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

“New ‘Jimmy’ Diesel Boosts Profits!

Jack Cole Company reports new GM ‘6-71E’ engine gets over 7 miles per gallon, reduces maintenance costs less than 15 cents per mile for parts and labor.

“Still The Fuel Economy Leader

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

The Fuel Pincher Diesel

Fuel Squeezer 307

Detroit Diesel

Engine Division of General Motors, Detroit, Michigan

Even Better Performance

Proven Reliability

Still The Fuel Economy Leader

Detroit Diesel

The Series 60®
Fuel Economy Constrained by NOx

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

![Graph showing Best Point BSFC HD On-Highway Diesels over years with annotations for BSFC and Brake Thermal Efficiency]

*Best BSFC low speed marine diesel*
- 13 g/hp-hr NOx
- Unlimited cooling capacity
- 2 stroke
- 95 RPM
- Full Load
- Unlimited space and weight
- 51% Brake Thermal Efficiency

Courtesy of Volvo
Are the ARB’s targets achievable?

Relationship between Fuel Economy Improvement and Fuel Consumption Reduction

<table>
<thead>
<tr>
<th>Fuel Consumption Reduction</th>
<th>Fuel Economy Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>20%</td>
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<tr>
<td>40%</td>
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<td>60%</td>
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<td>80%</td>
<td>80%</td>
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<tr>
<td>100%</td>
<td>100%</td>
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</tbody>
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- **Not possible**
- **Not achievable**
- **Not achievable by tractor regulation**
- **Not feasible any time soon**

98 ton-mpg baseline
2009 best-in-class

**Second Law Limit**

**$80M concept tractor/trailer**

**$80M concept tractor**

**Contribution to $80M concept tractor FCR from feasible technologies**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engine</strong></td>
<td>Second law, maximum theoretically possible</td>
</tr>
<tr>
<td><strong>Aero CdW</strong></td>
<td>Less than ½ of best vehicle on the market</td>
</tr>
<tr>
<td><strong>Transmission &amp; Axle</strong></td>
<td>No friction, best axle and gearing available</td>
</tr>
<tr>
<td><strong>Auxiliaries</strong></td>
<td>No power consumption</td>
</tr>
<tr>
<td><strong>Overall Rolling Resistance</strong></td>
<td>Steel wheels</td>
</tr>
</tbody>
</table>

**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.

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.

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

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

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
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.