
# Application of Westport Fuel Systems' HPDI™ Technology to a Demonstration Truck

Westport Fuel Systems

# Westport Global Value Proposition

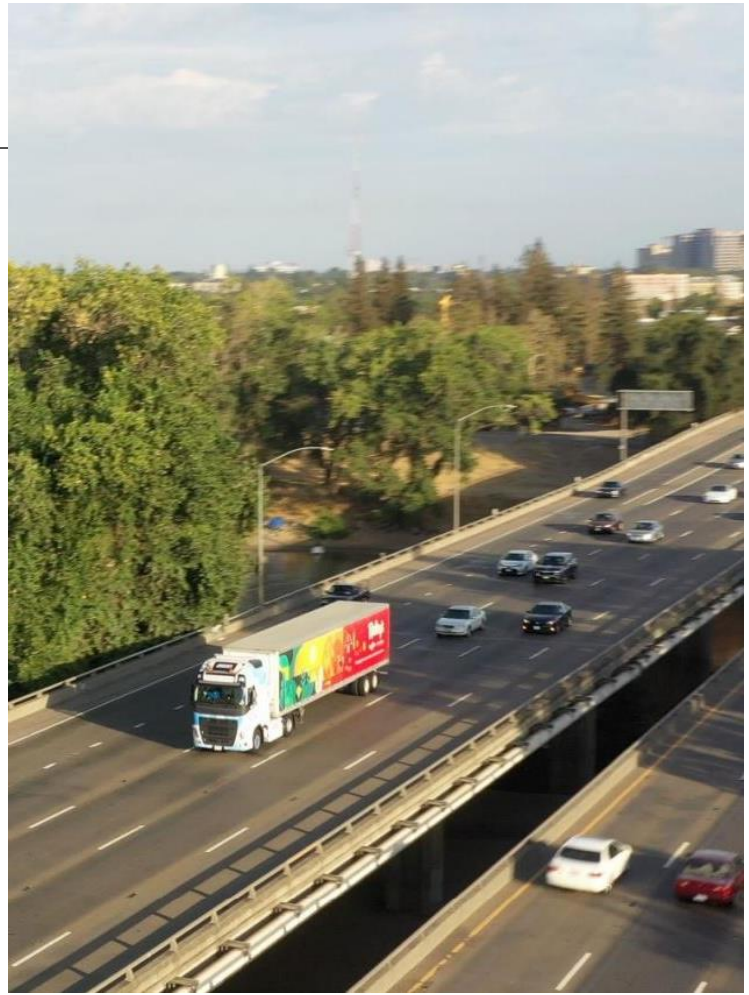
## Driving Cleaner Performance

While others are searching for new ways in overcoming emissions, Westport has turned innovations into answers.

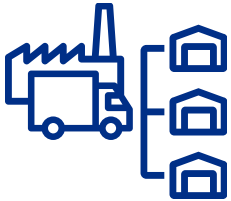
We're constantly innovating new, cleaner ways for industry to keep moving. Driving cleaner performance without compromise.

Creating a path to carbon neutrality by way of less emissions, less cost, and less footprint, and by being more mindful, more pragmatic, and more in tune with what the world requires today.

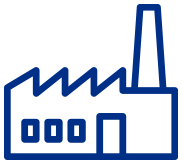
We are constantly seeking viable and valuable answers so that ALL can continue to drive forward and fuel the future.



