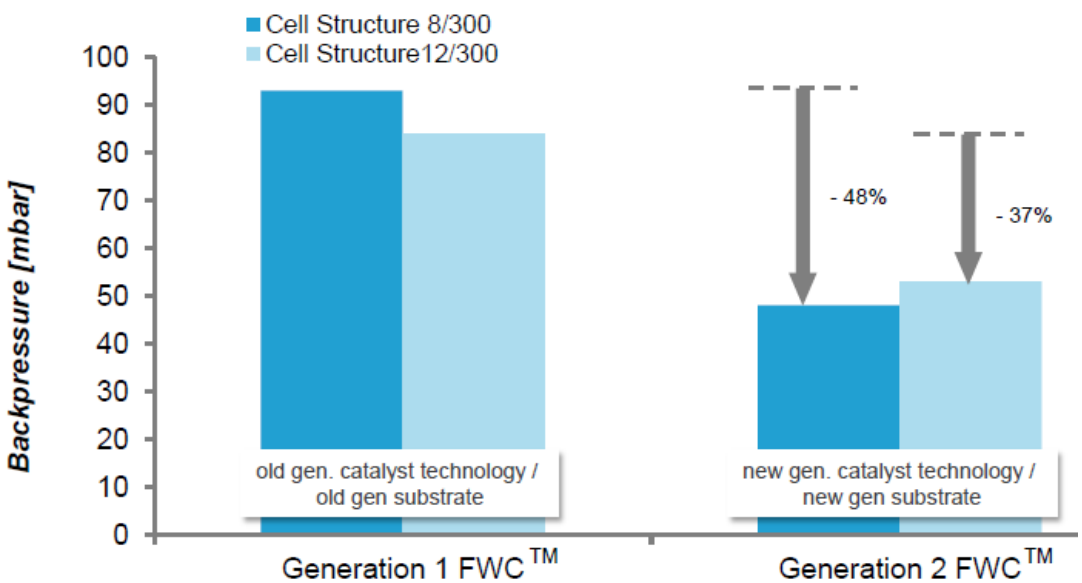
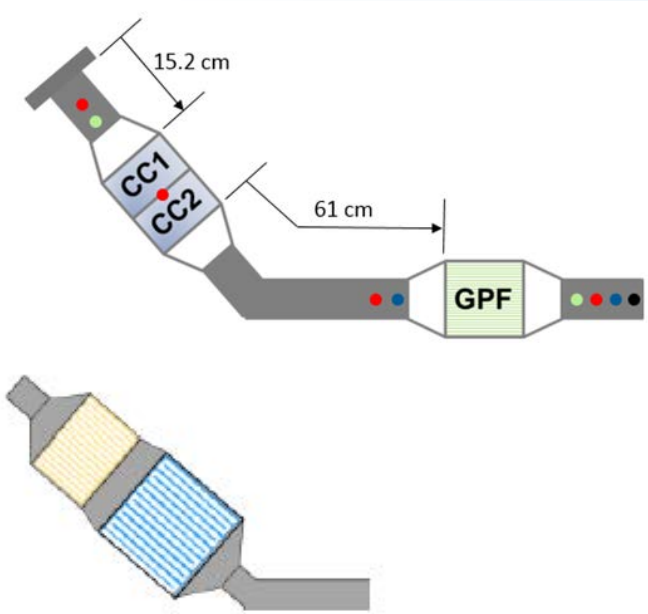
GPFs Designed to Minimize Back Pressure



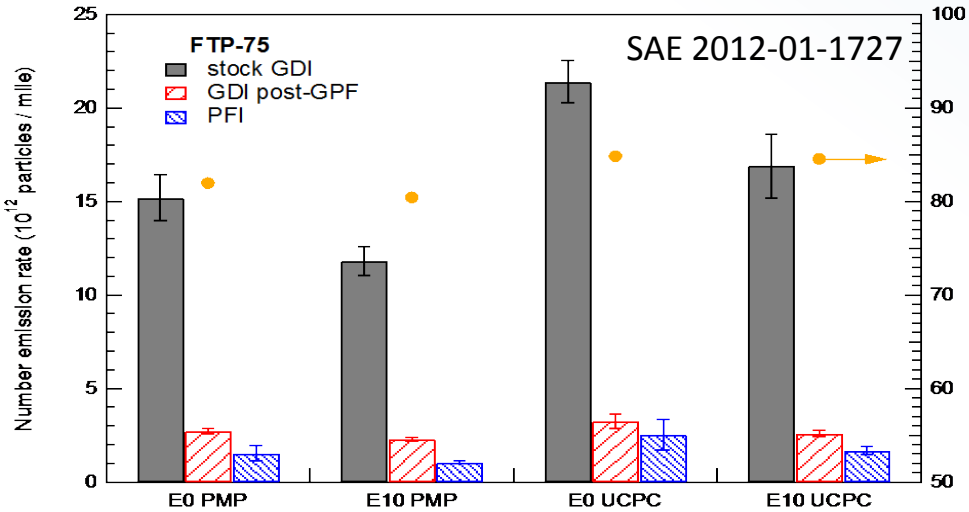
- Thinner wall high porosity substrates optimized for back pressure and fuel economy
- Porosity allows higher catalyst loadings and lower thermal mass
- Higher cell density provide higher geometric surface area
- Ford SAE paper 2016-01-0941 concluded no impact on fuel economy from GPF after 150K miles.

