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ECT – 2024 International Conference

Next Gen Filter Technology for Non-Road Engines in Emerging and Advanced Markets

Session – 8

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Information Security

Stop. Think. Protect.

Global Regulations
Non-Road

Non-Road		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
USA	EPA	Tier 4 Final										*Tier 5 (?)*
	CARB					SORE : Zero emitting < 19 kW (25 hp)					CARB Low NOx 90% + 1st GHG std (proposed 2029-2034)	
EU		Stage IV			Stage V							
JP		Tier 4 Final										*Tier 5 (?)*
Korea		Tier 4 Final	Stage V									
China		China Stage III (~ EU III A)			China Stage IV (~ EU III B + PN limit)						*China Stage V ?*	
India		BS III	BS IV (CEV 04/2021; TREM 01/2023)				CEV V 01/2025; TREM V 04/2026 ► 40% PM Reduction + PN Limit of 1E+12					
Brazil		Proconve MAR-I ~ US Tier 3 / EU III A						*Proconve MAR-II ~ US T4F / EU Stage IV/V?*				
Turkey		Stage IV (agriculture & forestry from 2021)			Stage V (Oct 2022)							
Chile					Stage V / Tier 4 (Oct 2023)							

Global Regulations: HDD Non-Road

Further tightening of NOx & PM standards will drive added content

Tractor

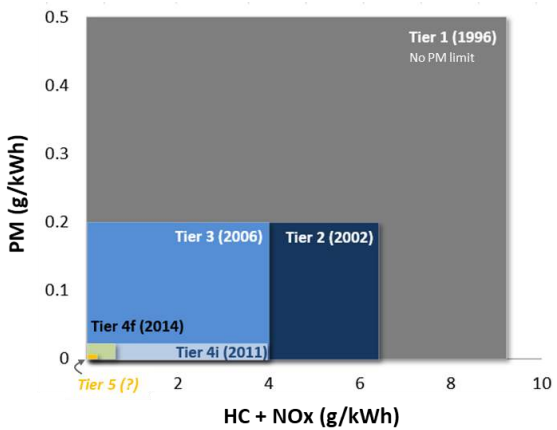
Excavator

Wheel Loader

Dozer

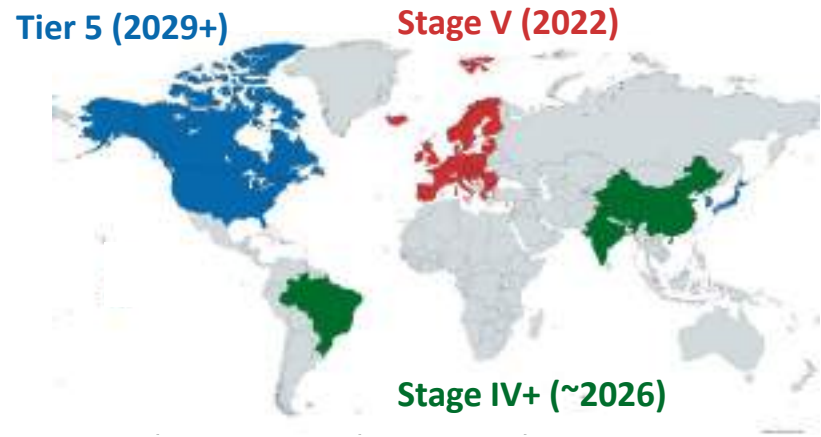
Backhoe

PM & gas emissions have been reduced by 90% in last 2 decades



- California is considering 75 – 90% reduction in NOx & PM
- Europe: emphasis on in-use monitoring
- Emerging markets will follow

Tighter standards are being implemented across the world



Region	Standard	Timing	Technology
N. America	Tier 5	2029+	DPF on all equipment Additional SCR content
Europe	Stage V	2022	PN Limit = DPF
China	Stage IV	2023	DPF + SCR
India	CEV V/TREM V	2025/2026	DPF + SCR
Brazil	Tier 4F	> 2026	SCR w/ limited DPF

