Cummins Westport
The Natural Choice
Near Zero Emissions
Why Lower NOx Emissions?

- High temperature engine combustion produces NO\textsubscript{x}
- Via complex reaction with sunlight NO\textsubscript{x} leads to NO\textsubscript{2}
- This Conversion leads to ground level ozone formation
- Reactive hydrocarbons can speed the conversion process
- Natural Gas hydrocarbons are less reactive than diesel
- In most urban areas lower engine related NO\textsubscript{x} will reduce ground level ozone
NOx is not Just a Southern California Issue

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)
California NOx Improvement.

- California’s poor PM and Ozone air quality is pushing government to take significant steps for NOx improvement
  - Fund technology development and demonstration
  - Offer end-user incentives to offset incremental vehicle costs, customers will request product!

### Additional Reductions Needed

- Health impacts still significant
- Localized impacts still remain
- Near and long term reductions still needed for air quality and SIP

- If the entire on-road fleet complies with 2010 NOx standards
  - NAAQS for PM and Ozone will still be exceeded
  - NOx contributes to secondary formation of PM (nitrates)
How California (ARB) Plans to Get There

- Already a 98% NOx reduction with current standards comparing 1985 to 2010 EPA
- Now ARB has established three optional low NOx emissions standards
  - 0.02 g ~ “Near Zero” NOx emissions, 90% reduction in NOx from current (2010) standards

ARB 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.
Introducing Cummins Westport’s Path to Lower Emissions
Near Zero Emissions Natural Gas Engine

- CWI has been working on a project supported by the SCAQMD, CEC & SoCal Gas to develop technology that would reduce NOx emissions to below the 0.02 g/bhp-hr “Near Zero” level

- In 2014, CWI completed laboratory-based R&D, using prototype hardware, testing the ISL G for near zero emissions while maintaining current architecture

- 2015 work included
  - Component and engine design for high volume manufacture
  - Extensive component / system validation to demonstrate performance, reliability and durability, including field testing in California
  - Emissions certification

- 2016 Production begins

<table>
<thead>
<tr>
<th>Emissions Criteria</th>
<th>Reduction</th>
<th>Near Zero</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter (PM)</td>
<td>↓ 80% below EPA standards</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Oxides (NOx)</td>
<td>↓ 90% below EPA standards</td>
<td>✓</td>
</tr>
<tr>
<td>Engine related Methane (CH₄)</td>
<td>↓ 70% reduction (crankcase and tailpipe)</td>
<td></td>
</tr>
<tr>
<td>Greenhouse Gases (CO₂ equivalent)</td>
<td>↓ 9% reduction (technology pathway for further reduction in 2019/2020)</td>
<td>✓</td>
</tr>
</tbody>
</table>
EPA and California ARB Certifications

Current ISL G certification
- PM is 80% below the EPA standard
- NOx is 35% below the standard

<table>
<thead>
<tr>
<th></th>
<th>NMHC</th>
<th>NOx</th>
<th>CO</th>
<th>PM</th>
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<tbody>
<tr>
<td></td>
<td>FTP</td>
<td>EURO</td>
<td>FTP</td>
<td>EURO</td>
</tr>
<tr>
<td>STD</td>
<td>0.14</td>
<td>0.14</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>CERT</td>
<td>0.06</td>
<td>0.06</td>
<td>0.13</td>
<td>0.01</td>
</tr>
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</table>

ISL G Near Zero certification
- PM is 90% below the EPA standard
- NOx is 50% below the NZ standard!
- CO2 is 16% below NZ Standard!

<table>
<thead>
<tr>
<th></th>
<th>NMHC</th>
<th>NOx</th>
<th>CO</th>
<th>PM</th>
</tr>
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<tbody>
<tr>
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<td>FTP</td>
<td>EURO</td>
<td>FTP</td>
<td>EURO</td>
</tr>
<tr>
<td>STD</td>
<td>0.14</td>
<td>0.14</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>CERT</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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NOx is 50% below STD
PM is 90% below STD
CO2 is 16% below STD
RNG compatibility enables GHG emission reduction to near zero levels as well (landfills, dairies, waste water streams, etc.)
NZ is ready now… how clean do you want to be and how fast?

