Cummins Hydrogen Engine Update

Agenda

- Destination Zero
- Fuel Agnostic Platform
- Hydrogen Internal Combustion Engines
- R&D

WHAT IS DESTINATION ZERO?

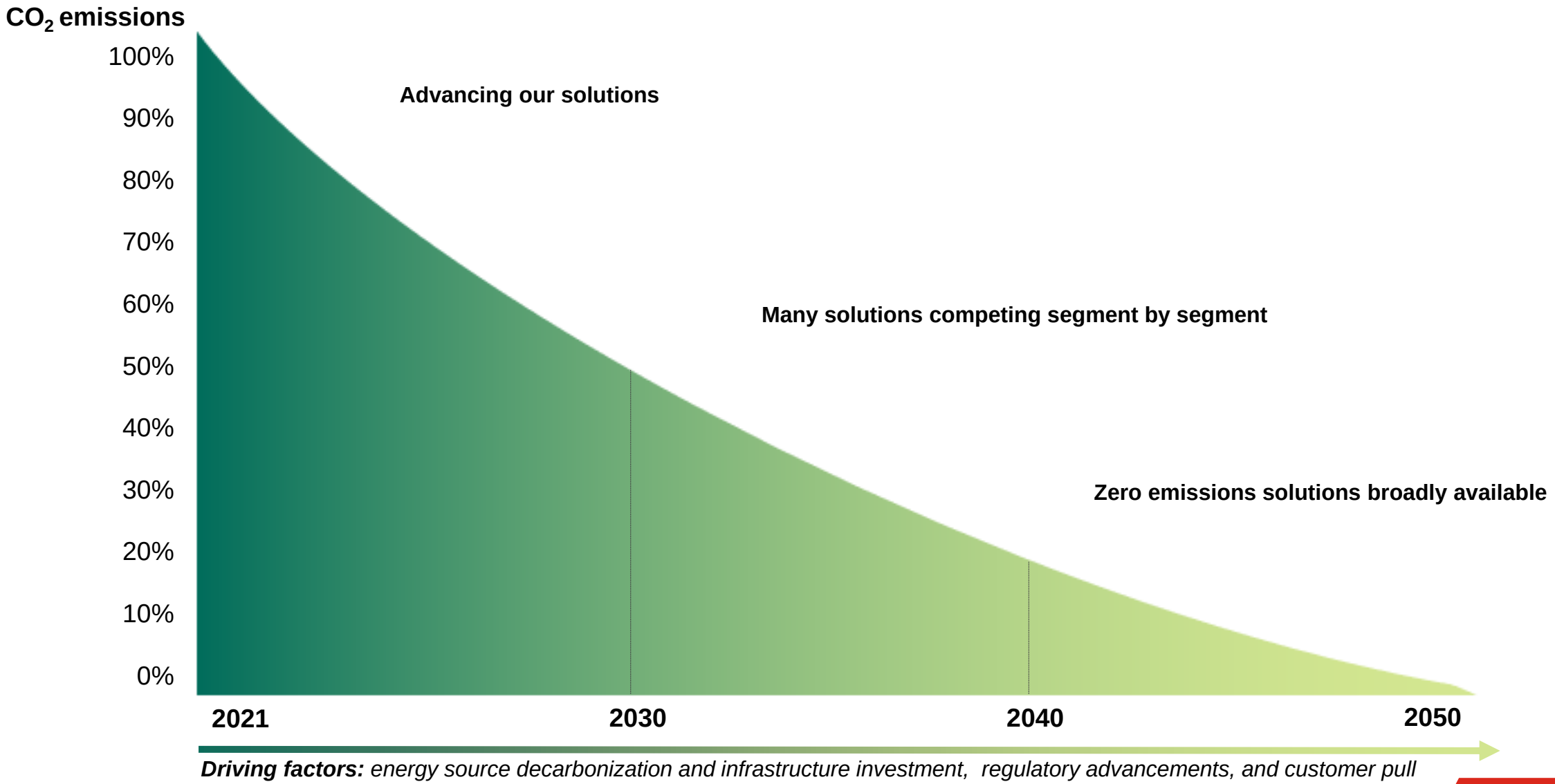
Lower emissions today

Reduce well-to-wheels emissions

Drive wide-scale customer adoption

Achieve zero emissions by 2050

REACHING DESTINATION ZERO



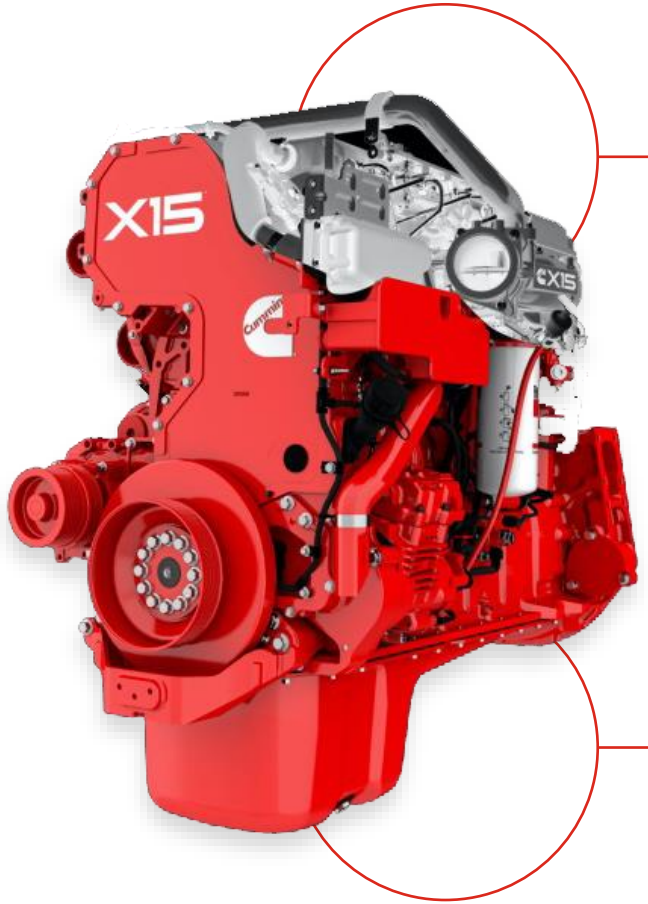
Driving factors: *energy source decarbonization and infrastructure investment, regulatory advancements, and customer pull*