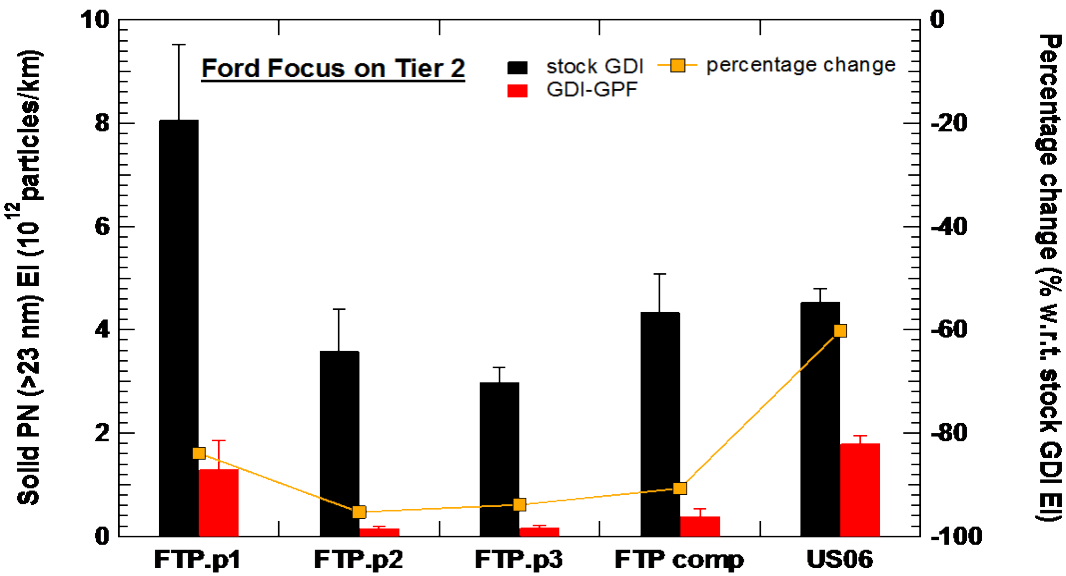




HKIPT Conf, 10/15

GPF Effectively Reduces GDI Particle Emissions – MECA/Environment Canada Test Program



