REDUCING PM EMISSIONS: AN AUTOMOBILE MANUFACTURER PERSPECTIVE

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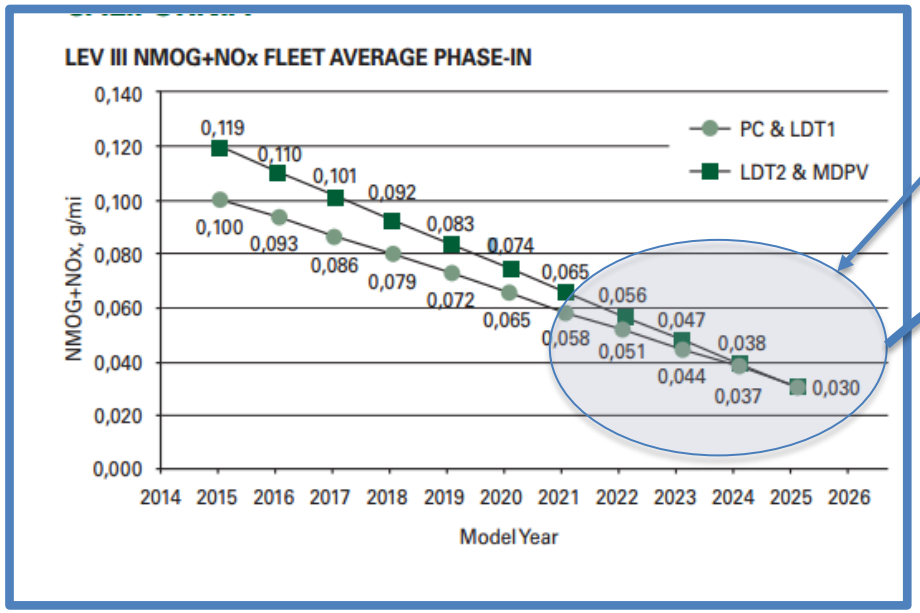
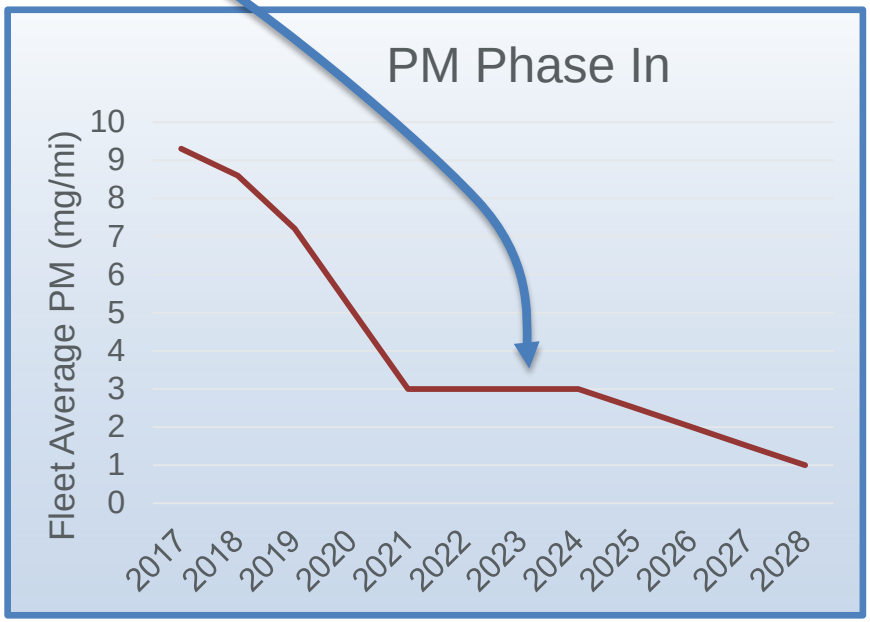
GENERAL MOTORS

REGULATION SNAPSHOT:



From 2022 to 2025 >75% of our product will be engineered to SULEV30 requirements



Interactions between PM and gaseous emissions make lower PM difficult with low NMOG+NOx

