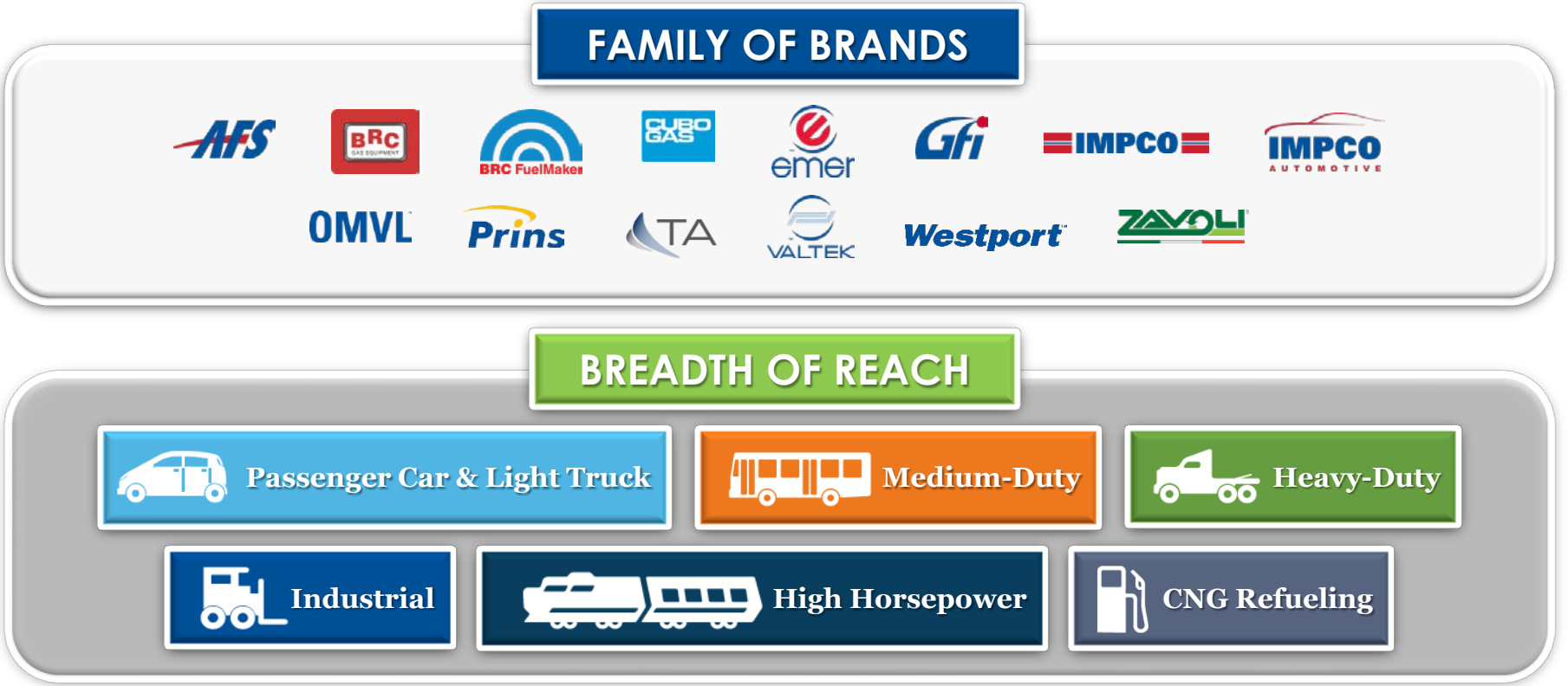

Westport™
PRODUCT & TECHNOLOGY
UPDATE – NGVTF OCT 2016
Brad Douville, Vice President, Business
Development & Product Management

New Merged Company

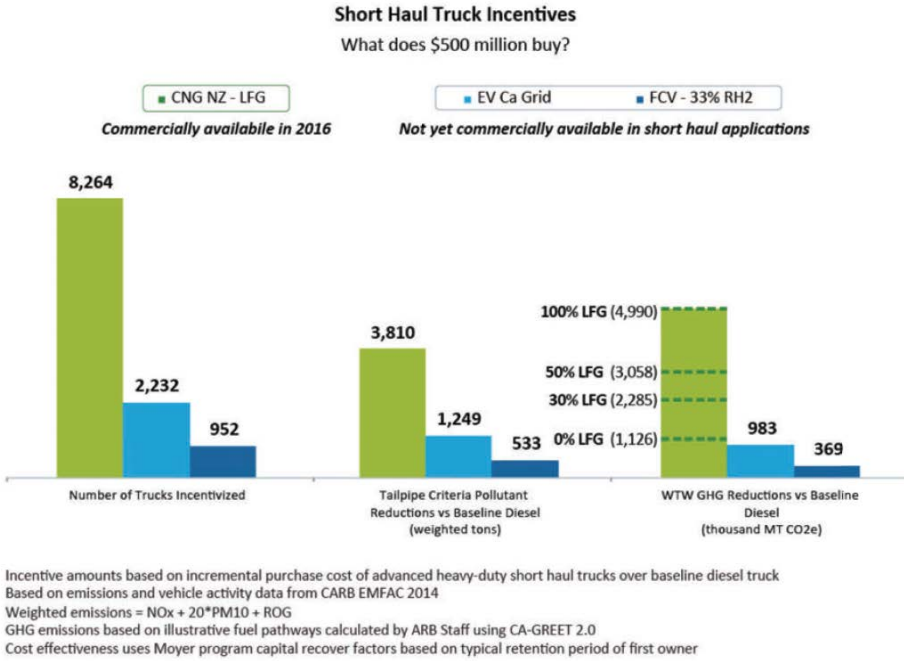
- Westport Innovations Inc. and Fuel Systems Solutions Inc. merged on June 1, 2016 to create Westport Fuel Systems Inc.
- A premier, global company for the engineering, manufacturing and supply of alternative fuel systems and components.