CUMMINS FUEL-AGNOSTIC PLATFORM

NEW TECHNOLOGY APPROACH

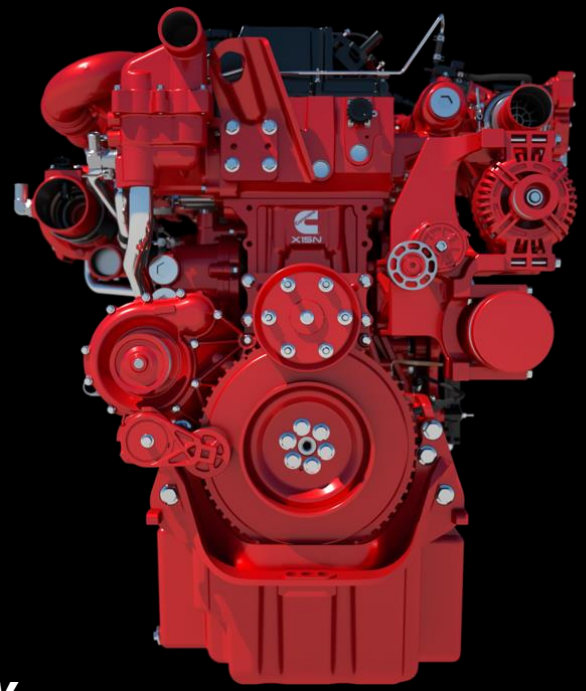
New fuel-agnostic engine platforms are derived from a common base engine, meaning they have a high degree of parts commonality.

Each engine version will operate using a different, single fuel.



Above the head gasket will have different components for different fuel types.

Below the head gasket of each engine will largely have similar components.

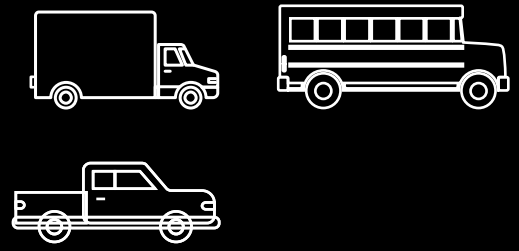


Heavy-duty

Clean Diesel
Natural Gas
Hydrogen

Medium-duty

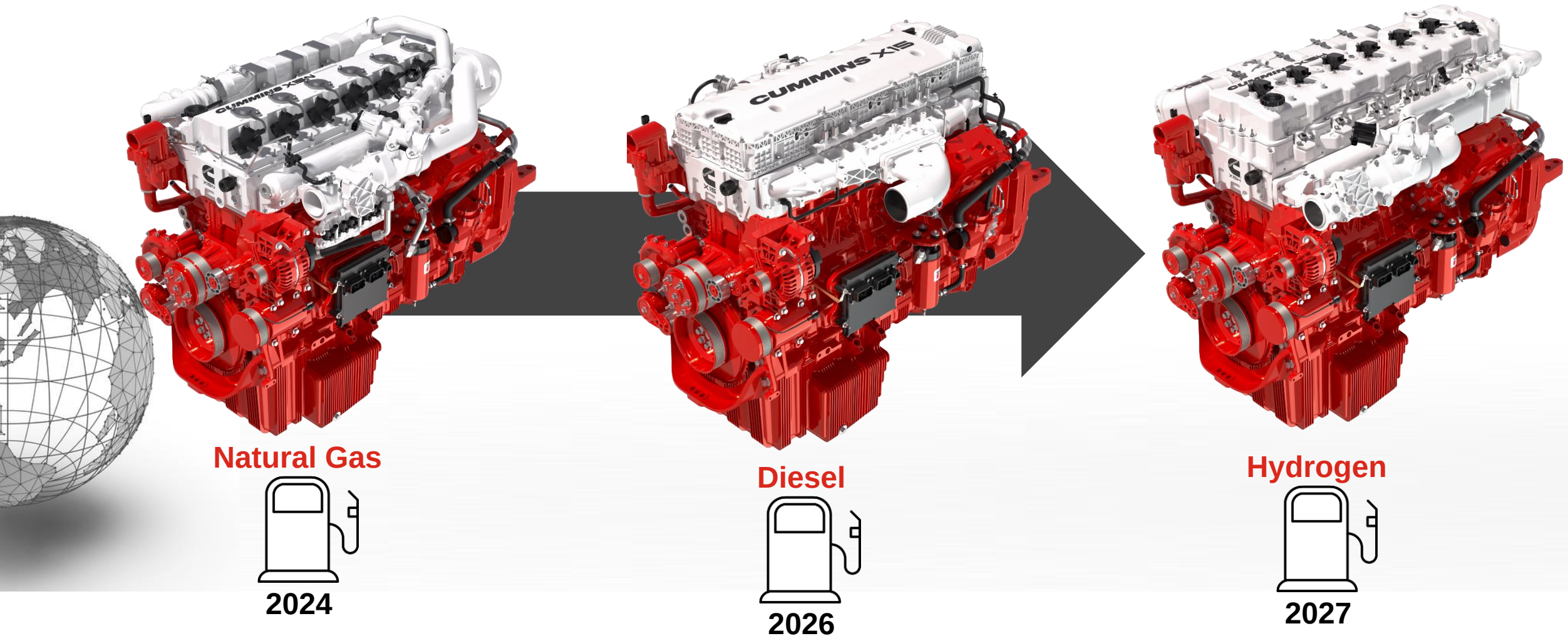
Gasoline
Propane
Clean Diesel
Natural Gas
Hydrogen