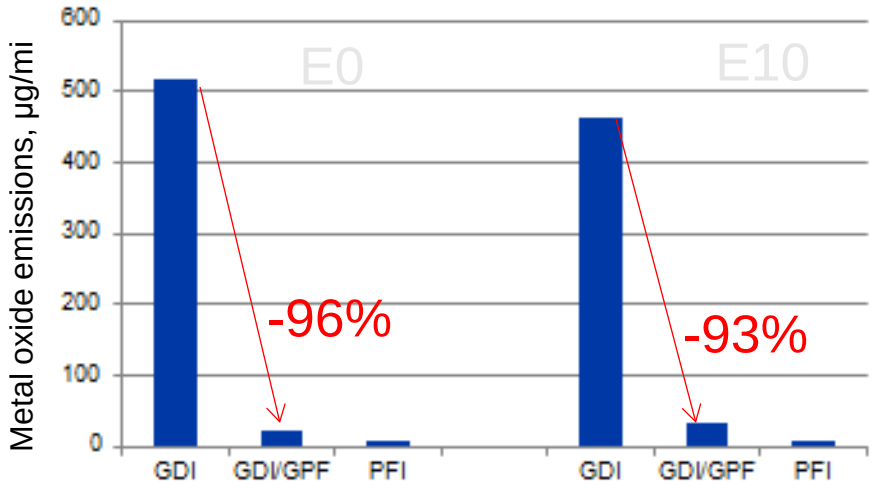


Source: Environment Canada, 2016

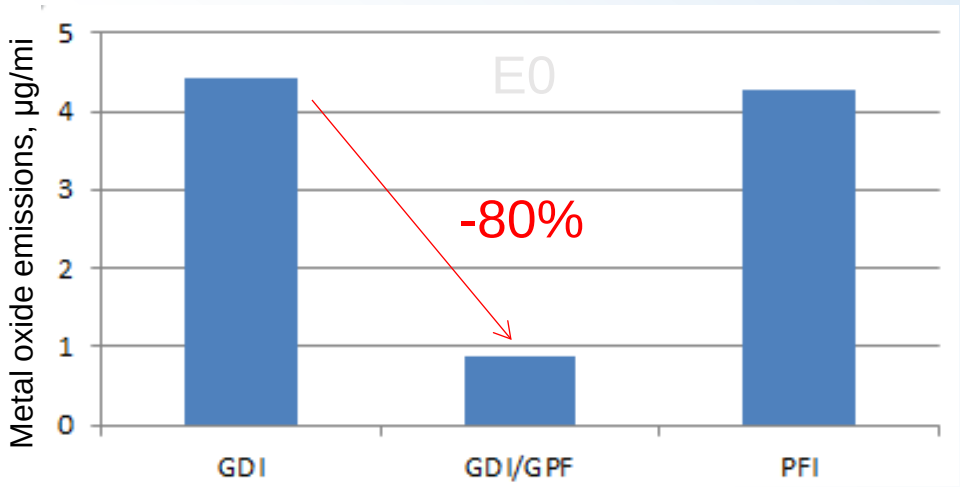
- GDI shows higher particle number emissions than PFI
- Highest PM emissions during cold-start and acceleration
- GPF efficiencies of around 85%
- GPF regeneration under US06
- E10 vs. E0 – relatively small effects at normal ambient temps.
- Both PFI and GDI emit ultrafine particles below 23 nm

GPF Effectively Reduces Ultrafine Metal Oxide Ash Particulates

US06



FTP-75

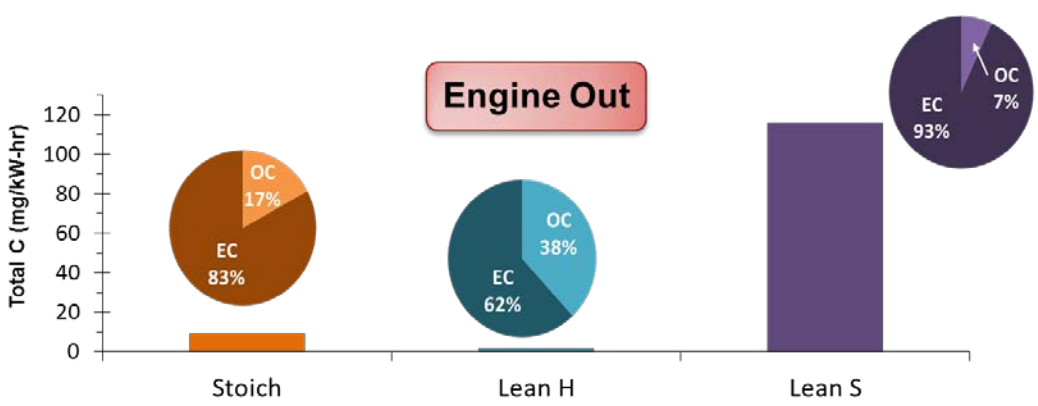


- Metal oxide ash particles have been shown to exhibited high oxidative stress response
- These ultrafine particles are less than 10 nm
- High concentrations observed under high-load (US06)
- GPF demonstrated high removal efficiency.