Current control programs drive all HD vehicles to 2010 0.2 NOx standard by 2023… rapid progress but still not enough to hit Clean Air targets

A NZ NGV advocacy program overlay could reduce NOx 50% below current controls (around 60 extra tons per day)
Emissions Reduction Impact - NOx

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2016</th>
<th>ISL G NZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx (g/hp-hr)</td>
<td>2.5</td>
<td>0.2</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>PM (g/hp-hr)</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

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Greenhouse Gas

- Greenhouse gases are essential to maintaining the temperature of the Earth as they reduce the loss of heat into space and help control global temperatures through the greenhouse effect.
- Increased emissions of greenhouse gases can cause global warming.
- Carbon Emissions are gaining in importance by government and industry.
- Carbon dioxide, methane, nitrous oxide and three groups of fluorinated gases (sulfur hexafluoride HFCs, and PFCs) are the major greenhouse gases.

Natural gas is a low carbon fuel.

<table>
<thead>
<tr>
<th>From GREET1_2015</th>
<th>CNG</th>
<th>LNG</th>
<th>Diesel</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Carbon Content per Unit of Energy (gCO₂/MJ)</td>
<td>56.3</td>
<td>56.5</td>
<td>74.9</td>
<td>72.7</td>
</tr>
<tr>
<td>CNG compared to Petroleum</td>
<td>25% lower</td>
<td>22% lower</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Greenhouse Gas Reduction

Potential further GHG reductions to near zero levels when used with renewable natural gas (RNG)

Greenhouse Gas Emissions Criteria
- Engine related Methane ($\text{CH}_4$) reduction: ↓70% reduction (crankcase and tailpipe)
- Greenhouse Gases ($\text{CO}_2$ equivalent) reduction: ↓11% reduction (technology pathway for further reduction in 2019/2020)

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Use Renewable Natural Gas

- The use of renewable natural gas as a fuel reduces greenhouse gas emissions.
- Biogas is a mixture of methane and other gases produced from the natural decomposition of organic materials in landfills, composting or agriculture.
- Purifying biogas to “pipeline quality” produces Renewable Natural Gas (RNG) or biomethane that is a pipeline-quality natural gas substitute.
- Converting the methane that leaks from landfills or other sources to biomethane fuel has significant greenhouse gas emissions reduction benefits.
- In addition, there’s a 100% displacement of fossil fuels as RNG is a renewable resource.
Renewable Natural Gas (RNG) Improves GHG Profile

- Landfill gas and biogas that has been processed to “pipeline quality” is **RNG**
- ISL G can operate on up to 100% **RNG** or as it sometimes called, biomethane.
- ISL G / ISX12 G engines are currently in operation with renewable natural gas from landfills (landfill gas) & dairy farms (biogas)
<table>
<thead>
<tr>
<th>gm/kilometer</th>
<th>Extraction</th>
<th>Processing</th>
<th>Fueling, Transportation and Storage</th>
<th>Vehicle Operation</th>
<th>C in End Use Fuel from CO2 in Air (RNG)</th>
<th>Total gm/km</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas (CNG)</td>
<td>124.7</td>
<td>118.4</td>
<td>58.4</td>
<td>1290.7</td>
<td>0</td>
<td>1592.2</td>
<td>-11.1 %</td>
</tr>
<tr>
<td>Natural Gas (CNG)</td>
<td>124.7</td>
<td>118.4</td>
<td>58.4</td>
<td>1214.7</td>
<td>0</td>
<td>1516.1</td>
<td>-15.3 %</td>
</tr>
<tr>
<td>Renewable Natural Gas (CNG - Landfill)</td>
<td>0</td>
<td>31.7</td>
<td>45.3</td>
<td>1214.7</td>
<td>-1141.4</td>
<td>193.6</td>
<td>-89.2 %</td>
</tr>
<tr>
<td>Diesel</td>
<td>103.2</td>
<td>328.1</td>
<td>9.3</td>
<td>1350.2</td>
<td>0</td>
<td>1790.8</td>
<td>Baseline</td>
</tr>
</tbody>
</table>

Source: GHG Emissions for Ontario Natural Gas Buses – GH Genius Feb 2016

- Baseline ISL G natural gas reduces GHG WTW emissions by 11%
- ISL G Near Zero improves WTW GHG reduction to 15%
- Use of RNG with ISL G Near Zero improves GHG reduction to 89%
  - For every 50,000 miles save 128 metric tons of CO2
Greenhouse gas (CO2) Measured in Metric Tons

One Metric Ton of CO2 = 4 tractor trailers full!

