

Cummins Next Heavy Duty Natural Gas



Agenda

- Destination Zero
- Fuel Agnostic Platform
- Natural Gas Overview
- Current Product Portfolio
- 2024 X15N
- Heavy Duty R&D

WHAT IS DESTINATION ZERO?



**Lower
emissions today**



**Reduce well-to-
wheels emissions**

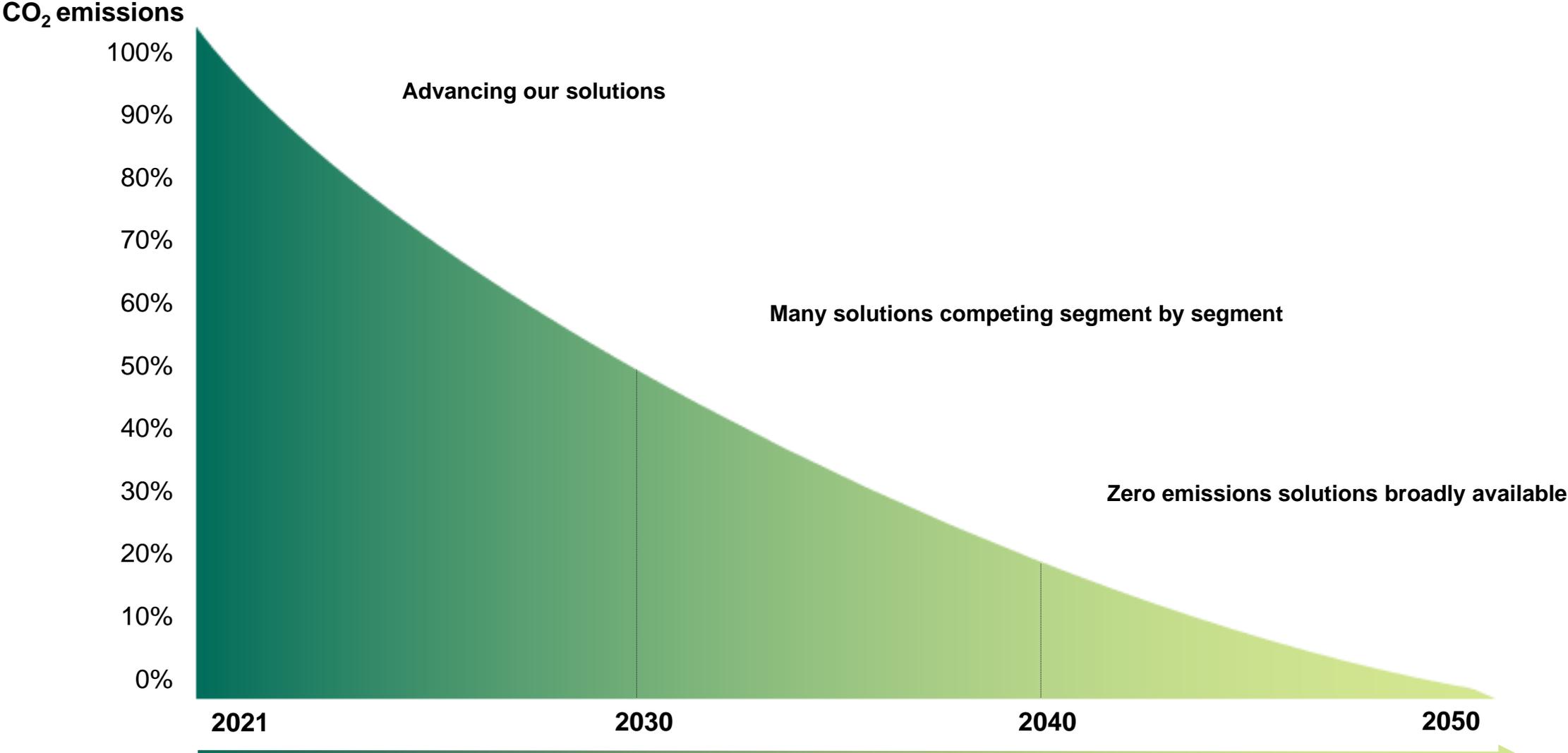


**Drive wide-scale
customer adoption**



