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

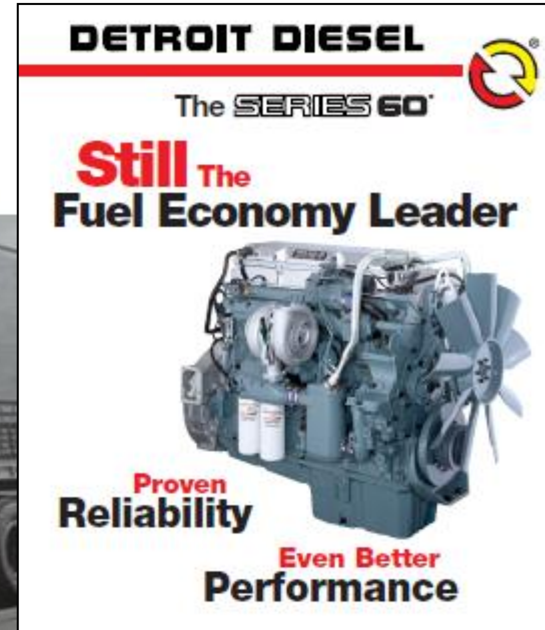
David Kayes, Derek Rotz

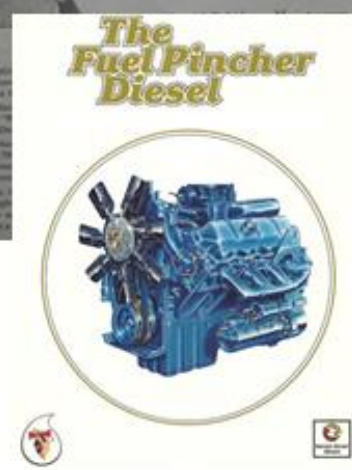
April 22, 2015

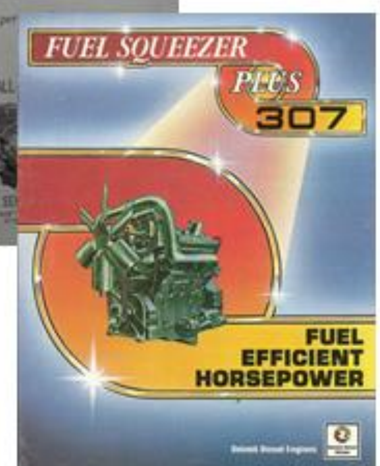
Mercedes-Benz FREIGHTLINER FUSO WESTERN STAR Thomas DETROIT

