

ACEC and Chrysler ATS Perspective CLEERS 2013

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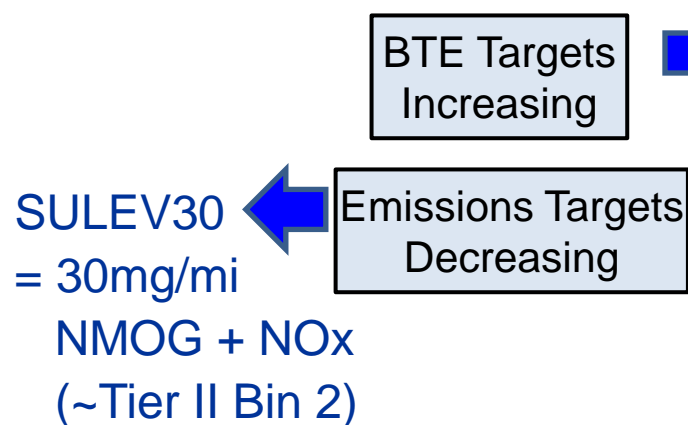
PT Application Engineering

April 11, 2013

Background (ACEC)

- Complement the ACEC engine technical team roadmap by demonstrating commercially viable, low temperature catalytic approaches for treating exhaust emissions as an enabler for advanced combustion strategies.

Emission Challenge



Technology Pathway	Fuel	2010 Baselines			2020 Stretch Goals		
		Peak Efficiency ¹	Efficiency ¹ @ 2000 RPM, 2 bar BMEP	Efficiency ¹ @ 2000 RPM, 20% Load	Peak Efficiency ²	Efficiency ² @ 2000 RPM, 2 bar BMEP	Efficiency ² @ 2000 RPM, 20% Load
Hybrid Application	Gasoline	38%	25%	25%	20% Increase		
Naturally Aspirated	Gasoline	36%	23%	23%			
Downsized Boosted	Gasoline	37%	22%	29%			
	Diesel	40%	26%	32%			

¹ Entries are Brake Thermal Efficiency (%)

² Entries are percentage (%) increase over the baselines

³ BMEP = Brake Mean Effective Pressure (bar)

These are stretch goals intended to drive combustion research; goals to be confirmed in 2012CY by thermodynamic analysis.

Assumptions

(based on ACEC BTE targets):

- Expected exhaust heat generated **is insufficient** for current aftertreatment technologies to operate at a SULEV30 level (**T < 200C**).

Emission Challenge

Current
Fed & CA Std.