**Achieve zero
emissions by 2050**

REACHING DESTINATION ZERO



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

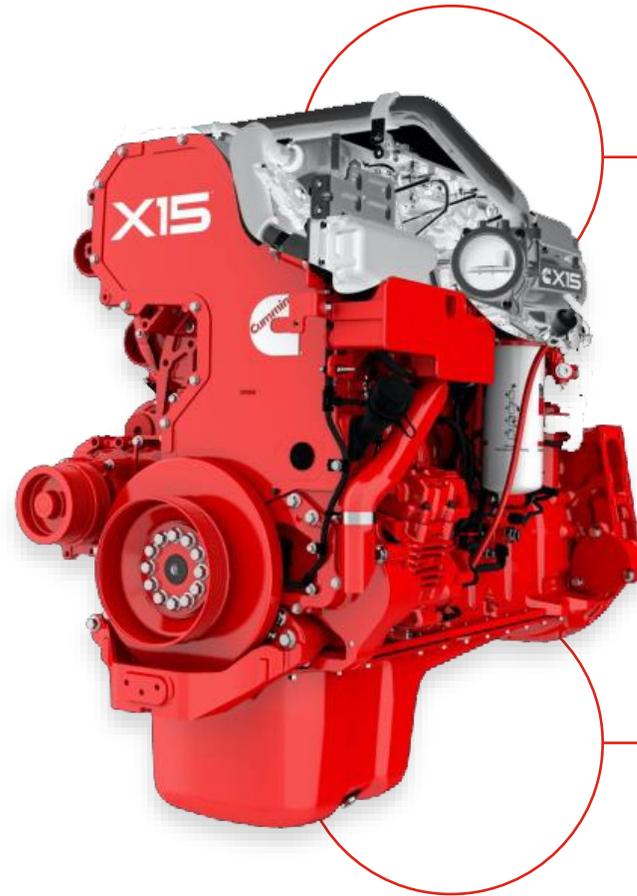
CUMMINS FUEL-AGNOSTIC PLATFORM



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.



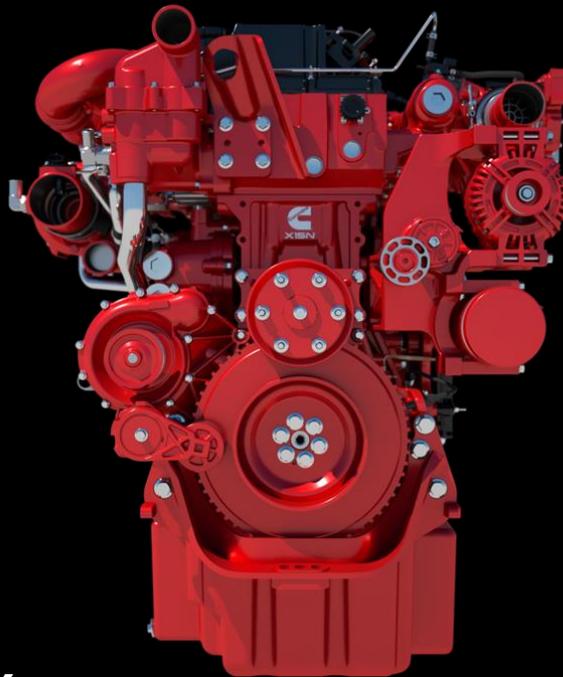
Above the head gasket will have different components for different fuel types.