INTRODUCTION

Our Core Mission

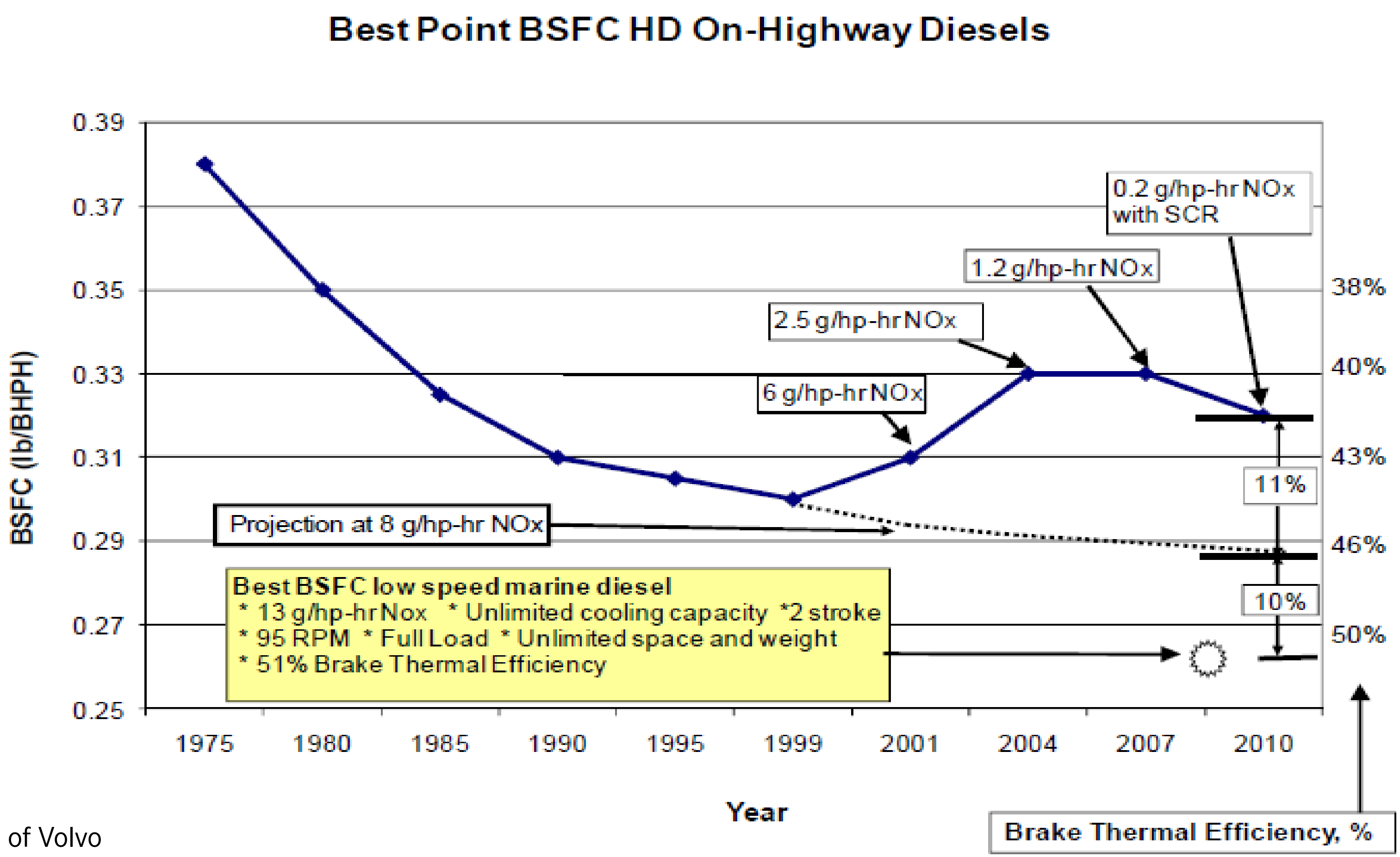






Fuel Economy Constrained by NOx

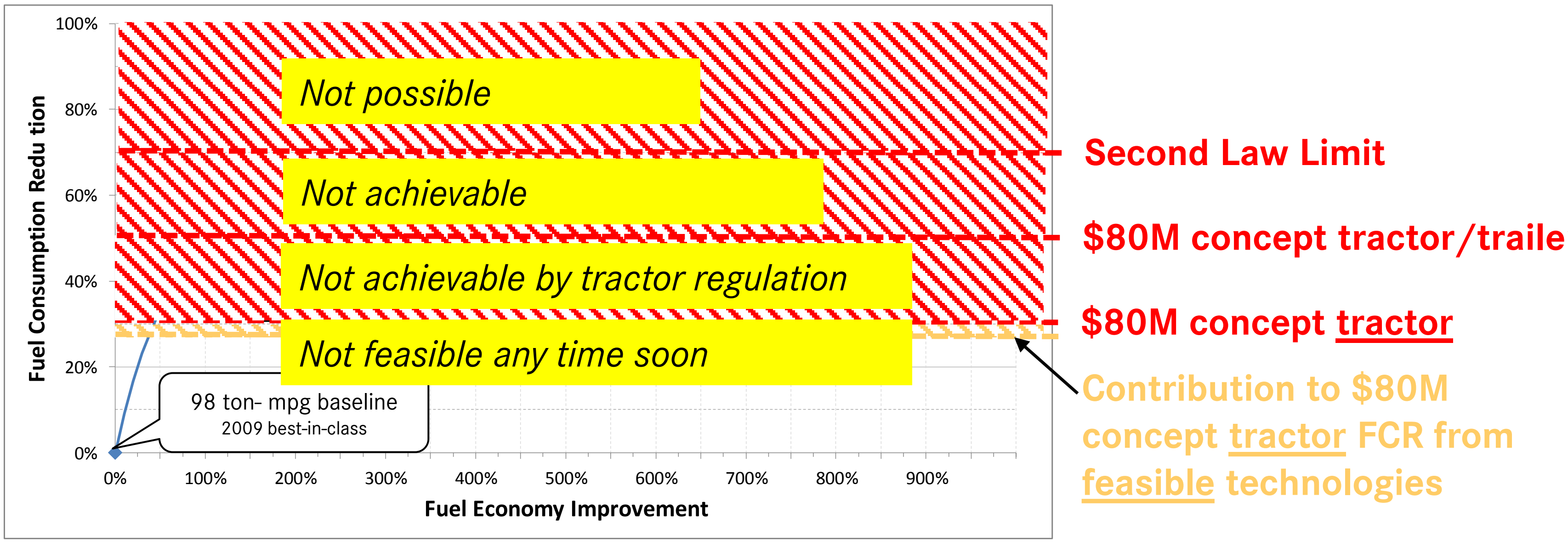
SuperTruck engine improvements were only achievable with increased engine-out NOx