Efficient low temperature
reduction technologies for
HCs, CO & NO_x

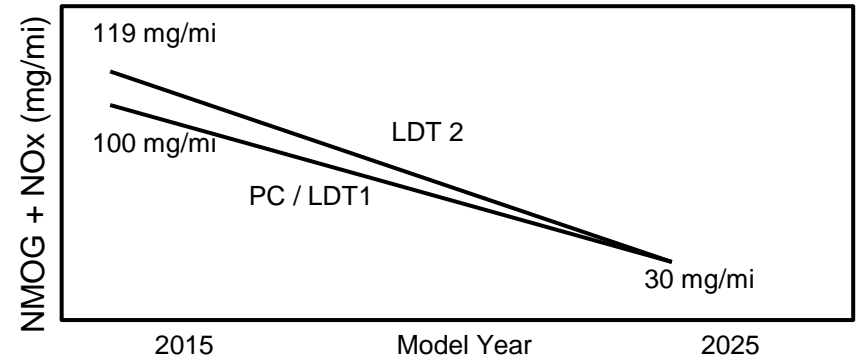
SULEV30
Tier III/ LEV III

PM / PN standards

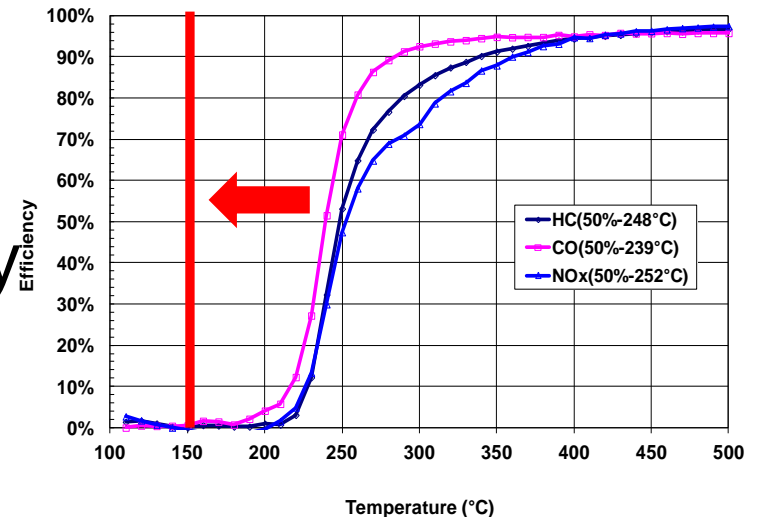
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• Aftertreatment Challenge:

- Meet NMOG + NO_x standard
 - SULEV30
 - Employ 150C technology
- Particulate
 - < 1mg/mi



Laboratory Light-off Performance of Three-Way Catalyst for Gasoline Applications, Following Simulated in-use 100K mile Aging