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



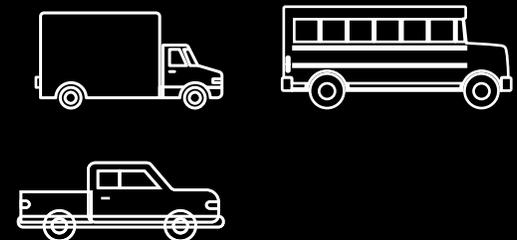
Heavy-duty

Clean Diesel
Natural Gas
Hydrogen



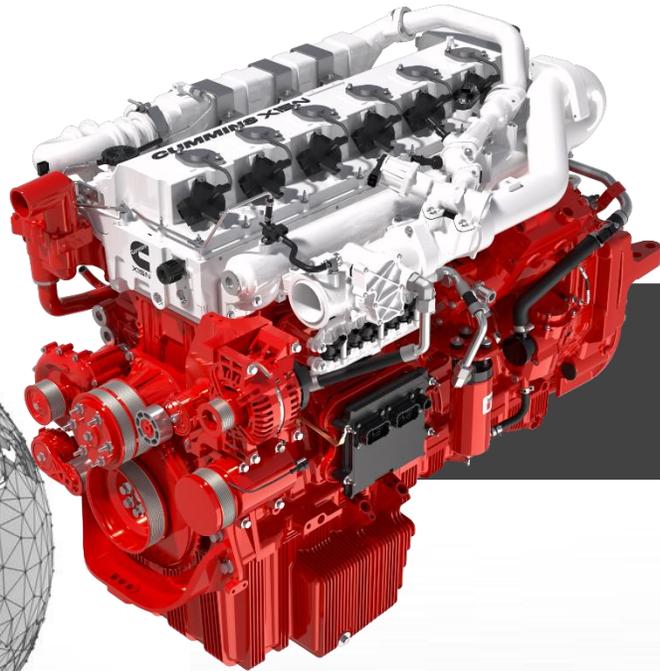
Medium-duty

Gasoline
Propane
Clean Diesel
Natural Gas
Hydrogen



X15 GLOBAL PLATFORM: FUEL AGNOSTIC

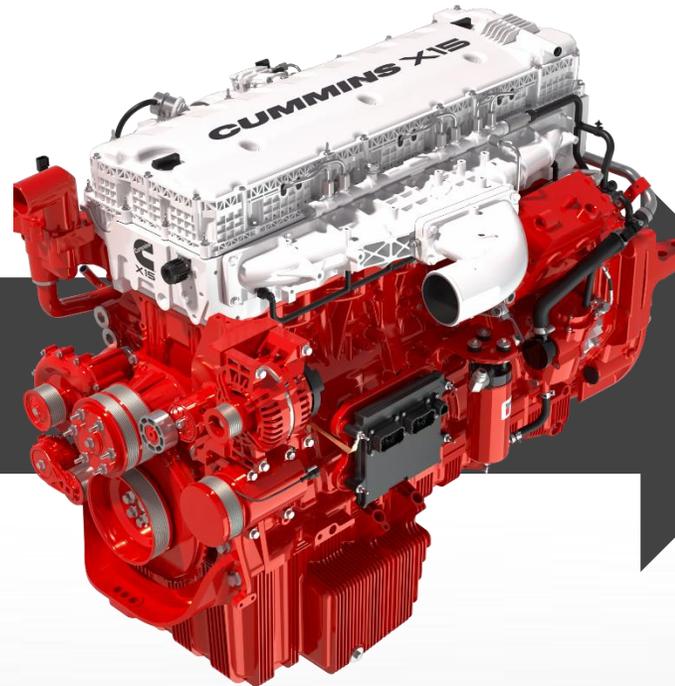
Reliable | Durable | Scale | Common



Natural Gas



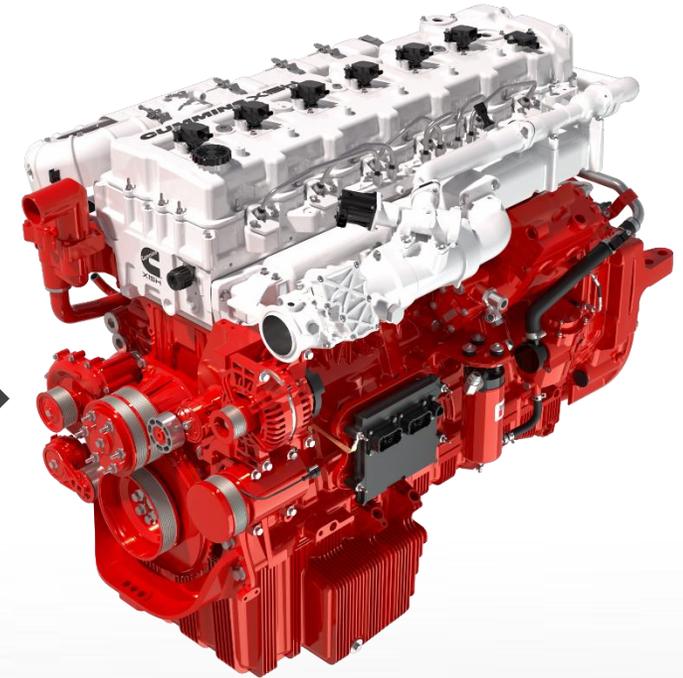
2024



Diesel



2026



Hydrogen



2027

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



**Win with
Natural Gas**



NATURAL GAS VALUE DRIVERS



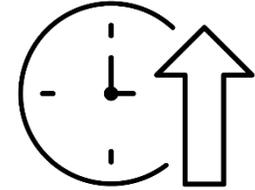
Environmental & Sustainability Benefits

- Lower GHG and NOx levels at the tailpipe
- Potential to reach sub-zero well to wheel emissions with Renewable Natural Gas (RNG)
- Start reducing total transportation footprint today



Economic Benefits

- Low cost of fuel
- Can provide competitive advantage to help you win business
- Much lower incremental vehicle cost than BEV / Fuel Cell



Operational Benefits

- Least disruptive and most mature alternative fuel technology (for all applications and routes)
- Only alternative fuel that can supply required range and power for long-haul/heavy-duty vehicles
- High level of parts commonality with diesel

CUMMINS AND NATURAL GAS POWER

Cummins has been building natural gas engines **since 1986**

Cummins is the **only manufacturer** in the U.S. developing and producing heavy and medium-duty commercial renewable natural gas engines

Cummins natural gas engines operate on renewable or fossil natural gas stored on-board as **compressed natural gas (CNG) or liquid natural gas (LNG)**

Most fleets operating natural gas engines do so for **8-12 years of service**

98% of all class 8 tractors with ISX12N engines are **day cabs**

Majority of private fleets switching to RNG power are advancing a **corporate environmental sustainability plan to reduce corporate carbon or GHG** liabilities