Represents global product plan. Products may not be available in all regions. Subject to change.

X15 GLOBAL PLATFORM: FUEL AGNOSTIC

Reliable | Durable | Scale | Common



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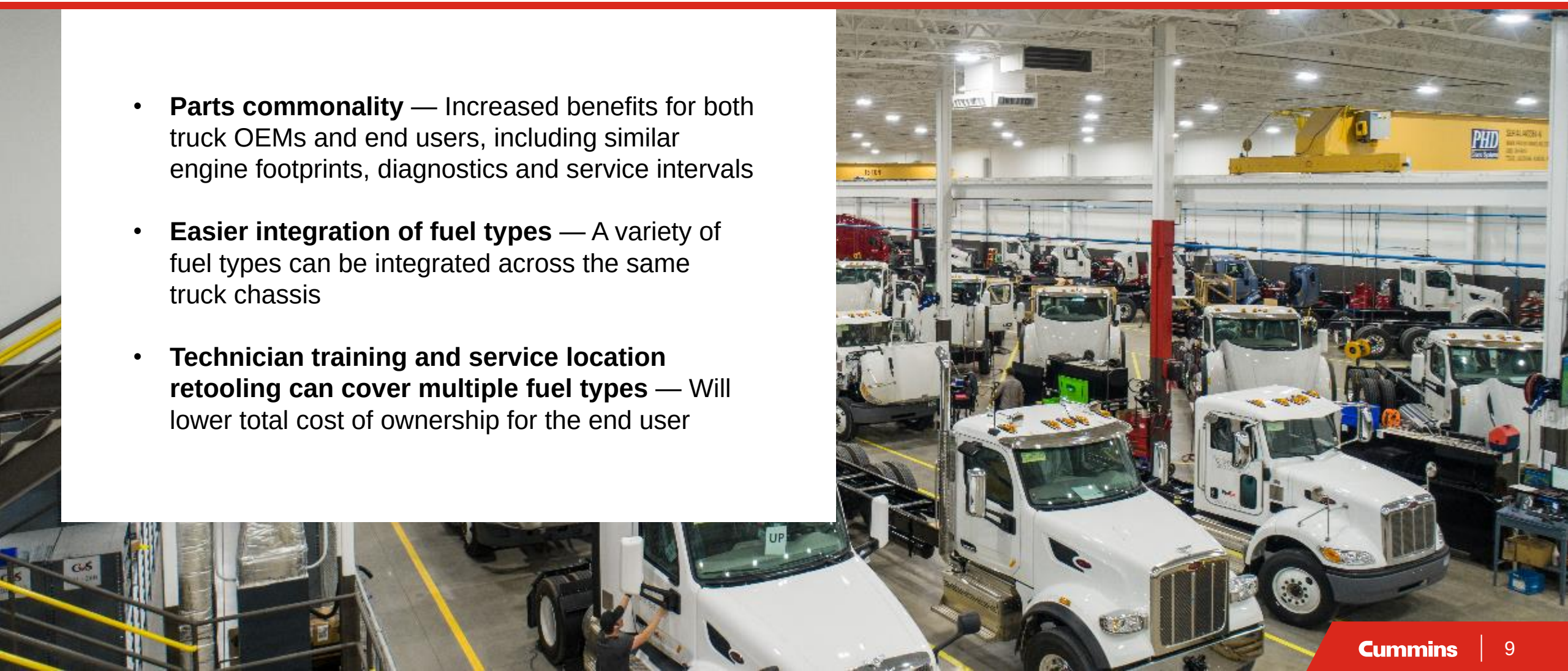
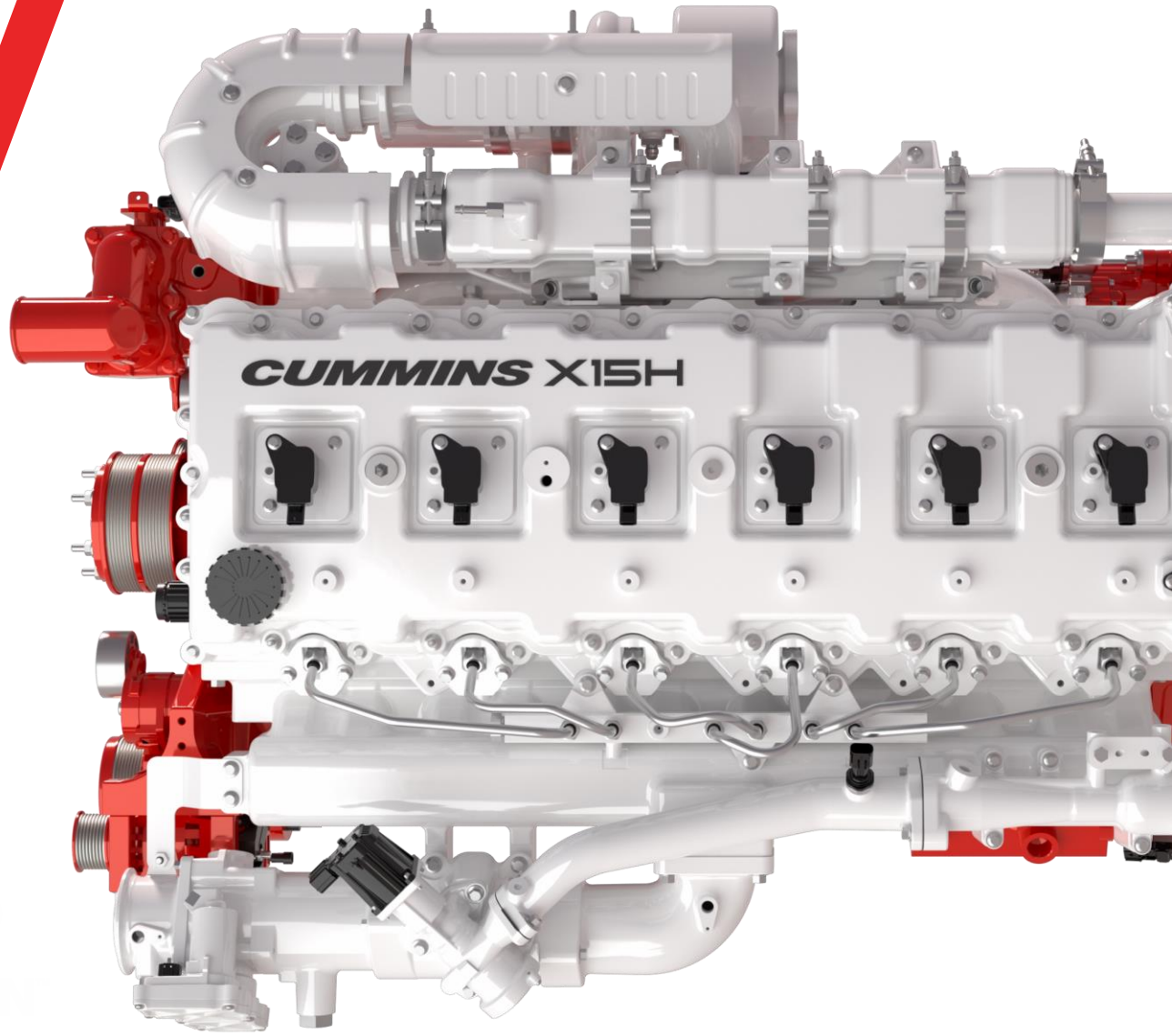
BENEFITS TO OEMS AND END USERS