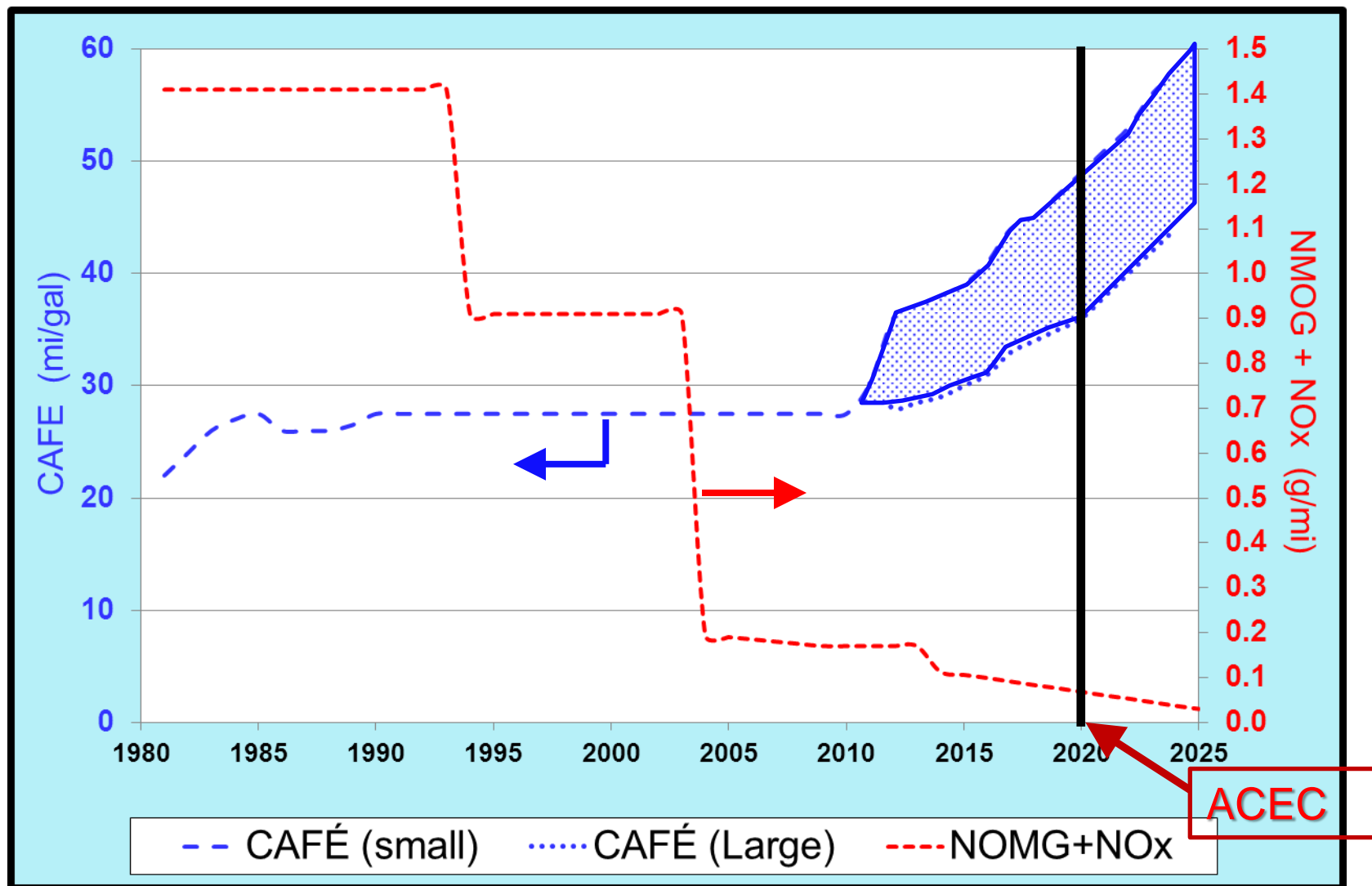


150C lightoff / steady state operation implies revolutionary vs. evolutionary approach.

Emission Challenge

- Key drivers demand technology improvements:
 - Mandated fuel economy gains and GHG / CO₂ reduction
 - Future emissions standard for LEV III / Tier III
- Fuel economy and emissions are inter-related
 - Proposed combustion advancements (in ACEC program) require unique emission control solutions, common challenges include:
 - Lower exhaust temperatures
 - Control of NO_x under fuel lean conditions
 - Incorporation of PM control into gasoline engine systems
- Current technology is limited by:
 - Catalyst light-off and potential steady state operating performance
 - Fuel sulfur
 - Full useful life durability

Emission Challenge (CAFE & Emission Standards)



Higher BTE Forcing Low T Aftertreatment Pathway

Fuel

Diesel

Gasoline (E10/E15)

E85

CNG

Combustion Strategy (downsized and boosted)

Diesel (conv./HCCI)

GDI (lean)

Stoichiometric

Temperature Strategy

Ambient

Heated Catalysts

Secondary Air

Waste Heat Recovery

Aftertreatment Strategy

Low T Lightoff/Steady-State Catalysts Absorbers Lean NOx PGM content

Emission Need

Engine Technologies:

Dilute Gasoline
Combustion



Clean Diesel
Combustion



Low Temperature
Combustion



Fuels



System
Solution

Emission Control Needs:

Lean NOx Control



PM Control



Cold Start Challenges



Low Temperature CO and HC
Control



Impacts of Fuel Composition on HC
Control



Aging Effects
(Thermal and Chemical)



- Joint agreement on:
 - Lower exhaust temperature and challenges during warm-up will result from more efficient combustion strategies
 - Low temperature aftertreatment must be included in ACEC roadmap
 - 90% conversion for NOx and HC at 150 deg C is our stretch target for 2020
 - Current aftertreatment is inadequate to meet this goal
 - New project proposals should identify required resources and include role of suppliers and OEM's
 - OEM's will support these projects subject to approval of requests by APTLC

Background (Chrysler)

- Powertain Application Complexity is growing significantly due to increasing GHG/CAFE/CO₂ and Tailpipe/Evaporative Emission Regulatory Requirements (all regions) in combination with Marketing/Commercial opportunities.
- LEVIII (Partial Zero Emissions Vehicle) requires all 3 of the following:
 - SULEV30 Tailpipe Emissions = 30 mg (combined NMOG + NOx)
 - 150K miles warranty on emissions related components
 - Zero Evaporative Emissions System



Summary (courtesy of Tim Johnson/Corning)



- **Regulations**

- LEVIII finalized, Tier 3? RDE in Europe developing and very important
- US (2025) and EU (2020) LD CO2 regs finalized. 3 yr consumer payback period indicated

- **Engines**

- LD diesel advancing incrementally.
- Gasoline engine technology advancing rapidly. Mild HEV, downsizing. High specific power.
- GDI PN development focus in Europe.
- Some new and attractive engine designs in research and early development.