The challenge is greater for vehicles with high engine displacement and mass

GM FAVORS PM CONTROL WITHIN THE ENGINE OVER AFTER-TREATMENT WITH A GPF

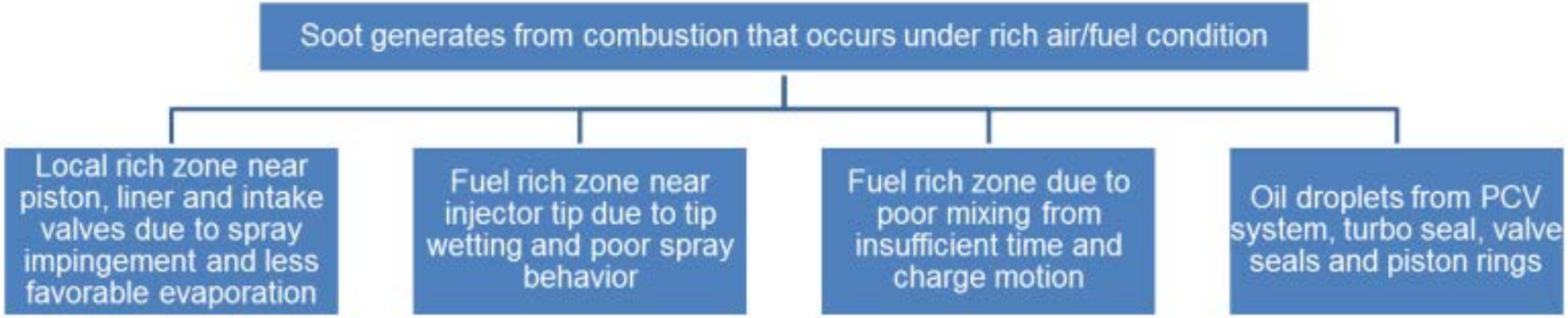
	GPF	Engine Mitigation
Particulate mitigation	+++	+
CO_2 emissions	- -	+
Reliability/Warranty	- -	+
Drive quality/ customer satisfaction	- -	+
Peak power	- - -	+
Engine protection	- -	+
Incentive for tampering	-	+ +
Cost	- -	+

Our approach:

1. Address the root cause of PM emissions from the engine
2. GPF is a “niche device” for low volume systems with unique challenges

Our Concern: We want to avoid the waste of adding GPF to obtain ~50% reductions because we “ran out of time” in 2022-2025

