Natural Gas Engines
What’s the Natural Gas Value Proposition?

Natural Gas as a Transportation Fuel

**ECONOMICS**
- Historically ~8:1+ price advantage Btu basis
- Long-term price stability
- Long-term price outlook
- No costly emissions control systems

**ABUNDANCE**
- U.S. #1 natural gas producer in the world
- 100+ years of affordable reserves
- Basins provide increased access to markets
- Production can grow rapidly with demand

**ENVIRONMENTAL**
- 27% lower CO2 emissions than petroleum
- 13 – 17% lower WTW GHG emissions
- Lower in-use NOx emissions
- Lower PM emissions
- Quieter engines
Cummins Broad Product Range

A major expansion of the range since the late 1990s, with twice the number of engine platforms covering 49 to 5100 horsepower.
On Highway Heavy Duty Engines Designed Specifically for Alternative Fuels

- Based on Reliable Cummins Engine Platforms
- Common parts and design provide heavy duty performance
- Engineered and Optimized Specifically for Alternative Fuel
- Continued improvement in reliability and cost of ownership
- Service Support through the Global Cummins Distributor network
2019 North America Product Line

**6.7L**
- Peak Rating: 240 hp / 560 lb-ft torque
- 33,000 lb. GVW
- School bus/MD Truck/Shuttle bus/Sweeper/Yard spotter
- EPA/ARB Low NOx
- 0.1 g/bhp-hr (50% reduction)

**8.9L**
- Peak Rating: 320 hp / 1000 lb-ft torque
- 66,000 lb. GVW
- Refuse/Transit/Regional P&D Truck/Mixers
- EPA/ARB Near Zero NOx
- 0.02 g/bhp-hr (90% Reduction)

**11.9L**
- Peak Rating: 400 hp / 1450 lb-ft torque
- 80,000 lb. GVW
- Regional Haul Truck/Tractor/Refuse
- EPA/ARB Near Zero NOx
- 0.02 g/bhp-hr (90% Reduction)

Coming in 2020 .02 NOx!
## Features:

<table>
<thead>
<tr>
<th></th>
<th>ISX12N</th>
<th>L9N</th>
<th>B6.7N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emission Certification</strong></td>
<td>EPA/CARB Near Zero (NZ) 0.02 g NOx</td>
<td>EPA/CARB Near Zero (NZ) 0.02 g NOx</td>
<td>EPA/CARB Optional Low NOx 0.1 g NOx</td>
</tr>
<tr>
<td>NOx Reduction to 2017 EPA</td>
<td>90%</td>
<td>90%</td>
<td>50%</td>
</tr>
<tr>
<td>OBD</td>
<td>2019</td>
<td>2018</td>
<td>2018</td>
</tr>
<tr>
<td>CCV</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>TWC</strong></td>
<td>• Increase in size (TBA)</td>
<td>• Same size as ‘17 ISL G NZ</td>
<td>• Same size as ‘17 ISB6.7 G</td>
</tr>
<tr>
<td></td>
<td>• One piece design</td>
<td>• One piece design</td>
<td>• One piece design</td>
</tr>
<tr>
<td></td>
<td>• Mid bed O2/Temp Sensor</td>
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<td>• Mid bed O2/Temp Sensor</td>
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<tr>
<td></td>
<td>• OEM Harness</td>
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</tr>
<tr>
<td><strong>Product Changes</strong></td>
<td>• New fuel system improves performance and reduces parts content</td>
<td>• Steel Pistons</td>
<td>• Additional crankcase pressure sensor</td>
</tr>
<tr>
<td></td>
<td>• On-engine electric CCV filter with 2 CCP sensors</td>
<td>• New Liners</td>
<td>• New CM2380 ECM</td>
</tr>
<tr>
<td></td>
<td>• CM2380 ECM</td>
<td>• Improved Ring Pack</td>
<td>• 500 kbaud datalink</td>
</tr>
<tr>
<td></td>
<td>• 500 kbaud datalink</td>
<td>• New Valve Seat Material</td>
<td>• New wiring harness</td>
</tr>
<tr>
<td></td>
<td>• New wiring harness</td>
<td>• New Oil Cooler</td>
<td>• New Ignition Control Module</td>
</tr>
<tr>
<td></td>
<td>• New 2380 ICM</td>
<td>• Improved Piston Cooling</td>
<td></td>
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<tr>
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<td></td>
<td>• Additional crankcase pressure sensor</td>
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</table>
Maintenance & Fluid Free Exhaust Treatment | Three-Way Catalyst