- **Diesel emission control**

- 98% deNOx desired to remove EGR. SCR systems showing continuous improvement.
- Durability issues being addressed.
- DPF+SCR systems advancing
- New LD system deNOx systems coming from Japan. Stoich diesel in transients, NH3 better-controlled storage. HT NSR (LNT) system going commercial.

- **Gasoline emissions control**

- GPF being defined. TWC on GPF shows advantages.
- Very advanced TWC zoning and layering technologies advancing

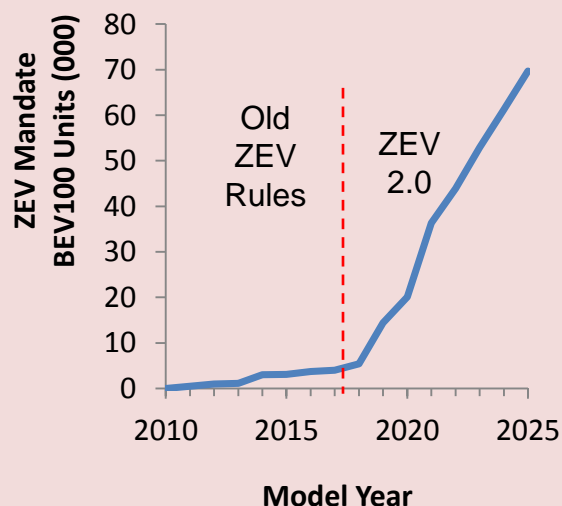
Three Related NAFTA Emission Regulations



Need to consider multiple emission regulations to develop an optimized compliance plan

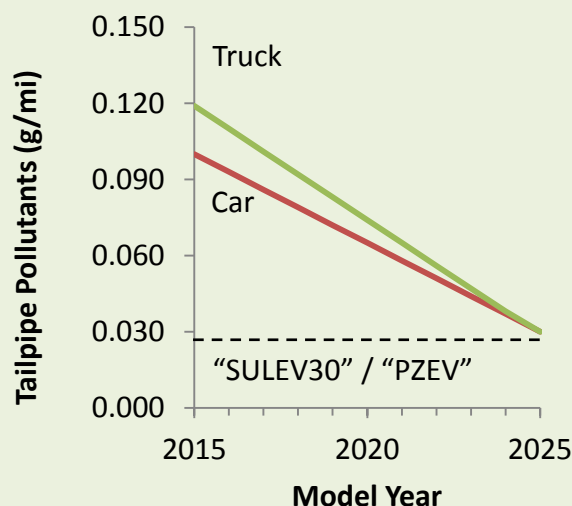
ZEV Mandate

- Technology forcing mandate to drive vehicle electrification
- Enforced by California and certain other states
- Requires base number of ZEVs (zero emission vehicles)