Family of Brands and Breadth of Reach



Opportunity
Gasoline-Derived Near Zero NOx Engines

- HD gasoline engines certify to same standards as diesel engines
- Established Near Zero (NZ) NOx techniques could be readily transferred to NG versions of these engines to bring them to the optional 0.02 g/bhp-hr standard
- NZ NOx engines are much more cost effective than BEVs in applications such as shuttle buses
- But will NZ NGVs qualify under the California SIP?



Incentive amounts based on incremental purchase cost of advanced heavy-duty short haul trucks over baseline diesel truck
Based on emissions and vehicle activity data from CARB EMFAC 2014
Weighted emissions = NOx + 20*PM10 + ROG
GHG emissions based on illustrative fuel pathways calculated by ARB Staff using CA-GREET 2.0
Cost effectiveness uses Moyer program capital recover factors based on typical retention period of first owner

Figure 29. Hypothetical comparison of truck deployments and benefits based on a $500 million investment

Ref: "Game Changer, Next Generation Heavy Duty Natural Gas Engines Fueled By Renewable Natural Gas, Gladstein, Neandross and Associates, 2016

Westport Engine Technology Applications

APPLICATION	FUEL CHOICE	ENGINE TECHNOLOGIES
High Horsepower • mining • rail • marine	LNG	high pressure direct injection
Heavy-Duty Vehicles • on-highway trucks		
Medium-Duty Vehicles	CNG	high efficiency spark ignited
Light-Duty Vehicles		

