

DAIMLER

DTNA recommendations for ARB's GHG Phase 2 rulemaking

ARB SYMPOSIUM ON CALIFORNIA'S DEVELOPMENT OF ITS PHASE 2 GREENHOUSE GAS EMISSION STANDARDS FOR ON-ROAD HEAVY-DUTY VEHICLES

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April 22, 2015





INTRODUCTION

Our Core Mission

June 15, 1966

NEW "JIMMY" DIESEL BOOSTS PROFITS!

Jack Cole Company reports new GM "6-71E" engine gets over 7 miles per gallon — engine maintenance costs less than 1/4 cent per mile for parts and labor

Figures coming from key highway haulers prove the new General Motors "71E" Diesel leads all others in economy as well as performance.

Birmingham, Alabama's Jack Cole Company operating a fleet of 74 GM Diesel-powered trucks reports nearly a million miles a month — reports that the new GM "6-71E" engines are delivering fuel mileage from 7.2 to 7.4 per gallon having payloads up to 40,000 lbs. Dozens of these units have been in service about a year — few more have recently been added.

Other "Jimmy" Diesels in this fleet have averaged about 250,000 to 275,000 miles without overhaul and with total engine maintenance cost of less than one-half cent per mile. Fleet Supervisor O. E. Jakes reports at least 300,000 miles before overhaul. He prefers GM Diesels because "overhaul cost less than other Diesels, ease of maintenance eliminates road failures and close tolerancing of fuel injection simplifies of tractors."

Compare features and specifications which horsepower and torque curves of the same cylinder and components. You'll find the "Jimmy" Diesel gives you more power with less weight — greater torque output across the entire driving range — low fuel input per equivalent horsepower. It means a profit-boosting increase in revenue and lower costs per mile!

Call your GM Diesel distributor about replacing present equipment. And when you're in the market for new trucks, be sure to ask for this great new GM "71E" Diesel — it's available for any make, 20,000 GVW and up!

Desk and low starting: "6-71E" — 147 h.p., "6-71F" — 155 h.p. Best Performance results because the amount of exhaust gases is diluted even higher power: "6-71E" — 147 h.p., "6-71F" — 155 h.p.

Write for literature on new lighter-weight 300-horsepower version of the "6-71E" Diesel engine. It weighs up to 500 lbs. less than conventional 300-h.p. engine.

DETROIT DIESEL Engine Division of General Motors, Detroit 28, Michigan

"Our Series 71 Diesels save us \$3,500 a year per truck"