CUMMINS NATURAL GAS ENGINES

B6.7N™



L9N™



ISX12N™



X15N™

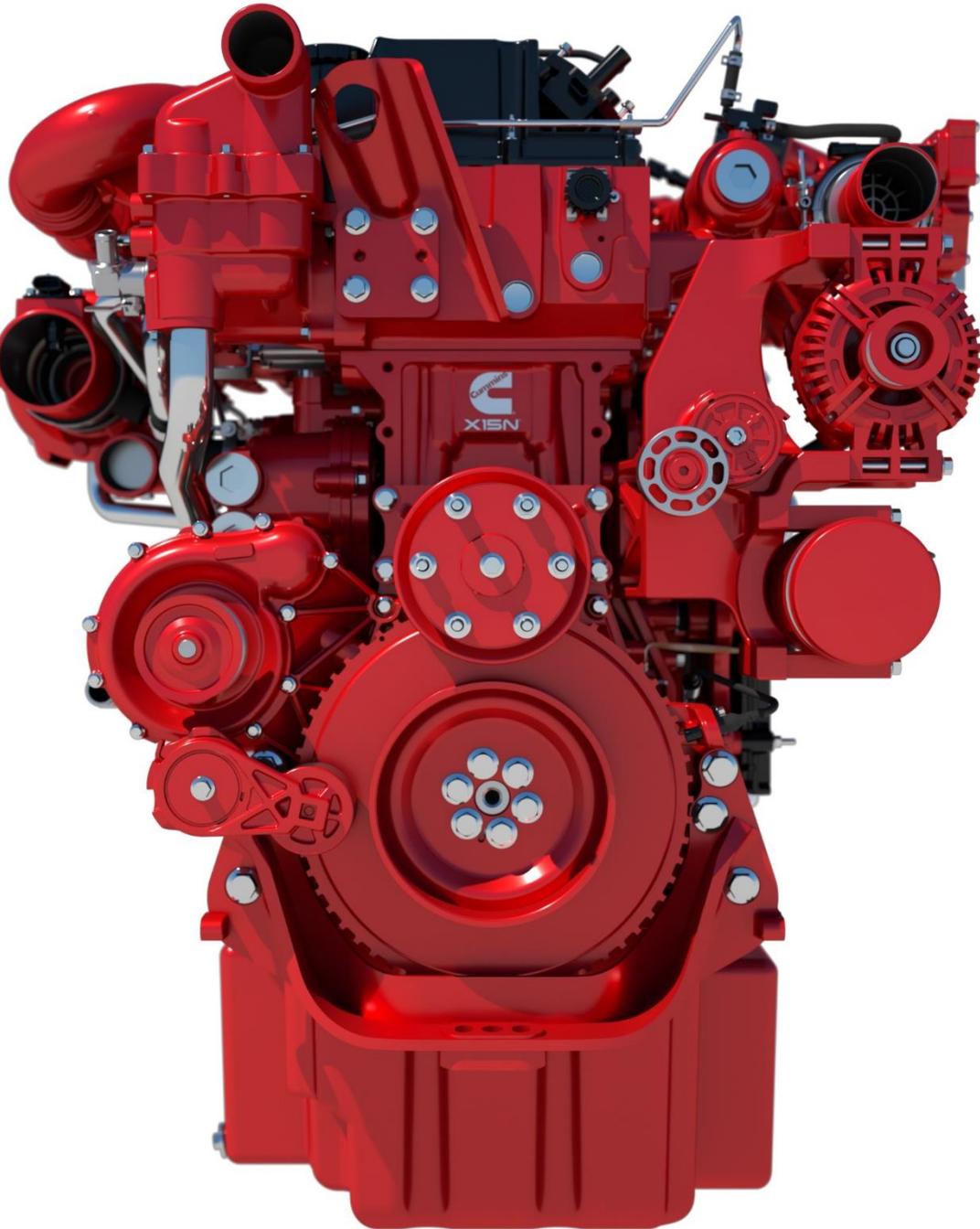


Coming in 2024

Certified Near Zero Optional Low NOx 0.02 g/bhp-hr

**THE CUMMINS
X15N —
A NATURAL GAS
ENGINE THAT
BRINGS
IT ALL
TOGETHER**





X15N HIGHLIGHTS

- The industry's first big-bore natural gas powertrain
- Designed for linehaul heavy duty applications
- Capable of meeting stringent CARB24/27 and future EPA NOx regulations
- Up to 500 hp /1,850 lb-ft of torque
- Compact 15 Liter – targeting ISX12N and 13L chassis installations
- ~500 lbs. lighter than diesel 15L engine
- Can utilize RNG for carbon-negative well to wheel emissions
- Maintenance-free passive aftertreatment system
- Manufactured in Jamestown, NY along with other heavy-duty Cummins engines

X15N Product Introduction

Design and deliverables to be confirmed through pending and final verification