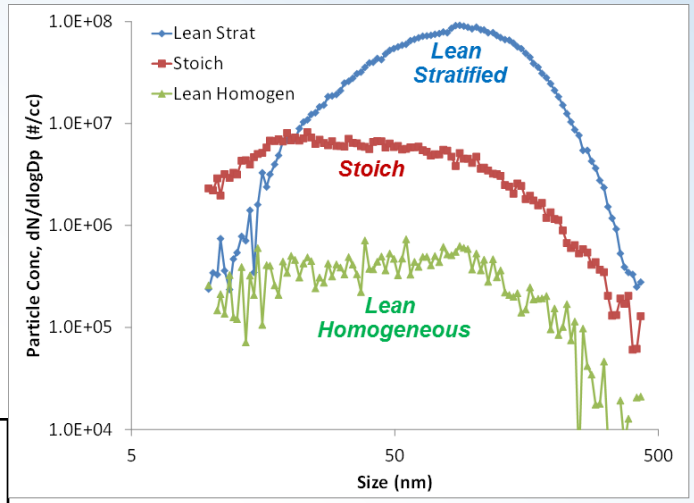
Source: Environment Canada, 2012

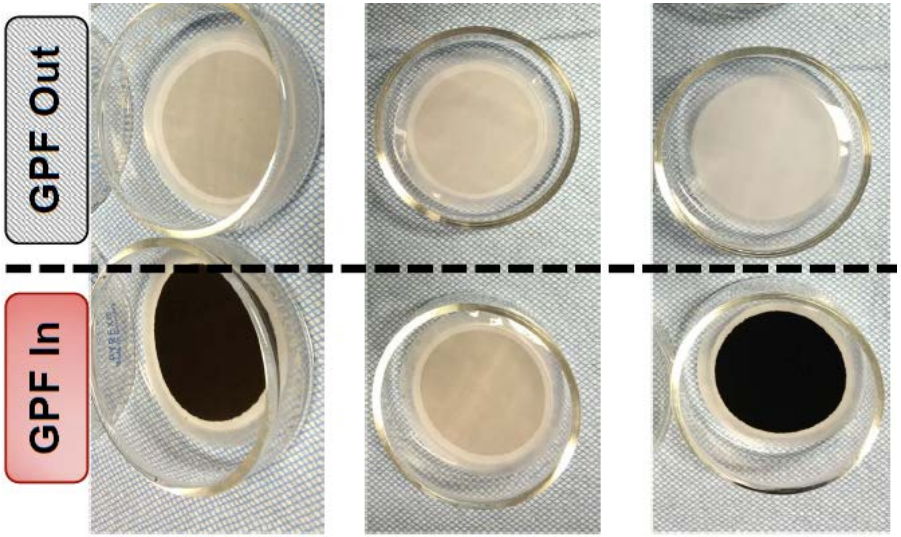
PM from Lean-burn GDI Engine

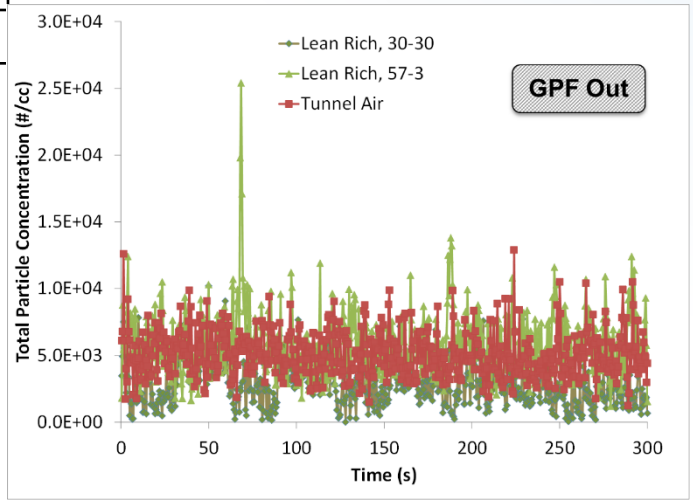
MECA Program at Oak Ridge National Lab



49%	16%	97%	OC Removal
97%	79%	> 99%	EC Removal
89%	55%	> 99%	TC Removal