SOURCES OF PARTICULATE EMISSIONS FROM GASOLINE ENGINES



GM is focused on innovation in each of these soot formation pathways

GM IS IMPROVING HARDWARE, CONTROLS AND CALIBRATIONS TO ACHIEVE PARTICULATE REDUCTIONS

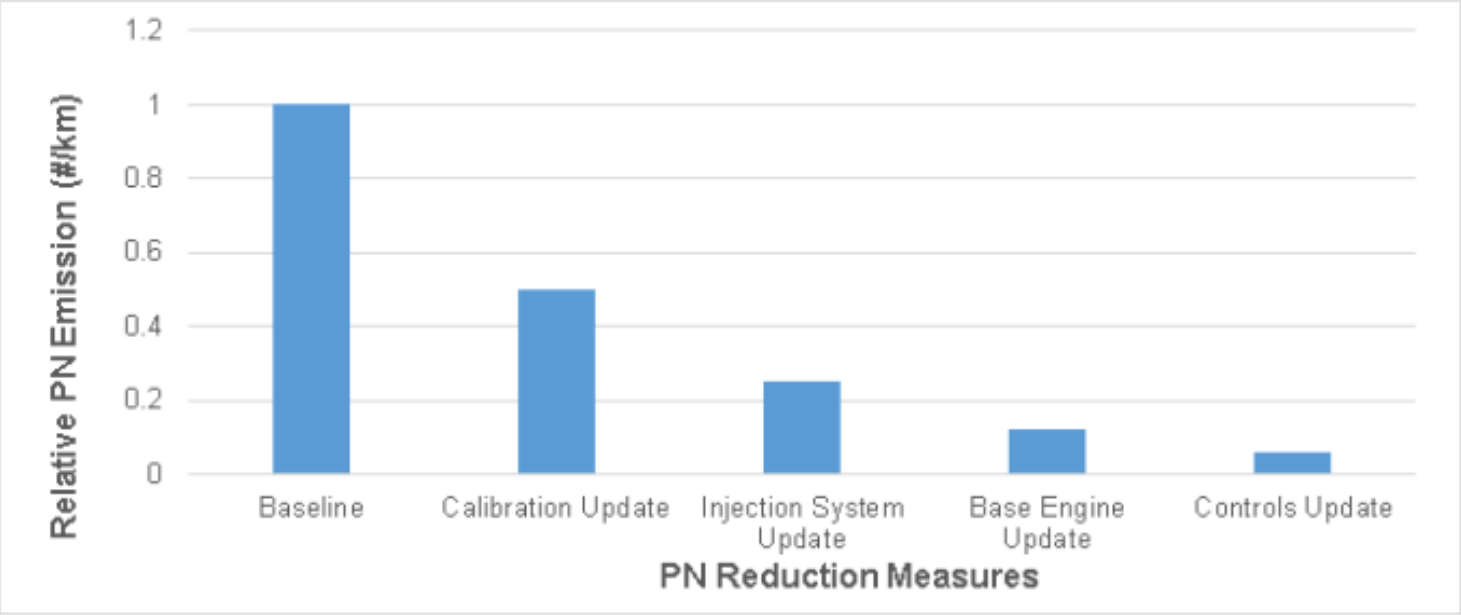


Figure 22: Impact of PN Control Measures on PN Reduction

Euro6c Particulate Emission Mitigation Using Piston Surface Temperature Measurement and Optical Visualization, Dr. Sharon X. Li (General Motors)

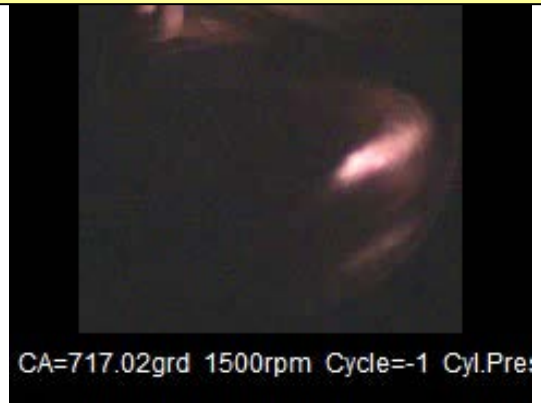
S. Li, 5/10/2016, 12th ISCD

https://www.avl.com/-/12th-international-symposium-on-combustion-diagnostics

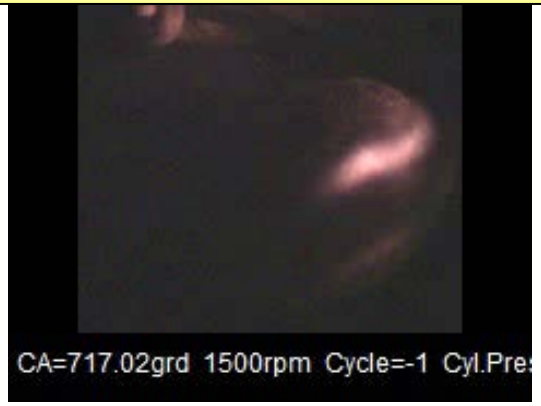
ENDOSCOPE VIDEO COMPARING SINGLE AND SPLIT INJECTIONS

- Cold engine operation (30ºC)
- Deposition of fuel on the piston and the associated pool fire is reduced by split injections