X15N™

- ❖ Industry-first & market-defining **Big Bore Natural Gas** Powertrain
- ❖ Capable to **meet stringent CARB24/27 and future EPA NOx** regulations
- ❖ **Compact 15 Liter** – Targeting fit in ISX12N & 13L chassis installations, 500 lbs lighter than current 15L diesels
- ❖ Up to a **10% Fuel Economy/GHG improvement** over ISX12N
- ❖ 12L-15L Diesel matching ratings - **up to 500hp & 1850lb-ft** of torque
- ❖ Compact **passive TWC aftertreatment** system
- ❖ **Integrated with Industry HD transmissions** – Endurant and Allison
- ❖ Incorporates Cummins **Powertrain Features & Strategies**
- ❖ Potential for **Carbon Negative Solution with RNG**

Base Engine

- EPA and CARB
- Rear Geartrain
- Advanced combustion management

Air Handling

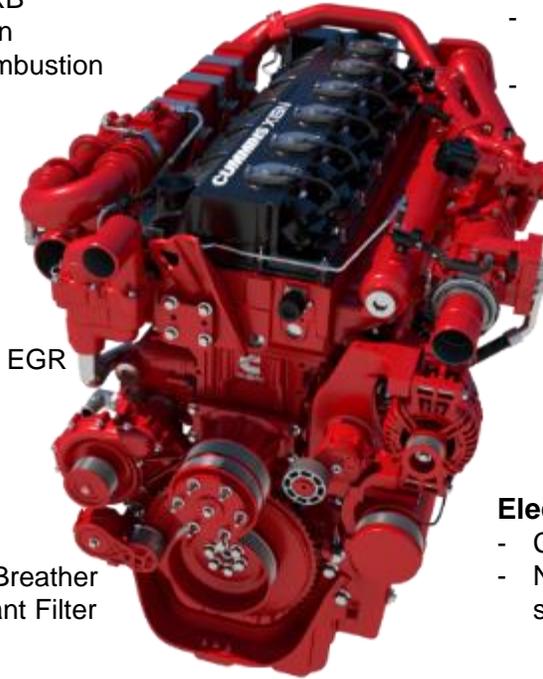
- Dual Wastegate Turbocharging
- Advanced Cooled EGR