Product Progression

Westport HPDI 2.0

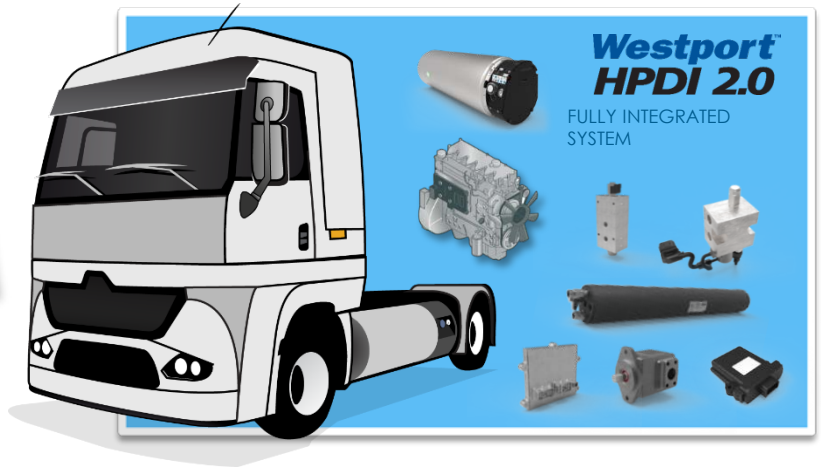
HPDI 1.0 Launched

HPDI 1.0 Production Ended

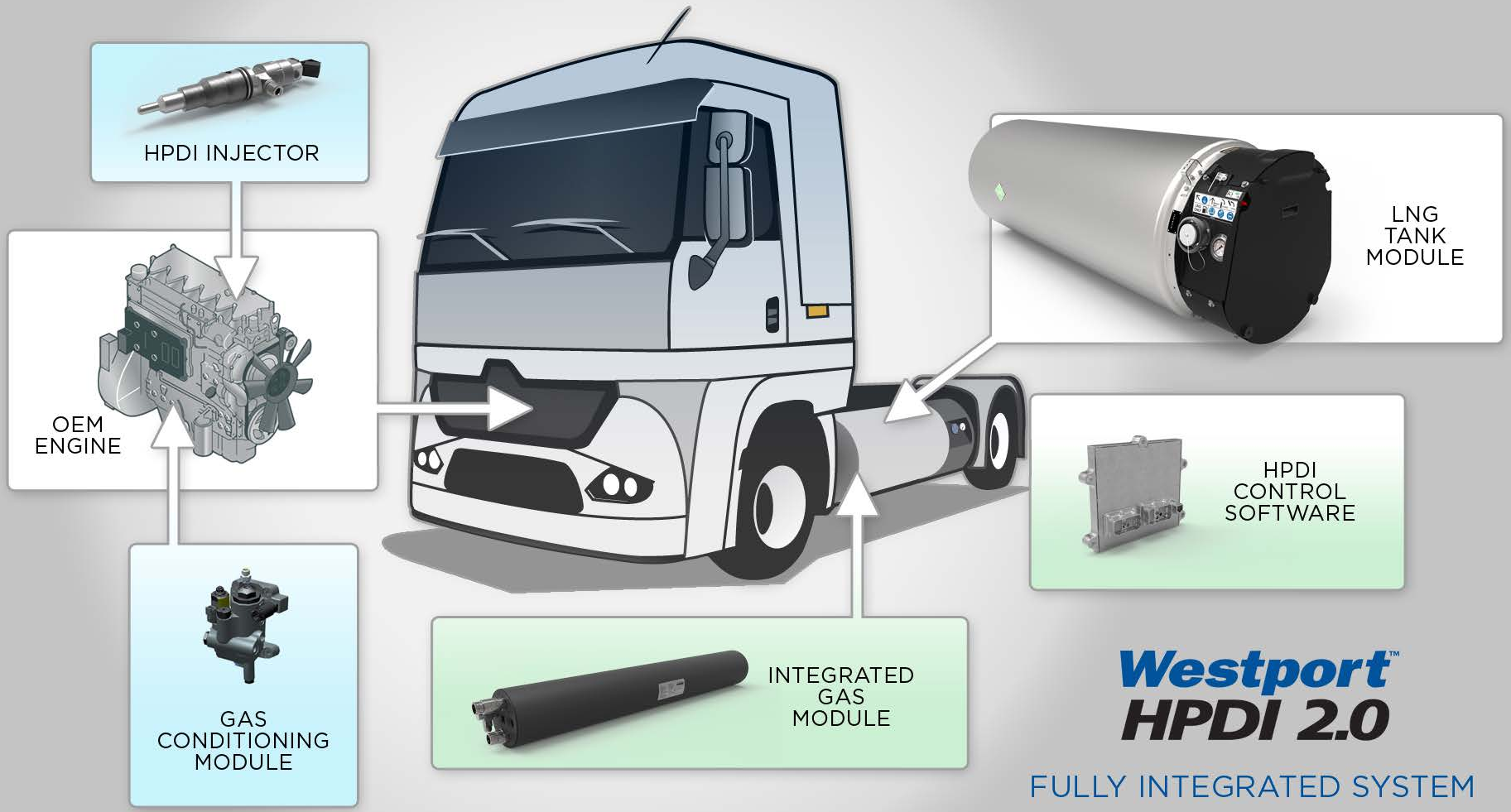
LAUNCH*

2010 2011 2012 2013 2014 2015 2016 2017

Start HPDI 2.0 Program



*Series production components available for delivery to OEMs


HPDI INJECTOR
OEM ENGINE
GAS CONDITIONING MODULE
INTEGRATED GAS MODULE
LNG TANK MODULE
HPDI CONTROL SOFTWARE
Westport™ HPDI 2.0
FULLY INTEGRATED SYSTEM

Westport™ HPDI 2.0

Technology Progression: Injector

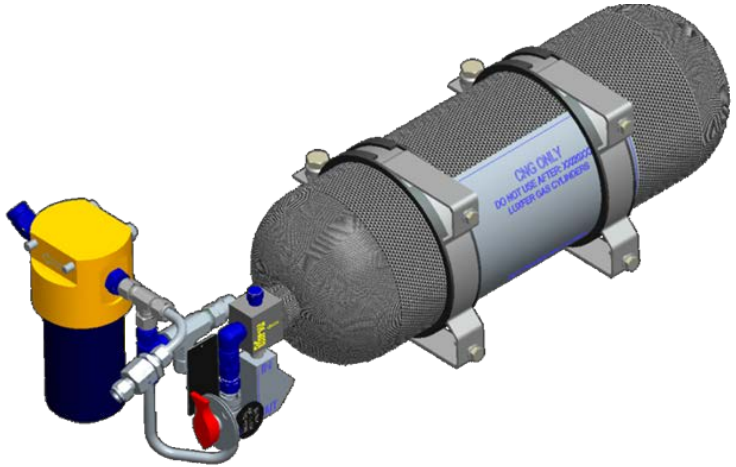
Westport™ HPDI 2.0

Gen 1 Gen 2

Technology Progression: IGM

Westport HPDI 2.0

Gen 1



Gen 2

Integrated Gas Module (IGM)

Westport LNG Tank Module

Westport HPDI 2.0

- Completely Re-Designed
- Cost Reduced, Quality Improved
- Integrated LNG Pump
- High & Low Pressure Variants
- Enables cold LNG for increased range and longer hold times

LNG Tank Validation Testing

Westport HPDI 2.0

- Example tests:
  - Bonfire
  - Vibration
  - Drop

LNG Pump (HHP)