One ISL G Near Zero running RNG removes 512 trailers full of CO2 per year
- Base ISL G engine design is the same
  - Engine will be factory built at Cummins Rocky Mount Engine Plant
  - Ratings, warranty and operational / maintenance procedures will be the same
  - No change in technician service certification requirements
- Closed Crankcase Ventilation (CCV) will be added to engine
  - CCV system reduces engine related methane emissions by 70%
  - CCV filter change required at 2,000 hours
- Three Way Catalyst will change to meet next level emissions
  - Remains maintenance free
  - Larger size catalyst with addition sensor added
  - New substrate composition for durability and emission performance
Closed Crankcase Ventilation (CCV) System

- Inlet (from valve cover)
- Outlet (to compressor inlet elbow)
- Coolant supply/return
- Filter (2,000 hour change)
- Oil drain (to supplied connection on block)
Summary

- Cummins Westport has certified the ISL G Near Zero (NZ) NOx with EPA and California ARB for Bus and Truck applications.

- Field testing is in progress in transit and refuse applications.

- ISL G NZ NOx engines will be factory built and available in 2016 for new Bus and Truck installations as well as for repowers of existing natural gas vehicles.
  - There are no plans for retrofit kits for existing engines.

- Zero Emission technology at conventional propulsion system values!
Why ISL G Near Zero vs Current ISL G?

- ISL G Near Zero has 90% lower NOx and 9% better GHG profile
  - Lowest emission mid range engine in North America
  - 10 - ISL G Near Zero engine NOx emissions equal one ISL G
    • Tenfold decrease in emissions for new and existing fleets
- ISL G Near Zero is better qualified for Non Attainment funding
  - Cleanest ICE technology available.
- ISL G Near Zero features all the latest engineering improvements from the ISL G
  - Natural gas fleets looking to replace existing natural gas vehicles or engines will notice a
    dramatic improvement in reliability an uptime performance
- ISL G Near Zero affords fleets the opportunity to market “Near Zero” emissions.
- ISL G Near Zero is the “go forward” product for CWI
  - OBD in 2018 will obsolete base ISL G
Near Zero Product Plan – Feb 2016
(Certified to ARB Near Zero NOx standard - 0.02 gm/bhp.hr.)

<table>
<thead>
<tr>
<th>Engine</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
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<tbody>
<tr>
<td>ISB6.7 G</td>
<td></td>
<td></td>
<td>Development Program Not Funded</td>
<td></td>
</tr>
<tr>
<td>ISB6.7 G NEAR ZERO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISL G</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ISL G NEAR ZERO</td>
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<td></td>
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<tr>
<td>ISX12 G</td>
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<tr>
<td>ISX12 G NEAR ZERO</td>
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</tr>
</tbody>
</table>

* ISB6.7 G will be certified at launch to California ARB optional Low NOx (0.1 gm/bhp-hr.)
Near Zero development funding for the ISB6.7 G has not be secured – no ISB6.7 G NZ in plan without funding
ISX12 G NZ will be available in 2018
Base ISL G and ISX12 G engines are not available post 2017 (not OBD compliant)

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# OEM Availability

<table>
<thead>
<tr>
<th></th>
<th>ISL G</th>
<th>ISX12 G</th>
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<tbody>
<tr>
<td><strong>Conventional Truck</strong></td>
<td></td>
<td></td>
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<tr>
<td>Freightliner</td>
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<td>International</td>
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<td>Kenworth</td>
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<tr>
<td>Mack</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Peterbilt</td>
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<td>Yes</td>
</tr>
<tr>
<td>Volvo</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Western Star</td>
<td>-</td>
<td>-</td>
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<tr>
<td><strong>Refuse Truck</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autocar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Crane Carrier</td>
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<td>-</td>
</tr>
<tr>
<td>Mack</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Peterbilt</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Coach</strong></td>
<td></td>
<td></td>
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<tr>
<td>MCI</td>
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<table>
<thead>
<tr>
<th><strong>OEM</strong></th>
<th><strong>ISL G</strong></th>
<th><strong>ISB6.7 G</strong></th>
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<tbody>
<tr>
<td>El Dorado</td>
<td>Yes</td>
<td>Pending</td>
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<tr>
<td>Gillig</td>
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<td>New Flyer</td>
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<td>Nova</td>
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<td>Blue Bird</td>
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<td>IC Bus</td>
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<tr>
<td>Thomas Built</td>
<td>Yes</td>
<td>Yes</td>
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</table>

**ISL G NZ Availability**

Pending OEM orders

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June 2016
More information... www.cumminswestport.com

- Natural Gas Academy: great source of information about NG, technology, vehicles
- Series of instructional videos, including engine walk-arounds and service & driver training videos
- Engine information – specs, features, maintenance intervals
- Product Brochures & Bulletins available for download

June 2016

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