- Similar to catalyst on gasoline passenger cars
- Packaged as a muffler with vertical or horizontal mount
- Weighs ~100 pounds
- Benefits:
  - More reliable, no downtime
  - Maintenance-free, no filters to clean or replace
  - No active regeneration required
  - No SCR fluid or maintenance or costs
Quiet Operation

- Spark ignition provides quiet operation
- Communities notice the natural gas noise advantage.
- **ONE** Diesel engine idling is louder than 10 natural gas engines idling together
Why is Near Zero needed?

Figure 2-1: Emissions Contribution from Mobile Sources

[Graph showing emissions contribution from mobile sources for GHG, NOx, and Diesel PM]

[Map showing attainment and nonattainment areas in the U.S. 8-hour ozone standard]

- Attainment (or Unclassifiable) Areas (2668 counties)
- Nonattainment Areas (432 entire counties)
- Nonattainment Areas (42 partial counties)
Counties Designated by EPA as Non-Attainment

EXTREME
- Los Angeles-South Coast Air Basin, CA
- San Joaquin Valley, CA

SEVERE 15
- Los Angeles-San Bernardino Counties, CA
- Riverside Co, (Coachella Valley), CA
- Sacramento Metro, CA

SERIOUS
- Porter County, IN
- Lake County, IN

MODERATE
- Floyd County, IN
- Clark County, IN
The Importance of Federal Standards for HD Vehicles

Current EPA HD vehicles emissions: 2010 @ 0.2 NOx standard....still not clean enough to hit California Clean Air Targets

- Cummins Near Zero RNG Engines are commercially available today moving goods with this technology will reduce corporate GHG liabilities immediately.
California Optional Low Emissions Tiers

**Low NOx**
- 0.1 g/bhp-hr
- 0.05 g/bhp-hr
- 0.02 g/bhp-hr

**Near Zero Emissions**
- 0.02 g/bhp-hr NOx
  - 90% reduction from current standard of 0.2 g/bhp-hr

**Zero Emissions**
- No tailpipe emissions
  - Regardless of how low (NOx, PM, GHG, etc.)

CEC* has defined this certified Near Zero emission level as equivalent to a 100% battery truck using electricity from a modern combined cycle natural gas power plant.
Renewable Natural Gas Improves GHG Profile

- Landfill gas and biogas that has been processed to “pipeline quality” is **RNG**
- CWI engines can operate on up to 100% **RNG** and are currently in operation with RNG from landfills (landfill gas) & dairy farms (biogas)
- RNG from some sources produces a negative carbon intensity – or sub-zero GHG emissions
Why Renewable Natural Gas Engine Technology?

Environmental Durability

- NOx is reduced by 90% below standard
- PM is reduced 90% below standard
- Renewable NG reduces Global Warming GHG emissions to Near Zero
  - Landfill source (GREET1_2016 and CA GREET2.0)
    - Up to 97% reduction in CO2
    - Up to 80% reduction in WTW GHG
Electric Equivalent NOx

- Assumes EV power is 100% sourced from renewable sources like RNG, wind power, or solar panels.
- Using current electric power grid to recharge batteries.
- ISX12N engine certified at 0.01 NOx emissions.