DETROIT DIESEL

The **SERIES 60**

Still The Fuel Economy Leader

Proven Reliability

Even Better Performance

The Fuel Pincher Diesel

FUEL SQUEEZER

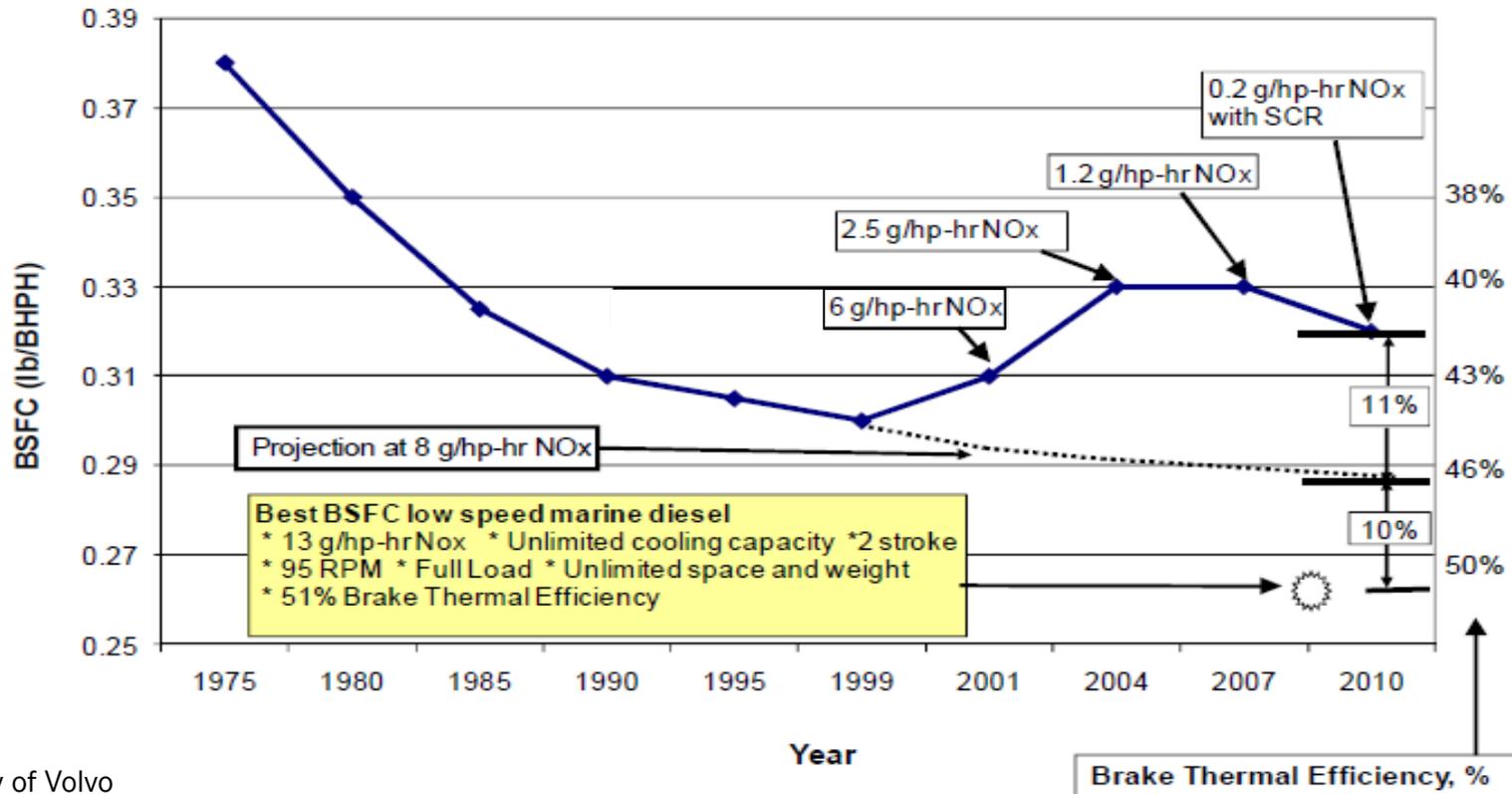
PEP'S 307

FUEL EFFICIENT HORSEPOWER

Fuel Economy Constrained by NOx

SuperTruck engine improvements were only achievable with increased engine-out NOx

