THE ROAD AHEAD FOR THE LEGACY DIESEL FLEET

Arvind Thiruvengadam Ph.D.
Principal Engineer

Carl Hergart Ph.D.
Director Powertrain Planning and Agency Relations

PACCAR POWERTRAIN

Introduction

- Global truck and engine manufacturer
- PACCAR has been around for 120 years
- We have seen technology transition from steam powered trucks to gasoline, diesel, electric and even hydrogen
- Diesel-powered trucks have served us well for over a century and will continue to play an important role in freight movement across the world

KENWORTH

Kenworth Australia

PACCAR MEXICO

Peterbilt

LEYLAND TRUCKS

DAF

PATH TO CLEAN DIESEL ENGINES

PACCAR POWERTRAIN

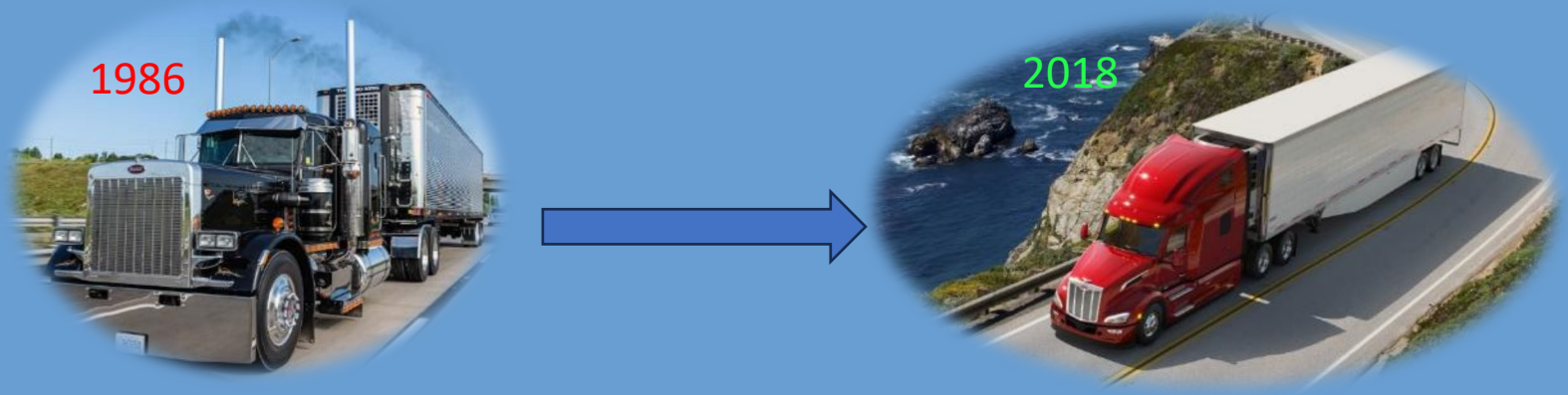
- USEPA 2010 Emissions Regulation
  - First significantly stringent in Particulate Matter (PM) and Oxides of Nitrogen (NO_x) standard
  - Incremental increase in engine technology needed to meet regulations
- In addition to reduction in regulated emissions significant reduction in unregulated emissions were observed
- Diesel engines have come a long way since this 2013 study
  - These advanced early model year 2010 engines can be considered legacy compared to current technology

	2010 % reduction relative to 2007 engines	2010 % reduction relative to 2004 engine
Single Ring Aromatics	50	91
PAH	97	99
NitroPAH	99	100
Alkanes	93	99
Polar	96	99
Hopanes & Steranes	89	100
Carbonyls	80	100
Inorganic Ions	87	92
Metals and Elements	81	100
Organic Carbon	36	97
Elemental Carbon	53	100
Dioxins and Furans[a]	88	100

[a]Relative to 1998 Technology Engine

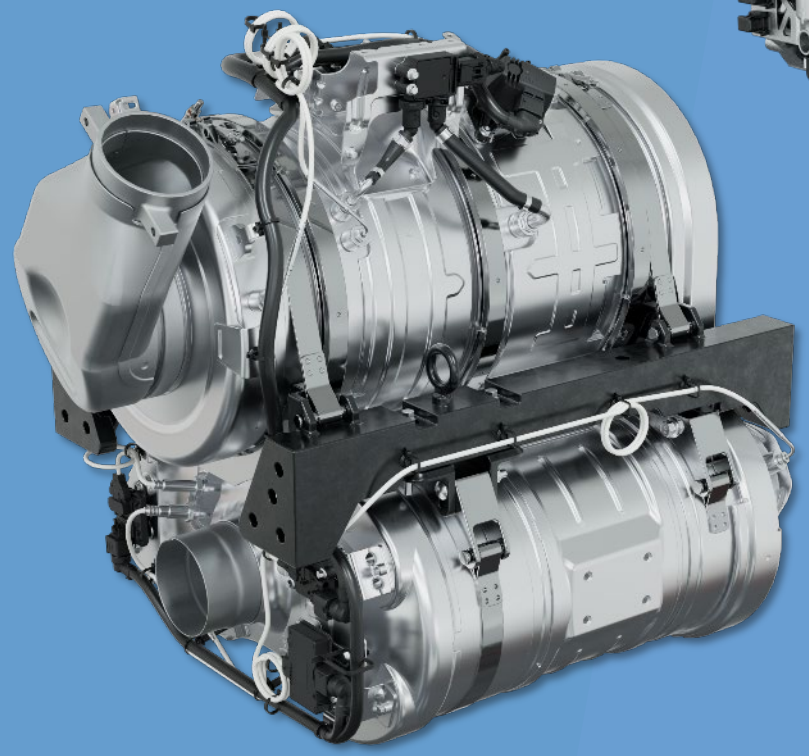
CRC Report: Phase 2 of the Advanced Collaborative Emissions Study, Nov 2013