- **Parts commonality** — Increased benefits for both truck OEMs and end users, including similar engine footprints, diagnostics and service intervals
- **Easier integration of fuel types** — A variety of fuel types can be integrated across the same truck chassis
- **Technician training and service location retooling can cover multiple fuel types** — Will lower total cost of ownership for the end user



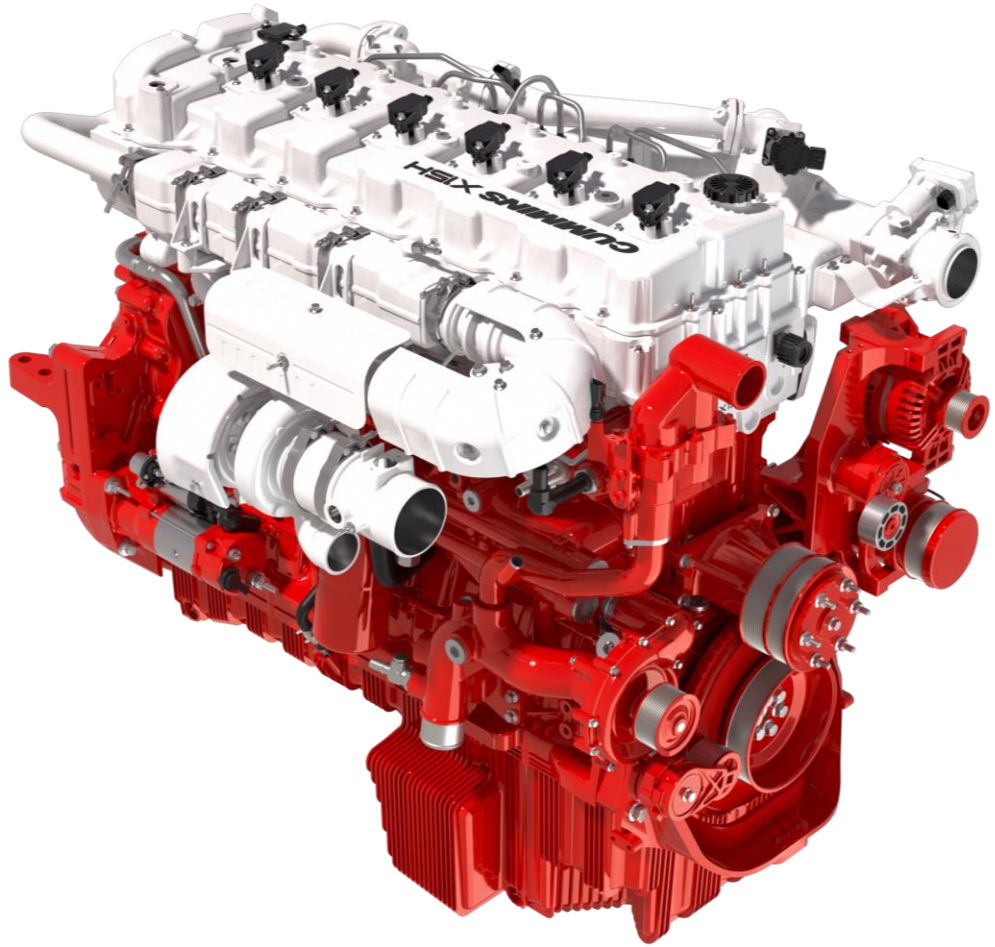
Hydrogen Internal Combustion Engines (ICE)