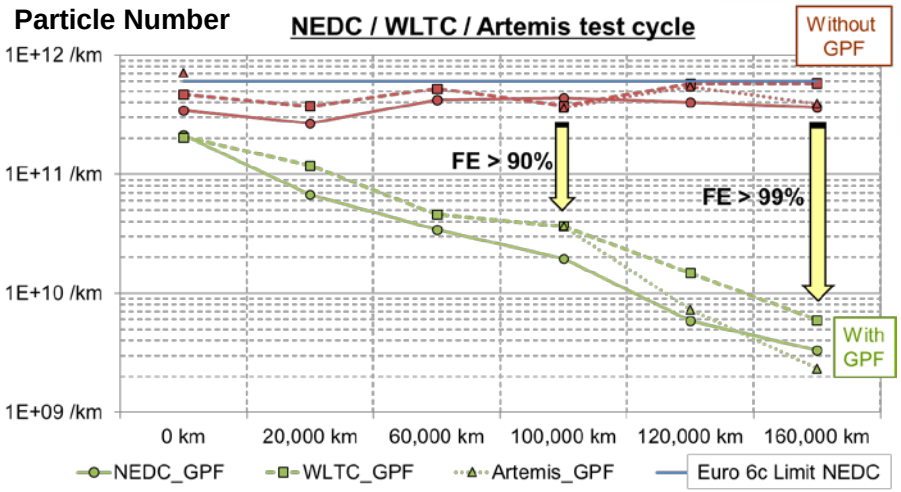


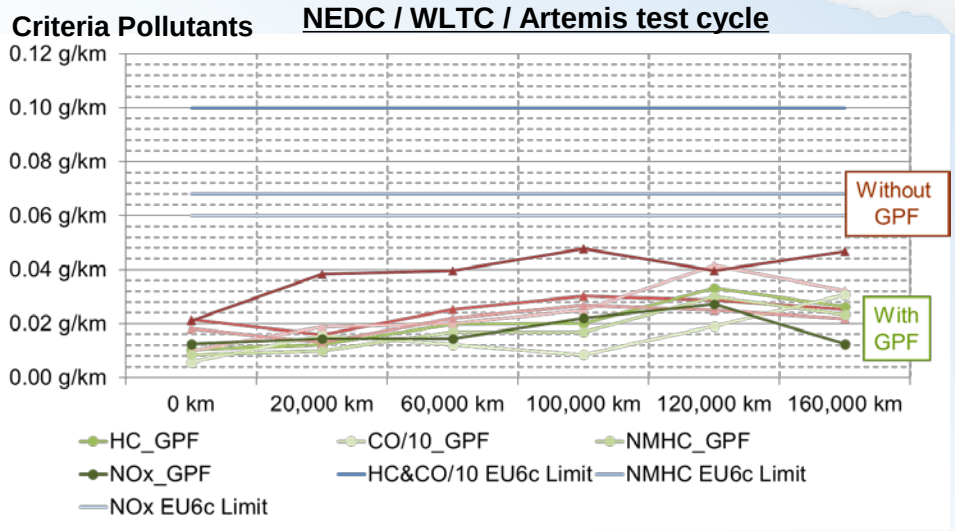


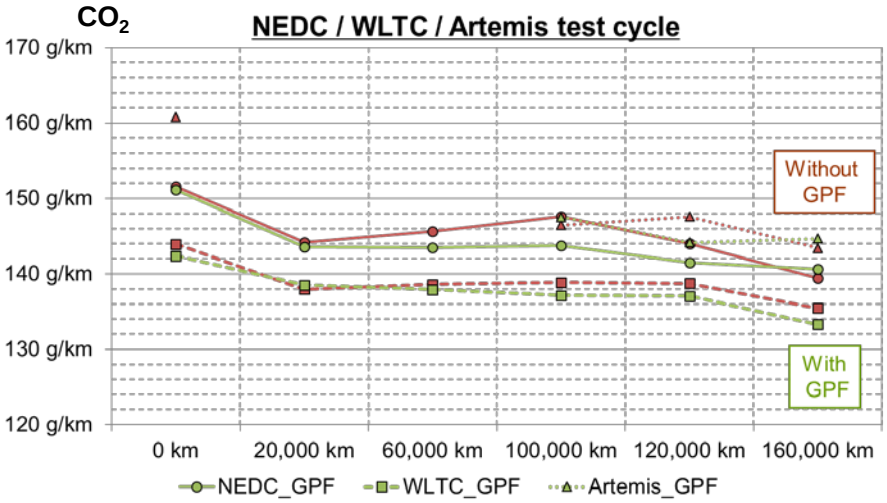


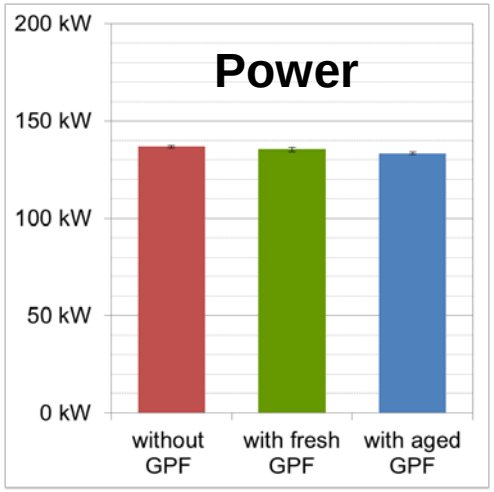
ORNL: SAE 2016-01-0937

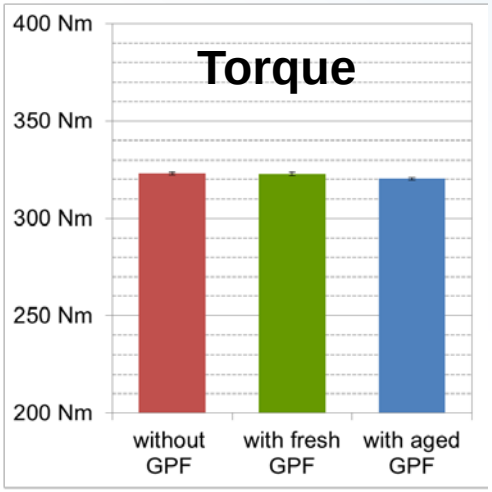
GPF Durability Demonstrated in Europe





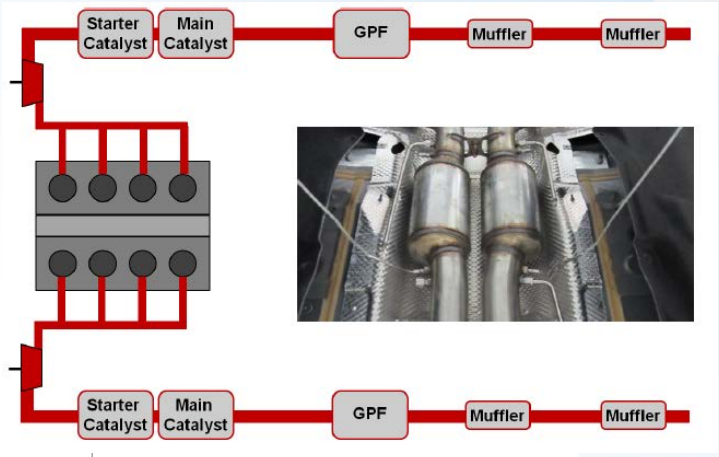