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 ½ of best vehicle on the market
Transmission & Axle	No friction, best axle and gearing available
Auxiliaries	No power consumption
Overall Rolling Resistance	Steel wheels

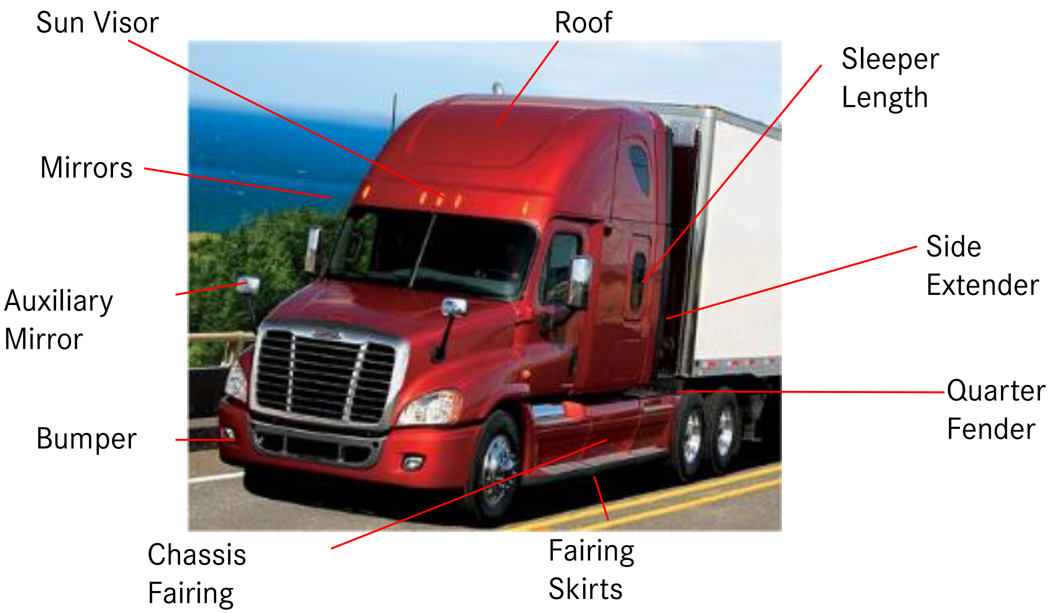
Bottom line: No, the tractor targets exceed what a tractor may feasibly achieve.