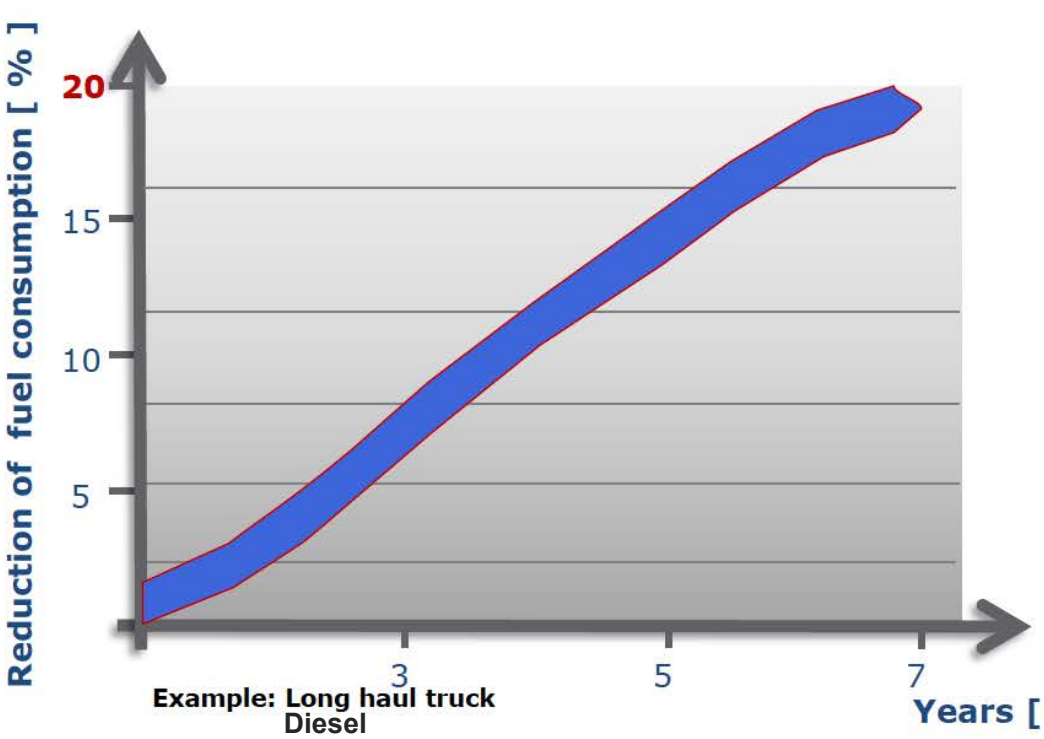
Westport™ HPDI 2.0

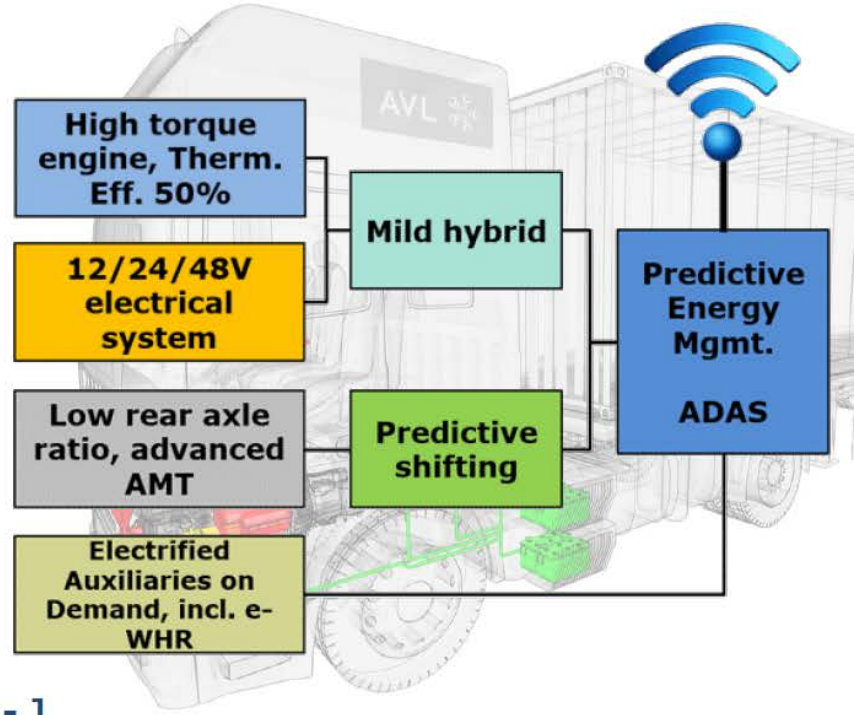
High Horsepower Applications
Mining, Rail & Marine

GHG Legislation for Commercial Vehicles

	Naming	Status	Introduction/ Validity	Evaluation Method	Limits	Severity
	**GHG** & Fuel Economy Phase 1	In place – fully phased in by 2018	**Until 2020**	Engine: Transient duty cycle Sim. vehicle standard: **GEM 2.0.1**	Engine:n475 g/hp-hr GHG 72 g/tonmile	**Moderate**
	GHG Phase 2	In publication	**2021 – 2027**	Engine: Transient duty cycle Sim. vehicle standard: **GEM 3.0**	Engine: approx. –7% GHG up to -25% (vs. 2017)	**Severe**
	**CO_2 Emission** monitoring and declaration	*Under discussion*	**In 2018**	**VECTO** vehicle simulation	Monitoring and declaration to public	**Severe**
	CO2 limits	Under discussion	**Exp. in 2022**	VECTO vehicle simulation	Limits TBD	-
	**Fuel Efficiency** for Diesel Vehicles 2015	In place	**Since 2015**	**JE05** & constant speed 80km/h	Tractor: 2.01 km/L (-12,2% vs 2002 level)	**Moderate**
	2025	Under discussion	**Exp. in 2025**	**JE05** & constant speed 80km/	Tractor reduction: -15%	**Severe**
	**Fuel Efficiency** Standard	*Under discussion*	**Exp. in 2018/21**	**Constant speed** 40/60km/h	In L/100km	**Moderate**
	**Fuel Cons.** Stage 2	In place	**Since 2014**	**C-WTVC**, Simulation based demonstration	Tractor av. 45 L/100km	**Moderate**
	Fuel Cons. Stage 3	Draft	**Exp. 2019**	**C-WTVC**, Simulation based demonstration	Tractor av. 38 L/100km, -15%	**Moderate**