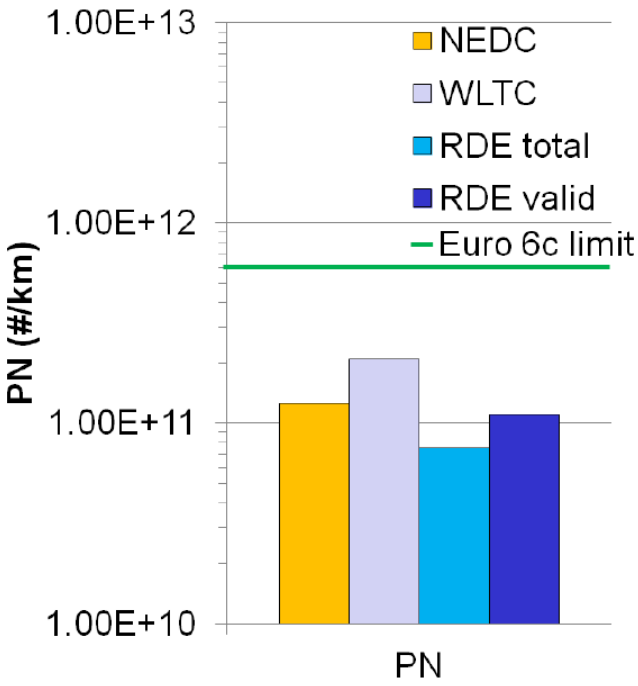


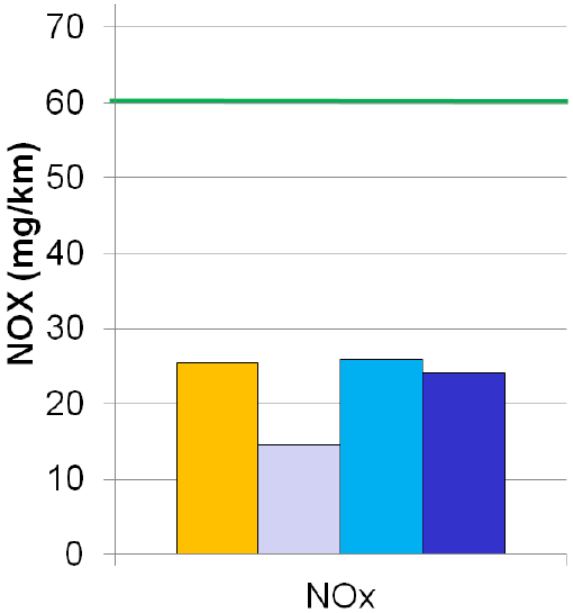


SAE 2015-01-1073

First Commercial GDI/GPF Tested



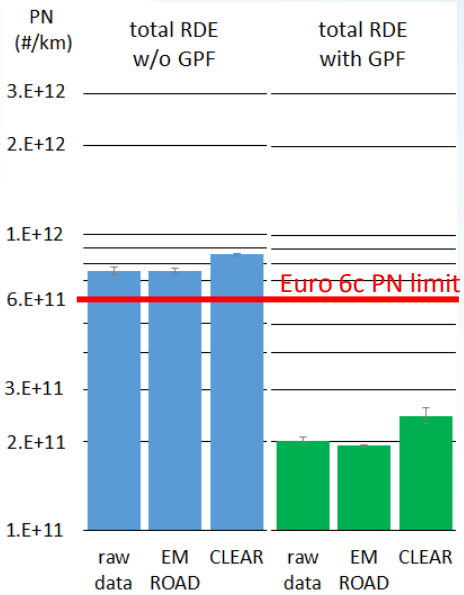


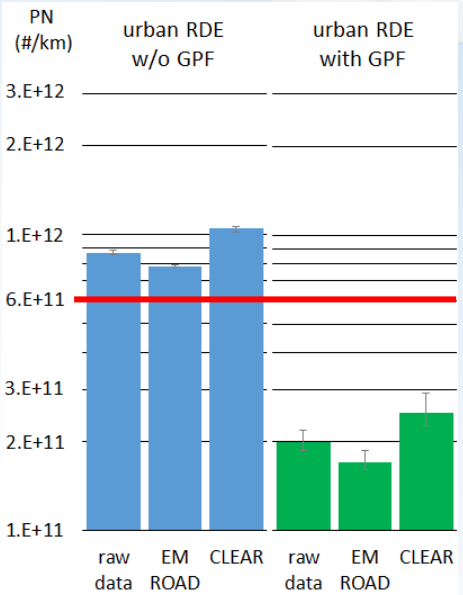


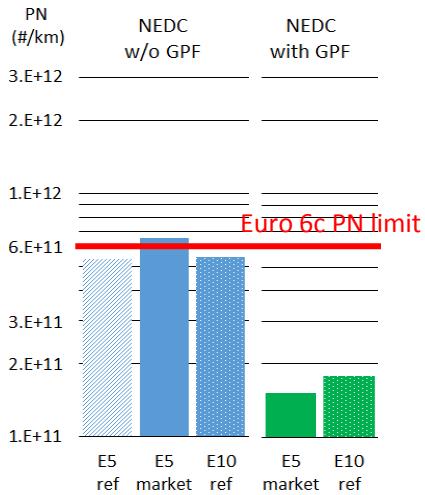
RDE total = before EMROAD; RDE valid = after EMROAD