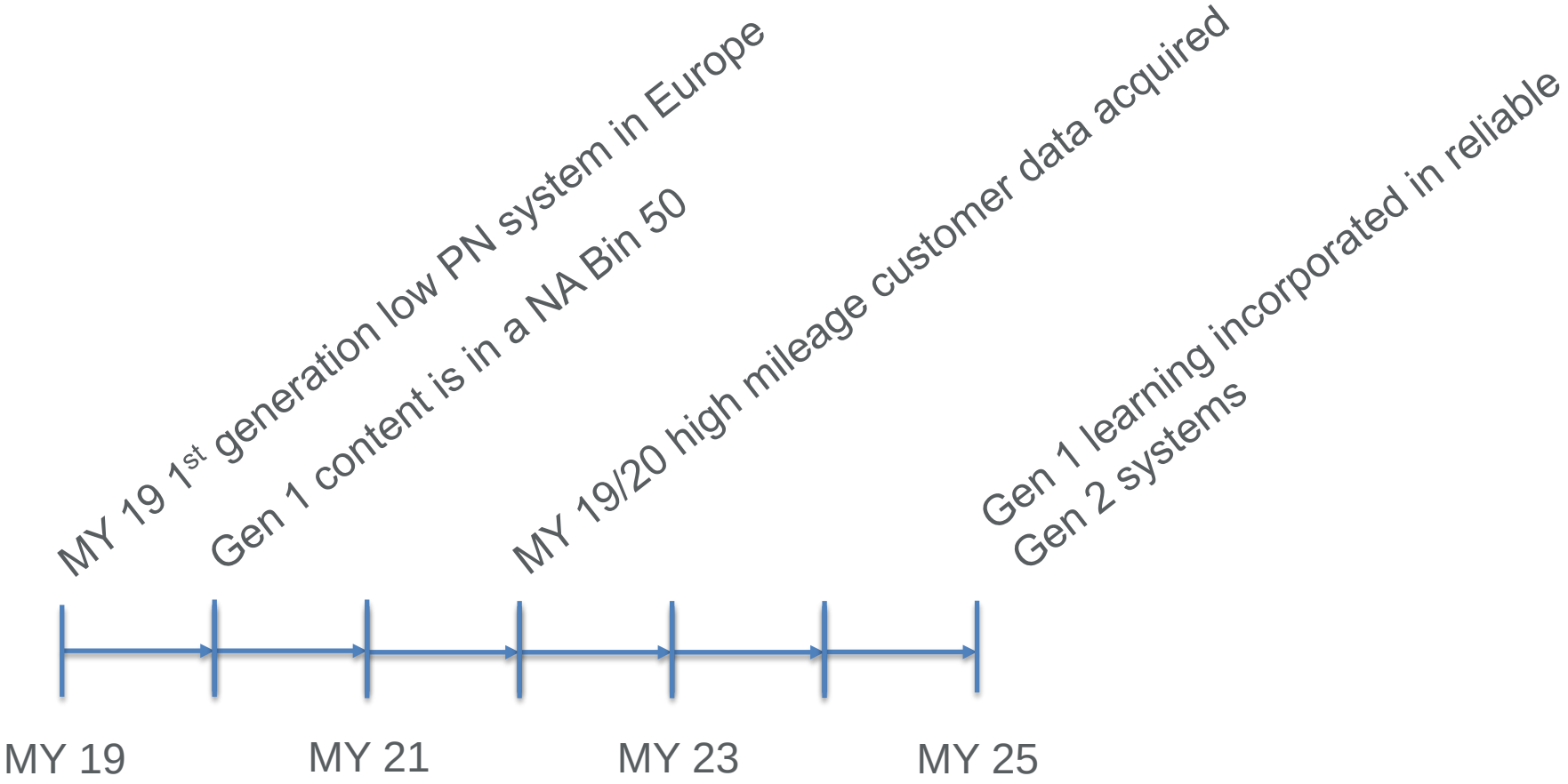
SOI 300º bTDC Single Injection



SOI 300º bTDC, Split Injection (60/40)