Lube and Cooling

- Closed Crankcase Breather
- Elimination of Coolant Filter

Exhaust System

- Single unit, maintenance free & fluid free, chassis mounted Three-Way Passive Catalyst



Vehicle Integration

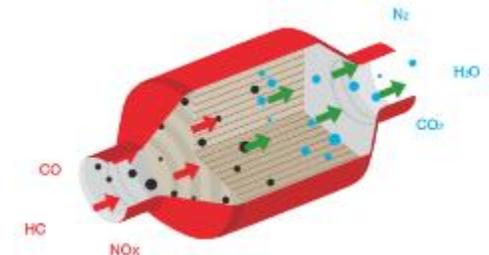
- Compact 15L design and reduced weight
- Integrated with Endurant (& Allison) transmissions
- Full powertrain feature suite

Fuel System

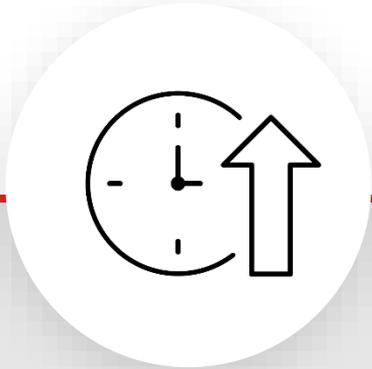
- Next generation fuel system
- Integrated with vehicle fuel system partners

Electronics System

- CM2380 ECM
- Next generation connectivity solutions

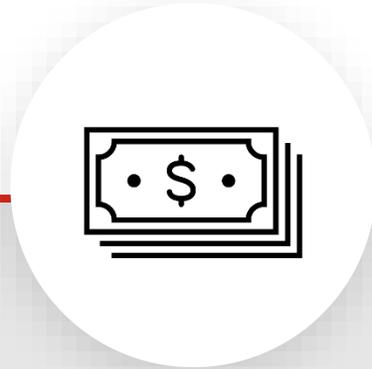


X15N VALUE DRIVERS



Enhanced Reliability (More Uptime)

- 50+ years of natural gas knowledge and know-how integrated into uptime design
- Reliability-enabling digital features
- Cummins service & support network



Lower Total Cost of Operation

- Up to 10% fuel economy improvements compared to current ISX12N
- Increased oil drain intervals
- Increased spark plug life
- Lower weight than ISX12N enables increased payload



Better Performance

- Increased power/torque
- Up to 500 hp/1850 lb-ft
- Broader peak torque speed band
- Improved transient response
- Increased braking power
- Endurant Transmission Integration