STEPS TO ACHIEVE TARGET CO_2 REDUCTION



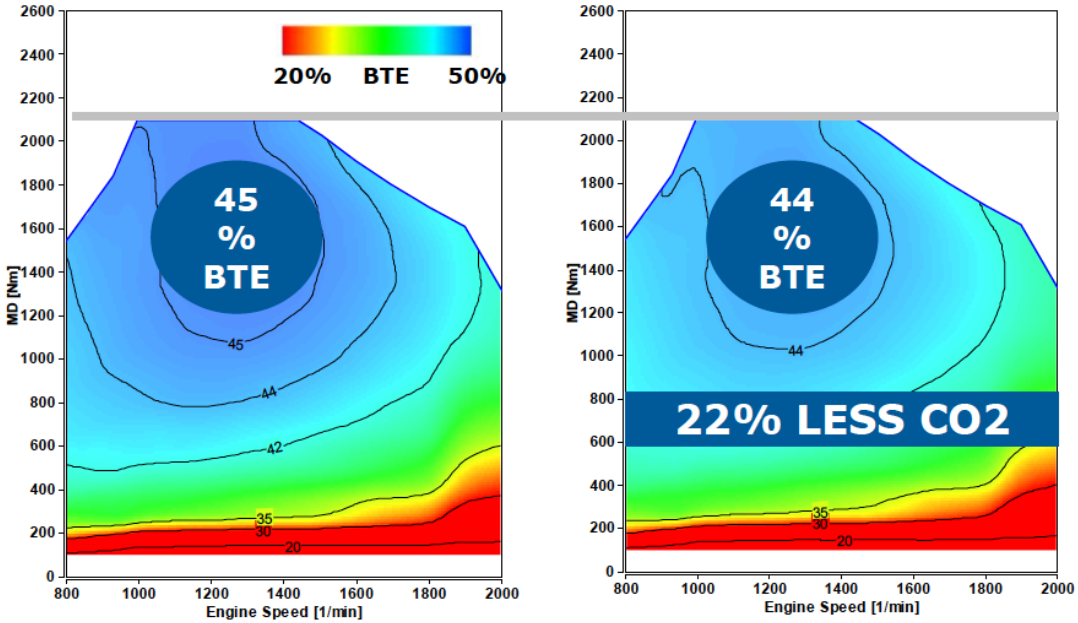


POSSIBLE BREAKTHROUGH TECHNOLOGY

IS THERE A SINGLE TECHNOLOGY THAT CAN REDUCE CO_2 BY MORE THAN 20%
(e.g. GHG Ph2)

BEST IN CLASS HD DIESEL ENGINE

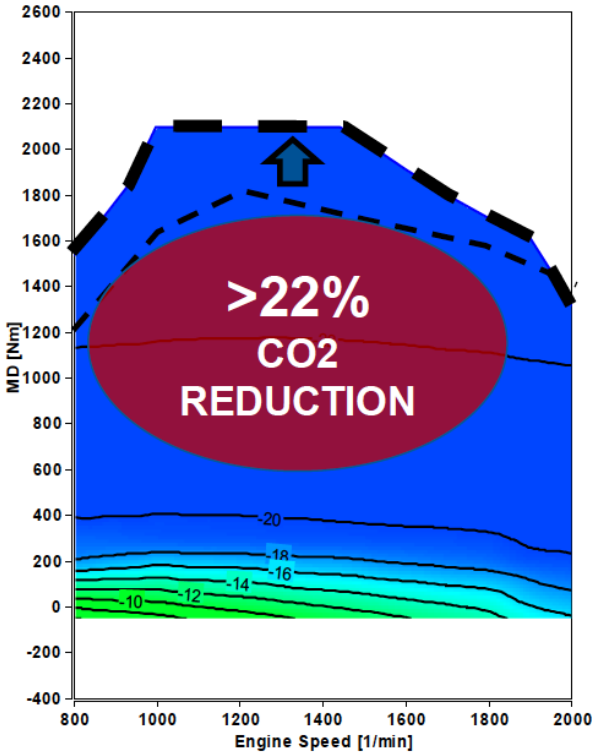
NATURAL GAS ENGINE

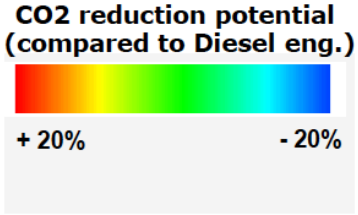


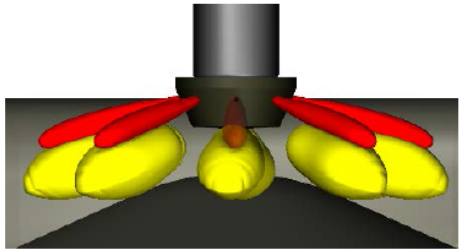
BRAKE THERMAL EFFICIENCY

AVL TEST RESULTS

CO2 REDUCTION POTENTIAL OF NATURAL GAS DIRECT INJECTION (HPDI)







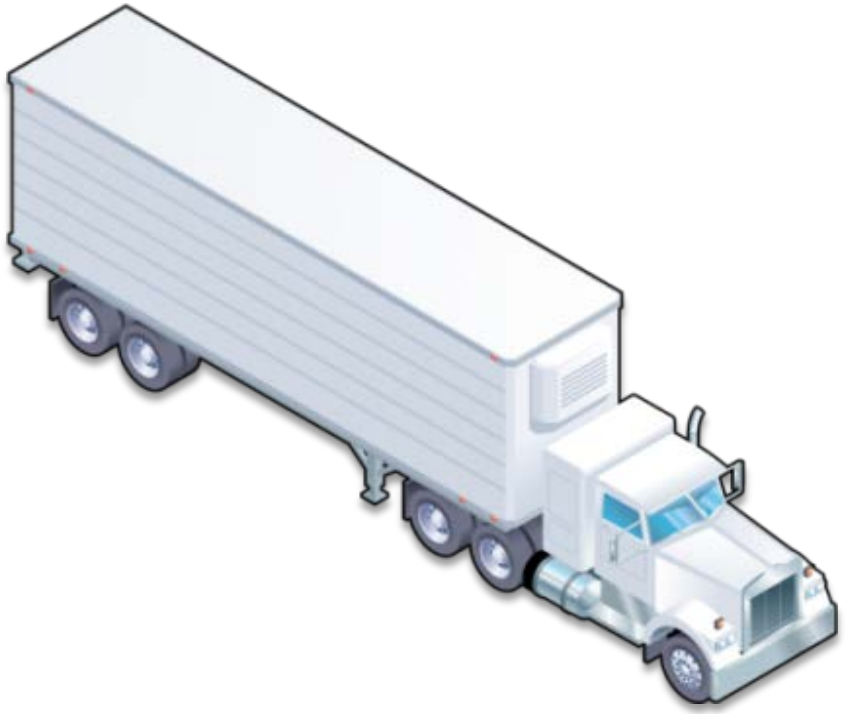
- SAME POWER DENSITY AS DIESEL
- >20% CO_2 REDUCTION
- CO_2 REDUCTION IN THE WHOLE MAP

AVL TEST RESULTS

Help Needed

Westport HPDI 2.0

- Industry & Government support needed to bring HPDI 2.0 to North America
- Natural Gas was excluded from DOE's SuperTruck I and II Programs with $135M and $80M in funding, respectively