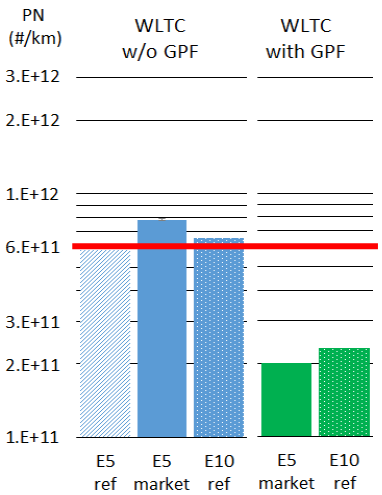
RDE Testing of Catalyzed GPF

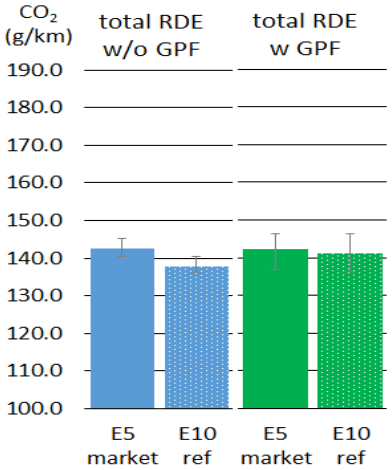
Association for Emissions Control by Catalyst AISBL