**The Cummins
X15N Next
Generation –
Heavy Duty
Natural Gas
R&D**

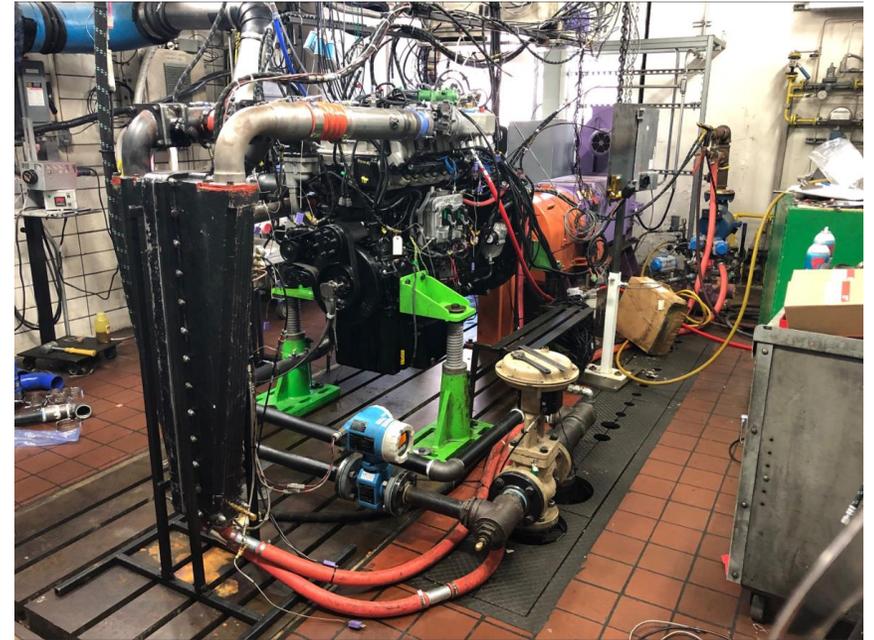


High Efficiency, Ultra Low Emissions Heavy Duty Natural Gas Engine

- Funded by NGV Consortium consisting of DOE, CEC & SCAQMD (2019 – 2023).
- 80% Complete.
- 15L Final Demo Engine.
- Advanced combustion, air-handling and fuel system development on 2024 X15N base engine.
- Objective: Efficiency improvements while maintaining Low NOx capability on a diesel like torque curve.

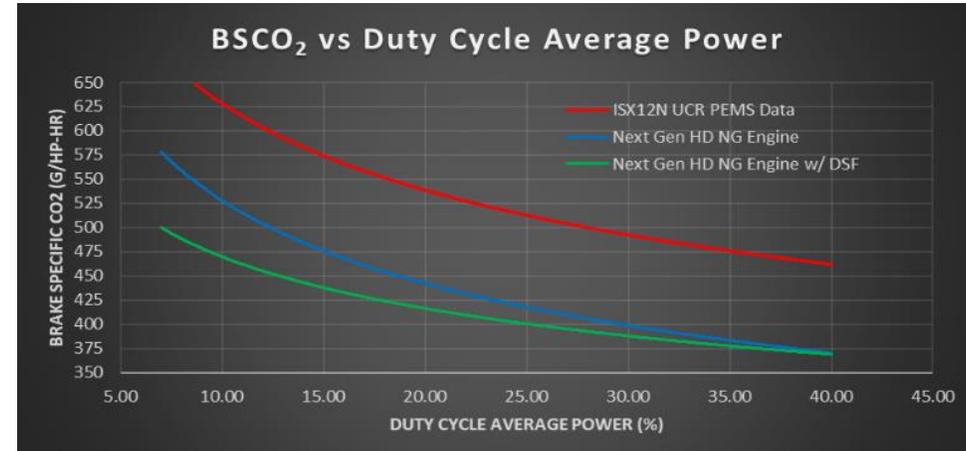
Engine Testing

- Prototype 15L multicylinder demo engine built, installed and commissioned in performance dyno test cell at Cummins Technical Center, Columbus, IN.
- Hardware robustness validated with over 300hrs engine runtime.
- Steady state calibrations developed for stable engine operation.
- Advanced technology hardware selection complete.
- Demonstrated target torque curve capability.
- Achieved program efficiency targets.
- Achieved improved efficiency across fuel map.
- Upcoming :
 - Efficiency and Emissions Demo Q2'23
 - Final Report Q3'23



Dynamic Skip Fire (DSF) w/ HD NG Engine

- Funded by DOE in partnership with Tula technologies (2021 – 2025).
- 30% Complete.



- Barriers being addressed:
 - Current HD NG engines Brake Specific CO2 (BSCO2) increase at lower average duty cycle powers.
- Relevance
 - Class 7-8 vocational trucks have considerable idle time and low average loads.
 - Demonstration of a path to <400 g/hp-hr CO2 emissions on vocational and tractor certification cycles.
- Objective : Design and develop advanced air-handling technology for HD NG engine to demonstrate improvement in BSCO2 emissions on low loaded cycles while maintaining capability to meet Low NOx emissions.

