



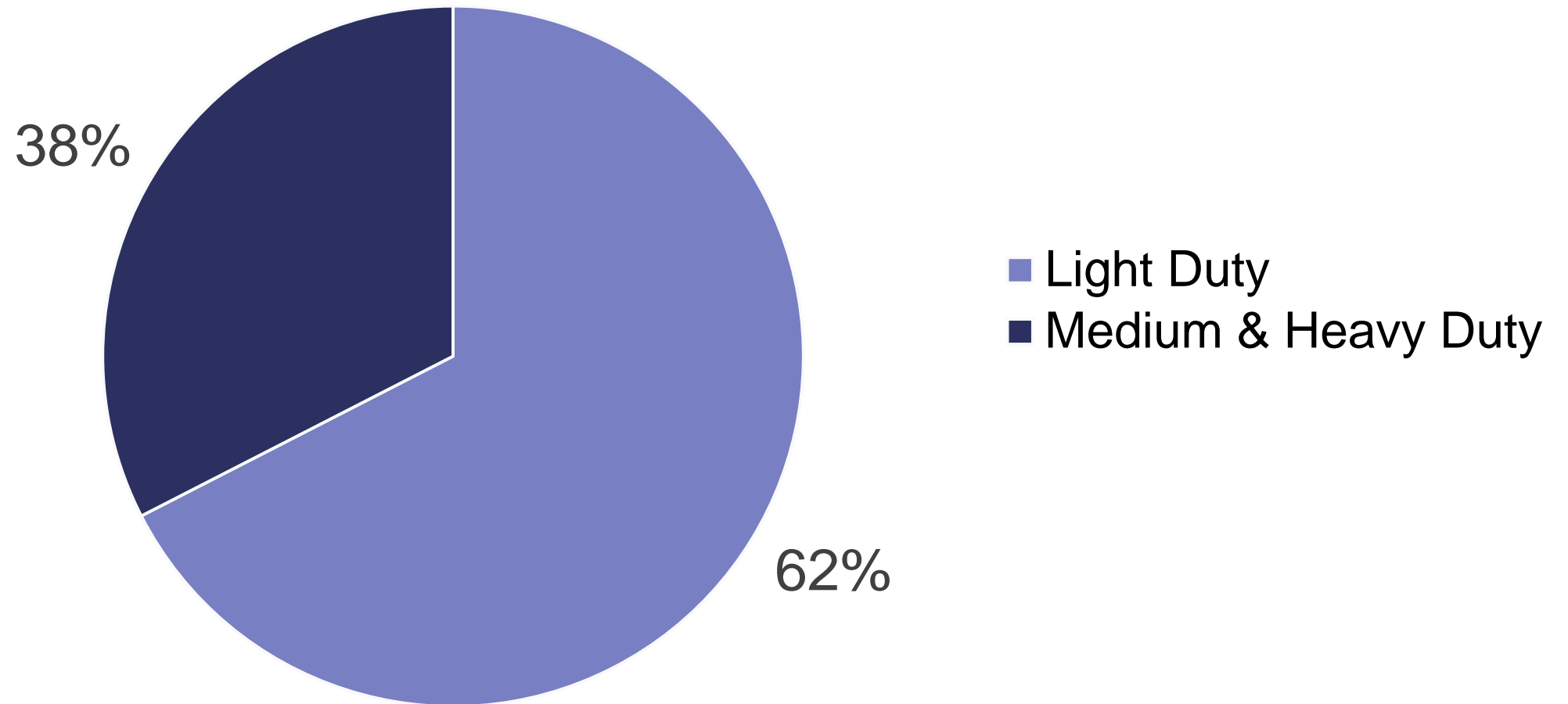
Heavy-Duty Engine Development & Market?

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Topics Today

- Traditional Autogas Vehicle Market
- New Opportunities for Propane in Medium & Heavy-Duty Engines
- Why?
- Propane Engine Power Using Direct Injection
- Engine Optimization w Propane
- Discussion of MD & HD Opportunities
- So What do We Go After & Why?

NEW PROPANE SALES 2016



Traditional Autogas Vehicle Market

- For years we've done well in lighter-duty vehicles
 - Taxis, pickups, vans, (especially high mileage)
 - Box vans like chip/bread trucks & small cutaway buses
 - Most <20,000 GVW
- But also some larger medium-duty vehicles
 - Bobtails (Ford propane engine), service/crane trucks & buses