# We're Changing the Way the World Moves



**Tier 1**
Transportation supplier with diverse business units



**Manufacturing**
7 global locations


**Accessing**
Full suite of renewable and alternative fuels

**Sales in 70**
countries, strong global footprint

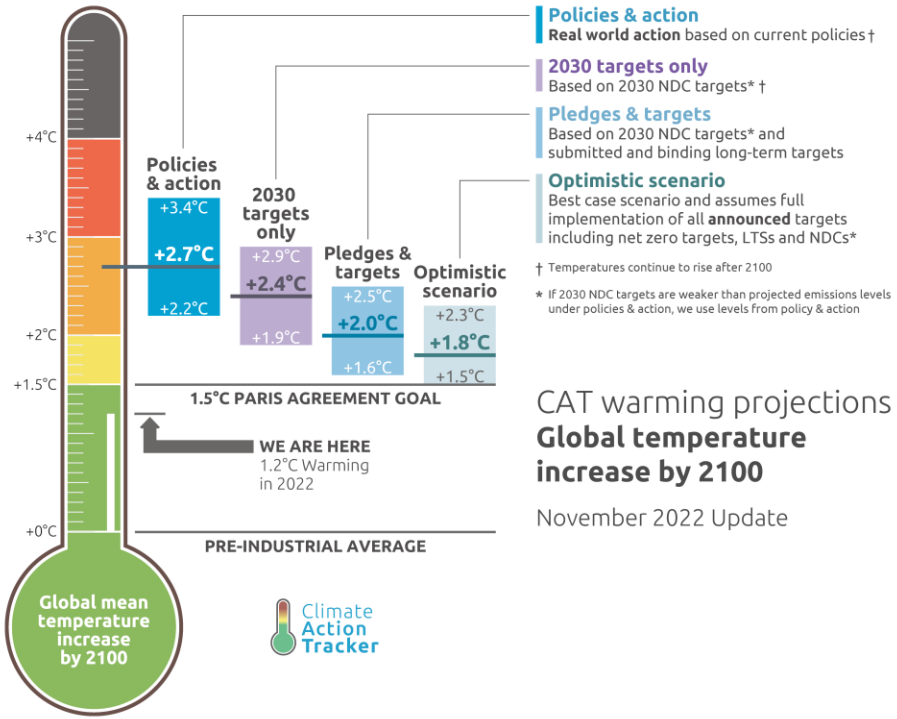
**>100**
Global distributors worldwide

**>1,400 Patents & Applications**
Robust patent portfolio

**We design, engineer & manufacture gaseous fuel systems & components to enable cleaner, affordable transportation**

# Greenhouse Gas Reduction: The Path to Hydrogen

- Technology solutions are being driven by GHG emission reductions
- Separate from EU regs; i.e.no $CO_2$ targets in EU VI or EU VII
- $CO_2$ fleet targets (TTW):
  - 15% by 2025
  - 45% by 2030
- Tank To Wheels (TTW) assumes no credit for renewable fuel




https://climateactiontracker.org/press/dash-for-gas-a-serious-threat-to-the-paris-agreements-warming-limit/

# EU Heavy-Duty Vehicles – Scale of the Challenge

## The Challenge:

- 6.2 million heavy-duty trucks
  - (projected to grow by 30+% by 2050)
- Energy hungry – approx. 640 TWh in 2020
- 28% of road transport emissions
- 80% of road freight delivered by trucks, > 30 tonne GVW
- More than 70% of HDV $CO_2$ originates from long-haul trucks, >30 tonne GVW