Timeline of Diesel-Derived Spark-Ignited NG Engine Innovations

Lean Burn Technology
Cummins L10G launched
1st CNG bus engine

1992

High excess air with turbocharging
Much lower NOx & PM than diesel
25% lower peak torque than diesel

Stoichiometric with Cooled EGR Technology
1st demonstrated in 2004
1st launched - CWI ISL G - in 2007

2004 **2007**

Oxygen-free exhaust using
cooled EGR → 3-way catalyst
15-25% lower peak torque
than diesel

High Efficiency SI (HESI) Technology
1st demonstrated

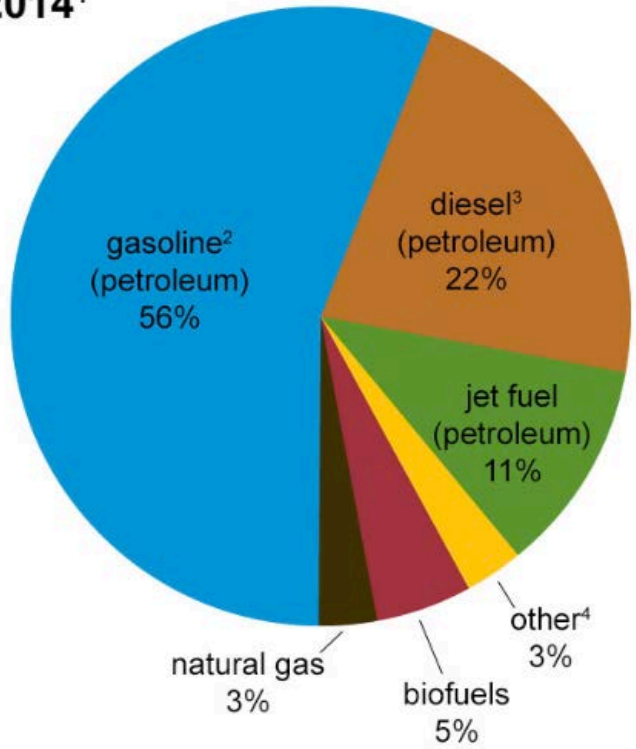
2014

Retains stoich + EGR combustion
Removes constraint of common cylinder head with diesel engine
Higher peak torque than diesel
Enables downsizing

- Tumble air motion
- High turbulent kinetic energy (TKE) at point of ignition

Gasoline Still by Far the Largest Share of Fuel Consumption Mix

Fuel used for U.S. transportation, 2014[1]



- 60% of transportation fuel is finished motor gasoline (including 4% ethanol)
- Mainly used in passenger cars, light and medium duty trucks

[1] Based on energy content
[2] Motor gasoline and aviation gas; excludes ethanol
[3] Excludes biodiesel
[4] Electricity, liquid petroleum gas, lubricants, residual fuel oil, and other fuels

Note: Due to rounding, data may not sum to exactly 100%.

Source: U.S. Energy Information Administration, *Monthly Energy Review* (March 2015), Tables 2.5 and 3.8c, preliminary data

Heavy Duty Pickup Trucks
(Class 2b/3)

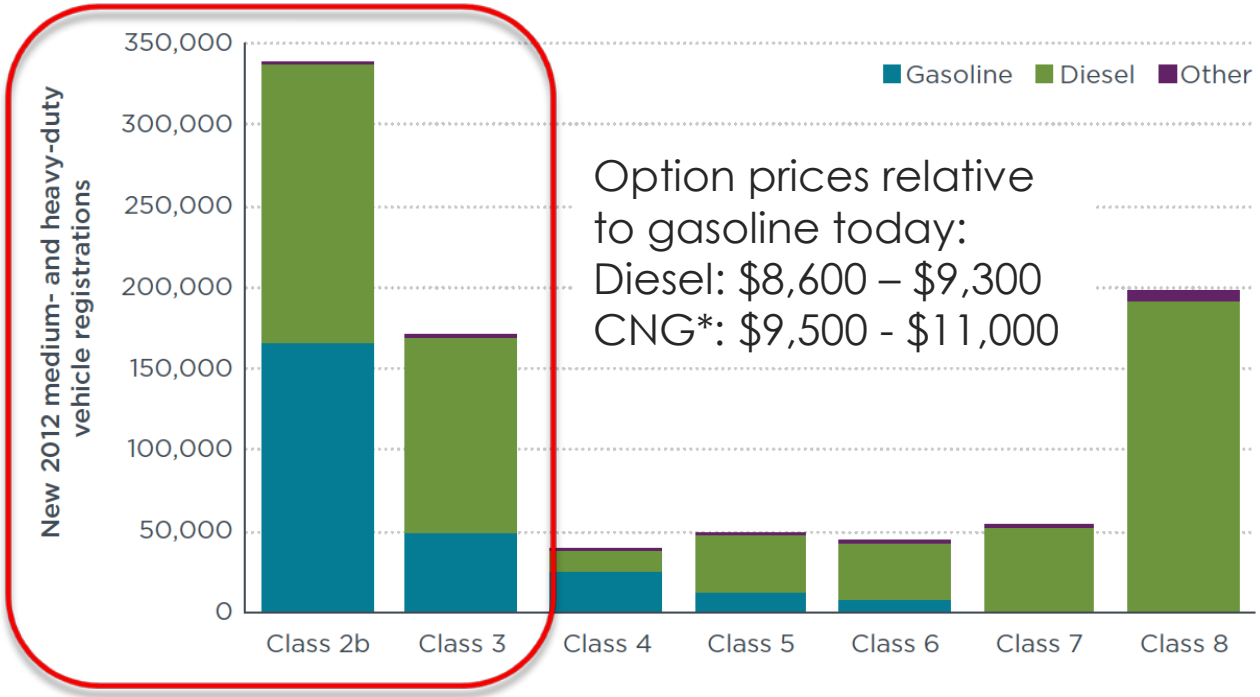
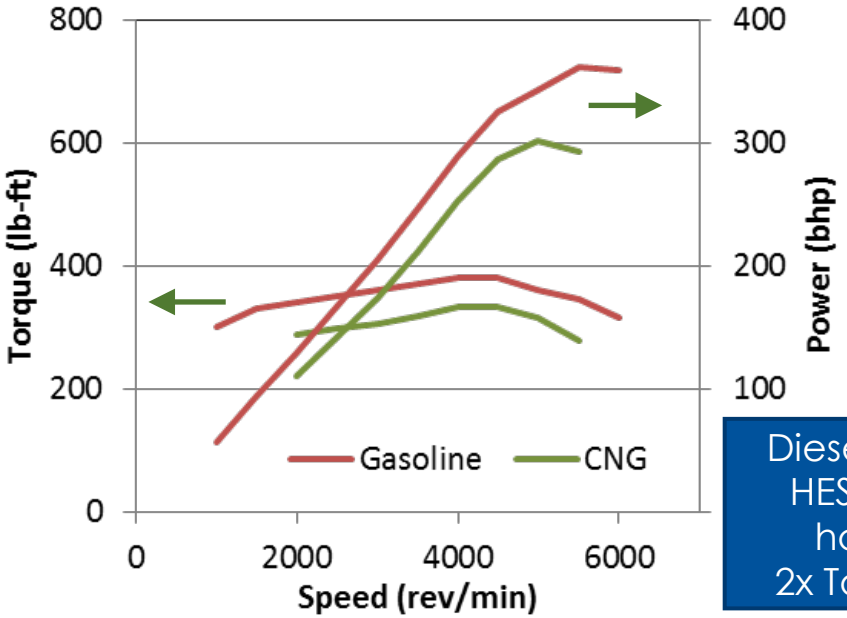