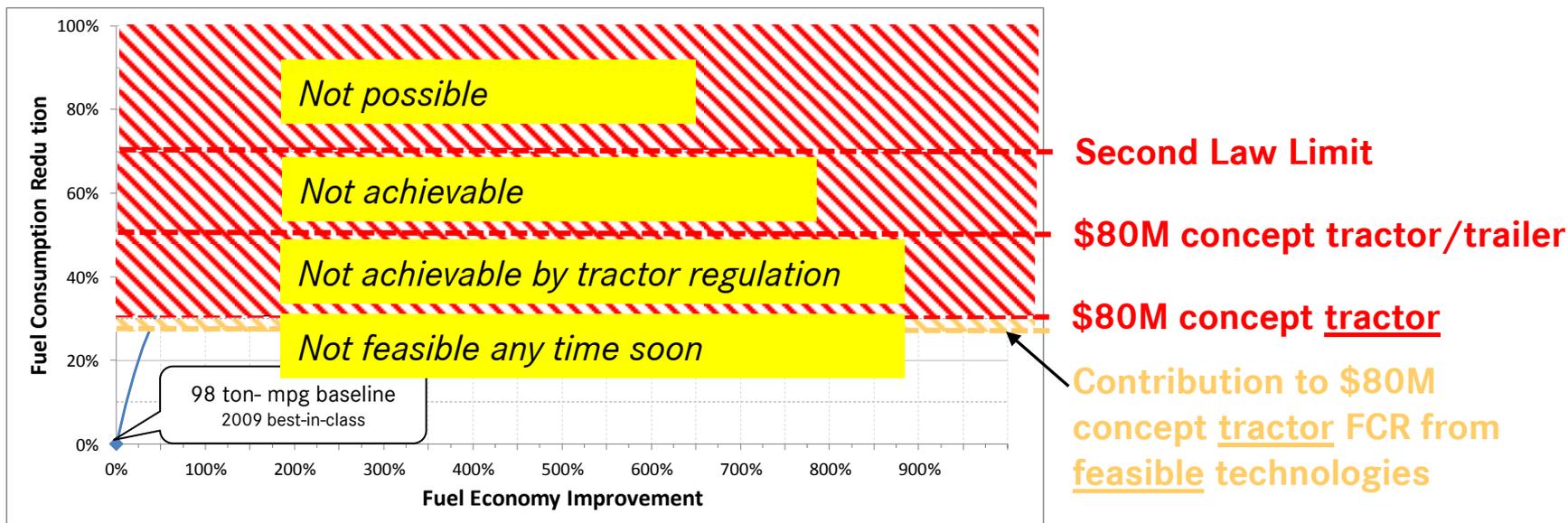
Best Point BSFC HD On-Highway Diesels



Courtesy of Volvo

Are the ARB's targets achievable?

Relationship between Fuel Economy Improvement and Fuel Consumption Reduction



	Second Law Limit Vehicle
Engine	Second law, maximum theoretically possible
Aero CdW	Less than 1/2 of best vehicle on the market
Transmission & Axle	No friction, best axle and gearing available
Auxiliaries	No power consumption
Overall Rolling Resistance	Steel wheels

Bottom line: No, the tractor targets exceed what a tractor may feasibly achieve.

And the regulators must account for the fact that—even if technology costs and feasibilities were not issues—not all vehicles can be Super Truck.

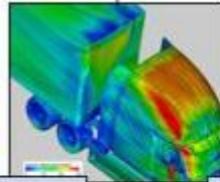
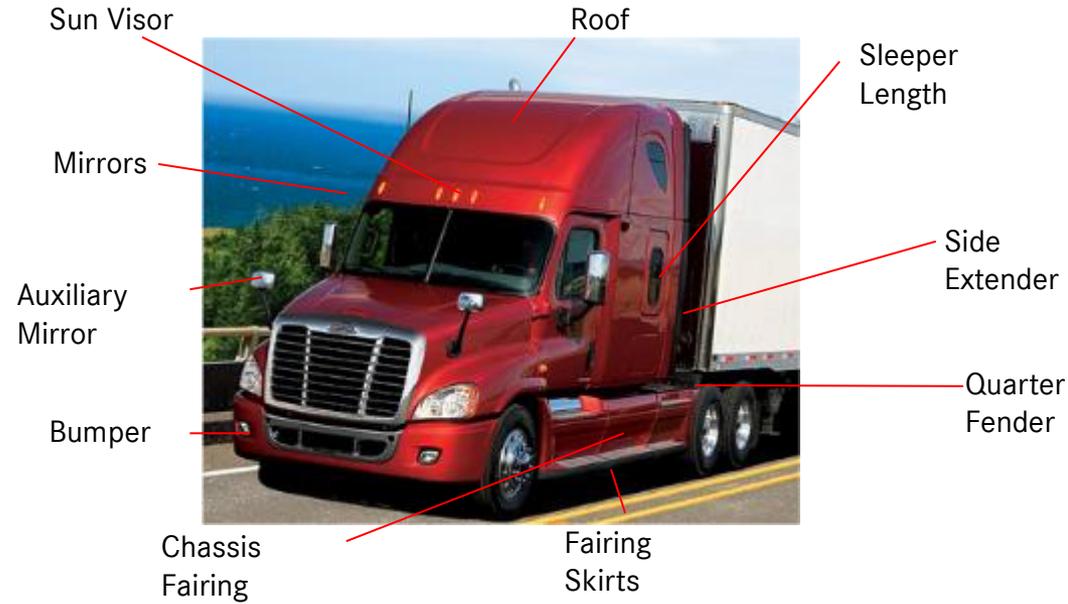


Bottom line: for any regulatory subcategory, standards must be based on technologies' FCRs times their achievable market penetration rates.