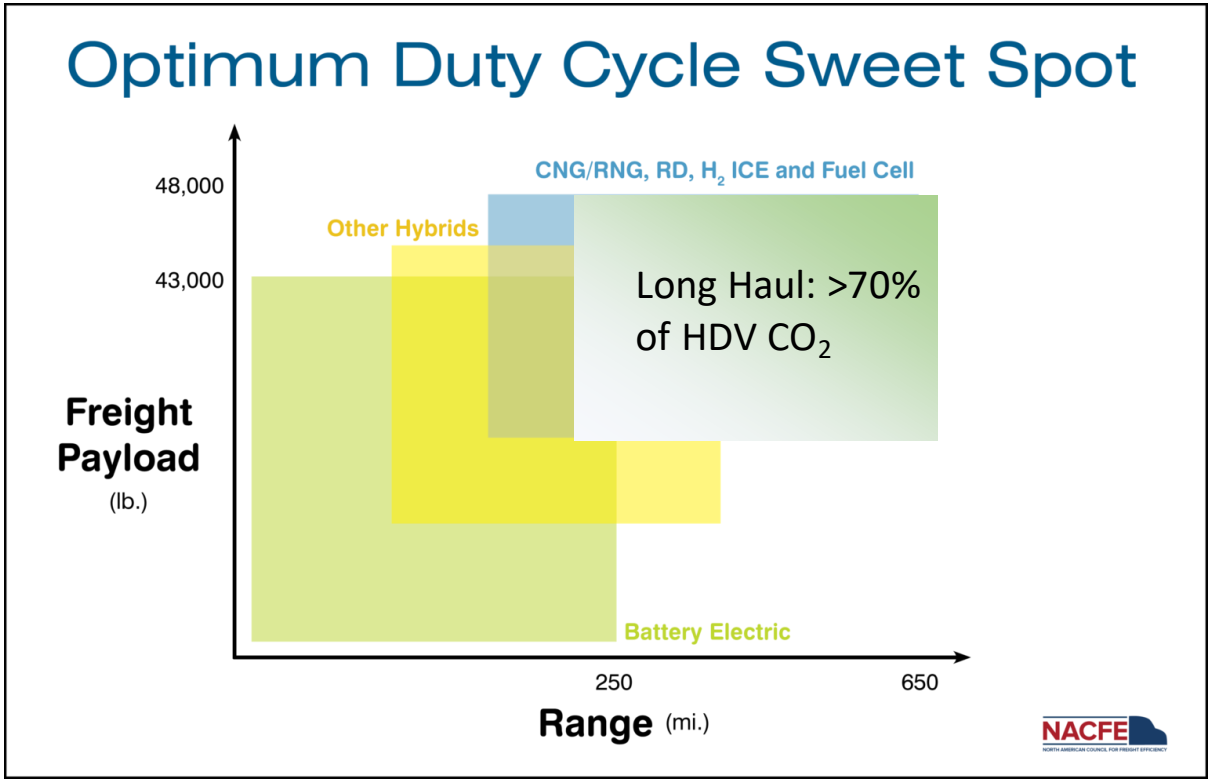
## What is needed?

Urgently need low $CO_2$ solutions for long-haul trucks that drive Well-to-Wheel and Life Cycle $CO_2$ reductions

- Quickly Deployable Solutions
- Innovative Solutions
- Ambitious Solutions
- Efficient Solutions
- Cost-Effective Solutions
- Practical Solutions

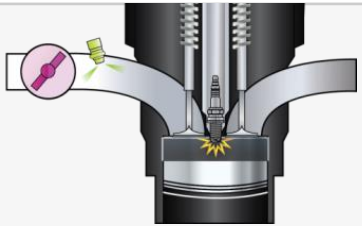
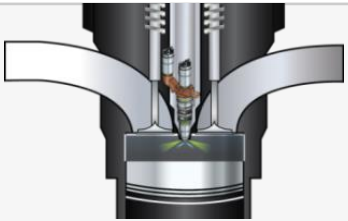
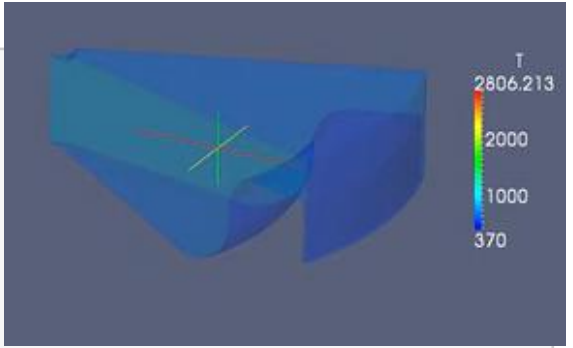
# HD Technology Solutions vs Vehicle Usage

- Multiple solutions for decarbonizing transportation:
  - BEVs
  - FCEVs
  - $H_2$ ICEs
  - + Hybrids
- NACFE Study:
  - BEVs + hybrids - short haul
  - FCEVs and $H_2$ ICEs - long haul