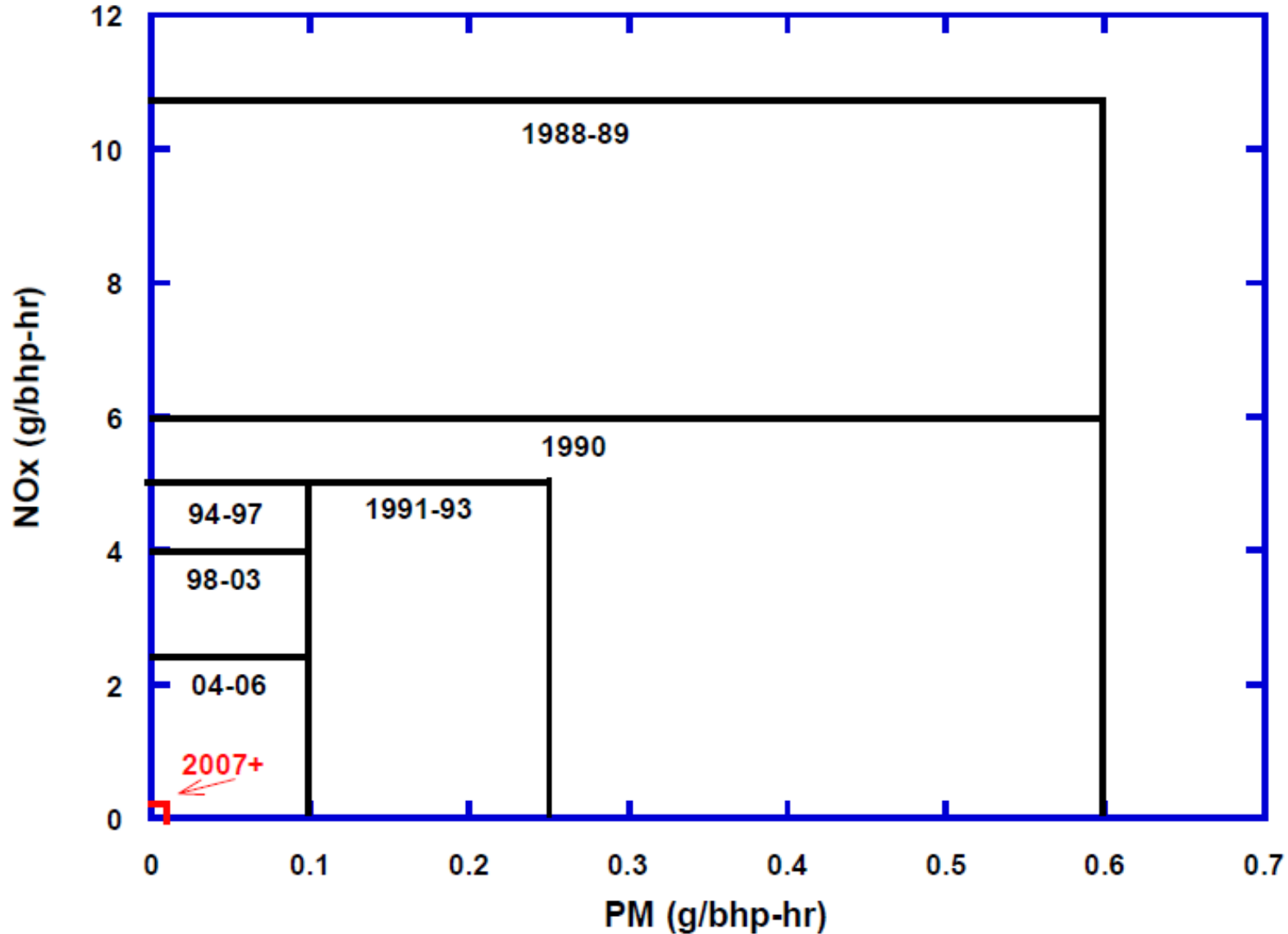
Traditional Vehicle & Engine Challenges

- Issues of space, tankage & range for smaller vehicles
- Working w conversion systems & certification: delays
- OEMs continued to show little interest or success
- Heavier-duty engines were either rich burn w high heat problems, or lean burn w boost & higher pressures but knock limited
- Nagging warranty issues, some engine durability problems
- Higher costs & less competitive vehicles associated w above
- Always close enough to do some, but rarely went big

Progress for Propane in Medium- & Heavy-Duty Vehicles / Engines

- Roush very helpful in quality of vehicles w OEM involvement
- Other fuel suppliers keep making better systems
- 6.0L, 6.8L, 8.0L & 8.8L engines creating new opportunities
- But still all expensive, and not fully competitive w other options
- P has emerged as a leading ultra low NOx & low particulate fuel, we're amazingly clean w affordable & workable technology

HD NOx & PM Emission Standards (30 years)



New Opportunities for Propane in Engines

- P is still a high energy fuel w many advantages
- Engine technology continues to improve & change
- Direct Injection (DI, GDI or SIDI) is a game changer
- PERC working w SwRI began to look into benefits of P in DI
- Started confirming engineering design prospects for:
 - Higher cylinder pressures for efficiency
 - Managed combustion for high power output

New Opportunities for Propane in Engines

- SwRI conducted extensive tests on the Ford 3.5L 2 turbo V6 DI with positive results as reported by Mike Ross
- In summary we found higher output, manageable exhaust temps, higher efficiency, and low emissions. Quite a combination!
- We also had been looking into other engine strategies applicable to P such as high EGR developed in the DOE ARES program in the 2000s and implemented by Cummins Westport using NG
- And Mike found an engine created by Cummins called ETHOS running on ethanol using these same strategies we wanted for P

Cummins Ethos Engine

This HD 2.8L engine was demonstrated in a large bread/chip van



New Opportunities for Propane in Medium- & Heavy-Duty Vehicles / Engines

- Turns out that ethanol & P are premium fuels for DI
 - High octane rating
 - P vaporizes rapidly
 - Good cooling from vaporization
- CWI uses some of these technologies in their NG engines
- E-Controls is using many of these in their new NG engines
- But neither can use and gain further DI advantages w NG
- P can provide high torque, and high HP engines

BMEP for Different Fuels & Engine Technologies

- 26-30 Propane in high-tech engines
- 26-29 Ethanol in high-tech engines
- 20-25 Diesel
- 17-24 High-tech gaso engines
- 10-13 Typical gasoline engines

BMEP = The average (**mean**) **pressure** which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measured (**brake**) power output.

So What's Next?

- High output and efficient P engines are under development
- These engines will change the market for using P in medium- and HD engines & vehicles
- The technologies discussed & technical advantages for P are applicable in high output HD industrial engines, and vehicle engines in classes 3-8.
- Many of these advantages & some of the technologies can be used to lesser degrees in OEM light duty vehicles, too
- Have to get competition in engine availability

So Where Do We Go w P in Medium & HD Applications?

- Classes 3-7 should be ripe for P
- How do we get OEMs involved to take advantage of P vehicles?
- How big do we go?
- What about class 8?
- Your thoughts and questions?