Milestones

Budget Period 1 (05/01/21-02/28/23)

System Design and Analysis

- Project Kick-off
- Overhead Design Complete
- Initial Engine Control Architecture Defined
- Advanced Hardware Design Complete
- Go/No-Go: Advanced Hardware and Control System Architecture Defined**

Budget Period 2 (03/01/23-02/29/24)

Hardware Manufacturing, Rig Validation and Dyno Testing

- First spin of rig hardware complete
- Software bench test complete
- Initial engine map completed
- Advanced Hardware Robustness Demonstrated with Bench Test
- Go/No-Go: Engine Operation Demonstrated with new technology**

Budget Period 3 (03/01/24-02/28/25)

Vehicle Integration and Final Demonstration

- Drive Cycle Testing Complete
- Chassis Dyno Testing Complete
- Efficiency targets demonstrated

H2 Blending in NG Engines

- Hydrogen injection into natural gas pipeline is an industry evolving practice driven by carbon footprint reduction.
- Up to 20% being considered.
- But there are challenges : Knock, Spark Plug Life, Pre-ignition.
- What is Cummins doing :
 - Performance analysis to establish boundary conditions and CFD to estimate impact to combustion.
 - Testing at UCR on production MD L9N with 5% H2.
 - Plans to conduct testing on 15L HD NG engine.

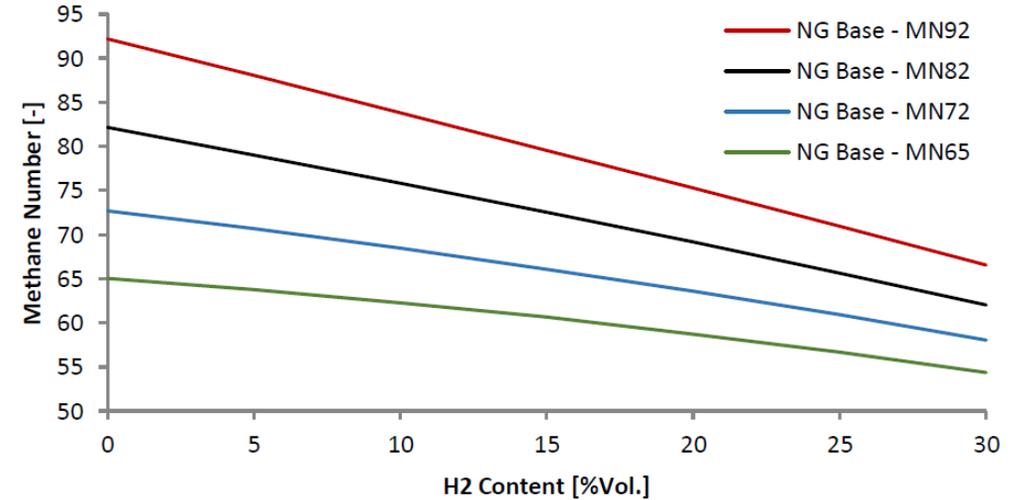


Figure 3. Methane Number of Natural Gas – Hydrogen Mixtures

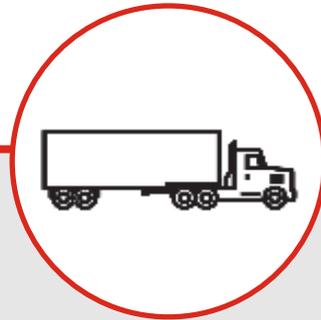
Conclusion

- Cummins is investing in next generation Natural Gas internal combustion engine R&D as a bridge to achieving zero emissions powertrain solutions.
- Technology advancements for fuel efficient, reliable, cleaner and cheaper engines than what is available today.
- Demonstrated diesel like torque curve capability with BTE improvements compared to production ISX12N on a 15L HD NG engine (opportunities for further improvement).
- Cummins R&D is also looking into solutions for H2 blending in NG.

Q+A

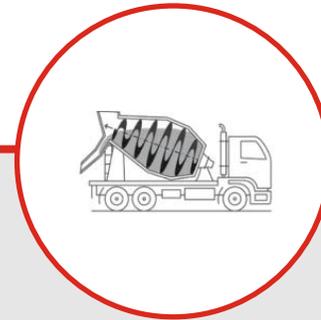


X15N MARKET OVERVIEW & APPLICATIONS



HEAVY-DUTY TRUCK

- Long Haul & Heavier Haul
- Regional Haul



VOCATIONAL TRUCK

- Cement Mixer
- Refuse & Roll Off
- Dump Truck