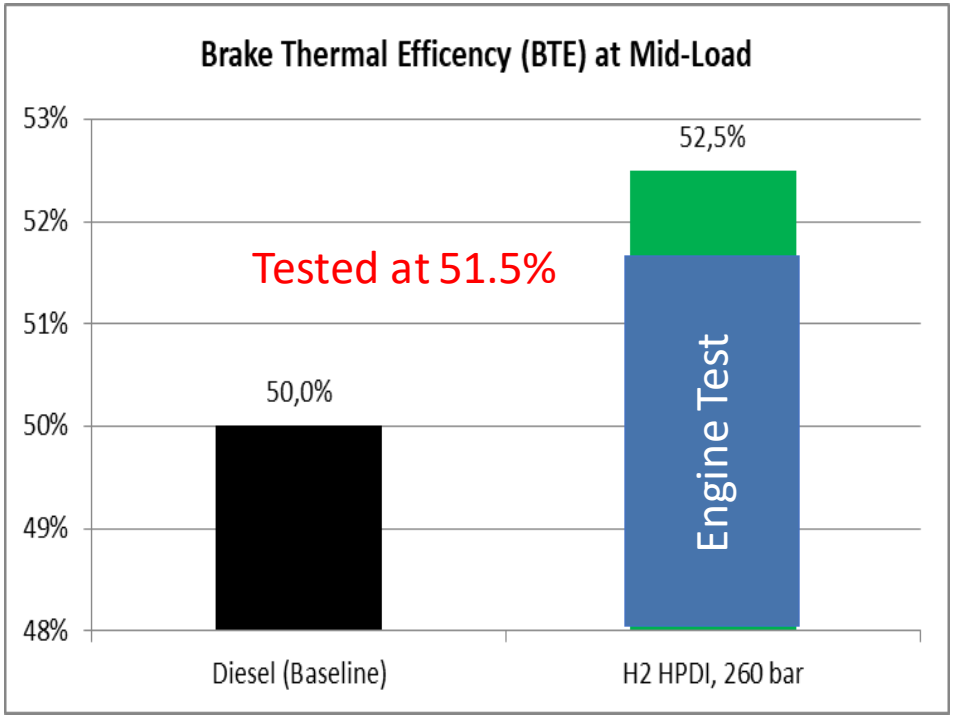



https://nacfe.org/research/electric-trucks/hydrogen/

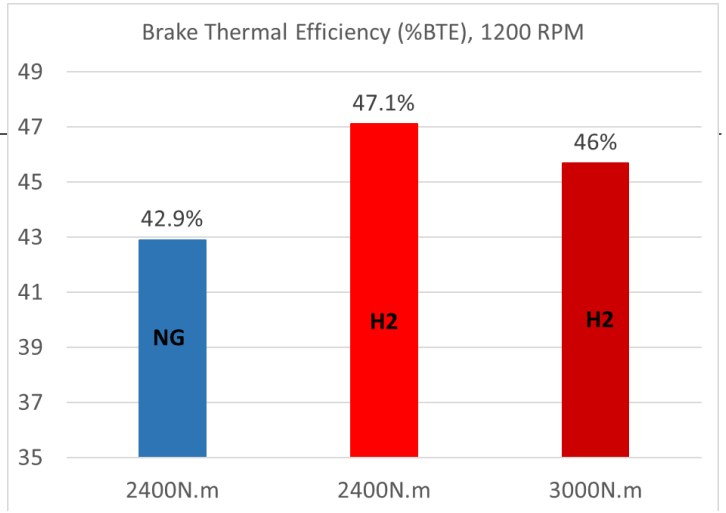
# NG / $H_2$ ICE Technologies

| |  Spark Ignited |  Compression Ignition (HPDI)   |
|---|---|---|
| How it works | • Fuel & air pre-mixed at low pressure<br>• Dedicated natural gas (100%)<br>• Ignition from spark plug<br>• Reduced compression ratio to avoid knock<br>• Simple 3-way catalyst<br>• Otto cycle (Stoichiometric)<br>• **Power / torque / efficiency typically lower than base diesel engine** | • High pressure direct injection of gas into combustion chamber<br>• **Same base diesel engine can be used**<br>  • Compression Ignition from diesel pilot<br>  • Same compression ratio as diesel to retain high efficiency<br>  • SCR & DPF (same as diesel)<br>• Diesel cycle - high substitution (~94% on typical road cycle)<br>• **Power / torque / efficiency can exceed base diesel engine on Hydrogen** |