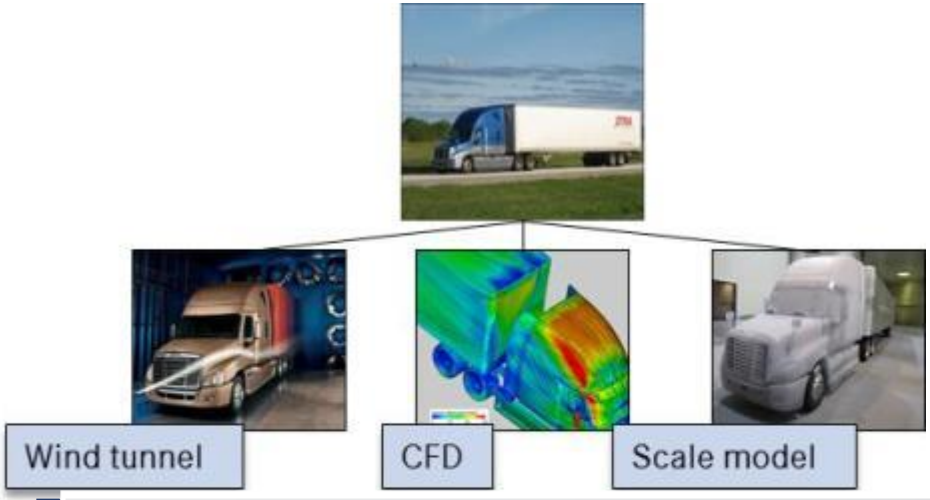
And the regulators must account for the fact that—even if technology costs and feasibilities were not issues--not all vehicles can be Super Truck.

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





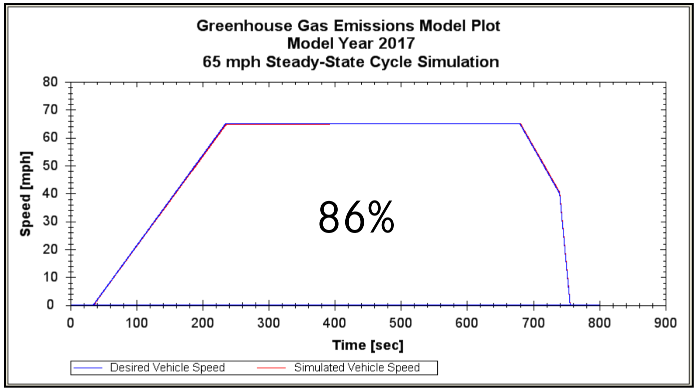
Manufacturer Name	Daimler									
Model Year	2013				EPA Defined					
Vehicle Family Name	DDTN2TRAC14C				User Entered					
Regulatory Subcategory	Class 8 Combination - Sleeper Cab - High Roof				GEM Input					
Input File Name	GEM_Input									
		Aerodynamics			Steer Tires	Drive Tires				
Configuration	Brand/Model Name	Bin	CdA (Test)	Cd (Bin)	CRR	CRR	Idle Reduction	Weight Reduction	VSL	
1	Lowest FEL	V	[redacted]				5	2800	55	
2	Highest Sales	V					5	210	65	
3	ARC 72 RR run 17	IV					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	

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

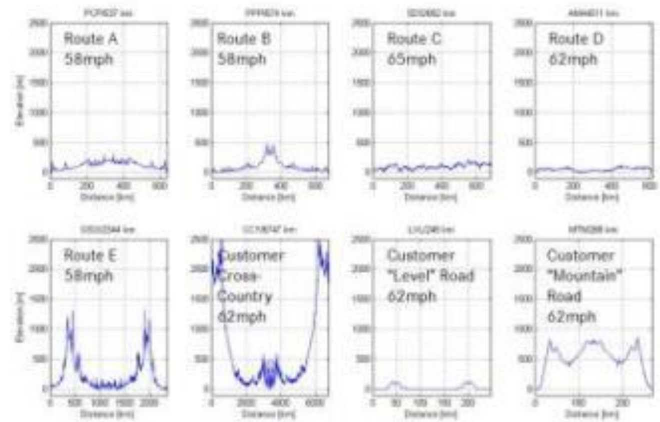
Among vocational vehicles, the variation is larger and the need for specific features greater

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

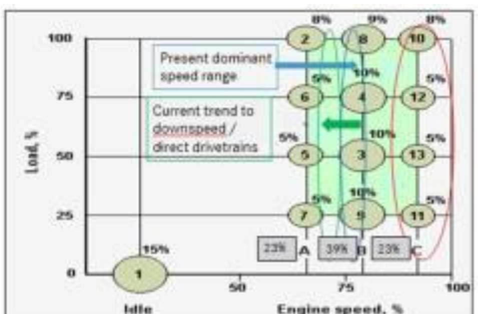


Issue: CA truck speed is 55 mph, while GEM is 86% 65 mph.