ISSUES REGARDING VEHICLE STANDARDS

Among tractors, there are a large number of variants requiring testing



Wind tunnel

CFD

Scale model

Manufacturer Name	Daimler	EPA Defined		User Entered		GEM Input			
Model Year	2013	EPA Defined		User Entered		GEM Input			
Vehicle Family Name	DDTN2TRAC14C	EPA Defined		User Entered		GEM Input			
Regulatory Subcategory	Class 8 Combination - Sleeper Cab - High Roof	EPA Defined		User Entered		GEM Input			
Input File Name	GEM_Input	EPA Defined		User Entered		GEM Input			
Configuration	Brand/Model Name	Bin	CdA (Test)	Cd (Bin)	Steer Tires CRR	Drive Tires CRR	Idle Reduction	Weight Reduction	VSL
1	Lowest FEL	V					5	2800	55
2	Highest Sales	V					5	210	65
3	ARC 72 RR run 17	V					0	0	65
4	ARC 72 RR run 16	V					0	0	65
5	ARC 72 RR run 15	V					5	0	65
6	ARC 72 RR run 14	V					5	0	65
7	ARC 72 RR run 13	V					0	0	65
8	ARC 72 RR run 12	V					5	0	65
9	ARC 72 RR run 19	V					0	0	65
10	Highest FEL (worst case vehicle)	I					0	0	65

Confidential

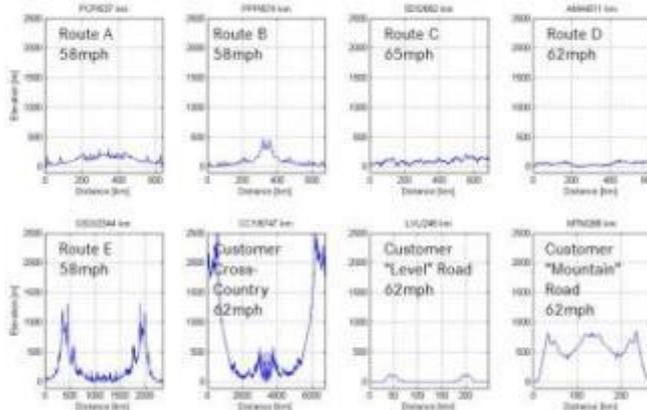
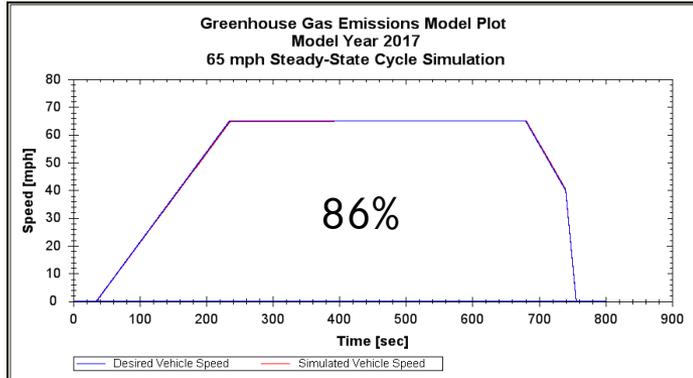
Bottom line: stringency of standards must be balanced with practicability of compliance.

Among vocational vehicles, the variation is larger and the need for specific features greater



Bottom line: stringency of standards must be balanced with the need for Californians to get services that vocational vehicles provide.

GHG drive cycles must be matched to real world

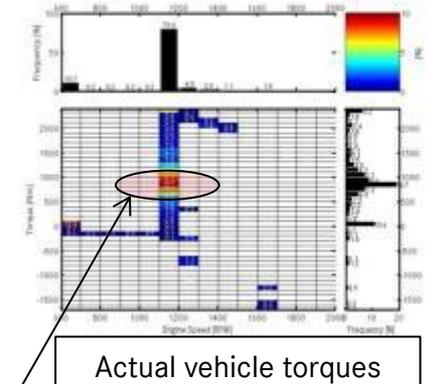
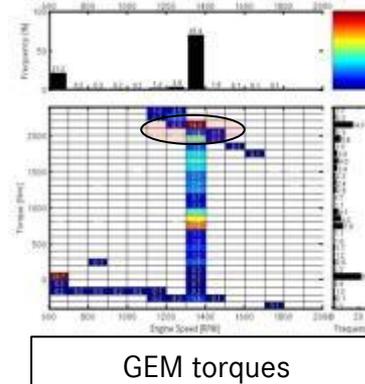
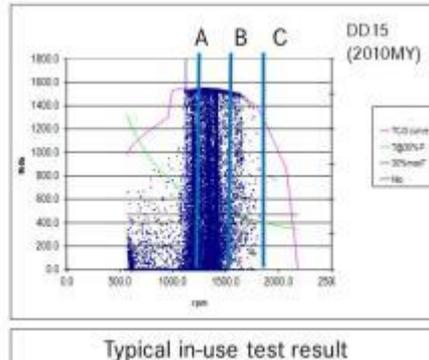
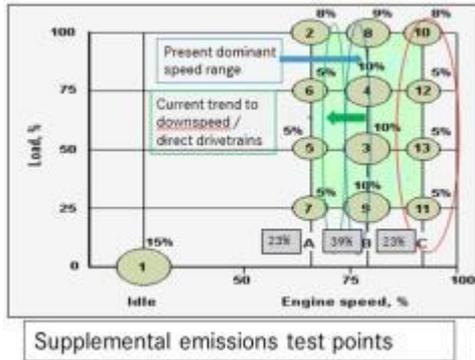