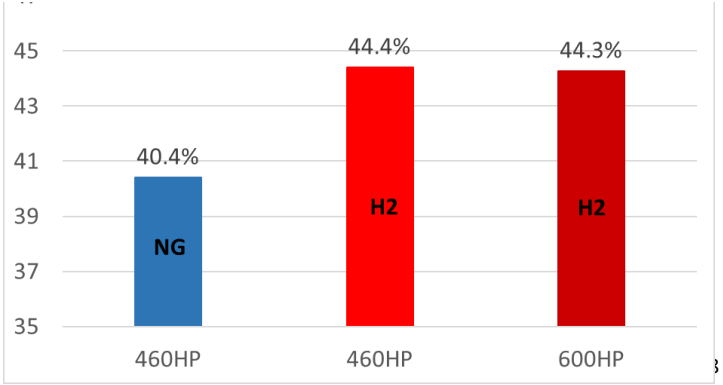
# $H_2$ HPDI – Results at a Glance




**Diesel vs $H_2$ HPDI on a Next Generation Diesel Engine (CFD & Test Results)**

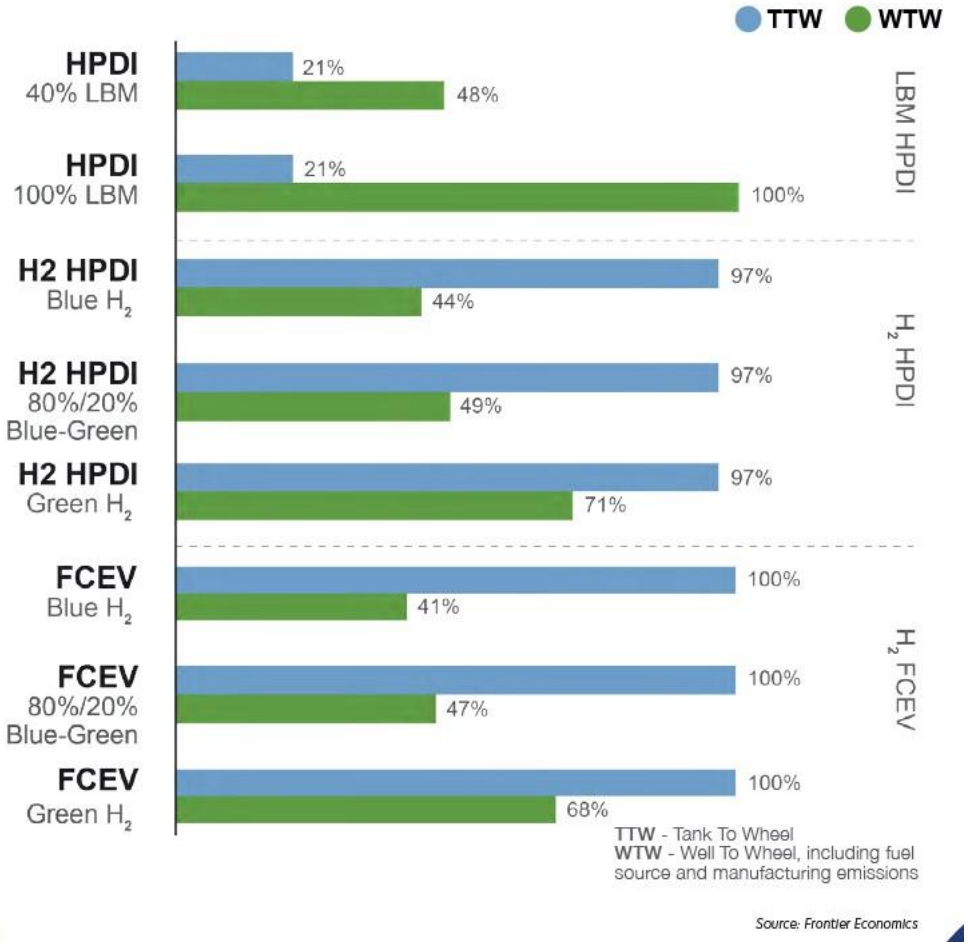



**Currently testing both single and multi-cylinder engines with multiple partners**

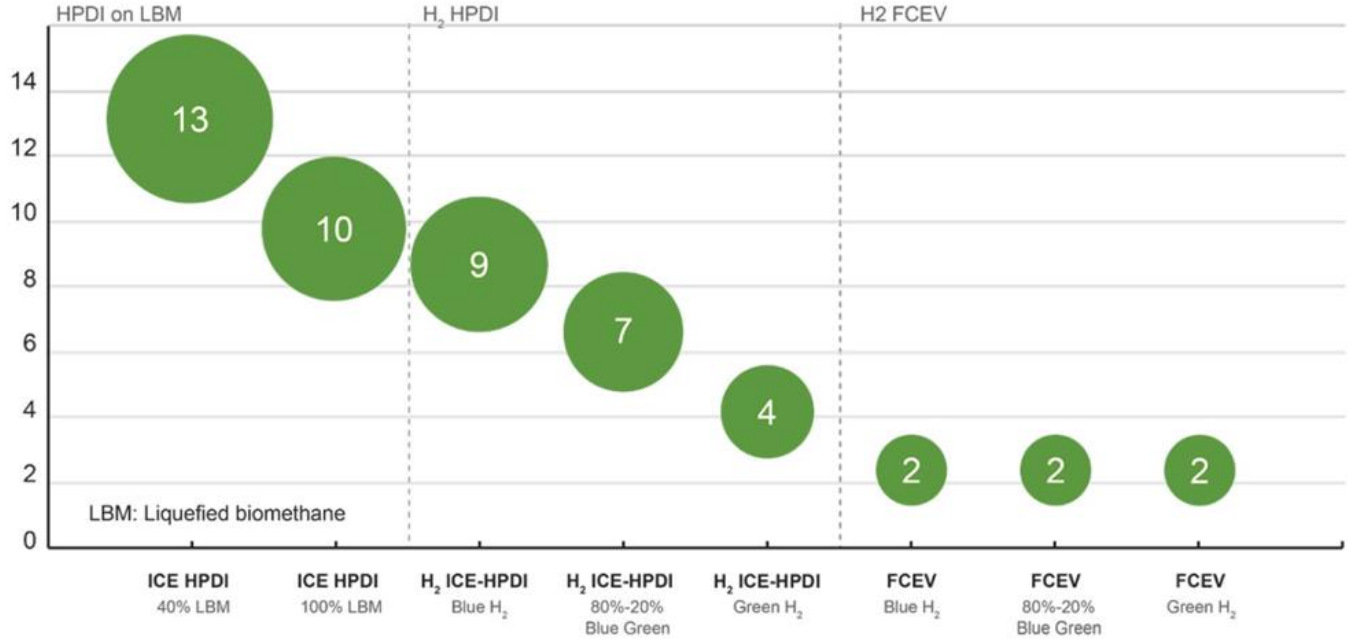


# $CO_2$ Reduction – TTW vs WTW

- Fuel source is critical
  - **TTW**:
    - $H_2$ HPDI can achieve up to 97% $CO_2$ reduction (mode dependent)
  - **WTW**:
    - Hydrogen manufacturing has a significant impact on $CO_2$ reduction.
    - Biomethane is promising depending on the blend – reductions of up to 100% are possible with ICEs
- **HPDI allows the same base engine to maximize net $CO_2$ reduction with either LBM or $H_2$**



# Cost Abatement in Tons of WTW $CO_2$ Reduced per €1,000 Invested




Analysis based on Frontier Economics: "$CO_2$ Emission Abatement Costs of Gas Mobility and Other Road Transport Options"