Comparison of Current Global HDD NR Regulation Requirements

56 to 560 kW Non-Road Engines	US Tier 4F (2014+)	EU Stage V (2022)	India CEV V/TREM V (2025/2026)	China Stage IV (2023)
Emissions Std (NRTC/NRMC)	• NOx – 0.40 g/kWh • PM – 0.02 g/kWh • PN – N/A	• NOx – 0.40 g/kWh • PM – 0.015 g/kWh • PN – 1E12 #/kWh	• NOx – 0.40 g/kWh • PM – 0.015 g/kWh • PN – 1E12 #/kWh	• NOx – 3.3 g/kWh (56-130kW) • – 2.0 g/kWh (130-560kW) • PM – 0.025 g/kWh • PN – 5E12 #/kWh
In-use compliance requirement	• General US NTE limits apply • NTE limit 1.25x	• Yes but no CF limit, gas only PEMS monitoring & reporting • 9 engines before 30% durability, and after 70% durability or 9 engines/yr for 4 years • EU VI similar WBW, 20% power threshold, >50% valid window, cold start excluded	• After 4/2026, gas emissions monitored and should meet CF = 2.0 • Deterioration factors (DF) can be used in place of durability testing	• OBD for NOx & PM • PEMS for NOx & CO Only • NOx limit = 2.5x cycle via WBW over ambient temperature window & altitude • DF can be used in place of durability testing • For V-SCR, SCR inlet temp requirement < 550°C monitored via OBD
Durability requirement	• 8,000 hours/10 years	• 8,000 hours	• 8,000 hours	• 8,000 hours

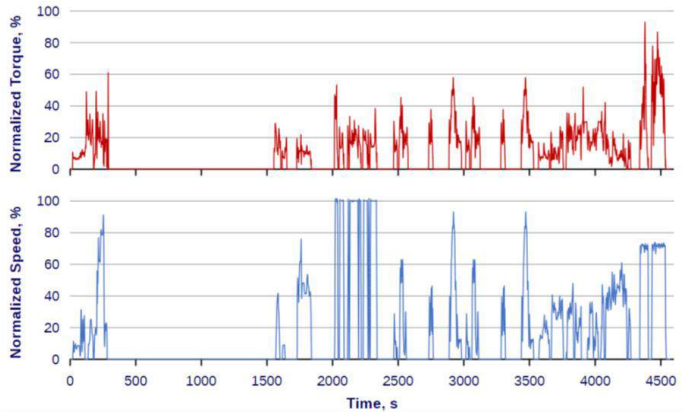
Proposed CARB Tier 5: 75 – 90% reduction in PM and NOx discussed

Timing: Board hearing planned for 2025. Implementation timeline TBD, currently 2029-2034

- Relative to Tier 4 Final standards:
  - Up to 75% reduction in NOx & PM for < 56 kW engines
  - 90% reduction in NOx & 75% reduction in PM for 56-560 kW → **NOx limit = 0.04, PM = 0.005 g/kWh**
  - 50% reduction in NOx & PM for > 560 kW
- First-ever CO_2 tailpipe standard for diesel engines : 5-8.6% reduction
- New Low Load Application Cycle (LLAC) for certification
- Useful life maintained @ 8,000hrs but years increased to 15yr. for 56-560 kW engines. Extended warranties TBD.
- Idling measures (engine shut-off for prolonged idling)
- Manufacturer-run in-use testing program – potentially moving average window (MAW) type, similar to on-road

Test cycles

Nonroad Transient Cycle (NRTC)
Steady-State (RMC C1 8-mode)
Low Load Application Cycle (LLAC) – *new, being developed at SWRI*