A Practical Solution for Decarbonization



Hydrogen Internal Combustion Engines (ICE)

- Cummins announced the testing of hydrogen internal combustion (ICE) technology in July 2021.
- Hydrogen ICE technology pairs clean zero carbon hydrogen fuel with the proven technology of internal combustion engines, resulting in an important complement to Cummins Destination Zero initiative.
- The development of the 6.7-liter hydrogen engine will focus on medium-duty truck, buses, and construction applications, such as excavators and wheel loaders.
- A new 15-liter platform offers the potential to bring hydrogen gas-fueled engine capability to heavy duty long-haul trucks.



Hydrogen ICE:

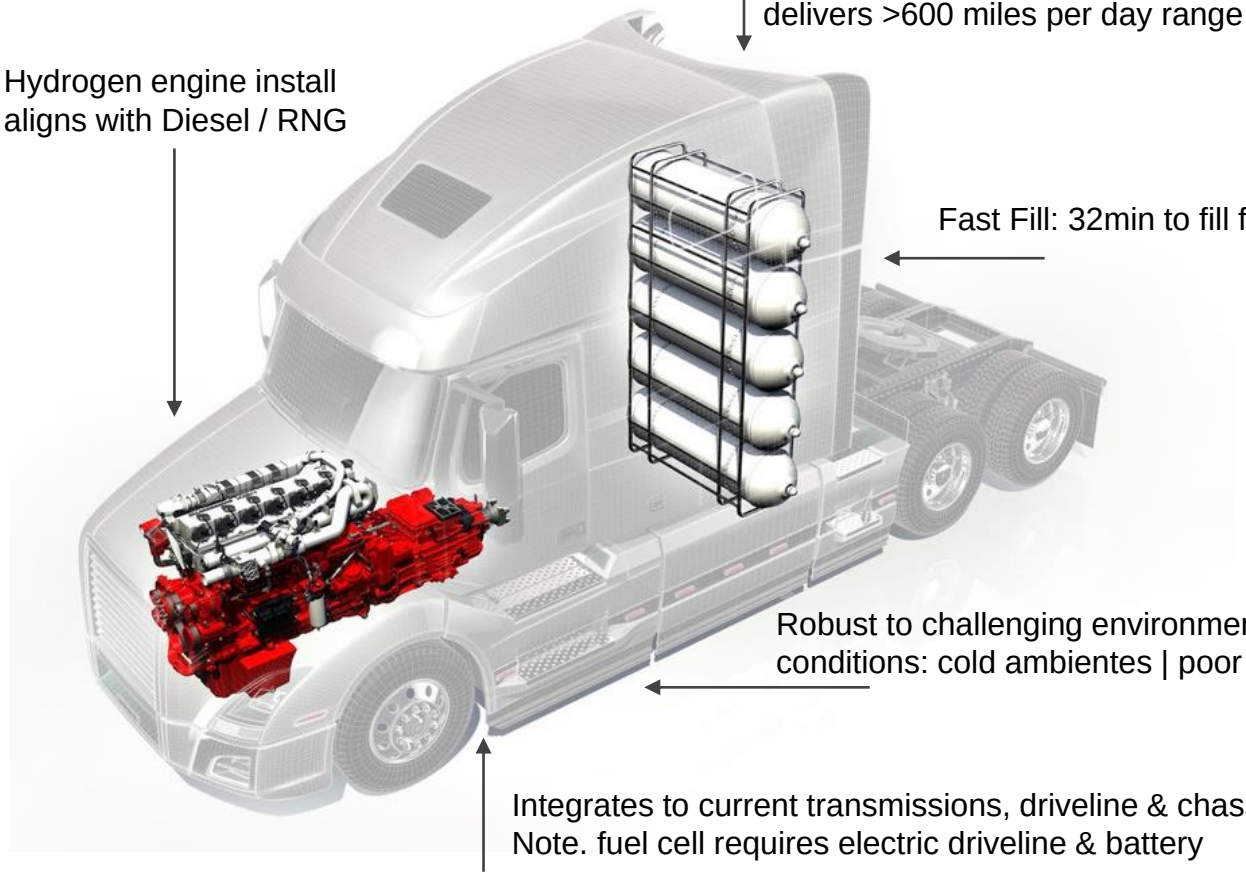
2027 | North America | Line Haul | 120K miles/year | 500+ mi range

Lowest initial price Zero-Carbon Vehicle

Diesel 9 MPG = 8 miles / kg hydrogen

80 kg hydrogen storage unit @ 700bar
delivers >600 miles per day range @ 8 mi / kg

Hydrogen engine install
aligns with Diesel / RNG



Fast Fill: 32min to fill from empty

Robust to challenging environmental
conditions: cold ambientes | poor air quality

Integrates to current transmissions, driveline & chassis.
Note. fuel cell requires electric driveline & battery

Hydrogen Fuel

- Zero-carbon fuel
- Global market developing
- Distribution model similar to diesel - highly portable
- Fuel during extended power outages
- Fast fill compared to electric