***HPDI-equipped trucks provide <u>cost-effective $CO_2$ reductions</u>***

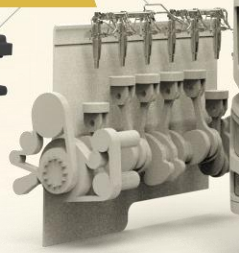
# Demonstration $H_2$ HPDI Trucks

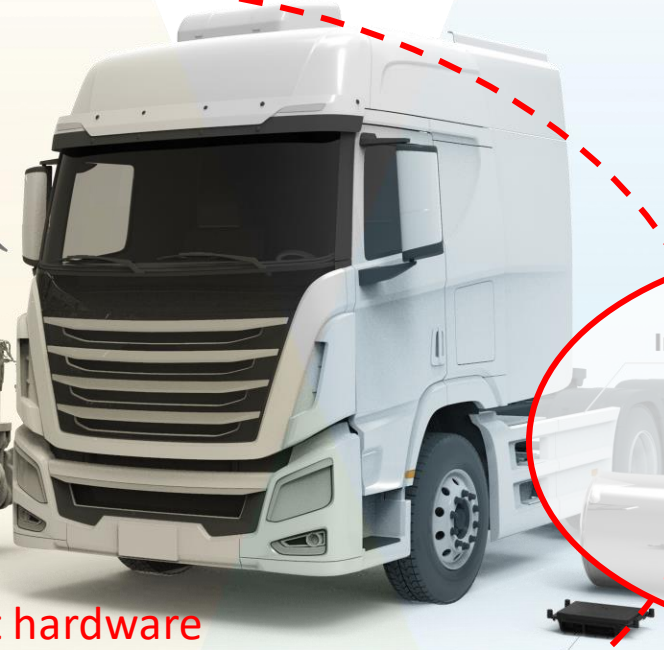
HPDI Injector

Gas Rail

OEM ENGINE

Gas Conditioning Module





HPDI Control Software

Demo trucks use current hardware

On-Engine

$H_2$ Tank Array

Integrated Gas Module

LNG TANK MODULE

Remove LNG tank and add $H_2$ Tanks

Off-Engine

# $H_2$ Demonstration Trucks

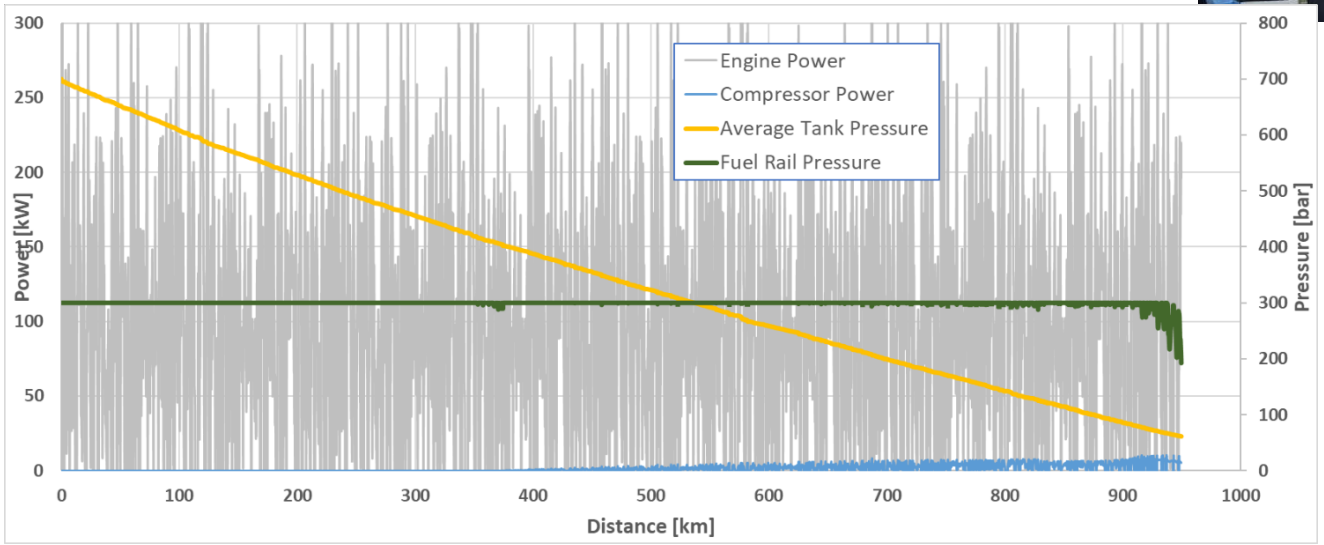
- Westport has built two $H_2$ HPDI demonstration trucks
  - Both trucks are converted from commercially available NG HPDI European models
  - Truck #1 is US-based
  - Truck #2 is European based