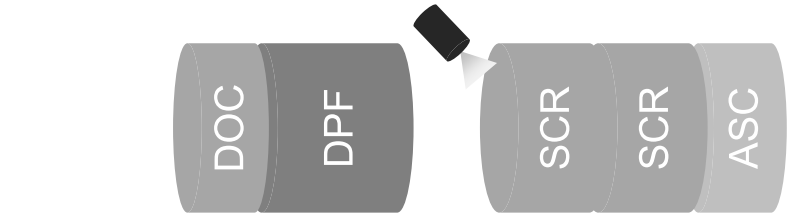


Average load : LLAC 15% vs. 35% on NRTC

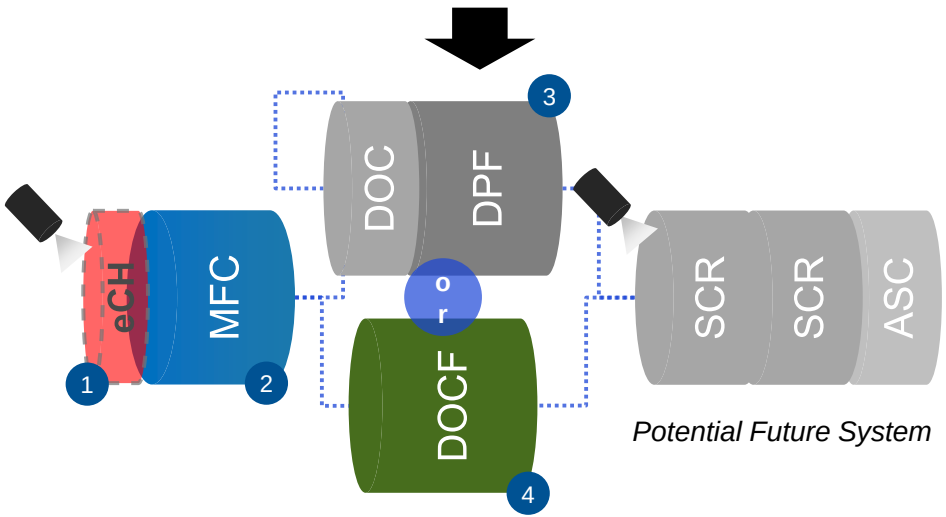
Note
EPA has not yet proposed a Federal Tier 5 standard

Potential Next-Gen Non-Road System Architectures

- Expectations that SCR volume will increase
- Innovation in DPF technology enables improved performance



Baseline Tier4F System



Potential Future System

1. *Potential:* **Catalyst heaters** positioned strategically with urea dosing points to maximize SCR function (pre or post urea injection)
2. Addition of **MFC** (pre-SCR) to meet cold-start NOx performance targets
3. Similar to on-road **DOC** and **DPF** technology
   - DPF shift to advanced microstructures for improved PN FE performance; equivalent or improved thermal mass
   - Alternative plug patterns or thinner webs for increased ash storage capacity, backpressure benefits
4. *Potential:* Integration of **DOC on Filter** (PGM Zoned)
   - Thermal mass and packaging reduction
   - Soot load estimation and DPF thermal management become more critical

Future Product Directions – General Trends

- We continue to expand our current product portfolio **to meet increasing emissions standards** and **optimize the total system cost** for our customers!
- If our current products don't meet your needs, the account team can involve Corning experts on specific issues, to talk about future product direction.

- **Substrates**
- Lower pressure drop, Δp
  - Thinner walls to larger diameters
- Extruded skin to larger diameters
- Alternative materials for low temperature applications

- **Filters**
- More ash storage
  - Higher ACT ratios
  - Alternative plug patterns
- Higher filtration efficiency for PN
  - Novel microstructures
  - Surface treatment (APT technology)
- Lower Δp filter designs
  - Thinner walls
- Extruded skin to larger diameters

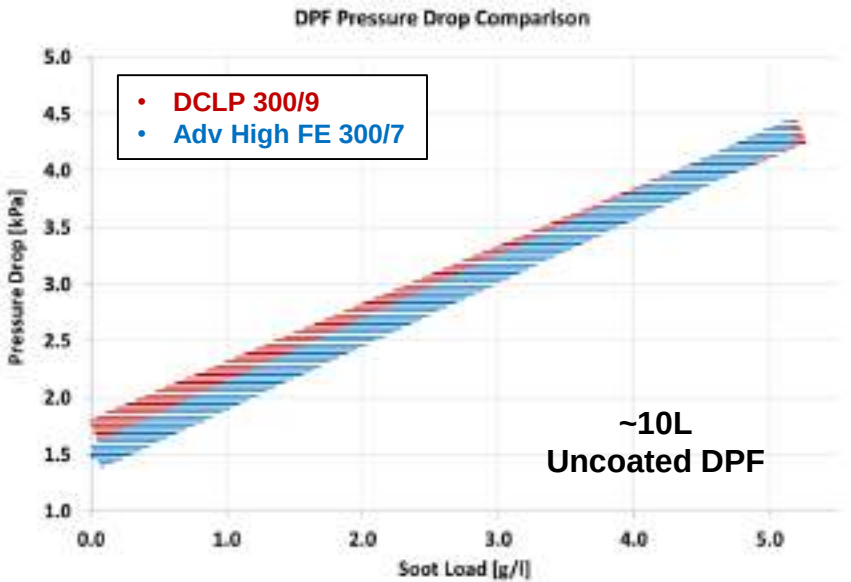
Next Generation NR DPF Solutions for Global Markets