Supply Chain

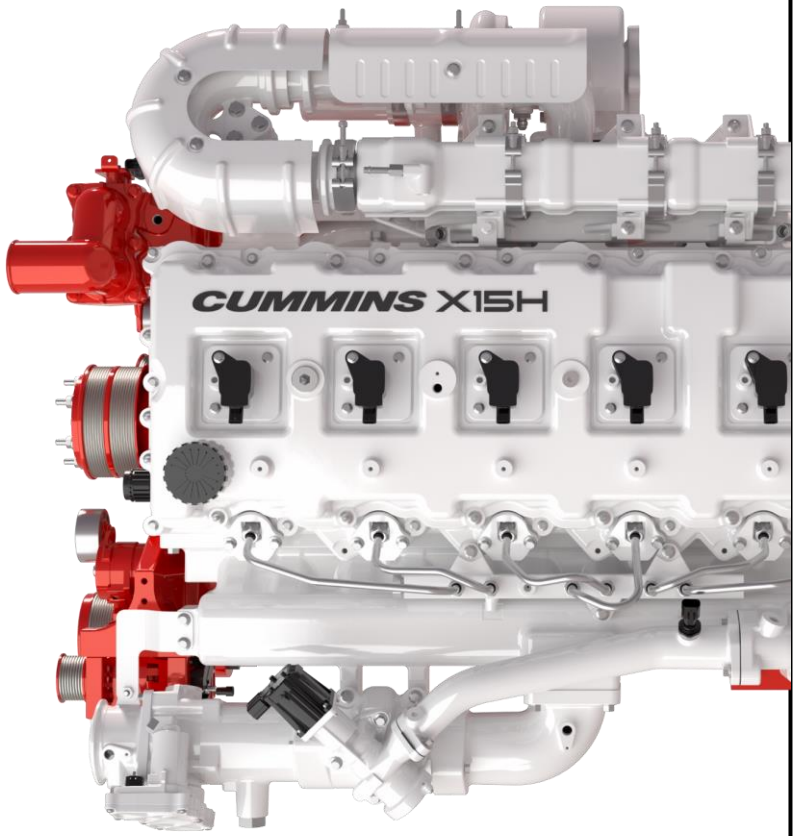
- Leverages existing manufacturing base for chassis and powertrain components
- Does not compete with passenger car industry for battery materials

Calculate your Fuel Economy

- 1.13 kg H2 has the same amount of energy with 1 gallon diesel fuel. The X15H will have similar efficiency with current diesel engines. 9 MPG diesel means 9 miles per 1.13 kg H2, or 7.96 miles per kg H2.

VECTO & GEM: CO2 score forecasted to be equivalent to battery electric and fuel cell powertrains

Hydrogen ICE: A practical solution



Cummins and the industry are all working towards a common goal, decarbonization; however, uncertainty exists

Cummins is actively exploring Hydrogen Internal Combustion Engines (ICE) and building market interest around this practical zero-carbon fueled technology

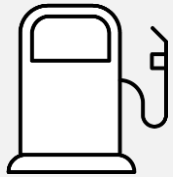
Investing in multiple zero-carbon technologies is critical to ensure fleets have options and competition exist

Cummins is receiving increasing interest in Hydrogen ICE due to its low cost and commonality with current powertrains

By signaling interest in Hydrogen ICE, the industry can help ensure both government policy and regulations support this practical technology

Different Use Cases: Complementary Technologies

Diesel



Versatile
Reliable
Low Cost
Ubiquitous

Use Case

Regulations

Incentives

ESG

Infrastructure

Business Model

…

Zero CO_2 Technologies

- H2 Fuel Cell
- H2 Internal Combustion Engine (ICE)
- Renewable Natural Gas
- Renewable Diesel

- Battery Electric Vehicles

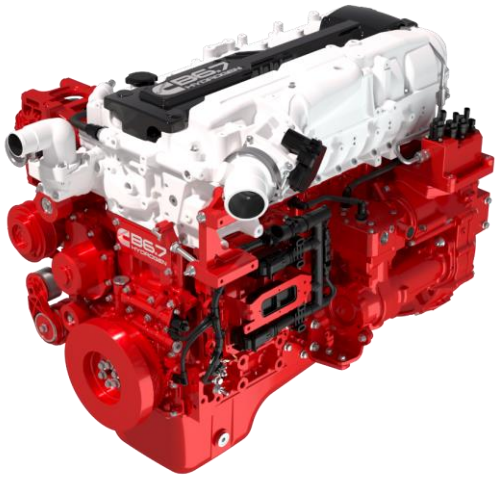
Urban | **Regional** | **Long Haul**

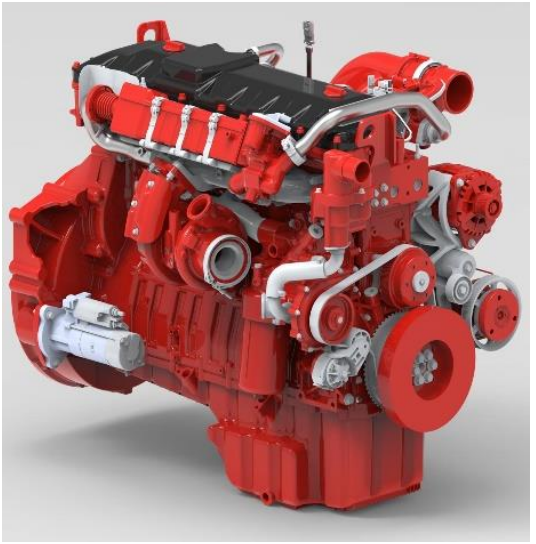
Daily Mileage (miles)
Daily Usage (hours)