Figure 2. New 2012 heavy-duty vehicle registrations by class and fuel type (Polk, 2013)

* Refers to today's gasoline-derived NG engines with conventional CNG cylinders

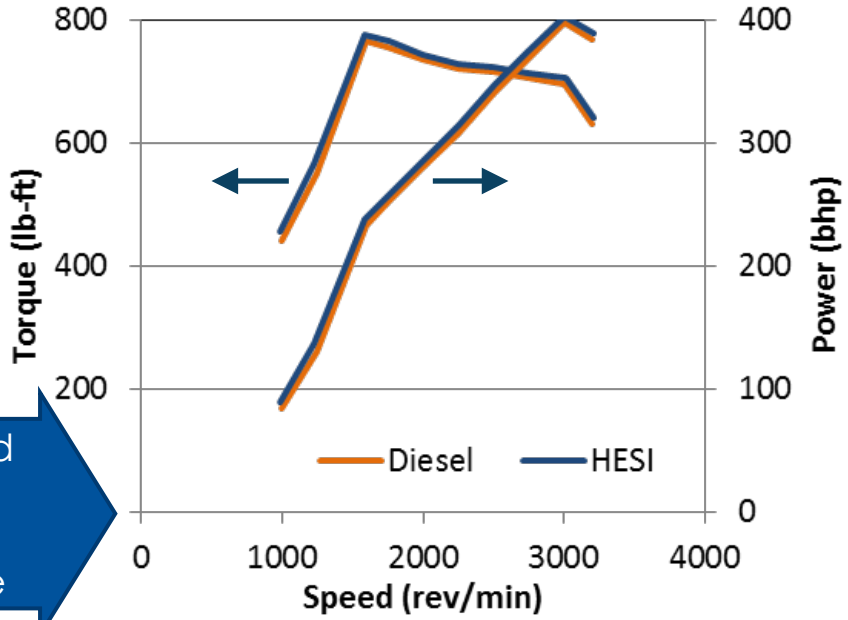
HD Pickup Truck Engine Power & Torque

GASOLINE / CNG

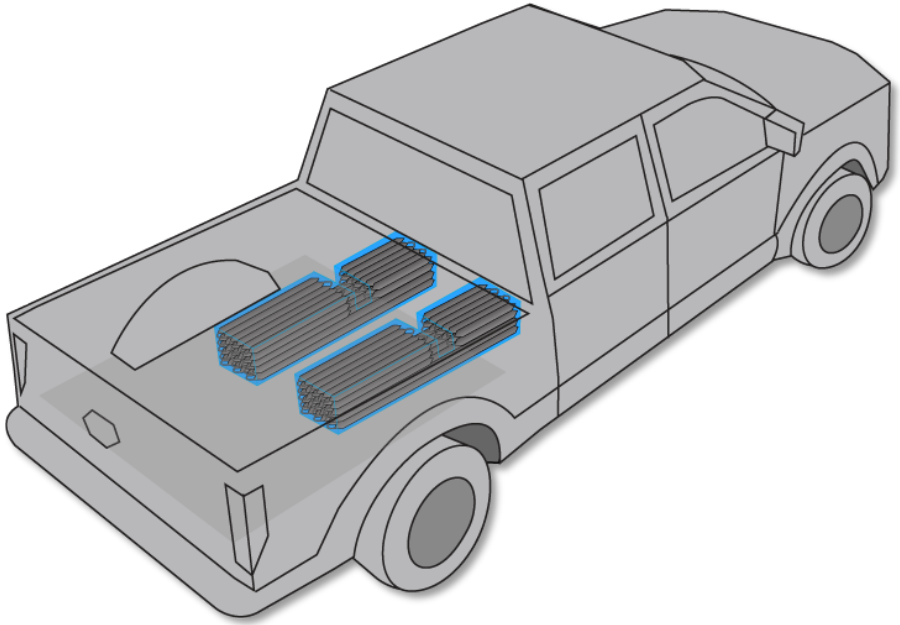


Diesel and HESI NG have 2x Torque

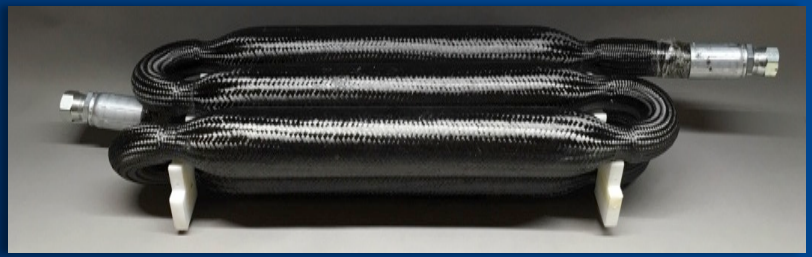
DIESEL / HESI CNG



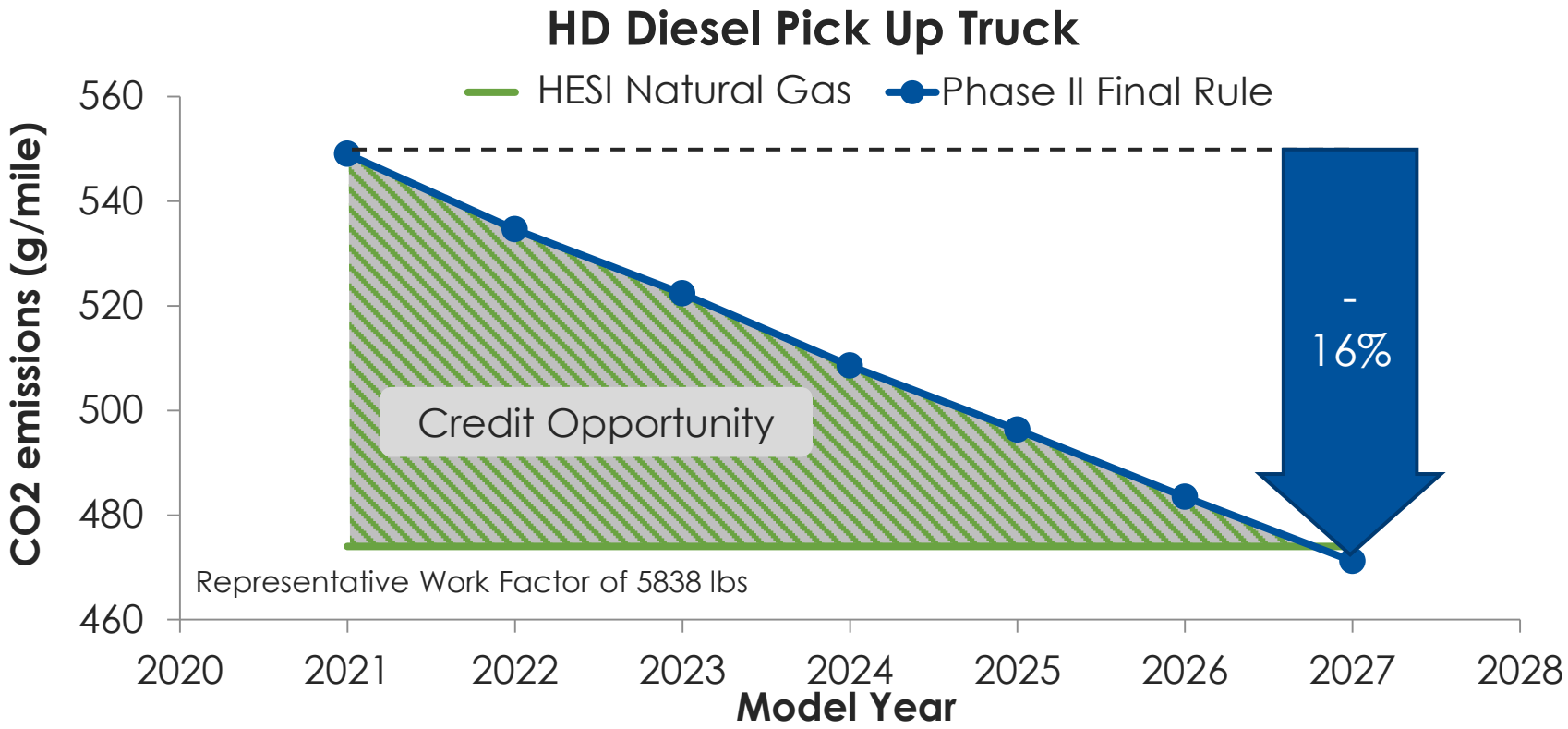
Conformable CNG Tanks



- Folds to fit anywhere
- Lighter, lower-cost systems
- Seamless design
- Continuous manufacturing
- Industry standard materials



Early Compliance & Credit Generation



Proposed SuperPickupTruck Program

- One year ago: Proposed $50M from DOE:
  - Follow-up to arpa-e MOVE program
  - Low-cost home refuelling
  - Conformable CNG tanks
  - High efficiency, high performance powertrains
  - Self-refueling vehicles
  - Adsorbed NG
- Have since de-scoped to $12M program:
  - Conformable CNG tanks
  - High efficiency, high performance powertrains
  - Consortium funding nearly there – still $2-4M short!

Summary of Opportunities

1. NZ NOx CNG shuttle buses

Westport™ WING POWER SYSTEM

2. >20% GHG reduction LNG HD trucks

Westport™ HPDI 2.0

3. -16% GHG MD/LD trucks

SuperPickup Truck Program

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