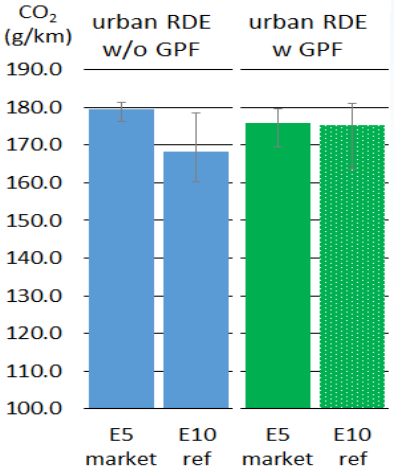






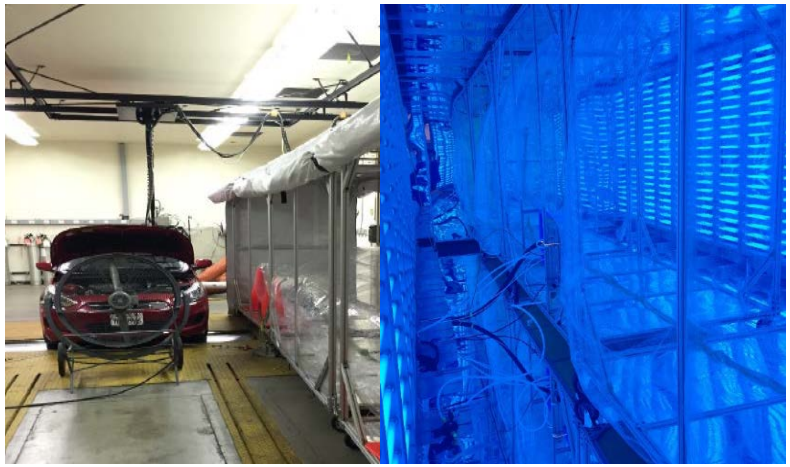


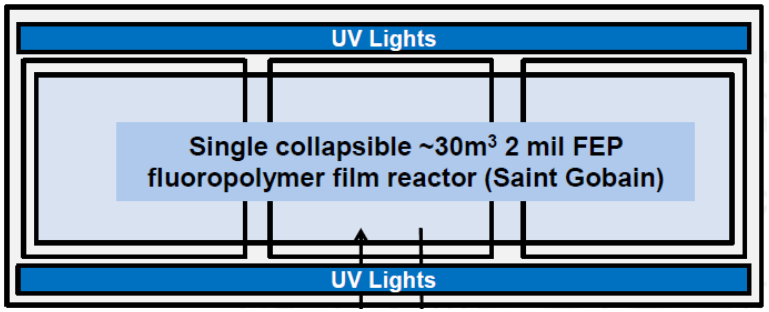


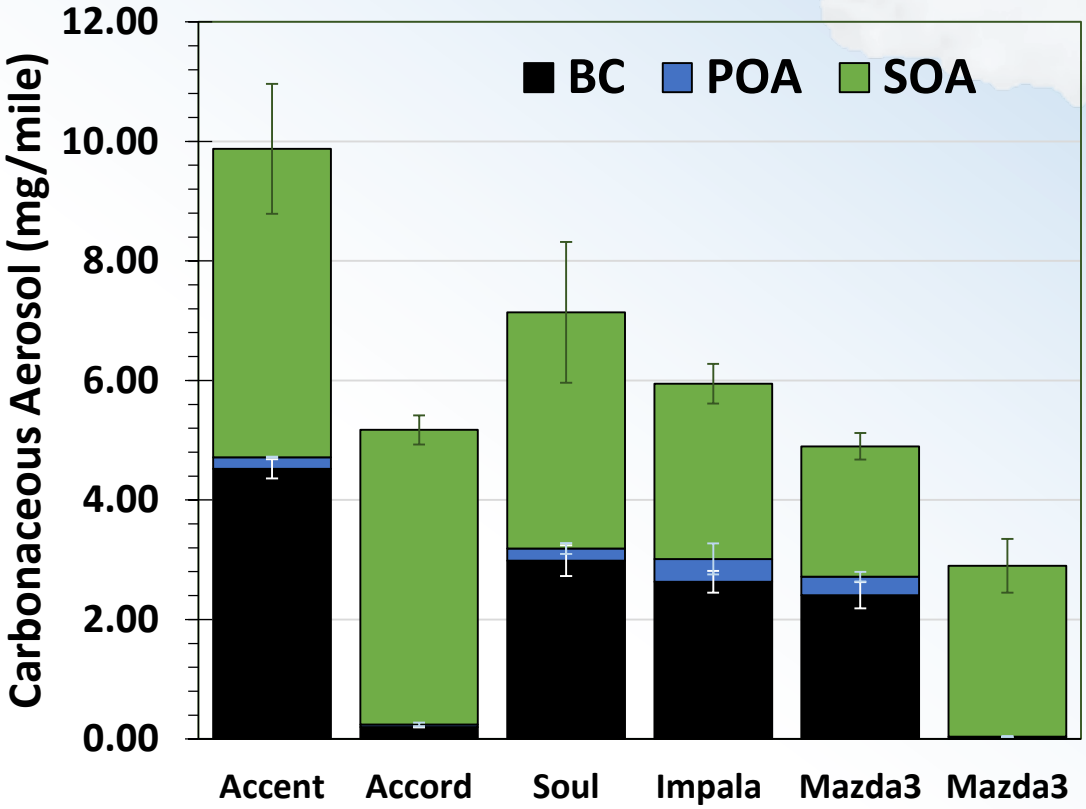


http://www.aecc.be/en/Publications/RDE%20PN_Technical_Seminar.html.

CE-CERT GDI Aerosol and PM Characterization





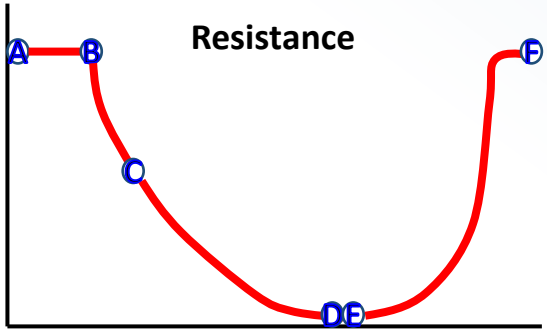


Source: CE-CERT, Karavalakis, 2016

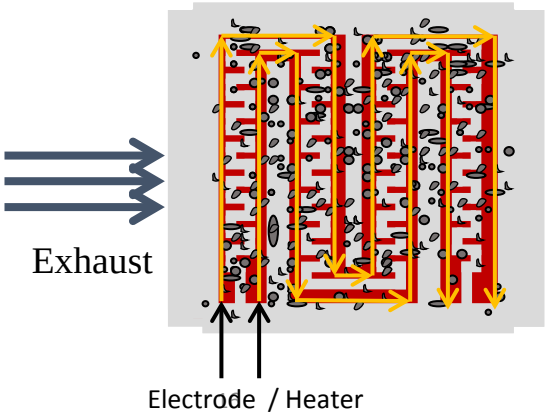
- SCAQMD/MECA program to characterize primary and secondary PM/PN
- MECA demonstrating catalyzed GPF technology on two advanced technology vehicles
- PM profile is vehicle technology and calibration specific
- Study will characterize PAH emissions

OBD Sensor Technology Being Developed for GPFs

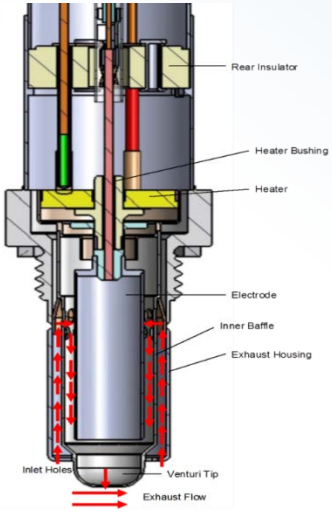
- GDI response time is longer than diesel
- Stoichiometric operation poses challenges for sensor regeneration
- Correlating PN and PM between vehicles



Accumulator sensor



Electrostatic Sensor



Summary and Conclusions

- Vehicle combustion strategy, fuel and calibration affects PM and PN emissions.
- ARB has concluded that 1 mg/mile PM can be measured using existing test methods
- Fuel Injection and filter technologies demonstrated ability to meet EU PN standard and LEV III 1 mg/mile standard
- GPFs have demonstrated no measurable fuel economy impacts. First commercial introduction in 2015, more in 2017.
- Several OEMs have announced broad deployment of GPFs on tens of millions of vehicles by 2022 in Europe.
- Particle number regulations in Europe, India and China will demand best available technologies in 2017-2023 timeframe.