200
Up to 4

400
Up to 6

Cummins Hydrogen Engines

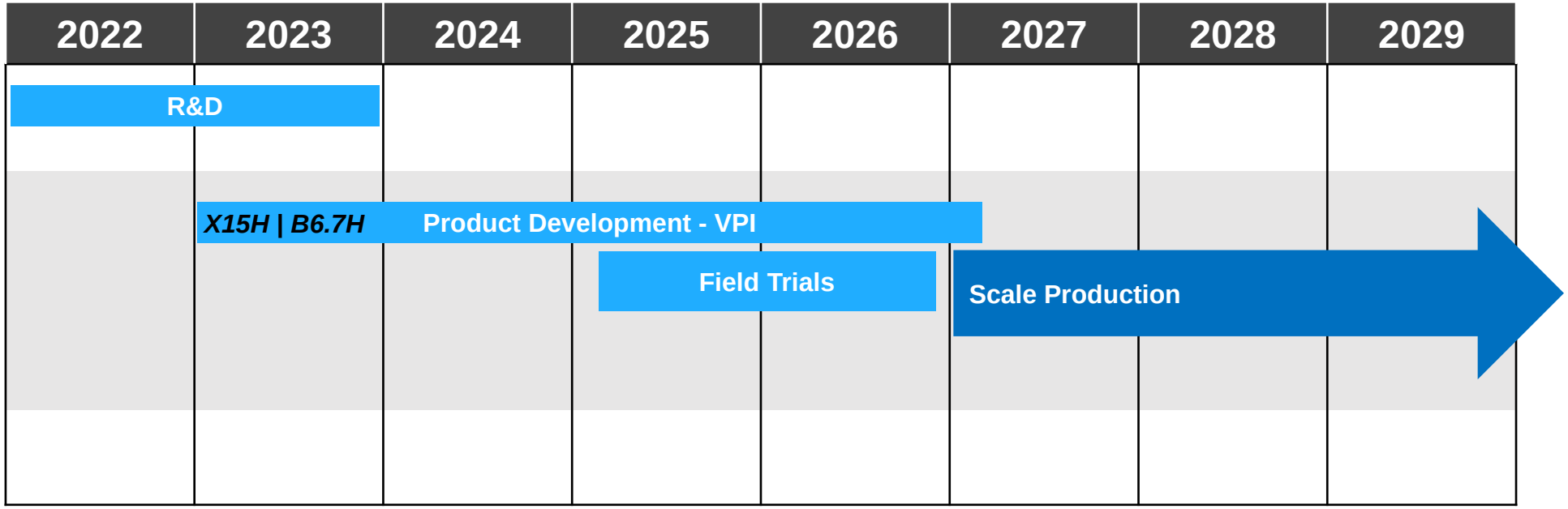




Engine	*B6.7H*	*X10H*	*X15H*
Displacement	6.7L	9.9L	14.5L
Power	170 – 215 kW 230 – 290 hp	220 – 280 kW 300 – 375 hp	300 – 400 kW 400 – 530 hp
Torque	900 – 1100 Nm 650 – 810 ft lb	1300 – 2000 Nm 950 – 1500 ft lb	2100 – 2600 Nm 1550 – 1900 ft lb
Emission Level	Euro VII | China NS VII | EPA 2027 | Stage V | T4F		
Architecture	Pent Roof Cylinder Head, Tumble Combustion, Spark Ignited, Direct Inject, Lean Burn, SCR Aftertreatment		

Product Introduction: Directional

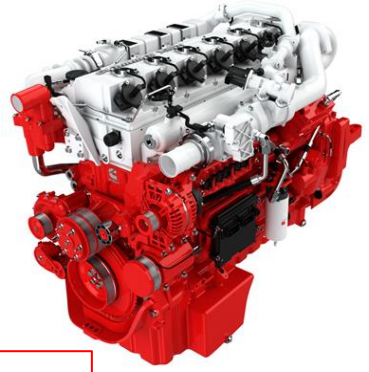
Global



H_2 ICE Architecture Considerations

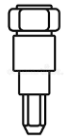
Challenges

Solutions



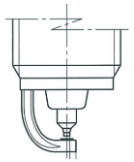
High air demand

Advanced valvetrain and turbo technology



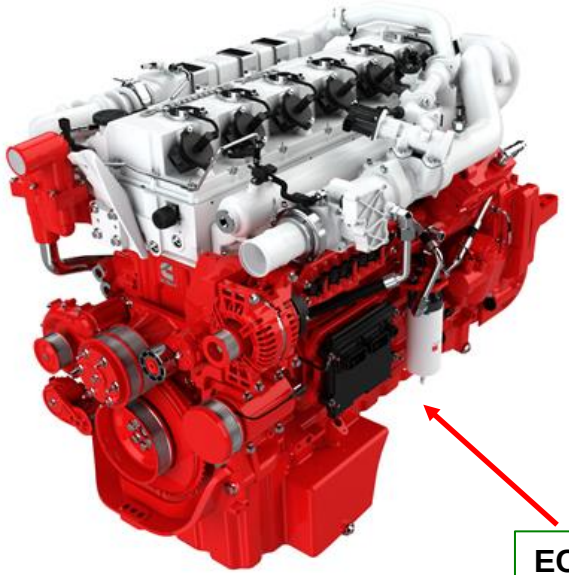
IMOP (Intake Manifold Over Pressure)

H_2 DI fuel system.