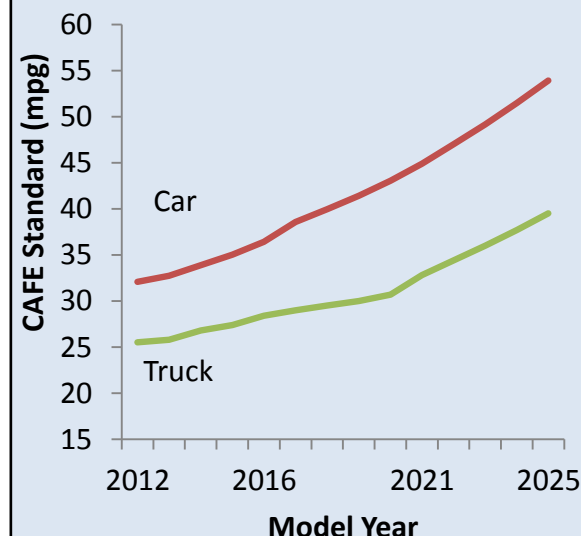
Tailpipe Criteria Emissions

- CARB:
 - **LEV III** starts in 2015MY
- EPA:
 - **Tier 3** on hold
 - 2018MY estimated start
- Compliance based on sales weighted fleet average emissions

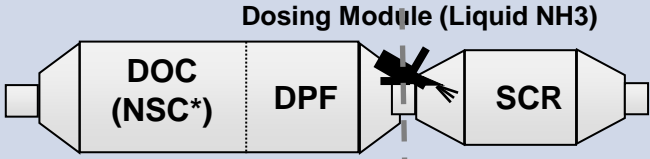
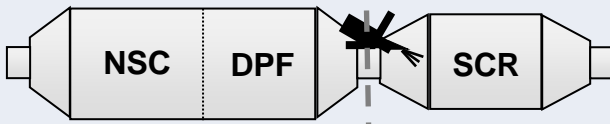
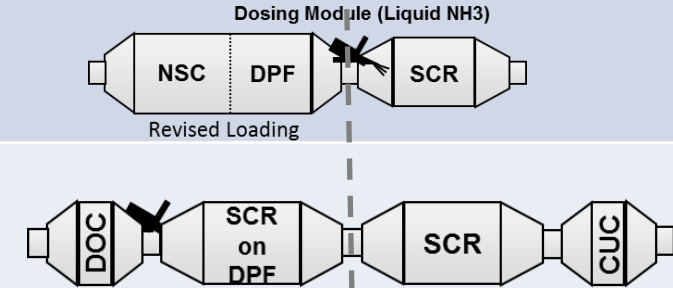


Fuel Economy (CAFE) / GHG

- Miles per gallon for CAFE – enforced nationwide by NHTSA
- Grams per mile for CO₂ – enforced nationwide by EPA
- Compliance based on sales weighted fleet average CO₂ emissions and fuel economy



Diesel Emissions Technology Assessment

Emissions Level/Risk Assessment	Vehicle Load	Engine Upgrades	Aftertreatment Update & Additional OBD sensors		OBD Requirement Risk Assessment
			Close Coupled	Underfloor	
Bin 5 LEV II in 2014MY ULEV125 in 2017MY	All NAFTA Vehicles	-Low Press. Cooled EGR* -High Press. EGR -Idle Stop Start (opt)			Sensors: -Lambda DOC in -Temp (3) DOC, DPF, SCR in -NOX (2) EO, SCR out -PM Sensor SCR out
ULEV70 In 2019MY ULEV50 In 2022MY	All NAFTA Vehicles	-Low Press. Cooled EGR* -High Pressure EGR -2000 Bar Fuel Press -Improved Combustion (CR) -Idle Stop Start			Sensors: -Lambda DOC in -Temp (3) DOC, DPF, SCR in -NOX (2) EO, SCR out -PM Sensor SCR out
SULEV30 in 2025MY	All NAFTA Vehicles	-Low Press. Cooled EGR* -High Pressure EGR -2200→ 2500 Bar Fuel Press -Improved Combustion (Bowl Design) -Idle Stop Start			Sensors: -Lambda DOC in -Temp (3) DOC, SCR on DPF, SCR in -NOX (3) EO, Mid, TP -PM Sensor SCR out



Achievable with current technology



Achievable with minor fine tuning of aftertreatment and calibration. OBD deficiencies exist with current technology.



Feasibility with current technology not yet confirmed, could be required significant work and technology innovation. LEVIII OBD emission threshold limits are pending regulatory definition (not expected near-term)

IV. Goals and Timeline