Route	Hilliness Factor
LVL:	34
D:	62
B:	76
A:	94
CCY:	100
EPA/NHTSA65:	100
EPA/NHTSA55:	100
C:	108
E:	120
MTN:	180

Route	Coast Factor
LVL:	54.4
B:	96.5
A:	106.2
D:	106.9
E:	118.6
CCY:	148.1
MTN:	164.6
C:	183.8
EPA/NHTSA65:	259.4
EPA/NHTSA55:	259.6

SPEED LIMIT 55

Issue: CA truck speed is 55 mph, while GEM is 86% 65 mph.



Highest frequency at mid-torque

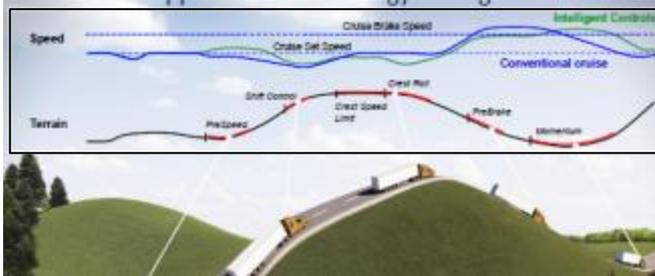
Bottom line: with HDV industry moving toward powertrain matching, the regulatory drive cycles should 1) be full vehicle and 2) match in-use driving.



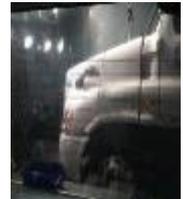
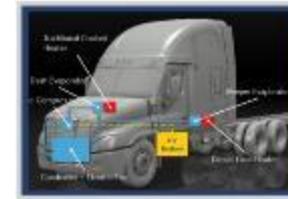