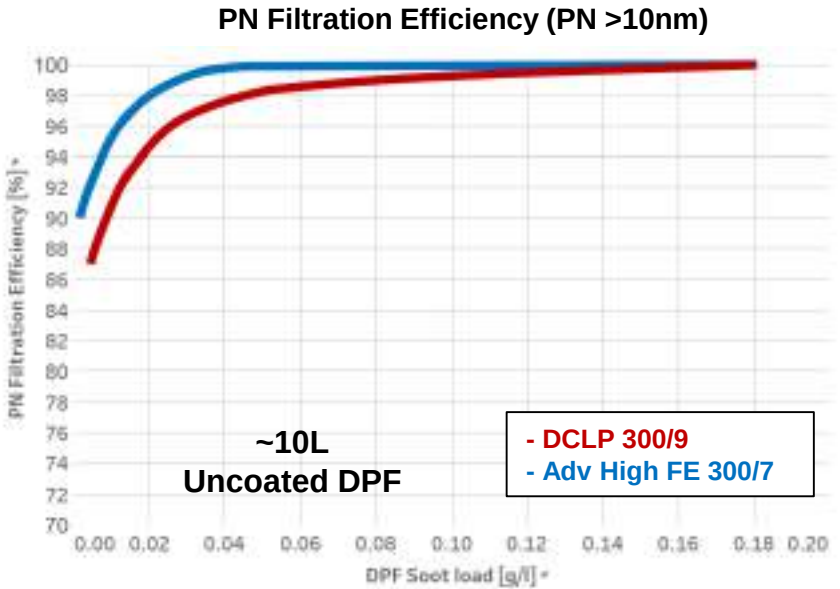
– Option 1 → Higher Ash Storage, Lower Pressure Drop, slightly better PN filtration than DCLP 300/9
– Option 2 → superior PN filtration, equivalent Pressure Drop and soot capacity than DCLP 300/9

Attributes	US Tier 4F/ EU Stage V	China NR IV/India BS IV CEV/TREM V	Advanced High FE DPFs for CEV/TREM V and beyond	
			Option 1	Option 2
Geometry (nominal CPSI/WT)	300/7 ACT	300/9 ACT	300/7 ACT	300/9 ACT
Median Pore Size (µm)	Medium	Medium	Low	Low
Ash Capacity	++	+	++	+
		+	+	++
Soot Capacity (Regen Interval)	**Reference**	++	+	++

Performance Comparison – DCLP vs Advanced High FE DPF

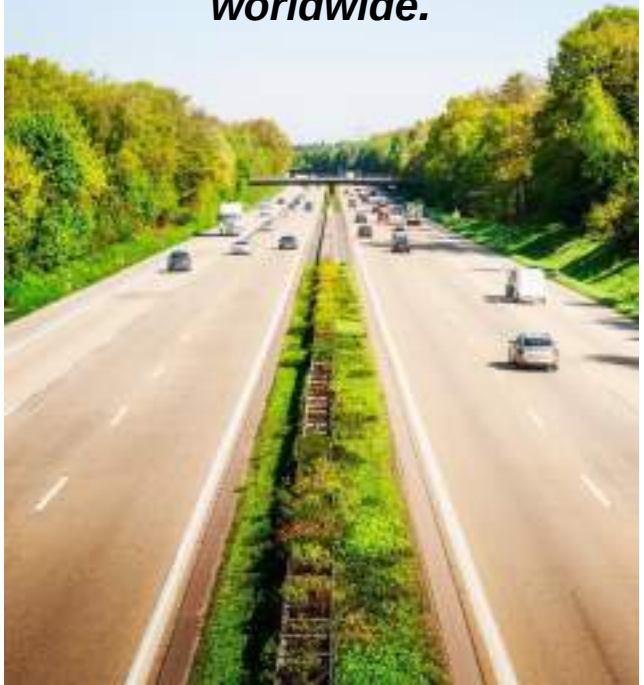
– High FE DPF provides better PN Filtration at low soot loads with minimal impact on Pressure Drop





Corning Environmental Technologies

*Helping our customers meet new emissions standards and enabling **cleaner air worldwide.***

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