Preignition and knock

Optimized Ignition system and advanced power cylinder cooling



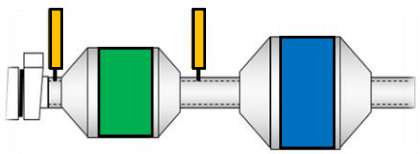
ECU and software is progressed from existing system.

Crankcase H_2 and moisture

Power cylinder design and crankcase ventilation

Risk of H_2 damage

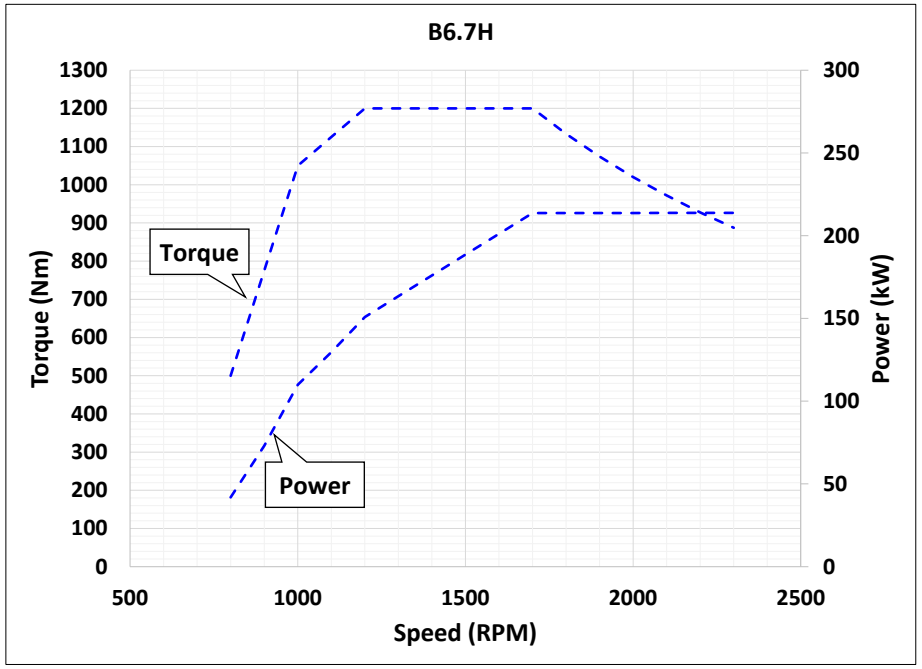
Develop process and methodology to quantify H2 damage; field data to qualify material for applications.

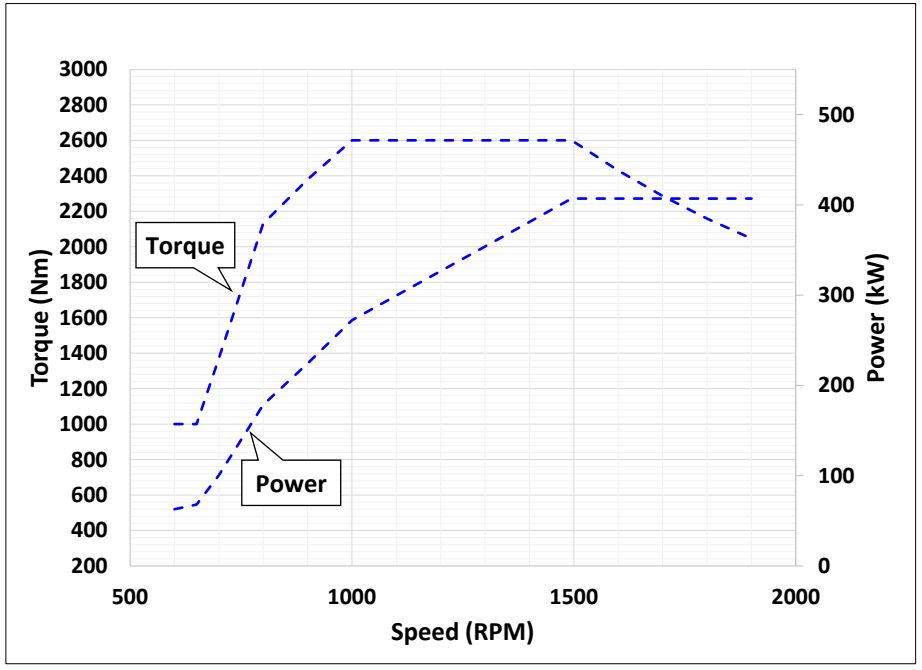


Aftertreatment

Advanced conventional catalytic technology, thermal management strategies for NOx reduction

R&D





B6.7H

32 kW/L

X15H

28 kW/L

- Several hours of multicylinder engine testing completed on the 6.7L and 15L platforms.
- Demonstrated the target peak torque, power and BTE.

Recent Announcements

Hydrogen ICE partnerships (additional under NDA)

"WERNER ENTERPRISES SIGNS LETTER OF INTENT PLANNING TO SECURE 500 X15H ENGINES FROM CUMMINS" Link
September 7, 2022

"TRANSPORT ENTERPRISE LEASING PLANNING TO INTEGRATE CUMMINS' X15H INTO HEAVY DUTY TRUCK FLEETS" Link August 31, 2022

"CUMMINS, TATA MOTORS TEAM UP FOR HYDROGEN-POWERED ENGINES" Link
November 14, 2022

TATA

VERSATILE

"CUMMINS AND VERSATILE HYDROGEN ENGINE PARTNERSHIP ANNOUNCED"
Link August 29, 2022

DAIMLER TRUCK
B6.7H Concept Truck

Q+A


Cummins