TECHNOLOGY DEEP DIVE

Multiple Approaches to Reduce Braking Losses

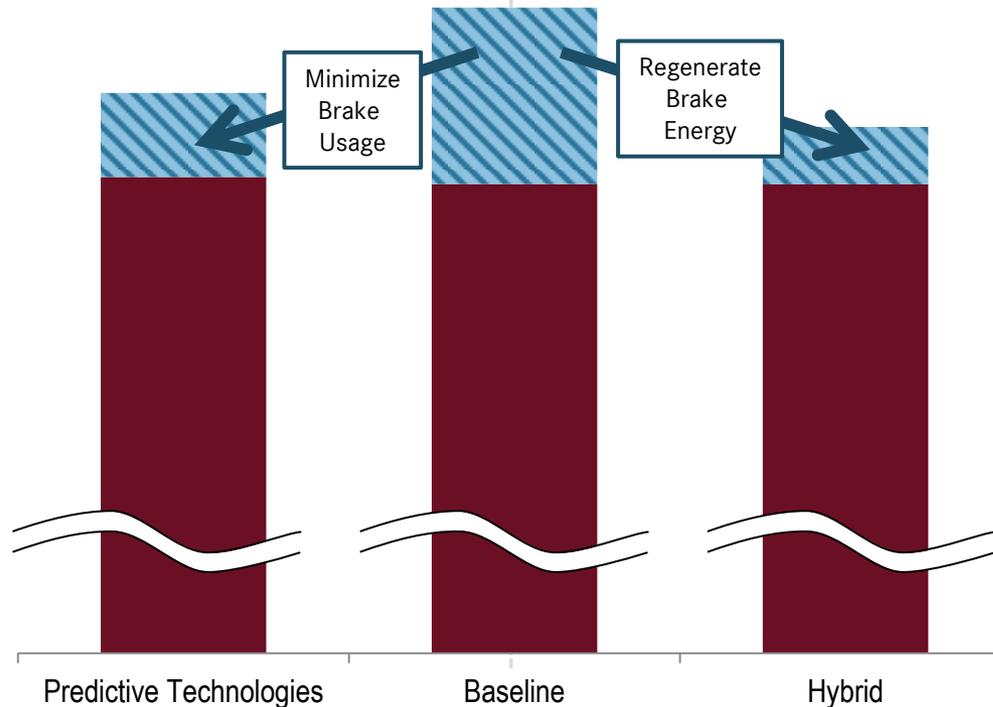


Courtesy of Volvo Trucks



Energy Consumption on Highway Route

■ Propulsion to overcome braking losses ■ Positive Propulsion



Predictive Technologies

- Terrain-based powertrain controls (e.g. PCC, eCoast)
- Minimal hardware, weight, cost

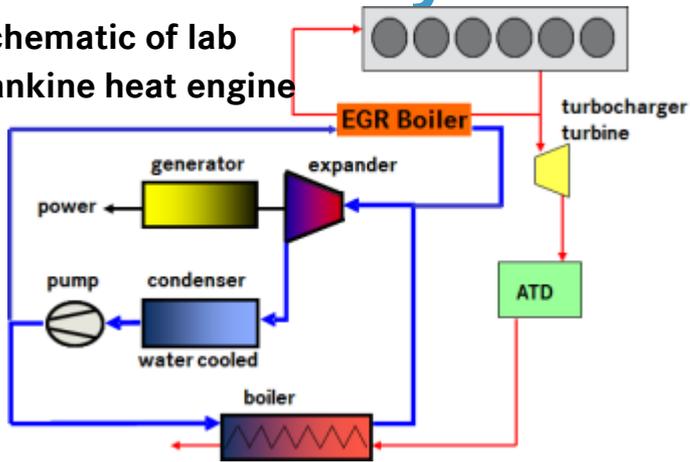
Hybrid

- Regenerate braking energy based on terrain and traffic conditions
- Additional hardware, weight, and cost (*High Voltage Motor, Inverter and Li-Ion Battery*)

➔ Most of benefit is derived at minimal hardware, weight, and cost

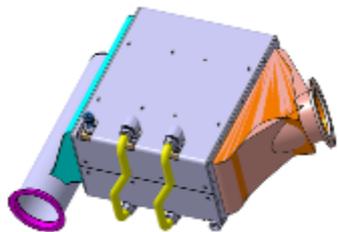
Similar analysis: WHR Barriers

Schematic of lab Rankine heat engine



System functional on A-sample SuperTruck prototype.

Boiler

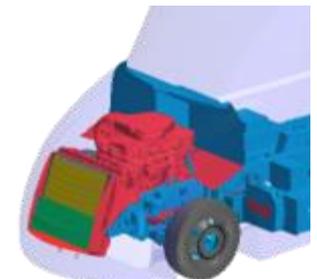


Scroll Expander



- Current trends in engine and vehicle technologies pose great challenges to WHR:
 - Better aerodynamics reduces engine load and consequently WHR potential.
 - Aerodynamic tractor profiles can require a paradigm shift in heat rejection approaches, more so with an on-board WHR system.
 - Diesel combustion with high efficiency aftertreatment is trending towards more efficient combustion, further reducing the WHR potential.
- Working fluid selection
 - Thermodynamic characteristics, GWP, ODP, flammability, toxicity, cost, etc.
- Beyond technology demonstration, further optimization
- Extensive OBD development and implementation required
- Required for such a complex technology:
 - Payback, cost
 - Reliability, durability
 - Packaging, weight

Cooling System



Technology-neutral standards with system-level regulation approach allows manufacturers to optimize for real-world fuel efficiency, picking off most cost-effective technologies first

GRAPH IS OMITTED FROM PUBLICATION ON INTERNET BUT WILL BE SHOWN AND DISCUSSED AT SYMPOSIUM.

Bottom line: the more manufacturers can innovate without restrictions, the more likely technologies will penetrate into the market and the less we have to divert engineering resources to inviable technologies. That is a win-win.

The optimal approach is a balance of vehicle GHG reductions and more