- Onboard storage is currently 16kg in a four-tank array with no compressor


# $H_2$ Demonstration Trucks – Next Steps

- Increase fuel storage:
  - 80kg of fuel w/ no compressor < 600km range* with Smart Tank strategies


**Simulated Highway / Moderately Hilly Route (20-tonne load)**




- Add a compressor:
  - 80kg of fuel w/ compressor would allow up to ~900km range*

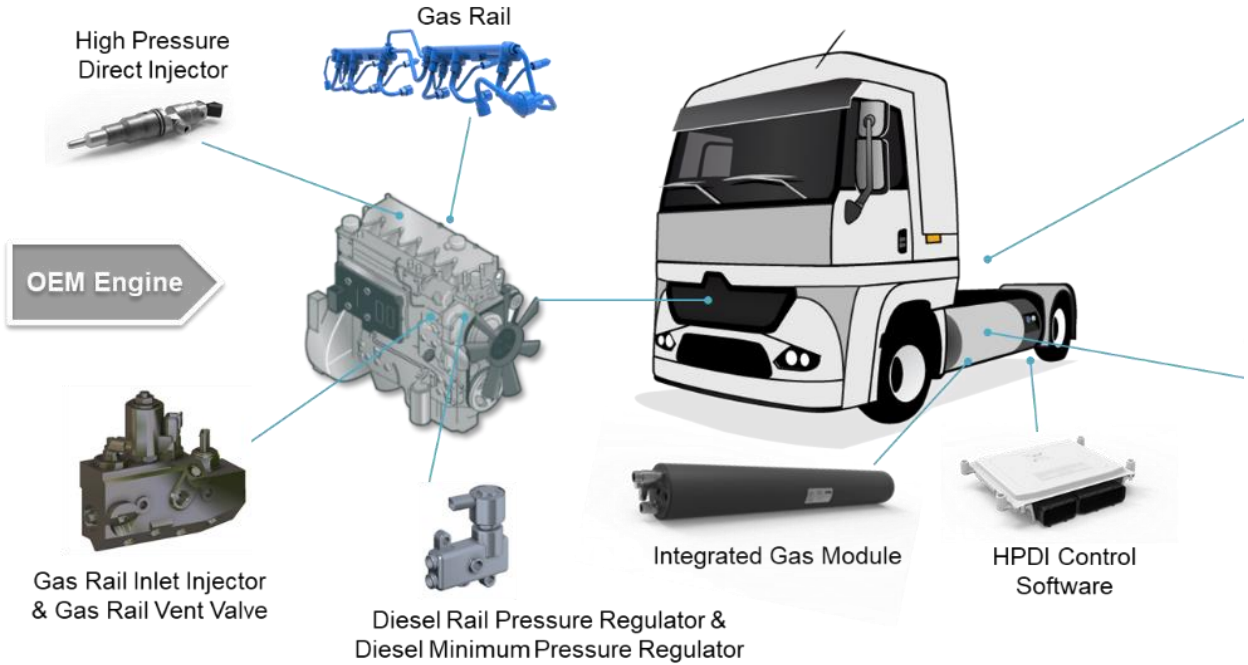
* Cycle/load dependent

# Looking to the Future – A Flexible System

## On Engine

## On Chassis

## Off-Engine System



## Summary

- Westport's HPDI™ fuel system can be used with Biomethane or Hydrogen
- HPDI combustion allows the **highest power density** and the **highest efficiency** for using hydrogen in an internal combustion engine for heavy duty applications.
- $H_2$ HPDI has already demonstrated **near-zero $CO_2$** emissions.
- $H_2$ HPDI offers a lower TCO and more **cost-effective** $CO_2$ reductions than Heavy Duty competitors.
- $H_2$ HPDI interest is growing from OEMs, with multiple development projects recently announced and underway.

## Contact Info

- Thank you!
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