Source: South Coast Air Quality Management District Science & Technology Advancement Department.
Sub-zero Carbon Intensity

2018 - ISX12N and L9N: Sub-zero Emissions with RNG: Cleaner than EV class 8 trucks.
Heavy Duty Truck/Bus Emissions Reduction Impact - NOx

<table>
<thead>
<tr>
<th>Year</th>
<th>NOx (g/hp-hr)</th>
<th>PM (g/hp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>10.8</td>
<td>0.59</td>
</tr>
<tr>
<td>1990</td>
<td>6</td>
<td>0.59</td>
</tr>
<tr>
<td>1991</td>
<td>5</td>
<td>0.25</td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>0.05</td>
</tr>
<tr>
<td>2010</td>
<td>0.2</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Natural Gas Playbook

CWIplaybook.com

- Online Natural Gas Playbook with tips and tools to help customers with the successful adoption of natural gas into truck, refuse, school bus, and transit applications.
- Featuring a Well-to-Wheel GHG emissions calculator and a Payback calculator.
- Organized into 5 sections to guide customers:
  1. Assess
  2. Specify
  3. Prepare
  4. Implement
  5. Operate & Maintain
- “Print to PDF” feature allow users to create their own Playbook of reference material.
# Natural Gas Playbook Emissions Calculator

## RESULTS

<table>
<thead>
<tr>
<th>Region</th>
<th>US Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Specification/Model</td>
<td>GREET1_2016</td>
</tr>
<tr>
<td>Annual Total WTW GHG (CO2eq) Savings with NGVs (Metric Tonnes per year)</td>
<td>5,893.3</td>
</tr>
<tr>
<td>% Reduction Relative to Current Vehicle Fleet</td>
<td>80.4%</td>
</tr>
<tr>
<td>Truck Equivalent GHG Avoided by Converting to NGV</td>
<td>20.1</td>
</tr>
<tr>
<td># of Near Zero Gas Trucks it Would Take to Generate GHG of Current Fleet</td>
<td>127.4</td>
</tr>
<tr>
<td>Tailpipe NOx Emissions Reduction with NGV</td>
<td>90%</td>
</tr>
</tbody>
</table>
# GHG Engine Emission Calculator

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<tr>
<td>GHG Specification/Model</td>
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</tr>
<tr>
<td>Application</td>
<td>Heavy Duty Truck</td>
</tr>
<tr>
<td>Model Year / Vintage</td>
<td>2013</td>
</tr>
<tr>
<td># Vehicles to Replace</td>
<td>1000</td>
</tr>
<tr>
<td>Vehicle Fuel Economy and Distance</td>
<td>100,000 Miles @ 7MPG</td>
</tr>
<tr>
<td>Fuel Type</td>
<td>CNG</td>
</tr>
<tr>
<td>Use RNG</td>
<td>YES</td>
</tr>
</tbody>
</table>

## Results

| Annual Total WTW GHG (CO2eq) Savings with NGVs (Metric Tonnes per year) | 156,131.2 |
| % Reduction Relative to Current Vehicle Fleet | 79.8% |
| Current vehicle equivalent GHG avoided by converting to NGV | 797.5 |
| # of Near Zero vehicles it would take to generate GHG of current fleet | 4,939.3 |
| Tailpipe NOx Emissions Reduction with NGV | 90% |
| CWI Engine Model Selected | ISX12N |
ISX12 G Engines in Motion

2015

Attainment and Nonattainment Areas in the U.S.
8-hour Ozone Standard

- Attainment (or Unclassifiable) Areas (2668 counties)
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ISX12 G Engines in Motion

2018

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8-hour Ozone Standard

- Attainment (or Unclassifiable) Areas (2668 counties)
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2019 OEM Availability
Benefits:

- **Maintenance & Fluid Free Exhaust Treatment** – same as your automobiles, no fluids, no regeneration downtime, no cleaning or replacing exhaust treatment filters
- **Environmental** – Cleanest, most cost effective commercial goods movement power available in the world today and for the foreseeable future, GHG credits transfer to shipper
- **Low Engine Exhaust Emissions** – NG engines broadly accepted by state regulators and agencies with significant funding incentives in many states.
- **Economics** – lower cost per mile than any other technologies operating in return to base or urban applications.
Moving Goods with Natural Gas Engines
Moving Goods with Natural Gas Engines

INDIANA
Thank You!

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