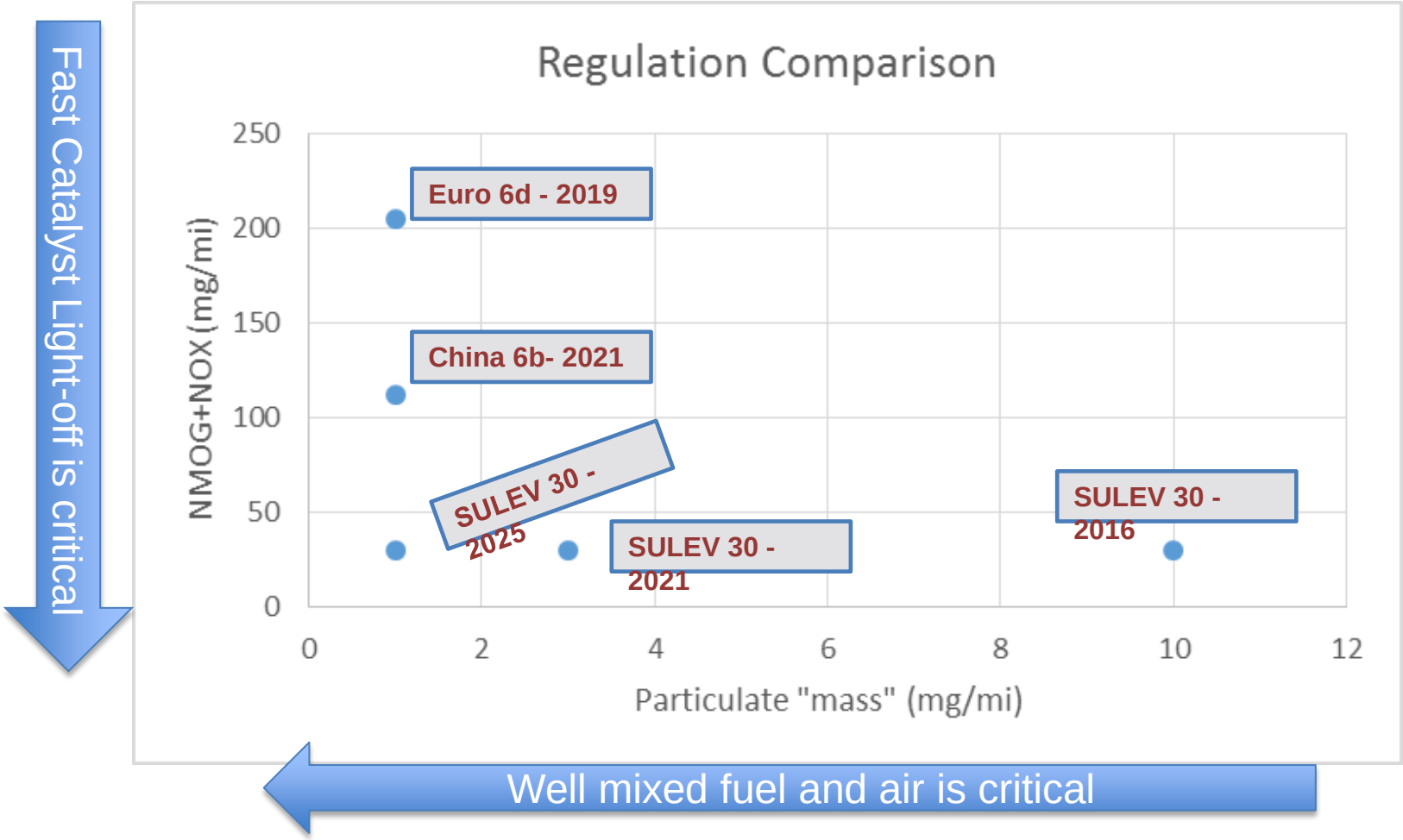


HIGH MILEAGE CUSTOMER VEHICLES PROVE THE RELIABILITY OF EMISSION CONTROL SYSTEMS



GM is committed to implementing systems that robustly comply in customer vehicles
A learning cycle takes about 6 years to show up in production

EURO 6 AND CHINA 6 REQUIREMENTS ARE QUITE DIFFERENT FROM LEV3



An estimate of 6e11 #/km = 1.0 mg/mi was used to achieve a common x axis

CONFLICT BETWEEN LOW PM AND LOW NMOG+NOX

- During a drive, most of the NMOG+NOx and particulates are generated just after starting
  - PM comes from cold engine surfaces and poorly vaporized fuel
  - NMOG+NOx comes from a cold catalyst

- PM is best mitigated by having a homogenous mixture of fuel and air

- NMOG+NOx is best mitigated by having a stratified mixture
  - Stratified operation enables very late spark timing
  - Late spark timing generates high amounts of exhaust heat with very low hydrocarbon emissions

- For low PM SULEV30 emission controls these 2 competing requirements must be balanced much differently than in a Euro 6 system
  - And not to be ignored the North American product mix is very different from Europe and China

- GM is actively working on low PM SULEV30 systems across the product portfolio

INTERACTION OF PM MASS MEASUREMENTS AND INNOVATION SPEED

- At the 1 mg/mi level, GM observes about +/- 0.5 mg/mi of measurement noise
- Typically, PM improvements are a combination of many changes each of which are on the order of .1 mg/mi
- Innovation is slow when the measurement noise is greater than the signal from an improvement step
  - It's not impossible, but it is slow
- GM is working with industry and government to improve particulate measurement technology to make it more appropriate for low level PM measurements

SUMMARY AND CONCLUSIONS

- Emissions regulations are changing simultaneously in every major market and these changes are straining GM's engineering capacity
  - Both the capacity for innovation and implementation

- GM supported the LEV3 rulemaking because it had 4 critical components
  - 50 state systems to reduce complexity
  - 10 year NMOG+NOx fleet average reductions
  - 1 mg/mi PM phase-in beginning in 2025
  - NMOG+NOx fleet averages

- GM is concerned that early phase-in of 1 mg/mi PM will drive content (GPF) that eliminates 50 state systems
  - For high volume applications GPF would be an interim solution to provide about 50% conversion