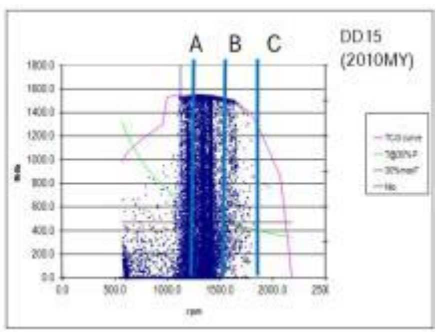


Route	Hilliness Factor
LVL:	34
D:	62
B:	76
A:	94
CCY:	100
EPA/NHTSA65:	100
EPA/NHTSA55:	100
C:	108
E:	120
MTN:	180

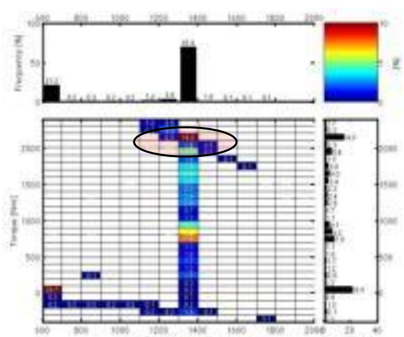
Route	Coast Factor
LVL:	54.4
B:	96.5
A:	106.2
D:	106.9
E:	118.4
CCY:	148.1
MTN:	164.6
C:	183.8
EPA/NHTSA65:	259.4
EPA/NHTSA55:	259.6



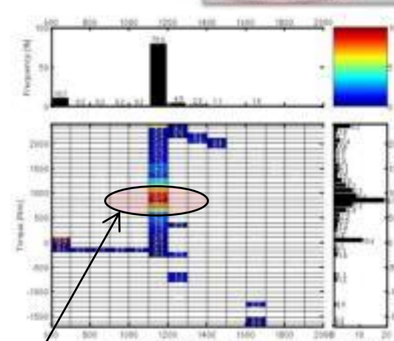
Supplemental emissions test points



Typical in-use test result



GEM torques



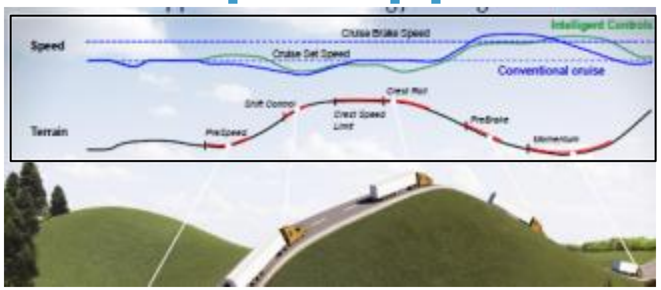
Actual vehicle torques

Highest frequency at mid-torque

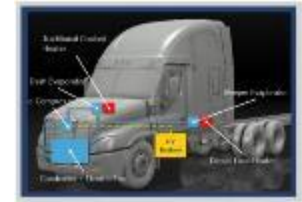
Bottom line: with HDV industry moving toward powertrain matching, the regulatory drive cycles should 1) be full vehicle and 2) match in-use driving.