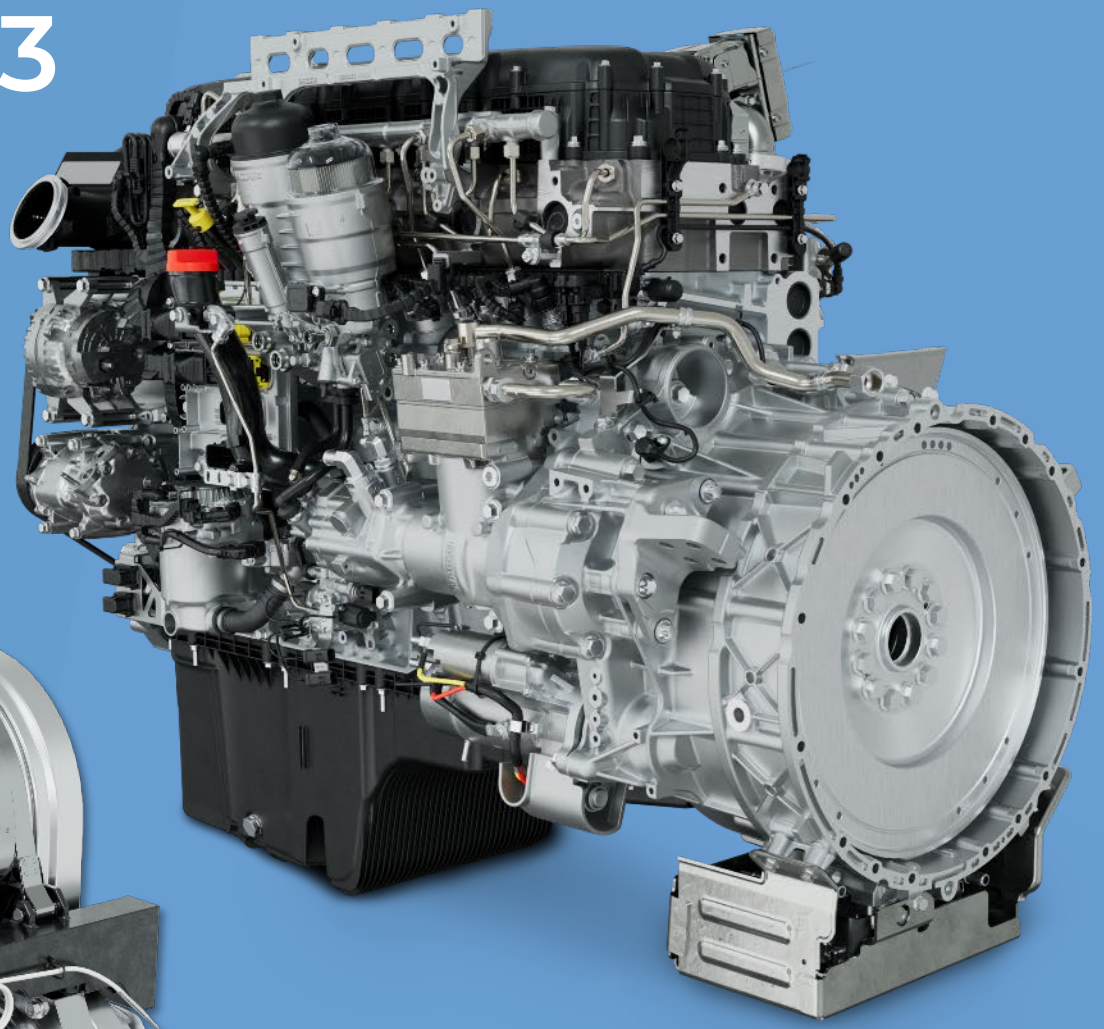
PAH: Poly Aromatic Hydrocarbons



CARB 24 MX-13

Only Fully CARB-Compliant Engine in the Market





455HP and 510HP

Extensive Testing in Real-world Conditions

1.1M miles
Driven on public roads

-30°F
Winter Test
@ Yellowknife, Canada

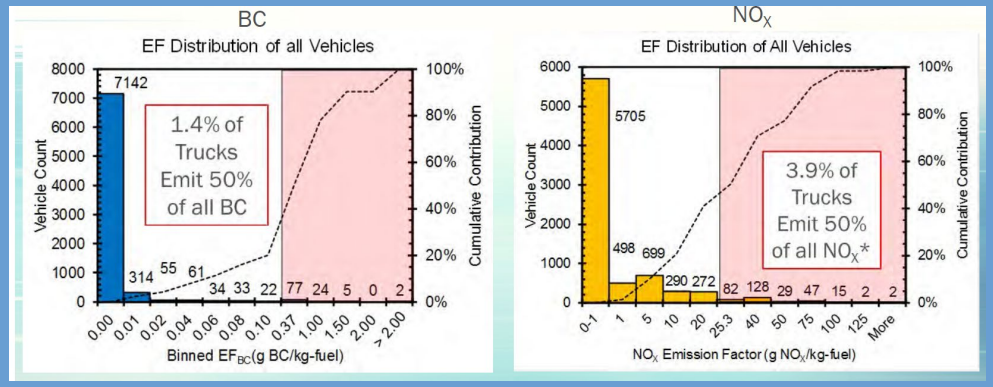
120°F
Summer Test
@ Death Valley

12,000 Feet
above Sea level
High Elevation
@ Eisenhower Pass
&
Loveland Pass

Legacy Vs New Technology

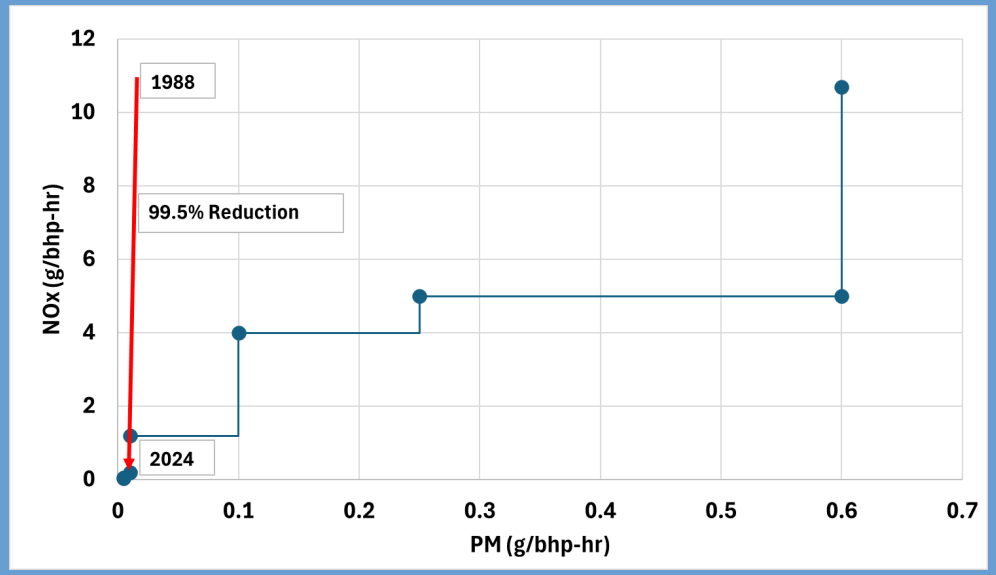
PACCAR POWERTRAIN

- Legacy vehicle emissions footprint
  - Small population contributes to large fraction of soot and NO_x emissions
- In comparison emissions from modern diesel engines are in some parts of the world cleaner than ambient air concentrations of PM
- Majority of the vehicle operation results in tailpipe NO_x and PM mass emissions below the detection limits of analytical instruments
  - Tire and brake wear emissions are higher than tailpipe PM mass emissions
- Common misconception
  - Older engines have better fuel economy
- While engines are becoming cleaner, engine efficiency has continuously improved
- Upkeep and maintenance of modern diesel engine is highly critical
  - Engine components and aftertreatment age continuously, periodic and preventative maintenance ensures longevity of emissions reduction potential



Hu, S., Approaches to Quanitfying Heavy-Duty In-Use Vehicles Emissions in California

BC: Black Carbon; EF: Emissions Factor



Conclusion

- Modern engines are extremely clean
- Critical to deploy best available technology
- Broad product portfolio is necessary
  - Clean Diesels
  - BEV trucks
- Low carbon fuels such as hydrogen fueled engines have proven to be a comparable clean alternative to diesel technology
- A clear well-to-wheel assessment of air quality impact is necessary