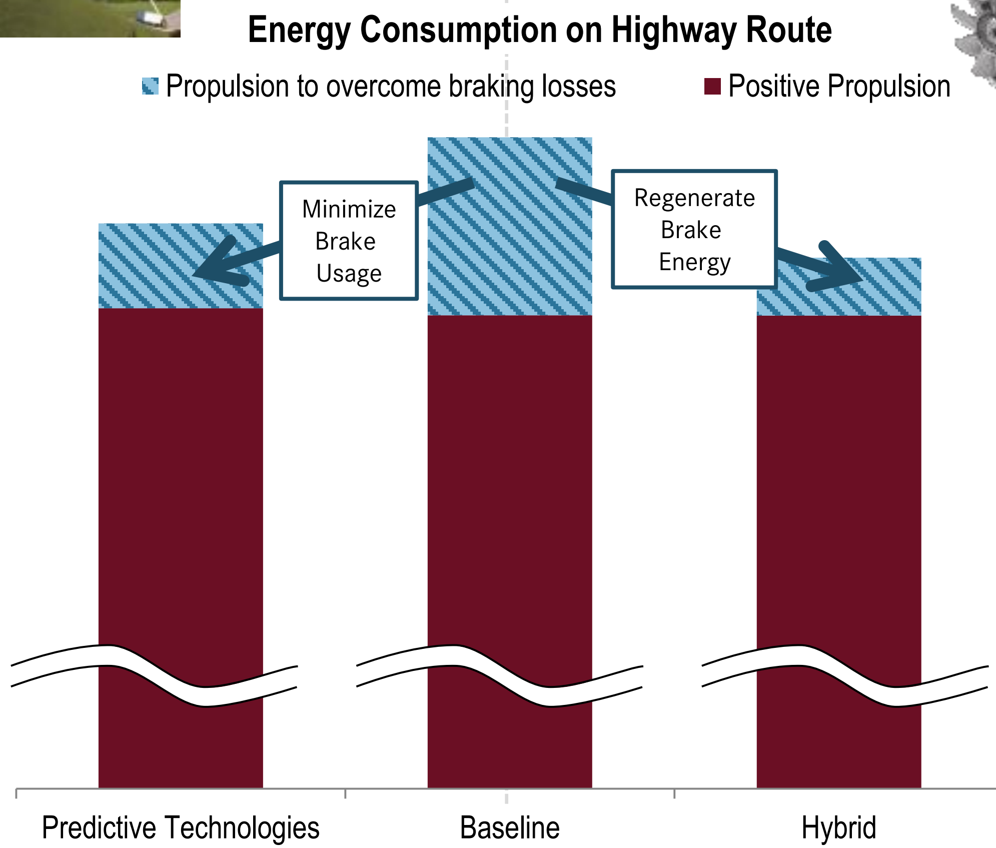
TECHNOLOGY DEEP DIVE

Multiple Approaches to Reduce Braking Losses



Courtesy of Volvo Trucks





Predictive Technologies

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

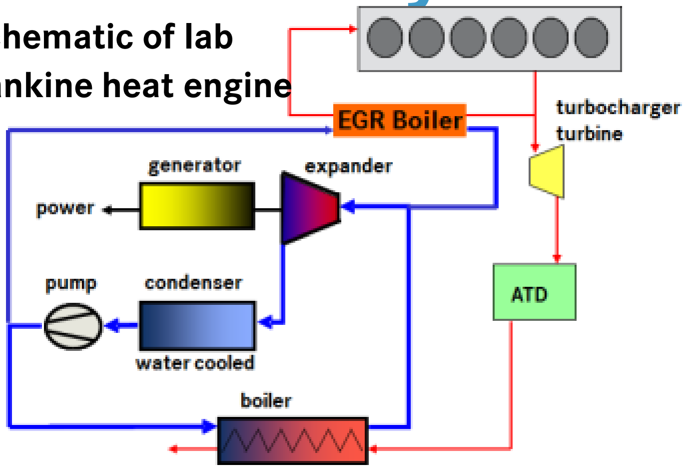
Hybrid

- 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***

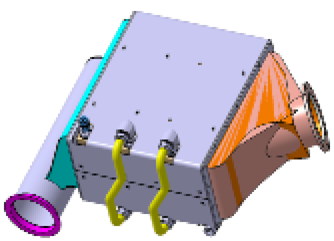
Similar analysis: WHR Barriers

Schematic of lab Rankine heat engine



System functional on A-sample SuperTruck prototype.

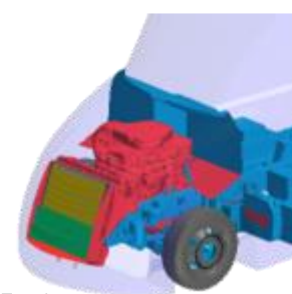
Boiler



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